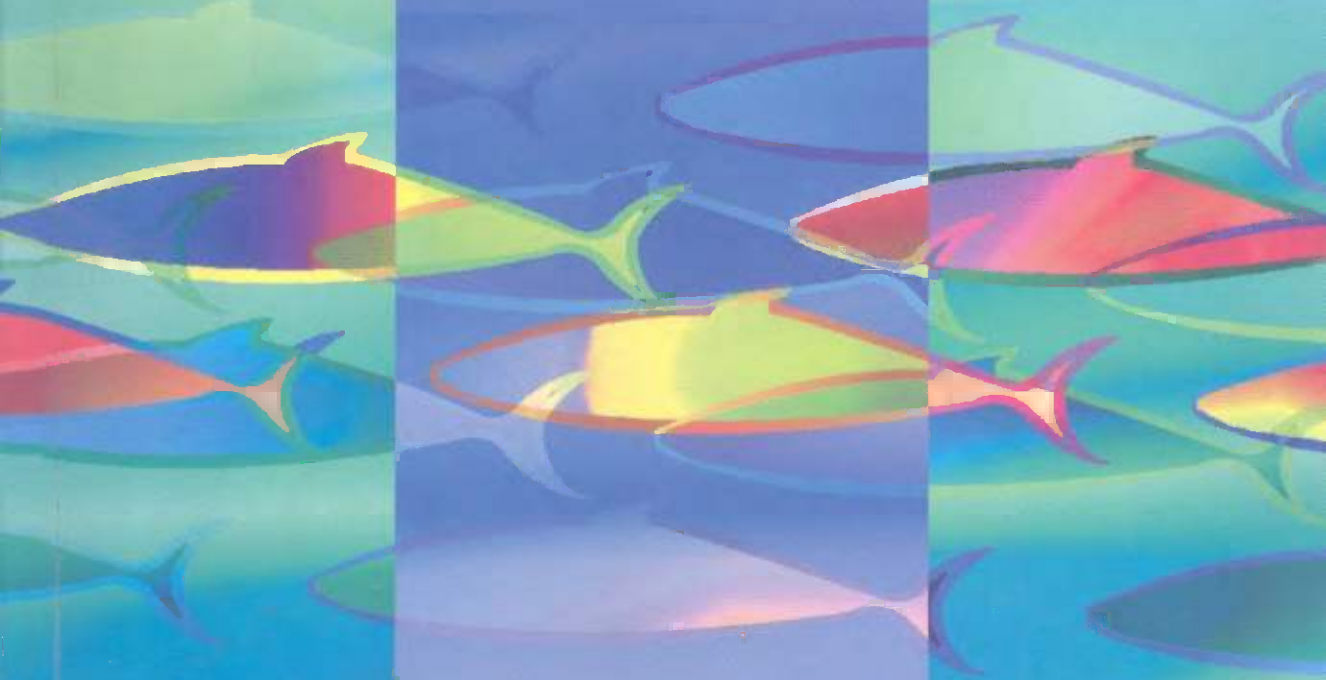
SMALL PELAGIC RESOURCES AND THEIR FISHERIES IN THE ASIA-PACIFIC REGION



ASIA-PACIFIC FISHERY COMMISSION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC

RAP Publication 1997/31

SMALL PELAGIC RESOURCES AND THEIR FISHERIES IN THE ASIA-PACIFIC REGION

Proceedings of the First Session of the
APFIC Working Party on Marine Fisheries
Bangkok, Thailand, 13-16 May 1997

Asia-Pacific Fishery Commission
Food and Agriculture Organization of the United Nations
Regional Office for Asia and the Pacific
Bangkok, Thailand, 1997

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Opinions expressed in this publication are those of the author(s) alone and do not imply any opinion whatsoever on the part of FAO and APFIC.

NOTICE OF COPYRIGHT

The copyright in this publication is vested in the Food and Agriculture Organization of the United Nations. This publication may not be reproduced, in whole or in part, by any method or process, without written permission from the copyright holder. Applications for such permission with a statement of the purpose and extent of the reproduction desired should be made through and addressed to the Senior Fishery Officer, FAO Regional Office for Asia and the Pacific, Maliwan Mansion, Phra Athit Road, Bangkok 10200, Thailand.

PREPARATION OF THIS DOCUMENT

This Proceedings consists of the Conclusion and Recommendations of and the papers presented at the First Session of the APFIC Working Party on Marine Fisheries held in Bangkok, Thailand, from 13 to 16 May 1997. The papers have been edited by M. Devaraj of the Central Marine Fisheries Research Institute, Cochin, India, and P. Martosubroto of the Fishery Resources Division,Fisheries Department, FAO, Rome,

Devaraj, M., and P. Martosubroto (Eds). 1997.
Small Pelagic Resources and their Fisheries in the Asia-Pacific region. Proceedings of the APFIC Working Party on Marine Fisheries, First Session, 13 - 16 May 1997, Bangkok, Thailand. RAP Publication 1997/31, 445 p.

ABSTRACT

The publication contains the report of and the papers on small pelagic resources and their fisheries presented at the First Session of the APFIC Working Party on Marine Fisheries held in Bangkok, Thailand, 13 - 16 May 1997. The first section contains review on small pelagic resources and their fisheries in the Asia-Pacific region and the conclusion and recommendations of the Working Party, while the second section contains 11 papers presented and discussed at the Session. The third section are additional reports provided by the scientists of the Central Marine Fisheries Research Institute in Cochin, India, to fill the gap relevant to issues addressed, especially those related to environmental factors and future collaborative activities.

Distribution:

Participants at the Meeting
Members of the Asia-Pacific Fishery Commission (APFIC)
FAO Fisheries Department
Fishery Officers in FAO Regional Offices

PREFACE

The APFIC Working Party on Marine Fisheries convened its First Session at the FAO Regional Office for Asia and the Pacific in Bangkok, Thailand, 13 to 16 May 1997, to address issues concerning small pelagic resources and their fisheries in the Asia-Pacific region. The Session was attended by its members from Australia, China, India, Indonesia, Malaysia, Philippines, Sri Lanka and Thailand, as well as representatives from Japan and the Southeast Asian Fisheries Development Center (SEAFDEC). The list of participants appears in Appendix A.

The Working Party discussed various issues confronting the small pelagic fisheries including issues relating to biological and oceanographic studies, problems associated with stock identification and assessment as well as issues confronting the management of the fisheries. Country papers presented at the Session formed the main source of the discussion upon which conclusion and recommendations were formulated.

It is widely known that the small pelagic resources are sensitive to environmental changes. Trend of landings of the Japanese pilchard (*Sardinops melanostictus*) showed a clear fluctuation in the last decade where the catch had declined since 1988 and dropped to a low level in 1995. It was believed that such fluctuation was very much related to the environmental changes occuring in the Northwest Pacific Ocean. The presence of Dr. Andrew Bakun, an oceanographer who has dealt with global environmental changes, and his presentation at the Session regarding the impact of global environmental changes on the small pelagic fisheries in various regions provided a general understanding on the potential impacts of local and global environmental variations on the well being of the small pelagic resources.

The Working Party noted the paucity of information on environmental aspects especially in the Southeast Asian countries. However, an enormous amount of information and data relating to the oceanographic features of the northern Indian Ocean are available in the Central Marine Fisheries Research Institute (CMFRI) in Cochin, India. The Indian participant, Dr. M. Devaraj who is also the Director of the Institute, agreed to provide such information through a review paper on the matter to complement the papers presented at the Session. Working closely with Dr. Devaraj, several scientists of CMFRI subsequently contributed additional papers which appear in Section III of the Proceedings. These papers addressed environmental aspects of the northern Indian Ocean, common issues in the assessment of tropical, short-lived and multispecies fisheries and their consequences in the management decision.

Unlike the oceanographic data from the northern Indian Ocean which are available in one country, those from the South China Sea region are scattered in various institutions in many countries which prevents one from conducting a relatively quick analysis that can be included in the current proceedings. Such a review, hopefully, could be presented in future session of the Working Party.

The editors acknowledge the contributions of members of the Working Party and additional information supplied by them after the Session. Special appreciation goes to staff of the CMFRI who contributed papers and provided secretarial assistance as well as facilitated endless communications with the co-editor during the finalization of the editing process. Last but not the least, the editors are grateful to the APFIC Secretariat, especially to Dr. Veravat Hongskul and Ms. P. David, in organizing the Session and their continued support until the final publication of the proceedings.

The Editors

CONTENTS

	Page
SECTION I:	
Review of the Small Pelagic Resources and their Exploitation in the Asia-Pacific Region (P. Martosubroto)	1-16
A Comparative Account of the Small Pelagic Fisheries in the APFIC Region (M. Devaraj and E. Vivekanandan)	17-61
Conclusion and Recommendations of the Workshop	62-65
Appendix A: List of participants	66-68
SECTION II:	
Small Pelagic Resources in Australia (C. O'Brien)	69-72
Review of the Small Pelagic Resources and their Fisheries in the Chinese Waters (Q. Tang, X., L. Tong, Jin, F. Li, W. Jiang and X. Liang)	73-90
Status, Prospects and Management of Small Pelagic Fisheries in India (M. Devaraj, K.N. Kurup, N.G. K. Pillai, K. Balan, E. Vivekanandan and R. Sathiadhas)	91-198
Review of Small Pelagic Fisheries of Indonesia (J. Widodo)	199-226
Review of the Small Pelagic Resources and their Fisheries in Japan (T. Wada)	227-243
Small Pelagic Fish Resources and their Fisheries in Malaysia (Phaik-Ean Chee)	244-258
Review of the Philippine Small Pelagic Resources and their Fisheries (R. Calvelo)	259-299
Review of the Small Pelagic Fisheries of Sri Lanka (P. Dayaratne)	300-336
Review of the Small Pelagic Resources and their Fisheries in the Gulf of Thailand (S. Chullasorn)	337-364
Small Pelagic Fisheries in the South China Sea (H. Yanagawa)	365-380

SECTION III:

Fisheries Environment in the APFIC Region with Particular Emphasis on the Northern Indian Ocean (V.N. Pillai, M. Devaraj, and E. Vivekanandan)	381-424
Stock Assessment Implications and Management Options for the Small Pelagics in the APFIC Region (M. Srinath and M. Devaraj)	425-436
Regional Cooperation for Managing Marine Fish Stocks in the APFIC Region (M. Devaraj and E. Vivekanandan)	437-445

SECTION I

REVIEW OF THE SMALL PELAGIC RESOURCES AND THEIR EXPLOITATION IN THE ASIA-PACIFIC REGION

by

Purwito Martosubroto
Marine Resources Service, Fishery Resources Division
Fisheries Department, FAO, Rome, Italy

Abstract

The total landings of the small pelagics in the APFIC region have been declining since 1988 from 13.1 million mt to 12.7 million mt in 1995 at the rate of 6% in 7 years. The catches in Japan declined from 6.3 million mt in 1988 to 2.4 million mt in 1995 due to decline in the Japanese sardine landings. China has emerged as the world leader in fish production. The catches of the Indian oil sardine fluctuated widely along the Indian southwest coast. This is also true with some of the major small pelagics in the Asia-Pacific region. It is recommended that the assessment of the small pelagic stocks in the region should take into account both fishing effort and environmental data.

INTRODUCTION

Among the twenty member states of the APFIC (Australia, Bangladesh, Cambodia, China, France, India, Indonesia, Japan, Korea Republic, Malaysia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand, U.K., U.S.A. and Vietnam), only Nepal is landlocked. This review deals with the small pelagic resources in the Indian Ocean (FAO Fishing Areas 51 and 57) and in the Pacific Ocean (Areas 61 and 71) where most of the APFIC member states had been fishing (Fig. 1), and the catches by the APFIC member states beyond these areas were excluded.

The small pelagic resources defined here include those species belonging to the ISCCAAP groups: jacks, mullet, sauries (group 34), herrings, sardines, anchovies (35), mackerels, snoeks, cutlassfish (37), some members of tuna groups (36) especially the seerfishes (*Scomberomorus* spp.) and small tunas (*Auxis* spp., *Euthynus* spp. and *Katsuwonus pelamis*). The fisheries statistics of Cambodia, Myanmar and Vietnam and to a limited extent also of Bangladesh, which were not detailed enough to allow proper breakdown into species groups, posed a constraint in this review. However, on the basis of the catches in the neighbouring states (of these four states) where the small pelagic catches constituted about 35% of the total catch, the small pelagic catches of these four countries were derived. Therefore, detailed analysis on the basis of species groups for these countries was not possible.

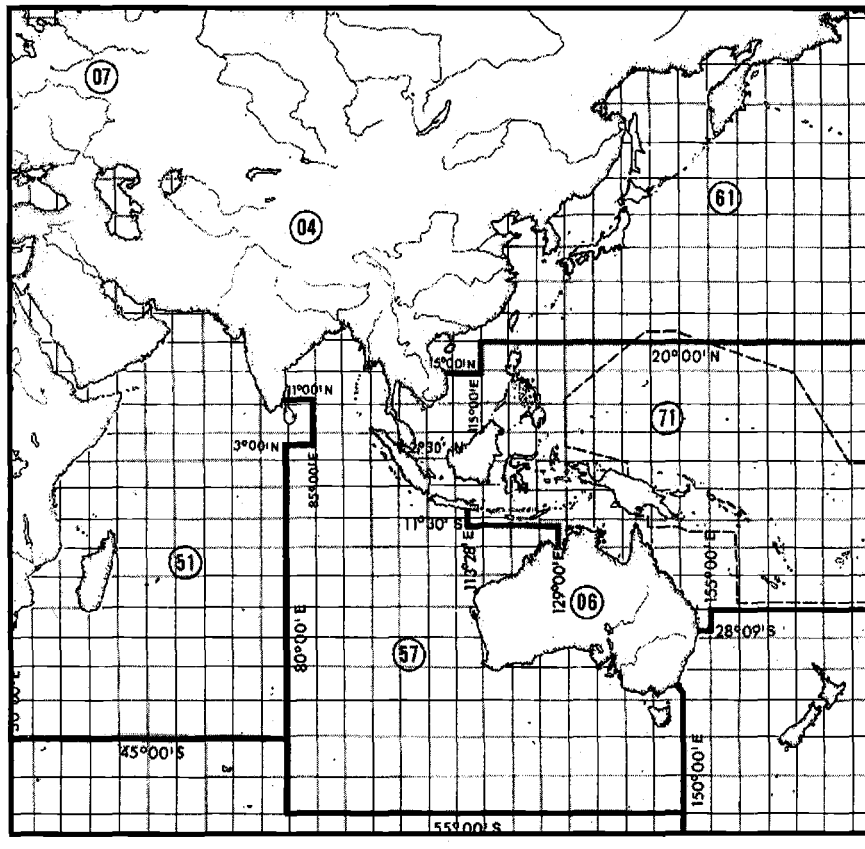


Fig. 1. Geographical boundaries of FAO statistical areas.

The small pelagic resources defined here include those species belonging to the ISCCAAP groups: jacks, mullet, sauries (group 34), herrings, sardines, anchovies (35), mackerels, snoeks, cutlassfish (37), some members of tuna groups (36) especially the seerfishes (*Scomberomorus* spp.) and small tunas (*Auxis* spp., *Euthynus* spp. and *Katsuwonus pelamis*). The fisheries statistics of Cambodia, Myanmar and Vietnam and to a limited extent also of Bangladesh, which were not detailed enough to allow proper breakdown into species groups, posed a constraint in this review. However, on the basis of the catches in the neighbouring states (of these four states) where the small pelagic catches constituted about 35% of the total catch, the small pelagic catches of these four countries were derived. Therefore, detailed analysis on the basis of species groups for these countries was not possible.

The trends in the landings of the small pelagics in the APFIC region (fishing areas 51, 57, 61 & 71) indicate a continuing increase since 1950 (Fig. 2), decline in the last part of the 1980's from 13.1 million mt in 1988 to 12.9 million mt in 1990 and a second drop to 12.1 million mt in 1992 from 12.9 million mt in 1991. A slow increase occurred in the following years with a record of 12.7 million mt in 1995.

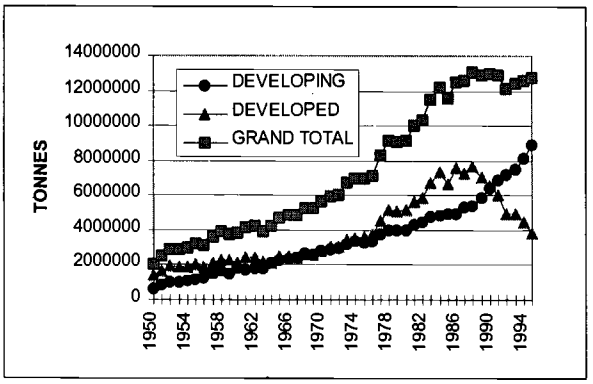


Fig. 2. Trends in the landings of the small pelagics in the APFIC member states

The main developed member states in the APFIC fishing region are Australia, Japan and to a limited extent also France and USA whose fleets fished for tuna in the respective Western Indian Ocean and Western Central Pacific. The share of the catches of the developing states had surpassed those of the developed states in 1990 and continued ever since. Of the 12.7 million mt of catches in 1995, 8.9 million mt or 70% was contributed by the fourteen developing states. The decline in the total small pelagic catches in the region was due to the drop in the catches in Japan from 6.3 million mt in 1988 to only 2.4 million mt in 1995. China surpassed Japan for the first time in 1995 with a total catch of 2.8 million mt. Indonesia ranked third with a catch of 1.3 million mt, while the rest of the member countries of the APFIC contributed catches of less than a million tonnes each.

WESTERN INDIAN OCEAN (AREA 51)

The total landings of the small pelagics in the Western Indian Ocean reched 1 million mt in 1992, but slightly dropped to 959 000 mt in 1995. India, Pakistan and Sri Lanka are the three member states of the APFIC bordering the Western Indian Ocean and their catches in 1995 contributed 94% to the total small pelagic landing in this area (Fig. 3). The rest were from France (5%), Japan (0.1%) and Korea Republic (0.5%). India had been in the lead and its landing contributed 64% to the total, followed by Pakistan 20% and Sri Lanka 10%, while the rest were from the non-APFIC member states.

In terms of the ISCCAAP groups, the herrings and sardines group (group 35) had been dominant in the catch, followed by the mackerels (group 37) and the jacks (group 34). India had been leading in the landings of the sardines (*Sardinella* spp.), but unfortunately the landings of the sardines had declined recently (Fig. 4). The peak landing of 250 000 mt occurred in 1983, but dropped to the lowest of 26 000 mt in 1995, when it was surpassed by Pakistan (55 000 mt).

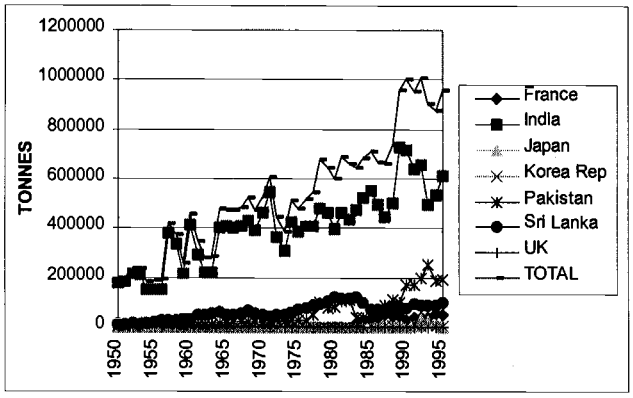


Fig. 3. Trend in the landings of the small pelagics in the APFIC member states in the Western Indian Ocean.

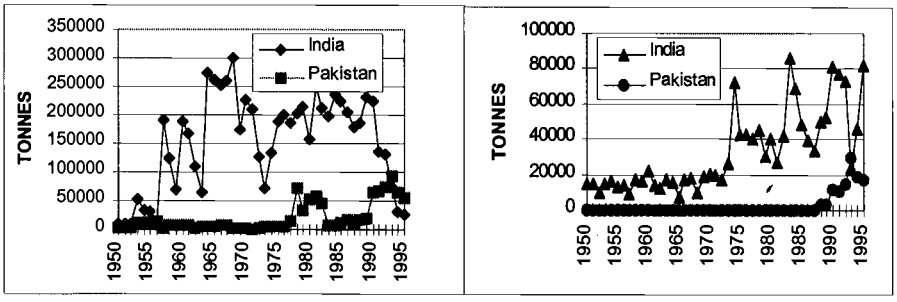


Fig. 4. Trends in the landings of the sardines (*Sardinella* spp., left) and anchovies (right) in the APFIC member states in the Western Indian Ocean.

The landings of the anchovies fluctuated significantly in India, which contributed the maximum to the anchovy landings in the APFIC area (Fig. 4, right). The Indian landing peaked at 85 000 mt in 1983, went down to 31 000 mt in 1987, raised again to 80 000 mt in 1990 and went down to 23 000 mt before finally increasing to 81 000 mt in 1995.

The fluctuations in the landings were quite significant in the case of the cutlassfish (*Trichiurus* spp., see Fig.5) and pomfrets (*Pampus* spp. and *Formio niger*)also. The Indian landings of the cutlassfish peaked at 53 000 mt in 1985, fluctuated thereafter and finally dropped to 24 000 mt in 1995. In the case of the pomfrets, the peak of 41 000 mt occurred in 1974, but fluctuated thereafter until it reached down to 28 000 mt in 1995.

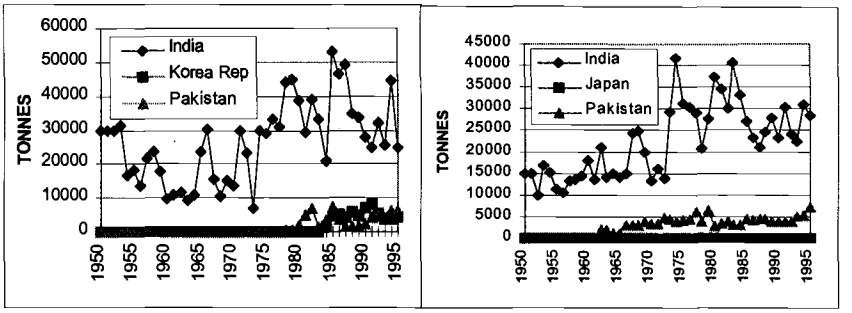


Fig. 5. Trends in the landings of the cutlassfish (*Trichiurus* spp., left) and pomfrets (right) in the APFIC member states in the Western Indian Ocean

In the case of the short mackerels (*Rastrelliger* spp.) India also dominated the catch in the region (Fig. 6). The catch fluctuated very widely, peaking in 1971 at 200 000 mt which dropped down to as low as 24 000 mt in 1974, raised again with various fluctuations and finally reached 160 000 mt in 1995. The Japanese fleet recorded a catch of only 127 mt in 1977.

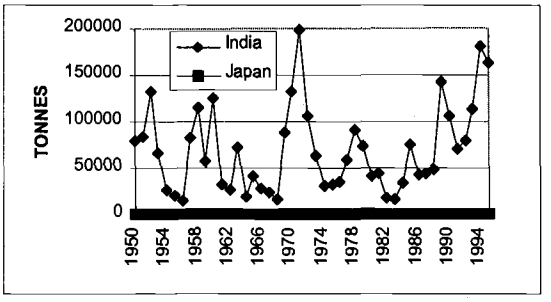


Fig. 6. Trends in the landings of the short mackerels (*Rastrelliger* spp.) in the APFIC member states in the Western Indian Ocean.

The domination of Sri Lanka in the landings of the small tunas was taken over by India and France beginning in the early 1980's with the peak of Indian landing in 1989 at 51 000 mt while France attained the peak of 55 000 mt in 1994. All countries experienced lower catches in 1995 than a year earlier (Fig. 7).

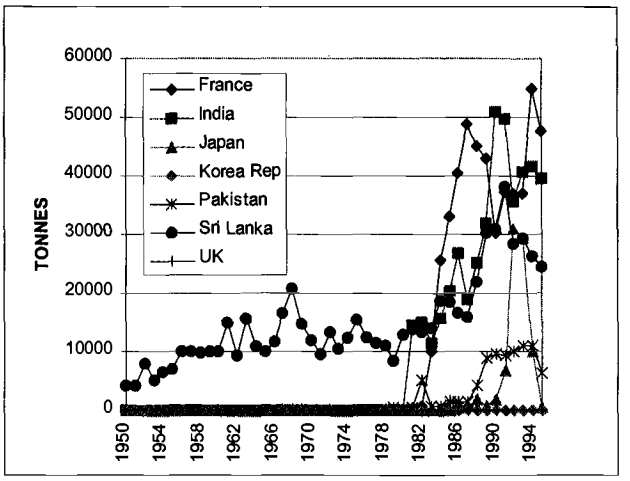


Fig. 7. Trends in the landings of the small tunas in the APFIC member states in the Western Indian Ocean.

EASTERN INDIAN OCEAN (AREA 57)

In the Eastern Indian Ocean (Fishing Area 57), the small pelagic catches in 1995 amounted to 1.1 million mt (Fig. 8), mostly contributed by Indonesia (28%), Thailand (26.2%), India (25.8%) and Malaysia (15.8%). The landings continued to increase since 1950 with much faster growth rate in the last two decades. Although a late comer, Thailand's catches increased much faster than in the other countries in the last decade.

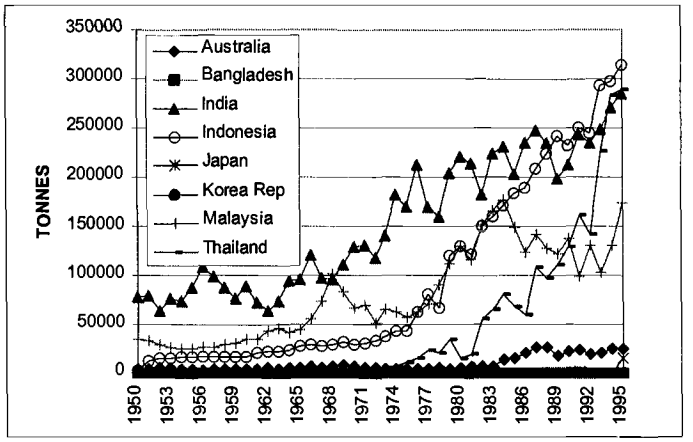


Fig. 8. Trends in the landings of the small pelagics in the APFIC member states in the Eastern Indian Ocean.

Contrary to the Western Indian Ocean, the landings of the herrings (group 35), jacks (34) and mackerels (37) were of somewhat similar quantity although the landings of the herrings were a bit higher (Fig. 9). The landings were 320 000 mt for the herrings, 307 000 mt for the mackerels and 303 000 mt for the jacks.

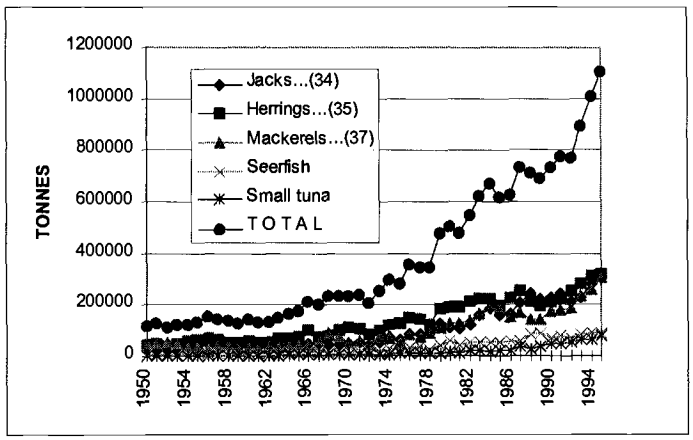


Fig. 9. Trends in the landings of the small pelagics in the APFIC member states in the Eastern Indian Ocean.

The anchovies and the sardines are important and contributed 142 000 mt and 124 000 mt respectively in 1995 to the catches in the region. Thailand, Malaysia, Indonesia and India dominated the anchovy catches, while India, Indonesia and Thailand dominated the sardine landings in this area (Fig. 10). Thailand's catches showed a spectacular increase from less than 1 000 mt in 1990 to 68 000 mt in 1995, a spectacular 67 fold increase. The presence of light purseseines from the Gulf of Thailand contributed to the increase (Chullasorn, pets. com.).

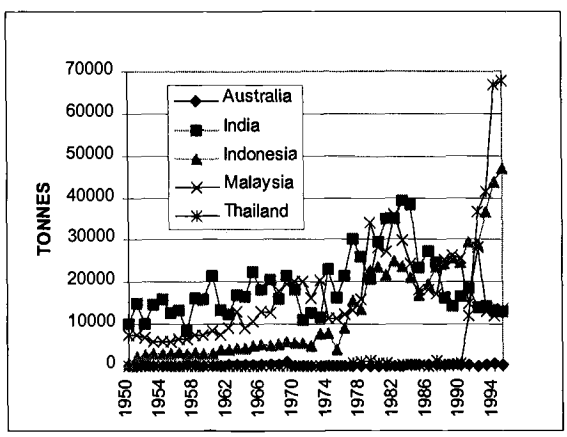


Fig. 10. Trends in the landings of the anchovies in the APFIC member states in the Eastern Indian Ocean.

The landings of the sardines (*Sardinella* spp.) showed an interesting phenomenon where the catches showed an abrupt fivefold increase in India from less than 10 000 mt in 1974 to almost 60 000 mt in 1975, which made India the main producer ever since (Fig. 11). The dominant species in the catches was the oil sardine, *Sardinella longiceps*. The fluctuations in the catches occur in India roughly in three to four year periods.

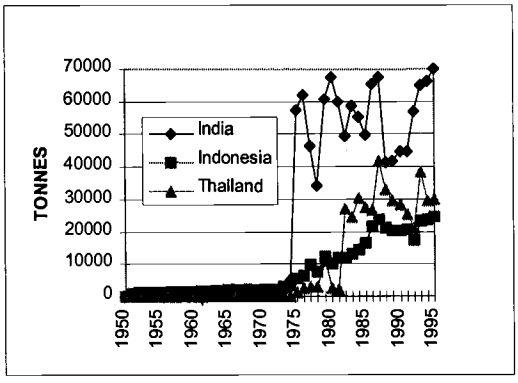


Fig. 11. Trends in the landings of the sardines (*Sardinella* spp.) in the APFIC member states in the Eastern Indian Ocean.

Among the landings of the mackerels group (37), the contribution of the short mackerels (*Rastrelliger* spp.) was outstanding, with the catch in 1995 amounting to 257 000 mt (Fig. 12). The spectacular increase of 68% in the last two years was demonstrated by Malaysia whose catch in 1995 amounted to 100 000 mt. Thailand, Indonesia and India ranked second, third and fourth behind Malaysia. The catch in Malaysia seems to indicate three important peaks namely, in 1968, 1984 and possibly 1995 or roughly three cycles with intervals of 8 to 11 years.

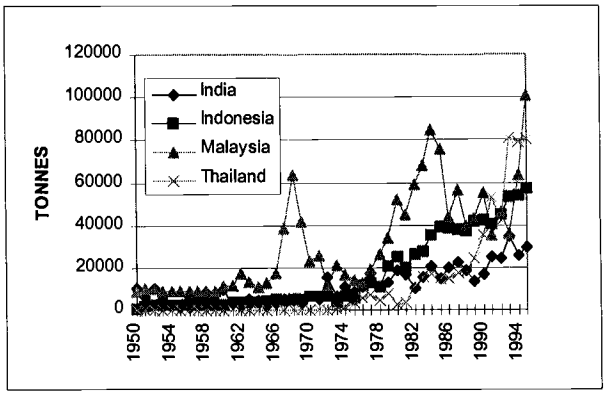


Fig. 12. Trends in the landings of the short mackerels (*Rastrelliger* spp.) in the APFIC member states in the Eastern Indian Ocean.

The landings of the scads (*Decapterus* spp.) demonstrate a sudden increase after 1980 both for Indonesia and Thailand, and a slow increase for Malaysia (Fig. 13). The total landings of the scads in 1995 amounted to 670 000 mt. *Decapterus ruselli* seems to be the main species of scads in this region. It is interesting that the catches of the scads in India which were negligible till the 1980's, began to increase significantly with the advent of the purseseine and ringseine fisheries along the southwest coast (Devaraj *et al.*, 1997, this volume). That this is not reflected in Fig. 13 is due to the fact that the FAO uses the nominal statistics furnished by the goverment of India, which is somewhat different from the data collected by the CMFRI, Cochin, India.

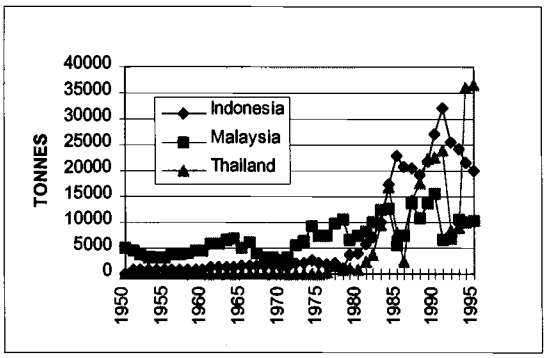


Fig. 13. Trends in the landings of the round scads (*Decapterus* spp.) in the APFIC member states in the Eastern Indian Ocean.

The seerfish (*Scomberomorus* spp.) are another important group in the region, with Indonesia leading the landing since the 1980's, which reached 63 000 mt in 1995, followed by India (19 000 mt), while the other countries landed below 7 000 mt each (Fig. 14). The catch by distant water fishing fleets (Japan and Korea Republic) had been diminishing since the later part of the1980's. In the case of the small tunas (Fig. 15), the landings fluctuated since the 1980's, with Indonesia, India and Thailand dominating the fishery. Indonesia landed 24 000 mt in 1995, followed by India 19 000 mt and Thailand 17 000 mt. Surprisingly, the Japanese catch which was less than 1 000 mt per year in the last decade increased in 1995 to 15 000 mt.

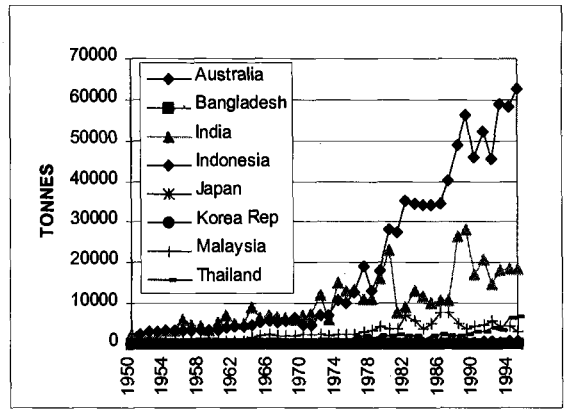


Fig. 14. Trends in the landings of the seerfish (*Scomberomorus* spp.) in the APFIC member states in the Eastern Indian Ocean.

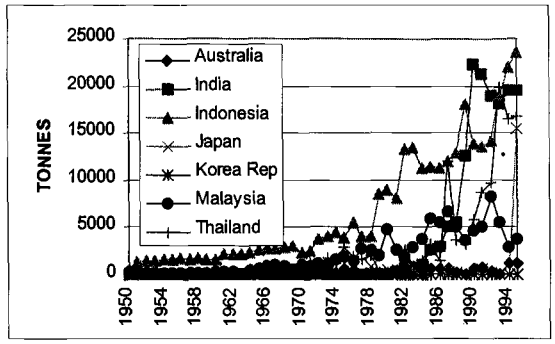


Fig. 15. Trends in the landings of the small tunas in the APFIC member states in the Eastern Indian Ocean.

WESTERN CENTRAL PACIFIC (AREA 71)

The small pelagic landings by the APFIC member states in this region were much higher than in the Western and Eastern Indian Ocean as they amounted to 3.8 million mt in 1995, with Indonesia leading the catches (37%), followed by the Philippines (30%) and Thailand (15%) (Fig. 16).

In terms of the ISSCAAP groups, the contribution by the jacks group (30%) was higher than that by the herrings (28%) and the mackerels (11%) (Fig. 17).

The anchovies and the sardines were the main groups of herrings (35). The anchovy landings (Fig. 17, right) were mainly contributed by Indonesia, Thailand and the Philippines, which accounted for 106 000 mt, 105 000 mt and 72 000 mt respectively in 1995. The fluctuations in the catches were clearly evident from the data for the Philippines and Thailand. The peak catch in the Philippines was 125 000 mt in 1988, but was followed by a continuous decrease until 1995. The catch in Thailand was very low in 1987, but increased up to 1993, before declining again the following years. It is interesting to note that while *Stolephorus* spp. were a

dominant fishery in this region, the catches in the Eastern Indian Ocean in the last three years have been surpassed by the catches of other groups of anchovies.

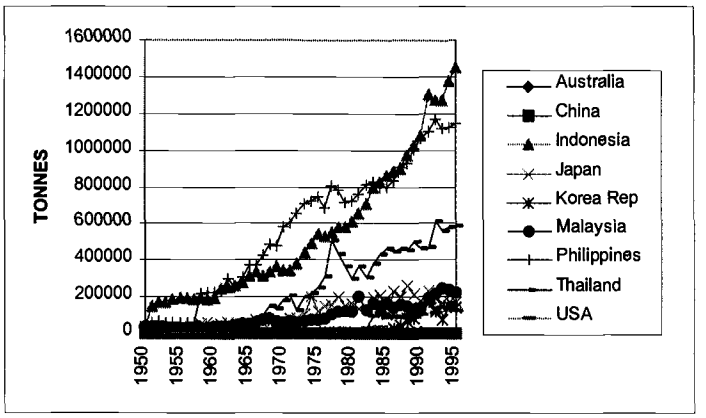


Fig. 16. Trends in the landings of the small pelagics in the APFIC member states in the Western Central Pacific.

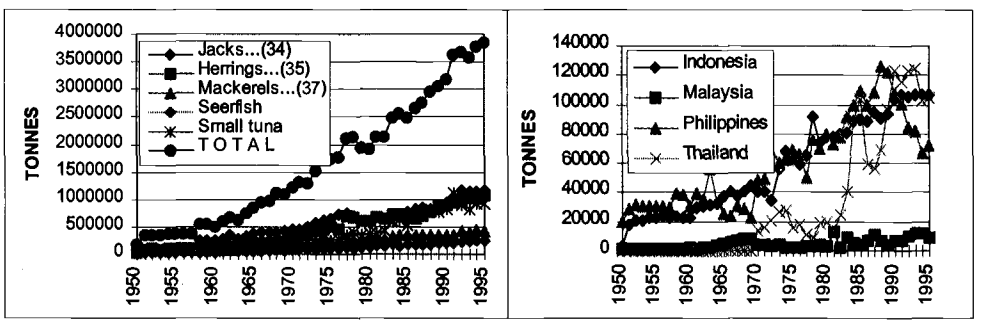


Fig. 17. Trends in the landings of the major species groups (left) and anchovies (right) in the APFIC member states in the Western Central Pacific.

In the case of the sardines also, Indonesia, the Philippines and Thailand were the main contributors, accounting for 287 000 mt, 270 000 mt and 127 000 mt respectively (Fig. 18). The landings in the Philippines show a sharp increase in the last 6 years, but the drop in the catch in 1986 in these three countries, suggests the influence of environmental factors. The landings by Japan had been negligible.

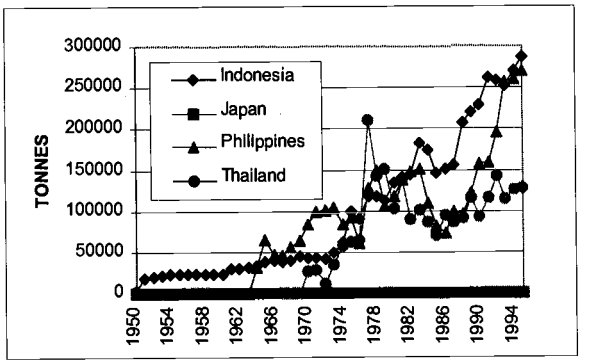


Fig. 18. Trends in the landings of the sardines (*Sardinella* spp.) in the APFIC member states in the Western Central Pacific.

The short mackerel (*Rastrelliger* spp.) catches in the region came largely from Thailand prior to 1991, when Indonesia surpassed Thailand ever since (Fig. 19). The catch in Indonesia reached 143 000 mt in 1995 and in Thailand 135 000 mt, which was followed by the Philippines and Malaysia. The catch in Thailand showed three significant peaks, namely, in 1968, 1979 and 1984. Less sgnificant peaks were seen in the catches in Malaysia in 1968, 1981 and 1993.

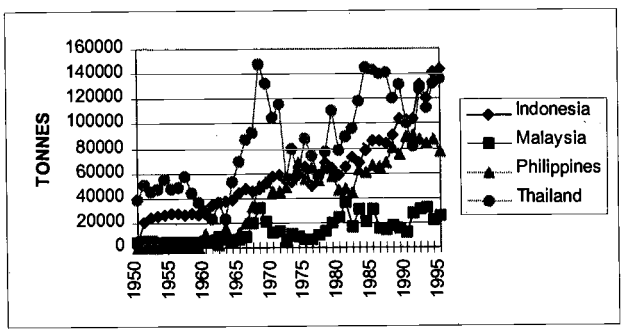


Fig. 19. Trends in the landings of the short mackerels (*Rastrelliger* spp.) in the APFIC member states in the Western Central Pacific.

The scads (*Decapterus* spp.) production in the region reached 560 000 mt in 1995 (Fig. 20), with the main contribution by the Philippines(47%), followed by Indonesia (37%), Malaysia(8%) and Thailand (7%). The Philippines' catches had been ahead since 1958 and surpassed only in 1995 by Indonesia. The Thai catches peaked in 1977, but dropped afterwards.

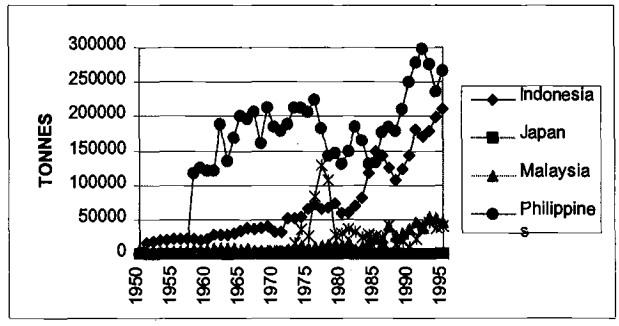


Fig. 20. Trends in the landings of the roundscads (*Decapterus* spp.) in the APFIC member states in the Western Central Pacific.

In the case of the seerfish (Fig. 21), the landings in Indonesia were always far ahead of the landings in the other states. Its landings in 1995 amounted to 207 000 mt, while in the other countries the catch was less than 15 000 mt each.

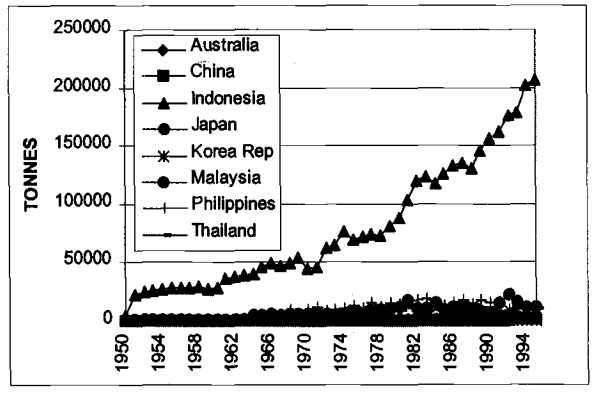


Fig. 21. Trends in the landings of the seerfish (*Scomberomorus* spp.) in the APFIC member states in Western Central Pacific.

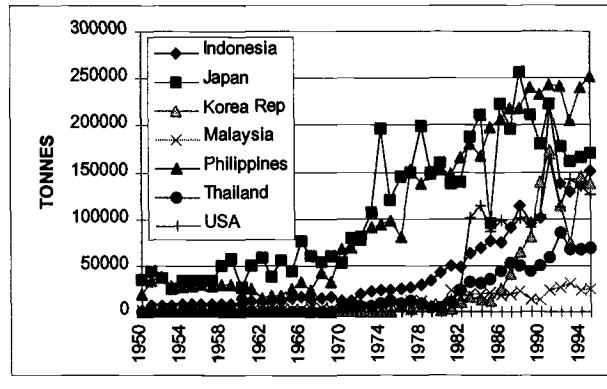


Fig. 22. Trends in the landings of the small tunas in the APFIC member states in the Western Central Pacific.

The Philippines was leading in the catches of the small tunas with 252 000 mt in 1995, followed by Japan 169 000 mt, Indonesia 151 000 mt, Korea Republic 138 000 mt, U.S.A 126 000 mt and Thailand 69 000 mt (Fig. 22).

NORTHWEST PACIFIC (AREA 61)

The small pelagic catches in the APFIC member states in this region declined from its peak of 8.2 million mt in 1988 to 6.3 million mt in 1995 as a result of the decline in the catches in Japan (Fig. 23). The increase in the catches in China was not able to compensate for the decline in the Japanese catch, since her catch was only a bit higher than the Japanese catch in 1995. The collapse of the pilchard (*Sardinops melanoptictus*) in the Japanese catch from 4.5 million mt in 1986 to 661 000 mt in 1995 was the main reason for the decline of the small pelagic catch in this region. China and Korea Republic contributed only 58 000 mt and 32 000 mt respectively.

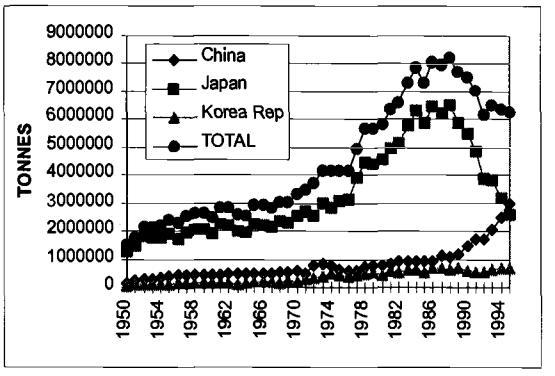


Fig. 23. Trends in the landings of the small pelagics in the APFIC member states in the Northwest Pacific.

Another declining trend in the catches was shown by the chub mackerels (*Scomber* spp., Fig. 24). The catch went down since the Japanese peak landings of 1.7 million mt in 1978 to as low as 469 000 mt in 1995. The landings in China and Korea Republic remained always below the Japanese catches. The horse mackerels (*Trachurus* spp.) declined in Japan from their peak of 518 000 mt in 1965 to as low as 60 000 mt in 1980, although the catches revived again and reached 310 000 mt in 1995 (Fig. 24, right).

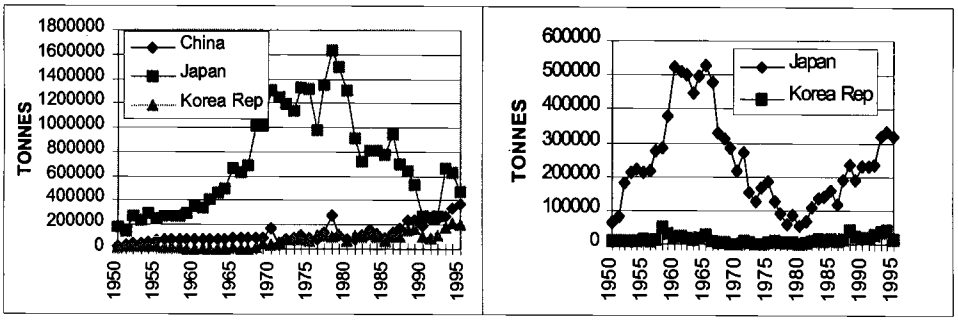


Fig. 24. Trends in the landings of the chub mackerels (*Scomber* spp., left) and horse mackerels (*Trachurus* spp., right) in the APFIC member states in the Northwest Pacific.

The small pelagic catches in China demonstrated an increasing trend, especially in the case of the anchovy, which landed 489 000 mt in 1995 as against just 54 000 mt in 1990 (Fig. 25). Similar trends happened in the catches of the round scads (*Decapterus* spp.) which in the last three years increased from 261 000 mt to 515 000 mt in 1995(Fig. 25, right). A spectacular increasing trend in the catches in China was demonstrated by the cutlassfish (*Trichiurus* spp.), which increased about three folds in the last 8 years, from 366 000 mt in 1988 to 1.0 million mt in 1995 (Fig. 26).

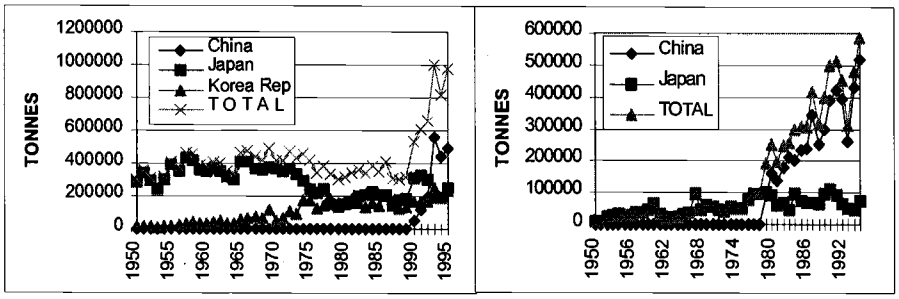


Fig. 25. Trends in the landings of the anchovies (left) and round scads (*Decapterus* spp., right) in the APFIC member states in the Northwest Pacific.

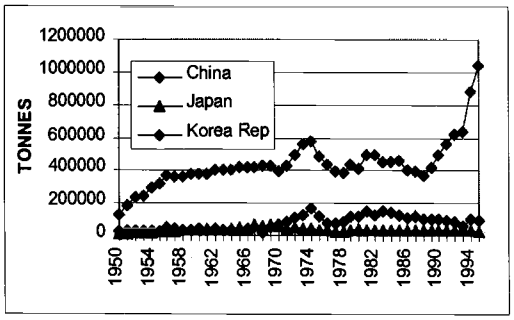


Fig. 26. Trends in the landings of the cutlassfish (*Trichiurus* spp.) in the APFIC member states in the Northwest Pacific.

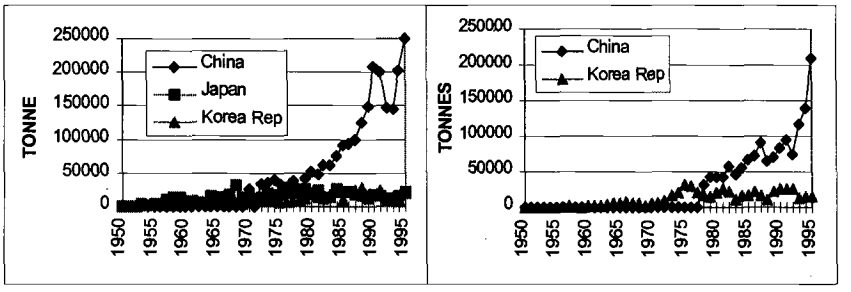


Fig. 27. Trends in the landings of the seerfish (*Scomberomorus* spp., left) and pomfrets (right) in the APFIC member states in the Northwest Pacific.

The seerfish (*Scomberomorus* spp.) and pomfrets (*Pampus* spp. and *Formio niger*) are the other groups that showed increasing trend in the last decade (Fig. 27). The catches of the seerfish doubled from 125 000 mt in 1988 to 250 000 mt in 1995, while that of the pomfrets increased by more than three folds from 64 000 mt to 209 000 mt in the same period.

CONCLUSIONS

Despite the general increasing trends in the catches of the small pelagics in the APFIC region in the last 45 years (1950-1995), some resources exhibited declining trends. Among those which tended to decline, the decline was very conspicuous in the case of the Japanese pilchard. Good time series of information on the level of fishing and environmental parameters available in Japan provides a strong basis to believe that such a drastic decline is related to the longterm environmental changes.

In the absence of fishing effort data and the lack of environment information in the APFIC region (with the exception of Japan), it is difficult to be certain whether the declines in the resources relate to only one of the above factors or both. Although the tropical environment is generally less variable than the temperate environment, understanding the dynamics of the tropical environment becomes an important factor in the assessment of the small pelagic resources. It is recommended that future assessment of the small pelagic resources in the region should take into account the important environmental parameters.

REFERENCES

FAO. 1995. Fishery Statistics. Catches and Landings. Vol. 80: 713p.

FAO. 1997. FISHSTAT Software. FAO/FIDI.

A COMPARATIVE ACCOUNT OF THE SMALL PELAGIC FISHERIES IN THE APFIC REGION

by

M. Devaraj and E. Vivekanandan
Central Marine Fisheries Research Institute
Cochin-682014, India

Abstract

The production of the small pelagics in the APFIC region was 1.2 mt/sq. km during 1995. Among the four areas in the region, the small pelagics have registered (i) the maximum annual fluctuations in the western Indian Ocean; (ii) the highest increase during the past two decades along the west coast of Thailand in the eastern Indian Ocean; and (iii) the consistent decline in the landings during the past one decade along the Japanese coast in the northwest Pacific Ocean. The short mackerels emerged as the largest fishery in the APFIC region, forming 19.5% of the landings of the small pelagics in 1995. The group consisting of the sardines and the anchovies has shown clear signs of decline during the past one decade in almost the entire region. Most of the small pelagics have unique biological characteristics such as fast growth, short longevity, late maturity, high natural mortality, shoaling behaviour, high fecundity and severe recruitment fluctuations. As many species of the small pelagics undertake migration, collaborative research programmes and close coordination are required among the APFIC countries for the stock assessment of all the major species. The management measures under implementation in these countries have been reviewed, with suggestions for regional cooperation for the management of the stocks of the small pelagics.

INTRODUCTION

The Asia-Pacific Fishery Commission covers four oceanic areas, which have been classified by the FAO as the western Indian Ocean (FAO Statistical Area 51), eastern Indian Ocean (Area 57), northwest Pacific Ocean (Area 61) and western central Pacific Ocean (Area 71). The APFIC region is one of the major producers of marine fish as it contributed 37.5 million mt (44%) to the total world marine fish catch of 84.7 million mt in 1995. The region is quite unique as the world number one fish producer (China), fish exporter (Thailand) and fish importer (Japan) are located in this area. The number of people involved in the fisheries sector in this area is probably the highest in the world, with China and India contributing the maximum. The coastal fisheries sector in this region could develop rapidly through the last 30 years because of the favourable institutional, environmental, socioeconomic, biological and technological factors. This region has also experienced one of the most dramatic rises and falls of a fishery, that of the Japanese sardine, twice in this century.

All the countries in this region have traditionally harvested the small pelagics in their coastal waters and a large population of fishermen are dependent on these resources. However, the history and the current status of the fisheries for the small

pelagics vary greatly from country to country. For instance, the purseseines were introduced in the Gulf of Thailand in the 1920s (Chinese purseseines), in the Philippine waters in the 1940s, in the Java Sea and in the Arabian Sea (southwest coast of India) in the early 1970s; and, there are regions such as the Bay of Bengal (east coast of India), where the purseseines have not been introduced so far. Due to the differences in the pace of development of fisheries, many resources of the coastal waters in this region are under different phases of exploitation. Despite the large volume of information collected in recent years on the fisheries and the important biological features of the exploited stocks, explicit assessment has scarcely been made for many of the stocks, resulting in uncertainties in the formulation of appropriate policies. However, there are several indications suggesting that many stocks of small pelagics are being heavily exploited in recent years. It is being increasingly recognized that there is a need for proper management of fisheries for sustaining the catches rather than increasing them. Under these circumstances, many countries have established several regulatory measures for the conservation of the resources as well as for the alleviation of sectoral conflicts among the fishermen. While a few countries have partially succeeded, many others have failed in their attempts and the fisheries remain largely as open access properties especially in the western Indian Ocean, eastern Indian Ocean and western central Pacific Ocean. Considering the migratory nature of the small pelagics, it is evident that proper assessment and rational utilization of shared stocks are possible only with international cooperation.

The areas in the APFIC region vary greatly in their physical and environmental conditions. The region encompasses typical tropical areas (for e.g., the Persian Gulf, Arabian Sea, Yellow Sea, Gulf of Thailand) and the near-polar regions (for e.g., southeast of Africa, Okhotsk Sea, western Bering Sea). It also encompasses distinct oceanic areas of continuous upwelling and extremely high productive continental shelf (southwest coast of India, Gulf of Thailand, South China Sea), areas of narrow continental shelf with highly productive fishery resources (western Bering Sea, southeast Kamchatka Peninsula), areas of low productivity (coastal East Africa from Somalia to Mozambique), thousands of islands that have their own characteristic oceanic or near-oceanic features (Philippines, Indonesia, Seychelles, Mauritius, Comoros). All these factors determine the distribution, abundance and characteristics of the fish stocks. The environmental factors in these vastly diverse ecosystems govern the stock fluctuations, especially those of the small pelagics such as the Japanese sardine and Indian oil sardine. These factors and their influence on the fisheries have not been understood adequately. A critical evaluation of the long-term trends and fluctuations in the environmental conditions and their influence on the small pelagics is very vital to the sustained growth of these fisheries.

In addition to the climatic differences, there are also significant differences among the countries in terms of the GDP, importance of fisheries to their economies and other diversities such as ethnic, cultural, political, religious and social background. Despite these diversities, there are a number of basic similarities in the fisheries for the small pelagics. The complex nature of the fisheries, generally declining fish stocks, uncertainties in production, difficulties in enforcing

management options and dependence of a huge human population on the small pelagics for employment and for food are some of the common problems in the APFIC region. This paper presents a compilation of the available information on these aspects in some of the APFIC member countries. For evaluating the current status of the small pelagic fisheries, the papers on this subject relating to the APFIC region (Martosubroto, 1997), India (Devaraj *et. al.*, 1997), Sri Lanka (Dayaratne, 1997), Australia (O'Brien, 1997), Gulf of Thailand (Chullasorn, 1997), Malaysia (Chee, 1997), Indonesia (Widodo, 1997), Philippines (Calvelo, 1997), South China Sea (Yanagawa, 1997), China (Tang *et. al.*, 1997) and Japan (Wada, 1997), which were presented in the workshop, have been primarily referred to, in addition to those by the FAO (1995; 1996).

PRODUCTION TRENDS IN THE SMALL PELAGICS IN THE APFIC AREA

During 1950-1995, the global marine fish production increased from 18.6 millionmtto 84.7 million mt, an increase of about 4.5 times. During this period, the marine fish production in the APFIC region increased from 6.35 million mt to 37.45 million mt (Table 1), an increase of nearly 6 times. Consequently, the contribution of marine fish production in the APFIC region to the global production increased from 34% in 1950 to 45% in 1995. The landings of the small pelagics in the APFIC region increased by 5 times, from 2.19 million mt to 10.95 million mt. The landings of the small pelagics increased almost consistently during 1950-1988, but gradually decreased from 11.60 million mt in 1988 to 10.95 million mt in 1995, a decline of 6% in the 7 year period.

The data on the landings in the four areas of the APFIC region show a fairly large variability among the areas as would be expected due to large differences in the potential yield as a result of features such as upwelling and river run inputs. The landings of the small pelagics ranged from 0.5 mt/sq.km. in the eastern Indian Ocean to 2.2 mt/sq.km in the northwest Pacific Ocean (Table 2). Inspite of the differences in the yield, the landings of the small pelagics in all the areas considerably increased during 1950-1995. There were, of course, periods of stagnations and fluctuations, and short-term and long-term decreases of individual fisheries which were rather unique to specific areas. The increase in the landings of the small pelagics was low, i.e., 3.6 times and 4.2 times in the northwest Pacific and the western Indian Oceans, respectively (Table 1). The increase was comparatively higher in the eastern Indian (9.2 times) and the western central Pacific Oceans (20.4 times). Consequently, the contribution of the northwest Pacific and the western Indian Oceans to the small pelagics production of the four APFIC areas decreased from 77.6% (1950) to 56.6% (1995) and from 11.0% (1950) to 9.1% (1995), respectively (Table 3). The contribution of the eastern Indian and western central Pacific Oceans increased from 5.5% (1950) to 10.1% (1995) and from 5.9% (1950) to 24.2% (1995), respectively. Clearly, the chronicles of marine fisheries as well as the fisheries of the small pelagics in these areas have undergone considerable changes during the four decades.

Western Indian Ocean

The western Indian Ocean encompasses areas of nearly continuous upwelling (off the Oman coast) as well as areas with seasonal, monsoon induced upwelling (off the coast of Iran and Pakistan and the Arabian Sea), which extends to the west coast of India. The Gulf of Aden and the Somali coast are also monsoon-driven upwelling areas that experience seasons of high productivity. The Persian Gulf, a shallow enclosed area, is characterised by warm saline waters which possess certain unique fisheries characteristics. The Red Sea, which is enclosed and has a narrow continental shelf, also has fisheries situations special to that area. The western Indian Ocean has a few small oceanic islands, the Seychelles, Mauritius and the Comoros, with their own characteristic oceanic or near-oceanic fisheries. Further to the south, South Africa has fisheries of temperate and subantarctic nature (FAO, 1996).

The total marine fish production in the western Indian Ocean increased by 6.6 times, from 0.55 million mt in 1950 to 3.65 million mt in 1995; and the production of the small pelagics by 4.2 times, from 0.24 million mt to 1.00 million mt. In other words, the contribution of the small pelagics to the total production decreased from 43.6% to 27.4%. The fisheries for the small pelagics in the western Indian Ocean exhibit the following characteristics, which constitute the major factors underlying the decline in their contribution to the total landings: (i) Unlike the demersal and large pelagic fisheries which registered an almost consistent increase in the landings during 1950-1995, the landings of the small pelagics fluctuated widely. For instance, the landings decreased from 0.56 million mt in 1960 to 0.37 million mt in 1963 and recovered to 0.54 million mt in 1964 itself; the landings increased from 0.56 million mt in 1969 to 0.82 million mt in 1971 and decreased to 0.56 million mt in 1973. Among the four areas of the APFIC, the small pelagics have registered the maximum annual fluctuations in the western Indian Ocean. Catches of the Indian oil sardine, jacks, herrings and short mackerels have fluctuated widely over the last four decades. (ii) The catches of the oil sardine along the southwest coast of the India and the pelagic percomorphs in the Persian Gulf and the Gulf of Oman, where these species form the basis of the most important commercial fisheries, have declined in the 1990s. (iii) In contrast, the catches of the large pelagics have increased steadily since the 1950s, with large increases in the skipjack and yellowfin tuna landings since the early 1980s. (iv) The catches of the demersal species also have increased steadily since 1950, with particularly large increases of the croakers and drums since the early 1980s. (v) Following heavy demand for the penaeid shrimps, the bottom trawl fishery targetted them and the catches of the shrimps increased sharply since the mid 1980s.

Of the 33 countries bordering the western Indian Ocean, India (53%), Pakistan (17%) and Sri Lanka (7%) contributed 77% of the small pelagics landings of the area.

1. *India*

The west coast of India and the Lakshadweep Islands in the Arabian Sea have been classified under the western Indian Ocean and the east coast and the Andaman & Nicobar Islands in the Bay of Bengal under the eastern Indian Ocean. The annual average landings of the small pelagics along the west coast of India increased from 0.20 million mt during 1950-54 to 0.76 million mt during 1991-95 (Table 4). The increase was possible due to the mechanization of the fishing vessels and the introduction of trawlers and synthetic filaments in the 1960s; introduction of purseseiners in the early 1970s; and the motorization of the traditional fishing craft in the 1980s. The Indian mackerel (17.7%), oil sardine and other sardines (13.3%), Bombayduck (12.6%), scads (10.7%), ribbonfishes (10.1%) and anchovies (6.8%) dominated the landings. The three dominant species, viz., the Indian mackerel *Rastrelliger kanagurta* (southwest coast), the Indian oil sardine *Sardinella longiceps*(southwest coast) and the Bombayduck *Harpodon nehereus* (northwest coast) are abundant along the specific areas in the west coast and their landings are the most fluctuating. Several environmental parameters such as the onset and intensity of the southwest monsoon, sunspot activity, variations in the pattern of coastal currents, salinity, dissolved oxygen, sinking of the offshore waters and sea level characterise the nature and intensity of upwelling, which leads to high plankton productivity, and in turn, determines the abundance of the pelagic stocks. The oil sardine fishery is causing concern in recent years as its annual average production, which increased from 0.03 million mt during 1950-54 to 0.23 million mt during 1965-69, consistently declined since then and was 0.12 million mt during 1990-95 along the southwest coast of India (Devaraj *et. al.*, 1997).

The unicorn cod, *Bregmaceros meclellandi* which formed a minor fishery (6880 mt/year) along the northwest coast during 1950-54, ceased to be a fishery any longer. In view of the consistency in the decline of the fishery during the past four decades, the unicorn cod may have to be listed as a vulnerable species and strategies devised to restore the population.

The resources of the small pelagics are exploited by an array of craft and gears. Till the close of the 1970s, shoreseines, boatseines, castnet, *rampani* (large shoreseines) and gillnets were employed in the fisheries for the small pelagics. With the advent of purseseining in the 1970s, the traditional fishing systems began to lose their importance. The situation got further changed in the 1980s with the popularization of the ringseines (mini purseseines), coupled with the steady growth of the motorized fleet (traditional craft with outboard and /or inboard motor). The purseseines and ringseines have almost replaced the *rampanies* (large shoreseines) and boatseines. Presently, the trawls, purseseines and gillnets with specific mesh sizes are operated from mechanized vessels, and ringseines, boatseines and gillnets either from motorized or nonmotorized craft. The mechanized, motorized and nonmotorized vessels contributed 53%, 27% and 20% to the landings of the small pelagics during 1991-95. Unlike most other countries where the purseseiners contributed 75% to the catches of the small pelagics, the 520 purseseiners, which are restricted to the southwest coast, landed < 10% of the small pelagics in the west coast of India. The trawlers, which outnumber the purseseiners by about 40 times,

contributed 20% of the small pelagics. The trawls, which have been modified with a high opening, effectively exploit the pelagic stocks such as the Indian mackerel, jacks, scads and ribbonfishes which undertake diurnal vertical migration. Pelagic or midwater trawls are not operated, as experimental trawling did not yield encouraging results. The ringseines, which are very popular in the motorized sector, landed 0.18 million mt annually during 1991-95, which is a significant growth since the introduction of the gear in the mid 1980s. The ringseines contributed nearly 40% of the oil sardine landings. The jacks, scads and anchovies also have emerged as major fisheries of the ringseines. The ringseines are very efficient as the mesh size is very small (8 to 10mm) and the length of some of the nets is 1 km. Following complaints of mass destruction of juveniles of small pelagics by the ringseines, the operation is banned legally in a few places, but it is not implemented effectively.

1. *Sri Lanka*

The annual catches of the small pelagics increased from 35 000 mt during 1967-68 to 90 000 mt in 1983 mainly due to the motorization of the traditional craft and the introduction of synthetic nylon nets for gillnetting. However, the production dropped in 1984-85 and is presently stagnating at around 70 000 mt for the past one decade mainly due to the civil disturbances in the northern and eastern parts of the island nation. The continental shelf is wider and the fish productivity is higher in the north and east coasts than in the other coasts and more than 45% of the small pelagics were landed in the north and east coasts prior to the civil disturbances.

Sardines constituted about 50% of the landings of the small pelagics, followed by the herrings and the scads. Among the sardines, *S. longiceps, S. sirm, S. jussieu* and *S. fimbriata* were relatively dominant. Until 1980, the main fishing gears engaged in the exploitation of the small pelagics were the beachseines and the gillnets. In the early 1980s, purseseines were introduced and there were 69 purseseiners in 1990. This development led to conflicts between the fishers engaged in beachseining & gillnetting and those engaged in purseseining as all of them exploit the same resource. Following the conflicts, fishing regulations were formulated, which restricted the area of operation of the purseseiners beyond 10-15 km from the coast. In addition to this problem, it has been reported that the catch rate of the purseseiners declined from 185.7 kg/fishing operation (1985) to 52.0 kg/operation (1993) (Dayaratne, 1997)

Eastern Indian Ocean

The eastern Indian Ocean includes the Bay of Bengal in the north, the Andaman Sea and the northern part of the Malacca Straits in the east, and the waters around the west and south of Australia. The main shelf areas include those of the Bays of Bengal and Martaban, and the narrower shelf areas on the western and southern sides of Indonesia and Australia. Most of the fisheries for the small pelagics are concentrated in these shelf areas. The resources range from typical tropical species in the northern part of the area, to temperate species in the waters of the southern latitudes, west and south of Australia (FAO, 1996).

Catches in this area have increased consistently and remarkably during the last four decades (1950-1995). The total capture fisheries landings increased by 12.3 times, from 0.30 million mt (1950) to 3.70 million mt (1995) (Table 1); the landings of the small pelagics increased by 9.2 times, from 0.12 million mt in 1950 and peaked at 1.10 million mt in 1995. The landings of the small pelagics increased significantly in all the countries in this area. The moderate increase from 1950 to the 1970s was followed by a more rapid increase in the last two decades. In India, the production sharply increased from the year 1972, in Indonesia and Malaysia from 1975 and in Thailand, from 1982. Bangladesh is not a major marine fishing nation due to its historic focus on the large freshwater fishery resources. The statistics on fish catches in Bangladesh started only in 1984 and it was recorded that the landings of the small pelagics increased from 55 000 mt in 1984 to 125 000 mt in 1995. Toli shad, an estuarine species, dominate the marine catches. It is only in Australia, the landings, though increasing, were very low (25 000 mt) and formed only about 2% of the small pelagic landings of the eastern Indian Ocean area.

1. *Australia*

The only major fishery for the small pelagics is the pilchard fishery (*Sardinops sagax*) in western Australia. Commercial fishing for the pilchard began in the 1970s and the current catches are about 16 000 mt. The pilchard are exploited using purseseines with 20 mm mesh. It is estimated that the spawning stock biomass is 40 000 mt (O'Brien, 1997). Though there is scope for increasing the landings, the pilchard are not taken seriously as they are considered as low-value and sold as fish bait.

2. *India*

During 1950-1995, the annual landings of the small pelagics in the east coast of India increased by 4 times, from 72 000 mt to 280 000 mt (Table 4). Compared to the west coast, the annual fluctuations were less and the landings consistently increased in the east coast. However, consequent upon very high increases in the landings in other countries in the area such as Thailand and Indonesia, the contribution of India to the small pelagic landings of the eastern Indian Ocean decreased from 60% in 1950 to 26% in 1995.

Unlike the west coast, there is no single species that dominates the fishery. Sardines, Indian mackerel, anchovies and hilsa shad constitute about 50% of the landings. Interestingly, the catches of the Indian oil sardine, which constitute a dominant, highly fluctuating and a consistently declining fishery in the west coast, are continuously on the rise in the east coast since 1985. The annual average landings of the oil sardine were 38 536 mt in the southeast coast during 1991-95, but historically the oil sardine formed only a minor fishery here prior to 1985. The reasons for the increase are not clearly understood, but it seems to be due to (i) the migration of the stock from the west coast following intensive fishing pressure of ringseine operations, and/or (ii)increase in the productivity of the coastal waters of the southeast coast following heavy land discharges of organically rich wastewaters

and likely shifts in the upwelling from the immediately continuous southwest coast (Devaraj *et. al.*, 1997).

Pelagic trawls, purseseines and ringseines are not operated along the east coast of India, as experimental and exploratory fishing indicated that the concentrations of small pelagics are not high enough for commercial exploitation by purseseiners or midwater trawlers. The small pelagics are landed by the trawls and by the conventional small meshed gillnets, bagnets and boatseines operated either from motorized or nonmotorized craft.

3. *Indonesia*

The Indonesian waters are partly in the eastern Indian Ocean and partly in the western central Pacific Ocean. The former includes the southern part of Java, western Sumatra and the adjoining islands. The latter includes a chain of Pacific islands and a chain of islands between Malaysia and Australia. Being the largest archipelagic state in the world, there is a high diversity of fish species. The status of marine fisheries development in Indonesia varies according to the geographical area and the concentration of human population. Hence, the fisheries management measures vary according to the development phase of the fishery.

Of the 1.35 million mt of small pelagics landed in Indonesia in 1995, only 16.7% was from the eastern Indian Ocean area and the rest from the western central Pacific area. However, the landings increased at an equally high rate during 1950-1995 in both the areas. The landings from the eastern Indian Ocean area increased from a mere 5 000 mt in 1950 to 225 000 mt in 1995 (Table 3). The increase was steep since 1976. The contribution of Indonesia to the small pelagic landings of the eastern Indian Ocean increased subsequently from 4.0% to 20.5%. The landings of the short mackerels, *Rastrelliger brachysoma* and *R. kanagurta* increased from about 7 000 mt in 1975 to 58 000 mt in 1995; the sardines from 6 000 mt to 25 000 mt; the anchovies from 3 600 mt to 47 000 mt; and the scads from 2 300 mt in 1975 to 32 500 mt in 1990, but decreased to 20 000 mt in 1995. Barring the landings of the scads which decreased between 1990 and 1995, all the other fisheries registered an increasing trend during the past four decades. Introduction of purseseines in the 1970s and the use of lights as fish lures during purseseining have substantially increased the landings of almost all the species of the small pelagics along the Indonesian coast.

4. *Malaysia*

The west coast of the peninsular Malaysia in the northern Malacca Strait is a part of the eastern Indian Ocean and the east coast is a part of the western central Pacific Ocean. The annual landings of the small pelagics in the west coast of Malaysia fluctuated very widely during 1950-1994. However, the trend in the landings could be categorised into 3 phases: (i) a stagnant phase during 1950-1965 when the annual landings ranged between 35 000 mt and 45 000 mt; (ii) a developing phase during 1966-1985 when the landings increased from 50 000 mt to 175 000 mt; and (iii) a highly fluctuating phase during 1986-1994 when the landings

fluctuated widely, but were generally on the decline. The purseseiners, which were indtroduced during the late 1960s paved the way for increasing the catches of the small pelagics. During the 1970s and the 1980s, the emphasis on the use of traditional fishing gears such as driftnets shifted to a low key as more and more purseseines were employed. The number of purseseiners and the landings of the small pelagics reached the maximum of 377 and 175 000 mt, respectively along the west coast in 1985. Subsequently, the landings reduced to 105 000 mt in 1992 and the number of purseseiners also gradually reduced to 172 as the returns from the catches dwindled. However, the efficiency of purseseining was improved considerably during 1992-1994 through the introduction of colour echosounders, sonar, geographical positioning systems and FADs like spotlights. The use of spotlights as FADs facilitated the exploitation of a wide range of species, thereby making the fish purseseines less selective. Following these developments, the landings again increased and reached 180 000 mt in 1994.

In addition to the purseseiners, the trawlers have played a key role in developing the fisheries for the small pelagics. By employing high opening bottom trawls, the trawlers exploited large quantities of short mackerels. The contribution of the trawlers to the landings of the short mackerels in the west coast increased from <1% in 1970 to 13%, 30% and 29% in 1980, 1990 and 1994, respectively. On the contrary, the contribution of the purseseiners dropped from 99% in 1970 to 81%, 37% and 23% in 1980, 1990 and 1994, respectively.

The short mackerel are the mainstay of the fishery, contributing 56% to the landings of the small pelagics in 1994. *R. brachysoma* constituted 84% of the catches and *R. kanagurta* 16%. The other small pelagics that contribute to the fishery of the west coast are the bigeye scad, round scads, sardines, hardtail scad, round herrings and small tunas.

5. *Thailand*

The west coast of Thailand is located in the Andaman Sea and in the northern Malacca Strait in the eastern Indian Ocean and the east coast of Thailand is located in the Gulf of Thailand (western central Pacific Ocean). The landings in the west and east coasts were 260 000 mt and 500 000 mt, respectively in 1994 (Table 4). Though the west coast landed only 34% of the total landings of the small pelagics in the country, the increase in the landings along the west coast was phenomenal. During 1972-1995, the landings increased from a mere 2 000 mt to 260 000 mt, an increase of 130 times, which is the highest increase for any area among the APFIC countries during these two decades. During this period, purseseining developed extensively and some of the Thai fleets fished in other countries through various joint agreements. The joint venture fishery agreement between Thailand, Malaysia and Indonesia covers the whole of the northern Malacca Strait.

The landings of a few groups of small pelagics sharply increased during the past decades whereas those of a few others registered increases, but fluctuated widely. The landings of the anchovies increased from a mere 1 000 mt in 1990 to

68 000 mt in 1995, an increase of 68 times in 5 years and the landings of the short mackerels increased from 3 000 mt in 1981 to 78 000 mt in 1995. The increased number of light purseseine fleet from the Gulf of Thailand operating in this area contributed to the high landing of anchovies. The landings of the sardines increased from 2 400 mt in 1981 to 42 000 mt in 1986, but fluctuated widely since then. The landings of the scads also fluctuated severely from 2 000 mt in 1986 to 24 000 mt in 1991, to 9 000 mt in 1992 and then to 37 000 mt in 1995.

Northwest Pacific Ocean

This area encompasses a number of distinct ocean subareas, many containing particular extensive areas of highly productive continental shelves such as the northern portion of the South China Sea, the East China Sea, the Yellow Sea, the Sea of Japan and the Sea of Okhotsk. Other subareas have less extensive continental shelves, but are nevertheless also sites of productive fishery resources (e.g., the western portion of the Bering Sea, the eastern edges of the Ryukyu Islands, Japan and the Kuril Islands, and the southeastern part of the Kamchatka Peninsula), being characterised by zones of enrichment and concentration of biological processes related to interactions and confluences of swift western ocean bondary currents (FAO, 1996).

The trends in the landings of the small pelagics in the northwest Pacific Ocean have passed through 3 distinct phases: (i) moderate increase from 1.70 million mt (1950) to 4.75 million mt (1975); (ii) sharp increase from 4.70 million mt (1976) to 9.20 million mt (1986); and (iii) consistent and sharp decline from 9.20 million mt (1986) to 6.20 million mt (1995). Among the APFIC areas, the northwest Pacific Ocean is the only area where the landings have decreased consistently during the past one decade. The sharp increase and the subsequent fall in the landings were primarily due to the Japanese sardine (or Japanese pilchard), *Sardinops melanostictus*. The landings of this species increased from about 20 000 mt n 1972 to a historical peak of 5.4 million mt in 1988, and to an equally drastic decline in the next 7 years to reach 0.8 million mt in 1995. The contribution of the sardine to the landings of the small pelagics in the northwest Pacific Ocean decreased from 60% in 1985 to 13% in 1995.

Among the countries bordering the northwest Pacific Ocean, China and Japan land the maximum quantities of small pelagics. In 1995, these two countries landed nearly 90% of the small pelagics of the entire area.

1. *China*

The Chinese waters, which include the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea, encompass a total area of 4.87 million sq.km. As the coastline of China is very long and extends 37° latitudes from south to north, there is great difference in the temperature between the southern and the northern regions. Accordingly, warm temperate and cold water species occur in specific regions. The warm and warm temperate water species spawn in water temperature

between 18°C and 30°C whereas the optimum temperature for the spawning of the cold water species is 3°C to 5°C.

The production of the small pelagics gradually increased from 0.13 million mt in 1950 to 1.02 million mt in 1988, and thereafter, quickly to 2.50 million mt in 1995 (Table 4). The major species forming the fisheries are the scad (*Decapterus maruadsi*), Japanese anchovy (*Engraulis japonicus*), Japanese mackerel (*Pneumatophorus japonicus*) and Spanish mackerel (*Scomberomorus niphonius*); the catches of these species were 515 000 mt, 489 000 mt, 372 000 mt and 227 000 mt respectively in 1995. These four species together contributed about 64% to the landings of the small pelagics. The fast development of the fisheries for the small pelagics during 1985-1995 was made possible through a clear understanding of the migratory behaviour of the individual species and by employing suitable gears in the appropriate areas of abundance. The scad and the Japanese mackerel are exploited by employing purseseiners with light attractants in the eastern and southern parts of the Yellow Sea during autumn and winter where they migrate for spawning; and in the feeding grounds in the East China Sea during spring and summer. In addition to this aimed fishing, the other gears employed include the driftnet in the western part of the Yellow Sea and the purseseine with a bag in the Fujian Province.

The Japanese anchovy, which did not form a fishery prior to the 1980s, are being exploited since the late 1980s. The annual landings of the species which were 40 000 mt in 1989, steeply increased to 489 000 mt in 1995. By conducting trial trawling during 1986-89, pelagic trawling was found to be very efficient for the anchovy fishery. Following this, pelagic pair trawlers were introduced and in 1995, there were 100 pairs of 370 hp trawlers for the anchovy fishery, which harvested 3 to 4 mt/haul when the anchovies migrated to the wintering grounds during November-February. When the anchovies migrate to the spawning grounds near the coast in the Yellow Sea and the Bohai Sea during May-June, they are exploited by using small trawlers and during the peak spawning period, by employing different kinds of fixednets along the coast.

The Japanese sardine were not found in the China waters before the 1970s. In the mid 1970s, the Kyushu stock of this warm temperate species moved to the southern and central parts of the Yellow Sea and to the South China Sea and formed a fishery since then. The landings of this species exhibit an increasing trend, from 21 000 mt in 1989 to 58 000 mt in 1995. They are caught by purseseine and setnet.

The growth of the Chinese fisheries resulted, at least to some extent, from the relaxation of domestic price controls and the consequent incentive to deploy excess fishing capacity, resulting in significant increase in fishing effort. The total power of the Chinese vessels operating in the East China Sea increased by a factor of 7.6 between the 1960s and the the early 1990s, while the catches increased by a factor of 2.6. Thus, the cpue decreased by a factor of 3.0 (FAO, 1995). This was accompanied by a dramatic shift in the catches from high-valued, large fish to low-valued, small fish, and from demersal and pelagic predators to small pelagics. The contribution of the small pelagics, which was only 16% of the total marine catch of China during 1972-1983, increased to 37% during 1990-1995. The quantity of

mature fishes in the catches dropped significantly, with the bulk of the present catches consisting of immature fish (FAO, 1995).

2. *Japan*

The production trend of the small pelagics in Japan during 1976-1995 depicts one of the most eventful marine fisheries variations in the world. The production, which was increasing steadily from 1.2 million mt in 1950 to 2.9 million mt in 1976, suddenly shot up to 6.3 million mt in 1988, only to decline subsequently to 2.1 million mt n 1995. The marine fish catch of Japan, which was the highest in the world throughout the 1980s, decreased since 1988 and in 1991, China exceeded Japan in catch volume for the first time and since 1992, the apparent gap has continued to widen. These variations were due to a single species, the Japanese sardine (or pilchard). From an annual production of 0.3 million mt in 1910, the sardine fishery off Japan grew rapidly in the 1930s to become the largest single species fishery (2.5 million mt in 1940) that existed in the world at that time. In the early 1940s, the population abruptly collapsed. It remained at extremely depressed levels for nearly three decades (0.01 to 0.3 million mt per year) and then suddenly exploded in the mid 1970s and attained the peak of 4.5 million mt in 1988. Again, similar to the earlier collapse, the fishery rapidly declined for the second time and reached 0.6 million mt in 1995. It is reported that the catches have further declined in 1996 and currently the stock has touched a very low level. Japanese scientists are convinced that the fluctuations in the sardine abundance are not the result of fishing, but governed by ecosystem changes which may be related to climate variations (FAO, 1996). It is believed that the abundance is affected by the changes in the Kuroshio current lasting for periods of one decade to many decades.

The Japanese anchovy catches, which stongly increased off China, decreased off Japan from 0.3 million mt in 1990 to 0.2 million mt in 1994. The Pacific herring *Clupea pallasi*, which formed a major fishery in the 1910s (annual average landings: 1.1 million mt), also declined to 0.2 million mt in 1940 and reached a seriously low level from the 1970s onwards upto the present along the Japanese coast. The landings of the chub mackerel *Scomber japonicus* were highly fluctuating, ranging from 0.2 million mt (1991) to 0.9 millionmt (1986) during 1985-1994. Of the major species of small pelagics of Japan, the fisheries for the jack mackerel *Trachurus japonicus* and the Pacific saury *Cololabis saira* are stable.

The large and medium type purseseiners contribute <70% to the landings of the sardine, jack mackerel, chub mackerel and scads. An unit of large/medium type purseseiner consists of a netting boat (100 mt GRT) accompanied by one or two search boats and two or three carrier boats. Following the decline in the sardine catch, the number of units decreased from 208 in 1989 to 132 in 1994 and the number of fishing trips from 14 177 to 7 739, respectively. In spite of the decrease in the effort, the cpue decreased from 279 kg per trip (1989) to 175 kg per trip (1994). As the anchovy concentration is in the inshore waters, small scale fisheries involving small purseseines and boatseines are engaged in the anchovy fishery. On the other hand, almost 99% of the Pacific saury was caught by liftnets with fish attracting lights.

Considerable portions of the sardine (70%), jack mackerel (43%), chub mackerel (54%) and anchovy (60%) are used as food for aquaculture or processed to fish meal and fish oil. Following the decline in the catches, the import of fish oil and fish meal has substantially increased in Japan during 1990-1995.

Western Central Pacific Ocean

This area extends from the seas of the Southeast Asian countries down to the north and east Australia and further eastwards to the smaller island countries of the south Pacific. The area is dominated by a vast continental shelf which is bordered in the north by the Southeast Asian countries and in the southeast by Indonesia and Australia. The majority of this shelf area lies within the EEZs of the Southeast Asian countries, which, therefore, make a major contribution to the total production of the area. In 1994, the catches by Indonesia, Malaysia, Philippines and Thailand accounted for 97% of the total landings of the western central Pacific Ocean (FAO, 1996).

The catches of the small pelagics in this area have risen almost consistently since 1950, barring a decline only in some years. The catches increased from 0.13 million mt in 1950 to 2.65 million mt in 1995, an increase of over 20 times. However, individual countries in the area had periods of stagnation, e.g., the catches of Indonesia stagnated for 10 years between 1951 and 1960; the catches of Philippines for 12 years between 1975 and 1986; and the catches of Thailand for 18 years from 1978 to 1995. Among the four countries contributing to the bulk of the catches of the small pelagics, the overall increase during 1950-1995 was very rapid in Indonesia and the Philippines, compared to that of Malaysia and Thailand.

1. *Indonesia*

The western central Pacific Ocean area of the Indonesian waters includes the south Malacca Strait, the Java Sea, the Banda Sea, the Makassar Strait and the Sulawesi Sea. The Java Sea has emerged as the major fisheries centre of Indonesia. The catches of the small pelagics, which increased from 25 000 mt in 1950 to 1.1 million mt in 1995, were steep between 1972 and 1995 (Table 4). During this period, the catches of scads, trevallies, mackerels and sardines increased considerably.

The purseseine was introduced in the Java Sea in the early 1970s, and since then, it has emerged as the major gear exploiting the small pelagics. The purseseine fleet increased steadily both in number and efficiency and its operations extended from the traditional fishing grounds in the Java Sea to the Makassar Strait in the east and the South China Sea in the northwest. The operation of the purseseines increased from 4 495 gear units in 1983 to 6 929 units in 1992 and the CPUE also increased from 55.8 mt/unit in 1983 to 70.5 mt/unit in 1992. In 1992, the purseseiners landed nearly 50% of the total catches of the small pelagics. In addition to the purseseines, other seines such as the payang type seine, Danishseine and beachseine are also used, but restricted to the coastal waters. Whereas the CPUE of the payangseine increased from 9.8m mt/unit gear in 1983 to 12.6 mt/unit

in 1992, the CPUE of the Danishseine and beachseine were stable at around 6 mt/unit in 1983 and 9 mt/unit in 1992 during the 10-year period. These traditional gears are used either from small sized motorized or nonmotorized craft. There were large number of these craft operating all along the coast, but they were getting reduced in number. They are either being withdrawn from operation or are modified as mini purseseiners. In general, there is no drastic change in the CPUE of the major fishing gears as far as the fisheries for the small pelagics in Indonesia are concerned.

2. *Malaysia*

The east coast of the peninsular Malaysia, Sarawak and Sabah is in the western central Pacific Ocean. With the encouragement given for the development of offshore fishing in the Malaysian EEZ in recent years, the fishing activities have increased steadily in the South China Sea area off the east coast of Malaysia, Sarawak and Sabah. However, compared to the substantial increase in the catches of the small pelagics by Indonesia and Thailand, the increase in the catches by Malaysia was moderate. Unlike the west coast fisheries which concentrated in the northern Malacca Strait and had distinct stagnant, developing and fluctuating phases during 1950-1995, the landings in the east coast increased consistently from 40 000 mt in 1950 to 200 000 mt in 1995 (Table 4). As the east and west coast fisheries were based on two different fishing areas, the catch composition along these two coastal areas was also different. Whereas the short mackerels dominated by *R. rachysoma* contributed 56% to the landings of the small pelagics in the west coast during 1994, the catches were dominated by *R. kanagurta* in the east coast. The scads (selar scads and round scads) contributed 43% to the catches. The purseseines landed 70% of the landings and the trawls $<10\%$. The number of purseseiners increased from 178 (1978) to 431 (1990) and decreased to 295 (1994) in the east coast. During 1978-1985, the cpue ranged from 62.2 mt/craft/year to 96.8 mt/craft/year whereas during 1986-1994, the CPUE declined and ranged from 23.2 mt/craft/year to 47.8 mt/craft/year. Driftnets of varying lengths and mesh sizes are also engaged in exploiting the small pelagics mostly in the inshore waters.

3. *The Philippines*

The Philippines comprises 7 100 islands and a narrow continental shelf. It is bound by the Pacific Ocean on the east, Celebes Sea and Bornean waters on the south and the China Sea on the east and north. The Sulu Sea, where upwelling occurs, is a productive area. The other major fishing grounds are Visayan Sea, Moro Gulf, Tayabas Bay, Bohol Sea, Lamon Bay and Batangas coast.

The production of the small pelagics increased rapidly from 0.02 million mt in 1957 to 0.62 million mt in 1975 and was stagnating around 0.6 million mt till 1985. The production increased once again and reached 0.94 million mt in 1991 and was stagnating around 0.9 million mt till 1995. The scads (mostly round scad and bigeye scad) formed 30%, the sardines formed 30%, short mackerels 9% and anchovies 8% of the landings of the small pelagics. Though the production of each of these major four fisheries increased several times during 1950-1995, they were

characterised by specific production trends. The landings of the scads fluctuated between 0.16 million mt (1963) and 0.22 million mt (1976) for 27 years (1962-1988) before reaching a peak of 0.3 million mt in 1992. The landings of the sardines fluctuated severely for 14 years (1973-1986) between 60 000 mt and 150 000 mt, but increased rapidly in the subsequent years to reach the peak of 265 000 mt in 1995. The landings of the short mackerels did not increase much after 1974 and were fluctuating between 70 000 mt and 80 000 mt. The landings of the anchovies, which were also fluctuating, reached the peak of 130 000 mt in 1988, but sharply decreased to 73 000 mt in 1995.

The small pelagics are exploited by a number of craft and gears. Offshore vessels of 3 GRT and above operate beyond 15 km from the shore while the coastal vessels, which are either motorized or nonmotorized and are less than 3 GRT, operate in the waters within 15 km. Purseseines, bagnets, trawls, ringnets and Danishseines are operated from the offshore vessels. During 1991-1995, the purseseines contributed 64.5%, ringnets 15.3%, bagnets 9.9% and trawls 6.1% to the landings of the small pelagics. The purseseiners, trawlers and bagnetters, which were introduced in the Philippine waters as early as the 1940s, increased in number, and there were 516 purseseiners in 1982, 932 trawlers in 1983 and 1009 bagnetters in 1965. The operation of these vessels was restricted in the subsequent years åsd the cpue started declining. However, the efficiency of the purseseiners was increased by using FADs and by employing carrier vessels. The carrier vessels assist the purseseiners, ringnetters and the trawlers by maximizing the fishing time of the fishing vessels. The operation of the ringnet, which was introduced in the 1970s, also increased, and there were >500 ringnetters in 1995. Nevertheless, the landings of the small pelagics from the offshore vessels doubled during 1984-1995, forming 70% of the total landings of the small pelagics in 1995. In 1984, the offshore fisheries contributed only 50% to the landings. The landings of the small pelagics from coastal fisheries remained stagnant during 1985-95.

4. *Thailand*

The east and south coasts of Thailand border the Gulf of Thailand which is located in the western central Pacific Ocean. The Gulf of Thailand is considered to be one of the most productive areas of the world. The nature of the marine fishery resources is typical of the Indo-Pacific fauna. The landings of the small pelagics in the entire Gulf of Thailand were 639 000 mt in 1995, of which nearly 80% (500 000 mt) was landed by Thailand. The Thai production of small pelagics consistently increased from 40 000 mt in 1950 to 500 000 mt in 1995. The major fishery groups contributing to the landings of the small pelagics in 1995 were: mackerels (27.0%), sårdines (24.0%), anchovies(16.1%), coastal tunas (15.6%) and scads (15.1%). The landings of all these groups, especially that of the mackerels fluctuated severely during 1950-1995. Of the five species of mackerels recorded, *R.neglectus* and *R.brachysoma* are abundant in the coastal waters and *R.kanagurta, R.faughni* and *Rastrelliger sp.* in the offshore waters. The landings of the mackerels increased from 20 000 mt in 1963 to 150 000 mt in 1968, decreased to 58 000 mt in 1971, and after further fluctuations, reached 150 000 mt in 1984, again declined to 80 000 mt in 1991 and was up again to 135 000 mt in 1995.

The fisheries for the small pelagics in the Gulf of Thailand have developed around purseseine. The Chinese purseseine, which was introduced in the 1920s to catch the mackerels, gained popularity and was later modified as the Thai purseseine. Since the early 1960s, the fisheries developed rapidly, resulting from the modification of the fishing gears, entry of fishing fleets into new fishing grounds and the development of support facilities and other infrastructures. The landings of the small pelagics increased from 30 000 mtin 1960 to 200 000 mt in 1971. In 1973, the fishing grounds for the round scads *Decapterus dayi, D.killiche* and *D. macrosoma* were discovered in the central part of the Gulf, resulting in substantial increases in the catches of the scads from 660 mt in 1972 to 129 800 mt in 1977. Intensive fishing for the round scads for five years by engaging purseseines with coconut fronds as luring device heavily exploited the resources, resulting in the depletion of the stocks. The catches of the scads declined to 28 000 mt in 1979 and fluctuated between 10 000 mt and 30 000 mt till 1995. However, the development of fish luring lights since 1978, large purseseines to catch coastal tunas and hardtail scad in deeper waters since 1982 and anchovy fisheries by using small meshed purseseines with luring devices since 1983 resulted in an overall increase in the production of the small pelagics. From 1971 to 1994, the number of luring purseseiners increased from 33 to 930, Thai purseseiners from 328 to 657, anchovy purseseiners from 42 to 285, pair trawlers from 522 to 1978 (in 1990) and otter trawlers from 2 203 to 8 830 (in 1990). These efficient craft and gears have either reduced or replaced the traditional encircling and drift gillnets, pushnets and beam trawl. The number of pair trawlers and otter trawlers has also been reducing since 1990. As a result of the rapid development and expansion of the pelagic fisheries, it is clear that all the stocks in the Gulf of Thailand are being fully exploited and a few stocks are subjected to overexploitation.

Production trends in major fisheries

The small pelagics mentioned here are the ones which are listed under group 24 (shads etc), group 34 (jacks, scads, mullets etc), group 35 (herrings, sardines, anchovies etc) and group 37 (coastal tunas, mackerels, snoeks etc) in the ISSCAAP (International Standard Statistical Classification of Aquatic Animals and Plants). During 1995, the groups 24,34,35 and 37 constituted 2.2%, 34.2%, 33.8% and 29.8% of the landings of the small pelagics, respectively in the entire APFIC area (Table 5). The contribution of these fisheries in each region has undergone considerable changes during 1950-1995. Whereas the contributions of groups 24 and 34 increased in each oceanic region, the contribution of group 35 decreased in the eastern Indian Ocean and in the northwest Pacific Ocean and that of the group 37 decreased considerably in all the regions except in the northwest Pacific Ocean. By analysing the production levels, the composition and the peak landings during 1950-1995, the following trends in the APFIC area are discernible: (i) The landings of the jacks, scads and sauries have attained the peak only in 1995, and hence, are on the rise in all the regions. (ii) The group 35, which recorded the highest landings in the western Indian Ocean in 1990 and in the northwest Pacific Ocean in 1988, has shown clear signs of decline after attaining the peak. The strongly shoaling species in this group, viz., the sardines off the southwest coast of India and off Japan, and the anchovies off India, Malaysia, Philippines and Japan are the species

causing concern. (iii) Though the contribution of group 37 has decreased considerably in three regions, the fact that the landings in 1995 remain very close to the respective highest regional landings, suggests that the landings of this group are relatively stable compared to group 35.

The fisheries for the small pelagics are contributed by hundreds of species. Nevertheless, four fisheries, the scads, sardines, anchovies and short mackerels are abundantly distributed throughout the APFIC area, together forming 60% of the landings of the small pelagics.

Scads

The fisheries for the scads *Decapterus spp.* are probably the most successful ones among the small pelagics during 1950-1995. The catches of the scads increased phenomenally off China, Indonesia, Philippines and moderately off Japan and Malaysia (Table 6). The scad fishery is relatively small in the western Indian Ocean, where the jacks form formidable fisheries. The landings of the scads in the APFIC area were about 1.3 million mt in 1995, which was about 12% of the landings of the small pelagics. The discovery of the fishing grounds in the central part of the Gulf of Thailand, the deployment of luring and aggregating devices during purseseining and the operation of high opening trawls and pair trawlers contributed to the increases in the catches of the scads. Though the catches are generally on the increase in the entire area, they are stagnant in the Gulf of Thailand and are on the decline off the southern part of the Java Sea in the 1990s.

Sardines

The landings of the sardines, which recorded drastic declines in the 1990s, were 1.95 million mt (18% of the small pelagics) in 1995. The landings of the Indian oil sardine *Sardinella longiceps* off the southwest coast of India and of the Japanese sardine (or pilchard) *Sardinops melanostictus* off the Japanese coast, which have registered serious fluctuations over the past decades, are on a declining trend in the 1990s (Table 7). Among the small pelagics, these two stocks cause serious concern in the APFIC area. Contrary to the landings of the Indian oil sardine and the Japanese sardine, the landings of the other species of sardines increased considerably. The landings of *Sardinella gibbosa, S. fimbriata* and *Dussumieria spp.* increased in the Gulf of Thailand and off Indonesia, the Philippines and the east coast of India.

Anchovies

The total landings of the anchovies in the APFIC area were 1.24 million mt in 1995, which was 11.3% of the landings of the small pelagics. The Japanese anchovy *Engraulis japonicus* form a sizeable fishery in the Yellow Sea, East China Sea and Japan Sea, landing 489 000 mt and 200 000 mt in China and Japan, respectively in 1995 (Table 8). The Gulf of Thailand and the Java Sea are also highly productive regions for the anchovies, especially for *Stolephorus heterolobus*. The development of pelagic trawling in China and small meshed purseseines with

fish luring lamps in Thailand and Indonesia are the major reasons for the increase in the landings of the anchovies. However, the landings off Japan, east coast of India and west coast of Malaysia are on the decline during the past one decade.

Short mackerels

The short mackerels have emerged as the largest group in the APFIC area. The landings were 2.13 million mt, forming 19.5% of the landings of the small pelagics in 1995. The major species are *Pneumatophorus japonicus* in the northwest Pacific Ocean and *Rastrelliger kanagurta* and *R. brachysoma* in the other three regions. The landings in China, Indonesia and Thailand are consistently on the rise for the past few years (Table 9). The landings of the mackerels are highly fluctuating in all the regions, making it extremely difficult to arrive at definite conclusions on the status of the fishery.

BIOLOGICAL CHARACTERISTICS OF SMALL PELAGICS

Our understanding of the biological characteristics of the fisheries resources form the general basis for planning appropriate assistance to the fishing industries and the fishermen in obtaining sustainable catches. During the past one decade, considerable progress has been made in the APFIC countries in defining the biological criteria used in determining the quantum of catch that could be realised from a given stock without reducing its abundance beyond certain level. The progress in determining the biological mechanisms, especially the growth, spawning, recruitment and mortality has been quite substantial.

Growth, fecundity and spawning

Though the environmental conditions of the APFIC area range from tropical to sub-Antarctic and sub-Arctic climates, majority of the countries experience tropical and subtropical climates. Hence, the problems in estimating the growth of the tropical fishes are encountered in most of the stocks in the APFIC area. In the absence of suitable methods for the determination of the age and growth of tropical fishes, several numerical methods developed in recent years, have allowed the conversion of length frequency data into age composition. Overlapping of the successive modal classes and the difficulty in collecting representative, nonselective, unbiased population samples are the frequent sources of problems in the application of this method. This problem is acute in the case of the small pelagics which have strong shoaling behaviour. The shoal is made up of fishes of the same size, and so, it is difficult to get a representative sample of the size composition of the population, especially from the most popular gear, the purseseine. By reviewing the growth pattern of tropical fishes, Devaraj and Vivekanandan (MS) have concluded that the range of growth coefficient values (K) in the von Bertalanffy growth equation is very wide among the small pelagics compared to other taxonomic groups. This problem is likely to affect the length-based models for estimating growth, mortality and other population parameters. Nevertheless, the freedom with which the length frequency method has been used for the determination of growth gives the impression that there is no alternative to the length frequency method. In

the 1980s and the 1990s, this method has been repeated on the same or other species in different APFIC countries year after year, thus generating considerable information on the growth parameters of the exploited stocks. The major advancement during this period has been the effective employment of computer programmes such as the ELEFAN, LFSA and FiSAT.

Table 10 provides the annual growth coefficient values (K) of a few dominant species of small pelagics in the APFIC area. The small pelagics, as a group, have the following unique growth and reproductive characteristics: (i) The K values are uniformly high and the life span is short for most of the species. In other words, the small pelagics grow fast towards their small size limits, which is a major difference compared to other taxonomic groups. (ii) Due to this, the small pelagics are subjected to more recruitment fluctuations (Csirke, 1988). (iii) Many species of the small pelagics attain 60% of their $L\infty$ at the end of the first year itself and reach L max in 2 to 3 years. A few species of sardines attain even 80% of their $L\infty$ at the end of the first year. In comparison, most of the large pelagics and demersals attain only about 30% of their $L\infty$ at the end of the I year and reach L max in about 8 years (Devaraj and Vivekanandan, MS). (iv) Most species of small pelagics attain first maturity at a very late stage of their life. For instance, the sardines and short mackerels attain first maturity at $<70\%$ of their $L\infty$. On the other hand, the large pelagics and demersals attain first maturity at a very early stage of their life ($<40\%$ of $L\infty$). As the reproductive process demands considerable energy, the growth rate of fishes decreases after they attain maturity. The small pelagics, which have fast growth rate and short longevity, delay the process of maturation and prolong the body growth process for a comparatively longer duration in their life than the other groups. (v) Conceptually, small sized and fast growing fishes have high natural mortalities, and warmer the ambient water, still higher the natural mortality (Pauly, 1980). These factors indicate very high natural mortality for most of the stocks of small pelagics. It has been recognized that there is a relationship between mortality and growth of several fish species. The ratio of M/K for the sardines ranged from 1.90 to 2.33 and for all the other speceis between 1.30 and 2.00 (Table 10). Clearly, the sardines have a very high natural mortality in relation to their growth. As the body size of sardines, anchovies, short mackerels, shads and many species of scads are small, the predation mortality on these fishes should be very high. Unfortunately, there is no proper estimate on the predation mortality of the small pelagics. (vi) Most small pelagics are filter feeders or particulate plankton feeders. Hence they congregate in the upwelling areas where the physical environment produces a large biomass of phytoplankton and zooplankton. Due to their low trophic level, the shoaling small pelagics feed on the large plankton biomass thereby allowing them to reach high biomass levels. (vii) The small pelagics have very high fecundity, but estimations of the fecundity of individual fishes greatly vary within the species according to their sizes. For instance, the fecundity of individuals of different sizes of the scad *D. maruadsi* ranges from 25 200 to 218 800 in the East China Sea (Tang and Tong, 1997) and from 38 000 to 515 000 in the Gulf of Thailand (Chullasorn, 1997); the fecundity of *S. crumenopthalmus* between 42 000 and 484 000 (Widodo, 1997), that of *R.brachysoma* between 11 300 and 119 300 in the Manila Bay (Calvelo, 1997) and the relative fecundity of *S.gibbosa* between 12 800 and 41 300 in the Bay of Bengal (Devaraj *et al.*, 1997). It is not clear how far

this individual variation in fecundity regulates recruitment. The theories on density dependent fecundity and/or fecundity dependent recruitment have not been adequately established for the stocks of the small pelagics. As the indivitual-to-individual and year-to-year variations in fecundity could cause high recruitment variabilities, an objective way has to be evolved for translating the population level consequences of variations in fecundity on the recruitment and the fisheries.

Migration

Almost all marine fishes undertake one form of migration or the other, the understanding of which, is important for planning a successful fishery. The migration could be either vertical, which is often diurnal, or horizontal which may be either along the coastline or between inshore waters and the highseas and may extend for a longterm. Though the small pelagics are not known to undertake long distance interoceanic migrations similar to the highsea tunas, the groups such as the short mackerels, Spanish mackerels, scads and trevallies have been recorded to migrate fairly long distances between fishing and spawning grounds. The shads migrate between estuaries and inshore waters. The implication of the migratory behaviour is that a large sea area must be covered in order to obtain random samples for the assessment of population parameters. One example of the source of bias is the estimation of population parameters based on samples drawn from the spawning grounds, where shoals consisting of larger individuals are dominant. For a few temperate species such as the North Sea herring, the migratory patterns have been fairly well studied and ways to avoid bias in sampling and misinterpretation of results have been devised. On the contrary, the knowledge on the migration of most of the tropical pelagic stocks is very limited.

Another important reason for the necessity to study migration is to find solution to the problems of stock sharing between countries. The complex problems involved in shared stocks are the problems of stock identification and migration routes. Based on migration, Caddy (1982) has classified marine fisheries resources into the following five categories: (i) stocks that remain almost entirely within a single national jurisdiction; (ii) nonmigratory stocks lying across the boundary between adjacent zones and continuously available in each zone; (iii) migratory stocks moving across boundary areas, but available in each zone only on a seasonal basis; (iv) highsea stocks that are occasionally or partially available inside national areas; and (v) highsea stocks which occur outside the EEZs. Most of the small pelagics are under category (iii) and stock identification and knowledge on the migratory route are the prerequisites for the management of these stocks. Several ways have been suggested to monitor migration (Sparre and Venema, 1992): (i) One easy way is to follow the commercial landings and tap the knowledge of the fishermen. (ii) Acoustic equipments could be used to map the distribution and estimate the abundance of small pelagics. (iii) Tagging is probably the best way to study migration. Sophisticated acoustic and radio tags have been developed, which allow continuous observation of the movements of a single fish.

The FAO/SEAFDEC workshop on shared stocks has identified at least 40 stocks as currently being shared by two or more countries in Southeast Asia (FAO, 1985). The following are the major species shared by Thailand, Malaysia, Indonesia and Philippines in the western central Pacific Ocean: the round scads *D. macrosoma* and *D. maruadsi;* the trevallies *Caranx spp., Carangoides spp., Alectis spp.* and *Selaroides spp.*; the sardines *Sardinella spp.*, the short mackerels *R .kanagurta, R. brachysoma* and *R.faughni*; the Spanish mackerels *Scomberomorus spp.*, and the coastal tunas *Auxis spp., Euthynnus affinis* and *Thunnus tonggol* (FAO, 1985). The other probable shared stocks in the APFIC region are : (i) between India and Pakistan in the western Indian Ocean: the trevallies *Caranx* spp. and *Carangoides* spp., the grenadier anchovy *Coilia dussumieri, Thryssa* spp., the short mackerel *R. kanagurta*, the Spanish mackerels *S. commerson* and *S. guttatus* and the coastal tunas; (ii) between India and Sri Lanka in the eastern and western Indian Oceans: the sardines *Sardinella* spp. (including the Indian oil sardine *S.longiceps*), the short mackerel *R. kanagurta*, the small tuna *Auxis thazard* and the flyingfishes *Hirundichthys* spp.; (iii) between India and Bangladesh: the Bombay duck *Harpodon nehereus,* the hilsa shad *Hilsa ilisha* and others; (iv) between China and Japan in the northwest Pacific Ocean: the scad *D. maruadsi*, the Japanese sardine *S. melanostictus*, the scaled sardine *Harengula zunasi*, the Japanese anchovy *E. japonicus,* the Japanese mackerel *P. japonicus* and the Spanish mackerel *S. niphonius.*

In order to identify the shared stocks and to assess their status, information on the environmental factors which influence their distribution, abundance and migration is vital. Despite acknowledging the importance of tagging studies, no collaborative regional research approach has been initiated in the APFIC region. Research to answer questions on geographic limits, spawning areas and seasons, nursery grounds etc of the migratory species is weak or lacking. Collaborative research on these subjects should form an important agenda for the regional research organizations.

STOCK ASSESSMENT OF SMALL PELAGICS IN THE APFIC REGION

The shoaling small pelagic stocks usually do not fit well into the conventional population dynamics models because of their highly variable characteristics, thus making their assessment and management difficult and uncertain (Csirke, 1988). The immediate response of the stocks to the variations in the environment and their migratory nature make the assessment very complex. The best known examples are the Japanese sardine, Indian oil sardine, the scads, the short mackerels and the coastal tunas. The effects of environmental variations on the stocks are often confused with the changes in the stock that may occur due to fishing. Several estimates of the stocks of the small pelagics made on the basis of the conventional models have been upset by the large changes in the stock abundance due to various perturbations in the environment. For instance, the potential yield of the small pelagics in the northwest Pacific was estimated to be 5.8 to 6.5 million mt in 1985 with a scope to increase the catch by only 0.1 to 0.2 million mt at the maximum (Chikuni, 1985). It was thought that the total catch of

the five major species had reached the maximum or even the excess level. Contrary to these estimates, the catch of the small pelagics reached, temporarily 9.2 million mt during 1986-1988. A change in the oceanographic conditions along the Pacific coast of Japan appears to be the most likely explanation. This phenomenon of the small pelagics tends to invalidate the estimates of the potential yield from any given area. Beverton (1963) concluded that, from the point of view of the overall fisheries prospects, fishing for the small pelagics is a high risk activity as compared to fishing for the more reliable and robust demersal stocks for which the conventional stock assessment models work much better.

The basic methods potentially available for monitoring the abundance of the small pelagics are the same as those used for estimating the abundance of other groups of fish. However, there are specific reasons for the uncertainties in the assessment of the stocks of the small pelagics (Devaraj and Vivekanandan, MS): (i) The highly variable nature of the stocks is one of the major reasons. (ii) As the small pelagics are fast growing and live a short span of life, decrease or increase in recruitment will be quickly followed by a severe decrease or increase in the stock size and vice versa. The quick changes in the stock size necessitate decision making on the management measures at very short notice and the existing stock assessment methods may not suit this requirement. (iii) The CPUE may not be a reliable indicator of the abundance. The catch/haul or catch/h will be high if one shoal is sighted even if the stock had declined to a very low level. The catch/haul may estimate the average size of shoal, rather than the population abundance. Catchability may be more reliable if the effort includes search time. (iv) It is difficult to quantify the fishing efficiency of gears employed in exploiting the small pelagics. In the trawl fisheries for the demersal stocks, development and improvement of the gear involve building larger vessels with higher engine power, increasing the mouth opening of the net, reducing the codend mesh size etc. These factors could be quantified and the effort could be estimated on a standard term. Improvements in the pelagic gears involve changes in techniques in fish finding such as acoustic instruments and in fish aggregation such as light lures, which are difficult to measure and standardize. (v) A fish shoal is normally made up of fish of about the same size, and hence, it is difficult to get a representative sample of the length composition of the population which would affect length-based assessment of the stocks.

There are a few methods that tend to work better for the small pelagics. Acoustic surveys are suitable for pelagic fishes and may provide reliable indices of abundance when used in a longterm monitoring programme, but may be misleading when employed as a one time estimate of absolute biomass (Csirke, 1988). The relation between the biomass and the acoustic properties is still uncertain, and species identification generally requires direct biological sampling, usually with nets. Different vessels and equipments could give different acoustic measurements and cross calibration is necessary for comparing the survey results. Egg and larval surveys also seem to work reasonably well in estimating the abundance of those species which release easily identifiable pelagic eggs.

Notwithstanding the limitations in estimating the stocks of the small pelagics, several assessments have been made in the APFIC region in recent years (Table 11). Most of the estimates have been made in localised areas without properly considering the geographical distribution of the stocks. It is possible that a portion of the stock is overexploited in one area or country, but is underexploited in another. The high concentration of the Indian oil sardine extends along the southwest coast of India in the Arabian Sea (between 8°N and 16°N latitudes), along the northwestern coast of Sri Lanka, and, since the mid 1980s, along the southeast coast of India in the Bay of Bengal between 8°N and 16°N. It is not clear whether the fishery is supported by a single stock or several stocks. Whereas the stock in the southwest coast of India is being overexploited by purseseines and ringseines, the newly emerging stock off the southeast coast appears to be underexploited in the absence of purseseines and ringseines as only the conventional gillnets operated from motorized and nonmotorized craft exploit this stock. The Japanese sardine are, again, an example of how a stock gets distributed over a wide geographical area depending on the prevailing environmental conditions. The following stocks of the sardine *S.melanostictus* have been identified: (i) the Pacific stock, (ii) the Ashizuri stock, (iii) the Kyushu stock and (iv) the Japan Sea stock (Chikuni, 1985). During the temporary periods of high catches (1930s and 1980s), it was only the Kyushu stock which dominated over the others by extending its distribution and spawning grounds in the south-north direction from the southern tip of Kyushu (25°N) up to the Pacific coasts of Japan (55°N). The stock identity was lost during these periods as there was a mixing with other stocks. The stock was shared and intensively exploited by the Japanese, Korean and the USSR vessels in the 1930s and the 1980s, but in the 1990s, the Chinese vessels too joined the fray as the stock extended to the East China Sea and the Yellow Sea. With the drastic decline in the abundance during 1940-1980 and in the 1990s, however, the original stock appears to have separated itself into the four stocks mentioned above. Similarly, understanding of the geographical distribution and abundance of stocks is available only to a limited extent for the other resources in the APFIC areas, such as the short mackerels in the western central Pacific Ocean. SEAFDEC, with limited success, initiated the improvement in the collection of statistics of multispecies fisheries in the countries in the western central Pacific Ocean for stock assessment purposes. Without identification of stocks and the knowledge of their geographical areas of distribution of the species concerned, stock assessment of the species could not be wholesome. The current pace of development on the estimation of the stock parameters in the individual countries is in the right direction.

The actions which are required now for meaningful stock assessments are as follows: (i) Identification of geographical distribution and abundance of major stocks. (ii) Collective compilation of basic data essential for stock assessment in the whole geographic areas of distribution of each stock. Such collection and compilation of data require uniformity in the estimations, especially the catch, effort and size composition. (iii) Collective analysis of the data to provide reliable estimates on the potential yield of the stock and to suggest the optimum level of fishing. (iv) Identification of the overexploited stocks and mechanisms to limit fishing on the heavily exploited stocks, which would often require an international machinery. These measures require close coordination of the countries, which are involved in harvesting the same stock.

MANAGEMENT OF SMALL PELAGICS

In the IPFC meetings conducted prior to the 1970s, the discussions used to be generally centring around questions of development of marine fisheries and improvement of catches. In the succeeding years, particularly after the late 1980's the emphasis gradually shifted from improving the catches to sustaining the catches and from fisheries exploitation to fisheries management. During the earlier phases of fisheries development, the resources remained rather underutilized, whereas in the subsequent phases, most of the resources were either fully exploited or, as feared, overexploited. Although the possibility of expanding the fisheries to the offshore has been repeatedly considered by the coastal countries, particularly by India, Indonesia, Malaysia and Thailand, no convincing evidence of the existence of such resources has ever been provided (FAO, 1996). Hence, the concerned countries have developed mechanisms of managing their fisheries for sustaining the resources and the catches. Regular monitoring surveys are being conducted in many of these countries with the objective of assessing the status of the stocks in response to fishing and environmental changes. The results of these evaluations, however, do not play a major role in the management decisions and in implementing the decisions. Therefore, the priority of fisheries in the APFIC region revolves around the issues of strengthening and implementing the management measures for sustaining the resources and their fisheries.

In principle, the management of the fisheries for the small pelagics involves the same problems as the management of the other fisheries. However, certain features such as migration and dispersal of the stocks and response to the changes in the environment and the consequent instabilities pose uncertainities and problems to the managers. There are not many practical ways of manipulating the physical events influencing the seas and the fish stocks to serve the objective of fisheries management. However, identification and understanding of those physical events and their role in influencing the fish stocks are necessary to plan the anthropogenic activities concerned with fisheries. Even if the major causes of dramatic changes in the stocks are recognised due to the environmental perturbations rather than due to fishing, a management strategy is required when the stock is declining. Such a strategy is essential to conserve the spawning stock and to maintain reproduction at a safe level. This approach should help to slow down the rate of collapse on the one hand and to hasten the recovery on the other. There are examples, the herring fishery of British Columbia, where severe restrictions were imposed soon after an environment-caused decline became apparent, and the stock subsequently recovered quickly. It appears that if appropriate action is taken (which may be temporary, but should be strictly implemented), the stocks may not be allowed to collapse completely.

The effects of the natural causes on the rise and fall of the fish stocks are apparent only for a few stocks, viz., the Japanese sardine, the Indian oil sardine and the Pacific herring. It appears that the other major stocks such as the anchovies, scads and short mackerels are tolerant to changes in the environmental conditions and their stock fluctuations may be due to either density dependent species

replacement, as suggested by many researchers (Antony Raja, 1969; Chikuni, 1985; Devaraj *et. al.*, 1997) or fishing.

Management practices in vogue in the APFIC region

From the production trends of the small pelagics during 1950-1995, it is evident that most of the fisheries in the western Indian Ocean, eastern Indian Ocean and western central Pacific Ocean have passed through the following three distinct phases: (i) a stagnant initial phase when the catches were low; (ii) a steep increase following the introduction and expansion of efficient craft and gears such as the purseseiners and the pelagic trawlers, the operations of which were aided by fishing luring and aggregating devices; and (iii) a stagnant, or in some fisheries, a declining third phase, which is conspicuous in recent years. It appears that the increase in the number and efficiency of fishing craft and gears has sustained the catches only for a few years and the fish stocks could withstand no further increase in fishing pressure. Realising this, the APFIC member countries follow such management measures as closed seasons, closed areas, licensing the vessels, limiting the number of vessels, mesh size regulation etc. (Table 12).

(i) *Western Indian Ocean countries*

In the western Indian Ocean, the large number of small fishing vessels operating a variety of gears makes monitoring of the status of the stocks and the implementation of fisheries management difficult. Given the huge fisher population and the lack of alternative employment, the fishing intensity remains high in the west coast of India, Pakistan and Sri Lanka. In the west coast of India, *ad hoc* management measures are being implemented by restricting the operation of purseseiners and ringseiners during the southwest monsoon period (June-August). Due to decreasing catch rates, the number of purseseiners and ringseiners has stabilized during the 1990s. The most important management measures for the small pelagics in Sri Lanka are the regulation of beachseine and purseseine, by limiting the number and size of craft, mesh size of the gear and the area of operation.

(ii) *Eastern Indian Ocean countries*

Scientific management of fisheries resources is not yet well established in many regions of the eastern Indian Ocean, although development has reached a point where it is necessary. Fisheries management involving the control of effort is better established in Malaysia than in the rest of the region, except in Australia, where resource management is effectively implemented. For the pilchard fishery in western Australia, the fleet has been rationalised over time since the introduction of individual transferable quotas based on total allowable catch, which has been fixed at 25% of the estimated total biomass (O'Brien, 1997).

(iii) *Western Central Pacific Ocean countries*

In the western central Pacific Ocean countries, various conventional management measures are in vogue to restrict fishing effort, although fishing

intensity keeps increasing. The stocks of short mackerels and round scads are heavily exploited in the Malacca Strait, the Java Sea, the central part of the Gulf of Thailand and the coastal waters of the Philippines; the sardines are heavily exploited in the Bali Strait. Evidently, management actions have not been entirely successful in decreasing the fishing capacity and there is an indication of overcapacity of fishing vessels. Overexploitation of resources is continuing in the various sections of the coasts of Thailand, the Philippines and Indonesia. The increase in the catches in the region in the 1970s and the 1980s was due to, in addition to the increase in the number and efficiency of fishing craft and gears, the extension of fishing to new grounds, as the catches from the traditional areas were sharply decreasing. Some of the catches made by Thailand were reported to have originated from outside its waters in the late 1970s (FAO, 1992); Indonesia increased its catches in the 1980s through the development of fisheries in the eastern part of the country; and Malaysia through the development of industrial fishing in its east coast. These countries fish in the waters of their neighbouring countries also through various bilateral agreements. Indonesia provides fishing access to foreign fleets 16 km off its archipelago in the South China Sea and on the Pacific side. Malaysia, despite the impediments in the buyback scheme of fishing vessels introduced in 1985, is once again initiating reintroduction of the scheme to reduce fishing pressure in the coastal waters. Compared to the Southeast Asian countries, the fishing intensity in the southern part of the western central Pacific (Australia and New Zealand) is low.

(iv) *Northwest Pacific Ocean countries*

Among the APFIC areas, management schemes are well developed in the northwest Pacific. Japan, especially, is following a set of effective management measures covering the entire fisheries along its coast. The three major laws of fisheries are concerned with: (i) control of fishing effort, (ii) conservation of resources and prevention of conflicts between fishermen; and (iii) coordination and self reliance in cooperative association with harmonious fishing and resources management (Chikuni, 1985). Fishing licenses are given to individuals who belong to the fisheries cooperatives. Fishing effort in each of the fisheries is regulated by a combination of the total number of vessels to be licensed, size category and the allowable engine power for each vessel size. The activities are coordinated by well organized bodies, in which the fishermen, scientists and representatives of public interest serve as members. Ironically, the Japanese fisheries, which have been the best managed fisheries in the APFIC region, have historically witnessed the maximum number of drastic production collapses. In 1997, Japan has begun a new management system based on total allowable catch (TAC) in addition to the existing systems (Wada, 1997). The Japanese sardine, short mackerels, jack mackerel and Pacific saury are the target species for management by the TAC system. There will be provision to allocate the TAC to individual fishermen also (Individual Quota System). China is also following stringent management measures such as closed fishing areas, closed fishing seasons and restriction of effort. Boat building and licensing are regulated. The fishermen have to pay a tax of about 30% of the total profit per capita towards fish resource protection and enhancement (Tang *et al.*, 1997).

(v) *International organizations associated with fisheries management in the APFIC region*

Besides the research, development and management network in the individual countries, there are several international organizations in the APFIC region which assist and coordinate national and international programmes in fisheries development, promote regional research activities and examine management problems. The Indian Ocean Fishery Commission (IOFC) and the Indian Ocean Tuna Commission (IOTC) for the western and eastern Indian Ocean; the Bay of Bengal Programme (BOBP) for the eastern Indian Ocean; the South Pacific Fisheries Forum Agency (FFA), the Southeast Asian Fisheries Development Centre (SEAFDEC), the International Center for Living Aquatic Resources Management (ICLARM), the Asia-Pacific Fishery Commission (APFIC), and the Indonesian-Malaysian-Thailand Growth Triangle (IMTGT) Project are the major international organizations involved in the regional promotion of the western central Pacific Ocean fisheries. In the northwest Pacific, there is no functional multilateral organization, although such an organization would be helpful in the assessment and management of shared stocks. Five bilateral fisheries agreements between individual countries exist currently in the northwest Pacific region. All these promotional bodies are only advisory and do not have any regulatory power.

Problems in managing the fisheries for the small pelagics

Most of the developing countries in the western Indian Ocean, eastern Indian Ocean and western central Pacific Ocean experience severe constraints in effectively implementing the regulatory measures. The major constraints which are common for the developing countries in these areas are as follows: (i) The natural variabilities and inadequate scientific information on stock abundance are being increasingly recognized as the causes for the uncertainities in fisheries management. (ii) As the small pelagics consist essentially of low value fish groups with large biomass, their fisheries are carried out by a large number of small scale fishermen who are totally dependent on these fisheries for their day-to-day life. In India alone, there are 180 000 nonmotorized and 32 000 motorized craft and about 0.7 million active fishers (70 % of the total 1million active marine fishers) engaged in the fisheries for the small pelagics. Considering their socioeconomic status, the government has not imposed any restriction on their fishing activities and has limited the management measures to the mechanised craft and to some extent, to the motorized craft. (iii) The intrinsic inefficiencies in fisheries management in the tropical developing countries also need to be examined and considered seriously. For instance, the restriction of fishing effort could take various forms such as the restriction on the number of vessels, number of days at sea, fishing hours, engine power, length of net, fish holding capacity of the vessels etc. Restriction of any of these parameters either partly or fully makes fishing inefficient. To overcome the restrictions, the fishers select and expand the parameters which are not subjected to restrictions. If the number of vessels is restricted, the number of fishing days is increased; if the number of fishing days is restricted, the fishing efficiency is increased by investing in larger and powerful vessels; if the fish-hold capacity is

restricted, fast moving vessels and carrier boats are used. If there are simultaneous restriction on the number of vessels and days, fishing duration per day and engine capacity are increased, and sophisticated fish finding equipments, fish aggregating devices and efficient gears are inducted. The small pelagics are of low commercial value and expensive vessels and equipments are required to realise high rates of profitability. Therefore, only those who invest heavily could survive and the artisanal fishers find the going tough. (iv) The dwindling catches and the fishing restrictions often result in conflicts between the fishermen. (v) In almost every fishery, evaluation of the effects of the management measures is virtually impossible due to the lack of appropriate data, relevant to the situation, before the regulation was introduced. (vi) For the fisheries management system to be effective, monitoring, control and surveillance are necessary to enforce the regulations. Many of the developing countries do not have a proper surveillance system as it is an expensive practice. Due to these constraints, fisheries management in the developing countries in the APFIC region, by and large, has not been functioning well.

Human activities (other than fishing) in the coastal areas

In addition to the climatic and hydrographic factors which *inter alia*, cause fluctuations in the abundance of the small pelagics, there are several anthropogenic activities in the APFIC region, threatening the health of the stocks and the wellbeing of the fishing communities. In addition to overfishing in the coastal areas, the anthropogenic activities include oil and gas extraction, reef and tin mining, cutting of mangroves, and sewage discharges which result in habitat degradation and pollution of the aquatic environment. These activities which are on the increase, cause serious pressures on the environment, with direct and indirect impact on the fish stocks. The main problems in the developing countries in the APFIC region include high population pressure in the coastal areas and poor facilities for waste treatment, as indicated by high levels of coliform bacteria and BOD (Table 13). Most of the domestic sewage is generally discharged raw directly into the coastal waters that may adversely affect the coastal ecosystem. Significant growth in agricultural operations has also increased the amounts of herbicides and pesticides in rivers which may reduce the survival of juvenile fishes, shrimps and molluscs in coastal areas. Other human induced activities include increased terrestrial runoff of silt due to land reclamation and deforestation leading to siltation and changes in water temperature, salinity and transparency, with consequent damages to the coral reefs and aquatic vegetations. These factors are of importance since a high percentage of marine fish production comes from stocks which pass their early and most vulnerable stages in coastal waters (FAO, 1992). In the inshore waters of China and Japan, anthropogenic induced problems such as land reclamation, heavy metal pollution and oil spills affect the fisheries. The frequency of red tides appears to be increasing. In the southern coast of Australia, viral epidemics are causing large scale mortality of pilchards. Another matter of concern is the destruction of marine habitats. Coral reefs and mangroves are degraded in many countries bordering the Bay of Bengal with pristine areas now being found only in small pockets along the Gulf of Mannar in the southeast coast of India, the west coast of Sumatra and along the northern Andaman Sea coast of Thailand. Realising the

values of mangroves and coral reefs and their importance in sustaining the coral ecosystems, a few countries have gazetted these areas as marine parks and closed them for all forms of fishing activities. Unplanned tourism development in the coastal areas also has resulted in the destruction of habitats.

The wider impact of these human disturbances on the stocks of the small pelagics, either on shortterm or longterm basis, could not be immediately quantified. For instance, it would be difficult to demonstrate that destruction of 100 sq.km. of mangroves in a particular locality would lead to loss of x tonnes of fish. Another basic difficulty in examining the effects of these factors on the fish stocks is that of distinguishing between human and natural causes. At the international level, there is need for research on the effects of human activities on the fish stocks. There is also need for analysing the economic relationship between land and sea uses and the resources and communities affected or benefitted by these uses. It is estimated that 80% of marine pollution comes from land-based sources, whereas their harmful effects are felt by the coastal fisheries. Perhaps the governments could think of pricing systems for natural resource uses. In Japan where communities have exclusive rights to fishing areas, those who wish to use areas for other purposes (for disposal of wastes etc), must pay the affected communities for these uses (FAO, 1993). An integrated and holistic approach to coastal zone management has to be taken urgently in addressing these problems following the guidelines which already exist in many countries. Promoting awareness on the impact of inappropriate uses of resources on fisheries has to be given much greater importance. The participation and cooperation of all users of the coastal zone, including the public and the private sectors and the NGOs are important.

Suggested management measures

Considering the geographical distribution and migration of the small pelagics, it is being increasingly recognized that effective management of the resources has to be done at two levels, national and regional. National management should be concerned with the actual implementation of the various policies which have been evolved for bringing about sustained development while regional management should seek to identify the common issues and facilitate their resolution for the benefit of the member countries of the region as a whole. For evolving and implementing stronger national management measures, management networks and work programmes are required in each country. They include: (i) establishment of a body for fisheries management with representatives from the fishermen, industry, scientists, NGOs, managers, financial institutions and politicians; (ii) data collection for catch and effort, important biological characteristics, marketing situation, price structure, social responses to fisheries events; (iii) classification of fisheries based on their geographic distribution and status of exploitation; (iv) periodic review of the status of fisheries, existing management policies and identification of the areas of weaknesses; (v) regulation of other human activities in the coastal areas; (vi) modification of the policies wherever necessary by focussing attention on management for sustaining the catches rather than increasing the catches in the coastal areas; (vii) evolving strong national policies by removing open access and common property rights; (viii) development of alternative activities for the extra

manpower, if any, by interacting with the concerned parties; (ix) inculcating in the fishermen the necessity for responsible fishing and designing fisheries which would be regulated by the fishermen themselves; (x) development of mechanisms of accountability among the fishers on their catches, earnings and expenses on fishing; (xi) improvement of research, development and training facilities; (xii) development of a strong mechanism of implementing the policies and surveillance; (xiii) allocation of separate funds for fisheries management; (xiv) development of good legal frameworks; (xv) development of postharvest technologies and a good marketing system; and (xvi) evolving system for the prevention of disasters due to natural calamities and for restoration, rehabilitation and reestablishment of the affected men and materials.

For evolving regional level management measures, the following actions are necessary: (i) formation of a strong body to design regional policies; (ii) development of a mechanism to strengthen national management measures; (iii) identification of the regional changes in fisheries, especially the shared stocks and periodically advising the member countries; (iv) provision of strong scientific support for fisheries development by imparting training on the technological changes; (v) development of a system for communication, exchange of data and interaction on management experiences among the member countries; (vi) promotion of compatibility and consensus among the countries in sharing the stocks based on mutually agreed stock assessment studies; and (vii) generation of adequate funds for implementing the management programmes.

A critical scrutiny of the available information on the small pelagics in the APFIC region reveals that a few important aspects have not been considered hitherto in evolving and implementing management policies in the APFIC region:

(i) It is important that a uniform method of data collection is evolved for the estimation of fishing effort and fishing efficiency of all the major gears. As the nonselective gears such as the purseseine often catch several fish groups in a single haul, thereby influencing the stocks of all the concerned groups, it is more appropriate that the assessment of the status of exploitation is gear-based rather than single fishery-based, say, the sardine fisheries or the anchovy fisheries. Further, this kind of information is important in assessing how the regulatory measures applied on one particular fleet/gear in the fishery affect the remaining fleets, and to determine whether regulating one kind of fleet alone will be beneficial.

(ii) Information available on the relationship between the environmental factors and production is very limited, especially for the western Indian Ocean, eastern Indian Ocean and western central Pacific Ocean regions. Collaborative oceanographic cruises, experimental fishing and tagging should be conducted in these areas.

(iii) Collaborative research works on shared stocks such as the scads, mackerels and coastal tunas should be conducted among the countries in the APFIC region. These research efforts should focus on the assessment of the resources in the EEZ and international waters and for recommending proper sharing of these resources.

To prove the possibility of interactions between the shared stocks between and among the coastal countries, the SEAFDEC has recommended the need to do collaborative research to determine similarity/dissimilarity in stocks through tagging, electrophoretic and mitochondrial DNA studies, morphology or any other means.

(iv) Remote sensing is one technology which has not been put into proper use for fisheries purposes. For the marine environment, this technology offers immense opportunity to learn more about the dynamics of sea surface temperature (SST) and colour (chlorophyll) which are of critical importance especially in relating surface features including primary productivity with the small pelagics. Details of the effects of the monsoons on the oceanographic parameters could be monitored and mapped out, which would be helpful in determining and predicting the spatial and temporal distribution of the stocks. Remote sensing facilities already exist in countries such as India, Japan and China. At present, India is using this technology to locate potential fishing zones (PFZs), especially of the pelagics. The forecasts of the PFZs have been found to be valid in the case of the small pelagics, and the abundance of oil sardine has been observed to be related to optimum SST and dissolved oxygen concentration. Although only a beginning has been made, the results obtained in India and elsewhere do indicate the possible future applications of satellite derived chlorophyll and SST distribution for the purpose of directing and controlling fishing effort.

(v) The advancements in postharvest technologies and marketing are still inadequate in many APFIC countries and do not match with or correspond to the rapid advancements made in harvesting technologies. Most of the small pelagics are low value fishes, characterised by unpredictably sudden high or low landings, leading to sudden glut or scarcity in the market. Hence, the postharvest technologies and the market should be able to cope up with the abrupt changes in fish arrivals. As the small pelagics are a cheap source of protein for the large coastal populations, any rise in their prices will seriously affect the poor and depress their access to the limited supplies. The postharvest technologies for the small pelagics present 3 distinct scenarios in the APFIC region: (i) In India and Sri Lanka, the small pelagics are consumed mostly in fresh condition or sun-dried during periods of glut. There is large scope for these countries to develop suitable postharvest technologies for the production of value added fish and fish-based products. Development of value added products reduces wastage of fish and arrests further lowering of the value through drying and salting during periods of glut in these countries. (ii) The Southeast Asian countries have developed a number of value added products in the past two decades, with an increasing amount of them destined for export. In recent years, there are complaints of increase in prices of fish due to the importance given to export. (iii) In countries such as Australia and Japan, the sardines and anchovies are primarily used as fish meal in aquaculture farms and as baits in fishing operations. It is essential that these countries launch programmes on increasing the utilization of low value species for direct human consumption in view of the rapidly increasing demand for fish products in these countries, which are increasingly becoming fish importers.

The nature of the issues in managing the fisheries is common to many countries in the APFIC region. The implementation of the management schemes will be expensive, but the costs can be reduced by proper planning and by involving the fishing communities. Clearly, there is need for a strong political will to conserve the fishery resources and sustain the benefits to the countries in the region.

REFERENCES

Annigeri, G.G., K.N.Kurup, M.Kumaran, Madan Mohan, G.Luther, P.N.R.Nair, P. Rohit, G.M.Kulkarni, J.C.Gnanamuthu and K.V.N. Rao. 1992. Stock assessment of oil sardine, *Sardinella longiceps* val., off west coast of India. *Indian J. Fish.*, 39(3,4): 125-135.

Antony Raja, B.T. 1969. The Indian oil sardine. *Bull.Cent.Mar.Fish.Res.Inst.* 16:1-128.

Bennet, P., P.N.R. Nair, G. Luther, G.G. Annigeri, S.S. Rangen and K.N. Kurup 1992. Resource characteristics and stock assessment of lesser sardines in the Indian waters. *Indian J.Fish.*, 39(3,4): 136-151.

Beverton, R.J.H. 1963. Maturation, growth and mortality of clupeid and engraulid stocks in relation to fishing. *Rapp.P-V.Reun. CIEM,* 140:67-83.

Caddy, J.F. 1982. Some considerations relevant to the definition of shared stocks and their allocation between adjacent economic zones. *FAO Fish. Circ.*,749: 44p.

Calvelo, R.R. 1997. Review of the Philippine small pelagic resources and their fisheries In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 259-299.

Chee, P.E. 1997. Small pelagic fish resources and their fisheries in Malaysia In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 244-258.

Chikuni, S. 1985. The fish resources of the northwest pacific. *FAO Fish. Tech. Pap.*, 266: 190 p.

Chullasorn, S. 1997. Review of the small pelagic resources and their fisheries in the Gulf of Thailand In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 337-364.

Corpuz, A., J.Saeger and V. Sambilay. 1985. Population dynamics of commercially important fishes in Philippine waters. *Dept. Mar. Fish., Univ. of Philippines, Tech. Rep.* 6: 100 p.

Csirke, J. 1988. Small shoaling pelagic fish stocks. In: Gulland, J.A. (ed) Fish population dynamics. John Wiley, 271-302.

Dayaratne, P. 1997. Review of the small pelagic fisheries of Sri Lanka In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 300-336.

Devaraj, M., I. Fernandez and S.S. Kamat. 1994. Dynamics of the exploited Indian mackerel *Rastrelliger kanagurta* stock along the southwest coast of India. *J. mar. biol. Ass. India,* 36 (1,2): 110-151.

Devaraj, M., K.N.Kurup, N.G.K. Pillai, K. Balan, E. Vivekanandan and R. Sathiadhas 1997. Status, prospects and management of small pelagic fisheries in India In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 91-198.

Ding, R., C. Gu and Z. Yan. 1988. Estimation of biomass and sustainable yield of Japanese sardine in the eastern part of the East China Sea and the Yellow Sea. East China Sea Fisheries Research Institute, p.11.

FAO. 1985. Shared pelagic resources in southeast Asia. *FAO Fish. Rep.* 337: 26 p.

FAO. 1992. Review of the state of world fishery resources, Part 1. The marine resources. *FAO Fish. Circ.,* 710: 114 p.

FAO. 1993. Marine fisheries and the law of the sea: a decade of change. *FAO Fish. Circ.,* 853: 66 p.

FAO. 1995. Review of the state of world fishery resources: marine fisheries. *FAO Fish. Circ.,* 884: 105p.

FAO. 1996. Review of the state of world fishery resources: marine fisheries. *FAO Fish. Circ.,*920:87 p.

Fernandez, I., and M. Devaraj. 1996. Dynamics of the gold spotted grenadier anchovy (*Coilia dussumieri*) stock along the northwest coast of India. *Indian J. Fish.,* 43 (1): 27-38.

George, P.C., B.T.Antony Raja and K.C.George. 1977. Fishery resources of the Indian Exclusive Economic Zone. *Souvenir, Silver Jubilee, Integrated Fisheries Project, p* 79-116.

Ingles, J., and D. Pauly. 1984. An atlas of the growth, mortality and recruitment of Philippine fishes. *ICLARM Tech. Rep.,* 13: 84 p.

Kurian, A., and K.N. Kurup. 1992. Stock assessment of Bombayduck *Harpodon nehereus (Ham)* off Maharashtra coast. *Indian J. Fish.*, 39 (3,4): 243-248.

Luther, G., K.V.N.Rao, G.Gopakumar, C.Muthiah, N.G. K.Pillai, P.Rohit, K.N.Kurup, S.Reuben, P. Devadoss, G.S.Rao, P.S.Bennet and N.S. Radhakrishnan. 1992. Resource characteristics and stock assessment of white baits. *Indian J. Fish.*, 39 (3,4): 152-168.

Mansor, M.I. 1987. On the status of the *Rastrelliger* and *Decapterus* fisheries of the west coast of Peninsular Malaysia in 1984-1985. *BOBP Report*, 39: 81-100.

Martosubroto, P. 1997. Review of the small pelagic resources and their exploitation in the Asia-Pacific region In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 1-16.

Noble, A., G.Gopakumar, N.G.Pillai, G.M.Kulkarni, K.N.Kurup, S.Reuben, M.Sivadas and T.M.Yohannan. 1992. Assessment of mackerel stock along the Indian coast. *Indian J. Fish.*, 39(3,4): 119-124.

O'Brien, C. 1997. Small pelagic resources in Australia In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 69-72.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. Int. Explor. Mer.*, 39: 175-192.

Reuben, S., H.M.Kasim, S.Sivakami, P.N.R.Nair, K.N.Kurup, M.Sivadas, A.Noble, K.V.S.Nair and S.G.Raje. 1992. Fishery, biology and stock assessment of carangid resources from the Indian seas. *Indian J. Fish.* 39(3,4):195-234.

Sparre, P., and S.C.Venema. 1992. Introduction to tropical fish stock assessment. *FAO Tech. Pap.* 306/1: 376 p.

Suwarso, B. 1993. Length-weight relationship of the main pelagic fishes of the Java Sea. Java Sea pelagic fishery assessment Project, Jakarta.

Tang, Q., L. Tong, X. Jin, F. Li, W. Jiang and X. Liang. 1997. Review of the small pelagic resources and their fisheries in the Chinese waters In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 73-90.

Thiagarajan, R., S.Lazarus, Y.A. Sastry, M.Z. Khan, H.M.Kasim and K.S. Scariah. 1992. Stock assessment of the ribbon fish, *Trichiurus lepturus* form the Indian waters. *Indian J. Fish.*, 39(3,4): 182-194.

Wada, T. 1997. Review of the small pelagic resources and their fisheries in Japan In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 227-243.

Widodo, J. 1988. Population biology of russel's scad (*Decapterus russelli*) in the Java Sea, Indonesia. In: Venema, S.C., J.M. Christensen and D.Pauly (eds) Contribution to tropical fisheries biology. *FAO Fish. Rep.*, 389: 308-323.

Widodo, J. 1997. Review of the small pelagic fishery of Indonesia In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 199-226.

Yanagawa, H. 1997. Small pelagic fisheries in the South China Sea area In Devaraj, M., and P. Martosubroto (eds). Small pelagic resources and their fisheries in the Asia-Pacific region: proceedings of the APFIC Workshop, p. 365-380.

Table 1. Landings (million mt) of small pelagics in the APFIC areas in 1950 and 1995; figures in parentheses represent total landings.

Area	Landings 1950	Landings 1995	Increase in landings	Highest landings	Year	Remarks on small pelagics landings
Western Indian Ocean	0.24 (0.55)	1.00 (3.65)	4.2 times (6.6 times)	1.06	1990	Severe annual fluctuations
Eastern Indian Ocean	0.12 (0.30)	1.10 (3.70)	9.2 times (12.3 times)	1.10	1995	Consistent increase
Northwest Pacific Ocean	1.70 (4.90)	6.20 (21.80)	3.6 times (4.5 times)	9.20	1986	Increase during 1950-87; consistent decline since then
Western Central Pacific Ocean	0.13 (0.60)	2.65 (8.30)	20.4 times (13.8 times)	2.65	1995	Consistent increase
All areas	2.19 (6.35)	10.95 (37.45)	5.0 times (5.9 times)	11.6	1988	Increase during 1950-88; gradual decline since then

Table 2. Production of total fish and small pelagics in the APFIC areas during 1995.

Oceanic region	Continental shelf area (000sq.km.)	Total catch (t/sq.km.)	Potential* (t/sq.km)	Small pelagics catch(t/sq.km)	% of small pelagics
Western Indian	790	4.6	16.4	1.3	28.3
Eastern Indian	2210	1.7	4.5	0.5	29.4
Northwest Pacific	2770	7.9	9.4	2.2	27.8
Western Central Pacific	3120	2.7	3.5	0.9	33.3
APFIC area	8890	4.2	6.7	1.2	28.5

* calculated from FAO (1996)

Table 3. Percentage contribution of each area to the production of small pelagics.

Oceanic area	1950	1995
Western Indian	11.0	9.1
Eastern Indian	5.5	10.1
Northwest Pacific	77.6	56.6
Western Central Pacific	5.9	24.2

Table 4. Comparison of small pelagic landings in 1950 and 1995 (from Martosubroto, 1997).

Region/country	Landings (mt) 1950	1995	Increase	Remarks
Western Indian				
India	200000	760000	4 times	Annual fluctuations in major fisheries
Sri Lanka	5000	70000	14 times	Highest (90000 t) in 1983; stagnant at around 70000mtsince then
Eastern Indian				
Australia	14000	25000	6 times	Pilchard is the only fishery
India	72000	280000	4 times	Increase since 1984
Indonesia	5000	225000	45 times	Steep increase since 1975
Malaysia	35000	175000	5 times	Steep increase during 1975-1984
Thailand	2000	260000	130 times	Moderate increase during 1972-1981; steep increase since then
Northwest Pacific				
China	125000	2500000	20 times	Steep increase since 1988
Japan	1200000	2100000	75%	Reached peak of 6.25 millionmtin 1988; sharply declined since then
Western Central Pacific				
Indonesia	25000	1100000	44 times	Consistent increase; pronouced since 1972
Malaysia	40000	200000	5 times	Consistent increase
Philippines	25000	900000	36 times	Steep increase between 1958-1975 and 1986-1991
Thailand	40000	500000	12 times	Consistent increase

Table 5. Landings (million mt) of major fishery groups; the figures in parentheses represent percentage contribution to the landings of small pelagics.

Group/ ISSCAAP No.	Western Indian Ocean Peak landings 1950	1995	millionmt	year	Eastern Indian Ocean Peak landings 1950	1995	millionmt	year	Northwest Pacific Ocean Peak landings 1950	1995	millionmt	year	Western Central Pacific Ocean Peak landings 1950	1995	millionmt	year	Total 1950	1995
Shads etc (No.24)	0.001 (0.1)	0.01 (1.0)	0.03	1984	Negl.	0.17 (15.5)	0.18	1992	Negl.	0.05 (0.8)	0.05	1995	Negl.	0.01 (0.4)	0.10	1995	0.01 (0.5)	0.24 (2.2)
Jacks, sauries, scads etc (No.34)	0.06 (25.0)	0.37 (37.0)	0.37	1995	0.03 (25.0)	0.30 (27.3)	0.30	1995	0.40 (23.5)	1.90 (30.6)	1.90	1995	0.03 (23.0)	1.17 (44.1)	1.17	1995	0.52 (23.6)	3.74 (34.2)
Herrings, sardines, anchovies etc (No.35)	0.07 (29.1)	0.37 (37.0)	0.58	1990	0.04 (33.3)	0.32 (29.0)	0.32	1995	0.90 (53.0)	1.95 (31.5)	6.20	1988	0.05 (38.5)	1.06 (40.0)	1.06	1995	1.06 (48.2)	3.70 (33.8)
Mackerels, snoeks etc (No.37)	0.11 (45.8)	0.25 (25.0)	0.27	1993	0.05 (41.7)	0.31 (28.2)	0.31	1995	0.40 (23.5)	2.30 (37.1)	2.80	1978	0.05 (38.5)	0.41 (15.5)	0.45	1994	0.61 (27.7)	3.27 (29.8)

Table 6. Comparison of landings of scads in 1950 and 1995 (from Martosubroto, 1997).

Oceanic region/ country	Landings (mt)			Remarks
	1950	1995	Increase	
Western Indian				
India	-	2000		Consistent increase
Pakistan	-	2000		Consistent increase
Eastern Indian				
Indonesia	-	20000	-	Increase during 1979-1991; on the decline since then
Malaysia	5000	9000	2 times	Gradual increase
Thailand	-	37000	-	Steep increase since 1981; but highly fluctuating
Northwest Pacific				
China	50000	515000	10 times	Consistent increase
Japan	10000	50000	5 times	Consistent increase
Western Central Pacific				
Indonesia	1000	210000	210 times	Consistent increase
Malaysia	1000	35000	35 times	Consistent increase
Philippines	-	270000	-	Very high increase, especially in 1958, 1975 & 1992
Thailand	1000	96283	96 times	Spurt in 1977 (130000 mt) from nil catch; stagnant around 80000 mt since then

Table 7. Comparison of landings of sardines in 1950 and 1995 (from Martosubroto, 1997).

Oceanic region/country	Landings (mt)			Remarks
	1950	1995	Increase	
Western Indian				
India	5000	92000	14 times	Highly fluctuating in a cycle of 5-6 years
Pakistan	1000	50000	50 times	Increase during 1978-82 and 1990-93
Eastern Indian				
India	1000	70000	70 times	Sudden increase in 1975; fluctuating since then
Indonesia	1000	25000	25 times	Increasing since 1977
Thailand	1000	30000	30 times	Sudden increase in 1982; fluctuating since then
Northwest Pacific				
China	Nil	58000		Fishery since 1970s; increasing trend
Japan	250000	600000	2.5 times	Spurt since 1973, reaches 4.5 million mt in 1988 and declines to 0.6 million mt in 1995

Table 8. Comparison of landings of anchovies in 1950 and in 1995 (from Martosubroto, 1997)

Oceanic region/country	Landings (mt) 1950	1995	Increase	Remarks
Western Indian				
India	15000	82000	5.5 times	Stagnant during 1950-72; sudden increase since then but highly fluctuating
Pakistan	1000	18000	18 times	Sudden increase since 1988
Eastern Indian				
India	10000	12000	Marginal	Reached 36000 mt in 1983; declining
Indonesia	1000	37000	37 times	since then
Malaysia	8000	11000	Marginal	Stagnant during 1950-75; increase since then, steep since 1985
Thailand	1000	68000	68 times	Declining since 1982 (from 35 000 mt) Stagnant (< 1 000 mt) during 1950-90; phenomenal rise since then
Northwest Pacific				
China	1000	489000	489 times	Steep increase in 1990s
Japan	40000	200000	Nil	Declining trend
	0			
Western Central Pacific				
Indonesia	2500	100000	40 times	Consistent increase
Malaysia	2000	10000	5 times	Gradual increase
Philippines	2000	68000	34 times	Fluctuated but increased till 1987 (130000 mt); Steep decline since then
Thailand	500	100000	200 times	Moderate increase during (1970-81); steep during 1982-85 and 1988-90

Table 9. Comparison of landings of short mackerels in 1950 and in 1995 (from Martosubroto, 1997).

Oceanic region/country	Landings (mt) 1950	1995	Increase	Remarks
Western Indian				
India	60000	135000	2.2 times	Fluctuating
Eastern Indian				
India	10000	24000	2.4 times	Fluctuating
Indonesia	1000	50000	50 times	Consistent increase
Malaysia	10000	100000	10 times	Highly fluctuating
Thailand	1000	78000	78 times	Steep increase since 1981
Northwest Pacific				
China	132000	372000	3 times	Consistent increase
Japan	*	660000	7 times	High landings during 1965-75; highly
	90000			fluctuating
Western Central Pacific				
Indonesia	5000	140000	28 times	Consistent increase
Malaysia	5000	18000	3.6 times	Moderate increase
Philippines	1000	75000	75 times	Increase during 1964-74 and 1983-90
Thailand	40000	135000	3.4 times	Highly fluctuating

* landings for the year 1986.

Table 10. Biological characteristics of a few species of small pelagics in the APFIC region.

Species	Locality	Loo (mm)	K (annual)	M	M/K	Reference
			SCADS			
Decapterus russelli	West coast of India	232	1.08	1.90	1.76	Reuben, *et al.*, 1992
- do -	Malaysia	240-270	0.81-1.01	1.63-1.82	1.8-2.0	Mansor, 1987
- do -	Java Sea	245-283	0.4-1.2	0.65-2.18	0.7-2.2	Widodo, 1988
- do -	Philippines	330	0.80	1.60	2.00	Ingles & Pauly, 1984
D. macrosoma	Java Sea	231-256	0.7-1.1	0.62-1.86	1.90	Widodo, 1988
- do -	Philippines	230-330	0.50-1.26	1.10-2.20	2.00	Ingles & Pauly, 1984
D. maruadsi	Manila Bay	269-330	0.45-0.80	1.03-1.50	2.00	Corpuz *et al.* 1985
			JACKS & TREVALLIES			
Caranx carangus	East coast of India	444	0.65	0.95	1.46	Reuben, *et al.* 1992
C. leptolepis	- do -	213	1.43	2.19	1.53	- do -
Selar crumenophthalmus	Gulf of Thailand	284	2.40	3.30	1.37	Chullasorn, 1997
Selaroides leptolepis	East coast of India	202	0.82	1.35	1.65-1.77	Reuben, *et al.* 1992
- do -	Java Sea	220	1.20	2.21	1.84	Suwarso, 1993
Alepes kalla	West coast of India	171	0.83	1.40	1.69	Reuben, *et al.* 1992
A. djeddaba	- do -	326	0.61	0.99	1.62	- do -
Atule mate	- do -	340	0.85	1.22	1.44	- do -
Atropus atropus	- do -	440	1.00	1.26	1.26	- do -
			SARDINES			
Sardinella longiceps	West coast of India	207	1.60	3.60	2.25	Annigeri, *et al.* 1992
- do -	Philippines	210	1.10	2.10	1.91	Ingles & Pauly, 1984
S. albella	East coast of India	152	1.41	3.10	2.20	Bennet *et. al.* 1992
S. gibbosa	- do -	171	1.44	3.20	2.22	- do -
S. fimbriata	West coast of India	220	0.98	2.16	2.20	- do -
- do -	Philippines	140-220	0.70-1.60	1.63-3.0	1.91-2.3	Ingles & Pauly, 1984
S. *sirm*	East coast of India	380	0.53	1.16	2.19	Bennet, *et al.* 1992
- do -	Philippines	273	0.86	1.66	1.93	Ingles & Pauly, 1984
Dussumieria acuta	- do -	210	1.05	1.97	1.90	Corpuz, *et al.* 1985

Table 10 Cont'd.

Species	Locality	Loo (mm)	K (annual)	M	M/K	Reference
ANCHOVIES						
Stolephorus devisi	West coast of India	113	2.04	2.61	1.28	Luther, *et al.* 1992
S. bataviensis	- do -	116	2.03	2.61	1.29	- do -
- do -	East coast of India	135	1.40	2.25	1.61	- do -
S. indicus	Manila Bay	157-163	1.05-1.42	2.23-2.67	1.9-2.1	Ingles & Pauly, 1984
S. punctifer	- do -	92-106	1.15-1.85	2.55-3.53	1.9-2.3	Ingles & Pauly, 1984
S. heterolobus	Gulf of Thailand	89	1.80	3.54	1.97	Chullasorn, 1997
- do -	Philippines	120	1.60	3.10	1.94	Ingles & Pauly, 1984
Coilia dussumieri	West coast of India	265	1.07	2.15	2.00	Fernandez & Devaraj, 1996
SHORT MACKERELS						
Rastrelliger brachysoma	Malaysia	240-338	0.52-1.04	1.22-1.92	2.00	Mansor, 1987
- do -	Samar Sea	245-340	1.1-1.6	2.89-3.10	1.5-1.8	Corpuz , *et al.* 1985
R. kanagurta	West coast of India	238	2.84	1.24	0.44	Devaraj, *et al.* 1994
- do -	Gulf of Thailand	229	2.76	3.75	1.36	Chullasorn, 1997
- do -	Malaysia	290-357	0.73-1.21	1.97-2.01	1.7-2.0	Mansor, 1987
- do -	Java Sea	239-262	0.65-2.78	1.00-2.58	1.60	Suwarso, 1993
- do -	Samar Sea	280	1.55	2.43	1.56	Corpuz, *et al.* 1985

Table 11. Stock assessment of a few major groups of small pelagics in APFIC countries.

Group/Species	Location	Period	Annual stock (mt)	MSY (mt)	Reference	Annual yield(mt)	Exploitation level
WESTERN INDIAN OCEAN							
Oil sardine	Southwest coast of India	1984-88		150000	Annigeri, *et al.* 1992	117000 (1996)	Over
Lesser sardine	Southwest coast of India	1976	90000		George, *et al.*, 1977	43458 (1991-95)	Fully
Anchovies	Westcoast of India	1984-88		57300	Luther, *et al.* 1992	52000 (1991-95)	Fully
Indian mackerel	Southwest coast of India	1934-73		70788	Devaraj, *et al.*, 1994	113860 (1991-95)	Over
Ribbonfish	West coast of India	1984-88		65600	Thiagarajan, *et al.*, 1992	60000 (1991-95)	Fully
Horsemackerel	West coast of India	1985-89		11500	Reuben, *et al.*, 1992	18230 (1991-95)	Over
Bombayduck	Northwest coast of India	1982-86	76893	54631	Kurian & Kurup, 1992	85766 (1996)	Over
All small pelagics	Sri Lanka			95000	Dayaratne, 1997	65000 (1993)	Optimum
EASTERN INDIAN OCEAN							
Lesser sardines	Southeast coast of India	1976	170000		George, *et al.*, 1977	50268 (1991-95)	Under
Anchovies	Southeast coast of India	1984-88		30500	Luther, *et al.*, 1992	20115 (1991-95)	Under
Indian mackerel	Southeast coast of India	1984-88		25300	Noble, *et al.*, 1992	40285 (1991-95)	Over
Ribbonfish	Southeast coast of India	1984-88		20400	Thiagarajan, *et al.*, 1992	20773 (1991-95)	Fully
Pilchard	Western Australia			40000	O'Brien, 1997	16000 (1995)	Under

Table 11 Cont'd.

Group/Species	Location	Period	Annual stock (mt)	MSY (mt)	Reference	Annual yield(mt)	Exploitation level
WESTERN CENTRAL PACIFIC OCEAN							
Sardines	Gulf of Thailand	1990-91		104000	FAO, 1995	-	Over
Anchovies	- do -	- do -		104000	- do -	-	Over
Indian mackerel	- do -	- do -		32866	- do -	-	Optimum
Indo-Pacific mackerel	- do -	- do -		75250	- do -	70451 (1982-91)	Fully
- do -	- do -	1984-93		104000	- do -	- do -	- do -
NORTHWEST PACIFIC OCEAN							
Japanese sardine	East China Sea, Southwest of Japan & Yellow Sea	1986-88	650000	370000	Ding, *et al.*, 1988	-	Under
Scaled sardine	Bohai Sea & Yellow Sea	1986-88		35000	Tang, *et al.*, 1997	35000 (1995)	Optimum
Japanese anchovy	East China Sea & Yellow Sea	1984-93	3000000 500000	1500000	Tang, *et al.*, 1997	489000 (1995)	Under
Japanese mackerel	East China Sea & Yellow Sea	1978-82		300000	Tang, *et al.*, 1997	372000	Over

Table 12. Management measures in practice for small pelagics in the APFIC region.

Country	Level of exploitation	Groups	Basis for conclusion	Reasons for the status	Management measures	Reference
India	Over	Sardines, mackerel in the southwest coast	Decline in CPUE of PS & RS	Intensive fishing, small mesh	(i)Closed season (ii)Closed areas for mech.vessels	Devaraj, *et al.*, 1997
	Under	Sardines in southeast coast	Recent emergence of oil sardine fishery	No PS; pelagics exploited only traditional craft	(i)Closed areas for mech.vessels	
Sri Lanka	Optimum	All small pelagics in southwest & southeast coast	FAO study in 1981; update required	Motorization; increase in PS	(i)Area of PS operation restricted	Dayaratne, 1997
	Under	All small pelagics in northwest & northeast coast	Regular fishing affected	Political	Nil	
Thailand	Over	Sardines, round scads, anchovies	By comparing MSY and present yield	Increase in number & efficiency of PS	(i)Closed season (ii)Closed areas for PS & TR (iii)Restriction on lures & mesh size	Chullasorn, 1997; FAO, 1997
	Fully	Mackerels, big eye scads & all other small pelagics	- do -	- do -		
Malaysia	Over	All small pelagics in east coast	Decline in cpue since 1985	Increase in number & efficiency of PS	(i)Closed areas (ii)Strict licensing	Chee, 1997
	Optimum	All small pelagics in west coast	CPUE stable	PS fishery developed recently	- do -	

PS: Purseseine; TR:Trawl; RS: Ringseine; TAC: Total Allowable Catch; ITQ: Individual Transferable Quota.

Table 12 Cont'd.

Country	Level of exploitation	Groups	Basis for conclusion	Reasons for the status	Management measures	Reference
Indonesia	Fully	All small pelagics in Java Sea & Bali Strait	Decline in landings	Increase in number & efficiency of PS Surveillance; Social control on fishing	(i)Trawl ban (ii)Licensing (iii)Closed areas, seasons (iv)TAC	Widodo, 1997
	Optimum	All small pelagics in other coasts	CPUE stable			
Philippines	Heavily	All small pelagics	Decline in cpue	Increase in number & efficiency of PS, RN, TR	(i)Closed areas (ii)Closed seasons	Calvelo, 1997
China	Over	Japanese mackerel, Pacific herring	Small sized individuals on the increase	Increase in effort	(i)Closed areas (ii)Closed seasons (iii)Strict licensing (iv)Regulations in boat building (v)30% of profit per capita for management	Tang, *et al.*, 1997
	Optimum	Scaled sardine & many others	Stock-catch estimations	Stocks able to withstand increase in effort		
	Under	Japanese anchovy, Japanese sardines	- do -	Emergence of new fisheries		
Japan	Over	Japanese sardine Chub mackerel	Stock estimation - do -	Environmental fluctuations	(i)Closed areas (ii)Closed seasons (iii)Licensing (iv)Effort control (v)Community based management (v)TAC & ITQ	Chikuni, 1985; Wada, 1997
	Fully	Japanese anchovy, Pacific saury	- do - - do -	Appropriate management measures		
	Optimum	Jack mackerel	- do -	- do -		

PS: Purseseine; TR:Trawl; RS: Ringseine; TAC: Total Allowable Catch; ITQ: Individual Transferable Quota

Table 13. Human activities (other than regular fishing) in the coastal areas and their possible effects on the small pelagics.

	Types of activities	Possible effects
(i)	Dense human population and discharge of large quantities of untreated domestic waste water	Faecal coliform and BOD levels high leading to eutrophication; incidence of red tide often causes fish mortality
(ii)	Runoff of agrochemicals and industrial discharge	Hazardous chemicals are lethel beyond certain level
(iii)	Heavy phosphorous loading in estuaries	- do -
(iv)	Removal of mangroves for wood; mining of coral reefs for lime	Destruction of nursery grounds
(v)	Oil pollution by ships and fishing vessels	Shadowing effect and reduction in DO leading to mass mortality
(vi)	Unplanned tourism development	Beach erosion and habitat disturbance
(vii)	Terrestrial runoff of silt due to land reclamation and deforestation	Change in marine environment effects juvenile population
(viii)	Fishing by using cyanide & other lethal chemicals	Detrimental to a whole range of organisms in the area

CONCLUSION AND RECOMMENDATIONS OF THE APFIC WORKING PARTY ON MARINE FISHERIES

The following are the conclusion and recommendations of the Working Party:

CONCLUSION

1. Major important species of the small pelagic resources in the Asia-Pacific region include those belonging to shads (*Hilsa* spp.), mackerels (*Rastrelliger* spp., *Scomber* spp.), sardines (*Sardinella* spp., *Sardinops* spp., *Dussumeria* spp.), scads (*Decapterus* spp., *Selar* spp., *Atule* spp.), torpedo/hardtail scad (*Megalaspis cordyla*), jacks (*Caranx* spp.), anchovies (*Stolephorus* spp., other Engraulids), seerfishes (*Scomberomorus* spp.), small tunas (*Auxis* spp., *Euthynus* spp., *Thunus tonggol, Sarda* spp.), hairtails (*Trichiurus* spp.), wolf- herrings (*Chirocentrus* spp.), barracudas (*Sphyraena* spp.), butterfishes (*Stromateus* spp.), black pomfret (*Formio niger*), Bombay-duck (*Harpadon nehereus*), flyingfishes (*Hirundichthys* spp.), mullets (*Mugil* spp., *Liza* spp.), dolphinfishes (*Coryphaena* spp.), and cobia (*Rachycentron canadum*). The majority of the small pelagic resources are used for local human consumption while lesser amounts are used in the production of animal feed.

2. Total catch of small pelagic fishes in the Asia-Pacific region in 1995 amounted to at least 11 million tonnes, a drop of 6% in the seven year period due to the collapse of the Japanese pilchard fisheries since 1988. The catch of other countries have shown an increasing trend with China being the leading contributor followed by the Philippines, Indonesia and Thailand. The majority of catches of individual countries showed annual fluctuations, this can be attributed to fluctuations in catches of certain species groups. Changes in environmental conditions in the North Pacific over the last decade are beleieved to have contributed to the decline of the Japanese pilchard (*Sardinops melanostictus*).

3. Despite the multitude of marine species in tropical environments and the shoaling behaviour of small pelagic resources (which violates the basic assumption of a constant catchability coefficient in the stock assessment), the assessment of the small pelagic resources in the Asia-Pacific region has relied on a single species approach. Nonetheless, the results in many cases show a good fit to yield curves. Increased awareness by scientists on the importance of environmental factors to the dynamics of the small pelagic resources should result in a more cautious attitude toward interpretation of assessments. The migratory nature of small pelagic resources adds further complexity to their assessment. Caution need to be taken in using only length frequency analyses.

4. Following the review of small pelagic resources and their fisheries, research capability and fisheries management capacity of developing countries in the Asia-Pacific region, gaps in knowledge have been identified which include, *inter alia* : (1) identification of pelagic fish species and fish stocks; (2) inadequate understanding of the distribution, spawning, feeding and migration of fish stocks; (3) lack of facilities for fish aging other than using length based methods; (4)

inadequate catch/effort data as well as standardized effort; (5) insufficient use of oceanographic and atmospheric data in diagnosing the status of small pelagic stocks; (6) lack of communication among scientists in the region, in particular those working on the same species.

5. In the case of fisheries management in the Asia-Pacific region, an overall lack of resources by management institutions in most countries has contributed to ineffective management practices. This has resulted in the frequent occurrence of conflicting policies and the absence of sound management plans. Moreover, low levels of awareness, understanding and appreciation of the need for fisheries management, within the industry and the public at large, has led to serious difficulties in the effective application of management measures.

RECOMMENDATIONS

After intensive discussion and deliberation, the Working Party recommended the following :

1. Effort be made toward better species and stock identification to facilitate a common understanding of the distribution of species and potential shared stocks. Exchange of specimens, comparison with access to reference collections and analyses for stock identification are encouraged (electrophoresis/DNA analysis, tagging).

2. In addition to the study of growth and mortality using length frequency analyses, basic biological studies on important species need to be carried out, in particular, spawning, feeding, migration and larval distribution. Such studies should form the basis for assessing stocks and their fisheries. Studies on the examination of oceanographic and environmental parameters as well as tagging should be encouraged.

3. Use of remote sensing data relevant to marine environments in support of the fishery oceanographic studies should be promoted. (A modest effort in assembling and summarizing available maritime climatic data and satellite imagery might produce important advances in understanding pelagic fish stock dynamics in the region).

4. Caution needs to be taken in the analysis and interpretation of catch-effort in small pelagic fisheries due to constant changes in fishing technology, e.g. the use of luring devices (light, FAD), the use of new navigational aids (GPS, sonar). Effort should be made to promote the development of logbook or similar systems to collect catch and effort data from various fishing grounds.

5. Closer sub-regional/regional cooperation needs to be strengthened to make use of institutions in the region which may have relevant research facilities for fish taxonomy, racial analysis, tagging techniques, stock assessment, remote sensing technology, accoustic techniques, etc.

6. Greater use of existing fishery databases for storing and accessing research information is very much encouraged (e.g., FISHBASE, POPDYN, etc.).

7. Exchange of information on research activities especially those on shared stocks need to be strengthened. Electronic facilities (e.g., e-mail) should be used to enhance communication among scientists in the region.

8. Promotion of the precautionary approach to fisheries management needs to be emphasized, especially with respect to small pelagic fisheries.

9. In assuring the sustainable development of small pelagic fisheries in the Asia-Pacific region, it is recommended that fisheries managers comprehend and put into practice the Code of Conduct of Responsible Fisheries.

MAJOR SMALL PELAGIC RESOURCES IN THE APFIC REGION

No.	FAO Fishing Area	51	57		71				61	
	Subregional Area	1	2	3	4	5	6	7	8	9
	Species Group	Western Indian Ocean	Eastern Indian Ocean	Malacca Strait	Gulf of Thailand	South China Sea	Celebes Sea (Sulawesi Sea)	Australia (Northern)	East China Sea	Sea of Japan
1.	Mackerels: - *Rastrelliger* spp. - *Scomber japonicus*	xx	xx	xx	xx	xx	xx	-	- xx	- xx
2.	Scads (*Decapterus* spp., *Selar* spp., *Atule* spp.)	xx	x	xx	xx	xx	xx	-	xx	xx
3.	Torpedo Scad (*Megalaspis cordyla*)	xx	x	xx	xx	xx	xx	-	x	-
4.	Sardines - *Sardinella* spp.) - *Dussumieria* spp.) - *Sardinops*	xx	xx	xx	xx	xx	xx	- -	 xx	 xx
5.	Jacks - *Caranx* spp. - *Trachurus* spp.	xx	xx	xx	xx	xx	xx	x	- xx	- x
6.	Seerfishes (*Scomberomorus* spp.)	xx	xx	xx	xx	xx	xx	-	xx	x
7.	Small tunas (*Auxis* spp., *Euthynus* spp., *Thunus tonggol*, *Sarda* spp.)	xx	x	xx	xx	xx	xx	-	x	-
8.	Anchovies (*Stolephorus* spp.)	x	x	x	x	x	x	-	xx	xx
9.	Bombay duck(*Harpadon nehereus*)	x	xx	-	-	x	-	-	-	-
10.	Hairtails (*Trichiurus* spp.)	xx	xx	x	x	x	x	-	x	x
11.	Shads (*Hilsa* spp.)	x	xx	-	x	-	-	-	-	-
12.	Wolf-herring (*Chirocentrus* spp.)	x	xx	xx	x	x	x	-	-	-
13.	Barracudas (*Sphyraena* spp.)	xx	xx	x	x	x	x	-	x	x
14.	Promfrets (*Formio niger*, *Stromateus* spp.)	x	xx	x	x	x	x	-	xx	-
15.	Flyingfishes (*Hirundichthys* spp.)	xx	xx	-	-	x	x	-	x	x
16.	Mullets (*Mugil* spp. *Liza* spp.)	xx	x	x	x	x	-	x	x	x

x : Being exploited by coastal states
xx : Potential transboundary pelagic stocks

Appendix A

LIST OF PARTICIPANTS

AUSTRALIA	Chris O'Brien Research Scientist, Fisheries Resources Branch Bureau of Resources Sciences Department of Primary Industries and Energy P.O. Box E11 Queen Victoria Terrace Parkes, ACT 2600
CHINA	Ling Tong Deputy Chief, Director's Office Yellow Sea Fisheries Research Institute Chinese Academy of Fishery Sciences 106 Nanjing Road, Qingdao 266071
INDIA	M. Devaraj Director Central Marine Fisheries Research Institute (CMFRI) P.B. No. 1603, Tatapuram P.O. Ernakulam Cochin 682014
INDONESIA	J. Widodo Research Institute for Marine Fisheries Agency for Agricultural Research and Development Ministry of Agriculture Jl. Pasir Putih I Jakarta 14430
JAPAN	T. Wada National Research Institute of Fisheries Science 2-12-4, Fukura, Kanazawa-ku Yokohama 236
MALAYSIA	Chee Phaik Ean (Ms) Senior Scientist Fisheries Research Institute 11960 Batu Maung Penang

PHILIPPINES	R.R. Calvelo (Ms) Senior Fishery Biologist Bureau of Fisheries and Aquatic Resources Department of Agriculture and Food 860 Quezon Avenue, Arcadia Bldg. Quezon City, Metro Manila 3008
SRI LANKA	P. Dayaratne (Ms) Director, Marine Biological Resources Division National Aquatic Resources and Research and Development Agency Crow Island, Mattakkuliya Colombo 15
THAILAND	Somsak Chullasorn Director Marine Fisheries Division Department of Fisheries Ministry of Agriculture Chatuchak, Bangkok 10900
SEAFDEC	Ismail Taufid bin Md. Yusoff Chief Marine Fishery Resources Development and Management Department (MFRDMD) Southeast Asian Fisheries Development Center (SEAFDEC) Fisheries Garden, Chendering 21080 Kuala Terengganu Malaysia H. Yanagawa Marine Fishery Resources Development and Management Department (MFRDMD) Southeast Asian Fisheries Development Center (SEAFDEC) Fisheries Garden, Chendering 21080 Kuala Terengganu Malaysia

FAO

Andrew Bakun
Fishery Resources Division
Fisheries Department, FAO Headquarters
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel.: (396) 5705-6469
Fax: (396) 5705-3020
Email: andrew.bakun@fao.org

Purwito Martosubroto
Technical Secretary of the APFIC
Working Party on Marine Fisheries
Fishery Resources Division
Fisheries Department, FAO Headquarters
Viale delle Terme di Caracalla
00100 Rome, Italy
Tel.: (396) 5705-6469
Fax: (396) 5705-3020
Email:purwito.martosubroto@fao.org

Veravat Hongskul
Senior Fishery Officer and APFIC Secretary
FAO Regional Office for Asia and the Pacific
Phra Athit Road, Bangkok 10200
Thailand
Tel.: (662) 281-7844 ext. 176
Fax: (662) 280-0445
Email:veravat. hongskul@fao.org

SECTION II

SMALL PELAGIC RESOURCES IN AUSTRALIA

by

Chris O'Brien
Bureau of Resource Sciences, Department of Primary Industries and Energy, Canberra 2601,Australia.

Abstract

The spawning stock of the major pelagic species, the pilchard, has been estimated to be 40 000 mt off the western Australia coast and current annual catch is 16 000 mt. The pilchard are sold mostly as pet food and as bait for the anglers. There are specific regional research, management and development plans for the Western Australia pilchard fishery. However, considering the low value of this fishery, the ongoing research is kept to the miminum.

INTRODUCTION

Pilchards (*Sardinops sagax*) are the main pelagic species fished in Australia. Currently the total catch of pilchards is about 16 000 mt. Smaller amounts (< 1 000 mt) of herring (*Nematalosa* spp.), tommy ruff (*Arripis georgianus*), garfish (*Hyporhamphus* spp.), anchovies (*Engraulis australis*), sprats (*Hyperlophus vittatus)* and other small pelagics are also taken. This paper focuses on the major fishery for the pilchards in Western Australia.

Fishing for the pilchards in Australia began in the 1800s, but significant commercial fishing began only in the 1970s. The largest fishery for the pilchards is in Western Australia where current catches are about 10 000 mt. Smaller catches are taken in South Australia, Victoria and New South Wales. Research indicates that there are three separate breeding populations of pilchards in Australia: an east coast population, a southeast population and a southwest population.

THE WESTERN AUSTRALIA PILCHARD FISHERY

Fishing for the pilchards in Western Australia expanded rapidly in the 1970s in response to a demand for bait from the tuna fishing industry. The introduction of a pet food market in 1984 provided further incentive to fishers to increase their catches. Currently the total catch is about 10 000 mt valued at over $A6 million.

There are currently fifty licensed boats in the Western Australia pilchard fishery operating from five ports. The largest catches are taken in the winter (June to August) using purseseine gear with a 20 mm mesh net. Fishing is usually in the early morning or late afternoon. Sonar, depth sounders or visual cues such as seabirds feeding or dark ripples of a school near the surface are used to locate schools. Wheat-germ or chicken feed is used to attract the fish. The pilchards are brailed onboard using dipnets and placed into a freezer or brine tank. In general, the pilchards are between 15 and 17 cm long and 4 to 6 years old.

In Australia, most pilchards are sold for pet food or as bait for anglers, fish traps, rock lobster pots and tuna. Some are canned or sold fresh for human consumption. Australian tuna farmers import about 15 000 mt of pilchards per year from California and Europe. Apparently, the overseas product is preferred as it has a higher fat content than the Australian pilchards, and is more consistently available. Western Australian rock lobster fishers also import a similar amount of pilchards for bait.

RESOURCE ASSESSMENT

There is inadequate knowledge of the pilchard stocks in most fishing areas. In Victoria, South Australia, New South Wales and Queensland, it is likely that the stocks are underfished. By contrast , the pilchard stocks off southwest Australia are heavily fished. The rapid development of the pilchard fishery in Western Australia during the 1980s prompted the Fisheries Department to commission an intensive research program to estimate the size of the stocks, their geographical boundaries and biological characteristics. Otolith aging was attempted; however, it was found that pilchard otoliths have a large number of accessory bands which confound normal aging techniques. Plankton surveys to find eggs and larvae were carried out to reveal where spawning takes place. Gonads were examined to determine the spawning season, the number of times an individual fish spawns each season and fecundity. This information was combined to estimate a spawning stock biomass of 40 000 mt.

Catch and effort information on the Western Australian pilchard fishery has been collected using logbooks since 1987. This has enabled fisheries scientists to estimate abundance indices from catch rates. Although catch rate information can be useful, care needs be taken when interpreting the catch rates of schooling fishes. It is possible to maintain good catches of pilchards despite a falling biomass because the remaining fish will continue to aggregate and therefore maintain catch rates. The implication of this is that even a small drop in catch rates could mean that there has been a significant decline in the amount of fish available. A further complication to the interpretation of the catch rate derived abundance indices of pilchards is that any change in their catchability due to spatial, temporal or environmental factors can lower catch rates even though there has been no change in stock abundance.

It is preferable to use a range of information to determine the status of a fish stock. However, lower-value species generally do not attract the resources to undertake comprehensive assessments. For the small pelagic fisheries in Australia, in addition to the logbook data, fishery managers strive to maintain communications with fishers to gain an insight to the fishery, and overall, take a precautionary approach to management.

MANAGEMENT

In Victoria and New South Wales, pilchard catches are part of multispecies, multimethod limited entry commercial fisheries.

In the Western Australia pilchard fishery, there are specific regional management and development plans. The fleet has been rationalised over time since

the introduction of individual transferable quotas based on a total allowable catch. The rapid increase in the fleet for the pilchards in Western Australia prompted the Fisheries Department to commission an intensive research program; however, considering the low value of the pilchard fishery relative to other fisheries, this level of research is not ongoing. The research did, however, result in a substantial amount of high-quality baseline information and allowed managers to set a total allowable catch with some confidence (the TAC is about 25% of the estimated total biomass).

Queensland rejects a proposal to develop a commercial fishery for pilchards

In 1995, the Queensland Fisheries Management Authority rejected a proposal to develop a commercial fishery for the pilchards off southeast Queensland. The Authority gave four reasons for their decision: 1) The use of purse seine methods has lead to a severe overfishing of pelagic species in other countries; 2) the purseseine method would not discriminate among the range of small pelagic species found in the waters of southeast Queensland (concerns were raised by recreational and commercial fishers that a pilchard fishery would reduce the availability of food for tuna and billfish); 3) the operation could not generate enough information (research) to be able to determine whether it could be sustainable; and, 4) the 600 mt total allowable catch proposed was considered to be too low for a developmental fishery. The decision of the Queensland authorities to reject the proposal is an example of the precautionary approach to fisheries management.

The pilchard kill of 1995

Tonnes of dead pilchards were found floating offshore and washed up on beaches around the southern coasts of Australia between March and June. Similar events occurred in New Zealand. A recent paper on the event concluded that environmental factors such as upwellings and phytoplankton blooms were unlikely to have been the cause of the moralities. However, the researchers were unable to discount the effect of a pathogen (probably a *Herpes* type virus) Debate is ongoing regarding the source of the pathogen. Obviously, the importation of about 30 000 mt of Californian and European pilchards and herrings by rock lobster fishers in Western Australia and tuna farms in South Australia has come under scrutiny. The possible transmission of disease from imports of bait and food to wild caught fisheries is a serious issue for fisheries managers in Australia.

BIBLIOGRAPHY

ABARE. 1996. Australian Fisheries Statistics. Australian Bureau of Agricultural and Resource Economics, Canberra. 48 pp.

Anon. 1995. The Queensland Fisherman. November 1995. 9-11p.

Griffen, D.A. 1997. The 1995 mass mortality of pilchards; no role found for physical, biological or oceanographical factors in Australia. Marine and Freshwater Research, 48(1): 27-42p.

Kailola, P. *et al.* 1993. Australian Fisheries Resources. Bureau of Resources Sciences, Canberra. 422 pp.

Fletcher, R. 1992. Small fish and dark waters - a special report on W.A's humble pilchard. Western Fisheries, Autumn 1992. 22-26p.

Young, C. 1994. Getting the good oil on pilchards. Western Fisheries, Summer 1994. 20-22p.

REVIEW OF THE SMALL PELAGIC RESOURCES AND THEIR FISHERIES IN THE CHINESE WATERS

by

Q. Tang, L.Tong, X. Jin, F. Li, W. Jiang and X. Liang
Yellow Sea Fisheries Research Institute
Qingdao 266071, China

Abstract

The catches of the Chinese herring increased from 19 000 mt (1986) to 47 000 mt (1995), chub mackerel from 132 000 mt (1986) to 372 000 mt (1995), Japanese anchovy from 40 000 mt (1989) to 489 000 mt (1995), Japanese scad from 238 000 mt (1986) to 515 000 mt (1995), Spanish mackerel from 94 000 mt (1986) to 227 000 mt (1995) and silver pomfret from 71 000 mt (1986) to 209 000 mt (1995) in the Chinese waters. The total pelagic catches increased from 1 732 000 mt (1986) to 4 227 000 mt (1995). The biological characteristics and migratory pattern of the major species have been studied. Stock assessment studies have revealed that most of the stocks are being optimally exploited, barring the stocks of the Yellow Sea herring and the Chinese herring, which are on the decline. Through management regulations, fishing effort has been effectively controlled and the production structure of marine fishery readjusted appropriately.

INTRODUCTION

The resources of the small pelagics are abundant in the Chinese coastal waters. Most of them belong to warm water or warm temperate species. The small pelagics, with a mean annual catch of 413 500 mt during 1979-1983 accounted for only 16.4% of the total marine catch in China. But the catch increased considerably accounting for 27 to 44% of the total marine catch in the last decade (1986-1995; Fig.1). The stocks which contribute an annual catch of more than 100 000 mt are the Pacific herring, Japanese mackerel, Spanish mackerel, butterfish, scads and Japanese anchovy. The significant increase in the catches of the pelagics in the last decade was greatly due to the fast growth of the Japanese anchovy and scad fisheries. The distribution and catches of the small pelagics, the status of their stocks , their biological and environmental characteristics and the management issues are presented in this account.

DISTRIBUTION AND FISHERIES OF SMALL PELAGICS

The Chinese waters which include the Bohai Sea, the Yellow Sea, mainly the East China Sea and the South China Sea, extend to 37 latitudes from south to north. They are semi-closed seas covering a total area of about 4.87 million km^2. The coastline of China is 180 000 km long. There are many islands located in the Chinese waters. The mean depth is 18 m in the Bohai Sea, 44 m in the Yellow Sea, 72 m in the East China Sea and 1 212 m in the South China Sea. The central areas of the Yellow Sea and the East China Sea are controlled mainly by the warm Kuroshio Current, which is characterized by high temperature and salinity. The circulation system of the Chinese seas consists mainly of the China coastal current

and the warm Kuroshio current. The biomass in the East China Sea is the highest in the Chinese waters, followed by the Bohai Sea, the Yellow Sea and the South China Sea.

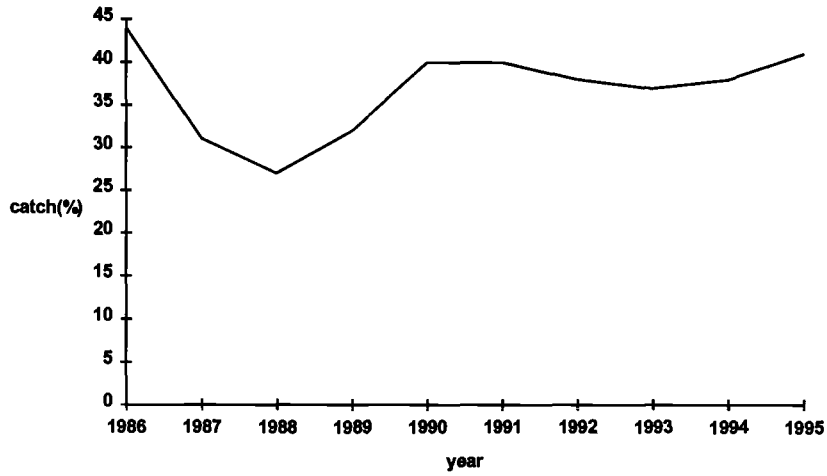


Fig. 1. The percentage of all pelagic catch in the total marine catch in China during 1986-1995.

However, the Japanese anchovy (*Engraulis japonicus*) is the most abundant pelagic fish in the Chinese waters currently with an annual biomass of over 3 million mt and catchability of 0.5 million mt as determined by a ten year winter survey conducted during 1984-1993. A bulk of the pelagic catch is composed of about 20 major species. Most of the small pelagic catch in the Chinese waters are of local stocks. Table 1 shows the annual catch of important species in the Chinese waters.

Table 1. The Chinese catch of important small pelagics during the last decade (1986 - 1995).

('000 mt)

Species	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Chinese herring	19	14	15	16	24	31	30	29	33	47
Chub mackerel	132	166	241	232	197	243	243	273	336	372
Japanese anchovy				40	54	113	193	557	439	489
Japanese pilchard				21	42	63	53	47	69	58
Japanese scad	238	345	251	320	381	420	392	261	431	515
Pacific herring				6	4	3	2	1	1	2
Spanish mackerel	94	99	125	148	209	201	147	146	203	227
Silver pomfret	71	91	64	71	83	95	73	117	138	209
Total pelagic catch	1732	1377	1228	1602	2102	2415	2619	2837	3438	4227

The warm water species and the warm temperate species of pelagics in the Chinese waters include mainly the chub mackerel (*Scomber japonicus*), Chinese herring (*llisha elongata*), Japanese pilchard (*Sardinops melanostictus*), Spanish mackerel (*Scomberomorus niphonius*), Japanese jack mackerel (*Trachurus japonicus*), *Setipinna taty*, scaled sardine (*Harengula zunasi*), Japanese scad (*Decapterus maruadsi*) and spotted sardine (*Clupanodon punctatus*). Only very few pelagics belong to cold water species, e.g., the Pacific herring (*Clupea harengus pallasi*) in the Yellow Sea. The spawning temperature of the warm water and warm temperate species is generally between 18°C and 30°C, but rarely down to the lowest of about 12°C. The optimum spawning temperature of the cold water species is 3 to 5°C. The Chinese small pelagics are planktivorous, feeding mainly on the zooplankton. Only some species feed on small fish and cephalopods.

Pacific herring (*Clupea harengus pallasi*)

The Pacific herring form a local stock inhabiting the central northern Yellow Sea (north of 34° N) (Ye *et al.*, 1980; Tang, 1991), but they are absent in the East and South China Seas. The fish inhabit the 60m - 90m depths from May to February every year. During wintering (December to February), they occupy mainly the Yellow Sea Depress (35° 10'-37° 10' N, 123° 30' - 125° 00' E) where the bottom temperature is 7 to 10°C and salinity 32 to 33‰. The mature fish migrate in batches north westwards to the Shandong Peninsula since late February or early March. The main population arrives at the shallow waters off the Shandong Peninsula for spawning in late March or early April. A small part of the stock spawn in the northernmost Yellow Sea. After spawning the herring migrate out of the spawning grounds for feeding. During May to November, they disperse for feeding in the 34° 35' - 38° 00' N, 122° 30' - 125° 15' E area. The juvenile herring start feeding before June in the nursery grounds, and migrate towards the deep waters for feeding from the beginning of July. The distribution of the juveniles is somewhat more northwards than that of the adults. The Yellow Sea stock undertakes diel vertical movements, with the fish staying at the bottom during the day and moving towards the surface during the night. When the atmospheric pressure reduces, the herring appear in the surface layer. Since the herring are a boreal species, the optimum water temperature for their spawning is in the range of 2 to 6°C. During feeding and wintering, the optimum water temperature ranges from 6 to 10°C. The stock is distributed in the areas controlled by the Yellow Sea cold watermass.

The Pacific herring are caught mainly by the purse seines and trawls. Some set fishing gears are also used in the Yellow Sea. The long history of the herring fishery is characterized by two peaks, the first in 1900 and the second in 1938, which was followed by a period of extremely poor catch or no catch (Tang, 1990). The fishery, which is determined by the size of the biomass (Fig. 2) was very important in China in the beginning of the 1970's when the catch contributed more than 20% to the total catch in the Yellow Sea and the Bohai Sea. The subsequent decades witnessed a drastic decline in the fishery, with its status reduced to a bycatch fishery currently.

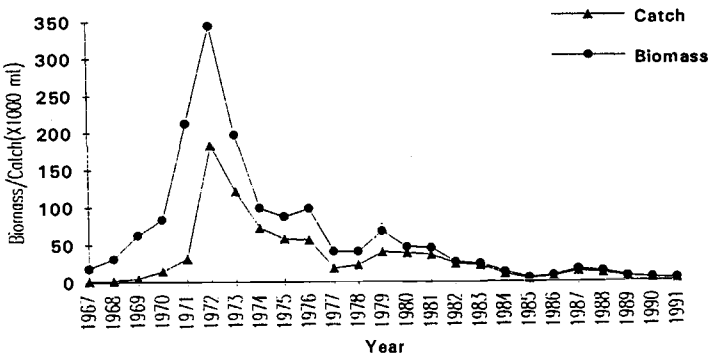


Fig. 2. Biomass and catch of the Pacific herring taken by China from the Yellow Sea during 1968-1991.

The recovery, growth and decline of the Pacific herring fishery seem to be associated with overfishing and climate change. The catch of the herring increased rapidly to a peak of more than 180 000 mt in 1972 and decreased sharply thereafter (Fig.2). Rainfall, wind and daylight are the major environmental factors affecting the fluctuations in recruitment. The long-term changes in the biomass could be correlated with a 36-year cycle of wetness oscillation in east China (Tang, 1991), but high fishing pressure undoubtedly speeds up depletion. The abundance of the annual adult stock has been reduced to about 1 000 to 3 000 mt in recent years (Liu *et al.*, 1990).

Chub mackerel (*Scomber japonicus*)

The chub mackerel are distributed in the northwest Pacific from the northern part of Japan to the South China Sea. There are two stocks of Japanese mackerel in the seas around China: the East China Sea stock and the Min-yue stock. The spawning migration of the East China Sea stock is positively correlated with the surface temperatures of the Yellow Sea and the East China Sea. Therefore, the surface temperature during the end of April to the beginning of May is regarded as an important factor in predicting the Japanese mackerel migration into the Yellow Sea for spawning. The spring fishing period in the mackerel spawning grounds in the Yellow Sea is closely linked with the distribution patterns of the water masses. The fish usually choose the confluence of the open sea with the inshore waters as their spawning grounds. When the open sea waters tend to flow strongly northward, the Japanese mackerel move northward, seeking the spawning grounds. The spawning grounds could also be forecast based on the isohaline of 32‰. The Min-yue mackerel stock is distributed in the shallow areas of 19° 00' - 22° 30' N; 115° 00' - 119° 00' E , which also serve as the spawning grounds. Some portion of the stock migrate into the East China Sea through the Taiwan Strait. After spawning, the mackerel disperse for feeding in the nearby areas, and then migrate back to the deeper areas in November (Wang and Zhu, 1984).

The main fishing gear used in the mackerel fishery is the light-luring purse seines in the autumn and the winter in the middle and east southern parts of the Yellow Sea and the East China Sea in the wintering grounds. The aimed purse seine fishery operates in the spring and the summer feeding grounds while the driftnet fishery operates during the spawning migration in the spring in the western part of the Yellow Sea. In the Fujian Province a certain kind of purse seine with a bag is used in aimed fishing. Some catch of the Japanese mackerel come as bycatch from the trawls. During 1986-1995, the annual catch of chub mackerel in China fluctuated from 132 000 to 372 000 mt. In recent years the feeding stock and wintering stock have been overexploited. The proportion of young mackerel increased in the catch, so also the fishing effort.

Japanese jack mackerel (*Trachurus japonicus*)

The Japanese jack mackerel are a warm water species found in China, Korea and Japan. In China, they are distributed in all the Chinese waters. The main fishing grounds are in the Guangdong Province and the southern part of the Fujian Province. The catch is derived from both the spawning stock and the feeding stock. The spawning stock is distributed in the Sea of Yuexi, Pearl River estuary and the coastal waters of Yuedong. In the Sea of Yuexi and off the Pearl River estuary the jack mackerel inhabit depths of 180m to 200m while in the coastal waters of Yuedong they occupy depths of 50m to 60m, extending to the shallow waters on the southwest of Taiwan. Spawning starts in October and ends in April. The stock in the nursery grounds is composed of O-year and one year old fish. The one year old fish are distributed along the northwest of the Dongsa islands, at depths of 80m to 150m while the 0-year group are found in the coastal areas of Yuedong and Minnan. The nursery phase lasts from March to September. The spawning stock in the coastal waters of Yuedong and the feeding stock in the coastal waters of Minnan exhibit the same pattern of migration. Spawning extends from December to February in the areas around the 50m to 60m isobaths along the southwest coast of Taiwan. The postspawners migrate towards the northeast into the coastal areas of Yuedong during March to May. The newly hatched larvae and the juveniles drift with the winds and currents into this area. The young fish are found widely distributed in the nearshore nursery areas of Yuedong and Minnan during June to August. With the decreasing water temperature during September to November they migrate from the northeast towards the southwest into the nearshore areas of Yuedong.

The jack mackerel are caught mainly by the light luring purse seiners and as bycatch by the trawlers. The annual catch of jack mackerel is quite unstable. The catch reached 9 974 mt in 1958, but decreased sharply to 4 000 mt in 1959, and after 1962 there was no fishery for the jack mackerel in the East China Sea and the Yellow Sea. However, the fishery for this species was relatively stable in the waters of Yuedong and Minnan, in the 1970s, the annual average catch was 910 mt from Minnan while the catch from Yuedong increased from the end of the 1970s to the beginning of the 1980s. The total catch in China was 2 412 mt, 3 026 mt, 2 435 mt and 4 031 mt respectively during 1979 to 1982, increasing steadily from 2 412 mt

in 1979 to 4 031 mt in 1982. The Guangdong Province alone contributed about 90% to the total catch in China.

Japanese anchovy (*Engraulis japonicus*)

The Japanese anchovy are distributed in the northwest Pacific extending from the southern Okhotsk Sea in the north to the northern South China Sea in the south. In the Chinese waters the anchovy stock inhabits the Yellow Sea, the Bohai Sea, the East China Sea and the northern South China Sea. During winter the stock occupies the Yellow Sea and the East China Sea areas between the latitudes of 26°N and 37°N, mainly at the bottom depths of 40m to 80m characterized by temperatures of 7 to 14°C. The winter distribution concentrates around two main centres, one in the central and southern Yellow Sea and another in the northern East China Sea. With increasing water temperature, the anchovy migrate towards the northwest from the wintering grounds in the southern Yellow Sea and the East China Sea. They migrate to the spawning grounds close to the coast in the Yellow Sea, the Bohai Sea and around the islands of Zhejiang Province from the beginning to the middle of May. The dense schools in the waters around the Shandong Peninsula and the Haizhou Bay formed during the middle of April to the middle of May afford good fishery in these areas. Between late spring and autumn the anchovy occupy the entire Yellow Sea and Bohai Sea. The main spawning takes place from April to June along the coast of the Liaoning, Shandong and Jiangsu Provinces. After spawning, the anchovy leave the coast to the middle of the Yellow Sea and the Bohai Sea for feeding, when the schools become relatively sparse (Li, 1987).

The average annual biomass of the anchovy was estimated to be about 3 million mt (range: 2.5 to 4.3 million mt) in the Yellow Sea and the East China Sea based on the winter acoustic surveys by R/V Beidou during 1984-1993 (Table 2). The stock attained the maximum size of 4.3 million mt during 1992-1993. However, it should be noted that the estimates are rather arbitrary owing to the differences in the acoustic coverage of the areas inhabited by the anchovy (Iversen and Zhu, 1993). The main fishing gears currently in use in the anchovy fishery in China include the pelagic trawls, big mesh trawls, different kinds of fixed nets, small mesh driftnets and small purse seines. During the spawning migration in the offshore of the Shandong Peninsula and in the Haizhou Bay, the small trawls are operated mainly . During the peak spawning in the Yellow Sea and the Bohai Sea from the mid-May to mid-June, different kinds of fixed nets take substantial catches of the anchovy along the coast. When the anchovy migrate for overwintering into the wintering grounds from November to February, the schools become very dense and stable, extending to vast areas and afford good catches to the pelagic trawls. The anchovy stock is caught mainly during the spawning season in spring and feeding season in summer along the coasts of the three provinces in the north of China. The stock in the wintering grounds, which is far away from the coast, is underexploited.

Table 2. Biomass of anchovy in the Yellow Sea and the East China Sea by acoustic assessment during 1986-1995.

Year	Number (x100 million)	Weight (million mt)
1986-1987	295.0	2.80
1987-1988	338.6	2.80
1988-1989	278.2	2.52
1989-1990	250.8	2.52
1990-1991	337.9	2.50
1991-1992	287.9	2.78
1992-1993	458.8	4.28
1993-1994	346.8	3.74
1994-1995	391.0	3.85

The total mortality (Z) was estimated for the different yearclasses comprising the 1986-1989 fishery in which the 1 year old or older fish were negligible, and hence Z was considered to be the estimate of natural mortality (M).The value of M for the stock in the Yellow Sea and the East China Sea is 0.9 and the potential annual yield is in the order of 0.5 million mt. After the publication of the results of the anchovy surveys by R/V Beidou, the government allocated much higher funds especially for developing the anchovy fishery. The R/V Beidou is a modern research vessel used for trial trawling as a single trawler. In the three years from 1986 to 1989, a total of 116 pelagic hauls were taken in the wintering fishing grounds and 777 mt of anchovy were caught. The maximum catch per haul was 50 mt, the maximum catch per hour 25 mt, the average catch per haul 7.1 mt and the average catch per hour 3.1 mt. In the experimental fishing by double trawlers each with 600 HP engine, the maximum catch per haul was 50 mt and the maximum catch per hour 11 mt. In pair trawlers, each with 200 HP engine, the maximum catch per haul was 6 mt and the maximum catch per hour was 2.4 mt. It has been established that the pelagic trawls are very efficient for the anchovy fishery in the wintering grounds in the Yellow Sea. There are about 100 pairs of 370 HP trawlers for the anchovy in the fishing season in Rongcheng, where the catch per haul was generally 3 to 4 mt and the maximum catch per haul 15 mt. Since 1991, the fishermen in Shandong and Liaoning provinces have been using extensively big mesh trawls, small mesh driftnets and different kinds of fixed nets for the spawning anchovy during the spring. As a result the annual yield increased rapidly by 4.8 times from 40 000 mt in 1989 to 193 000 mt in 1992, and peaked at about 580 000 mt in 1993, but declined to about 489 000 t by 1995 (Fig. 3). Most part of the anchovy catch are taken from the Shandong Peninsula and the Liaoning, Jiangsu and Zhejiang Provinces.

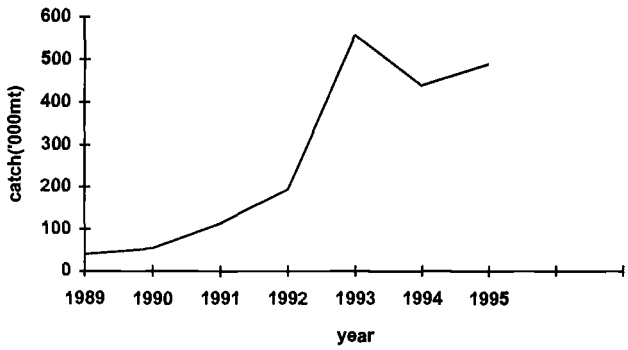


Fig.3. The yield of Japanese anchovy in China.

Japanese pilchard (*Sardinops melanostictus*)

The Japanese pilchard are warm temperate, they are widely distributed in the Northwest Pacific and afford one of the most lucrative fisheries globally. Four stocks have been identified; they include the Pacific stock, the Ashzuri stock, the Kyushu stock, and the Japan Sea stock (Chikuni, 1985). In recent years the Kyushu stock has been found in the East China Sea and the Yellow Sea also (Zhao *et al.*, 1990). The Japanese pilchard were not found in the Yellow Sea before the 1970s, but since 1976, they have been arriving in the southern and central parts of the Yellow Sea from late April to mid-May. Spawning occurs mainly along the Shandong Peninsula and to a limited extent in the Bohai Sea. After spawning, the feeding population schools often in the surface layer. In summer, they move gradually into the deeper layers and reach the central and southern Yellow Sea in the autumn. When the water temperature decreases, they migrate out of the Yellow Sea to the southeast. Evidently, temperature seems to directly influence the migration of the Japanese pilchard. The occurrence of the Japanese pilchard in the Yellow Sea is consistent with their recovery around Japan (Chikuni, 1985).

The Japanese pilchard are caught by the purse seines and set nets, but also form a good bycatch from other fisheries. Since they are a new fishery to China, the Japanese pilchard fishery statistics started in China only in 1989. The catch increased from 21 000 mt in 1989 to about 50 000 to 70 000 mt in the recent five years. According to the surveys conducted from 1986 to 1988 , the biomass of the Japanese pilchard is about 610 000 mt in the eastern East China Sea and the southwestern Japan Sea, and about 40 000 mt in the Yellow Sea(Ding *et al.*, 1988). The MSY, estimated to be around 300 000 mt indicates good potential for this fishery in the Yellow Sea and the East China Sea.

Scaled sardine (*Harengula zunasi*)

The scaled sardine are a temperate pelagic stock, distributed in the inshore of the Philippines, Japan, Korea and China. In China, they inhabit the Bohai Sea, the Yellow Sea and the East China Sea. The wintering grounds of the fish are located in the areas around the 100m isobath between the Saishu Island and the Goto Retto where the bottom temperature ranges from 10 to 13°C. The wintering season of the fish extends from January to March. In the first ten days of March, the fish begin their spawning migration in batches from the south to the northwest. From about the first to the twentieth of May, the shoals reach the spawning grounds in the offshore of Lusi, the Haizhou Bay, the offshore from Qingdao to Shidao, the offshore of Dalian and the Bays in the Bohai Sea. The spawning season extends from May to July, during which spawning take place much earlier in the south and late in the north. After spawning, the fish scatter about in the nearby grounds to feed in the inshore and form three different dense concentrations, one each in the Laizhou Bay, the Liaodong Bay and the estuary of the Sheyang river during June to October. They begin their wintering migration in September and October. In the latter half of November, they concentrate in the middle and the south of the Yellow Sea, but continue their migration towards the south. In the first ten days of January, the shoals return to their original wintering grounds. In the East China Sea, the scaled sardine occupy the inshore of the Fujian province throughout the year. According to their habitats, they could be divided generally into three local stocks, i.e., of the east Fujian, the middle Fujian and the south Fujian stocks. They undertake only short distance shifts in accordance with the prevalent temperature. In the spring and the summer, they migrate to the inshore and the estuaries to spawn and feed. In the autumn and the winter, they migrate into the deepsea areas. As the coastal East China Sea is controlled by the continental coastal current round the year, the water transparency is less than 5 m. The coastal Fujian province, which is about 50 m deep, is narrow, long and lies generally parallel to the coast with uniform depth from the northwest to the southwest.

Although the scaled sardine are caught by fixed nets, beachnets and driftnets in the Bohai Sea and the shallow areas of the Yellow Sea, they are exploited mainly by the demersal trawls and form a local traditional small-scale fishery in the Bohai Sea and the Yellow Sea. Investigations made in 1981 indicated the catch per haul of the trawl to be stable at 140 to 160 kg in these areas. The current annual yield of the fish in China is about 30 000 to 40 000 mt, but before 1985, it was 18 000 to 25 000 mt of which 60% came from the Bohai Sea and the Yellow Sea. Though the demersal trawl has been prohibited in the Bohai sea since 1988, its annual catch has been accounting for 30 000 to 40 000 mt during these years in China. The stock is relatively stable, and the present catch close to the MSY.

Japanese scad (*Decapterus maruadsi*)

The Japanese scads constitute a common fishery in the coastal waters of the South China Sea, the East China Sea, the Yellow Sea, Korea and Japan. There are at least two scad stocks, one in the East China Sea and another in the Minnan-Yuedong waters, different from each other in growth, age at first maturity, and

spawning season. In the East China Sea the scad are often associated with the Japanese mackerel, but their distribution extends farther south and closer to the shore. There are probably two overwintering grounds for the scad stock, one in the mid-south of the Taiwan Strait and the other in the Pengjia islands, north of Taiwan, where the depth ranges from 100 to 150m. The stock in the overwintering grounds in the mid-south of the Taiwan Strait, begins to leave these grounds in March and migrates towards the west and the north to spawn along the coastal areas between the middle and the east of Minnan. Spawning lasts from April to July, but is intense in May and June. The stock along the northern coast of Taiwan begins to migrate northerly to the coastal areas of the Zhejiang province in May and April. The fish reach the different spawning grounds at different times, according to the distance. Spawning lasts from April to September, but peaks in May and June. The adults and the young fish feed along the coastal waters, north of the Zhjiang province during July to October and begin to migrate southerly to their overwintering grounds, with the decrease in the water temperature in November. The distribution of the local Minnan-Yuedong stock is relatively stable. Mark recapture experiments show that the fish migrate to only short distances as the area is relatively small and affected by a branch of the Kuroshio Current. There are two densely occupied areas, one of which is south of Jiazi (22-22° 30'N and 116-116° 40'E) and another in the southern shelf of Taiwan (22° 10'-22° 40' N and 117° 30'-118° 10'E). While the fish in the south of Jiazi belong to the spawning stock those in the southern shelf of Taiwan belong to the feeding stock.

The Japanese scads are caught mainly by the light luring purse seines and a limited extent by the gillnets, driftnets, pair trawls and longlines. The Chinese catch of scad has been increasing steadily from 238 000 mt in 1986 to 515 000 mt in 1995, and hence, considered to be one of the most important commercial fisheries in China.

THE BIOLOGICAL AND ENVIRONMENTAL PARAMETERS

The small pelagics in the Chinese waters are characterized by very few age groups, early maturity, long spawning periods, high fecundity and fast growth. The pelagic stocks generally consist of 0 to 4 or 0 to 5 year groups, but the butterfish (*Stromateides argenteus*) stock consists of 0 to 7 year groups. Some species attain first maturity when the fish are one year old while nearly all other species mature at the age of two years. The duration of spawning extends to be progressively longer from the north to the south. As the temperature is higher in the northern South China Sea and the southern East China Sea, spawning lasts for 5 to 6 months, but in the cooler Yellow Sea and the Bohai Sea, spawning usually lasts for about two months only. The fecundity of the small pelagics varies much with species, ranging from 20 to 39 thousand eggs in some species and from 100 to 240 thousand eggs in others. However, the fecundity of the jack mackerel and the Japanese mackerel attains a maximum of 150 to 860 thousand eggs. The growth of the small pelagics is very fast at the age of one and two years and slow after 3 years. The small pelagics are of high fecundity, and normally the recruitment stock is greater than the surplus stock. Some of the biological parameters of the Chinese small pelagic stocks (Table 3) are outlined briefly below (Deng and Chuanyin, 1991).

Table 3. The biological parameters of the small pelagics in the Chinese waters.

Species	Age & dominant size groups in the stock		Maturity		Fecundity
	Age (y) groups	Fork length of dominant size group (mm)	Age (y)	Fork length	('000 eggs)
Chinese herring	1 to 13	-	2	280	14 to 197
Pacific herring	0 to 9	-	1 to 9	-	19 to 78
Japanese pilchard	2 to 6	200 to 220	2	-	21 to 90
Scaled sardine	0-5	110 to 135	1 to 2	-	3.5 to 5.5
Japanese anchovy	1 to 4	100 to 130	-	-	11
Japanese scad (East China Sea)	0 to 5	190 to 270	1	174	-
Japanese scad (Minnan-Yeudong)	1 to 5	180 to 190	1	130	25.2 to 218.8
Japanese mackerel	0 to 6	150 to 200	1	-	-
Chub mackerel (East China Sea)	1 to 8	310 to 370	1 to 2	260	234 to 860.5
Chub mackerel (Minnan-Yeudong)	1 to 5	230 to 280	1	210	150 to 200
Spanish mackerel	1 to 6	500 to 550	1 to 3	420	280 to 1100
Silver pomfret	1 to 6	150 to 230	1 to 2	120	18 to 240

Pacific herring (*Clupea harengus pallasi*)

The diet of the Pacific herring is relatively unitary, with *Euphausia pacifica* constituting more than 99% of the stomach contents by weight (Tang, 1980). The period of active feeding mainly extends from April to August, while during the remaining period there is very little or no feeding. Feeding intensity is primarily determined by the density of *Euphausia pacifica* and also by the depth and temperature, and hence the areas of distribution of the fish are not always the areas where *E. pacifica* density is the highest. During the period of active feeding of the herring in the Yellow Sea, no other zooplankton feeders are found in the herring distribution areas, except some benthos feeders. Therefore, there is no apparent food competition, although the food of herring is restricted essentially to one predominant item.

Embryonic development and hatching of the Pacific herring in the laboratory indicate the body length of the newly hatched larvae to be 5.2 to 6.8 mm (Jiang and Cheng, 1981). After 4 to 5 days, they reach 7.2 to 7.8 mm, and after 12 to 13 days, 9.9 to 11.2 mm. The growth is faster during the summer (June to August), accounting for 43% of annual increase in length at an average monthly increase of

14%; growth is low during the autumn. The change in the growth rate from the summer to the autumn is consistent with the feeding pattern (Tang, 1991). The relationship between fork length and weight, and the von Bertalanffy length growth and weight growth equations, fitted by Tang (1980) are as follows:

$W=7.938 \times 10^{-6} L^{3.02}$, $L_t = 305 (1-e^{-0.66(t+0.198)})$ and $W_t=253[1-e^{-0.66(t+0.198)}]^{3.02}$.

Most of the Pacific herrings mature when they are two years old and start spawning in February in very shallow waters of 3 to 7 m depth along the coast and the bays around the Shandong peninsula. Some of them spawn on the banks off the Liaodong peninsula and off west Korea. The main spawning season extends from March to April when the development exhibits a definite synchronism, and the individual absolute fecundity ranges from 19 300 to 78 100 eggs at the age of 2 to 6 years. The linear increase in absolute fecundity (F) with the net body weight (W_n) follows the equation of $F=0.0304W_n-0.409$. The herring spawn once in every reproductive season, which is very short. The eggs stick together and adhere to reefs, algae and other substrates. The hatching time decreases with the increase in temperature from about 12 to 14 days at 5.5 to 10°C to 7 to 8 days at 15 to 20°C (Jiang and Chang, 1981; Zhang *et al.*, 1983).

Chub mackerel (*Scomber japonicus*)

The Chub mackerel feed mainly on the zooplankton and small fish comprising more than 30 items, which include mainly the crustaceans (the euphausid *Euphausia pacifica,* the copepod *Calanus*, the amphipod *Themisto* gracilipes, and the decapods), Chaetognatha (*Sagitta crassa*), anchovies, small squids and fish eggs. In the East China Sea the mature mackerel range in length from 240 mm to 470 mm and in weight from 270 g to 1600 g but in the Min-Yue area they are 200 mm to 370 mm in length and 100 g to 670 g in weight. The maximum life span is about 10 years. The von Bertalanffy equations for length growth and weight growth are:

$L_t=425(1-e^{-0.53(t+0.8)})$ and $W=3.491*10^{-6} L^{3.276}$

Based on the data for 1978-1982, the average annual biomass in the East China Sea and the Yellow Sea has been estimated to be 500,000 t and the potential annual yield 300 000 mt to 320 000 mt.

Jack mackerel (*Trachurus japonicus*)

The feeding intensity of the jack mackerel is high in spring and autumn and low in winter. The fish feed mainly on plankton and rarely on small nekton and benthos. The common prey items belong to the Copepoda, Amphipoda, Macrura, Ostracoda, Euphausiacea, Pteropoda and the larvae of Crustacea, fish and cephalopods. The composition of the diet is different in different areas, largely due to the variations in the dominant organisms found in the feeding grounds.

The size of the jack mackerel caught in the northern South China Sea during the late 1970s ranged from 101 mm to 310 mm in fork length (mean = 178 mm) in which the 151mm to 200 mm group constituted 86.5% of the total catch. The weight of fish in the catch ranged from 21 g to 310 g (mean = 81 g) in which the 80 g to 100 g group formed 52.7% of the total catch. The jack mackerel live up to the maximum age of 6 years. The one year group is dominant constituting 68.2% of the catch followed by the second year group which makes up 27.9 % of the catch. The spawning stock is composed mainly of the one and two year old fish which make up 39.9% and 55.8% respectively of the total number of spawners. The growth is fastest in the first year of life when the fish attain a length of 174.8 mm. The annual length increments range from 20mm to 30mm between the age of two and three years. After four years of age the annual length increment is less than 20 mm. The fork lengths and body weights-at-age are given in Table 4. The length-weight relationship of jack mackerel can be described by:

$W=1.0835*10^{-5}L^{3.037}$ and the length growth by $L_t=320.97(1-e^{-0.217(t+2.61)})$.

Table 4. The fork length and body weight-at-age of the Japanese jack mackerel.

Age(y)	1	2	3	4	5	6
Length(mm)	175	202	227	248	259	276
Weight(g)	74	107	179	218	236	308

Japanese anchovy (*Engraulis japonicus*)

There are about 50 prey items in the diet of the Japanese anchovy, but the diet is dominated by the crustacean plankton which form about 60% of the total diet by weight. The main species are *Calanida pacifica, Sagitta crassa, Euphausia pacifica* and *Themisto gracilipes*. The anchovy hardly feed during the spawning season and during overwintering.

The distribution of the anchovy is closely related to water temperature. The temperature in the wintering grounds ranges from 9 to 14°C, with the average of about 12°C while the optimum temperature for spawning is 14 to 16°C. The temperature in the Yellow Sea and the East China Sea reaches over 20°C in the summer, when the anchovy are widely distributed in these areas. The anchovy undertake regular diurnal vertical movements, with school thickness of 20 to 40 m during night and 10 to 20 m during daytime in the center of the wintering grounds. In common with most other schooling fish, the behaviour of the anchovy is strongly influenced by the light regime. During the daytime the anchovy usually appear in dense schools at varying depths depending on the intensity of light and temperature, but in the night, the anchovy remain scattered in the surface layers or in the entire water column in the shallow waters. Schooling begins at dawn and increases in intensity and density with daylight.

been determined to be about 4 years and the fish length seldom exceed 16 cm. The growth equations fitted for the anchovy are :

$L_t = 16.3(1-e^{-0.8(t+0.2)})$ and $W = 4.0*10^{-3}*L^{3.09}$.

The spawning grounds of the anchovy extend over vast areas. When the anchovy reach the mature stage V just before the peak spawning season, the minimum fork length and net body weight of the female attain 90 mm and 5 g respectively. The average size of the spawners ranges from 103 mm to 117 mm fork length, comprising one and two year old fish. The spawning season extends from the beginning of May to about the middle of October, with peak spawning occurring from the middle of May to the end of June. The absolute fecundity ranges from 600 to 13 000 eggs, with a mean of 5 500 eggs while the absolute fecundity of the main fork length groups (103 to 117 mm) ranges from 2 500 to 11 000 eggs, with a mean of 5 700 eggs.

Japanese pilchard (*Sardinops melanostictus*)

The Japanese pilchard in the Yellow Sea and East China Sea feed predominantly on plankton which comprises 33 zooplankton items and 28 phytoplankton items. The copepods and diatoms form the major food. The larvae and the juveniles also feed mainly on the copepods and diatoms. The adult sardine feed on lamellibranch larvae and protozoan also. The number of food items increased with the increase in the fish length (Hu and Qian, 1988).

The size of the fish in the catch from the Yellow Sea ranged from 140 mm to 250 mm, with the dominant length group measuring 200-220 mm. The population consists of 2 to 6 year old fish, but dominated by 3 to 4 year old fish. The relationship of body weight and fork length, and the growth equations fitted for the Japanese pilchard are:

$W = 1.099x10^{-5}L^{2.97}$, $L_t = 284[1-e^{-0.258(t+1.42)}]$ and $W_t = 211[1-e^{-0.258(t+1.42)}]^{2.97}$

The Japanese pilchard begin to be mature when they are two years old. The absolute fecundity ranges from 21 000 to 90 000 eggs which are released in batches. At hatching, the larvae range from 3.1mm to 3.8 mm, and reach 5 mm after three days. In 7 to 9 months, the Japanese pilchard grow to a length of 60 to 80 mm. By December, the juvenile fish attain a length of 120 to 150 mm.

Scaled sardine (*Harengula zunasi*)

The scaled sardine feed mainly on plankton consisting of copepods and the larvae of lamellibranchs, gastropods and brachyurans. They feed occasionally on the polychaetes and diatoms also. The feeding intensity reduces considerably during the spawning season, when the stomachs of 20 to 75% fish have been found to be empty, as in the case of *Engraulis japonicus, Setipinna taty* and *Decapterus maruadsi*. The areas of distribution of these three species overlap sometimes with those of the scaled sardine, resulting in competition for food among them. All of

them, in turn form the food of *Pneumatophorus japonicus*, *Scomberomorus niphonius* and *Trichiurus haumela*. Together with *Engraulis japonicus*, the scaled sardine take the role of transfer of energy from the level of plankton to that of the carnivores in the same ecosystem.

The stock and the catches consist of 1 to 5 year old fish, with the 2 year old fish constituting 70 to 80% of all age groups. The size of the fish in the catches ranges from 60 mm to 165 mm fork length, with the 100 to 120 mm group forming the dominant group. The corresponding body weight ranges from 11 g to 60 g, and the dominant weight group 20 to 24 g. The male and female are indistinguishable. The relationship between the body weight and fork length is:

$W = 1.05 \times 10^{-3} L^{2.133}$, and the length growth equation $L_t = 186.68(1-e^{-0.24(t+2.47)})$

where t=age in years and L_t=fork length at age t. The scaled sardine grow fast attaining a body length of 30 to 40 mm in one and a half months after hatching and 75 to 98 mm four to five months after hatching. They begin to be mature at the age of 1 year and , all individuals are mature when they are 2 years old. After maturity, the body length growth slows down, but the increase in the weight growth is still significant. The seasonal difference in growth is significant, especially among the young fish of less than 1 year age. They grow fast in summer and autumn, but stagnate in winter. The maturing individuals also grow fast in summer and autumn, and slow in spring owing to the gonadial development. The spawning season extends from May to July with the peak during the middle of May to the beginning of June. The spawning season does not vary much with locations, but is generally earlier in the western sea areas, where the water temperature raises quickly in the shallow inland bays. The scaled sardine begin to mature at the age of 1 year, and all of them become mature after 2 years of age. The female mature somewhat earlier than the male. The total fecundity ranges generally from 4 000 to 45 000 eggs and the relative fecundity ranges from 190 to 2 000 eggs/g. All the mature eggs are spawned in a single batch. Fecundity increases with the increase in the body length and the gutted weight of fish.

Japanese scad (*Decapterus maruadsi*)

They feed on a wide variety of planktonic items, but the feeding intensity and food composition vary with time and space. In the eastern areas of Yuedong, they feed mainly on the macrurans, molluscs and small fishes. Although the ostracods, copepods and amphipods are often significant by number in the diet, their contribution is quite insignificant. In the western areas of Yuedong, the scad feed principally on the macrurans, copepods and ostracods (Liang Ying, 1979). Based on a survey conducted in 1962 in the northern shelf of the South China Sea, the food of the scad was found to be composed of 21 prey items which were dominated by the copepods, macrurans, ostracods, small fish, molluscs, amphipods and mysids. Crustacean larvae, foraminiferans, chaetognaths and euphausids are of less importance in the diet, while the others appear only occasionally in the diet. In the East China Sea, the scads feed on a wide variety of items, but dominated by the euphausids (mainly *Euphausia pacifica* and *Pseudeuphausia latifron*) and

chaetognaths (mainly *Sagitta*). The copepods, decaepods, cephalopods, brachyurans and stomatopods are less important in the diet.

The feeding stock in the East China Sea is composed of fish ranging from 170 mm to 320 mm fork length, but in the Yuedong area, the feeding stock is of fish ranging from 100 mm to 300 mm fork length. The spawning stocks are composed of fish 1 to 5 years old and the feeding stocks are comprised by fish 0 to 4 years old. The average size of the fish in the East China Sea is 236.6 mm fork length, while in the Yuedong and Minnan waters it is 198.8 mm fork length. The 1 and 2 year old fish are the dominant age groups in East China Sea while the Yuemin stock is dominated by the 1 year old fish. The relationship between the body weight and the fork length is $W=1.652*10^{-5} *L^{2.947}$ for the stock in the East China Sea and $W=5.616*10^{-5} *L^{2.7162}$ for the Yumin stock. The growth of the scad in the East China Sea can be described by the equations:

$L_t=361(1-e^{-0.276(t+1.846)})$ and $W_t=570(1-e^{-0.282(t+1.80)})^3$,

while the same for the Yumin stock are:

$L_t=328(1-e^{-0.31(t+1.74)})$ and $W_t=375(1-e^{-0.31(t+1.74)})^{2.7162}$

The sex ratio of the scad stock has been found to be about 1:1. Both male and female reach first maturity at the age of one year at a fork length of 174 mm. The fecundity first increases with age, and attains the maximum from April to August at the age 2 to 3 years, but then decreases with age. The spawning season extends from April to August in the East China Sea and from December to May in the Minnan waters.

MANAGEMENT

The Chinese government is quite concerned with and committed to the protection and sustainable utilization of the marine fisheries resources in the Chinese waters. A series of laws and regulations have been enacted and a strong Department of Fisheries Management established. The government regulations include closed fishing areas and periods, ban or limitation on certain fishing gears and methods, minimum mesh size regulations and other measures. In the Bohai Sea, the closed fishing season for trawling extends from June 20 to August 20 to protect the eggs and larvae while in the East China Sea, the larval protection areas, established in 1979, are in vogue since then. In 1995 and 1996, trawling was completely banned from 1st July to 31st August in the entire Yellow Sea and the East China Sea in order to protect the larvae and the young fish resources, with extremely good results. In addition, the government is also implementing a series of preferential policies in order to encourage mariculture in the coastal areas. Through these management measures, fishing effort has been effectively controlled, and the production structure of marine fishery is readjusted appropriately.

The Ministry of Agriculture issued in 1983 "The Temporary Rule of Marine Fishing Trawlers Management" for the regulation of the manufacture, import, renewal, transfer, scraping and licensing of fishing boats. In order to restrict the number of fishing boats in the coastal waters, further increase in fishing boats in the

Bohai Sea, Yellow Sea and East China Sea is strictly forbidden. In the South China Sea also such a strict control is needed. The fishing boats are levied a tax for the protection and enhancement of the fisheries resources. The tax the fishermen are required to pay varies with the power of the fishing boats and the location, but constitutes about 30 percent of the total profit per capita.

CONCLUSION AND RECOMMENDATIONS

The resources of the small pelagics are abundant in the Chinese waters and most of the stocks are being optimally exploited. However, the stock of the Yellow Sea herring and Chinese herring have been declining in the Chinese waters in recent years. The small pelagics are characterized by strong renewability and recruitment, so that the recruitment stocks are much bigger than the surplus stocks in years of normal recruitment. These characteristics indicate good potential for developing the fisheries for the small pelagics in the Chinese waters, especially in the South China Sea. The yield of the Japanese anchovy has gradually increased in the Chinese fishery in the Yellow Sea and the East China Sea where the stock has been estimated to be more than 3 million t and the catchable potential about 0.5 million annually. The small pelagics constitute the food of many apex carnivores in the Yellow Sea and the East China Sea. The ecological links of the small pelagics with other components of marine community need to be understood well and used as the basis for sustained development of marine fisheries in the Chinese waters. Protection of the spawning stocks is very crucial in ensuring that the recruitment is maintained at an optimum level. Based on these considerations, the Chinese government is implementing a number of measures to protect the marine fisheries resources for their sustainable utilization.

REFERENCES

Chikuni, S. 1985. The fish resources of the northwest Pacific. FAO Fish. Tech. Pap. (266):p190.

Deng, J and Zhao Chuanyin, 1991 Marine Fisheries Biology (in Chinese), Agriculture Press of China.

Ding, R., C. Gu and Z. Yan. 1988. Estimation of biomass and sustainable yield of Japanese sardine in the Eastern part of the East China Sea and the Yellow Sea. East China Sea Fisheries Research Institute. p11 (in Chinese).

Hu, Y. and X. Qian. 1988. Study on age and growth of Japanese sardine in the eastern part of East China Sea. East China Sea Fisheries Research Institute. p12. (in Chinese)

Jiang, Y. and J. Cheng. 1981. Preliminary observations on the artificial hatching and embryonic development of Huanghai herring. Acta Oceanol. Sinica. Vol.3(3):477-486 (in Chinese with English abstract).

Li, F. 1987. Study on the behaviour of reproduction of the anchovy (*Engraulis japonicus*) in the middle and southern part of the Yellow Sea. Marine Fisheries Research (in Chinese with English abstract), Qingdao.

Liu, X. *et al.*(ed.) 1990. Investigation and division of the Yellow and Bohai Seas fishery resources. Ocean Press. p295 (in Chinese).

Iversen, S.A. and D. Zhu. 1993. Stock size, distribution and biology of anchovy in the Yellow Sea and East China Sea. Fisheries Research, 16(1993) 147-163, Elsevier Science Publishers B.V., Amsterdam.

Tang, Q. 1980. Studies on the maturation, fecundity and growth characteristics of Yellow Sea herring, *Clupea harengus pallasi* (Valenciennes). Marine Fisheries Research. No.1:59-76 (in Chinese with English abstract).

Tang, Q. 1986. Estimation of fishing mortality and abundance of Pacific herring in the Yellow Sea by cohort analysis (VPA). Acta Oceanol. Sinica. Vol.6(1):132-141. (in Chinese with English abstract)

Tang, Q. 1990. The effects of long-term physical and biological perturbations of contemporary biomass yields of the Yellow Sea ecosystem. Paper for international conference on the Large Marine Ecosystem (LME) concept and its application to regional marine resource management. 1-6 Oct. 1990, Monaco. p39.

Tang, Q. 1991. Yellow Sea herring *Clupea pallasi*. In Deng, J. and C. Zhao, (ed.) Marine fishery biology: 296-356 (in Chinese).

Tang, Q and Ye Maozhong. 1990. Exploitation and Protection of Fisheries Resources in Shandong Province Offshore (in Chinese), Agriculture Press of China.

Wang, W. and D. Zhu.1984. Studies on the fisheries biology of mackerel (*Pneumatophorus japonicus* Houttuyn) in the Yellow Sea. Marine Fisheries Research (in Chinese with English abstract), Qingdao.

Ye, C., Q. Tang and Y. Qin. 1980. The Huanghai herring and their fisheries. J. Fisheries of China. Vol.4(4):339-352 (in Chinese with English abstract).

Zhang, Y. *et al.* 1983. Inshore fish egg and larvae off China. Shandong Science and Technology Press. p206 (in Chinese).

Zhao, C. *et al.*(ed.) 1990. Marine fishery resources of China. Zhejiang Science and Technology Press.p178 (in Chinese).

STATUS, PROSPECTS AND MANAGEMENT OF SMALL PELAGIC FISHERIES IN INDIA

by

M. Devaraj, K.N. Kurup, N.G.K. Pillai, K. Balan, E. Vivekanandan and R. Sathiadhas
Central Marine Fisheries Research Institute
Cochin 682014, India

Abstract

The annual small pelagic fish production increased from 0.30 million mt during 1950-54 to 1.24 million mt during 1996 along the Indian coast. The 4 fold increase was possible due to several technological advancements. The potential yield from the pelagic resources of the EEZ is estimated to be 2.2 million mt. As there is no further scope for increasing the production from the inshore waters, there is need to bring the outer shelf and oceanic waters into increasing levels of exploitation. During 1991-95, the northwest, southwest, southeast and northeast coasts contributed 28.3%, 40.4%, 24.8% and 6.6% to the small pelagic landings, respectively. Following the motorization of the traditional craft, the effort of the motorised craft increased from 0.71 million boatdays (1985) to 3.72 million boatdays (1996), resulting in a sharp decline in the CPUE from 163 kg/boatday to 98 kg/boatday. However, the CPUE in repsect of the small pelagics from the nonmortorized and mechanized sectors increased. The major gears in the fisheries include the trawl, pursesiene, ringseine and gillnets. During 1991-95, the Indian mackerel, anchovies, Bombayduck, oil sardine and other sardines constituted 15.4%, 12.5%, 10.0%, 8.2% amd 8.1% to the landings of the small pelagics. The fluctuations in the landings of the Indian mackerel, oil sardine and the biological characteristics and stock assessments of major species of small pelagics are discussed in the paper. The economic performance of the different sectors engaged in the fisheries for the small pelagics has been analyzed. The total value of the small pelagics landed during 1995 was Rs 22 157 million. For sustaining the small pelagic fisheries, suitable management measures have suggested.

INTRODUCTION

Among the various littoral states of the Asia-Pacific countries (Fig. 1), India enjoys a prominent position in marine fish production. The Indian coastline is 8 129 km long and the exclusive economic zone 2.02 million sq.km, including the continental shelf of 0.452 million sq. km. The shelf is narrow (32 km) at 15° N. Lat. on the southeast coast and wide (174.6 km) at 20° N .Lat. on the northwest coast (Fig.2). The current exploited shelf area (upto the 60 to 80 m depth line) covers hardly 5% of the EEZ, and yields annually 2.4 million tonnes of marine fish (1996). India is among the top ten fish producing countries of the world, contributing about 3% to the world marine fish production of about 85 million mt.

About 5 million fisherfolk inhabiting the coastal areas pursue fishing and allied activities for their livelihood. About 180 000 nonmotorized traditional fishing craft, 32 000 motorized traditional craft and 47 000 mechanized vessels are deployed in the marine fisheries sector. The nonmotorized and motorized craft operate essentially for the small pelagics which make considerable impact on the socioeconomics of the coastal communities. The development of fisheries, therefore, sans the development of the small pelagic fisheries, does not have much relevance in today's India. Consequently, small scale fisheries have been receiving comparatively high priorities in the successive five year plans, particularly for infrastructure development.

The Indian experience with the small scale fisheries sector is similar to that in any other tropical developing country. The multitude of species exploited by a large variety of fishing fleets makes the management of marine fisheries a difficult proposition. An attempt is made here to bring out the historic and current status of the small pelagic fisheries and to focus attention on their sustained development through appropriate plans of actions.

The Central Marine Fisheries Research Institute (CMFRI), established in 1947, is the premier organization for marine fisheries research in India. This institute is under the administrative control of the Indian Council of Agricultural Research (ICAR), an autonomous apex body pioneering and monitoring research in agriculture, animal husbandry and fisheries. Since its establishment, the institute began to acquire authentic statistics of marine fish production and to use it as the basis for planning various research and development programmes in the marine fisheries sector. For this purpose, the institute deploys a multistage stratified random sampling design for the estimation of marine fish production, fishing effort, cost and earnings. Authentic statistics of specieswise marine fish production, fishing effort, and their regional and seasonal variations are available since 1950. The material for this paper was drawn from the databank built up by the institute through this survey. Information on various aspects of marine fisheries is disseminated from this databank on a regular basis through a well developed computerized information system.

GROWTH PROFILE OF MARINE FISHERIES

Marine fisheries operations in the preindependence days used to be carried out at a subsistence level, almost exclusively by the traditional fishermen. Today, this sector has attained the status of a capital intensive industry, warranting close monitoring and management for sustained development. In the course of the past five decades, the annual marine fish production increased from about 0.6 million mt in the fifties to the current level of 2.4 million mt (Fig. 3). This phenomenal increase has been possible largely due to the R & D efforts initiated by the central and state governments through the successive five year plans. Considering the importance of fisheries as a source of protein, employment and foreign exchange, development of fisheries became a focal theme among the five year plan priorities set by the governments.

Introduction of mechanized fishing vessels and modern gear materials during the I & II five year plans (1951-1960); increase in the use of synthetic gear materials during the III five year plan (1961-1965); introduction of purseseining during the V five year plan (1974-1978); motorization of artisanal craft in 1979; and the substantial growth in the motorized artisanal fleet operating ringseines during 1985-1996 are the major reasons for the significant increase, not only in the marine fish production, but in the pelagic fish production as well (Table 1).

Table 1. Development thrusts in the marine fisheries sector through the plan periods from 1951 to 1996.

Plan period	Duration	Major developments	Average annual catch
I five year plan II five year plan	1951 to 1955 1956 to 1960	1. Mechanization of indigenous artisanal fishing craft 2. Introduction of mechanized fishing vessels 3. Introduction of modern gear materials 4. Infrastructure for preservation, processing, storage and transportation	P = 309168 mt (54.68%) D = 256244 mt (45.32%) T = 565412 mt P = 477607 mt (65.36%) D = 253092 mt (34.64%) T = 730699 mt
III five year plan Three annual plans	1961 to 1965 1966 to 1968	1. Substantial increase in the use of synthetic gear materials 2. Export trade	P = 465606 mt (63.78%) D = 264455 mt (36.22%) T = 730061 mt P = 58864 mt (65.09%) D = 315714 mt (34.91%) T = 904355 mt
IV five year plan	1969 to 1973	1. Imports of trawlers for deepsea fishing 2. Indigenous construction of deepsea trawlers 3. Fishing harbours at major & minor ports 4. Intensification of exploratory fishery surveys 5. Expansion of export trade	P = 618272 mt (57.77%) D = 451992 mt (42.23%) T = 1070264 mt
V five year plan	1974 to 1978	1. Diversification of fishing, introduction of purseseining	P = 641498 mt (48.36%) D = 684910 mt (51.64%) T = 1326408 mt
One annual plan	1979	2. Diversification of products 3. Motorization of artisanal craft	P = 693590 mt (50.78%) D = 672149 mt (49.22%) T = 1365739 mt
VI five year plan	1980 to 1984	4. Exploratory surveys in offshore grounds 5. Declaration of EEZ in 1977 6. MZI Act 1981 for regulation of foreign fishing vessels 7. Deepsea fishing through licensing, chartering and joint venture vessels	P = 716005 mt (49.90%) D = 718909 mt (50.10%) T = 1434914 mt
VII five year plan Two annual plans	1985 to 1989 1990 to 1991	1. New chartering policy of 1989 2. Development of deepsea fishing 3. Substantial growth in motorized artisanal fleet of ringseiners 4. Coastal shrimp aquaculture	P = 999127 mt (56.5%) D = 769913 mt (43.5%) T = 1769040 mt P = 1177719 mt (53.96%) D = 1004693 mt (46.04%) T = 2182412 mt
VIII five year plan	1992 to 1996	1. Deepsea fishing by joint venture 2. Development of coastal aquaculture 3. Substantial growth in motorized artisanal fleet of ringseiners 4. Export trade changes from a resource-based to food engineering-based industry	P = 1129807 mt (49.21%) D = 1166082 mt (50.79%) T = 2295889 mt

P = pelagic; D = demersal; T = total.

The annual small pelagic fish production increased from 0.3 million mt during 1950-1954 to about 1.24 million mt during 1996 (Table 2). The contribution of the small pelagics to the total production ranged from 46.6% to 63.5% during the five decades with an average of 51.4%.

Ample support provided by the R&D institutions, coupled with the investments by the private sector interested in export trade, supplemented the government efforts in expanding the growth of the sector. Production of pelagics and total fish registered significant increase during the decade of 1960-69, with a relative growth rate of 45% for the pelagics(Table 3), which was largely due to the expansion of the mechanized fleet. In the following decades (1970-79 and 1980-89), although there was an overall upward trend in production, the annual growth was only 22 to 27%, indicating optimum level of exploitation of all the resources in the inshore waters, upto about the 50 m isobath.

Table 2. Annual average landings of small pelagics, large pelagics and total marine fish landings in India during 1950-96 in mt.

Year	Small pelagics	Large pelagics	Total pelagics	Total Catch	% of pelagics in total	% of small pelagics in total	% of small pelagics in pelagics
1950-54	298935	8306	307242	561604	54.71	53.23	97.30
1955-59	407598	10257	417855	675413	61.87	60.35	97.55
1960-64	459462	14851	474313	738008	64.27	62.26	96.87
1965-69	565897	14213	580110	891435	65.08	63.48	97.55
1970-74	593981	23808	617788	1130788	54.63	52.53	96.15
1975-79	631586	36910	668496	1356626	49.28	46.56	94.48
1980-84	678796	47821	716005	1434914	49.90	47.31	94.80
1985-89	964148	34978	999127	1769040	56.48	54.50	96.50
1990-94	1184624	44081	1228705	2242412	54.79	52.83	96.41
1995	1126485	53554	1180039	2225028	53.03	50.63	95.46
1996	1242454	44359	1286813	2388239	53.88	52.02	96.55
1950-96	638974	33970	671815	1242406	54.07	51.43	95.11

Rapid motorization of the traditional craft gave fillip to production during 1990-95, enhancing the relative growth to 43%. However, production from the conventional grounds within the 50 m depth zone seems to have reached the optimum level consequent on the intensive operation of ringseines from the motorized craft as evident from the sharp decline in the relative growth (11%) during 1996. Perhaps, further increase in the growth rate could be achieved only through another technological advancement such as the extension of the fishing grounds beyond the 50 m isobath significantly.

In the case of the major pelagic stocks of oil sardine, Indian mackerel, tunas, seerfishes, pomfrets and Bombayduck, exploitation has already crossed or reached the MSY levels. The stocks of lesser sardines, whitebaits, carangids and ribbonfishes offer marginal scope of increased yields in the inshore grounds within

the 50 m depth. Certain remarkable changes in the composition of the catches have been observed over the years along the east coast. For example, in recent years, the oil sardine has been emerging as an important fishery all along the east coast where it was practically absent till the mid eighties. The Indian mackerel became relatively more significant in Andhrapradesh and Orissa in recent years than in the past.

Table 3. Growth in the average annual overall and pelagic fish production through five decades from 1950 to 1996.

Period	Production (MT)		Relative growth (%)	
	Pelagic	Overall	Pelagics	Overall
1950-59	362,548	618,501	-	-
1960-69	527,211	814,721	+45	+31
1970-79	643,142	1,243,707	+22	+53
1980-89	819,093	1,579,836	+27	+27
1990-95 (6 years)	1,174,934	2,239,514	+43	+42
1996	1,286,813	2,388,239	+11	+7

The stagnation in marine fish production at 2 to 2.4 million mt per year in recent years necessitated investigations to reassess the potential yield from the EEZ. A Working Group on the Revalidation of Potential Marine Fisheries of the Indian EEZ (1991) estimated the potential yield of the Indian EEZ to be 3.9 million mt of fish annually, comprising 2.2 million mt from the 0 to 50 m depth zone and 1.7 million mt from the region beyond. The current yield from the 0 to 50 m depth zone is at the optimum level, and hence, does not offer any scope of increasing the yield. Therefore, the region beyond the 50 m depth has to be the focus of expansion. At the rate of 11 kg fish required per year per capita, India requires about 7.2 million mt of fish by 2025 AD for its fish-eating population of about 700 million. Out of this, the marine sector will have to provide about 4.3 million mt from both capture fisheries and mariculture.

The Working Group on the Revalidation of Potential Marine Fisheries of the Indian EEZ (1991) indicated the potential yield from the pelagic resources of the EEZ to be 2 211 000 mt, comprising 461 000 mt from the northwest region, 834 000 mt from the southwest region, 241 000 mt from the southeast region, 178 000 mt from the northeast region and 497 000 mt from the other areas including the Andaman & Nicobar islands, Lakshadweep and the oceanic region. However, the current production of pelagics includes 310 000 mt from the northwest region, 460 000 mt from the southwest region, 278 000 mt from the southeast region and 69 000 mt from the northeast region. Thus, there is a gap of 597 000 mt from the EEZ of mainland India alone. Since the potential from the 0 to 50m depth zone is estimated to be 1 174 000 mt and the current production is already 1 117 000 mt, there is not much scope of further increase in production from this inshore zone,

and hence, the need to bring the outer shelf and oceanic waters into increasing levels of exploitation. The major stocks holding good potential in the outer shelf include the anchovies, carangids, ribbonfishes, tunas and sharks.

TRENDS IN PRODUCTION

Small pelagics

The small pelagics are defined as the pelagics excluding the highsea or oceanic tunas (skipjack & *Thunnus* spp.), billfishes and sharks. They comprise different taxonomic groups, which contribute to their rich species diversity, abundance and fisheries. From the available information on the distribution of marine fishes along the Indian coast (Fischer and Bianchi,1984; Smith and Heemstra,1986), it could be inferred that there are about 240 species of small pelagics (Table 4).

A few species of small pelagics enjoy wide geographical distribution while the others such as the shads and the Bombayduck have rather restricted distribution (Table 5, prepared in the APFIC Working Party Meeting during 13-16 May, 1997 at Bangkok). There is no strict body size-based dividing line that separates the small pelagics from the large pelagics. Species such as the Bombayduck which reach 390 mm total length are generally considered small pelagics. However, in this report, a few species of carangids, which are larger in body size (600-750 mm) than the Bombayduck, are, as a group, included in the small pelagics, together with several species of carangids such as the scads and others of smaller and intermediate sizes, which form sparse schools in almost the entire water column in the neritic region. With the same reasoning, the ribbonfishes, barracudas, dolphinfishes, cobia, seerfishes, coastal tunas etc. are also treated under the small pelagics. In addition to the differences in their body size and epipelagic habitat, there are several other characteristics which are unique to the small pelagics. Shoaling behaviour, planktonic or nektonic feeding, localised movement or short range migration and very high numerical abundance are a few characteristics, which distinguish the small pelagics from the rather long migratory, highly predatory and numerically less abundant large pelagics (highsea tunas, billfishes and sharks). Surprisingly, all the small pelagics that form fisheries are finfishes and the crustaceans and the cephalopods, which form about 20% of the total marine fisheries of India, are not represented in the catches of the small pelagics. However, a few species of squids, which migrate to the surface during nights, and the larvae of several species of crustaceans, which lead planktonic lives are represented in the catches in the finfish-dominated small pelagic fisheries.

Table 4. Major taxonomic categories of small pelagics and their species diversity.

Family	Group/Species	Number of species
I Clupeidae		
	1. Oil sardine*	1
	2. Lesser sardines* (including rainbow sardines)	14
	3. *Hilsa* spp. & other shads	15
	4. Whitebaits*	24
	5. *Thryssa* and *Thrissocles* spp.	10
	6. Wolf herrings	2
	7. Other clupeids	40
II Scombridae		
	1. Coastal tunas	7
	2. Seerfishes & wahoo	5
	3. Mackerels*	3
III Trichiuridae		
	1. Ribbonfishes*	8
IV Carangidae*		
	1. Round scads	2
	2. Golden scads	6
	3. Hardtail scad (or horse mackerel)	1
	4. Jacks	17
	5. Black pomfret	1
	6. Others	19
V Harpodontidae		
	1. Bombayduck	1
VI Stromateidae		
	1. Pomfrets	2
VII Coryphaenidae		
	1. Dolphinfishes	2
VIII Rachycentridae		
	1. Cobia	1
IX Mugildae		
	1. Mullets	22
X Sphyraenidae		
	1. Barracudas	7
XI Exocoetidae		
	1. Flyingfishes	10
XII Bregmacerotidae		
	1. Unicorn cod	1
XIII	Others	19
	Total small pelagics	240

* Major small pelagics

Table 5. Major small pelagic resources in the APFIC Region (as prepared in the APFIC Working Party Meeting during 13 - 16 May 1997 at Bangkok).

	FAO Fishing Area	51	57		71				61	
	Subregional Area	1	2	3	4	5	6	7	8	9
No	Species Group	Western Indian Ocean	Eastern Indian Ocean	Malacca Strait	Gulf of Thailand	South China Sea	Celebes Sea (Sulawesi Sea)	Australia (Northern)	East China Sea	Sea of Japan
1.	Mackerels: - *Rastrelliger* spp. - *Scomber japonicus*	xx	xx	xx	xx	xx	xx	-	- xx	- xx
2.	Scads (*Decapterus* spp., *Selar* spp., *Atule* spp.)	xx	x	xx	xx	xx	xx	-	xx	xx
3.	Torpedo Scad (*Megalaspis cordyla*)	xx	x	xx	xx	xx	xx	-	x	-
4.	Sardines - *Sardinella* spp. - *Dussumieria* spp. - *Sardinops*	xx	xx	xx	xx	xx	xx	- -	xx	xx
5.	Jacks - *Caranx* spp. - *Trachurus* spp.	xx	xx	xx	xx	xx	xx	x	- xx	- x
6.	Seerfishes (*Scomberomorus* spp.)	xx	xx	xx	xx	xx	xx	-	xx	x
7.	Small tunas (*Auxis* spp.,*Euthunus* spp., *Thunustonggol, Sarda* spp.)	xx	x	xx	xx	xx	xx	-	x	-
8.	Anchovies (*Stolephorus* spp.)	x	x	x	x	x	x	-	xx	xx
9.	Bombayduck (*Harpadon nehereus*)	x	xx	-	-	x	-	-	-	-
10.	Hairtails (*Trichiurus* spp.)	xx	xx	x	x	x	x	-	x	x
11.	Shads (*Hilsa* spp.)	x	xx	-	x	-	-	-	-	-
12.	Wolf-herring (*hirocentrus* spp.)	x	xx	xx	x	x	x	-	-	-
13.	Barracudas (*Sphyraena* spp.)	xx	xx	x	x	x	x	-	x	x
14.	Pomfrets (*Formio niger, Stromateus* spp.)	x	xx	x	x	x	x	-	xx	-
15.	Flyingfishes (*Hirundichthus* spp.)	xx	xx	-	-	x	x	-	x	x
16.	Mullets (*Mugil* spp., *Liza* spp.)	xx	x	x	x	x	-	x	x	x
17.	Dolphinfish (*Coryphaena* spp.)	-	x	x	x	x	x	x	x	x
18.	*Rachycentron canadus*	x	x	x	x	x	x	x	x	x

x : Being exploited by coastal states; xx: Potential transboundary pelagic stocks

Production trends: pelagics in relation to overall

Over the past five decades, marine fish production in India (Fig. 2) has been increasing progressively, though interspersed with years of stagnation, in between. From 0.6 million mt in 1950, production increased steadily to the current (1996) 2.42 million mt, registering a fourfold increase (Fig. 3). Until the mid seventies, the share of the pelagic stocks in the overall production remained very high with a consistently increasing trend from 54% in 1950 to 71% in 1960, and thereafter, at around 65% till the early seventies. The pelagic catches increased from 309 000 mt in 1950 to the current (1996) 1 286 813 mt (Table 3), registering nearly a fourfold increase. The growth in the production of the pelagics vis-a-vis the overall production could be gauged from the data in Table 3 and Fig. 4.

In the early years in the development of marine fisheries, the growth rate in the production of pelagic fisheries has been conspicuously higher than that of the overall production. Expectedly, this ought to have been the trend, as the development emphasis during the early plan periods upto 1969 has been on improving the traditional sector, which had the wherewithal only for exploiting the essentially pelagic stocks in the nearshore areas. This trend got reversed in the immediate decade of 1970-79 because of the rapid expansion of commercial trawling for shrimps for exports by the industrial sector, under initial subsidy support extended by the governments. Commercial trawling resulted in significantly high production of demersal finfishes also, besides shrimps and lobsters. Although the pelagic catches increased by 22 %, the trend in the overall production was set by the demersal finfish and crustacean catches. The next decade (1980-89) witnessed a growth of 27% in the pelagic catches as well as in the overall production. During this decade, there was rapid motorization of the traditional fishing craft, particularly in the latter half of the eighties. As a result, the stagnation in marine fish production witnessed in the first half of the eighties was replaced by accelerated production in the latter half, with the annual catch touching the 2 million mt mark in 1989. Since then, the annual production has been stagnating around 2.2 to 2.4 million mt, perhaps waiting for another technological change for a further take off from the present level. Intensive motorization of the traditional fishing craft resulted in a remarkable increase in the annual production, especially of the total pelagics, which increased from 835 000 mt in 1985, to 1 313 000 mt in 1989, registering a 71% growth; the small pelagics production showed an increase of about 74% during this period.

Production trends: small pelagics in relation to pelagics and overall

During 1991-95 the small pelagics constituted about 96% of the total pelagic catches, with the larger pelagics (mainly sharks, highsea tunas and billfishes) forming the remaining 4%. The larger pelagics formed about 2.2% of the overall fish production during this period (1991-95). Among the small pelagics, the sardines, mackerel, anchovies, carangids, Bombayduck and ribbonfishes together contributed 39.01% to the overall production; 73.3% to the total pelagics production and, 76.5% to the small pelagics production during 1991-95 (Table 6). The other small pelagics which include mainly the wolf herrings, shads, other

clupeids, barracudas, unicorn cod, pomfrets, seerfishes, coastal tunas and mullets, formed the remaining 23.49 % of the small pelagic catches.

Table 6. Average annual production (mt) of the major small pelagics (msp) through the successive 5-year periods during 1981-1995.

	1981-85	1986-90	1991-95	1996
Oil sardine	182,920	169,800	95,957	110,346
Lesser sardines	63,069	78,554	93,725	103,732
Anchovies	100,901	126,222	145,088	133,891
Bombayduck	110,064	96,918	110,771	85,766
Ribbonfishes	50,056	77,122	97,444	126,994
Carangids	48,794	122,461	163,285	145,860
Indian mackerel	40,595	147,503	174,922	274,135
Total	596,399	818,580	881,192	980,724
Total of pelagics	760,975	1,076,031	1,200,810	1,286,813
% of msp in pelagics	78.4	76.0	73.3	76.2
% of msp in small pelagics	84.3	78.7	76.5	78.9
% of msp in overall production	40.0	43.2	39.0	41.0

The small pelagics have been the mainstay of the pelagic catches consistently. Although the share of the larger pelagics (highsea tunas, billfishes and sharks) in the total pelagics has been increasing rather significantly, their contribution remains insignificant, relative to the smaller pelagics. The share of the small pelagics in the total pelagics has, over the years, seen only a marginal decrease, from 97.4% in the fifties to 95.9% currently. Therefore, in the ultimate analysis, the pelagics would mean basically the small pelagics only. The small pelagics of commercial bearing are mainly the oil sardine, lesser sardines, anchovies, Bombayduck, ribbonfishes, carangids and Indian mackerel. The trends in their average annual production through the successive 5 year periods in the past 15 years are dealt with in Table 6.

Except the oil sardine and the Bombayduck, catches of the other small pelagics have been increasing progressively from 1981 to 1995. While the Malabar upwelling extending from the Ratnagiri coast (Maharashtra state) to the Gulf of Mannar (Tamilnadu State) is the major area inhabited by the oil sardine stock, bulk of the Bombayduck stock is found in the northern Maharashtra to the southern Gujarat coast. Although the oil sardine catches have been decreasing in recent years, fisheries for this species have emerged all along the east coast from the mid eighties onwards. Whether the decreasing trend in the landings of the oil sardine is due to overexploitation by the purseseine and ringseine fleets in the major stock area

is yet to be established. The revival of the fishery in 1995 and 1996 may, however, prove the decreasing trend observed since the early nineties to be only a phase within a rhythmic cycle of about 11 years. The Bombayduck fishery has been maintaining an annual production of around 100 000 mt almost consistently over the last two decades. While the northwest coast contributes 86%, the northeast coast contributes 13% to the annual landings of the Bombayduck. The production of mackerel which used to be very high in the earlier years upto the 1970s, reached extremely low levels in the early eighties; however, it recovered rapidly from 28 000 mt in 1982 to 290 000 mt in 1989. The overall increase in the landings of the ribbonfishes is attributable mainly to their increase in the northwest region, in recent years.

Stock assessment of small pelagics

Assessment of stocks is esential for deciding guidelines for the rational exploitation and management of fisheries. The stocks and their levels of exploitation in respect of a number of species of small pelagics in the Indian seas have been determined on the basis of effort and catch data, biological parameters and primary production. The data presented in Table 24, which pertain to different time periods, have been effectively utilised as guidelines from time to time for evolving management options for the small pelagics fisheries.

Though 240 species constitute the fisheries along the Indian coast, it is only about 60 species belonging to 7 groups of small pelagics, viz., the oil sardine, lesser sardines, anchovies, Bombayduck, ribbonfishes, carangids and Indian mackerel that form the major small pelagics fisheries. The annual production of these 7 groups was 1 million mt in 1996, forming 76.2% of the small pelagics and 41.0% of the total marine landings (Table 6). The other small pelagics which include the wolfherrings, shads, barracudas, unicorn cod, mullets, seerfishes and coastal tunas formed only 23.8% of the small pelagics landings.

Pelagics production in relation to total marine fish production

During 1985-96, the production of the pelagics increased from 0.83 million mt in 1985 to 1.40 million mt in 1989 and declined subsequently and reached 1.29 million mt in 1996 (Fig. 4). The total marine fish production sharply increased from 1.6 million mt in 1985 to 2.2 million mt in 1989 and sustained at that level till 1995, but it increased further to 2.42 million mt in 1996. Consequently, the contribution of the pelagics to the total production increased from 58.4% in 1985 to 63.6% in 1989 and declined subsequently to 53.9% in 1996. The contribution of the pelagics to the total production, which showed an increasing trend consequent on the combined effect of motorization and the expansion of the ringseine fleet especially in the southwest coast, could make an impact upto 1989. The effect of this technological advancement could not be realized after 1989, though the advancements in other craft and gears such as the trawlers for the exploitation of the demersal stocks sustained the annual production around 2.2 million mt during 1989-1995 and increased it to 2.42 million mt in 1996.

Small pelagics production in relation to pelagics and total production

During 1985-96, the production of small pelagics increased from 0.80 million mt in 1985 to 1.24 million mt in 1996. However, the relative growth of the small pelagics production drastically declined from 30.7% during 1986- 90 (compared to 1985) to 11.4% during 1991- 95 and to 8.3% in 1996 (Table 7).

Table 7. Landings of pelagics in India during 1985 to 1996 (mt).

Name of fish	1985	Avg(86-90)	Avg(91-95)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	17650	14347	16007	13992
Oil sardine	120575	169800	95957	110346
Other sardines	59427	78554	93725	103732
Hilsa shad	9051	7862	25132	25648
Other shads	11824	11626	13507	6477
Anchovies	13	325	209	0
Coilia	26021	26632	33694	32093
Setipinna	1547	2290	2167	2316
Stolephorus	54367	69158	72224	60010
Thrissina	0	131	4	146
Thryssa	27710	27686	36790	36753
Other clupeids	34280	43270	50853	60670
II. Bombayduck	112453	96918	110771	85766
III. Halfbeaks and fullbeaks	1977	2251	2736	3360
IV. Flyingfishes	1235	4167	3273	965
V. Ribbonfishes	84341	77122	98808	126994
VI. Carangids				
Horse mackerel	3447	14497	20108	17652
Scads	7861	46768	86387	66790
Leather jackets	8665	4215	4965	5179
Other carangids	34523	56981	51825	56239
VII. Pomfrets				
Black pomfret	10166	13200	14213	12375
Silver pomfret	22660	24816	25253	22857
Chinese pomfret	99	326	595	515
VIII. Mackerels				
Indian mackerel	61230	147414	174896	274118
Other mackerels	0	89	26	17
IX. Seerfishes	33699	33874	41134	36633
X. Tunnies				
E. affinis	16582	21163	17107	14778
Auxis spp.	3076	6662	6352	11119
Others	6434	3477	3724	2834
XI. Barracudas	3116	7126	11700	13548
XII. Mullets	5088	5658	5737	5272
XIII. Unicorn cod	734	641	835	297
XIV. Miscellaneous	18353	23771	41851	32963

Table 7 cont'd

Name of fish	1985	Avg(86-90)	Avg(91-95)	1996
B. Large pelagics				
I. Sharks	33093	30243	40919	34075
II. Tunnies				
K. pelamis	85	318	182	458
T. tonggol	1086	728	3806	4058
III. Billfishes	877	892	1225	3514
IV. Miscellaneous	1652	1034	1822	2254
Small pelagics (t)	798204	1042816	1162565	1242454
Large pelagics (t)	36793	33215	47955	44359
Pelagics (t)	834997	1076031	1210520	1286813
Others (t)	687520	817048	1048355	1101426
Total (t)	1522517	1893080	2258875	2388239
% of pelagics in total	54.84	56.84	53.59	53.88
% of small pelagics in total	52.43	55.09	51.47	52.02
% of small pelagics in pelagics	95.59	96.91	96.04	96.55
Relative growth				
Small pelagics (%)		30.65	11.48	8.29
Large pelagics (%)		-9.72	44.38	-15.61
Pelagics (%)		28.87	12.50	7.25
Others (%)		18.84	28.31	4.01
Total (%)		24.34	19.32	5.73

The contribution of the small pelagics to the total production ranged from 51% to 55%; and to the pelagics production from 95.6% to 96.9% during 1985-96. The larger pelagics (highsea tunas, billfishes and sharks) formed only 3.1% to 4.4% of the pelagics landings.

Small pelagics production in the 4 geographical regions

During 1991-95, the northwest, southwest, southeast and northeast coasts contributed 28.3%, 40.4%, 24.8% and 6.6% to the small pelagics landings, respectively (Table 8). In other words, the west coast contributed 68.7% of the small pelagics landings. Most of the small pelagics fishery groups are dominant in one coastal region or another. For instance, the oil sardine (99.4%), lesser sardines (91.0%), whitebaits (98.7%) and Indian mackerel (87.7%) were dominant in the southwest and southeast coasts; the horse mackerel (90.6%) in the southwest and northwest coasts; the scads (89.2%) in the southwest coast; the Bombayduck (86.3%) and Coilia (83.7%) in the northwest coast; the flyingfishes in the southeast coast (90.2%); and the unicorn cod (99.7%) in the northwest coast (Table 8).

Table 8. Annual average (1991-95) landings (in tonnes) of pelagics in the 4 geographical regions of India and their percentage contribution.

Name of fish	Average 1991 - 1995 (in MT)					Contribution from different regions (%)			
	NE	SE	SW	NW	Total	NE	SE	SW	NW
A. Small pelagics									
I. Clupeids									
Wolf herrings	2002	4213	1836	7956	16007	12.51	26.32	11.47	49.70
Oil sardine	52	38536	56849	520	95956	0.05	40.16	59.24	0.54
Other sardines	1906	48362	36911	6547	93725	2.03	51.60	39.38	6.99
Hilsa shad	23181	782	183	986	25132	92.24	3.11	0.73	3.92
Other shads	136	9329	297	3746	13508	1.01	69.07	2.20	27.73
Anchovies	0	9	34	166	208	0.00	4.22	16.31	79.46
Coilia	3930	1538	126	28100	33694	11.66	4.56	0.37	83.40
Setipinna	1844	317	6	0	2167	85.12	14.62	0.26	0.00
Stolephorus	942	19524	51726	33	72224	1.30	27.03	71.62	0.05
Thrissina	0	2	1	0	3	6.25	62.50	31.25	0.00
Thryssa	1672	11083	12635	11399	36790	4.55	30.13	34.34	30.98
Other clupeids	3817	18227	19395	9414	50854	7.51	35.84	38.14	18.51
II. Bombayduck	14104	1095	3	95568	110771	12.73	0.99	0.00	86.28
III Halfbeaks and Fullbeaks	7	1216	1407	108	2737	0.24	44.42	51.40	3.94
IV. Flyingfishes	1	2953	297	22	3273	0.04	90.23	9.07	0.66
V. Ribbonfishes	4824	17313	12793	63878	97444	4.95	17.77	13.13	65.55
VI. Carangids									
Horse mackerel	789	1089	9692	8538	20108	3.92	5.42	48.20	42.46
Scads	109	4911	77068	4299	86388	0.13	5.69	89.21	4.98
Leather jackets	429	1850	1083	1603	4964	8.64	37.26	21.81	32.29
Other carangids	982	19492	24392	6959	51825	1.89	37.61	47.07	13.43
VII. Pomfrets									
Black pomfret	2135	2578	3913	5586	14212	15.02	18.14	27.54	39.30
Silver pomfret	5835	4110	1313	13995	25253	23.11	16.27	5.20	55.42
Chinese pomfret	102	18	374	101	595	17.08	3.03	62.95	16.95
VIII. Mackerels									
Indian mackerel	749	39524	113847	20775	174896	0.43	22.60	65.09	11.88
Other mackerels	5	6	13	3	27	17.91	23.88	47.01	11.19
IX. Seerfishes	3291	10503	9600	17740	41134	8.00	25.53	23.34	43.13
X. Tunnies									
E. affinis	121	3281	10629	3076	17107	0.71	19.18	62.13	17.98
Auxis spp.	3	451	5279	619	6352	0.05	7.11	83.10	9.75
Others	20	358	869	2477	3725	0.55	9.62	23.33	66.50
XI. Barracudas	39	5608	4502	1550	11699	0.34	47.93	38.48	13.25
XII. Mullets	830	1971	392	2544	5737	14.46	34.36	6.83	44.35
XIII. Unicorn cod	0	1	1	833	836	0.00	0.12	0.14	99.74
XIV. Miscellaneous	2623	18790	11432	9006	41851	6.27	44.90	27.32	21.52
B. Large pelagics									
I. Sharks	2825	9633	3891	24570	40919	6.90	23.54	9.51	60.05
II. Tunnies									
K. pelamis	0	148	23	11	1546	0.00	9.60	1.47	0.72
T. tonggol	0	243	463	3100	3806	0.01	6.37	12.17	81.45
III. Billfishes	18	391	209	607	1225	1.50	31.88	17.07	49.54
IV. Miscellaneous	102	805	117	798	1822	5.60	44.18	6.41	43.81
Small pelagics (mt)	76481	289041	468897	319670	1161201	6.59	24.89	40.38	27.53
Large pelagics (mt)	2945	11220	4703	29086	49319	5.97	22.75	9.54	58.98
Pelagics (mt)	79426	300261	473600	348757	1210520	6.56	24.80	39.12	28.81
Others (mt)	44138	240154	316966	455572	1048355	4.21	22.91	30.23	43.46
Total (mt)	123564	540415	790566	804329	2258875	5.47	23.92	35.00	35.61

Small pelagics production from different fishing sectors

The small pelagics are exploited by the nonmotorized traditional, motorized traditional and mechanized sectors. The annual total effort of all the three sectors decreased from 13.8 million boatdays in 1985 to 12.0 million boatdays during 1991-95 and to 11.7 million boatdays in 1996 (Table 9). As the small pelagics production increased during this period by 66%, the CPUE increased from 58 kg/boatday in 1985 to 96 kg/boatday during 1991-95 and 106 kg during 1996. Though the relative growth of small pelagics production declined from 30.7% during 1986-90 to 11.4% in 1991-95 and to 7.0% in 1996, the relative growth in the CPUE declined only marginally from 32.8% to 24.5% between 1986-90 and 1991-95, but significantly to 10.9% from 1991-95 to 1996. The CPUE of total fish production also registered a 69% increase during this period (Table 9).

Table 9. All sector landings of pelagics in India during 1985-96.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (mt)				
Small pelagics (mt)	798204	1042816	1162565	1242454
Large pelagics (mt)	36793	33215	47955	44359
Pelagics (mt)	834997	1076031	1210520	1286813
Others (mt)	687520	817048	1048355	1101426
Total (mt)	1522517	1893080	2258875	2388239
Effort in boatdays	13816050	13588487	12158065	11733576
Percentage				
Pelagics in total(%)	54.84	56.84	53.59	53.88
Small pelagics in total(%)	52.43	55.09	51.47	52.02
Small pelagics in total pelagics(%)	95.59	96.91	96.04	96.55
CPUE (kg)				
Small pelagics	58	77	96	106
Large pelagics	3	2	4	4
Total pelagics	60	79	100	110
Others	50	60	86	94
Total	110	139	186	204
Relative growth (%)				
Small pelagics		30.65	11.48	6.87
Large pelagics		-9.72	44.38	-7.50
Pelagics		28.87	12.50	6.30
Others		18.84	28.31	5.06
Total		24.34	19.32	5.73
Effort		-1.65	-10.53	-3.49
CPUE				
Small pelagics		32.83	24.60	10.74
Large pelagics		-8.21	61.36	-4.15
Total pelagics		31.02	25.73	10.15
Others		20.83	43.41	8.86
Total		26.42	33.36	9.55

Table 10. Non-mortorized sector landings of pelagics in India during 1985-1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	8506	5643	3302	1797
Oil sardine	18119	24616	26070	32894
Other sardines	48683	48562	28707	33668
Hilsa shad	653	1052	1160	739
Other shads	6066	5644	5254	1649
Anchovies	0	0	9	0
Coilia	6068	6383	9169	8364
Setipinna	460	868	415	198
Stolephorus	17737	29850	21764	14823
Thrissina	0	118	1	62
Thryssa	10246	7611	8263	6983
Other clupeids	20119	14116	11383	11185
II. Bombayduck	18551	19454	19584	16039
III. Halfbeaks and fullbeaks	1395	1377	1141	1642
IV. Flyingfishes	1234	4046	2716	49
V. Ribbonfishes	34444	17729	13354	7868
VI. Carangids				
Horse mackerel	936	1961	1768	3124
Scads	3574	5660	3922	5912
Leather jackets	4273	1534	948	648
Other carangids	15800	12983	11746	6466
VII. Pomfrets				
Black pomfret	2631	1766	1293	728
Silver pomfret	3673	4529	3630	1817
Chinese pomfret	10	30	31	65
VIII. Mackerels				
Indian mackerel	21380	29883	31502	13929
Other mackerels	0	42	3	0
IX. Seerfishes	10952	9014	6053	3895
X. Tunnies				
E. affinis	3421	3629	2352	2217
Auxis spp.	549	728	385	212
Others	435	157	57	65
XI. Barracudas	1653	2459	1230	1340
XII. Mullets	4609	5173	4776	4181
XIII. Unicorn cod	3	38	3	0
XIV. Miscellaneous	13114	11564	9714	6453
B. Large pelagics				
I. Sharks	12597	7833	5369	5035
II. Tunnies				
K. pelamis	0	15	71	0
T. tonggol	0	14	47	241
III. Billfishes	485	220	109	222
IV. Miscellaneous	645	351	306	194
Small pelagics (mt)	279294	278218	231705	189012
Large pelagics (mt)	13727	8433	5903	5692
Pelagics (mt)	293021	286651	237608	194705
Others (mt)	96144	93035	88152	85275
Total (mt)	389165	379686	325759	279980
Effort in boatdays	10216950	8905205	6425388	4678579

(i) Small pelagics production from the nonmotorized sector: Of the three sectors exploiting the small pelagics, the effort and catches of the nonmotorized sector alone declined during 1985-96. The effort declined from 10.2 million boatdays to 4.7 million boatdays and the small pelagics landings from 0.28 million mt to 0.19 million mt (Table 10).

The relative growth in the effort and catches also declined during this period. However, the CPUE of the small pelagics from the nonmotorized sector increased from 27 kg/boatday to 40 kg/boatday (Table 11). Following the reduction in effort and catches, the contribution of the nonmotorized sector to the production of small pelagics declined significantly from 48.8% to 15.2%. It is clear that the nonmotorised sector is giving way to the motorized and mechanized sectors in the production of small pelagics, and to the total fish production as well.

Table 11. Non-mortized sector landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	279294	278218	231705	189012
Large pelagics (mt)	13727	8433	5903	5692
Pelagics (mt)	293021	286651	237608	194705
Others (mt)	96144	93035	88152	85275
Total (mt)	389165	379686	325759	279980
Effort in boatdays	10216950	8905205	6425388	4678579
Percentage				
Pelagics in total(%)	75.29	75.50	72.94	69.54
Small pelagics in total(%)	71.77	73.28	71.13	67.51
Small pelagics in total pelagics(%)	95.32	97.06	97.52	97.08
CPUE (kg)				
Small pelagics	27	31	36	40
Large pelagics	1	1	1	1
Total pelagics	29	32	37	42
Others	9	10	14	18
Total	38	43	51	60
Relative growth (%)				
Small pelagics		-0.39	-16.72	-18.43
Large pelagics		-38.56	-30.00	-3.57
Pelagics		-2.17	-17.11	-18.06
Others		-3.23	-5.25	-3.26
Total		-2.44	-14.20	-14.05
Effort		-12.84	-27.85	-27.19
CPUE				
Small pelagics		14.29	15.42	12.03
Large pelagics		-29.51	-2.99	32.43
Total pelagics		12.24	14.88	12.54
Others		11.02	31.32	32.86
Total		11.94	18.91	18.04

(ii) *Small pelagics production from the motorized sector*: Fishing effort by the traditional craft fitted with outboard motor increased substantially from 0.71 million boatdays in 1985 to 3.72 million boatdays in 1996. As a result, the small pelagics landings by this sector increased from 0.12 million mt to 0.36 million mt and its

contribution to the small pelagics landings increased from 11.5.% to 29.3% from 1985 to 1996. However, the CPUE, which increased from 163 kg/boatday in 1985 to 199 kg/boatday during 1986-90, declined sharply to 98 kg/boatday in 1996. The decline in the relative growth of the CPUE was quite pronounced, mainly due to the low CPUE realized from the motorized gillnet fleet in the southeast coast, where this fleet expanded only in the 1990s. On the contrary, the motorized ringseine fleet operations in the southwest coast realized very high CPUE (Tables 12 & 13).

Table 12. Motorized sector landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	193	1023	3845	3441
Oil sardine	61861	95880	44337	57482
Other sardines	1120	9368	29311	26226
Hilsa shad	5	151	538	643
Other shads	0	229	4397	1737
Anchovies	0	0	0	0
Coilia	0	0	266	39
Setipinna	0	0	8	4
Stolephorus	26167	18768	26038	20724
Thrissina	0	0	1	105
Thryssa	352	2109	4908	7554
Other clupeids	1277	7324	15977	22967
II. Bombayduck	0	2	1305	280
III. Halfbeaks and fullbeaks	155	476	484	822
IV. Flyingfishes	0	16	43	899
V. Ribbonfishes	2307	2834	3630	10568
VI. Carangids				
Horse mackerel	79	3448	5635	3587
Scads	1022	17206	39251	14985
Leather jackets	162	387	1140	1303
Other carangids	3399	12817	7957	13344
VII. Pomfrets				
Black pomfret	367	1496	2261	2337
Silver pomfret	136	713	3149	3337
Chinese pomfret	4	43	126	10
VIII. Mackerels				
Indian mackerel	6213	44565	69574	134051
Other mackerels	0	4	0	1
IX. Seerfishes	4671	5662	17442	11834
X. Tunnies				
E. affinis	2753	9030	9343	7941
Auxis spp.	1644	3808	4428	10192
Others	426	1351	2782	2154
XI. Barracudas	206	541	1334	1706
XII. Mullets	88	134	313	317
XIII. Unicorn cod	0	0	42	0
XIV. Miscellaneous	563	1498	2894	3601

Table 12. Cont'd.

	Name of fish	1985	1986- 90 (Average)	1991-95 (Average)	1996
B.	Large pelagics				
	I. Sharks	1725	2340	9103	4152
	II. Tunnies				
	K. pelamis	44	202	39	394
	T. tonggol	341	139	2735	2501
	III. Billfishes	13	118	709	1339
	IV. Miscellaneous	10	48	253	84
	Small pelagics (mt)	115170	240884	302759	364191
	Large pelagics (mt)	2133	2846	12838	8470
	Pelagics (mt)	117303	243730	315597	372661
	Others (mt)	10325	35255	56609	71163
	Total (mt)	127628	278985	372207	443824
	Effort in boatdays	708165	1208091	2348112	3715571

Table 13. Motorized sector landings of pelagics and others in India during 1985 - 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	115170	240884	302759	364191
Large pelagics (mt)	2133	2846	12838	8470
Pelagics (mt)	117303	243730	315597	372661
Others (mt)	10325	35255	56609	71163
Total (mt)	127628	278985	372207	443824
Effort in boatdays	708165	1208091	2348112	3715571
Percentage				
Pelagics in total(%)	91.91	87.36	84.79	83.97
Small pelagics in total(%)	90.24	86.34	81.34	82.06
Small pelagics in total pelagics(%)	98.18	98.83	95.93	97.73
CPUE (kg)				
Small pelagics	163	199	129	98
Large pelagics	3	2	5	2
Total pelagics	166	202	134	100
Others	15	29	24	19
Total	180	231	159	119
Relative growth (%)				
Small pelagics		109.16	25.69	20.29
Large pelagics		33.40	351.09	-34.03
Pelagics		107.78	29.49	18.08
Others		241.47	60.57	25.71
Total		118.59	33.41	19.24
Effort		70.59	94.37	58.24
CPUE				
Small pelagics		22.60	-35.33	-23.98
Large pelagics		-21.80	132.08	-58.31
Total pelagics		21.80	-33.38	-25.38
Others		100.16	-17.39	-20.56
Total		28.14	-31.36	-24.64

Table 14. Mechanized sector landings of pelagics in India during 1985 to 96 (in mt.)

	Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A.	Small pelagics				
	I. Clupeids				
	Wolf herrings	8951	7681	8860	8501
	Oil sardine	40595	49304	25550	19968
	Other sardines	9624	20624	35707	43838
	Hilsa shad	8393	6659	23434	24204
	Other shads	5758	5753	3856	3060
	Anchovies	13	325	200	0
	Coilia	19953	20249	24259	23680
	Setipinna	1087	1422	1744	2120
	Stolephorus	10463	20540	24422	24457
	Thrissina	0	13	2	41
	Thryssa	17112	17966	23619	22111
	Other clupeids	12884	21830	23493	25259
	II. Bombayduck	93902	77462	89882	69427
	III. Halfbeaks and fullbeaks	427	398	1111	868
	IV. Flyingfishes	1	105	514	17
	V. Ribbonfishes	47590	56559	81824	108536
	VI. Carangids				
	Horse mackerel	2432	9088	12705	10732
	Scads	3265	23902	43214	45893
	Leather jackets	4230	2294	2877	3351
	Other carangids	14824	31181	32122	36133
	VII. Pomfrets				
	Black pomfret	7168	9938	10659	9231
	Silver pomfret	18851	19574	18474	16716
	Chinese pomfret	85	253	438	429
	VIII. Mackerels				
	Indian mackerel	33637	72966	73820	125317
	Other mackerels	0	43	23	16
	IX. Seerfishes	18076	19198	17639	18383
	X. Tunnies				
	E. affinis	10408	8504	5412	4205
	Auxis spp.	883	2126	1539	595
	Others	5573	1969	885	604
	XI. Barracudas	1257	4126	9136	10496
	XII. Mullets	391	351	648	774
	XIII. Unicorn cod	731	603	790	297
	XIV. Miscellaneous	21119	10709	19750	37262
B.	Large pelagics				
	I. Sharks	18771	20070	26446	24207
	II. Tunnies				
	K. pelamis	41	101	73	64
	T. tonggol	745	575	1024	1277
	III. Billfishes	379	554	407	1729
	IV. Miscellaneous	1056	635	1046	1542
	Small pelagics (mt)	419683	523714	618609	696521
	Large pelagics (mt)	20992	21935	28996	28819
	Pelagics (mt)	440675	545650	647605	725340
	Others (mt)	565049	688758	913304	928413
	Total (mt)	1005724	1234408	1560909	1653753
	Effort in boatdays	2890935	3475191	3384564	3339426

Table 15. Mechanized sector landings of pelagics and others in India during 1985 - 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	419683	523714	618609	696521
Large pelagics (mt)	20992	21935	28996	28819
Pelagics (mt)	440675	545650	647605	725340
Others (mt)	565049	688758	913304	928413
Total (mt)	1005724	1234408	1560909	1653753
Effort in boatdays	2890935	3475191	3384564	3339426
Percentage				
Pelagics in total(%)	43.82	44.20	41.49	43.86
Small pelagics in total(%)	41.73	42.43	39.63	42.12
Small pelagics in total pelagics(%)	95.24	95.98	95.52	96.03
CPUE (kg)				
Small pelagics	145	151	183	209
Large pelagics	7	6	9	9
Total pelagics	152	157	191	217
Others	195	198	270	278
Total	348	355	461	495
Relative growth (%)				
Small pelagics		24.79	18.12	12.59
Large pelagics		4.49	32.19	-0.61
Pelagics		23.82	18.69	12.00
Others		21.89	32.60	1.65
Total		22.74	26.45	5.95
Effort		20.21	-2.61	-1.33
CPUE				
Small pelagics		3.81	21.28	14.12
Large pelagics		-13.08	35.73	0.73
Total pelagics		3.00	21.86	13.52
Others		1.40	36.15	3.03
Total		2.10	29.84	7.38

(iii) *Small pelagics production from the mechanized sector*: Fishing effort by the mechanized craft increased from 2.9 million boatdays in 1985 to 3.3 million boatdays in 1996, resulting in the increase in the landings of the small pelagics by 66% and the CPUE from 145 kg/boatday to 209 kg/boatday. The contribution of the mechanized sector to the small pelagics production increased from 52.6% to 56.1%. However, the relative growth in production, which was 24.8% during 1986-90 gradually declined to 12.6% in 1996 (Tables 14 & 15).

Gearwise production of small pelagics

There is a wide array of gears employed in the small pelagic fisheries. The major gears include the purseseine and trawl operated from the mechanized vessels, ringseine operated from the motorized craft and gillnets operated from the nonmotorized, motorized and mechanized craft. The purseseines are operated along the southwest coast, where the small pelagics contribute more than 91% to their landings. Purseseine effort almost doubled from 56 000 boatdays in 1985 to 101 000 boatdays in 1996, but the small pelagics landings by the purseseiners declined from the maximum of 0.17 million mt per year during 1986-90 to 0.15 million mt

in 1996 and the CPUE from 2038 kg/boatday during 1986-90 to 1454 kg/boatday in 1996 (Tables 16 & 17).

Table 16. Purseseine landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Av.)	1991-95 (Av.)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	23	13	23	27
Oil sardine	40074	46404	12812	7162
Other sardines	5097	9136	16779	11340
Hilsa shad	3	60	88	8
Other shads	8	19	39	0
Anchovies	0	12	1	0
Coilia	5	1	94	0
Setipinna	0	0	6	0
Stolephorus	5427	10693	7813	2461
Thrissina	0	0	0	0
Thryssa	817	2844	3785	415
Other clupeids	794	2550	2025	1500
II. Bombayduck	0	0	0	2
III. Halfbeaks and fullbeaks	71	123	120	164
IV. Flyingfishes	0	0	0	0
V. Ribbonfishes	358	957	2184	13
VI. Carangids				
Horse mackerel	631	5333	6110	3987
Scads	1457	11673	17466	9058
Leather jackets	94	378	680	458
Other carangids	7285	11540	6347	4194
VII. Pomfrets				
Black pomfret	1303	1603	3615	2685
Silver pomfret	65	114	55	49
Chinese pomfret	0	10	8	0
VIII. Mackerels				
Indian mackerel	32140	66042	59415	100586
Other mackerels	0	0	0	0
IX. Seerfishes	148	344	289	1502
X. Tunnies				
E. affinis	2043	2669	2282	387
Auxis spp.	585	1081	1191	2
Others	81	74	20	14
XI. Barracudas	12	21	36	228
XII. Mullets	30	7	3	0
XIII. Unicorn cod	0	0	0	0
XIV. Miscellaneous	249	238	169	133
B. Large pelagics				
I. Sharks	83	102	40	0
II. Tunnies				
K. pelamis	0	26	0	0
T. tonggol	624	367	230	0
III. Billfishes	1	0	0	24
IV. Miscellaneous	2	1	0	0
Small pelagics (mt)	98800	173939	143455	146375
Large pelagics (mt)	710	496	270	24
Pelagics (mt)	99510	174435	143725	146400
Others (mt)	3588	8763	7342	2726
Total (mt)	103098	183198	151067	149126
Effort in boatdays	56121	85336	85765	100655

Table 17. Purseseine landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)				
Small pelagics (mt)	98800	173939	143455	146375
Large pelagics (mt)	710	496	270	24
Pelagics (mt)	99510	174435	143725	146400
Others (mt)	3588	8763	7342	2726
Total (mt)	103098	183198	151067	149126
Effort in boatdays	56121	85336	85765	100655
Percentage				
Pelagics in total(%)	96.52	95.22	95.14	98.17
Small pelagics in total(%)	95.83	94.95	94.96	98.16
Small pelagics in total pelagics(%)	99.29	99.72	99.81	99.98
CPUE (kg)				
Small pelagics	1760	2038	1673	1454
Large pelagics	13	6	3	0
Total pelagics	1773	2044	1676	1454
Others	64	103	86	27
Total	1837	2147	1761	1482
Relative growth (%)				
Small pelagics		76.05	-17.53	2.04
Large pelagics		-30.16	-45.46	-91.11
Pelagics		75.29	-17.61	1.86
Others		144.22	-16.22	-62.86
Total		77.69	-17.54	-1.28
Effort		52.06	0.50	17.36
CPUE				
Small pelagics		15.78	-17.94	-13.06
Large pelagics		-54.07	-45.73	-92.43
Total pelagics		15.28	-18.02	-13.21
Others		60.61	-16.64	-68.36
Total		16.86	-17.95	-15.89

The ringseines, which are operated along the Kerala coast, increased their effort from 0.17 million boatdays in 1985 to 0.24 million boatdays in 1996. The small pelagics which contribute about 90% to the landings of the ringseines, increased from 0.13 million mt during 1986-90 to 0.18 million mt during 1991-95,but decreased to 0.16 million mt in 1996. The ringseine CPUE for the small pelagics and the total catch also declined, particularly in 1996, mainly due to the drastic reduction in the oil sardine catch (Tables 18 & 19).

The operation of gillnets decreased from the annual average of 1.1 million boatdays during 1986-90 to 0.9 million boatdays in 1996 while the production of small pelagics increased from 0.73 million mt in 1985 to the annual average of 0.9 million mt during 1991- 95 and declined to 0.84 million mt in 1996. The average CPUE ranged from 80 kg/boatday during 1986- 90 to 89 kg/boatday in 1996 (Tables 20 & 21).

Table 18. Ringseine landings of pelagics in India during 1986 to 1996 (in mt).

Name of fish	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics			
I. Clupeids			
Wolf herrings	9	25	0
Oil sardine	62320	38033	21977
Other sardines	5971	18652	3363
Hilsa shad	38	11	0
Other shads	15	103	0
Anchovies	0	0	0
Coilia	0	0	3
Setipinna	0	0	0
Stolephorus	8778	20650	18048
Thrissina	0	0	0
Thryssa	531	2629	3939
Other clupeids	3218	8593	14868
II. Bombayduck	0	0	0
III. Halfbeaks and fullbeaks	222	125	108
IV. Flyingfishes	0	0	0
V. Ribbonfishes	31	88	20
VI. Carangids			
Horse mackerel	2469	620	309
Scads	8109	36885	9929
Leather jackets	131	77	37
Other carangids	3170	2195	2253
VII. Pomfrets			
Black pomfret	113	613	1321
Silver pomfret	108	90	750
Chinese pomfret	0	73	0
VIII. Mackerels			
Indian mackerel	28725	48731	86091
Other mackerels	0	0	0
IX. Seerfishes	92	122	8
X. Tunnies			
E. affinis	2960	600	11
Auxis spp.	481	1107	1
Others	0	11	2
XI. Barracudas	161	108	9
XII. Mullets	50	92	9
XIII. Unicorn cod	0	0	0
XIV. Miscellaneous	450	632	446
B. Large pelagics			
I. Sharks	17	68	14
II. Tunnies			
K. pelamis	90	4	0
T. tonggol	0	0	0
III. Billfishes	0	8	7
IV. Miscellaneous	0	0	0
Small pelagics (mt)	128154	180868	163502
Large pelagics (mt)	108	80	21
Pelagics (mt)	128262	180948	163523
Others (mt)	9562	13319	20359
Total (mt)	137825	194267	183882
Effort in boatdays	167564	251973	240277

Table 19. Ringseine landings of pelagics and others in India during 1985 to 1996.

	1986-90 (Average)	1991-95 (Average)	1996
Absolute values (mt)			
Small pelagics (mt)	128154	180868	163502
Large pelagics (mt)	108	80	21
Pelagics (mt)	128262	180948	163523
Others (mt)	9562	13319	20359
Total (mt)	137825	194267	183882
Effort in boatdays	167564	251973	240277
Percentage			
Pelagics in total(%)	93.06	93.14	88.93
Small pelagics in total(%)	92.98	93.10	88.92
Small pelagics in total pelagics(%)	99.92	99.96	99.99
CPUE (kg)			
Small pelagics	765	718	680
Large pelagics	1	0	0
Total pelagics	765	718	681
Others	57	53	85
Total	823	771	765
Relative growth (%)			
Small pelagics		41.13	-9.60
Large pelagics		-25.89	-73.64
Pelagics		41.08	-9.63
Others		39.29	52.85
Total		40.95	-5.35
Effort		50.37	-4.64
CPUE			
Small pelagics		-6.15	-5.20
Large pelagics		-50.71	-72.36
Total pelagics		-6.18	-5.23
Others		-7.37	60.29
Total		-6.27	-0.74

The operation of gillnets decreased from the annual average of 1.1 million boatdays during 1986-90 to 0.9 million boatdays in 1996 while the production of small pelagics increased from 0.73 million mt in 1985 to the annual average of 0.9 million mt during 1991- 95 and declined to 0.84 million mt in 1996. The average CPUE ranged from 80 kg/boatday during 1986- 90 to 89 kg/boatday in 1996 (Tables 20 & 21).

Though the trawls are operated as bottom trawls, they land substantial quantities of small pelagics, which increased from 90 455 mt in 1985 to 356 698 mt in 1996 and the CPUE substantially from 63 kg/boatday in 1995 to 192 kg/boatday in 1996. The increase during 1991-96 was due to the substantial increase in the ribbonfishes and *Coilia dussumieri* along the northwest coast. The contribution of the small pelagics to the total trawl landings increased from 16.2% in 1985 to 29.1% in 1996 (Tables 22 & 23).

Table 20. Gillnet landings of pelagics in India during 1985 to 1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	4363	4620	3287	2669
Oil sardine	177	279	2110	464
Other sardines	2302	7765	8306	11758
Hilsa shad	2632	6046	22410	24089
Other shads	5024	3849	2348	1956
Anchovies	0	9	1	0
Coilia	29	100	93	17
Setipinna	2	30	21	81
Stolephorus	0	31	427	1018
Thrissina	0	0	0	0
Thryssa	320	356	1322	1066
Other clupeids	2646	6084	4861	3183
II. Bombayduck	95	132	721	868
III. Halfbeaks and fullbeaks	166	209	235	491
IV. Flyingfishes	1	10	142	7
V. Ribbonfishes	2684	4364	2915	1606
VI. Carangids				
Horse mackerel	1148	1697	1358	1154
Scads	19	35	56	63
Leather jackets	2846	1312	1123	1090
Other carangids	1050	1611	2291	2465
VII. Pomfrets				
Black pomfret	5001	6940	3902	2568
Silver pomfret	12327	12826	10158	6758
Chinese pomfret	68	118	110	209
VIII. Mackerels				
Indian mackerel	836	1376	5053	4610
Other mackerels	0	36	6	0
IX. Seerfishes	14889	14000	10428	9740
X. Tunnies				
E. affinis	7468	4624	2443	2986
Auxis spp.	297	917	296	554
Others	5328	1694	613	319
XI. Barracudas	305	571	579	658
XII. Mullets	14	91	314	101
XIII. Unicorn cod	0	0	0	2
XIV. Miscellaneous	790	1631	2420	1509
B. Large pelagics				
I. Sharks	11848	8762	5863	7067
II. Tunnies				
K. pelamis	28	70	52	61
T. tonggol	78	177	708	1234
III. Billfishes	336	529	312	1467
IV. Miscellaneous	135	190	191	180
Small pelagics (mt)	72827	83365	90349	84059
Large pelagics (mt)	12425	9729	7126	10009
Pelagics (mt)	85251	93094	97475	94068
Others (mt)	22640	22189	20443	21490
Total (mt)	107891	115283	117919	115558
Effort in boatdays	774835	1044456	910058	946643

Table 21. Gillnet landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (t)				
Small pelagics (t)	72827	83365	90349	84059
Large pelagics (t)	12425	9729	7126	10009
Pelagics (t)	85251	93094	97475	94068
Others (t)	22640	22189	20443	21490
Total (t)	107891	115283	117919	115558
Effort in boatdays	774835	1044456	910058	946643
Percentage				
Pelagics in total(%)	79.02	80.75	82.66	81.40
Small pelagics in total(%)	67.50	72.31	76.62	72.74
Small pelagics in total pelagics(%)	85.43	89.55	92.69	89.36
CPUE (kg)				
Small pelagics	94	80	99	89
Large pelagics	16	9	8	11
Total pelagics	110	89	107	99
Others	29	21	22	23
Total	139	110	130	122
Relative growth (%)				
Small pelagics		14.47	8.38	-6.96
Large pelagics		-21.69	-26.75	40.45
Pelagics		9.20	4.71	-3.50
Others		-1.99	-7.87	5.12
Total		6.85	2.29	-2.00
Effort		34.80	-12.87	4.02
CPUE				
Small pelagics		-15.08	24.38	-10.56
Large pelagics		-41.91	-15.94	35.02
Total pelagics		-18.99	20.17	-7.23
Others		-27.29	5.74	1.06
Total		-20.73	17.39	-5.79

Table 22. Trawl landings of pelagics in India during 1985-1996 (in mt).

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
A. Small pelagics				
I. Clupeids				
Wolf herrings	2799	2516	4893	5180
Oil sardine	277	2405	10088	7442
Other sardines	2177	3421	10016	19769
Hilsa shad	115	107	347	102
Other shads	547	1617	1350	1099
Anchovies	0	169	196	0
Coilia	4930	8449	9530	12129
Setipinna	804	1024	1015	1469
Stolephorus	4957	9552	16110	20879
Thrissina	0	11	2	0
Thryssa	15681	14125	17280	19499
Other clupeids	7647	11820	15392	19343
II. Bombayduck	1160	4033	6402	12666
III. Halfbeaks and fullbeaks	0	64	742	110
IV. Flyingfishes	0	2	355	10
V. Ribbonfishes	28284	43425	68051	100158

Table 22 Cont'd.

Name of fish	1985	1986-90 (Average)	1991-95 (Average)	1996
VI. Carangids				
Horse mackerel	635	1918	4979	5415
Scads	1789	11917	25691	36699
Leather jackets	1117	515	967	1679
Other carangids	5626	17020	22832	28872
VII. Pomfrets				
Black pomfret	673	1035	2859	3870
Silver pomfret	1971	3685	5608	7943
Chinese pomfret	17	124	313	182
VIII. Mackerels				
Indian mackerel	622	5290	9082	19990
Other mackerels	0	6	17	16
IX. Seerfishes	2222	2966	6030	6694
X. Tunnies				
E. affinis	874	343	594	655
Auxis spp.	0	15	38	31
Others	150	173	230	268
XI. Barracudas	937	3436	8235	9439
XII. Mullets	255	168	295	666
XIII. Unicorn cod	0	41	3	0
XIV. Miscellaneous	4189	6762	14145	14424
B. Large pelagics				
I. Sharks	5967	7044	11892	12294
II. Tunnies				
K. pelamis	13	4	11	1
T. tonggol	43	1	81	36
III. Billfishes	41	20	59	182
IV. Miscellaneous	294	316	683	527
Small pelagics (mt)	90455	158154	263690	356698
Large pelagics (mt)	6358	7385	12725	13040
Pelagics (mt)	96814	165538	276415	369738
Others (mt)	459757	582419	817729	856292
Total (mt)	556571	747957	1094145	1226030
Effort in boatdays	1444604	1818617	1980276	1853567

Groupwise production of small pelagics

The gearwise production of individual fisheries (specieswise or groupwise) has undergone considerable changes during 1985-96. For example, the purseseine landing of the Indian mackerel was only 32 140 mt in 1985, but increased by 3 times to 100 586 mt in 1996 (Table 16). On the contrary, the purseseine landings of the oil sardine drastically reduced from 40 074 mt in 1985 to 7 162 mt in 1996. The Indian mackerel, which formed 31% of the purseseine landings in 1985, increased to 67% in 1996 while the oil sardine, which formed 39% of the purseseine landings in 1985, decreased to a mere 5% in 1996. The other important fisheries in the purseseine sector include the lesser sardines, carangids and whitebaits (Table 16).

The ringseine landings of the Indian mackerel increased substantially from 28 725 mt in 1985 to 86 091 mt in 1996 while the landings of the oil sardine declined from 62 320 mt to 21 977 mt (Table 18). The other important constituents of the ringseine landings include the whitebaits and carangids (Table 18). The gillnet landings of the hilsa shad increased considerably from 2 632 mt in 1985 to 24 089 mt in 1996 (Table 20), mainly due to the heavy landings in the northeast coast, where a special type of gillnet promoted by the Bay of Bengal Programme is being operated in the current decade of the 1990s. The landings of the lesser sardines and the Indian mackerel also increased, especially along the Tamilnadu coast (Table 20).

Table 23. Trawl landings of pelagics and others in India during 1985 to 1996.

	1985	1986-90 (Avg)	1991-95 (Avg)	1996
Absolute values (mt)				
Small pelagics (mt)	90455	158154	263690	356698
Large pelagics (mt)	6358	7385	12725	13040
Pelagics (mt)	96814	165538	276415	369738
Others (mt)	459757	582419	817729	856292
Total (mt)	556571	747957	1094145	1226030
Effort in boatdays	1444604	1818617	1980276	1853567
Percentage				
Pelagics in total(%)	17.39	22.13	25.26	30.16
Small pelagics in total(%)	16.25	21.14	24.10	29.09
Small pelagics in total pelagics(%)	93.43	95.54	95.40	96.47
CPUE (kg)				
Small pelagics	62.62	86.96	133	192.44
Large pelagics	4.40	4.06	6	7.04
Total pelagics	67.02	91.02	140	199.47
Others	318.26	320.25	413	461.97
Total	385.28	411.28	553	661.44
Relative growth (%)				
Small pelagics		74.84	66.73	34.41
Large pelagics		16.14	72.32	1.13
Pelagics		70.99	66.98	32.86
Others		26.68	40.40	3.76
Total		34.39	46.28	11.10
Effort		25.89	8.89	-6.46
CPUE				
Small pelagics		38.88	53.12	43.69
Large pelagics		-7.75	58.25	8.11
Total pelagics		35.82	53.35	42.04
Others		0.63	28.94	10.93
Total		6.75	34.34	18.77

The bottom trawls exploit the small pelagics also as many of them undertake diurnal vertical migration. The trawl landings of ribbonfish increased from 28 284 mt to 100 158 mt, the carangids from 9 167 mt to 72 665 mt, the whitebaits from 4 957 mt to 20 879 mt, the lesser sardines from 2 177 mt to 19 769 mt, and the Indian mackerel from 622 mt to 19 990 mt from 1985 to 1996 (Table 22).

Regionwise production of small pelagics

On the basis of the general physical and topographical features of the sea and the sea bottom, and the distribution pattern of various fish stocks and their fisheries, the Indian coast could be broadly divided into the west coast and the east coast. The continental shelf of the northwest coast comprising the maritime states of Gujarat and Maharashtra is very wide with extensive fishing grounds where the sea bottom is generally muddy. The continental shelf of the southwest coast covering the states of Goa, Karnataka, Kerala and the west coast portion of Tamilnadu is rather narrow, and hence, the fishing grounds are less extensive. The sea bottom in the inshore fishing grounds of the southwest shelf is muddy. Some of the most productive grounds which support rich fisheries for stocks like the Indian mackerel, oil sardine, whitebaits and shrimps are located in the inner shelf of the southwest coast. The southeast coast comprising Tamilnadu, Pondicherry and Andhrapradesh is characterized by coral and rocky grounds interspersed with even grounds in the Gulf of Mannar and muddy bottom in the other regions. The sea bottom of the northeast coast (Orissa and West Bengal) which is mainly muddy in the depth range of 25 m to 100 m, is quite suitable for bottom trawling; the continental shelf between 100 m and 140 m depths and some regions beyond, are generally of uneven bottom.

It could be seen from Table 8 that during 1991-95 the west coast accounted for 70.6% of the total small pelagics landings and the east coast 29.4%.

(i) *Northeast coast*: The northeast coast produced only 5.5% of the total small pelagics during 1991-95 (Table 8). The average annual landing of the small pelagics was 58 519 mt during 1985-'96 which formed 57.2% of the total landings. The total landings of this region including the landings of the large pelagics and the small pelagics reached the maximum in 1993, but declined subsequently (Figs 5 & 6).

(ii) *Southeast coast*: In the southeast coast, the average annual small pelagics landings during 1985-96 reached 259 138 mt, forming 53.6% of the total landings. The total landings, total pelagics and small pelagics gradually increased and reached the highest of 618 539 mt, 358 964 mt and 349 590 mt, respectively in 1996 (Figs 7 & 8). The fleet of motorized catamarans keeps expanding in the southeast coast since the early 1990s, resulting in almost a continuous increase in the landings of the small pelagics.

(iii) *Southwest coast*: The production of total fish, pelagics and small pelagics was the maximum in the southwest coast compared to the other regions, except in 1996. During 1985-96 the average annual total landings reached 762 704 mt, the pelagics 475 495 mt and the small pelagics 469 897 mt (Figs 9 & 10). The southwest coast contributed 44.3% to the total small pelagics landings in the country. The production of small pelagics, which was maximum in 1989 (0.7 million mt), gradually declined to 0.47 million mt in 1996. Obviously, the benefits of the adoption of the ringseines operating from the motorized traditional craft in the 1980s seem to have culminated in the 1990s.

(iv) *Northwest coast*: Unlike in the southwest coast, the total fish landings in the northwest coast increased consistently during 1985-96 (Fig. 11). The landings of the small pelagics (304 792 mt), which formed only 42.7% of the total landings in the northwest coast compared to 61.6% in the southwest coast, did not decrease during 1985-96. After the increase in the small pelagics landings in 1989, the production stabilized around 350 000 mt in the subsequent years (Fig. 12). Though the ringseines do not exist and the extent of motorization of the traditional craft is comparatively less in the northwest coast than in the southwest coast, intensive fishing operations by multiday trawlers beyond the 50 m isobath and the traditional dolnet fishing land very high catches of ribbonfishes and the grenadier anchovy *Coilia dussumieri* along the northwest coast, as observed during 1985-96. On account of these reasons, the total landings in the northwest coast (0.85 million mt) could surpass that in the southwest coast (0.79 million mt) in 1996.

Estimates of total stock and MSY of small pelagics

Assessment of stocks is essential for deciding the guidelines for the rational exploitation and management of fisheries. The status of the exploited stocks and their levels of exploitation for a number of small pelagics stocks in the Indian seas have been determined on the basis of the data on effort and catch, biological parameters and primary production pertaining to different time periods, and the results are being used as the basis for the management of the small pelagics fisheries (Table 24).

For estimating the MSY and the optimum effort, the Schaefer (1954) model was fitted for the time series data on catch and standardized effort. For standardizing the fishing effort, the catch per boatday realized by the purseseiners and the ringseiners, which are the major craft-gear systems employed in the fisheries for the small pelagics along the southwest coast, was used. On this basis, a weighted average CPUE was calculated and was used to standardize the fishing effort on the all-India level. The standard units, converted to different operating units, have been used for determining the optimum fleet size of the mechanized sector. The MSY and the optimum fleet thus calculated revealed that the number of trawlers presently under operation (30 200) has exceeded the optimum number (10 638) (Table 25). Similarly, the number of purseseiners (980) has also exceeded the optimum fleet (736). However, there is scope for increasing the fleet of gillnetters and bagnetters in the northeast, southeast and northwest coasts (Table 25).

Table 24. Assessment of stocks of small pelagics in different regions of the Indian seas by various researchers.

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploitation level	1996 catch (mt)	Reference
S. longiceps	SW	1958-67	440,000	210,000	212,304	174,356	Under	110,346	Banerji, 1973
- do-	SW	1965-76	484,000	-	290,000	198,440	Under	(all India)	Sekharan, 1976
- do-	SW	1974	810,000	390,000	-	210,000	Under		ANON, 1976
- do-	SW	1972-77	400,000	-	-	136,000	Under		George *et al.*, 1997
- do-	SW	1972-76	-	-	195,000	134,000	Under		
-do-	West	1984-88	-	-	150,000	117,000	Optimum		Annigeri *et al.*,1992
Lesser sardines	Andaman	1976	20,000	-	-	-	-	-	George *et al.*, 1997
- do-	NE	- do-	30,000	-	-	-	-	-	
- do-	SE	- do-	140,000	-	-	-	-	-	- do-
- do-	SW	- do-	80,000	-	-	-	-	-	- do-
- do-	NW	- do-	10,000	-	-	-	-	-	- do-
- do-	All India	- do-	280,000	-	-	-	Under	103,732	- do-
S.gibbosa	Goa- Karnataka	1984-88	-	-	4,600	4,100	Under	(all India)	Sam Bannet *et al.*,
- do-	Tamil Nadu	- do-	-	-	20,600	20,000	Optimum		1992
- do-	Andhra Pradesh	- do-	-	-	5,000	5,000	Optimum	Lesser sardine)	- do-

Table 24 Cont'd

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploitation level	1996 catch (mt)	Reference
Stolephorus devisi	East coast	1984-88	-	-	12,300	11,400	Under		Luther *et al.*, 1992
-do-									-do-
	West	-do-	-	-	25,200	19,100	Under		
S. bataviensis	East	1984-88	-	-	9,900	9,400	Under		Luther *et al.*, 1992
-do-	West	-do-	-	-	14,100	14,100	Optimum		-do
R. kanagurta	Southwest	1958-67	-	-	90,600	58,781	Under	-	Banerji, 1973
-do-	-do-	1960-71	130,000	-	87,000	65,000	Under	-	Sekharan, 1976
-do-	-do-	1972-76	-	-	105,000	68,000	Under	-	George *et al.*, 1997
-do-	-do-	1972-73	-	450,000	-	94,000	Under	-	ANON, 1974
-do-	East	1984-88	-	-	25,300	23,700	Optimum	275,677	Noble *et al.*, 1992
-do-	West	-do-	-	-	50,700	49,800	Optimum	(all India)	-do-
-do-	Southwest	1934-73	-	-	70,788	62,198	Optimum		Devaraj *et al.*, 1994
T. lepturus	East	1984-88	-	-	20,400	-	Over	126,994	Thiagarajan *et al.*,
-do-	West	-do-	-	-	65,600	23,733	Under	(all India)	1972
M.cordyla	All India	1985-89	-	-	14,161	6,627	Under	17,652	Reuben *et al.*, 1992

Table 24 Cont'd

Species	Area	Period	Annual stock (mt)	Standing crop (mt)	MSY (mt)	Yield * (mt)	Exploitation level	1996 catch (mt)	Reference
D. russelli	All India	1985-89	-	-	28,707	19,055	Under	66,790 (all scads)	Reuben *et al.*, 1992
C. carangus	Tamil Nadu	1985-89	-	-	2,600	2,314	Under	-	-do-
S. leptolepis	Tamil Nadu	1985-89	-	-	6,583	5,726	Under	-	-do-
A. atropus	Tamil Nadu	1985-89	-	-	953	977	Over	-	-do-
A. kalla	Kerala	1985-89	-	-	15,700	14,264	Optimum	-	-do-
A. djeddaba	Kerala	1985-89	-	-	11,420	4,297	Under	-	-do-
A. mate	Kerala	1985-89	-	-	4,305	3364	Under	-	-do-
H. nehereus	Northwest	1982-86	76,893	-	54,631	52,213	Over	85,766	Kurian & Kurup, 1992
-do-	-do-	1975-86	-	-	55,000	57,000	Over		Kurian, 1988
-do-	-do-	1956-83	189,844	-	-	-	Over		Fernandez & Devaraj, 1996a.

* Annual yield during the respective study period

Table 25. Optimum fleet size under the mechanized sector against MSY (mt).

	MTN*	MPS**	MGN***	MBN****
I Northeast				
Total MSY	35668	Nil	48923	18782
Effort MSY (in boatdays)	94914	Nil	213720	28459
Vessels required (number)	509	Nil	1450	192
Vessels in operation	1600	Nil	120	120
II Southeast				
Total MSY	280538	Nil	34883	919
Effort MSY (in boatdays)	669427	Nil	509405	1276
Vessels required (number)	3599	Nil	3471	9
Vessels in operation	8300	Nil	650	175
III Southwest				
Total MSY	354626	111718	2348	Nil
Effort MSY (in boatdays)	801705	70547	18325	Nil
Vessels required (number)	4283	607	124	Nil
Vessels in operation	9500	850	1100	190
IV Northwest				
Total MSY	437644	40816	28641	2111
Effort MSY (in boatdays)	419463	15106	165618	22171
Vessels required (number)	2247	129	1110	147
Vessels in operation	10800	130	1250	1110
V All India				
Total MSY	1108476	152534	114795	21812
Effort MSY (in boatdays)	1985509	85653	907068	51906
Vessels required (number)	10638	736	6155	348
Vessels in operation	30200	980	3400	1495

* @180 Fishing days per year (Trawler)
** @120 fishing days per year (Purseseiner)
*** @150 fishing days per year (Gillnetter)
**** @150 fishing days per year (Bagnetter

MAJOR SMALL PELAGIC STOCKS

The pelagics occupy an important position in India's marine fisheries. They constituted about 54% of the total landings during 1996. Among the pelagics, the small pelagics were predominant, contributing about 96% to the total landings of the pelagics. Among the small pelagics, the Indian mackerel and the carangids were the most predominant, contributing 7.74% and 7.22% respectively to the overall marine fish landings during 1991-95. Among the other small pelagics, the anchovies formed 6.41%, followed by the Bombayduck (4.9%), ribbonfishes (4.31%), oil sardine (4.25%), lesser sardines (4.15%), other clupeids (2.25%), hilsa shad (1.11%) and barracudas (0.52%) in the overall marine fish landings during this

period (Table 8). The distribution, production, biology and trade aspects of the major small pelagics are summarized below.

Oil sardine

Distribution: In the world average annual production of around 280 000 mt of Indian oil sardine *(Sardinella longiceps)* during 1988-92, the Indian contribution of 190 000 mt formed 67.7%. The oil sardine are a major inshore small pelagic, distributed in narrow belts extending to a distance of 3 km to 20 km from the coast. Their geographic distribution extends widely from Seychelles through Somalia, Africa, Pakistan, India and Indonesia to the Philippines. Along the Indian peninsula, there is greater concentration of the oil sardine stock in the Malabar upwelling zone along the southwest coast between 8°N and 16°N latitudes, although in recent years a new fishery for this species has emerged along the east coast as well.

Means of exploitation: Till the close of the 1970s, various artisanal fishing craft operating gears like the shoreseines, boatseines, castnets, *rampanies* (huge shoreseines) and small meshed gillnets used to be engaged in the oil sardine fishery along the southwest coast. With the advent of purseseining in the late 1970s, first in Goa and then in Karnataka and to a limited scale in Kerala, the traditional fishing systems began to lose their importance in the fisheries for the small pelagics in these states. The situation got further aggravated in the 1980s with the popularization of the ringseines in Kerala and *Mattabala* (a variant of the ringseine) in Karnataka, coupled with the steady growth of motorized fleets of traditional fishing craft in these states. The purseseines and the ringseines have almost replaced the *rampanies* (yendi) in Karnataka and the boatseines in Kerala.

Fishing season : The oil sardine fishery commences along the southwest coast soon after the outbreak of the southwest monsoon (June) and continues till March-April. Usually the fishery starts first in the south (9°N latitude, i.e., Quilon) and progresses to the north (17°N latitude, i.e., Ratnagiri), probably in sequence with the early upwelling in the southern area. The above cycle of events is repeated every year. The beginning of the fishery is marked by the entry of large sized fish in the advanced stages of maturity followed by the 0 yearclass. The commercial fishery is supported by the 0 and 1 yearclass fish. The success of the oil sardine fishery along the southwest coast depends mainly on the recruitment strength of the early juveniles of the size 5 cm to 10 cm during the postmonsoon months. The juveniles begin to appear in the fishery from late August and form the mainstay of the fishery in the southern region, whereas in the northern region they begin to appear from late September onwards. The oil sardine always move in shoals, the size of the individual shoals being generally 2 m to 25m long and 1 m to 20m wide. The oil sardine shoals move at a speed of about 5km per hour and are known to descend to subsurface depths during daytime.

All India production: The Indian oil sardine production in the recent 10-year period (1986-95) reveals two phases : one of increasing trend in the first 5-year period (1986-90) followed by a decreasing trend in the second 5-year period (1991-95). From 78 000 mt in 1986, the production rose to 279 000 mt in 1989 and 261 000

mt in 1990, but subsequently suffered a steep fall to 47 000 mt in 1994 (Fig. 13). The oil sardine catch of 110 000 mt in 1996 shows an improvement by 15% over the average annual landings of 96 000 mt of 1991-95. The average annual catch in the southwest coast in the second half (1991-95) was only 57 000 mt compared to 150 000 mt during the first 5-year period (1986-90). However, a redeeming feature with the fishery was the phenomenal improvement in its landings in the southeast coast (Tamilnadu) in recent years where it did not form a conspicuous fishery in the earlier years. The average annual landings in the southeast coast increased from 15 000 mt during 1986-90 (42% of all India catch) to 39 000 mt during 1991-95, which is very significant, both biologically and commercially. The emergence of the oil sardine fishery along the southeast coast warrants further investigations to establish the causative factors responsible for its geographic expansion. The fishery has also newly emerged along the northeast coast (Orissa and West Bengal) during the last 5 years, from a position of almost no landings during 1986-90 to 52 mt during 1991-95. However, the qualitative change that has occurred in the southeast and northeast region is very important and warrants investigations as to the causes, on the following aspects.

(i) The landings of the oil sardine have increased in the southeast coast *viz-a-vis* the decline in the southwest coast during the same period. The possibility of migration between these two regions needs to be examined through tagging experiments. (ii) If the shift in the fishery is due to migration, the causes for the migration would require to be elucidated. (iii) A major development along the southeast coast since 1990 is the emergence of large number of shrimp farms along the coastal areas. About 120 000 ha of coastal area has been converted into shrimp farms (mainly along the east coast), which discharge huge quantities of organically very rich wastewater into the sea, inducing planktonic bloom which the oil sardine are able to utilize effectively. Congregation of marine fishes in the areas of wastewater discharge is well known.

Regionwise production: The oil sardine formed 4.25% of the overall marine fish production in the country during 1991-95 against 9.0% during 1986-90. During 1991-95 the share of the oil sardine in the overall marine fish production in the northeast region was only 0.04% in the annual average of 124 000 mt, in the southeast region it was 7.1% in the annual average of 540 000 mt, in the southwest region it formed 7.2% in the annual average of 791 000 mt, and in the northwest region it formed only 0.06% in the annual average of 804 000 mt. The share of the different regions in the overall all-India production of oil sardine varied from 0.05% for the northeast region to 59.24% for the southwest region, the southeast and the northwest regions forming 40.16% and 0.54% respectively. A major share of the landings of the oil sardine in the southeast region was contributed by the nonmechanized traditional gears which, at the current (average for 1991-95) level, was about of 25 000 mt, forming 52.6 % of the total oil sardine catch in this region.

Gearwise production: The major gears that exploit the oil sardine stock are the purseseines and the ringseines operated from the motorized (outboard) traditional craft in the southwest region and gillnets in the southeast region. During 1991-95, the purseseine fleet in the southwest region contributed an annual average of 13% to

the overall production of oil sardine in the country, while the same fleet contributed 0.3% from the southern part of the northwest region (Ratnagiri area) to the national oil sardine catch, heralding the beginning of commercial purseseining in the Ratnagiri area of the northwest region. During 1986-90, the boatseines, purseseines and ringseines from the southwest coast contributed 77% to the overall landings of the oil sardine, while during 1991-95, these gears contributed only 54% to the oil sardine landings. The purseseine fleet contribution reduced from 27.23% to 13.06%, while the ringseine fleet contribution improved marginally from 36.74% during 1986-90 to 39.65% during 1991-95 along the southwest coast. During 1991-95, the traditional gears operated by the nonmotorised craft landed an annual average of 25 000 mt forming 63.8% of the oil sardine catch of the southeast coast.

Factors influencing fluctuations: The oil sardine fishery is known for its highly erratic and fluctuating behaviour. Hornell (1910) attributed the fluctuations to the changes in the production of diatoms, food availability to the fry and the prevalence or absence of favourable hydrological conditions. There is also a view that the fluctuations are related to the shifts in the migratory path of the fish, causing variations in the vulnerability of the stocks to fishing, owing to the limited range of the traditional fishing operations. Devanesan (1943) attributed the low catches to the overfishing of the immature fish, while Nair (1952) and Nair and Subrahmanian (1955) attributed the changes to the availability and abundance of the diatom *Fragilaria oceanica* in the inshore waters. Murty and Edelman (1970) stated that the intensity of the monsoon along the west coast of India above a critical value would be favourable for the enrichment of the sea not only with nutrients, but also with dissolved oxygen. Sam Bennet (1973) expressed the view that the total number of fish in the population would not exceed the limits determined by the food resources and the rate of reproduction; if the numerical strength of a particular generation was large enough to utilize almost completely the food resources, the successive generations would become progressively weak in numbers, till the most dominant generation got reduced in its strength.

As observed by Sekharan and Dhulkhed (1963), the success of a given year's fishery was found to be determined by the abundance of the 0-yearclass. However, this was not always true. For example, the 1-year old fish dominated the catch of 124 000 mt in 1958-59. Although generally the 1-year old fish were next in abundance to the 0-yearclass, the 2-year old fish were more abundant than the 1-year old in some years, for instance, in 1955-56, 1956-57 and 1964-65. Such dominance of the older groups over the younger ones could be attributed to the changes in the availability and poor recruitment into the fishery. Since rainfall during the spawning season has been found to determine spawning success, rainfall data could be used to differentiate changes in recruitment from changes in availability.

For spawning to be a success, the average rainfall per day during the peak spawning season (mostly June to August) should be 30 mm. Spawning takes place around the new moon, and its success depends on whether optimum rainfall prevails a week before and after the new moon day. In the 1963 and 1965 spawning seasons, the average daily rainfall was much below the optimum: 13 mm and 18.3 mm

respectively, which led to large scale preovulation follicular breakdown, called atresia. As a result, the 1963 catch declined to a mere 64 000 mt from the previous year's 110 000 mt, when the rainfall was 31.6 mm/day (Antony Raja, 1967). However, the 1965 catch (262 000 mt) did not slump as it was constituted mainly by 1 year old fish (150-160 mm size group) (Sam Bennet, 1968; Antony Raja, 1972) resulting from the 1964 spawning when the rainfall was 29.2 mm/day. If the 1964 spawning success restored the 1965 fishery, the same should hold for the 1964-65 situation, but it did not. Therefore, a number of factors in interaction with each other seems to determine the success of the fishery. The important factors include rainfall, availability and accessibility to the gear in operation, migratory pattern, survival of the eggs and larvae, and the intensity of upwelling.

Food and feeding habits: The adult oil sardine feed mainly on the diatoms, dinoflagellates, tintinnids and zooplankton. Among the diatoms, *Fragilaria oceanica, Pluerosigma, Coscinodiscus* and *Biddulphia,* and among the bluegreen algae *Trichodesmium thiebautii* are frequently met with in the diet The dinophyceae consist of *Procentrum, Ceratium* and *Perdinium.* Among the zooplankton, *Acrocalanus, Paracalanus, Oithona, Harpacticoids, Lucifer* and larval polychaetes are common. The juveniles are carnivorous while the postlarvae feed mainly on the diatoms. *F. oceanica* seems to be a good indicator of the abundance of the oil sardine stock in the coastal waters. During actual spawning, there seems to be cessation in feeding activity.

Age & growth and age composition: Divergent findings made by various authors about the age, growth rate and life span of the oil sardine reveal two distinctly different sets of results (Table 26) . The differences between the two sets are very sharp in the first year of age, but progressively narrow down at the 2 and 3 years of age. At the age of 4 years, the results agree each other very closely. A reanalysis of the length frequency data from Sekharan and Dhulkhed (1963) by means of the scatter diagram method of length frequency analysis (Devaraj, 1983b) confirms the second category results (1 year= 146 mm, 2 year=171 mm, 3 year=186 mm and 4 year = 194 mm) to be the correct estimate of length at age in years, which also implies growth to be very rapid in the first year, but very slow subsequently.

Considering the bagnet (*mathikollivala*) in Kerala as the standard gear, the age composition of the oil sardine catch was computed for the southwest coast. The average number of fish caught in one unit of *mathikollivala* per year for the 12-year period 1954-55 to 1965-66 was 24 983 comprising 77%, 17%, 5% and 1% of 0,1, 2 and 3 year old fish respectively. During this period, the 0-year group dominated in all the years except in 1958-59, it was comparatively poor in 1955-56 and 1963-64 (4 000 fish/unit), fairly good in 1956-57 and 1958-59 (8 000 /unit), improved further in 1954-55, 1957-58, 1959-60, 1962-63 and 1965-66 (20 000/unit), still better in 1960-61 and 1961-62 (30 000/unit), and most abundant in 1964-65 (45 000/unit).

Table 26. The length-at-age in respect of the oil sardine determined by various authors.

	Author	Age in years and total length in mm				Remarks
		1	2	3	4	
1.	Hornell & Nayudu, 1924	150 170	-	-	-	SL given by the authors has been converted to TL.
2.	Chidambaram, 1950	100	145	183	205	The authors supposed that even fish of 150 mm
3.	Nair, 1952	100	150	190	210	length were immature on
4.	Sekharan, 1965	100	-	-	-	the basis of
5.	Balan, 1968	143	164	186		growth rings on
6.	Bensam, 1968	145-175	175	-	-	scales.
7.	Sekharan & Dhulkhed, 1963	100	150	-	-	
8.	Sam Bennet, 1968	100	150	175	190	
9.	Antony Raja, 1970	150-160	170-180	-	-	
10.	Prabhu & Dhulkhed, 1970	100-110	150-160	175-180	-	
11.	Banerji, 1973	146	171	186	194	On the basis of von Betalanffy growth eq. applied to length at-age data.
12.	Devaraj, MS	146	171	186	-	By reanalysing the data in Sekharan & Dhulkhed (1963) by means of a scatter diagram of modal lengths against time in months.

(1) to (12) results fall in 2 sets shown below:

Age in years	**1**	**2**	**3**	**4**
Set (1)	100-110	145-160	175-183	190-210
Set (2)	143-160	164-180	186	194
Banerji's estimates within category (2)	146	171	186	194

Size at maturity, fecundity, spawning and broods per yearclass: The oil sardine attain sexual maturity at the age of one year at a length of 150 mm. The active spawners in the oozing condition measure 150 to 170 mm. The sexes are separate. In spent and recovering fish, the males could be distinguished by an externally visible muscular papilla in the cloaca while the females could be identified by the presence of a membranous papilla behind the anal opening. The sex ratio appears to vary. Some investigators found the females to be predominant upto the size at first maturity, but a reduction in sexwise segregation among the ripe fish, and equal representation of sex among the juveniles and spawners. A recent study by Annigeri *et al.* (1992) indicated the dominance of the females in all the observation centres along the east and west coasts during 1984-88. The relative fecundity varies from 70 000 to 80 000 ova in the 1 to 2 year old fish (the left ovary produces on an average 40 000 eggs and the right ovary 38 000 eggs), but on an average a female produces 48 000 eggs per batch. Fecundity is directly proportional to the weight of the ovary, which in turn is generally related to the size of the fish.

Gravid and spent fish and juveniles occur in the nearshore waters off Kerala and Karnataka during June to August. Spawning has been observed at a distance of about 15 km from the shore along the 30 m isobath in the surface and column from Quilon to Karwar. Isolated cases of spawning in the nearshore areas have been observed off Kasargod and off Cochin during July. Spawning usually takes place at night, a few days before and after the new moon days. According to Antony Raja (1973), a daily rainfall of 20 to 30 mm during June to August may indicate good recruitment. Seasons of feeble or severe rainfall coincide with extensive atresia in the ovaries that may lead to a reduction in the spawning potential of the population, and consequent recruitment failures (Antony Raja, 1973)

Although the spawning season is generally held to extend from June to October, there is reason to believe that spawning may commence in January and last till October, but the main spawning seems to last for only 3 to 6 months or exceptionally it may be over in just one month. The commencement and the duration of spawning seem to vary from year to year, as evident from the time of origin of the broods, traced from the analysis of the 1957-63 length frequency data for Mangalore. The spawning season as traced back from this analysis for the 1957-62 period is given in Table 27.

Table 27. The spawning season of the oil sardine as traced from the 1957-63 length frequency data for Mangalore.

Year	Spawning season	Duration in months	No. of broods
1957	Mid March to mid June	4	1
1958	June	1	1
1959	Mid January to mid June	6	1
1960	January to March	3	1
1961	Mid May to August	4	1
1962	March to July	5	1

Thus, within the total duration of spawning, whether it is one month or up to 6 months, spawning intensity is found to be more or less uniform without a definite break or peak. As a result of uniform spawning, only one brood is released during each spawning season. The longer the duration of spawning, the wider is the distribution of the modal lengths for the younger size groups of a given brood in the scatter diagram of modal analysis. As the brood grows to complete about one year of age, the scatter values tend to become narrower in distribution. Such a change in the nature of the distribution of the scatter values seems to result from two reasons: (1) faster growth of that section of the brood that is still in the 0-yearclass; (2) abrupt fall in the growth rate of fish of the same brood, which have attained 1-year of age.

Contrary to this finding of the existence of only a single brood per yearclass, earlier studies seem to suggest each yearclass to be comprising more than one brood. Sekharan (1965) recognized two broods per yearclass in the length frequency data for Calicut. On the basis of the monthly length frequency curves for several years from commercial samples collected from 5 centres along the west coast, Banerji (1973) recognized two broods per yearclass corresponding to the two spawnings, one in June to July and the other in July to August. Antony Raja (1967) observed the spawning season off Calicut to be June to October within which he surmised two major spawnings, one in late June - early July and the other in late July to early August, giving rise to two broods. He further contended that the first brood released in June to July faced less competition for food and space, and hence, grew much faster than the second one. In order to reconcile these differences, the data in Table 28 taken from Antony Raja (1972), were critically examined.

Table 28. Frequency of broods per yearclass of oil sardine based on the length frequency data for Calicut.

Year	Month	Spurts in spawning	Modal length (mm)	Product of spawning in	Age in months
1961	October	1	115	July	3
	November	2	110	August	3
1962	November	1	65	July-August	1-2
1963	September	1	110	July	3
	October	2	95	August	2
	October	3	70	September	1
1964	August	1	115	June	2
	August	2	80	July	1.5
1965	August	1	105	June-July	1-2
	August	2	35	July-August	0.5 -1

The 5th column in Table 28 indicates that within each spawning season, spawning takes place mostly in spurts (1961, 1964 & 1965) at an interval of a

month. During some years, there is only a single spurt (1962) and in others three spurts (1963) at an interval of one month. Spawning is centred around the newmoon day and the spurts represent group spawning by the spawning section of the population, not necessarily representing the number of batches of ova spawned per fish. While it is true that the modal lengths representing the products of the spawning spurts are distinctly recognizable in the length frequency data, so long as their distribution pattern in the length frequency data does not produce distinct alignments into separate broods, they cannot be treated as representing distinct broods. Thus, the 2 or more spawning spurts within a given spawning season seem to give rise only to a single brood comprising a yearclass.

Shoaling and migration: Different types of surface and bottom shoals have been described by Balan (1961). The 0-yearclass migrate *en masse* from the offshore to the inshore areas simultaneously all over the sardine centres along the southwest coast towards the end of the southwest monsoon. The new recruits, after reaching the inshore areas, continue to get reinforced uninterruptedly through the entry of fresh recruits, inspite of heavy fishing pressure. With the warming up of the surface waters and the deepening of the thermocline in summer (March to May), the shoals gradually move back to the offshore areas, vacating first from the north and then from the southern centres, every year. Large scale tagging of oil sardine was carried out by the CMFRI from several centres on the east and west coasts of India during 1967-68 and 1968-69 (Prabhu and Venkataraman, 1970). The recoveries were limited. Hence no definite conclusions could be drawn regarding the migration of this fish, but the limited recoveries revealed only local dispersal. A programme of intensive tagging of oil sardine is essential in view of the recent emergence of this species along the east coast in commercial terms.

Stock assessment and management: Banerji (1973) estimated the total annual oil sardine stock in the southwest coast for the 1958-67 period to be 440 000 mt, the average standing crop 210 000 mt , and the MSY 212 304 mt for the optimum effort of 64.065 million manhours as against the average annual yield of 174 356 mt for the effort of 55.195 million manhours. Sekharan (1976) estimated the total annual stock to be 810 000 mt and the standing stock 390 000 mt. Based on acoustic and aereal surveys coupled with test fishing, the UNDP Pelagic Fisheries Project at Cochin estimated the annual standing stocks for the period 1972-77 to be 400 000 mt. Balan and Reghu (1979) also estimated the stock size to be about 400 000 mt. Annigeri *et al.* (1992), however, estimated the MSY to be 150 000 mt against a mean biomass of 107 000 mt, indicating scope for increasing production, but they also stated that increasing the fishing effort to the MSY level was not desirable as it would decrease the returns per boat considerably to uneconomic levels.

The recorded history of the Indian oil sardine fishery dates back to 1896. During the 60 years from 1896 to 1956, the entire catch was a mere 200 000 mt, the average annual catch being about 3 000 mt during these six decades; nearly 100 000 mt or 50% was landed in 1908, 1922 and 1923. However, commencing from 1957, a new phase began in the fishery for the oil sardine. Three distinct trends could be recognised in the post 1957 fishery.

(1) 1957-1963, when the average annual catch was 130 000 mt at an average effort of about 55 million manhours.

(2) 1964-1971, when the annual catch nearly doubled to 255 000 mt at an annual effort of about 65 million manhours.

(3) 1972-1977, when the catch per year was 145 000 mt at an annual effort of 60 million manhours, thus registering a reversal to the 1957- 63 peirod, with no corresponding decline in effort.

The doubling of the catch during the 1964-71 period does not seem to have led to the decline in the biomass during 1972-77; the annual stock has remained virtually the same at 400 000 mt in the 1958-77 periods. The slight decline in the effort during 1972-77 could not have resulted in such a major slump in the catch. Changes in the availability of the stock to the inshore fishery, seem to have set the changing trends in the catch. Only a small part of the stock seems to have been available to the inshore fishery of the 1972-77 period, a major part of the stock having remained in grounds beyond the reach of the traditional inshore gear. Such setbacks to the fishery paved the way for the growth of the purseseine fleet, since 1976. It is, however, very important to limit the growth of the purseseine fleet to prevent stock depletion and diminishing returns. It has been estimated that the oil sardine and mackerel stocks alone could support a fleet of 425 purseseiners including 235 for Kerala, 135 for Karnataka and 55 for Goa. Such a deployment would sustain the 1978 catch per unit effort of 5 mt per boat per day either oil sardine or mackerel, or both at the rate of 120 fishing days per year. Besides causing social concerns, the purseseines may cause considerable damage to the stocks, particularly in the context of an array of ringseine fleets operating in Kerala and Karnataka. The entire biomass of the oil sardine and mackerel is distributed in a total of 61 000 schools (25 000 oil sardine and 36 000 mackerel schools) covering an area of 4 800 sq.km along the southwest coast (Anon., 1976). The average biomass per school of oil sardine is 16 mt and mackerel 12.5 mt. The purseseine catches, on occasions, are as high as 40 mt per day per boat, equivalent to about 2 to 3 times the school size. Such decimating power of the purseseiner provides enough warning for stringent checks on the growth of this fleet, as well as of the ringseiners.

Utilization: Owing to the increasing demand for fresh fish from the local and the interior markets and easy availability of ice and quick transportation facilities, a good amount of oil sardine catch is now consumed in fresh condition. However, during periods of glut, a portion of the catch is cured with salt and sundried. Although sardines have been successfully canned in India since the British days, the canning industry suffered serious problems from time to time owing to several technical and practical difficulties. The oil sardine are rich in oil which is extracted for various industrial uses. After the extraction of the oil, the residue forms the guano which is used as a valuable manure in plantation crops because of the high nitrogen and phosphate content. Sardine fishmeal is in great demand in the livestock and shrimp feed industry.

Lesser sardines

Species:The species of *Sardinella* other than *S. longiceps* (oil sardine) and the rainbow sardines (*Dussumieria acuta* and *D. hasselti)* constitute the lesser sardines, which support lucrative fisheries especially along the southeast and Kerala coasts. Out of the 15 species of *Sardinella* in the Indo-Pacific region, 12 occur in the Indian Ocean. The sardines are typical shoaling fish occurring within the 50 m isobath in the coastal waters. The species that constitute the major lesser sardine fisheries include *Sardinella albella, S. gibbosa, S. fimbriata, S. sirm, S. dayi, S. sindensis, S. melanura, S. clupeoides* and *S. jonesi.*

Distribution: The lesser sardines are tropical, occurring along the coasts of Arabia, Red Sea, Madagascar, India, Sri Lanka, Malaysia, Singapore, Philippines, Australia and China. Along the Indian coast, while a few species are dominant in one region, a few other species are dominant in the other. In the Goa-Karnataka region (Konkan coast) , *S. gibbosa, S.dayi, S.fimbriata* and *S. albella* are quite abundant. In Kerala, *S. gibbosa, S. sindensis* and *S. sirm* dominate the lesser sardines, while the lesser known species such as *S. clupeiodes, S.fimbriata, S. melanura* and *S. jonesi* occur occasionally. *S. albella* and *S. gibbosa* are dominant in the Palk Bay and the Gulf of Mannar while *S. sirm* are limited to the peninsular tip between Vizhinjam and Tuticorin. *S. gibbosa, S. albella, S. dayi, S. sirm, S. clupeoides, S. fimbriata* and *S. gibbosa* are abundant in the central region of the east coast.

Means of exploitation: The traditional nonmotorized and motorized craft as well as the mechanized craft are employed in the lesser sardine fisheries. While the dugout and plankbuilt craft are used in the inshore waters, the purseseiners, gillnetters and trawlers are employed in the grounds extending upto the 42 m to 60 m isobath. The most widely used gears in the southwest coast include the boatseines, ringseines, purseseines and gillnets. The purseseines, which replaced the rampani in Karnataka, enhanced the lesser sardine catch in this state considerably. The trawlers operating in the nearshore grounds upto the 40 m isobath also land sardines in considerable quantities along the Karnataka coast. Small meshed gillnet is the main gear for the lesser sardine fisheries in the southeast coast.

All India production: The lesser sardines constituted 8.4% of the landings of the pelagics during 1986- 90 and 4.2 % during 1991-95. The average annual yield was 78 553 mt during 1986-90 and 93 725 mt during 1991-95 (Table 8), registering an increase of 19% (Fig. 14). During 1986-95 the landings ranged from 68 000 mt in 1986 to 125 000 mt in 1995, but declined slightly to 104 000 mt during 1996.

Regionwise production: During 1991-95, the lesser sardines formed 1.5% of the overall marine fish landings in the northeast region, 9% in the southeast region, 4.7% in the southwest region and 0.8% in the northwest region. The southeast region contributed the maximum of 51.6% (Table 8) to the total lesser sardine production, followed by the southwest region (39.4%), the northwest region (7%) and the northeast region (2%).

Gearwise production: The major gear employed in the fishery is the gillnet (especially along the southeast region), which contributed 9.7% to the total lesser sardine landings in India during 1986-90 and 10.2% during 1991-95 (Tables 20 & 21). The purseseiner fleet accounted for 10.1% and 12.3% of the lesser sardine landings during 1986-90 and 1991-95 respectively, while the ringseiner fleet accounted for 7.6% and 19.9% during 1986-90 and 1991-95 respectively in the southwest coast. Besides the gillnets, a variety of other traditional gears also contribute substantially to the landings of the lesser sardines in the southeast region. Out of the average annual landings of 48 362 mt in the southeast region during 1991-95 the share of the nonmechanized fleet was 24 000 mt (49.8%).

Food and feeding habits: The lesser sardines generally feed on a wide variety of plankton. There is considerable similarity in the food consumed by the different species, and general agreement between the items found in the gut and in the plankton. *S. gibbosa* feed on copepods, *Mysis*, *Lucifer*, prawn and crab larvae, fish eggs and larvae, *Acetes* etc., while *S. albella* feed mainly on copepods, *Lucifer*, *Acetes*, *Mysis*, fish larvae, bivalve larvae etc. Both phytoplankton and copepods form the main food of *S. fimbriata,* while prawn and other crustacean larvae, *Acetes*, molluscan larvae etc. form the major food of *S. dayi*. The minor food items found in the lesser sardine diet include small penaeids, larval bivalves, decapod larvae, *Lucifer* and fish eggs.

In all the species of sardines, the gillrakers increase in number with size. For example, *S. albella* and *S. gibbosa* of 35 mm length possess only 45 and 44 gillrakers respectively, while at 164 mm, they possess 98 and 89 gillrakers respectively. *S. fimbriata* possess 43 and 81 gillrakers respectively, at the above lengths while *S. sirm* and *S. clupeoides* have only 26 and 42 gillrakers respectively at comparable lengths. Only *S. longiceps* possess the largest number of 145 and 258 gillrakers in the juvenile and adult stages respectively. A distinct relation is discernible between the number of gillrakers and the stock size, with species possessing large number of gillrakers developing into high volume stocks, particularly in upwelling areas taking advantage of the immense phytoplankton filtration capabilities. The only exception to this relation is that the oil sardine stock could not establish into a major stock in the Arabian upwelling area as most of the phytoplankton is lost into the mesopelagic realm where they support immense stocks of lantern fishes.

Size at maturity, fecundity and spawning: *S. gibbosa, S. albella, S. fimbriata* and *S. dayi* below 100 mm in total length are either indeterminate or immature with gonads in stage I or II of maturity. Fish measuring above 100 mm in length show varying degrees of sexual maturity. As the spawning season approaches, most of them in the length range of 100 mm to 120 mm attain maturing conditions, while those measuring above 120 mm in length become fully mature. The minimum size of *S. gibbosa* at maturity is 115 mm, but it varied from centre to centre, as in some localities it was found to be 139 mm. *S. fimbriata* attain sexual maturity at a length of 135 mm to 185 mm (Sam Bennet *et al.*, 1992), while *S. dayi* attain first maturity around 140 mm. The relative fecundity of *S. gibbosa* varied from 12 786 to 41 326

The lesser sardines exhibit considerable variations in their spawning seasons depending on the species and regions. Although there is protracted spawning almost throughout year, peaks are evident, but individual fish seems to spawn only once in the case of *S. albella, S. gibbosa* and *S. fimbriata,* twice in the case of *S. longiceps* and thrice in the case of *S. sirm* within the same spawing season. Unlike the oil sardine, the lesser sardines seem to release 3 to 4 broods per year (Table 29).

Population parametres, stock assessment and management: The length at age of 1 year is 125 mm to 135mm in the case of *S. albella*, *S. gibbosa* and *S. fimbriata*, 146 mm for *S. longiceps* and 170 mm for *S. sirm*. Based on the values of K, M and t_{max}, the growth of these sardines in relation to their life span is the fastest (K= 1 or more) in the first three species with a shorter life span of 2 years, but slow (K=0.53) in the last two species where the life span is three to four years. The direct relation between K and M is also obvious in these sardines (Table 30). The high values of M for the stocks of *S. albella, S. gibbosa* and *S. fimbriata* are in tune with their fast growth in the first year of life and their role as the main forage (over 90%) of all epipelagic predators such as the seerfishes, dorabs and leather jackets in the Palk Bay and the seerfishes, tunas, billfishes and sharks in the Gulf of Mannar.

Table 29. Spawning frequency & season and broods per yearclass in respect of the lesser sardines in the Indian seas in relation to the oil sardine.

Species	Area	Spawning		No. of broods per yearclass
		Season	Frequency per year	
S. albella	Palk Bay	Feb.-Mar. to Jun.-July	One	-
	Gulf of Mannar	Mar. to June		
	Malabar	Sept. to May with peak in March to May		
S. gibbosa	Palk Bay & Gulf of Mannar	Feb.-Mar. to June-July	One	-
	Lawson's Bay	Feb. to May		
	Malabar	Jan. to May		
S. fimbriata	Tuticorin (Gulf of Mannar)	Oct. to Nov.		
	Vizhinjam	Throughout with peak in May-June, Aug. and Oct.-Nov.	One(2 in Java Sea)	3 to 4
S.sirm	Tuticorin (Gulf of Mannar)	Nov. to Dec. Feb. to March May to June	Three	4
D. hasselti	Southwest coast	Premonsoon & monsoon (March to September	-	-
S. longiceps	Southwest coast	June to Oct.	Two	1

Table 30. Lengths (mm) at age (years) and population parameters of lesser sardines in relation to *S.longiceps* in the Indian seas.

Species	Length (mm) at age (years)					Population parameters				
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
S. albella	125	145	-	-	145	152	1.41	103	0.72	3.10
S. gibbosa	135	160	-	-	168	171	1.44	102	0.60	3.20
S. fimbriata	128	185	-	-	185	220	0.98	120	0.66	2.16
S .sirm	170	240	292	-	300	380	0.53	140	0.47	1.16
D. hasselti	130	180	-	-	190	-	-	-	-	-
S. longiceps	146	171	186	194	225	207	0.53	155	0.70	1.17

The bulk of the lesser sardine catch consisted of the 0 yearclass (90 %) particularly before 1965 in the Palk Bay and the Gulf of Mannar because of torch fishing with handnets of 8.5 mm mesh, boatseine with 16.5 mm mesh and shoreseines of 9 mm mesh (used during March to April for the new recruits), 12 mm (mesh used during May to June for the fast growing postrecruits) and 14 mm mesh (during July for the near adults). In locations like the Konkan, North Canara and Vizhinjam coasts, where gillnets (26 mm mesh) are also used, the 0 and 1 yearclasses are present in equal proportions in the catches. In locations like Tuticorin and Malabar where the gillnets constitute the major gear, nearly 95% of the catches are of 1 yearclass and the remaining 5 % are 0 yearclass (Table 31). As torch fishing and boatseining are not practised in the Palk Bay and the Gulf of Mannar after 1965, recruitment overfishing seems to have minimised in these regions.

Table 31. Age composition (%) of lesser sardines in relation to *S.longiceps* in the Indian seas (*Torch fishing in vogue till 1965 in PB & GM was responsible for the predominance of zero year fish).

Species	Area	Age in years				Fishing season
		0	1	2	3	
S. albella	Palk Bay (PB) * & Gulf of Mannar (GM)	95	5	-	-	March to Sept.(PB) Oct. to April (GM)
	Malabar (1950s)	10	90	-	-	Jan. to May
S. gibbosa	Palk Bay (PB) Gulf of Mannar (GM) Lawson's Bay (LB)	95	5	-	-	Mar. to Sept. (PB) Oct. to April (GM) Nov. to April (LB)
S. fimbriata	Konkan (K) North Canara (NC) Vizhinjam (V)	50	50	-	-	Throughout the year with peak in Oct. to Dec. (K & NC) April to June (V)
	Malabar	10	90	-	-	
S. sirm	Tuticorin (Gulf of Mannar)	12	88	0.1	-	Nov. to March
S. longiceps	Quilon to Ratnagiri (southwest coast)	77	17	5	4	June-July to March-April

According to George *et al.* (1977), the total annual stock of the lesser sardines is 280 000 mt comprising 20 000 mt in the Andamans, 30 000 mt in the northeast coast, 140 000 mt in the southeast coast, 80 000 mt in the southwest coast and 10 000 mt in the northwest coast and the MSY is 140 000 mt (50% of the annual stock). However, according to Banerji (1973), the MSY for the 1958-67 period was only 53 000 mt. The average annual catch of 78 553 mt during 1986-90 and 93 725 mt during 1991-95 (Table 8) and the annual catch of 125 000 mt during 1995 match well with the MSY estimate of 140,000 mt made by George *et al.* (1977).

According to the UNDP-PFP, Cochin (Anon., 1974), the lesser sardines formed one of the many items comprising the biomass of the so called 'shallow water mix' together with the golden scad (*Caranx kalla*), silverbellies, glass perch (*Ambassis* spp.), whitefish (*Lactarius lactarius*) etc. along the southwest coast of India during 1972-73. The shallow water mix biomass was 142 000 mt (17% of the total pelagic biomass) during June-July 1972-73 along the 13° to 14° N latitude coast, 125 000 mt during November, 1972 along the 14° to 15° N latitude coast and 109 000 mt in January to February 1973 along the 14° to 15° N latitude coast while in the other months (March/April, April, May/June & July/Aug) it was 25 000 mt to 88 000 mt. With the approach of the southwest monsoon in May-June, the shallow water mix which is usually distributed near the bottom, changes to a more pelagic way of life and comes to the surface, obviously because of the emergence of the low oxygen layer towards the surface. They are not fully recorded by the echosounder, but might be sighted on or near the surface as schools. After the southwest monsoon, they return to their original habitats (subsurface) with the deepening of the thermocline and are well located by the echosounder.

Specific lesser sardine or rainbow sardine type of recordings have proved to be very scarce and erratic, being most frequently mixed with the shallow water mix as well as the whitebaits. The type of recordings recognized as the lesser sardines were often made in the area between 20m and 40m bottom depth. Fishing with pelagic trawls usually gave small catches, mainly of *S. fimbriata* and *D. hasselti* and occasionally *S. albella*. Seasonal southward migration of *S. fimbriata* and *S. albella* is evident from abundance shifting from the tip of the southwest coast (7°N latitude) in June-July to the east of Cape Comorin in the Gulf of Mannar (8°N latitude) in July-August. Similarly, *D. hasselti* move southwards from the Kasargode area (12°N latitude) in January to March through the (9° to 12°N latitude) and in May-June to the east of Cape Comorin (8°N latitude) in the Gulf of Mannar during July-August (Anon., 1974).

Utilization: The lesser sardines are a source of cheap protein for the rural poor in the coastal regions. The steep decline in the catches of the oil sardine in recent years has resulted in the increased demand for the lesser sardines. The sardines are consumed fresh in the coastal regions and transported with ice to the interior markets by road and train. Salted and sundried sardine products are sold in the hinterland states in India and also in countries like Sri Lanka and Hongkong. Smaller sardines are dried and used as important protein mix in the preparation of cattle, poultry, and shrimp feeds.

Table 26. The length-at-age in respect of the oil sardine determined by various authors.

	Author	Age in years and total length in mm				Remarks
		1	2	3	4	
1.	Hornell & Nayudu, 1924	150 170	-	-	-	SL given by the authors has been converted to TL.
2.	Chidambaram, 1950	100	145	183	205	The authors supposed that even fish of 150 mm
3.	Nair, 1952	100	150	190	210	length were immature on
4.	Sekharan, 1965	100	-	-	-	the basis of
5.	Balan, 1968	143	164	186		growth rings on
6.	Bensam, 1968	145- 175	175	-	-	scales.
7.	Sekharan & Dhulkhed, 1963	100	150	-	-	
8.	Sam Bennet, 1968	100	150	175	190	
9.	Antony Raja, 1970	150- 160	170- 180	-	-	
10.	Prabhu & Dhulkhed, 1970	100- 110	150- 160	175- 180	-	
11.	Banerji, 1973	146	171	186	194	On the basis of von Betalanffy growth eq. applied to length at-age data.
12.	Devaraj, MS	146	171	186	-	By reanalysing the data in Sekharan & Dhulkhed (1963) by means of a scatter diagram of modal lengths against time in months.

(1) to (12) results fall in 2 sets shown below:

Age in years	**1**	**2**	**3**	**4**
Set (1)	100-110	145-160	175-183	190-210
Set (2)	143-160	164-180	186	194
Banerji's estimates within category (2)	146	171	186	194

Anchovies

Species: The anchovies including the whitebaits in the Indian seas belong to five genera, viz., *Stolephorus, Coilia, Setipinna, Thryssa* and *Thrissina*. The whitebaits are the dominant component of the anchovy landings in India. The whitebait fishery comprises 10 species. They are *Stolephorus devisi, S. bataviensis, S. heterolobus, S. buccaneeri, S. andhraensis, S. baganensis, S. commersoni, S. indicus, S. insularis* and *S. dubiosus*. In the global marine fish production, the share of the anchovies during 1992 was 11%. The Indian contribution to the world anchovy production, during this period was 2%.

Distribution: The anchovies are widely distributed in the Indo-Pacific region. Considerable knowledge on the fishery potential and the biology of the whitebaits (*Stolephorus*) has been generated by the investigations of the FAO/UNDP Pelagic Fisheries Project (1971-75) along the southwest coast of India extending from Ratnagiri on the west coast (17°N) to Tuticorin (8° 14'N) on the east coast mainly within 50 m depth. Whereas *S. devisi, S.bataviensis, S. heterolobus, S. baganensis* and *S. buccaneeri* form the fishery in the area between Ratnagiri and the Gulf of Mannar, *S. commersoni* and *S. indicus* form the fishery in Palk Bay and further north in the Bay of Bengal. The grenadier anchovy, *Coilia dussumieri* are limited to the northwest coast, and to a limited extent, to the northeast coast.

Means of exploitation: The exploitation of the anvhovies does not pose much problem as they are easily amenable to different kinds of fishing. The major gears employed in the fishery are the boatseines, shoreseines, bagnets and gillnets, operated mainly by the catamarans and plankbuilt boats, most of them fitted with outboard engines. The purseseines, ringseines and bottom trawls also land good quantities of anchovies. In the southeast and the southwest coasts, the most common gears exploiting the whitebaits include the boatseines (codend stretched mesh 10 mm) and the shoreseines (codend stretched mesh 10 to 20 mm). On the southwest coast south of Quilon, gillnets, known as *netholivala* (mesh 15 mm), are specially employed for the whitebaits during the main fishing season. In Kerala these gears are mainly operated from the catamarans and small plankbuilt boats, fitted with outboard motors. In Andhra Pradesh, however, large plankbuilt boats, known as *masula* boats, are employed in operating large shoreseines for the anchovies and other small pelagics. During October-March, when the shoals are distributed all along the coast in shallow waters at 15 m to 30 m depth, they can be effectively fished with high opening midwater trawls (codend mesh size: 15 mm). The purseseines (common stretched mesh at the bunt, 14 to 18 mm) are operating in Karnataka and Kerala from mechanized boats since the seventies and the ringseines (mini purseseines with a mesh of 8 mm) are operating from plankbuilt boats and dugout canoes fitted with outboard motors, since the mid eighties in southern Karnataka and northern Kerala. The operational depth of these gears ranges from 15 m to 50 m. Dispersed whitebait shoals can easily be aggregated by light attraction at night and caught by small purseseines.

All India production: Among the anchovies, the whitebaits are the most important, with current (1991-95) average annual landings of 72 000 mt (Fig. 15; Table 8), forming almost 50% of the overall anchovy production of 145 000 mt. The grenadier anchovy *C.dussumieri* form 23%, *Thryssa* 25.3% and *Setipinna* 1.5% of the current anchovy landings (Table 8). The whitebaits form 60% in the southeast coast and 80% in the southwest coast of the total anchovy production in these regions. The grenadier anchovy dominate the anchovy fishery in the northwest and northeast regions, which contributed an annual average of 28 100 mt (27.4%) and 3 930 mt (5.7%) to the annual landings of anchovies of 39 698 mt and 8 328 mt respectively during 1991-95 in these regions. The national average annual catch of 126 624 mt of anchovies during 1986-90 increased to 145 086 mt during 1991-95, registering a growth of 15%. Currently, anchovies form 12% of the total catch of the pelagics. The anchovy landings have been showing an increasing trend during the last 10 years, as indicated above . This increase is mainly due to a 33% increase in *Thryssa,* 27% increase in *Coilia* and 4% increase in the whitebaits. The annual production of whitebaits varied from 51 000 mt to 100 000 mt during 1986-1995, with a remarkable increase from 51 000 mt in 1987 to 100 000 mt in 1988, but during the remaining period, it fluctuated from 54 000 mt in 1985 to 84 000 mt in 1991. Compared to the average annual landings of about 145 000 mt during 1991-95, the catch of anchovies during 1996 registered a fall of 9% to 131 000 mt. The whitebaits registered a fall of about 12 000 mt from 72 000 mt to 60 000 mt during the corresponding period.

Regionwise production: During 1991-95 the anchovies formed about 10.6% of the total landings of the pelagics in the northeast region, 10.8% in the southeast, 13.6% in the southwest and 11.1% in the northwest regions. About 72% of the landings of whitebaits occurred in the southwest region and 27% in the southeast region. About 83% of the landings of the grenadier anchovy came from the northwest region and 12% from the northeast region (Table 8).

Gearwise production: In Andhra Pradesh, 82% of the whitebait catch was obtained in the shoreseines, followed by the trawls (13%), boatseines (4%) and gillnets (1%). In Tamil Nadu, the gillnets, boatseines and shoreseines combinedly accounted for 83% of the annual whitebait catch, followed by the trawls (17%). In Karnataka, the purseseines contributed the highest (93%), followed by the trawls (6%) and others (1%) to the whitebait catch. In Kerala, on the other hand, the boatseines landed the bulk (65%) of the whitebait catch, followed by the gillnets (11%), trawls (11%), shoreseines (9%), ringseines (motorized units) (3%) and others (1%).

Food and feeding: The whitebaits feed mainly on copepods, small bivalves and crustaceans. *S. devisi* occasionally feed on phytoplankton such as *Coscinodiscus*. The grenadier anchovy feed on *Acetes*, fish larvae, copepods, ostracods and prawn juveniles. *Thryssa* spp. feed on prawns, *Acetes*, polychaetes and fishes (Menon and George, 1975).

Size at maturity, fecundity and spawning: The spawning of the whitebaits occurs for about 10 months a year. However, there are periods of peak spawning for every species. *S. devisi* are a multiple spawner, with spawning extending from November

to July with peak intensity during October-February off Mangalore (Table 32). The size at first maturity is around 62 mm (Table 33). The total number of ripe ova in the mature ovaries of *S. devisi* varies from 670 to 3 166 (Rao, 1988a). Along the southwest coast, the peak spawning of *S. bataviensis* takes place during February. The minimum size at first maturity is around 77 mm. The total number of ripe ova in the mature ovaries ranges from 972 to 2 571 (Rao, 1988b). The fecundities of the other whitebaits are: *S. heterolobus*: 1 000 to 2 500; *S. bataviensis*: 5 000 to 10 000; *S. buccaneeri*: 7 000 to 11 000; *S. indicus*: 9 000 to 14 000. The grenadier anchovy spawn once in their life time, with peak spawning during April-June. The size at first maturity is 186 mm (Table 33).

Migration: The whitebaits undertake seasonal migration along the southwest coast and the Gulf of Mannar in 4 distinct phases: (i) In October, when the northeast monsoon sets in, the shoals are discontinuously distributed in a narrow elongated band along the southwest coast from Mangalore to Cape Comorin (Fig. 16). (ii) During November to February, the shoals form a continuous wide belt with a disruption between 11°N and 12°N. (iii) During March-April, the shoals break up and begin their southward migration, which continues till July. (iv) In August, the southward migration culminates, with the bulk of the stock migrating towards north in the east coast and piling up between Cape Comorin and the central Gulf of Mannar in the east coast. The migration of the whitebaits follows the surface currents of the northeast and the southwest monsoons. During the southwest monsoon, the currents flow southwards along the west coast; and north and northeastwards in the Gulf of Mannar; during the northeast monsoon, the current flows in the reverse direction.

Table 32. Spawning frequency & season and broods per yearclass in respect of the anchovies in the Indian seas.

Species	Area	Spawning	
		Season	Frequency per year
S. devisi	Mangalore	Oct. to Feb.	Multiple
	Visakhapatnam	Feb. to Mar.; July	Two
	Madras	Apr. to June	One
	Cochin	Oct. to Nov.; Feb.	Two
	Vizhinjam	Mar.to May; Nov. to Dec.	Two
S. bataviensis	Visakhapatnam	Feb. to Mar.; June to July	Two
	Madras	Apr.; June to Aug.	Two
	Cochin	February	Two
C. dussumieri	Northwest coast	Apr. to June.	One
C. ramcarati	Hooghly estuaries	Dec. to Mar.; Aug.	Two
T. mystax	Calicut	Nov. to Mar.	Multiple

Population parameters, stock assessment and management: Stock assessment indicates that the increase in the production of the whitebaits from the present level will be marginal except in the case of *S. devisi* which is poorly exploited in both the coasts. A three-fold increase in effort along the east coast and six-fold increase in

effort along the west coast would be required to realise the coresponding MSYs by increasing the landings by 7.4% and 31.9% respectively. However, in multispecies, multigear fisheries, such projections could be only tentative, as there is no exclusive fishery for the whitebaits alone (Luther *et al.*,1992). While developing the anchovy fisheries further, the following fishing practices could be introduced: (1) high opening midwater trawls for the grounds in the 15 m to 30 m depth during October to March, which is the major fishing season (Table 34); (2) midwater trawls for the stocks that aggregate in the Gulf of Mannar during August to September; and (3) chumming the shoals using light luring devices and catching them with small purseseines.

Table 33. Lengths (mm) at age (years) and population parameters of anchovies in the Indian seas.

Species	Length (mm) at age (years)				Population parameters					
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
S. devisi	101	113	-	-	105	113	2.04	62	0.55	2.61
S. bataviensis	101	115	-	-	-	116	2.03	77	0.66	2.61
-do-	85	120	133	-	-	135	1.40	75	0.56	2.25
C. dussumieri	163 to 185	-	-	-	205	265	1.07	186	0.70	2.02 to 2.46
C. ramcarati	83	128	163	188	-	265	0.29	123	0.46	-
T. mystax	120	185	205	-	205	-	-	145	0.70	-

Utilization: Most of the anchovy catch is consumed in the fresh state except in times of glut when the surplus is dried and sent to interior markets. A small fraction of the fresh fish is used as baits in the hooks and line fishery. Improvements in cold storage facilities, introduction of artificial driers and canning in tomato sauce are some of the ways by which better utilization of anchovies could be ensured.

Indian mackerel

Distribution: The Indian mackerel, *Rastrelliger kanagurta,* distributed widely in the entire Indo-Pacific region, constitute the mainstay of the mackerel fishery in this region. In India, *R. kanagurta* are widely distributed along both the coasts, with very high concentrations along the southwest coast. *R. brachysoma*, occurring in the Andaman waters contribute very little to the fishery while *R. faughni* has been reported to occur only very rarely along the southeast coast of India. Nearly 90% of the world production of the Indian mackerel (*R. kanagurta*) is contributed by India. About 77% of the annual catch of the Indian mackerel comes from the west coast and 23% from the east coast.

Table 34. Age composition (%) of anchovies in the Indian seas.

Species	Area	Age in years				Fishing season
		0	1	2	3	
S. devisi	Mangalore	97	3	-	-	Oct. to Dec.; Jan. to Mar.
S. bataviensis	Mangalore	95	5	-	-	Oct. to Dec.; Jan. to Mar.
Coilia dussumieri	Northwest coast	76	24	-	-	Throughout the year
C. ramcarati	Hooghly estuaries	15	23	29	33	-

Means of exploitation: The major fishing craft engaged in the mackerel fishery include the motorized and nonmotorized catamarans, plankbuilt boats, dugout canoes, purseseiners and trawlers. The common gears employed include the shoreseines, boatseines, gillnets, hooks & lines, ringseines, purseseines and trawls.

All India production: The annual production of the Indian mackerel is characterized by wide fluctuations as evident from the catch records of the past fifty years. During the last 10 years, the production ranged from 113 000 mt in 1991 to 290 000 mt in 1989 (Fig. 17). Relatively higher landings were observed in the 5 year period from 1991 to 1995 (Table 8), when the production registered an increase of 19% over the production of the preceding 5 year period of 1986-90 (147 000 mt). The contribution of the mackerel to the total marine fish production remained at 7.8% during 1986-90 as well as during 1991-95. Compared to the average annual landings of 174 896 mt of 1991-95, the landings of mackerel showed a substantial growth in 1996 when the fishery yielded 274 118 mt.

Regionwise production: The Indian mackerel contributed 14.4% to the annual marine fish production in the southwest region and 7.3% in the southeast region during 1991-95 (Table 8). In recent years (1991-95), the contribution of the mackerel to the annual marine fish production in the northwest region increased significantly to 2.6%. At the current level (1991-95), the southwest region accounts for 65.1% of the total yield of mackerel in the country while the southeast region accounts for 22.6% and the northwest region 11.9% (Table 8). In the southeast region, the production during 1991-95 registered a conspicuous 68% increase over the average annual production of 24 000 mt for the 1986-90 period. Along this coast, the annual catch increased substantially from 21 000 mt in 1991 to 60 000 mt in 1992 and continued to sustain at moderately high levels thereafter. A similar trend could be observed in the northwest region as well, where there was more than twofold increase in the catch during 1991-95 from 9 000 mt per year during 1986-90; during 1991-95, the production registered a steep increase from 12 000 mt in 1992 to 29 000 mt in 1993 and sustained at this high level since then.

Gearwise production: Among the major gears that exploit the mackerel, purseseines and ringseines together contribute 62% to the overall production of mackerel in the southwest coast. The contribution of the purseseines, however, declined to 6.8% during 1991-95 compared to 44.8% during 1986-90 (Tables 16, 17, 18 & 19).

Food and feeding: The Indian mackerel feed primarily on the zooplankton at the juvenile stages and mainly on the phytoplankton in the adult stages (Chacko, 1949; Pradhan, 1956; Venkataraman, 1961; Noble, 1965). The most common food items are the diatoms, dinoflagellates, copepods, cladocerans, mysids etc. The intensity of feeding is very high in maturing and spent mackerel, but low in the spawners. Along certain areas off the west coast, two feeding maxima have been observed: one in October to December and the other in March to April when the fat content also increases appreciably. It is noteworthy that the feeding maxima are followed by the periods of brood release in January to February and April to May respectively.

Size at maturity, fecundity and spawning: The size at first maturity ranges from 184 mm to 225 mm in total length, depending on the locations and the annual variations in maturation (Devanesan and John, 1940; Chidambaram and Venkataraman, 1946; Pradhan, 1956) (Table 35).

Along the southwest coast, spawning is protracted, with definite peaks in different localities within the extended season of February to September. Surveys by the Pelagic Fisheries Project (Anon., 1976) found mackerel larvae in great abundance during March to August along the southwest coast. Along the east coast, spawning extends from October-November to April-May. The occurrence of mackerel larvae all along the Indian coast suggests spawning along the entire coast. The PFP (Anon., 1976) findings also corroborate spawning all along the coast. Observations by Pradhan (1956), Sekharan (1958), Radhakrishnan (1965), Vijayaraghavan (1965) and Rao (1967) reveal that the Indian mackerel spawn in succession, releasing the eggs in batches. According to Devanesan and John (1940) and Vijayaraghavan (1965) spawning of mackerel takes place mostly in the night. The ripe ovary has two distinct batches of ova, the maturing and ripe ones. During each spawning season, an individual mackerel spawns two batches of eggs in quick succession . However, the number of broods per yearclass of the west coast stock is limited in most of the years to just one (February to May) and rarely to two (February to May and October to November). Therefore, the two distinct batches of ova per fish cannot be directly related to the number of broods, separated from each other by a long duration of over five months. Instead, the number of broods may be related to the number of spawning peaks within a spawning season, each peak giving rise to a brood.

Devanesan and John (1940) estimated an average fecundity of 94 000 eggs. Rao (1967) found the absolute fecundity to be 110 000 eggs in 3 successive size groups in mackerel of 228 mm to 232 mm total length. Mackerel larvae and postlarvae have been collected along the southwest coast between 7°N and 12°N latitude at depths ranging from 10 to 200 metres. Evidently, the spawning takes place in the same grounds where the adults are distributed.

Population parameters, stock assessment and management: The values of growth parameters of the mackerel vary widely between different areas (Table 35), possibly due to the variations in the biotic and abiotic factors. Nevertheless, the growth coefficients have been found to be quite high for all the locations studied. It appears that the mackerel becomes (Table 36) physiologically old at 1.5 to 2 years (Table 36). In spite of the variations in the basic input data used by different authors during different time periods, there is a surprising uniformity in the conclusions arrived at regarding the stock size and the optimum yield. Analysing the mackerel fishery of the southwest coast for the years 1934-73, Devaraj *et al.* (1994) observed that the average catch was only 16.58% less than the MSY, with slight annual variations to the left or the right limb of the yield curve. Fishing at the F_{msy} has to be considered with utmost caution. Theoretically, exceeding the F_{msy} may result in wide fluctuations in the stock, and the return time to equilibrium may increase markedly. At present, the number of purseseiners has stabilized at about 500, comprising 90 in Kerala, 300 in Karnataka, 66 in Goa and 40 in southern Maharashtra, owing to poor

fluctuations in the stock, and the return time to equilibrium may increase markedly. At present, the number of purseseiners has stabilized at about 500, comprising 90 in Kerala, 300 in Karnataka, 66 in Goa and 40 in southern Maharashtra, owing to poor returns on investment. In the context of the same inshore fishing grounds, being exploited by various other fleets as well, the purseseine fishery has no prospect of expansion any further. According to Haywood (1982), the optimum number of purseseiners for Karnataka is 230 while according to Devaraj (1979), it is 275 in the absence of any major artisanal fishery, such as beachseining, which has been replaced by purseseining.

Table 35. Lengths (mm) at age (years) and population parameters of Indian mackerel.

Area	Length (mm) at age (years)				Population parameters				
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	Reference
Karwar	100	180	-	-	-	-	-	-	Pradhan, 1956
Southwest coast	195	235	252	-	266	0.83	-	-	Udupa & Bhat, 1984
- do -	226	-	-	-	238	2.84	184	0.77	Devaraj *et. al.*, 1994
- do -	245	-	-	-	265	2.60 - 3.80	-	-	Biradar, 1985
South Kanara	120 to 150	210 to 230	-	-	-	-	-	-	Sekharan,1958
Mangalore	150	225	266	289	316	0.60	-	-	Rao et al., 1965
- do -	140 to 160	220	-	-	-	-	-	-	Yohannan, 1977
Cochin	220	240	-	-	228	3.60	-	-	George & Banerji, 1968
Orissa	130	225	260	260	272	0.66	-	-	Pati, 1982
Andaman	148	218	265	265	390	0.74	255	0.65	Luther, 1973

Utilization: A good quantity of mackerel is consumed in fresh conditions along the coastal and nearby areas. During glut conditions the surplus catch is salted, sundried and sent to the interior markets. Export of frozen mackerel to the South East Asian countries seems possible, considering the surplus catches in certain years.

Table 36. Age composition (%) of Indian mackerel in different gears (Devaraj *et al.* 1994).

Gear	Area	Age in years				Period
		0	1	2	3	
Beachseine	Karwar	79	21	-	-	1948-59
- do -	Mangalore	90	10	-	-	1957-73
Gillnet	Calicut	75	25	-	-	1934-41
- do -	Cochin	98	2	-	-	1957-64
Pelagic trawl	Southwest	90	10	-	-	1972-75

Ribbonfishes

Species: The major species include *Trichiurus lepturus, Lepturacanthus, L. savala, Eupleurogrammus glossodon* and *R. muticus*.

Distribution: Ribbonfishes are widely distributed in the Indo-Pacific and the Atlantic. Six species constitute the commercial fishery in several areas along the Indian coast, but only *Trichiurus lepturus* and *Lepturacanthus savala* are the most abundant throughout the Indian coast while *E. intermedius* form a seasonal fishery in some major fishing centres, *E. muticus* along the northwest and northeast coast and *E. glossodon* and *T. auriga* (caught in small quantities) along the east coast. The landings of ribbonfishes in 1996 recorded 127 000 mt, registering a growth of 30% over the average annual catch of 97 000 mt during 1991-95.

Means of exploitation: The fleets employed in the ribbonfish fishery include the trawlers, motorized and nonmotorized catamarans, plankbuilt boats and dugout canoes while the principal gears include the trawls, boatseines, dolnets, shoreseines, hooks & line and gillnets.

All-India production: During 1983-90, the average annual world production of ribbonfishes was 688 312 mt, of which 14.2% was contributed by India. During 1991-95, the average annual ribbonfish catch of 97 444 mt was 26% higher than that for 1986-90 and formed 8.4% of the small pelagic catches and 4.3% of the total marine fish production in India (Fig. 18).

Regionwise production: During 1991-95, about 79% of the average annual catch was landed from the west coast and 21% from the east coast. The major share (65.5%) of the annual landings was obtained from the northwest region, followed by 16.4% from the southeast, 13.1% from the southwest and the rest 50% from the northeast region. The ribbonfish formed 7.9%, 1.6%, 3.0% and 3.9% of the total marine fish landings in the northwest, southwest, southeast and northeast regions respectively (Table 8).

Gearwise production: Among the major gears, the trawls contributed 70% (68 051 mt), the bagnets (including the dolnets of the northwest coast) 7%, the gillnets 3% and the purseseines 2.2% to the all India ribbonfishes during 1991-95.

Food and feeding: The ribbonfishes are carnivores, feeding predominantly on fishes and to a smaller extent on shrimps and other items (Venkataraman, 1944; Jacob, 1949; Devanesan and Chidambaram, 1948). Selectivity in feeding was reported by James (1967) and Prabhu (1955). While young ribbonfishes feed on smaller fishes and shrimps, the adults prey upon much larger items. Huge shoals of ribbonfishes are commonly noticed in coastal areas, chasing shoals of sardines, anchovies and scads.

Size at maturity, fecundity and spawning: The ribbonfishes (*T. lepturus, L. savala, E. glossodon* and *E. muticus)* spawn more than once a year (Table 37). Three batches of ova (immature, maturing and mature) are found in the ovaries. The

maturing and mature groups of ova are so sharply differentiated in the mature ovaries of all the four species that their spawning seems to take place at short intervals of time in quick succession. Although Prabhu (1955) indicated a short and definite spawning once a year in June for *T. lepturus* off Mandapam, subsequent observations clearly indicate prolonged spawning almost throughout the year, with two peaks. Prabhu (1955) estimated the relative fecundity of *T. lepturus* to be 16 000 ova while James *et* al. (1983) estimated the absolute fecundity to be 134 000 ova. Big shoals of *T. lepturus* are seen in the inshore waters after June in many locations along the Indian coast. Since the majority of the fish in such schools are above 45 cm in length (45 cm to 47 cm is the size at first maturity) and in just spent and spent recovering stages, it is possible that this schooling in the nearshore grounds is associated with spawning as well as active postspawning feeding on the youngones of other small pelagics during the peak monsoon season. Spawning in *L. savala, E. muticus* and *E. glossodon* is quite prolonged, taking place almost throughout the year, evidently because of the release of successive batches of eggs by individual fishes (James, 1967; Narasimham, 1976).

Table 37. Spawning frequency and season in respect of the ribbonfishes in the Indian seas.

Species	Area	Spawning	
		Season	Frequency per year
T. lepturus	Kakinada	Feb. to June	Two
	West coast	Apr. to June	One
	Madras	May to June; Nov. to Dec.	Two
	Mandapam	June	One
L. savala	Mandapam	Feb. to May	Two
E. glossodon	Kakinada	June to Aug.; Oct. to Jan.	Two
E. intermedius	Mandapam	May to Sep.	Multiple

Population parameters, stock assessment and management: The age and growth of *T. lepturus, L. savala* and *E. intermedius* from the Indian waters indicate a life span of 3 to 4 years (Table 38). Narasimham (1978) and James *et al.* (1983) reported that *T. lepturus* grow at a faster rate than the other ribbonfish species. The largest specimen of *T. lepturus* (115 cm in total length) found in the commercial catches at Kakinada (Andhra Pradesh) was considered to be 5 years old (Narasimham, 1978). The occurrence of *E. intermedius* of more than 43 cm in length indicates a life span of at least 4 years (James, 1967).

There is overfishing of the stock of *T. lepturus* along the east coast where the effort should be reduced by 33% (Thiagarajan *et al.,* 1992). Although the exploitation rates are high, there is scope for increasing the catch by extending the fishing areas, considering the large biomass recorded in experimental fishing (Somvanshi and Joseph, 1989). Along the west coast there is good scope of increasing the present effort, as the present yield of 77 000 mt (1991-95) is not even 50% of the estimated biomass of 223 773 mt.

Table 38. Lengths (mm) at age (years) and population parameters in respect of the ribbonfishes in the Indian seas.

Species	Length (mm) at age (years)				Population parameters				
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	Reference
T. lepturus	391	587	708	828	-	-	470	-	James *et al.*, 1983
- do -	427	686	879	1024	1454	0.29	450	0.31	Narasimham, 1983
- do -	512	825	1010	-	1297	0.50	-	-	Chakraborty, 1990
- do -	550	870	1050	1150	1290	0.56	-	-	Thiagarajan *et al.*, 1992
- do -	400	670	860	980	1260	0.38	610	-	- do -
E.intermedius	210	330	430	-	-	-	380	-	James, 1967

Utilization: The ribbonfishes are consumed fresh locally, and the surplus, if any, is salt cured or sundried. The good export market that once existed for Indian cured fish in Sri Lanka and Malaysia has now declined, but a new market for Indian deep frozen ribbonfish has emerged recently in the UAE, Singapore and Hong Kong. Following this, the ribbonfish, once considered a cheap fish, has become a high value commodity in the domestic market. Baits of ribbonfish are used in longlining and trolling for larger pelagics and larger demersals like the seerfishes, tunas, eels, sharks, catfishes and jewfishes.

Carangids

Species: There are 46 species of carangids occurring along the Indian coast, but the fisheries consist mainly of the horse mackerels, round scads, selar scads, queenfishes, trevallies, jacks and pompanos. The queenfishes and jacks attain large sizes, whereas the others are small, but form big schools. In recent years there has been a significant increase in the production of the carangids, which currently form about 7.2% of the total marine fish landings in India.

Distribution: Out of the 46 species of carangids, *Megalaspis cordyla, Decapterus russelli, Alepes kalla, Atropus atropus, Alepes djedaba, Atule mate, Caranx carangus* and *Selaroides leptolepis* contribute significantly to the carangid fisheries, which extend up to a depth of about 100m. While *M. cordyla* and *D. russelli* are quite important in the fishery all along the Indian coast, *A. kalla* and *A. atropus* form good fisheries along the southwest and northwest coasts respectively. The fishing for *A. djedaba* and *A. mate* is confined mainly to Kerala and that for *C. carangus* and *S. leptolepis* is limited to the southeast coast.

Means of exploitation: The catamarans, plankbuilt boats and trawlers which form the major fishing craft all along the Indian coast land good quantities of carangids. Gillnets (25 mm to 40 mm mesh), drift gillnets (50 mm to 80 mm & 80 mm to 120 mm mesh) made of nylon or garfil, boatseines (10 mm to 15 mm mesh), trawls (15 mm to 20 mm mesh), seinenets called *kachal* (25 mm to 30 mm mesh) and *jangal* (35 mm to 40 mm mesh) in the northeast coast and purseseines and ringseines(10 mm to 12 mm mesh) in the southwest coast, and hooks & line are principally used in

the exploitation of the carangids, among others. Although the carangids are not the target fisheries in any of these gears, they form a good component in the catches of these gears.

All-India Production: The average annual production of carangids during 1991-95 was 163 285 mt of which the scads alone formed 86 000 mt (52.9%) (Fig. 19). The carangids formed 7.2% of the total marine fish production in the country during 1991-95 (Table 8).

Regionwise production: During 1991-95, the average annual yields of *M. cordyla* and *D. russelli* were 20 000 mt and 86 000 mt respectively, which formed 0.9 and 3.8% of the total marine fish production in the country. In the southwest region, the carangids formed 14.2% of the total production during 1991-95. The average annual production of 163 285 mt during 1991-95 consisted of 112 000 mt from the southwest region (69%), 27 000 mt from the southeast region (17%), 21 000 mt from the northwest region (13%) and 2 000 mt from the northeast region (1%). *D. russelli* formed about 10% of the total landings in the southwest region, while in the other regions it formed only less than 1%. The southwest region contributed 48.2% of the landings of horse mackerel, while 42% came from the northwest region. However, 89% of the scad landings came from the southwest region (Table 8).

Gearwise production: A major portion of the landings came from the purseseines and ringseines in the southwest region. These two gears contributed 43% to the total carangid production in the country during 1991-95 (Tables 16, 17, 18 & 19). About 33% of the national production was contributed by the trawls, especially from the southern states (Tables 22 & 23).

Food and feeding: The carangids are carnivores, feeding predominantly on fishes and crustaceans. *Megalaspis cordyla* feed mainly on clupeids and crustaceans. The young ones measuring about 8 cm in length feed on postlarval fish, juvenile prawns and other crustaceans (Basheeruddin and Nayar,1961). *Decapterus russelli* feed on clupeids, diatoms, copepods and other crustaceans. The juveniles of 4 cm to 12 cm size feed on *Acetes*, copepods and other crustaceans.

Table 39. Lengths (mm) at age (years) and population parameters of carangids in the Indian seas.

Species	Length (mm) at age (years)				Population parameters					
	1	2	3	4	L_{max}	L_∞	K	l_m	l_m/l_∞	M
Caranx carangus	288	390	450	-	-	444	0.65	220	0.50	0.95
C. leptolepis	166	210	-	-	-	213	1.43	-	-	2.19
Megalaspis cordyla	358	485	510	-	-	554	1.03	250	0.45	0.93
Decapterus russelli	160	208	224	-	-	232	1.08	137	0.59	1.90
Atropus atropus	321	412	440	-	-	440	1.00	210	0.48	1.26
Selaroides leptolepis	158	170	198	-	-	202	0.82	88	0.44	1.35
Alepes kalla	101	142	160	-	-	171	0.83	129	0.75	1.40
A. djeddaba	185	236	289	-	-	326	0.61	189	0.58	0.99
Atule mate	205	278	315	-	-	340	0.85	172	0.51	1.22

Maturity and spawning: The size of *M. cordyla* at first maturity is 250 mm (Table 39). The spawning is prolonged, resulting in recruitment almost round the year. In the east coast, peak spawning occurs during March to May, followed by peak recruitment in April-May (Table 40). In the northwest and the southwest coasts, recruitment takes place in two different peaks. In the northwest coast, there is a minor recruitment in October and a major one in January, while in the southwest coast, the minor recruitment occurs in April and the major one in July. The spawning peak was found to be around July in the northwest coast, while along the southwest coast, the peak was in January.

Table 40. Spawning frequency and season in respect of the carangids in the Indian seas.

Species	Area	Spawning		No. of broods per yearclass
		Season	Frequency per year	
Megalaspis cordyla	East coast	March to May	Two	-
	Northwest	July	One	
	Southwest	January	One	
Decapterus russelli	East coast	April, August	Multiple	-
	Northwest	December, August	Multiple	
	Southwest	August, January	Multiple	
Selaroides leptolepis	East coast	October	One	-

The length of *D. russelli* at first maturity is 137 mm. Two batches of eggs are released in each spawning season. Spawning and recruitment are prolonged and almost continuous, but two peaks have been discerned in all the regions, with only minor variations. In the east coast, recruitment is quite pronounced around July, followed by a less pronounced one in November. Spawning is intense in April, but less intense in August. Along the northwest coast, recruitment is continuous, with peaks in June and January, due to the peak spawning in December and August respectively. Along the southwest coast, recruitment is highly pronounced in January and feeble in July. The size of *S. leptolepis* at first maturity varies from 88 mm to 101 mm. Major recruitment occurs in January, corresponding to intense spawning in October. Almost the entire catch along the Tamilnadu coast is comprised by the 0-yearclass (Table 41).

Stock assessment and management: The average annual catch of *M. cordyla* during 1985-89 was estimated to be 6 627 mt *vis-a-vis* the MSY of 14 161 mt comprising 1 056 mt for the east coast, 4 727 mt for the northwest and 8 378 mt for the southwest coast. In the southwest coast, the fishing effort should be increased by 81% to obtain the MSY.

The estimated average annual catch of the scad *D. russelli* during 1985-89 was 19 055 mt *vis-a-vis* the MSY of 28 707 mt comprising 2 799 mt for the east coast, 3 700 mt for the northeast coast and 22 208 mt for the southwest coast. The MSY was 5.7% more than the current annual catch for the east coast, 17% more for the northwest and 2% more for the southwest coast. The fishing effort on and the catch of *M.cordyla* and *D.russelli* have increased substantially in the subsequent years due to the expansion the fishing area.

Table 41. Age composition (%) of carangids in the Indian seas.

Species	Area	Age in years				Fishing season
		0	1	2	3	
Decapterus russelli	East coast	89	10	1	-	Throughout year
	Northwest	62	35	3	-	Oct. to March
	Southwest	54	45	1	-	Oct., Apr. to June
Caranx carangus	Tamilnadu	99	1	0	-	Throughout year
Selaroides leptolepis	Tamilnadu	99	1	0	-	Throughout year
Alepes kalla	Southwest	98	1	1	-	Nov. to Jan.; Apr. to June
Alepes djeddaba	Kerala	85	9	6	-	Jan., June, Nov.
Atule mate	Kerala	33	64	3	-	Nov. to May

C. carangus form a fishery along the Tamilnadu-Pondicherry coast, where the average annual production during 1985-89 was 2 720 mt, taken mainly by the trawlers. The current annual production of 2 314 mt is 13.5% lower than the MSY. Reduction in the current fishing effort by the trawlers is recommended to increase the yield to the level of the MSY.

S. leptolepis form a fishery only along the Tamilnadu coast, where the average annual landing during 1985-89 was 5 726 mt, taken mainly by the trawlers, *vis-a-vis* the MSY of 6 583 mt which is 9.5% higher than the present production. Reduction in fishing effort by about 39% is recommended to increase the yield to the MSY level.

A. atropus form a fishery along the northwest coast of India, where the average annual catch during 1985-89 was estimated to be 977 mt, of which 67.5% came from Maharashtra and the rest from Gujarat. The MSY is estimated to be 953 mt.

A. kalla form a fishery along the southwest coast where the average annual catch during 1985-89 was estimated to be 14 264 mt, of which 61% was from Kerala. The MSY is 1.36% more than the present yield, but the 41% increase from the current effort required to attain the MSY would not be economically viable.

A. djeddaba constitute a fishery only in Kerala where the average annual catch during 1985-89 was 4 297 mt. The stock is grossly underexploited, and hence it requires to increase the present effort by 221% to attain the MSY.

A. mate fishery is also limited to Kerala, where it is carried out mainly by hooks & lines and drift gillnets. The average annual catch during 1985-89 was estimated to be 3 364 mt against the MSY of 4 305 mt.

A detailed study on the stocks of the carangids by Reuben *et. al.* (1992) indicated underexploitation of *M. cordyla* along the southwest coast, *D. russelli* along the northeast and southeast coasts and *A. djeddaba* and *A. mate* along the southwest coast during 1985-89. However, the virgin biomass of these stocks has

declined to critical levels at the F_{msy}, leading possibly to recruitment overfishing. Reuben *et. al.* (1992) reported that larger individuals of *M. cordyla* (>205mm), *D. russelli* (>170mm) and *A. mate* (>210mm) were exposed to intensive exploitation by the gillnets, trawls and hooks & line, respectively. *C. carangus* and *S. leptolepis* are also overexploited along the southeast coast. Since the carangids are not the targets of these three major gears, the demand for any reduction in the effort by these gears from the present level cannot be justified unless the actual targets of these gears also exhibit signs of overexploitation.

Utilization: The carangids are high quality table fish in great demand and marketed mostly in fresh or iced condition because of the quick transportation facilities that exist in most places between the production and consuming centres. During peak landings, the surplus catch is deep frozen and stored for the lean season, which ensures steady prices and supplies. Since recently, larger species such as *C. malabaricus, C. melampygus, C. ignobilis, S. mate,* and *S. djeddaba* are being exported in frozen form.

Bombayduck

Distribution: The Bombayduck (*Harpodon nehereus*), which inhabit the waters upto the 50 m to 70 m isobath, form a major single species fishery along the northwest coast from Ratnagiri in Maharashtra to the Gulf of Kutch in the Saurashtra coast. They afford a seasonal fishery along the coasts of West Bengal, Orissa and the northern part of Andhra Pradesh. Bombayduck are inconspicuous or totally absent in the southwest and southeast coasts.

Means of exploitation:The dolnet operated by the plankbuilt boats is the primary gear used in the Bombayduck fishery along the northwest coast. It is a traditional labour-intensive stationary bagnet, made of synthetic filaments, highly specialized in design, working entirely by the forces of tide. The gillnets, boatseines and trawls are also employed in this fishery.

All India production: The average annual catch of Bombayduck was about 111 000 mt during 1986-95 when it ranged from 74 000 mt in 1987 to 136 000 mt in 1991 (Table 8; Fig. 20). The average catch during 1991-95 increased by 14% from the 1986-90 level, and formed 4.9% of the total marine fish landings in India. In 1996, the catch of 86 000 mt indicated a decline of 23% from the 1991- 95 average.

Regionwise production: Nearly 87% of the annual landings during 1991-95 came from the northwest coast and the rest from the northeast coast. Along the northwest coast, the fishing season begins by April with high catch rates, which dwindle with the progress of the season, recording the lowest values in February to March. The fishing season shows two distinct phases of productivity: (1) September to January, which is more productive, with the predominance of adults over the juveniles; (2) February to March, which is less productive, with juveniles forming a major part of the catch.

Saurashtra - Gulf of Cambay region (Fig. 21). The existence of the Gulf of Cambay, which serves as ideal nursery grounds appears to be the second most important factor, next to the tidal amplitude, responsible for the emergence of Bombayduck as a major stock along the northwest coast.

Table 43. Age composition (%) of Bombayduck in the Indian seas.

Area	Age in years				Period
	0	1	2	3	
Gujarat	59	21	20	-	1979
Maharashtra	21	29	50	-	1979
Saurashtra	75	18	7	-	1980-84
Northwest caost	44	52	3	1	1947-86

Population parameters, stock assessment and management: The annual growth coefficient (K) of the Bombayduck varies from 0.29 to 0.77 in the northwest coast. The K value for the Saurashtra coast is higher than that for the Maharashtra coast because of the predominance of the 0 yearclass in the former and the predominance of 1 and 2 yearclasses in the latter.

Fernandez and Devaraj (1996 a,b) reported that the mean Y_W/R for 1956-83 (5.95g) in relation to the MSY/R (11.88g) indicated an overexploitation of the Bombayduck stock by 17.6% in the northwest coast. By reducing the mean annual fishing effort by 8%, the average annual yield could be increased to the MSY of 189 844 mt. Since dolnetting is the major means of exploiting the Bombayduck fishery, the existing fleet of 2 428 (2 102 in Maharashtra and 326 in Gujarat) dolnetters could be reduced to the optimum of 2001 dolnetters to help maximise the yield of Bombayduck. Two more regulatory measures suggested to increase the yield are: (a) change over to 25 mm to 27 mm mesh at the codend of the dolnet, and (b) closing of fishing season during February to May, which should form the basic management strategy in future for the sustained development of this fishery.

Utilization: The Bombayduck are a very soft fish of low quality and highly perishable because of the high water content, and hence require to be disposed quickly for consumption in fresh condition. The bulk of the catch is sundried and sold in the interior markets while a small portion is converted into manure. Laminated Bombayduck are in good demand in some foreign markets.

Seerfishes

The seerfishes are one of the most valued fishes and hence form the target of drift gillnet and hooks & line fisheries. *Scomberomorus commerson, S. guttatus* and *S. lineolatus* occur along the Indian coast in addition to the wahoo, *Acanthocybium solandri*. *S. commerson* form about 56% of the seerfish landings. The annual seerfish production which ranged from 29 101 mt to 45 143 mt during 1985-96 formed 1.8% of the total marine fish landings. The northwest coast contributed 43.1% to the all-India seerfish landings followed by the southeast (25.5%) and the

southwest coasts (23.3%). The major gear used in the fishery is the drift gillnet of 7 cm to 17 cm mesh sizes which effectively exploit the commercial size groups through both gilling as well as entangling.

The seerfishes are exploited by hooks & lines, troll lines and trawls also. The growth parameters of the seerfishes have been studied in detail (Table 44). The length at first maturity of *S.commerson* is 750 mm and the spawning season extends from January to September during which a weak brood is released during January-February, a strong brood during April-May and another weak brood in July-August (Devaraj, 1983a). The same frequency and time of brood release is true with *S. guttatus* (Devaraj, 1987a) and *S.lineolatus* (Devaraj, 1986) also. *S. commerson* are known to be a migratory species. The young ones which are abundant in the southwest coast during June to September seem to move to the southwest coast and afford a fishery

Table 44. Length (mm) at age (years) and population parameters of seerfishes.

	Length (mm) at age (years)				Population parameters					
Species	1	2	3	4	L_∞	K	l_m	l_m/l_∞	M	**Reference**
Scomberomorus commerson	402	726	995	1186	2081	0.81	750	0.36	0.79	Devaraj, 1983a
- do -	-	-	-	-	1270 to 1768	0.50 to 0.66	-	-	0.71 to 0.90	Devaraj *et. al.*, MS
S. lineolatus	350	713	835	965	1683	0.18	700	0.42	-	Devaraj, 1983a
- do -	-	-	-	-	1268	0.86	-	-	-	Devaraj *et. al.*, MS
S. guttatus	315	650	725	859	1278	-	400	0.31	-	Devaraj, 1987a
- do -	-	-	-	-	680 to 1092	0.72 to 0.85	-	-	-	Devaraj, *et al.*, MS

The spawning season of *S. guttatus* extends from January to August, releasing a weak brood during January-February, a strong brood from March to July and another weak brood in August. The spawning season of *S.lineolatus* extends from January to May, releasing a weak brood in January and February, succeeded by a strong brood from March to May.

Along the southeast coast, the young ones of about 450 mm length form 91% of the catch. As exccessive exploitation of the stock before the size at first maturity may affect the spawning stock and recruitment, exploitation by small meshed gillnets along the southeast coast should be discouraged so as to ensure a good spawning stock and also to improve the catch along the southwest coast (Yohannan *et. al.*, 1992). *S. commerson* stock is being overexploited as the current level of effort is 80% more than the optimum along the east coast and 60% more than the optimum along the west coast. Operation of hooks & lines and gillnets of 150 mm to 200 mm mesh size may be encouraged for sustaining the seerfish fishery.

Coastal tunas

Of the 8 major species of tunas occurring along the Indian coast, 5 are coastal and 3 highsea and migratory. The coastal tunas are the kawakawa (*Euthynnus affinis)*, the frigate tuna (*Auxis thazard),* the bullet tuna (*A. rochei)*, the oriental bonito (*Sarda orientalis)* and the longtail tuna (*Thunnus tonggol)*. The annual tuna catch during 1985-96 ranged from 23 544 mt to 45 868 mt, of which about 70% was formed by the coastal tunas. The southwest coast contributed about 53% to the tuna landings, followed by the northwest coast (29%) and the southeast coast (18%). The coastal tunas are exploited by drift gillnets, hooks & lines and purseseines. The drift gillnets are more popular as they guarantee good returns. The gillnets contributed 54%, hooks & lines 27%, purseseines 17% and other gears 2% to the tuna production.

The coastal tunas are migratory and they appear in shoals in the southern part of the southwest coast in the premonsoon period (October to April). A part of this stock seems to migrate into the southeast coast, but a major portion of the stock migrates northward along the southwest coast, forming a peak fishery off Cochin during May to August and off Mangalore in October.

The studies conducted by James *et al.* (1992) for the period 1984-88 indicate that the exploitation of tunas, especially the coastal tunas from the traditional fishing grounds, has almost reached the optimum. Based on the population parameters (Table 45) and the stock estimates for the period 1984-88, the coastal tunas have been found to be exploited at the optimum level (James *et al.*, 1992). However, in the case of *E. affinis*, 66% decrease in the current effort has been suggested to optimise the fishery, while in the case of *A. thazard, A. rochei* and *T. tonggol,* increase in the current effort would increase the yield only marginally. The dwindling tuna catches at certain centres along the west coast suggests that indiscriminate motorization of the artisanal fleets may lead to overexploitation (James *et al.*, 1992). Extension of fishing to the offshore shelf through multiday drift gillnetting and purseseining, and intensification of troll-lining and handlining during the monsoon season may help augment the tuna catches from the west coast of India (James *et al.*, 1992).

Table 45. Length (mm) at age (years) and population parameters of coastal tunas.

Species	Length at age				Population parameters					Reference
	1	2	3	4	L_∞	K	l_m	l_m/l_∞	M	
Euthynnus affinis	314	466	571	644	810	0.37	430	0.53	0.62	Srinivasarangan *et al.*, 1944
Auxis thazard	292	422	503	550	630	0.49	305	0.48	1.02	Silas *et al.*, 1985a
A. rochei	160	280	340	-	370	0.64	-	-	1.02	James *et al.*, 1992
Thunnus tonggol	423	619	740	813	930	0.49	-	-	0.66	Silas *et al.*, 1985a
Sarda orientalis	447	580	630	650	660	1.01	-	-	-	Silas *et al.*, 1985b

Pomfrets

Among the small pelagics, the pomfrets are highly priced and consist of the silver pomfret (*Pampus argenteus*) and the Chinese pomfret (*P. chinensis*). The annual landings of 25 848 mt during 1991-95 comprised essentially the silver pomfret (25 253 mt or 97.7%). The length of the silver pomfret at first maturity is 240 mm and the L_{∞} 395 mm in the northwest coast (Khan *et al.*, 1992b). The spawning season is prolonged with peaks in April and August along the east coast (Pati, 1982) and February-August along the west coast (Gopalan, 1967). The area between the 55 m and 90 m depths off Cambay in the northwest coast and the sandheads area in the northeast coast form the breeding grounds of the silver pomfret (Khan, 1982). The northwest coast accounts for the maximum landings. The principal gear exploiting the adult pomfret is the drift gillnets while the dolnet exploits essentially the juveniles in the northwest coast. The MSY of the silver pomfret in Indian waters has been estimated to be 38 194 mt (Khan MS). As the fishery has collapsed in the northwest coast during the 1990s, restriction of dolnet operations to minimise recruitment overfishing and regulation of gillnets to minimise growth overfishing have been prescribed as management measures (Khan, MS).

Hilsa shad

The hilsa shad (*Hilsa ilisha*) form a prominent fishery in the northeast coast region. They are known to spend most of their life in the inshore areas and migrate into the estuaries and rivers for breeding. During 1986-95, the annual catch has been generally increasing, from 2 000 mt in 1988 to 30 000 mt in 1993. The hilsa shad formed 18.8% (25 133 mt) of the total fish landings during 1991-95 (annual average) in the northeast coast, which contributed 92% to the shad fishery of India. The gillnetters alone accounted for 87.7% of the shad catches landed during 1991-95 in the northeast coast. Recruitment to the fishery takes place at the minimum size of 150 mm and maximum size of 370 mm. The bulk of the fishery is constituted by fish in the size range of 260 mm to 480 mm. The hilsa shad attain maturity at a size of 350 mm to 370 mm and release only a single batch of ova each spawning season. Fecundity ranges from 467 100 to 1 369 500 eggs in fish in the size range of 370 mm to 540 mm. The shads other than the hilsa shad form fisheries in all the regions, particularly in the southeast and the northwest regions which accounted for 13 500 mt and 9 300 mt respectively in the average annual catch during 1991-95.

Barracudas

The barracudas, otherwise known as the seapikes of the family *Sphyraenidae,* are caught in sizeable quantities along the Indian coast. They are distributed in all tropical waters in depths of 1 m to 40 m. Though they form shoals, the larger ones prefer to be solitary. The barracudas are vigorous predators, feeding voraciously on other pelagic fishes. The larger fish are caught in hooks & lines, bottomset gillnets and drift gillnets, while the smaller ones are caught in trawls in fairly good quantities. The annual catch improved remarkably in recent years from a meagre 4 000 mt in 1986 to 14 000 mt in 1995. The barracudas may spawn more than once each season. The number of eggs released per batch increases with the age and ranges from 42 000 to 484 000 eggs.

Flyingfishes

The flyingfish fishery is limited to the coramandal coast in Tamilnadu. The seasonal fishery is supported mainly by *Hirundichthys coromandelensis*. The fishery commences by the middle of May and lasts till the middle of July, though occasionally it extends up to the middle of August. The flyingfishes seldom appear in discoloured water, and hence, early onset of monsoon conditions resulting in the discolouration of the seawater with silt from the river discharges, forces the fish to migrate away from the inshore grounds, and the fishing season comes to an abrupt end. The annual catches taken almost exclusively by the scoopnets, vary considerably from year to year contributing only about 0.1% to the total all India landings. The fish attain maturity at a size of 350 mm to 370 mm and spawn only a single batch of ova each season. The fecundity varies from 467 100 eggs to 1 369 500 eggs for fish in the size range of 370 mm to 540 mm.

Other clupeids

Among the other clupeids, the wolf herring (*Chirocentrus dorab*) form a fishery, and contribute about 0.7% to the total all India landings, of which about 50% comes from the northwest coast. Clupeids consisting of species of *Dussumieria, Escualosa, Ilisha, Nematalosa, Opisthopterus, Pellona, Reconda, Dorosoma, Chanos* etc together accounted for an annual average of 50 853 mt during 1991-95, forming 2.3% of the total all India landings. The northeast coast contributed 7.5%, the southeast 35.9%, the southwest 38.1% and the northwest 18.5% to the all India catch of these clupeids.

Mullets

Among the other small pelagics, the mullets form a fishery mainly in the northwest region, which contributed 44% to the annual average landings of 5 700 mt in 1991-95 followed by the southeast coast which contributed 34%.

Unicorn cod

During 1991-95 Maharashtra state landed 836 mt of unicorn cod.

Other small pelagic mix

The miscellaneous small pelagics mix yielded during 1991-95 an annual average of 42 000 mt which included 3 000 mt from the northeast region, 19 000 mt from the southeast region, 11 000 mt from the southwest region and 9 000 mt from the northwest region.

A SYNTHETIC ANALYSIS OF THE SMALL PELAGIC FISHERIES IN INDIA

Common features of small pelagics fisheries

From the foregoing account, it is clear that the small pelagics fisheries are characterised by the following features: (i) dominance of three species; (ii) highly fluctuating nature of their fisheries; (iii) area specific distribution of the dominant species; (iv) crucial role of the environment; and (v) unique biological characteristics. Interactions among these vital features determine the abundance of the small pelagics.

Dominance of three species: Though there are over 200 species of small pelagics along the Indian coast, only 3 species, namely, the oil sardine (*S. longiceps*), the Indian mackerel (*R.. kanagurta*) and the Bombayduck (*H. nehereus*) play a very dominant role, not only in the small pelagics fisheries, but also in the entire Indian marine fisheries. These three species together form 26.3% of the total marine fish landings (1950-1995). Adverse effects of any fishery dependent or independent factors on any of these 3 species would seriously affect the landings of the small pelagics, which are, therefore, highly vulnerable and subject to fluctuations. The great fishery of the Peruvian anchovy (*Engraulis ringens*) in the 1960s reached an estimated annual production of 12 million mt and subsequently collapsed due to the biological consequences of *El Nino,* also called the Southern Oscillation. This event is a classical example to demonstrate how a fishery based on a single species succumbs to an adverse natural phenomenon. This kind of situation is contrary to the one prevailing in the fisheries for the demersals, where the fishery is not dependent exclusively on any particular species and there are numerous species that play equally dominant roles.

Highly fluctuating fisheries: The landing pattern of the small pelagics could be categorized as follows: (a) fisheries which have fluctuated very widely (oil sardine, Bombayduck and Indian mackerel); (b) fisheries which have increased the landings fairly consistently (other sardines, *Hilsa* spp., whitebaits, *Thryssa* spp. *Coilia dussumieri*, carangids and ribbonfishes); and (c) the only fishery which has declined (unicorn cod). The landings of the unicorn cod (*Bregmaceros meclellandi),* which are restricted to the Maharashtra coast, have decreased from 6 880 mt per year during 1950-54 to 836 mt per year during 1991-95. In view of the consistently declining fishery, the unicorn cod may have to be listed as vulnerable or endangered, and strategies devised to restore the population.

It is now widely understood that the high latitude clupeid and small pelagics stocks are more variable on a decadal scale than the demersal stocks (Longhurst and Pauly, 1987). However, this trend does not hold good for all the clupeids or for all the small pelagics. Within the small pelagics, the catches of the 3 dominant species alone fluctuated. For instance, the deviation from the mean landings for the mackerel fluctuated from -48% (1965-69) to 28% (1970-74), then to -51% (1980-84) and subsequently to 103% (Fig. 22). On the other hand, the landings of *Thryssa* spp. consistently increased from -67% (1950-54) to 132% (1990-95) (Fig. 23).

Notwithstanding the overall increasing trend in marine fisheries production, the landings of the 3 species fluctuated widely from the average catches and were below the long-term mean values as late as 1980-1984 (mackerel and Bombayduck) and 1985-1995 (oil sardine). Hence, the most dominant species are the most fluctuating ones.

Area specific distribution of the dominant species

Another important characteristic of the small pelagics is the area specific abundance of the dominant species. The fisheries for the oil sardine, Bombayduck, flyingfishes and unicorn cod are restricted to the coastal waters of a single geographic zone, i.e., oil sardine to the southwest coast between 8°N and 16°N latitudes (92.6% of the total oil sardine landings) and the Bombayduck to the northwest coast between 18°N and 22°N latitudes (>90% of the Bombayduck landings), while their abundance in the other coastal zones is quite meagre. Similarly, the flyingfishes are restricted to the southeast coast and the unicorn cod to the northwest coast. Four groups/species (Indian mackerel, lesser sardines and whitebaits in the southwest and the southeast coasts; and the grenadier anchovy in the northwest and northeast coasts) form fisheries in two zones. The remaining groups exhibit much wider range and form fisheries in all the zones.

A full understanding of the reasons why the distribution and abundance of a few species are restricted to certain well defined sea areas is yet to emerge. There are considerable ecological variations, including ichthyofaunal, between adjacent sea areas inspite of their geographic continuity. If the populations of Bombayduck are restricted to the northern latitudes, especially along the northwest coast and to a limited extent along the northeast coast and the populations of the oil sardine and the mackerel restricted to the southern latitudes, there must be some key factors, which are distinctly different between the northern and southern coasts. Differences in temperature, salinity and food regimes are thought to be important factors. However, the thermal and salinity profiles in the coastal areas of the northern and southern latitudes are not very much different from each other. Devaraj (1987b) considered that these factors may be important, but do not appear to be the basic factors that bind the Bombayduck to the northern latitudes. High tidal amplitudes of about 5 m are characteristic of the northern latitudes. Neither strictly pelagic nor demersal, the Bombayduck effectively utilize the tidal oscillations for less energy-demanding movement for foraging on the sergestid shrimps and the grenadier anchovy, which are also associated with the tidal oscillations (Devaraj, 1987b). The reasons for the abundance of the oil sardine and mackerel populations in the southwest coast are fairly clear. Regular upwelling along the southwest coast leads to dense plankton blooms. Being plankton feeders, the oil sardine and mackerel, which form large shóals and require huge quantities of food, find the southwest coast an ideal location to forage.

In the long Indian coastline, it is only along the southwest coast, two of the three most dominant fisheries and another major fishery, the whitebaits, coexist. It is estimated that, on an average, 137 925 mt of oil sardine (92.6% of the total all-India oil sardine landings) and 78 816 mt of mackerel (76.7% of the total all-India

mackerel landings) were contributed by the southwest coast during 1970-1995. An inverse relationship between the abundance of the oil sardine and the mackerel has often been reported along the southwest coast. The periods of maximum landings of the oil sardine (for example, 1965-1969: average annual yield =229 833 mt) were the periods of least abundance of the mackerel and the periods of maximum abundance of the mackerel (1970-1974: aay =93 009 mt; 1990-1995: aay =117 722 mt) were the years of least abundance of the oil sardine (Fig. 24). As both the species are exploited by the same gears, the decadal variations may not be due to the effect of fishing. Longhurst and Wooster (1990) considered that the landings of the small pelagics reflected their relative abundance, and hence, it is likely that the fluctuations in the landings were due to the fluctuations in their abundance. Hornell (1910) and Antony Raja (1969) suggested a density dependent inverse relationship between the oil sardine and the mackerel populations on a year to year basis. However, Longhurst and Wooster (1990) and Madhupratap *et al.*(1994) did not find such an inverse correlation between the annual landings of the two stocks. In the present study, comparison of the pooled data for every 5 year periods has revealed an inverse correlation (r = -0.818) between the landings of the two species. Hence, the density dependent inverse relationship may not be evident on a yearly basis, but relevant on a longer time scale.

Crucial role of the environment: Several environmental parameters are considered to be determinants of the abundance of the oil sardine and the mackerel. The onset of the monsoon (Panikkar, 1949; Longhurst and Wooster, 1990) and the intensity of the monsoon (Pradhan and Reddy, 1962; Antony Raja,1969; 1972), sunspot activity (Srinath,MS), surface temperature (Noble, 1972; Pillai, 1991), variations in the pattern of coastal currents (Murty,1965), sudden increase in salinity (Rao *et al.*,1973; Pillai,1991), dissolved oxygen (Pillai, 1993), sinking of the offshore waters (Ramamirtham and Jayaraman,1961), sea level (Longhurst and Wooster,1990), and the availability of nutrients in the coastal waters (Madhupratap *et al.*,1994) are some of the causative factors considered to play crucial roles in determining the abundance of the oil sardine along the southwest coast.

The date of onset of the southwest monsoon over the Kerala coast appears to play a crucial role in determining the oil sardine abundance. The monsoon normally sets by June 1 and spreads northward towards Karnataka. Correlating the date of onset of the monsoon and the oil sardine abundance for 1900-1986, Longhurst and Wooster (1990) observed that the major periods of high oil sardine abundance were the ones when the monsoon onset was tending towards earlier, rather than late onset dates. The period of the southwest monsoon onset is the period of the lowest sea level (580 mm) while the period of the northeast monsoon is the period of the highest sea level (720 mm). The above average sea level in March-April (>650 mm) is associated with high landings while the below average sea level (<600 mm) is associated with low landings. Longhurst and Wooster (1990) concluded that low sea level during March-April implied either early wind-driven upwelling or early intensification of the equatorward coastal current, which had the greatest influence on the size of the oil sardine stock in the subsequent fishing season.

Antony Raja (1972) opined that the success of sardine recruitment could be predicted by the intensity of rainfall during the weeks of spawning. He found a significant correlation between rainfall and the subsequent abundance of 0-group oil sardine. However, the relationship between rainfall and abundance has been questioned by several authors. Perhaps, an appropriate combination of the onset, duration and intensity of the monsoon is necessary for successful recruitment of the oil sardine. The sardine take advantage of the situation and time their spawning to coincide with the appropriate conditions during the southwest monsoon. Delays in the onset of the monsoon or weak/failure of the monsoon and a weak upwelling would ultimately affect the spawning, recruitment and the fishery. This is evident from the poor recruitment of youngones to the fishery whenever the rainfall during the spawning season is poor. However, Fernandez and Devaraj (1996 a,b) have reported distinctly different pattern of relationship between monsoon and spawning of the Indian mackerel and the Bombayduck.

The interannual pattern of oil sardine abundance showed a striking similarity to the 11 year cycle of the sunspot activity. Recently, the sunspot activity was the lowest in April, 1994. Interestingly, the oil sardine catch by all the gears operating along the west coast of India was the lowest (4 000 mt) in 1994, which was a major crash in the recent history of this fishery (Fig. 25). Sunspot activity will be again at its peak by the turn of this century when the oil sardine landings are expected to revive to a significant level, and promising trends are already discernible since 1995. Sun is the ultimate source of energy, which determines, *inter alia*, the productivity of the bioshpere. The various physical, oceanographic and meteorological factors including the rainfall, upwelling and nutrient seem to be influenced by the intensity of sunspot activity, directly or indirectly. Thus, there is no unanimity over the factor(s) determining the abundance. The consensus among most researchers is that the abundance is related to upwelling and the consequent abundance of the planktonic food. The chain of events - physical, chemical and biological, leading to upwelling and the consequent high productivity, seem to constitute the factors directly influencing the abundance of the stock (Fig.26).

Unique biological characteristics: Though represented by different taxonomic families, the small pelagics, as a group, are characterized by certain unique combination of biological features which include formation of large schools, feeding on plankton or nekton, fast growth rate, short longevity and late maturation in relation to $L\infty$ (at about 70% of $L\infty$). Based on the von Bertalanffy growth parameters for 15 species of small pelagics, 14 species of large pelagics and 25 species of demersal finfishes occurring along the Indian coast, Devaraj and Vivekanandan (MS) concluded that the annual growth coefficient (K) of the small pelagics (1.12) is considerably higher than that of the large pelagics (0.27) and the demersals (0.64). The small pelagics such as the sardines, whitebaits and mackerel feed mainly on plankton (Table 46). Occupying a low trophic level, these groups are advantageously placed to get continuous food supply. The growth and abundance of the pelagics are associated with the blooms of phytoplankton, dominated by the diatoms. Moreover, the pelagic stocks occupy mainly the epipelagic zone which is generally eutrophic, particularly in the organically rich upwelling areas.

Table 46. Main food of a few small pelagics.

Species	Main food
Sardinella longiceps	
Adults	Diatoms, dinoflagellates, tintinnids
Juveniles	Zooplankton
Postlarvae	Diatoms, other microalgae
S. gibbosa	Zooplankton
S. albella	Zooplankton
S. fimbriata	Zooplankton, phytoplankton
S. dayi	Crustacean & molluscan larvae, *Acetes*
Stolephorus devisi	Zooplankton, occasionally phytoplankton
S. bataviensis	Zooplankton
Coilia dussumieri	Zooplankton, *Acetes*
Rastrelliger kanagurta	
Adults	Zooplankton, phytoplankton
Juveniles	Zooplankton
Harpodon nehereus	Juveniles of Bombayduck, clupeids, prawns, *Squilla*

Devaraj and Vivekanandan (MS) observed that the small pelagics attain, on an average, 60% of their $L\infty$ at the end of I year of age and reach the maximum length in 2 years, whereas many large pelagics attain only about 28% of their $L\infty$ at the end of the I year of their life and the maximum length in 8 years. The main difference between the small pelagics and other groups is that the small pelagics are short lived and fast growing and are therefore subjected to severe recruitment fluctuations (Devaraj *et al.*,1994; Fernandez and Devaraj,1996a,b). The small pelagics attain maturity at a very late stage of their life (length at first maturity at 70% of L_∞) compared to that of the large pelagics and demersals (length at first maturity at 40% of L_∞). Most small pelagics including the oil sardine and the Indian mackerel delay their maturation in order to prolong their body growth for a comparatively longer duration in their life, than the large pelagics and the demersals.

Most species of small pelagics are either continuous spawners or have prolonged spawning periods, a typical characteristic of tropical fishes. While the peak spawning of the oil sardine takes place during the southwest monsoon season, that of the Indian mackerel, whitebaits, Bombayduck and the grenadier anchovy does not take place during the southwest monsoon months. The mackerel reproduce intermittently throughout the year along the southwest coast (Blindheim and Monstad,1976) and the larvae occur in all the months, but the broods released in the premonsoon season only become successful and enter the fishery (Devaraj *et al.*,1994). The whitebaits tend to congregate south of the region of the oil sardine fishery and pile up in the central Gulf of Mannar during the peak southwest monsoon (July-August), and then migrate back northwards along the entire Kerala coast (Anon.,1976). Due to these reasons, it appears that spawning of the mackerel and the whitebaits is not influenced by the monsoon and upwelling, in the same way as that of the oil sardine.

Causes for the increasing production trend

Notwithstanding their natural fluctuations, the production of the small pelagics in India has shown an increasing trend over the past five decades, primarily because of the introduction of new fishing technologies and diversification of fishing operations, for example, the steady growth of the purseseiner and ringseiner fleets and the popularization of motorization of the indigenous fishing craft, particularly. along the southwest coast. As a result, not only the small pelagics in the grounds upto the 50 m isobath came to be optimally exploited, but the carangid stocks in grounds beyond the 50 m isobath began to be well exploited. The spurt in the development activities since the late eighties in the states of Gujarat and Maharashtra in the northwest and West Bengal and Orissa in the northeast also resulted in increasing production of small pelagics, besides others. While the development of infrastructure started quite early in the southern states, it started rather late in the northern states. The basic differences in the social perceptions and the traditional ethos of the coastal inhabitants also contributed to this delay in the development of infrastructure in the northern states.

Although commercial purseseining, which commenced in the southwest region in the latter half of the 1970's, rapidly increased the production of the small pelagics, it was at the expense of the very versatile gear *rampani*, traditionally used by most of the fishermen in Karnataka. The purseseine fishery resulted in the redeployment of labour, as the owners of the rampani, lured by the prospects of higher wages in mechanized fishing, enrolled themselves as labourers in the purseseiner fleet As the *rampanis* are shore- based in operation, they got deprived of the incoming shoals of small pelagics, obstructed by the purseseiners. Consequently, the rampani operators were forced to close down their entire fleet, to reconcile with the changed dispensation, albeit, with remonstrance and intersectoral conflicts. However, the shift from the traditional boatseine to the modern ringseine fishery in the southwest states of Kerala and Karnataka has been quite smooth as both are essentially in the hands of the small scale traditional fishermen. Some of the ringseines are one km long and they are operated mainly from the traditional motorized craft. Compared to the boatseines, the ringseines are more efficient, and there are complaints of mass destruction of juveniles of small pelagics, as the escapement is virtually negligible unlike the boatseine where it is about 50%. Therefore, ringseine operation is banned legally in some states (e.g., Kerala), but not yet implemented effectively. The enormity of the gear could be gauged from the proportion of the landings taken by this net in the southwest region alone in recent years. During 1991-95 it contributed 9% to the total marine fish production in the country, and 23 % to the total production in the southwest region. The emergence of the carangids in the ringseine fishery as a major item was possible because of the extension of fishing into distant grounds by the motorized boats. Small meshed (8 mm) ringseines enhanced the catches of whitebaits significantly. As a result, both carangid and whitebait catches became very prominent in the recent years.

The most obvious facts emerging from the foregoing analysis are summarized below:

(1) The current production of the small pelagics seems quite optimum, offering little scope for any conspicuous increase. After a certain level of fishing effort, the catch of small pelagics does not seem to bear any significant relation with effort, and therefore, the appropriate manipulation of fishing effort becomes a function of fisheries economics. As the small pelagic fisheries are already well developed, management measures could be left to the economics of the fishery for sustaining the catches on a long term basis. Development of suitable technologies for pelagic finfish breeding and seafarming assumes long term significance in the context of current plateauing of catches.

(2) The intrinsic nature of the annual fluctuations seems to be rooted in the interplay of the various fishery independent factors. The intractability of the nature and outcome of this interplay makes prediction unreliable. The fishery independent factors, believed to influence the production of the small pelagics, include sea surface level pressure and sunspot activity. A prediction model using sunspot activity and catch data in respect of the oil sardine and other small pelagics seems to be of great promise as a tool to forecast the yields in advance and thereby facilitate fleet deployment decisions.

(3) There are many instances of extreme gluts in the production of some of the small pelagics surpassing all predictions. On such occasions, fish move instantly from the sellers' markets to the sellers' yard with no buyers for want of proper infrastructure and logistics to process and store the surplus. This situation results in considerable withdrawal of fishing effort, with attendant starvation in the midst of plenty. Not only infrastructure for immediate transportation to the interior markets, but also networks of cold storages in the hinterlands as well as for conversion into value added products could alleviate this mysery, and offer atleast the minimum incentives for continuing the fishing operations. Although infrastructure in these sectors is much better developed today than in the past, there are still missing gaps requiring urgent steps.

(4) Motorization of traditional fishing craft coupled with the adoption of ringseining and purseseining has undoubtedly resulted in the uplifit of the social and economic status of fisherfolk considerably in recent years along the southwest coast. However, the indiscriminate increase in the size of the ringseiner and purseseiner fleets deploying very big seines with extremely small mesh sizes has resulted in the mass destruction of the prerecruits of small pelagics. Legal ban imposed on such nets is not implemented effectively owing mostly to social and political reasons. Use of multimesh nets with legal restriction on the mesh size may minimise this problem.

(5) The use of high opening fish trawls beyond the traditional fishing grounds indicates good scope of enhancing the production of carangids and ribbonfishes.

(6) The small pelagics stocks experience high rates of natural mortality, especially in the juvenile stages. It is, therefore, important to determine their stock-recruitment relationships to help formulate measures to ensure optimum spawning stocks.

(7) Management options based on stock assessments may differ from one stock to the other, and hence, their concurrent implementation is difficult in the multispecies small pelagics fisheries. Economic and social compulsions may also make inplementation of the recommended measures difficult. This situation calls for management objectives that would help maximise benefits from atleast the major individual stocks.

ECONOMIC PERFORMANCE OF FISHING UNITS ENGAGED IN PELAGIC FISHERIES

For the purpose of economic evaluation of the fishing units engaged in pelagic fishing, the small scale marine fisheries sector in India has been classified into three groups, viz., (1) the nonmotorized artisanal sector using indigenous (traditional) craft with traditional gears, (2) the motorized sector using indigenous (traditional) craft with outboard engines of <50 HP, and (3) the mechanized sector using inboard engines of 50 to 120 HP. The average initial investment in these fishing units has been worked out on the basis of the data collected for the sample units operating at selected centres in each region. Most of the outboard boats were old and their values were considered to be their resale values at the time of the observation. The gross investment on fishing equipments at current (1995) price thus calculated worked out to Rs 41 170 million comprising Rs 9 230 million in the artisanal sector, Rs 4 560 million in the motorized sector, Rs 23 880 million in the mechanized sector and Rs 3 500 million in the deepsea vessels. The manpower employed in active fishing alone was estimated as 1 million in marine fisheries. In the small scale fisheries sector, the average annual catch per unit ranged from 0.3 mt for a nonmechanized unit in the northwest coast to 280 mt for a purseseiner in the southwest coast.

Artisanal sector

The catamarans and the canoes are the most widely used traditional craft. The catamarans are in operation all along the Indian coast except in the northwest region. They require only low initial investment. The investment requirement of the catamarans operating gillnets varied from Rs 23 000 in the northeast to Rs 40 000 in the southeast regions (Table 47). The average annual catch of a catamaran unit with gillnet varies from 7 mt to 15 mt with gross earnings ranging from Rs 30 000 in the northeast coast to Rs 82 000 in the southwest coast (Table 48). The net profit ranged from Rs 4 000 to Rs 7 000 and the rate of return ranged from 23% to 35 %.

The economic performance of the nonmechanized plankbuilt canoes operating gillnets in the different coastal areas is given in Table 48. The average initial investment ranged from Rs 37 000 in the northwest coast to Rs 75 000 in the southwest coast, fetching annual gross earnings of Rs 48 000 to Rs 80 000. The net profit ranged from Rs 6 000 to Rs 10 000 with a rate of return of 25% to 32 %.

Table 47. Economic performance of traditional catamaran units operating gillnets in the different coastal areas of India during 1995.

Economic parameters	Catamaran with gillnets		
	Southwest	Southeast	Northeast
1. Average initial investment (Rs)	34,000	24,000	23,000
2. Average annual catch (mt)	15	13	7
3. Gross earnings (Rs)	82,000	60,000	30,000
4. Operating costs (Rs)	64,000	45,000	20,000
5. Fixed cost (Rs)	11,000	10,000	6,000
6. Total cost (Rs)	75,000	55,000	26,000
7. Net operating income (Rs)	18,000	15,000	10,000
8. Net profit (Rs)	7,000	5,000	4,000
9. Rate of return (%)	35	31	23
10. Payback period (years)	2.6	3.9	3.3

Table 48. Economic performance of nonmechanized plankbuilt canoes operating gillnets in the different coastal areas of India during 1995.

Economic parameters	Northwest	Southwest	Southeast	Northeast
1. Average initial investment (Rs)	45,000	75,000	60,000	37,000
2. Average annual catch (mt)	15	17.5	14.0	10
3. Gross earnings (Rs)	60,000	80,000	66,000	48,000
4. Operating costs (Rs)	38,000	50,000	40,000	28,000
5. Fixed cost (Rs)	16,000	20,000	20,000	14,000
6. Total cost (Rs)	54,000	70,000	60,000	42,000
7. Net operating income (Rs)	22,000	30,000	26,000	20,000
8. Net profit (Rs)	6,000	10,000	6,000	6,000
9. Rate of return (%)	30	27	25	32
10. Payback period (years)	3.1	3.8	3.5	2.7

Motorized sector

The economic performance of different types of motorized fishing units operating along the Indian coast is given in Table 49. The average initial investment of a motorized canoe operating gillnets in the northwest coast was about Rs 120 000. The annual gross earnings was Rs 150 000 as against the expenditure of Rs 135 000. The rate of return worked out to 28% and the payback period was 4.1 years. In the southwest coast, the ringseiners required the maximum investment of Rs 600 000 as against Rs 75 000 for the motorized canoes operating hooks & lines. The net profit (Rs 97 000) of the ringseiners was very high, which is reason enough for the proliferation of the ringseiners in the southwest coast. The operations of the motorized catamarans with gillnets, hooks & lines and canoes with gillnets in the southeast coast also indicated reasonably good profits. For these units, the rate of return ranged from 33% to 39% and the payback period of initial investment from 2.1 to 3.6 years. The average initial investment on a canoe with gillnet in the northeast coast was Rs 160 000, the rate of returns was 20% and the payback period of capital investment 6.7 years.

Table 49. Economic performance of motorized fishing units in different regions during 1995.

Economic parameters	North-west coast	Southwest coast			Southeast coast			North east coast
	Canoe + GN	Canoe + RS	Canoe + GN	Canoe + H&L	Catamaran GN	Catamaran H&L	Canoe + GN	Canoe + GN
1. Average initial investment(Rs x 10^3)	120	600	100	75	50	35	85	160
2. Annual catch (mt)	16.95	200	21	18.4	16.5	14.5	29	17
3. Gross eranings (Rs x 10^3)	150	675	108	150	76	82	138	118
4. Operating cost (Rs x 10^3)	115	402	69	109	54	65	84	70
5. Fixed cost (Rs x 10^3)	20	176	26	25	13	9	34	40
6. Total cost (Rs x 10^3)	135	578	95	134	67	74	118	110
7. Net operating income (Rs x 10^3)	35	273	39	41	22	17	54	48
8. Net profit (Rs x 10^3)	15	97	13	16	9	8	20	8
9. Rate of return (Rs x 10^3)	28	31	28	36	33	38	39	20
10. Payback period (years)	4.1	3.3	4.4	3.2	3.6	3	2.1	6.7

All major types of fishing units in the artisanal and motorized sectors are working on profit, not because of the higher levels of catch, but because of the good price. The nonmechanized fishing units are mostly operated as family enterprise in India. About 60% of the revenue is paid as wages to the crew or workers and most of them are owner-operators. Hence, the fishing income received by the owners is the net income plus the wages shared by the family labourers.

Mechanized sector

The operations of gillnetters are carried out all along the Indian coast whereas the operations of the dolnetters, purseseiners and pair trawlers are confined to certain regions. The purseseiners are operated only along the southwest coast, the dolnetters along the northwest coast and the pair trawlers along the coasts of the Gulf of Mannar and the Palk Bay in Tamilnadu.

The key economic indicators of mechanized boats operating gillnets in different coastal areas are given in Table 50. The average initial investment ranged from Rs 330 000 to Rs 450 000, fetching gross earnings of Rs 336 000 to Rs 520 000. The annual net profit ranged from Rs 34 000 to Rs 70 000 and the rate of return ranged from 28% to 38 %.

Table 50. Economic performance of mechanized gillnet units in the different regions of India during 1995.

Economic parameters	Northwest	Southwest	Southeast	Northeast
1. Average initial investment (Rs x 10^6)	0.330	0.450	0.350	0.400
2. Annual catch (mt)	22	18.0	23	29
3. Gross earnings (Rs x 10^6)	0.336	0.520	0.438	0.435
4. Annual operating cost (Rs x 10^6)	0.202	0.312	0.263	0.258
5. Fixed cost (Rs x 10^6)	0.100	0.138	0.105	0.125
6. Total cost (Rs x 10^6)	0.302	0.450	0.368	0.383
7. Net operating income (Rs x 10^6)	0.134	0.208	0.175	0.177
8. Annual net profit (Rs x 10^6)	0.034	0.070	0.70	0.052
9. Rate of return (%)	28	31	38	28
10. Payback period (years)	4.5	3.2	3.1	3.4

Dolnetters operating along the northwest coast of India required an average initial investment of Rs 320 000 (Table 51). The average annual revenue was Rs 454 000 and the annual net profit Rs 63 000. The rate of return worked out to 38 % and the payback period 3.2 years. The average investment of a purseseiner was about Rs 1 million and the average annual catch 280 t which realized a gross revenue of Rs 1.2 million. The operating cost was about Rs 580 000 and the fixed cost Rs 306 000, realizing a net earning of Rs 314 000 per year. The net income and the rate of return were high at Rs 314 000 and 46%, respectively (Table 51). The annual average gross earning of a pair trawler worked out to Rs 1.3 million as against the total annual cost of Rs 1.10 million, with a net profit of Rs 195 000 per year while the net income was Rs 195 000 and the rate of return 37 % (Table 51).

Table 51. Economic performance of mechanized boats operating purseseines, dolnets and pair trawls in different regions during 1995.

Economic parameters	Northwest	Southwest	Southeast
	Dolnetters	Purse seiners	Pair trawlers
1. Average initial investment (Rs x 10^3)	320	1000	900
2. Annual catch (mt)	51	280	150
3. Gross earnings (Rs x 10^3)	454	1200	1300
4. Operating cost (Rs x 10^3)	295	580	880
5. Fixed cost (Rs x 10^3)	96	306	225
6. Total cost (Rs x 10^3)	391	886	1105
7. Net operating income (Rs x 10^3)	159	620	420
8. Net income (Rs x 10^3)	63	314	195
9. Rate of return (%)	38	46	37
10. Payback period (years)	3.2	2.4	3.2

Gross earnings from small pelagics

The gross earnings from the small pelagics landings were estimated by conducting surveys in different landing centres along the Indian coast during 1995. It was estimated that the gross earnings amounted to Rs 22,157 million from 1 090 809 mt, at an average price of Rs 20/kg (Table 52). Though the small pelagics

formed 48.1% of the total landings in 1995, the earnings accounted for only 30.0% of the total gross earnings. As the demersals included the high value penaeid shrimps, cephalopods and perches, the average price of the demersals was Rs 44/kg.

Table 52. Catch and gross earnings from the small pelagics in India during 1995.

(at landing centre level)

Group	Price (Rs/kg)	Total catch (mt)	Value (Rs in millions)
Clupeids	9	419865	3778.8
Bombayduck	11	92687	1019.6
Flyingfishes	22	4090	90.0
Ribbonfishes	11	73743	811.2
Carangids	46	196832	9054.3
Pomfrets	50	44593	2229.7
Mackerel	11	176830	1945.1
Seerfishes	55	45853	2521.9
Coastal tunas	10	15000	150.0
Barracudas	28	14679	411.0
Mullets	22	6498	143.0
Unicorn cod	17	139	2.4
Total small pelagics	20	1090809	22157.0
Total large pelagics	24	24177	586.0
Demersals	44	1152142	51257.0
Total marine landings	33	2267128	74000.0

MANAGEMENT

The basic feature of marine fisheries in India is the free access to the resources. Fisheries management in India is broadly governed by the Indian Fisheries Act 1897, The Marine Fishing (Regulation) Bill 1978 formulated after the Exclusive Economic Zone Act 1977 and the various maritime state Marine Fishing (Regulation) Acts enacted in the 1980s. While marine fisheries in the 12 nm territorial sea are within the direct governance of the respective states, those outside fall under the jurisdiction of the central government. The regulatory measures formulated under the above Acts include prohibition of destruction of fish stocks by explosives, poisons and certain gears; regulation of fishing in the nursery areas; control of indiscriminate fishing of broodstocks in their migratory phase; and, leasing or licensing of fishing rights, particularly in the inland waters. The competition for the resources, especially in the nearshore areas obligated the maritime state governments to intervene and formulate regulatory measures through legislation.

The management measures imposed at present by the maritime state governments fall under two categories: (i) seasonal closure of operation, and (ii) restriction of fishing areas. These are aimed mainly at safeguarding the interests of the small scale and medium scale fisheries. Presently, the operations of the mechanized vessels are suspended for 1 to 2 months in the west coast during the southwest monsoon season. Considering the influence of the monsoon in

determining the abundance of the stocks of the small pelagics, suspension of purseseining and ringseining operated from the mechanized and motorized vessels is most relevant. The seasonal closure of fishing by the mechanized vessels is in vogue in the west coast for the past few years and such a measure has been introduced very recently in some areas in the east coast also. The decision on the closure is taken on a year-to-year basis by the maritime state governments, prior to or during the southwest monsoon season. Unlike the demersal fisheries, the fisheries for the small pelagics, even now, are mainly the activity of the artisanal fishers, operating nonmechanized or motorized craft. Considering the poor socioeconomic conditions of the artisanal fishers, the state governments have not imposed any restrictions on their fishing activities. Under the Marine Fishing Regulation Acts, promulgated by the maritime state governments, the areas of exclusive operation of the artisanal and mechanized vessels have been delineated. In general, the mechanized vessels are banned from operating in the inshore areas (extending to a distance of 5 to 10 km from the shore, earmarked exclusively for the artisanal craft). These Acts relating to the demarcation of the fishing areas, are beset with inherent weaknesses. First, there is no adequate surveillance system available with any state government to monitor the infringement of the rules of operations. Encroachment by the mechanized vessels in the areas demarcated for the artisanal fishers continues for more than a decade after the promulgation of the Acts. Second, demarcation of the fishing areas is basically meant for the protection of the interests of the artisanal fishers. In the process, the fishers operating the mechanized craft are at a disadvantage as they are denied exploitation of the much richer fishing grounds in the inshore waters. For instance, the biomass of the oil sardine is dense in the inshore waters, and hence, keeping the purseseine operators of Kerala and Karnataka outside the area of abundance of this stock is a disadvantage to them. It may, therefore, be necessary to modify the present regulations based on the feedbacks from various sectors so that all the stakeholders are benefited and the resources are exploited judiciously. Besides, regulations are imposed on fishing gears used in juvenile fisheries in the backwaters, estuaries and shallow inshore waters through licensing, mesh size regulation and minimum legal length at first capture. Among these, although the licensing of fishing gear engaged in the juvenile fisheries is in force in Kerala, its implementation has not been successful mainly owing to socioeconomic constraints, particularly the absence of alternative employment opportunities for the fishermen. Similarly, mesh size regulation could not be enforced due to the multispecies, multigear nature of marine fisheries and the socioeconomic reasons.

Some of these problems could be mitigated by a proper orientation of the management strategies. For example, (i) the rich whitebait, ribbonfish and carangid stocks along the southwest coast could be used as the basis for forcing the surplus purseseiners and midwater trawlers to operate in the offshore grounds beyond the 50 m isobath. (2) Some of the surplus shrimp trawlers using small codend mesh in the shallow grounds could be converted into fish trawlers with large meshes in much deeper grounds, both for the demersals and the pelagics. Others could be used in line or trap fisheries for the larger demersals in specific banks like the Kori Great Bank off Gujarat, Angiria Bank off Ratnagiri, Quilon Bank off Quilon, Wadge Bank off Kanyakumari and Pedro Bank in the Coromandel coast.

The small pelagic fisheries have reached a stage where, in addition to the regulation of fishing activity, it requires assistance from the governments for sustaining production. Satellite observations of the sea surface have progressed immensely consequent on India launching her own remote sensing satellites. The application of remote sensing for locating the areas of fish abundance has started in right earnest, which if proved to be successful, would be a great boon to the fishers. The satellite imageries provide continuous data on parameters such as sea surface temperature, chlorophyll, phytoplankton, sedimentation, coastal currents changes, etc. covering most of the EEZ. These data have several applications including mapping potential fishing zones (PFZs) and fisheries forecast on a short term as well as long term basis. Application of remote sensing for locating potential fishing zones will be extremely useful, particularly for the small pelagics fisheries. The National Remote Sensing Agency, Hyderabad is regularly receiving the imageries from the Indian satellites. These imageries are used to derive the SST values for the Indian seas, which are further interpreted to identify the PFZs. These identified PFZs are informed to the fishermen on a day-to-day basis through newspapers, television and radios by the maritime state governments and the Central Marine Fisheries Research Institute network of 13 research centres and 28 field centres. Groundtruth surveys and feedback information are very important components of remote sensing to verify the forecast. The CMFRI has reported substantial increase in fish catch in the PFZs when compared to the non PFZs. The abundance of the oil sardine is related to high SST and high dissolved oxygen concentration. The forecasts of the PFZs have been found to be more valid in the case of small pelagic stocks than of the demersal stocks. Although only a beginning has been made, the results do indicate the possible future applications of satellite derived chlorophyll and SST distribution for the purpose of directing and controlling fishing effort. There are still several intricacies that need to be addressed immediately for the meaningful application of remote sensing to marine fisheries: (i) There is considerable delay in data processing and distribution to the endusers, namely, the fishermen. (ii) The fishers contend that the information on the PFZs would be useful only if names of the dominant fish groups in the PFZs are known. Though identification of fish groups in the PFZs is not possible with the help of the present satellite imageries, the technology is being further upgraded to cater to these specific needs. (iii) An intricate question is the confidence the fishers seek to ensure lucrative yield from the PFZs. The solution shall depend on how fast the algorithm of prediction will be perfected.

The unpredictable nature of the major stocks of the small pelagics has made their markets highly vulnerable to price fluctuations. Most of the small pelagics are considered to be low value fish. The price of oil sardine, lesser sardines, *Thryssa* spp, whitebaits, grenadier anchovy and Bombayduck is Rs 10/kg in the landing centres. However, the price varies according to regional preferences. *Hilsa* spp are a delicacy in West Bengal and fetch more than Rs 70/kg. The Indian mackerel are preferred in the southwest coast, where they are priced at around Rs 25/kg. The sardines, whitebaits and Indian mackerel together with rice form the staple food of the coastal population in Kerala, Karnataka and Goa. The Bombayduck and grenadier anchovy form a regular item in the food of the coastal population in Maharashtra. The dependence of a large number of artisanal fishers and the coastal

population on the small pelagics underlines the socioeconomic importance of these low value fishes. However, the absence of a proper distribution system and the lack of optimum holding facilities at the landing sites are the major hurdles in the proper utilization of these fisheries. In most instances, the catch should be sold immediately, for whatever price offered, or risk a total loss. The only other option is to turn it into low value dried products. Major quantities of small pelagics are consumed fresh and on days of glut, the surplus is cured and sundried. Almost the entire landings of the small pelagics are consumed by the coastal population and due to their low value and high transportation cost, they seldom reach the interior parts of India. The maritime state governments should render assistance in channelling their distribution by identifying centres where demand could be stimulated, undertake physical improvements to wholesale and retail outlets and design mobile retail equipments. Considerable knowledge exists in the country on product development for the affluent markets. Small processing plants could be established in specific locations. High priority should be given to reduce postharvest losses and work in this direction should include the use of low cost energy sources in fish processing (for e.g., wind-driven ice plants, improved solar driers etc). The existing networks of fishers' cooperatives should be strengthened as a means of meeting the fishermen's economic needs of supplies and credits at low cost and profitable market outlets for their products.

RECOMMENDATIONS

1. The most prominent feature of the pelagic fisheries in general and the small pelagics in particular is their extreme annual fluctuations. The causative factors need to be identified through real time oceanographic data collected in relation to catches and the application of mathematical models to such data to attempt prediction.

2. Spawning of the various species of the small pelagics as a whole is intense throughout the year: some of them spawn intensely during the immediate premonsoon, some during the monsoon periods and others during the postmonsoon season. Therefore, spawning season cannot be used as the basis for banning fishing in any part of the year. However, fishing could be suspended in part or in full during the southwest monsoon season as is in vogue in states like Maharashtra, Karnataka and Kerala, as a means of reducing fishing effort to attain near optimum to optimum levels.

3. Further proliferation of ringseiners needs to be checked urgently.

4. As the small pelagic fisheries constitute the mainstay of the economy of the small fishermen, the areas close to the shore upto a distance of 5 km should be exclusively earmarked for fishing by the artisanal fishermen

5. Surveys of spawning population and stock-recruitment relationships need to beundertaken to bridge the gaps in our knowledge of the biology of the small pelagics.

6. Tagging and recovery studies on the oil sardine and the mackerel need to be undertaken on a regular basis.

7. Infrastructure facilities for storage and transportation of the catches to the interior markets require further strengthening to handle surplus catches of small pelagics.

8. Close monitoring of domestic, agriculture and industrial discharges into the nearshore areas is essential to safeguard the inshore stocks from pollution.

9. The maps giving predictions of the potential fishing zones based on remote sensing of sea surface features need to reach the active fishermen well in time to assist them in their fishing operations.

10. Reassessment of the marine fishery potential needs to be carried out on a regular quinquennial basis to determine changes in stock sizes.

REFERENCES

Anon. 1974. Survey results. 1972/73. *UNDP/FAO Pelagic Fishery Project* (IND 69/593) *Progress Report*, No. 6, 141 pp.

Anon. 1976. FAO/UNDP Pelagic Fishery Project Report No. 18. Plankton, fish eggs and larval studies. p. 1-22.

Annigeri, G.G., K. Narayana Kurup, M. Kumaran, G. Madan Mohan, Luther, P.N. Radhakrishnan Nair, Prathibha Rohit, G.M. Kulkarni, J.C. Gnanamuthu and K.V. Narayana Rao. 1992. Stock assessment of oil sardine, *Sardinella longiceps* Val., off west coast of India. *Indian J. Fish.*, 39(3,4): 125-135.

Antony Raja, B.T. 1967. Length weight relationship in the oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 14(1&2): 150-170.

Antony Raja, B.T. 1969. The Indian oil sardine. *Bull. Cent. Mar. Fish. Res. Inst.*, 16: 1-128.

Antony Raja, B.T. 1970. Estimation of age and growth of the Indian oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 17: 26-42.

Antony Raja, B.T. 1972. A forecast for the ensuing oil sardine fishery. *Seafood Exp. J.*, 4(10): 27-33.

Antony Raja, B.T. 1973. Forecasting the oil sardine fishery. *Indian J. Fish.*, 20(2): 599-609.

Balan, V. 1961. Some observations on the shoaling behaviour of the oil sardine, *Sardinella longiceps* Val. *Indian J. Fish.*, 8(1): 207-221.

Balan, V. 1968. Studies on the age and growth of the oil sardine *Sardinella longiceps* Val. by means of scales. *Indian J. Fish.*, 11A (2) (1964): 663-686.

Balan, V. and R. Reghu. 1979. The Indian oil sardine. *Mar. Fish. Infor. Serv. T&E Ser.* No. 14, p. 7-13.

Banerji, S.K. 1973. An assessment of the exploited pelagic fisheries of the Indian Seas. *Proc. Symp. Liv. Res. Seas around India,* Central Marine Fisheries Research Institute, Cochin, p. 114-135.

Bapat, S.V., S.K. Banergi and D.V. Bal. 1952. Observations on the biology of *Harpodon nehereus* (Hamilton). *J. Zool. Soc. India*, 3(2): 341-356.

Bapat, S.V. 1970. The Bombay Duck *Harpodon nehereus* (Ham.). *Bull. Cent. Mar. Fish. Res. Inst.*, 21: 1-66.

Basheeruddin, S. and K.N. Nayar. 1961. A preliminary study of the juvenile fishes of the coastal waters off Madras city. *Indian J. Fish.*, 8: 169.

Bensam, P. 1968. Growth variations in the Indian oil sardine *Sardinella longiceps* Valenciennes. *Indian J. Fish.*, 11A (2) (1964): 699-708.

Biradar, R.S. 1985. Population dynamics of Indian oil sardine and Indian mackerel off the southwest coast of India. *Dissertation Univ. of Bergen*, Norway, 42 pp.

Biradar, R.S. 1989. Stock assessment of Bombay duck (*Harpodon nehereus*) off Maharashtra, India. *Papers prepared by participants at FAO/DANIDA/ICR national follow-up Training Course in Fish stock assessment, Cochin, India,* from 2 to 28 November, 1987. FI: GCP/INT/392/DEN/1 1989.

Blindheim, J. and T. Monstad. 1976. A synopsis of the information pelagic resources off the southwest coast of India. *UNDP Pelagic Fish. Proj. Prog. Rep.* 18: 1-31.

Chacko, P.I. 1949. Food and feeding habits of the fishes of the Gulf of Mannar. *Proc. Indian Acad. Sci.* 29 : 83.

Chakraborty, S.K. 1990. Fishery, age, growth and mortality estimates of *Trichiurus lepturus* Linnaeus from Bombay waters. *Indian J. Fish.*, 37(1): 1-7.

Chidambaram, K. and R.S. Venkataraman. 1946. Tabular statements on the natural history of certain marine food fishes of the Madras Presidency - West coast. Govt. Press, Madras: 1-26.

Chidambaram, K. 1950. Studies on length frequency of the oil sardine, *Sardinella longiceps* Cuv. & Val. and on certain factors influencing their appearance on the Calicut coast of Madras Presidency. *Proc. Indian Acad. Sci.* 31 B. pp. 252-286.

Deshmukh and A. Kurian.1980. The Bombay Duck. *Mar. Fish. Infor. Serv. T&E Ser.*, No. 20: 1-9.

Devanesan, D.W. and V. John. 1940. On the natural history of *Rastrelliger kanagurta* (Russell) with special reference to its spawning season and eggs. *Curr. Sci.*, 9(10): 462-464.

Devanesan, D.W. 1943. A brief investigation into the causes of the fluctuations of the annual fishery of the oil sardine of Malabar, *Sardinella longiceps*, determination of its age and an account of the discovery of its eggs and spawning ground. *Madras Fish. Bull.* No. 28 (Report No. 1), p. 1-24.

Devanesan, D.W. and K. Chidambaram 1948. The common food fishes of Madras Presidency, Govt. Press, Madras.

Devaraj, M. 1979. Management problems in Indian mackerel and Indian oil sardine fisheries on the southwest coast of India. *Workshop on Ocean Management, Central Institute of Fisheries Education.* 4-5th April 1979, Bombay, India. *Abstract in* : India Today and Tomorrow.

Devaraj, M. 1983a. Maturity, spawning and fecundity of the king seer, *Scomberomorus commerson* (Lacepede) in the seas around Indian Peninsula. *Indian J. Fish.*, 30 (2): 203-230.

Devaraj, M. 1983b. Fish population dynamics, Course manual. *Bulletin of the Central Institute of Fisheries Education*, Bombay, No. 3(10) 83, 98 pp.

Devaraj, M. 1986. Maturity, spawning and fecundity of the streaked seer, *Scomberomorus lineolatus* (Cuvier & Valenciennes) in the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, 33(3): 293-319.

Devaraj, M. 1987a. Maturity, spawning and fecundity of the spotted seer, *Scomberomorus guttatus* in the Gulf of Mannar and Palk Bay. *Indian J. Fish.*, 34(1): 48-77.

Devaraj, M. 1987b. The natural cause and effect theory of fish abundance as the basis for human intervention in Indian marine fisheries. In: Advances in aquatic biology and fisheries, Prof. N.B. Nair felicitation volume, 251-256.

Devaraj, M., I. Fernandez and S.S. Kamat. 1994. Dynamics of the exploited Indian mackerel *Rastrelliger kanagurta* stock along the southwest coast of India. *J. mar. biol. Ass. India,* 36(1&2): 110-151.

Fernandez, I. and M. Devaraj. 1996a. Dynamics of the Bombayduck (*Harpodon nehereus*) stock along the northwest coast of India. *Indian J. Fish.*, 43(1): 1-11.

Fernandez, I. and M. Devaraj. 1996b. Dynamics of the gold-spotted grenadier anchovy (*Coilia dussumieri*) stock along the northwest coast of India. *Indian J. Fish.*, 43(1): 27-38.

Fischer, W. and G. Bianchi. 1984. FAO species identification sheets for fishing purposes. FAO, Rome, 335 pp.

George, K.C. and S.K. Banerji. 1968. Age and growth studies on the Indian mackerel *Rastrelliger kanagurta* with special reference to length frequency data collected from Cochin. *Indian J. Fish.*, 11(2): 621-638.

George, P.C., B.T. Antony Raja and K.C. George. 1977. Fishery resources of the Indian Economic Zone. *Souvenir*, Silver Jubilee, Integrated Fisheries Project, Cochin, India, Oct., 1977: 79-116.

Gopalan, U.K. 1967. Studies on the maturity and spawning of silver pomfret, *Pampus argenteus* in the Arabian Sea. *Bull. National Inst. Sci., India,* 38: 785-796.

Haywood, K. 1982. Purse seiners at Karnataka. Microcomputers employed to study the options at a fishery. *Fishing News International, September 1982*, 21(9): 26-27.

Hornell, J. 1910. Report on the results of a fishery cruise along the Malabar coast and to the Laccadive Islands in 1908. *Madras Fish. Bull.* 4 : 71.

Hornell, J. and M.R. Nayudu. 1924. A contribution to the life history of the Indian oil sardine with notes on the plankton of the Malabar coast. *Madras Fish. Bull.* XVII. No.5, pp. 129-197.

Jacob, P.K. 1949. The bionomics of ribbonfishes (*Trichiurus* spp.) and their fishery on the west coast of Madras Province. *J. Bombay Nat. Hist. Soc.*, 46(2): 261-264.

James, P.S.B.R. 1967. The ribbonfishes of the family Trichiuridae of India. *Mar. biol. Ass. India, Memoir I.* 226 pp.

James, P.S.B.R., T.R. Chandrasekhara Gupta and S.L. Shanbhogue 1983. Some aspects of the biology of the ribbonfish *Trichiurus lepturus* Linnaeus (1978). *J. Mar. Biol. Ass. India*, 20(1&2): 120-137.

James, P.S.B.R., P.P. Pillai, A.A. Jayaprakash and N.G.K. Pillai 1992. Tunas and billfishes. In: Monsoon fisheries of the west coast of India. *CMFRI Bulletin*, 45: 56-84.

Khan, M.Z. 1982. A probable nursery ground of silver pomfret *Pampus argenteus* off Nawabunder (Gujarat). *Indian J. Fish.*, 29: 257-261.

Khan, M.Z. 1985. Observations on the fishery of Bombayduck, *Harpodon nehereus* (Hamilton) along the Saurashtra coast. *Indian J. Fish.*, 32(4): 431-438.

Khan, M.Z., K.N. Kurup and A.P. Lipton. 1992. Status of Bombay duck *Harpodon nehereus* (Ham.) resource off Saurashtra coast. *Indian J. Fish.*, 39(3,4): 235-242.

Khan, M.Z., M. Kumaran, A.A. Jayaprakash, K.S. Scariah, V.M. Deshmukh and M.H. Dhulkhed. 1992. Stock assessment of pomfrets off west coast of India. *Indian J. Fish.*, 39: 249-259.

Kurian, A. 1988. Equilibrium state of the fishery for the Bombayduck *Harpodon nehereus* (Ham). An outcome of production ecology and exploitation interactions. *Proc. Symp. on living resources of Indian seas*, 225-234.

Kurian, A. 1989. Application of synthetic models for the assessment of Bombayduck, *Harpodon nehereus* (Ham.) stock off the Maharashtra coast. *Indian J. Fish.*, 36(4): 275-283.

Kurian, A. and K.N. Kurup. 1992. Stock assessment of Bombay duck *Harpodon nehereus* (Ham.) off Maharashtra coast. *Indian J. Fish.*, 39(3,4): 243-248.

Longhurst, A.R. and D. pauly. 1987. Ecology of tropical oceans. Academic Press, San Diego, 407 pp.

Longhurst, A.R. and W.S. Wooster. 1990. Abundance of oil sardine (*Sardinella longiceps*) and upwelling on the southwest coast of India. *Can. J. Fish. Aquat. Sci.*, 47: 2407-2419.

Luther, G. 1973. Observation on the biology and fishery of the Indian mackerel, *Rastrelliger kanagurta* (Cuvier) from Andaman Islands. *Indian J. Fish.*, 20(2): 425-447.

Luther, G., K.V. Narayana Rao, G. Gopakumar, C. Muthiah, N. Gopalakrishna Pillai, Prathibha Rohit, K. Narayana Kurup, S. Reuben, P. Devadoss, G. Syda Rao, P. Sam Bennet and N.S. Radhakrishnan. 1992. Resource characteristics and stock assessment of whitebaits. *Indian J. Fish.*, 39(3,4): 152-168.

Madhupratap, M., S.R. Shetye, K.N.V. Nair and R. Sreekumaran Nair. 1994. Oilsardine and Indian mackerel: Their fishery problems and coastal oceanography. *Curr. Sci.*, 66(5) : 340-348.

Menon, M.D. and K.C. George. 1975. White-bait resources of the southwest coast of India. *Sea food export Journal*, 7(1): 1- 14.

Murty, A.V.S. 1965. Studies on the surface mixed layer and its associated thermocline off the west coast of India and the inferences thereby for working out a prediction system of the pelagic fisheries of the region. *Indian J. Fish.*, 12(1): 118-135.

Murty, A.V.S. and M.S. Edelman. 1970. On the relation between the intensity of the southwest monsoon and the oil sardine fishery of India. *Indian J. Fish.* 13: 142-149.

Nair, R.V. 1952. Studies on the revival of the Indian oil sardine fishery. *Proc. Indo-Pacif. Fish. Coun.*, 4: 115-129.

Nair, R.V. and R. Subrahmanyan. 1955. The diatom *Fragilaria oceanica* Cleve, an indicator of abundance of the oil sardine *Sardinella longiceps* Cuv. & Val. *Curr. Sci.* 24 : 41.

Narasimham, K.A. 1976. Some observations on the biology of the ribbonfish *Eupleurogrammus muticus* (Gray). *Indian J. Fish.* (1974), 21(2): 479-494.

Narasimham, K.A. 1978. Age and growth of the ribbonfish *Trichiurus lepturus* Linnaeus. *Indian J. Fish.*, 23(1&2): 174-183.

Narasimham, K.A. 1983. On the fishery, mortality rates and yield per recruit of the ribbonfish *Trichiurus lepturus* Linnaeus. *Indian J. Fish.*, 30(1): 99-109.

Noble, A. 1965. The food and feeding habits of the Indian oil sardine *Sardinella longiceps* Valenciennes at Karwar. *Indian J. Fish.*, 12 A (1): 77-86.

Noble, A. 1972. Surface temperature and its relation to the duration of mackerel fishery at Karwar. *Indian J. Fish.*, 19: 167-170.

Noble, A., G. Gopakumar, N. Gopalakrishna Pillai, G.M. Kulkarni, K. Narayana Kurup, S.Ruben, M. Sivadas and T.M. Yohannan. 1992. Assessment of mackerel stock along the Indian coast. *Indian J. Fish.*, 39(3,4): 119-124.

Panikkar, N.K. 1949. A survey of the pelagic fisheries of the world. The biology of pelagic fishes. *Proc. IPFC*, 1: 123-132.

Pati, S. 1982. Studies on the maturation, spawning and migration of silver pomfret, *Pampus argenteus* (Euphrasen) from Bay of Bengal. *Matsya*, 8: 12-22.

Pillai, V.N. 1991. Salinity and thermal characteristics of the coastal waters off southwest coast of India and their relation to major pelagic fisheries of the region. *J. Mar. Biol. Ass. India*, 33 (1&2): 115-133.

Pillai, V.N. 1993. Variations in dissolved oxygen content of coastal waters along southwest coast of India in space and time. *Indian J. Mar. Sci.*, 22 : 279-282.

Prabhu, M.S. 1955. Some aspects of the biology of the ribbonfish, *Trichiurus haumela* (Forskal). *Indian J. Fish.*, 2(1): 132-163.

Prabhu, M.S. and M.H. Dhulkhed. 1970. The oil sardine fishery of the Mangalore zone during the season 1963-64 to 1967-68. *Indian J. Fish.*, 17: 57-75.

Prabhu, M.S. and G. Venkataraman. 1970. Mackerel and oil sardine tagging programme 1966-67 to 1968-69. *Bull. Cent. Mar. Fish. Res. Inst.*, No. 17, 38 pp.

Pradhan, L.B. 1956. Mackerel fishery of Karwar. *Indian J. Fish.*, 3(1): 141-185.

Pradhan, L.B. and C.V.G. Reddy. 1962. Fluctuations in mackerel landings at Calicut in relation to hydrographical factors. *Indian J. Fish.*, 9(1): 200-209.

Radhakrishnan, N. 1965. Oil sardine investigations at Karwar. *Indian J. Fish.*, 12A (1): 99-117.

Ramamirtham, C.P. and R. Jayaraman. 1961. Hydrographic features of the continental shelf waters off Cochin during 1958 and 1959. *J. mar. biol. Ass. India*, 2(2): 199-207.

Rao, D.S., C.P. Ramamirtham and T.S. Krishnan 1973. Oceanographic features and abundance of the pelagic fisheries along the west coast of India. *Proc. Symp. Living Resources of the Seas around India, CMFRI Spl. Publ.*, 400-413.

Rao, G.S. 1988a. Some aspects of biology of *Stolephorus devisi* (Whitley) from Mangalore area, Dakshina Kannada. *J. mar. biol. Ass. India*, 30: 28-36.

Rao, G.S. 1988b. Some aspects of biology of *Stolephorus bataviensis* from Mangalore area, Dakshina Kannada. *J. mar. biol. Ass. India*, 30: 107-113.

Rao, K.S. 1967. Food and feeding habits of fishes from trawl catches in the Bay of Bengal with observation on diurnal variation in the nature of the food. *Indian J. Fish.*, 11(1): 277-314.

Rao, K.V., K.V. Sekharan and M.J. Pradhan. 1965. On the mackerel fishery of the Mangalore area during the period 1957-1961. *Indian J. Fish.*, 9(2): 653-678.

Reuben, S., H.M. Kasim, S. Sivakami, P.N. Radhakrishnan Nair, K.N. Kurup, M. Sivadas, A. Noble, K.V. Somasekharan Nair and S.G. Raje. 1992. Fishery, biology and stock assessment of carangid resources from the Indian seas. *Indian J. Fish.*, 39(3,4): 195-234.

Sam Bennet, P. 1968. A method for predicting the Indian oil sardine fishery. *Symposium on the Living Resources of the Seas around India.* Abstracts, 8.

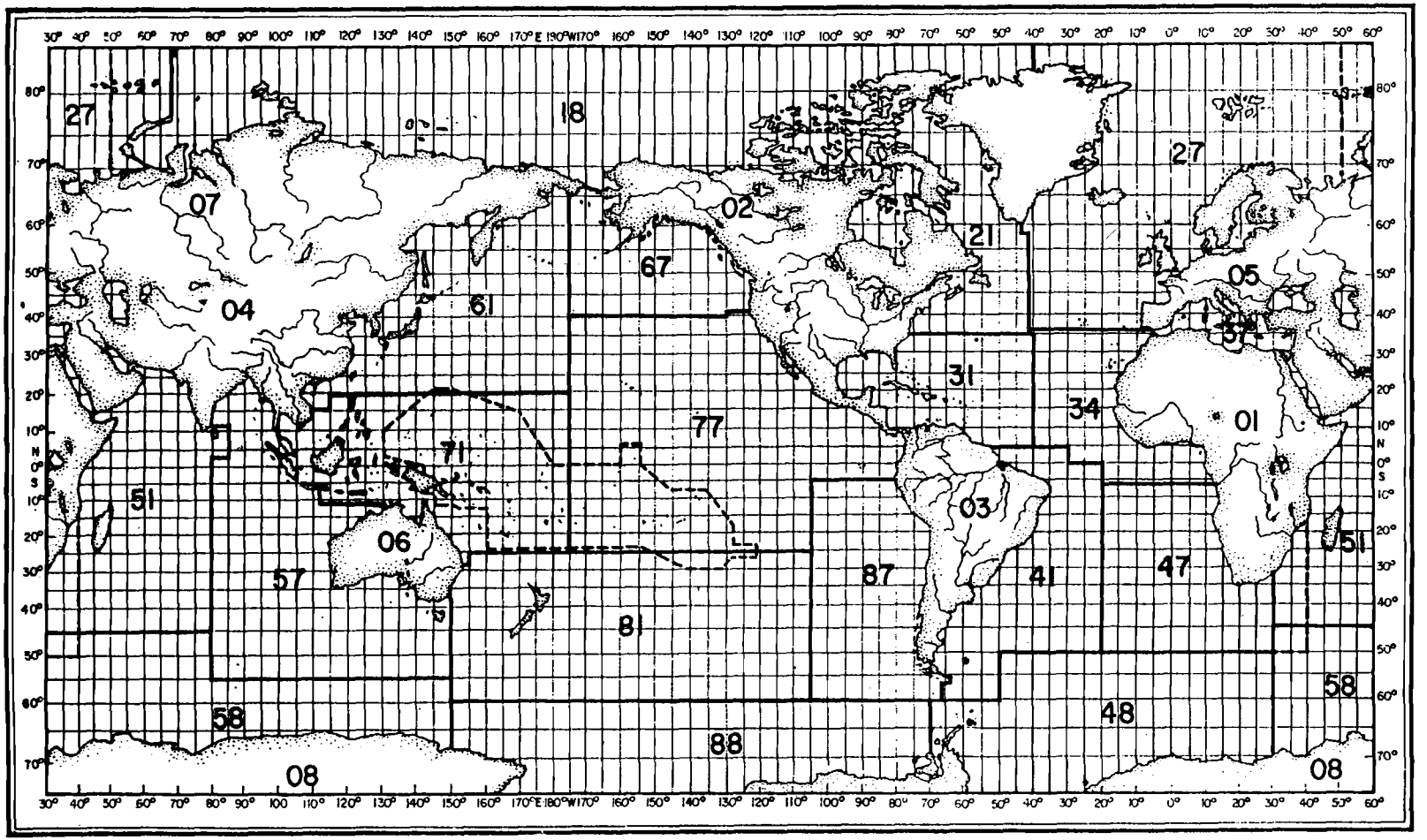


Fig. 1. Major fishing areas for statistical purposes.

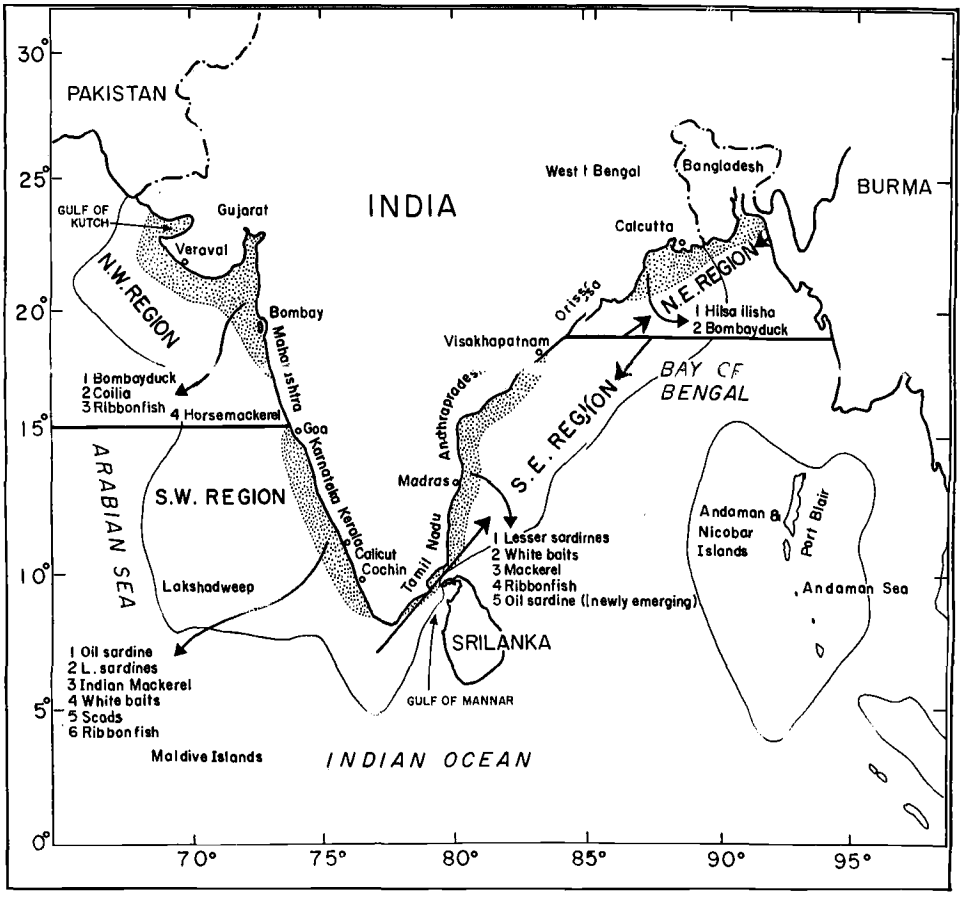


Fig. 2. Exclusive Economic Zone of India.

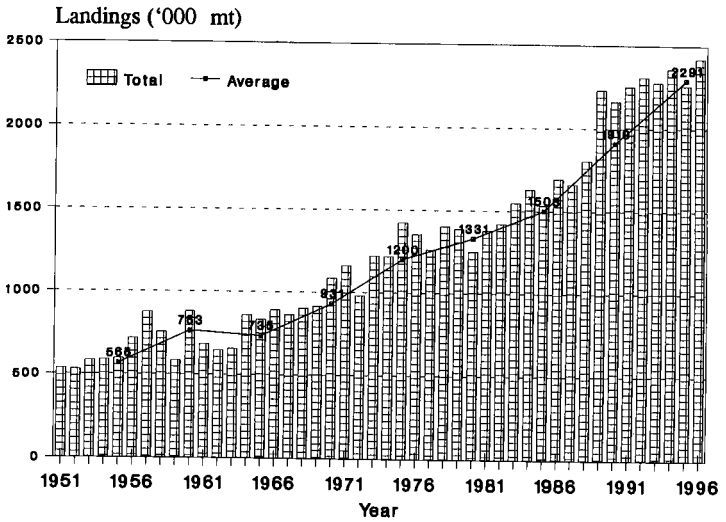
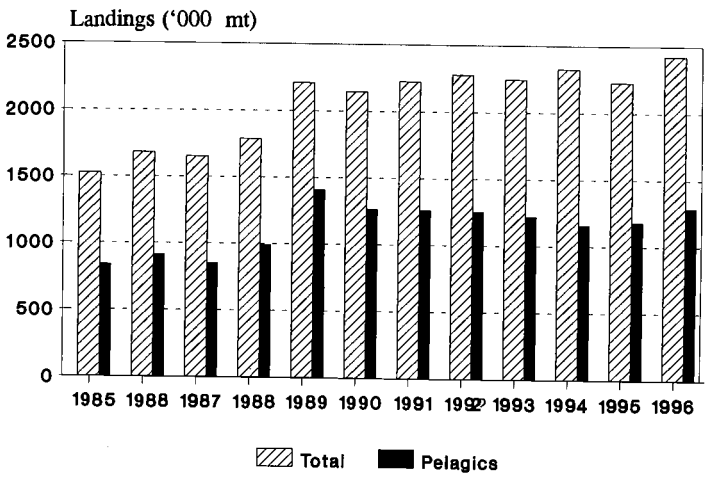
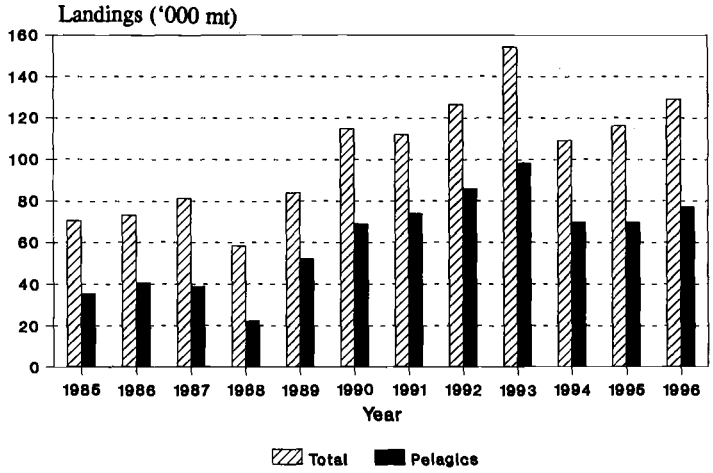


Fig. 3. All India marine fish landings: total & 5 year average during 1951-1996.



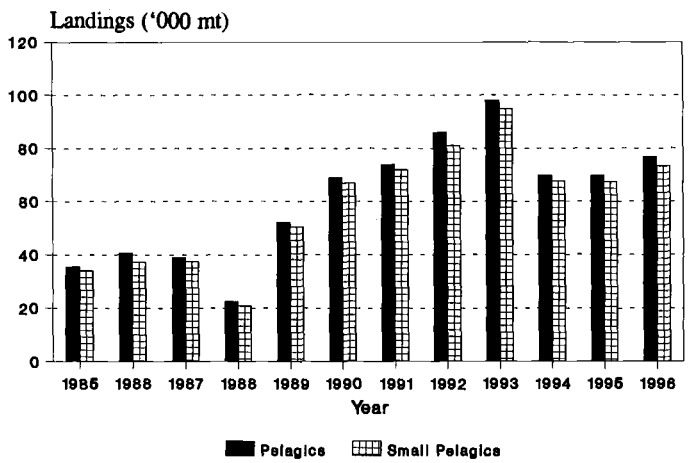
Avg. An. total= 2,058,695 mt
Avg. An. pelegic= 1,133,237 (55% of total)

Fig. 4. All India landings of total marine and pelagics during 1985-1996.



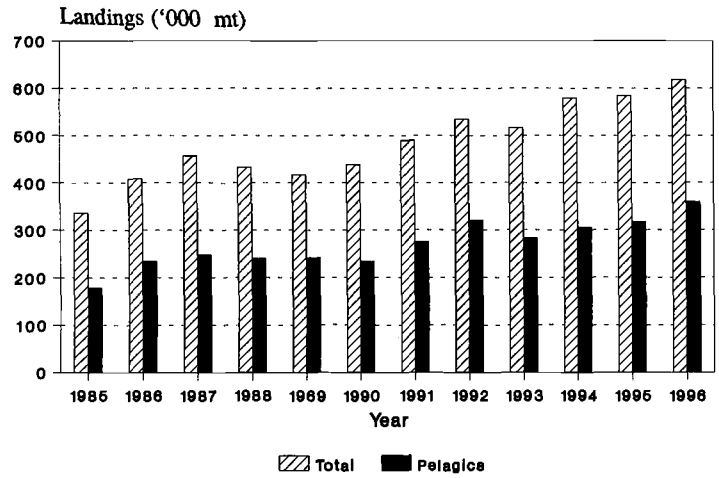
Avg. An. total= 102,339 mt
Avg. An. pelagic= 60,976 mt (59.6% of total)

Fig. 5. Northeast landings of total marine and pelagic during 1985-1996.



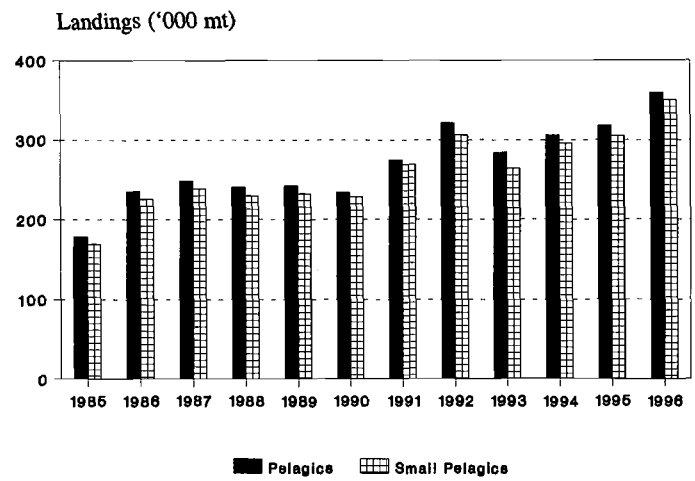
Avg. An. pel=60,976 mt
Avg. An. small pelagic= 58,519 mt (96% of total)

Fig. 6. Northeast landings of pelagics and small pelagics during 1985-1996.



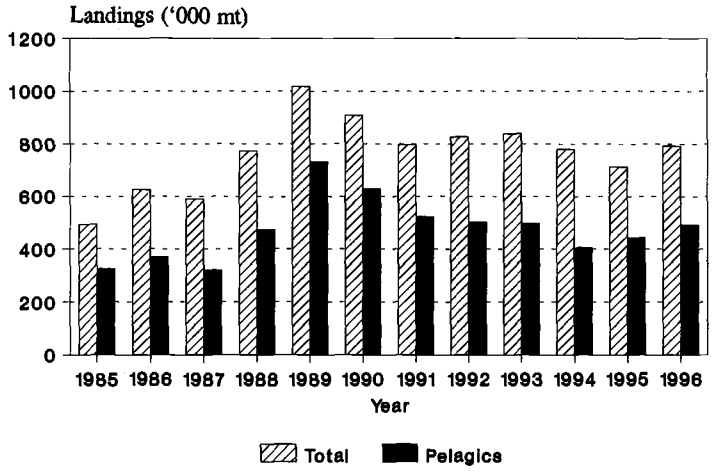
Avg. An. total= 483,911 mt
Avg. An. pelagic= 269,690 mt (55.7% of total)

Fig. 7. Southeast landings of total marine and pelagics during 1985-1996.



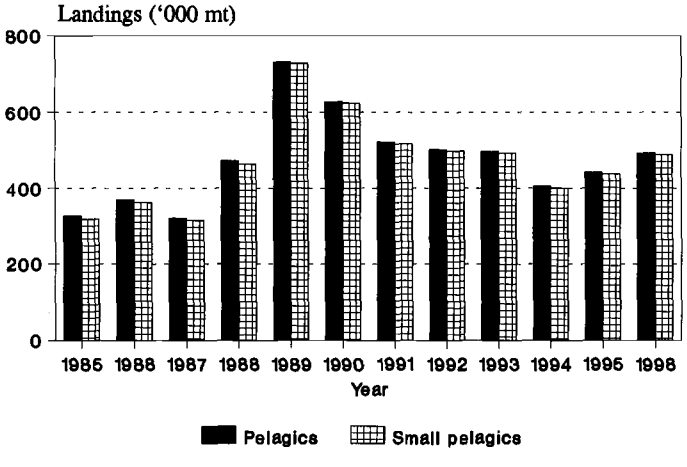
Avg. An. total= 269,690 mt
Avg. An. pelagic= 259,138 mt (96.1% of total)

Fig. 8. Southeast landings of pelagics and small pelagics during 1985-1996.



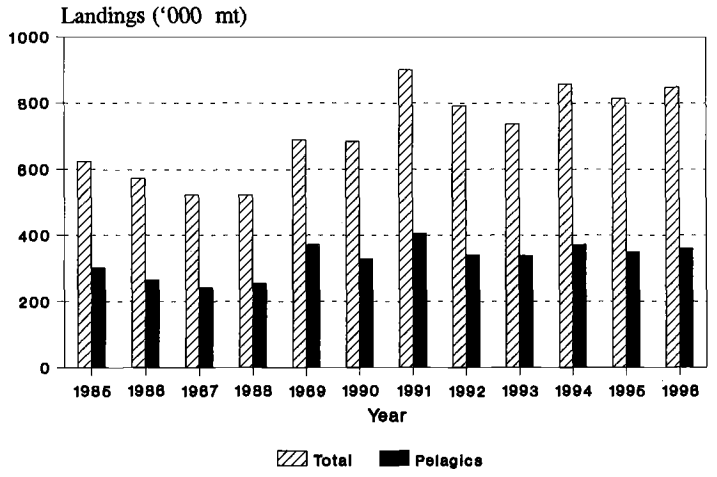
Avg. An. total= 762,704 mt
Avg. An. pelagic= 475,495 mt (562.3% of total)

Fig. 9. Southwest landings of total marine and pelagics during 1985-1996.



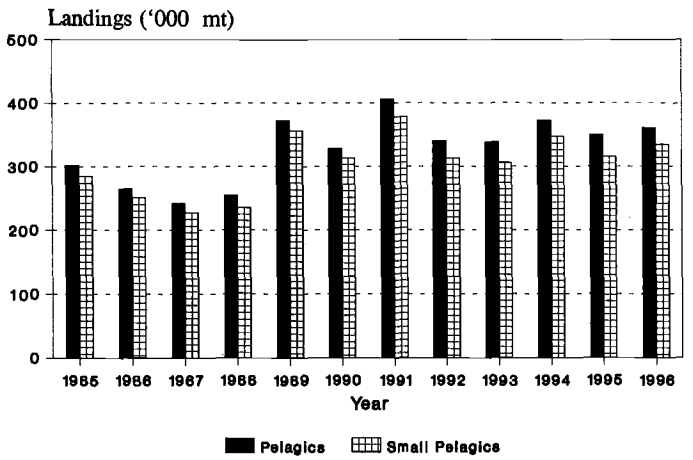
Avg. An. pelagic= 475,495 mt
Avg. An. small pelagic= 469,897 mt (98.8% of total)

Fig. 10. Southwest landings of pelagics and small pelagics during 1985-1996.



Avg. An. total= 713,199 mt
Avg. An. pelagic= 327,348 mt (45.9% of total)

Fig. 11. Northwest landings of total marine and pelagics during 1985-1996.



Avg. An. pelagic= 327,348 mt
Avg. An. small pelagic= 304,792 mt (93.1% of pelagic)

Fig. 12. Northwest landings of pelagics and small pelagics during 1985-1996.

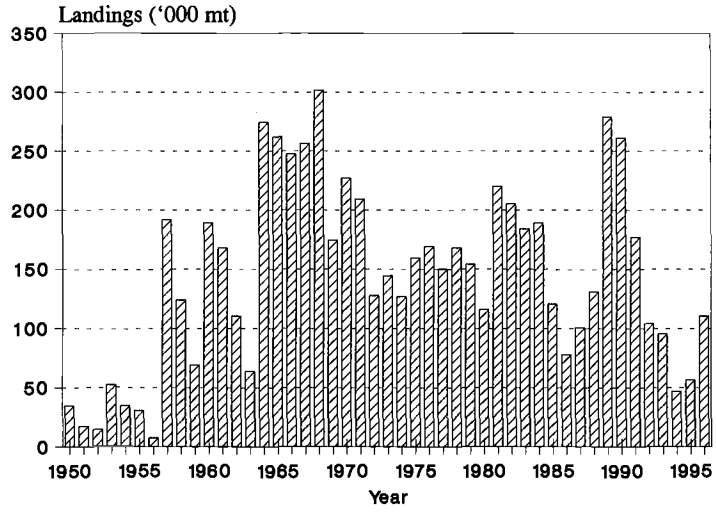


Fig. 13. All India oilsardine landings during 1950-1996.

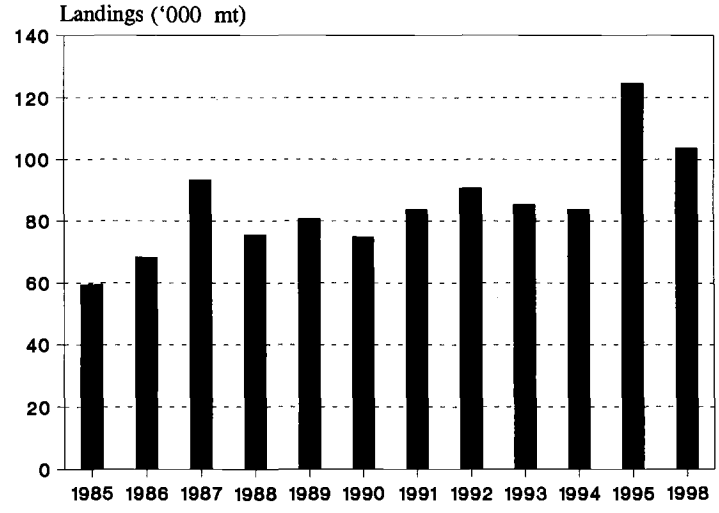


Fig. 14. All India lesser sardine landings during 1985-1996.

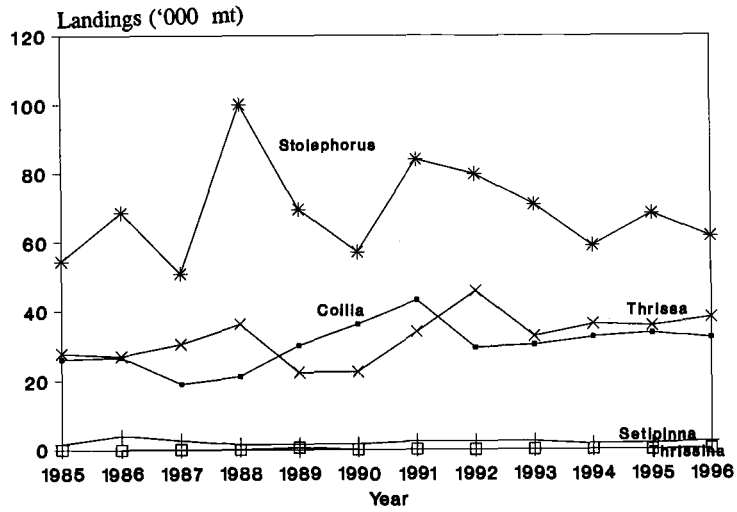


Fig. 15. All India landings of anchovies during 1985-1996.

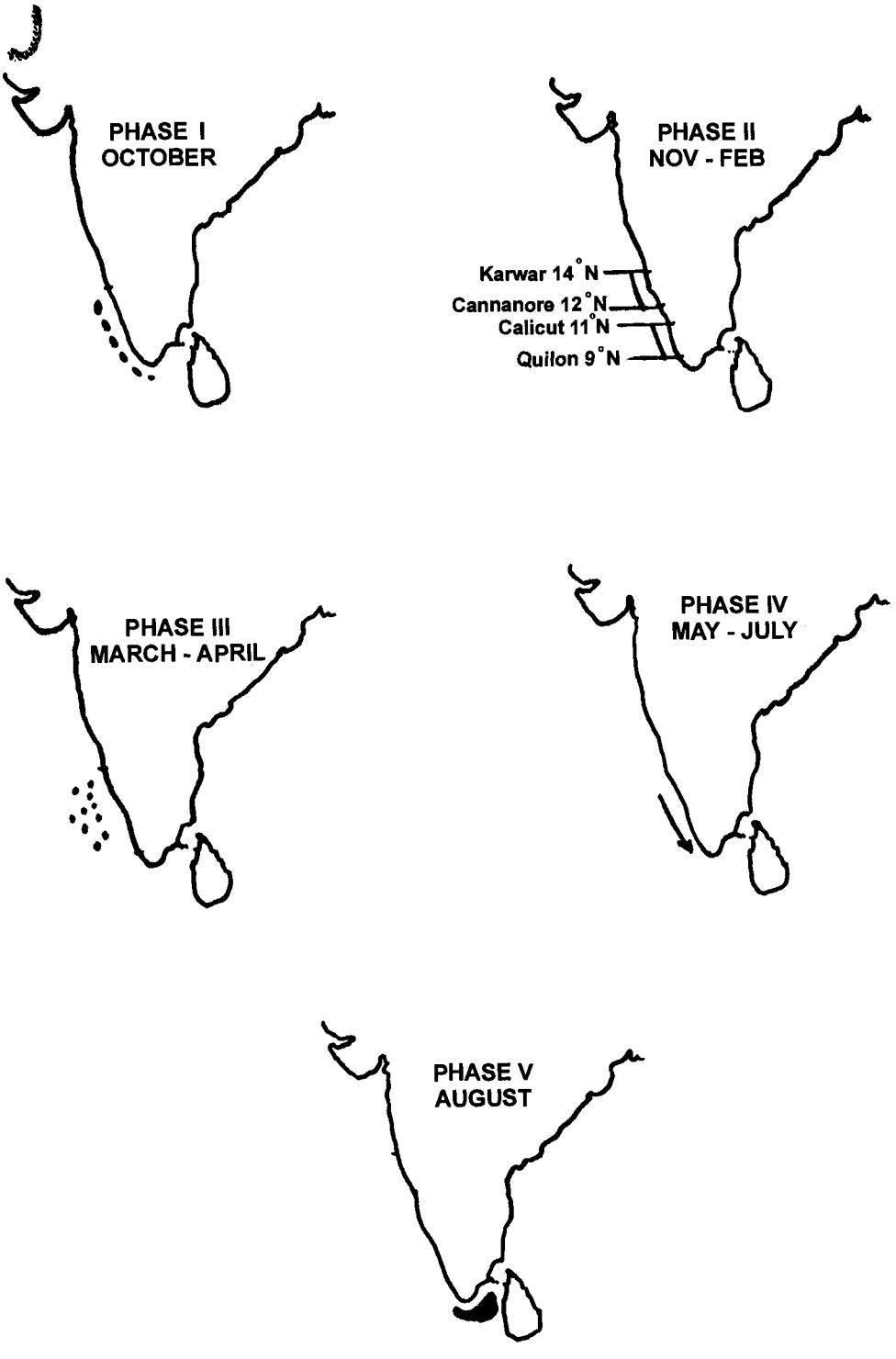


Fig. 16. Seasonal migration of whitebaits.

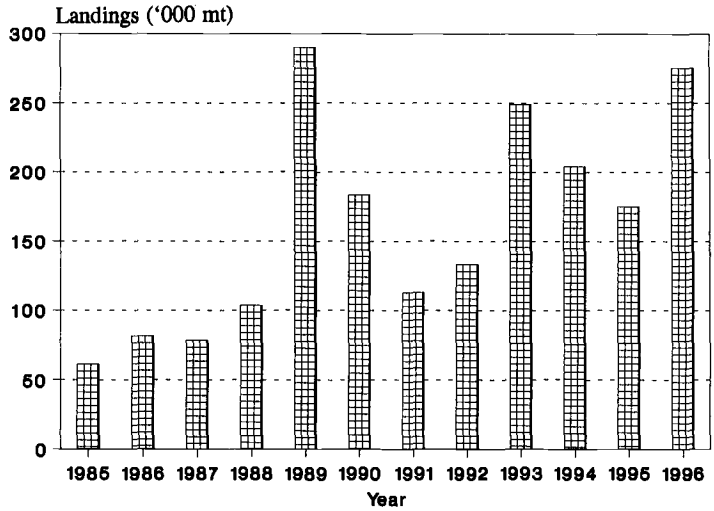


Fig. 17. All India landings of mackerel during 1985-1996.

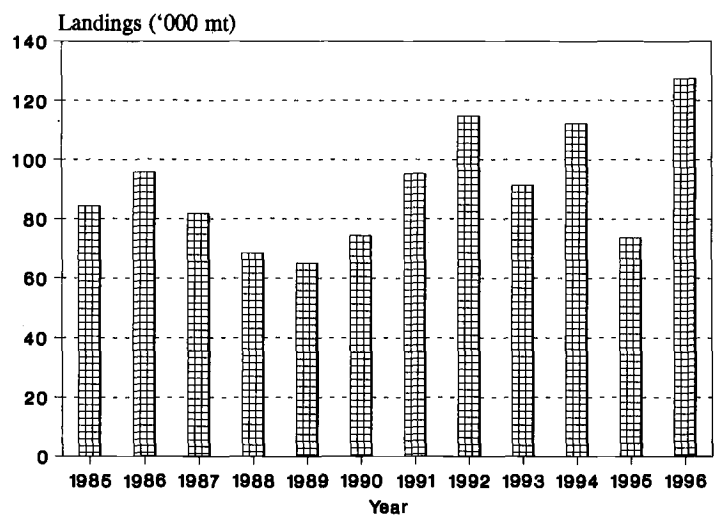


Fig. 18. All India landings of ribbonfishes during 1985-1996.

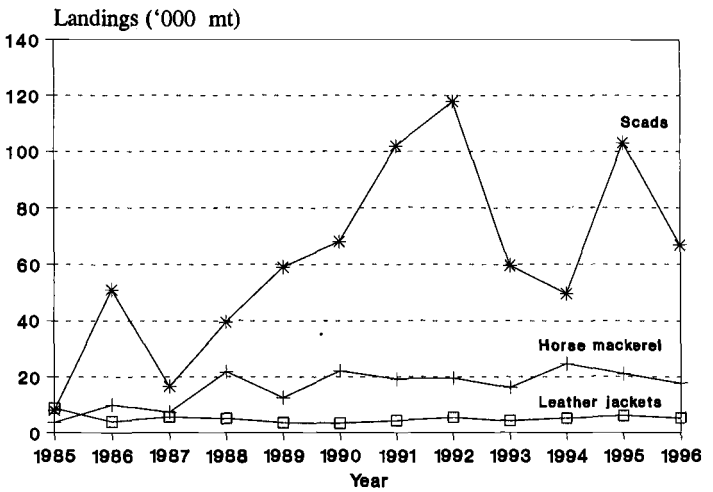


Fig. 19. All India landings of carangids during 1985-1996.

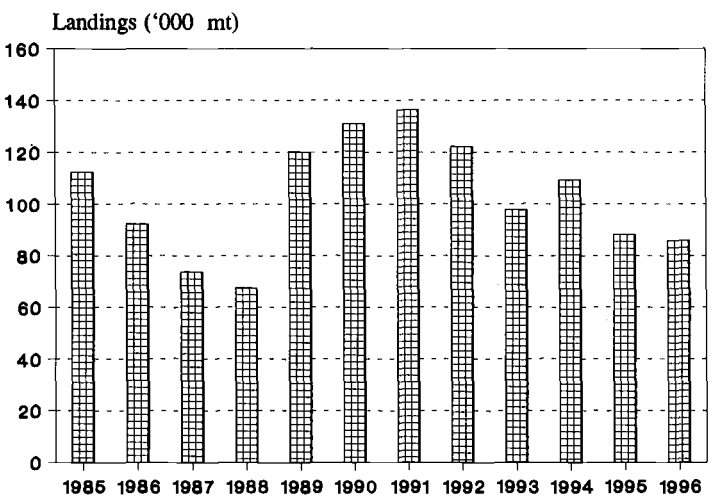


Fig. 20. All India landings of Bombayduck during 1985-1996.

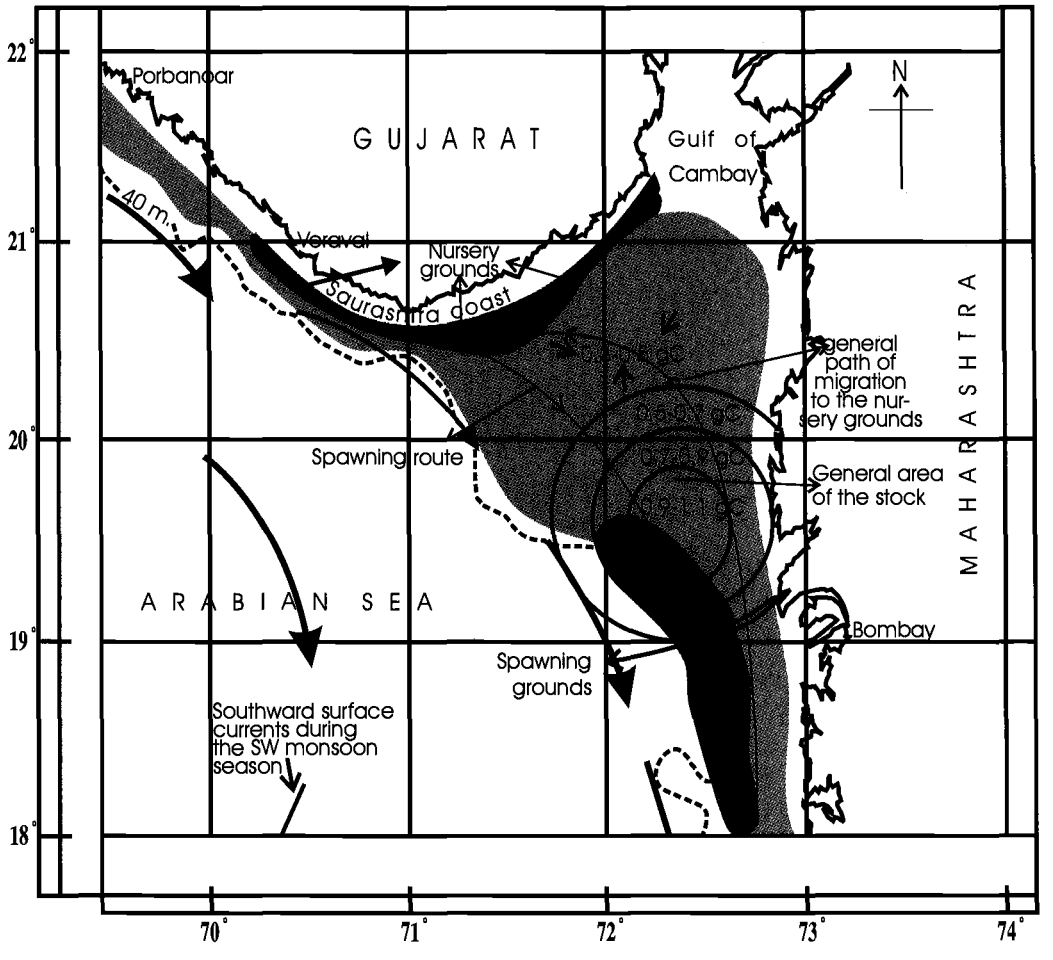


Fig.21 Migration of Bombayduck

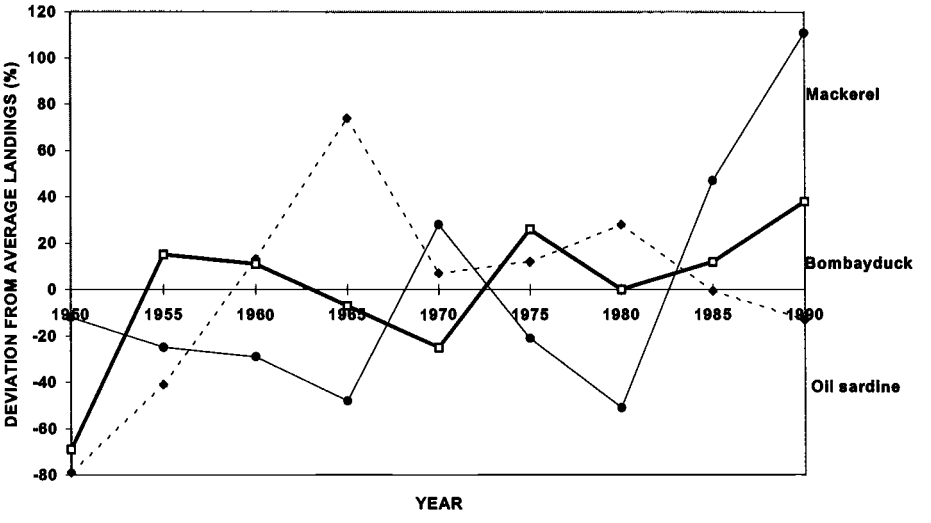


Fig. 22. All India landings of oil sardines, mackerel and Bombayduck expressed as deviations from the respective long term (1950-1995) mean values.

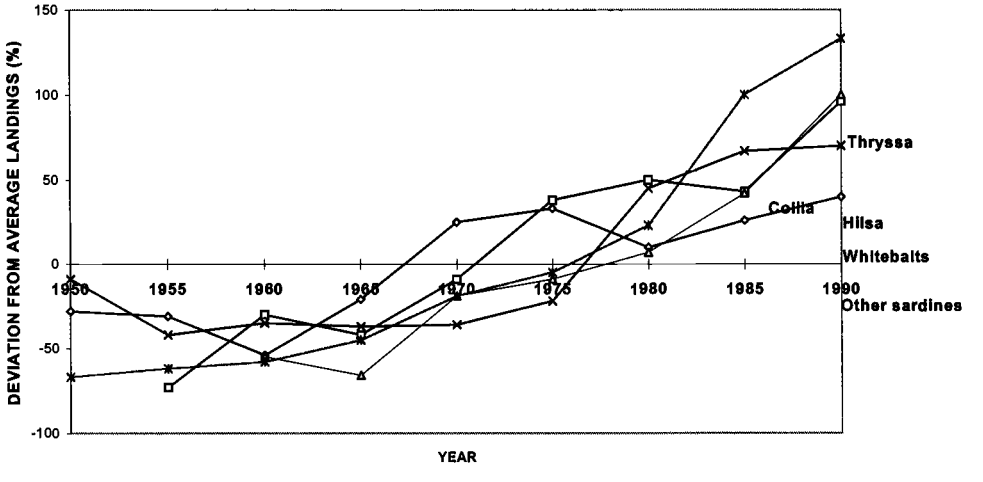


Fig. 23 All India landings of other small pelagics expressed as deviations from the respective long term (1950-1995) mean values.

Fig. 24. Annual catch of oil sardine and Indian mackerel from the SW coast of India

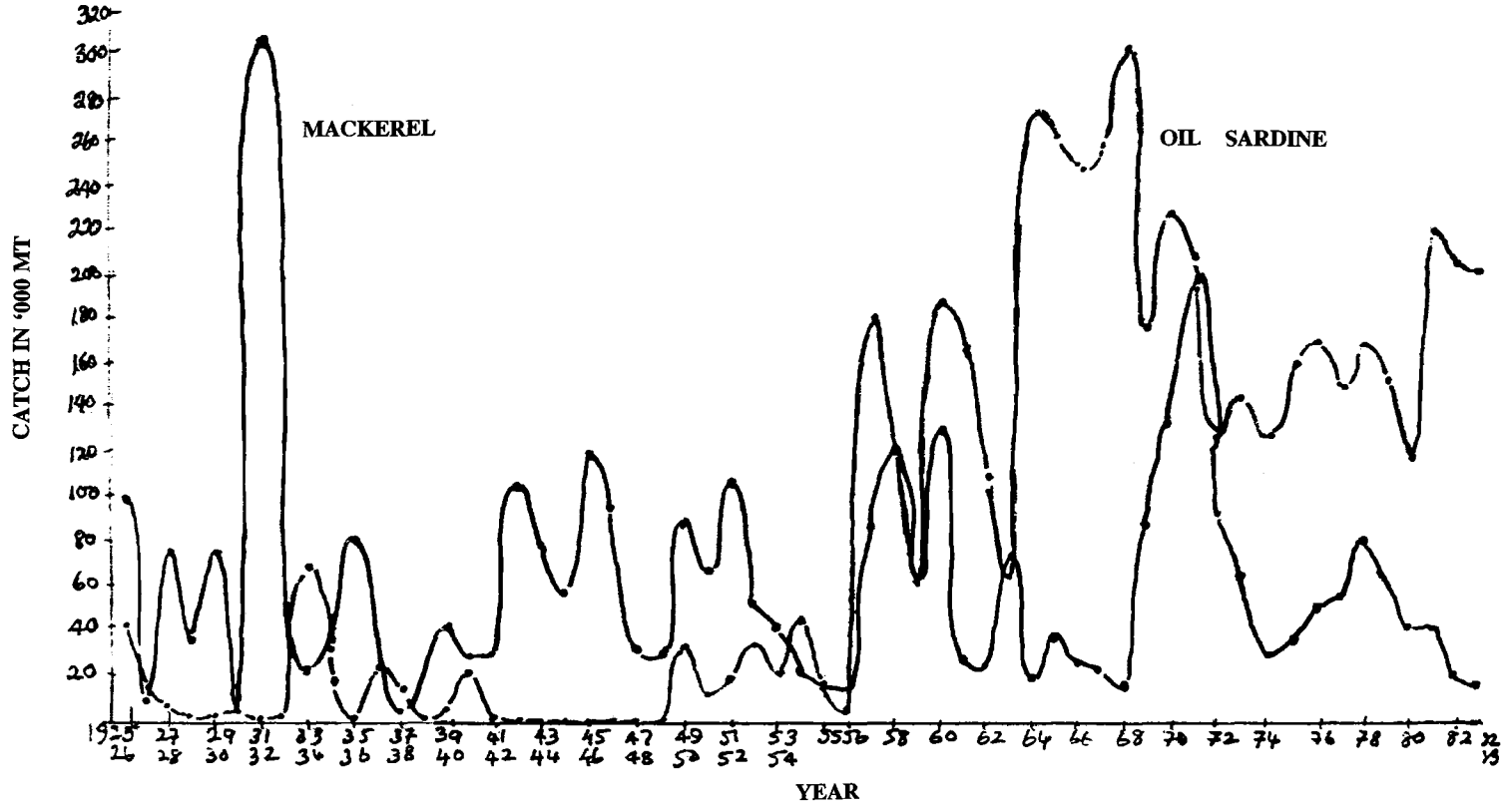


Fig. 24. Annual catch of oil sardine and Indian mackerel from the SW coast of India.

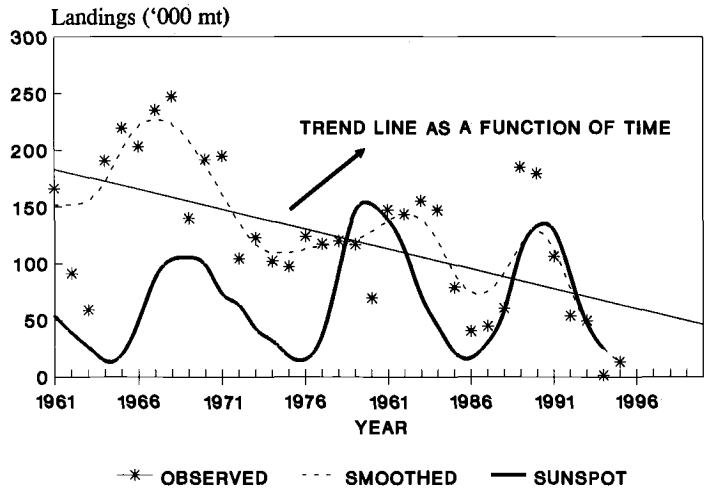


Fig. 25. Oilsardine landings in relation to solar activity in Kerala.

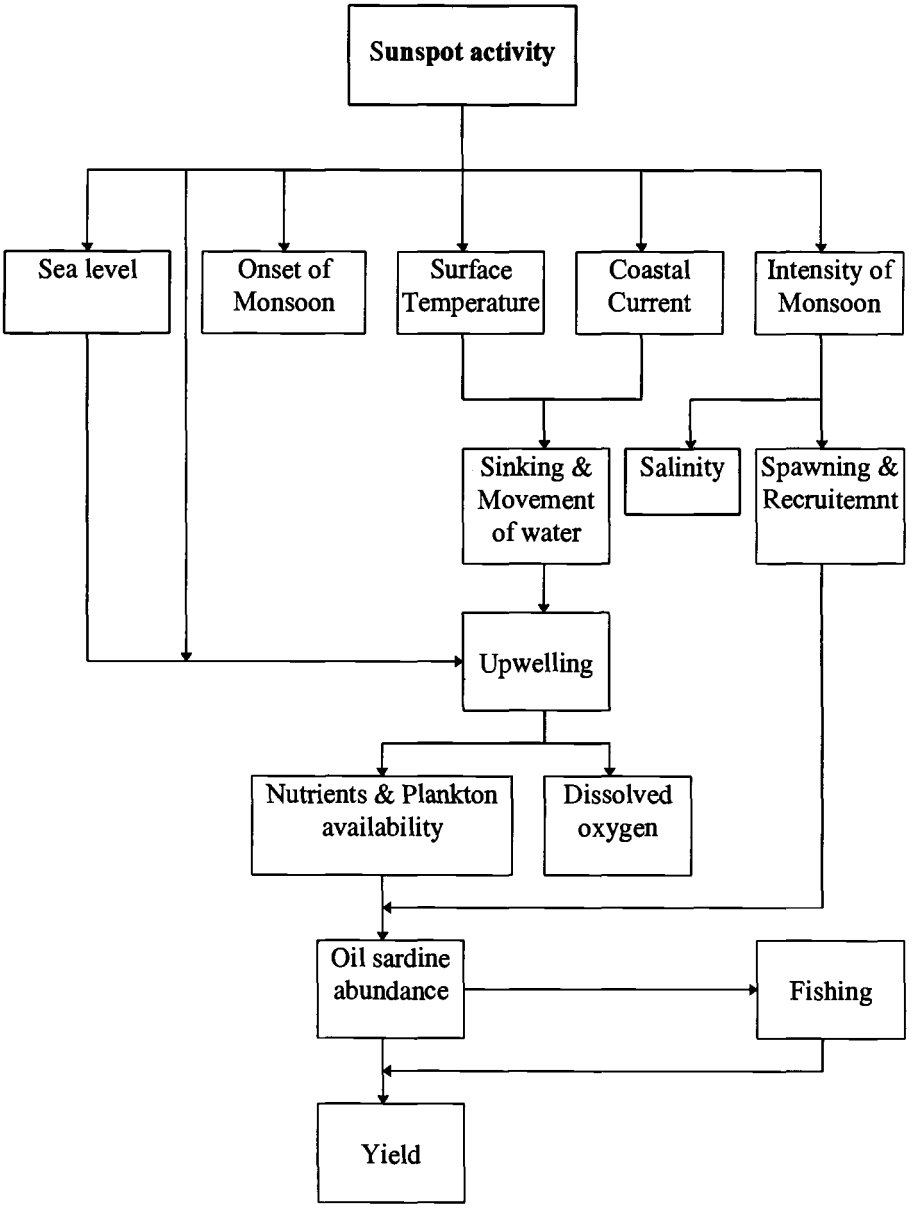


Fig. 26. Factors influencing oil sardine yield.

REVIEW OF THE SMALL PELAGIC FISHERIES OF INDONESIA

by

Johanes Widodo
Research Institute for Marine Fisheries Agency
for Agricultural Research and Development,
Ministry of Agriculture, Jl. Pasirputih I
Jakarta 14430, Indonesia

Abstract

The small pelagics constitute 48% of the total marine fish landings. The landings of the small pelagics increased from 700 000 mt in 1983 to 1 109 000 mt in 1992. The scads (196 000 mt), mackerels (177 000 mt), flat sardines (139 000 mt), round sardines (137 000 mt), anchovies (134 000 mt) and trevallies (100 000 mt) dominated the landings (in 1992). Purseseiners ranging in length from 10 m to 30 m are the major craft used in the Indonesian fisheries. The effort of the purseseiners increased from 4 500 units in 1983 to 6 900 units in 1994 and the cpue also increased from 56 mt/unit in 1983 to 70 mt/unit in 1992. The biological characteristics of the major species are dealt with and certain management options for sustaining the fisheries suggested.

INTRODUCTION

Indonesia is the largest archipelagic nation (Fig.1) in the world, consisting of more than 17 000 islands, 80 000 km of coastline and a total area of about 4.9 million km^2 including the archipelagic waters, the straits (considered as international sea passages) and territorial seas. Since the archipelagic state concept of the UNCLOS has come into force with effect from November 16, 1994, there is an additional 3 million km^2 area of exclusive economic zone (EEZ). The hydrographic pattern of Indonesian waters is predominantly influenced by the prevailing monsoon winds, which are oriented primarily southwest and southeast of the areas, north and south of equator respectively. These winds create substantial seasonal changes in the direction and velocity of the surface currents, salinity, and primary productivity (Wyrtki, 1961; Weber, 1976).

The fisheries of Indonesia are constituted by marine and freshwater components of which the capture fisheries form the most dominant source of supply. In 1994, marine fisheries accounted for 76% of the national fish production of 4.0 million mt while the inland fisheries including capture and culture-based fisheries contributed the remaining 24%. Indonesian waters are part of the fisheries regions of the Western Central Pacific and Eastern Indian Oceans. The former includes most of the countless Pacific islands and the chain of islands between Malaysia and Australia. There is a high diversity of fish including species of economic interest in this region. Consequently, Indonesian fisheries are concerned with both multispecies and multigear problems. In most cases the same fleet exploits several stocks and several fleets complete in exploiting the same resources. Indonesian marine fisheries resources consist essentially of the small pelagics,

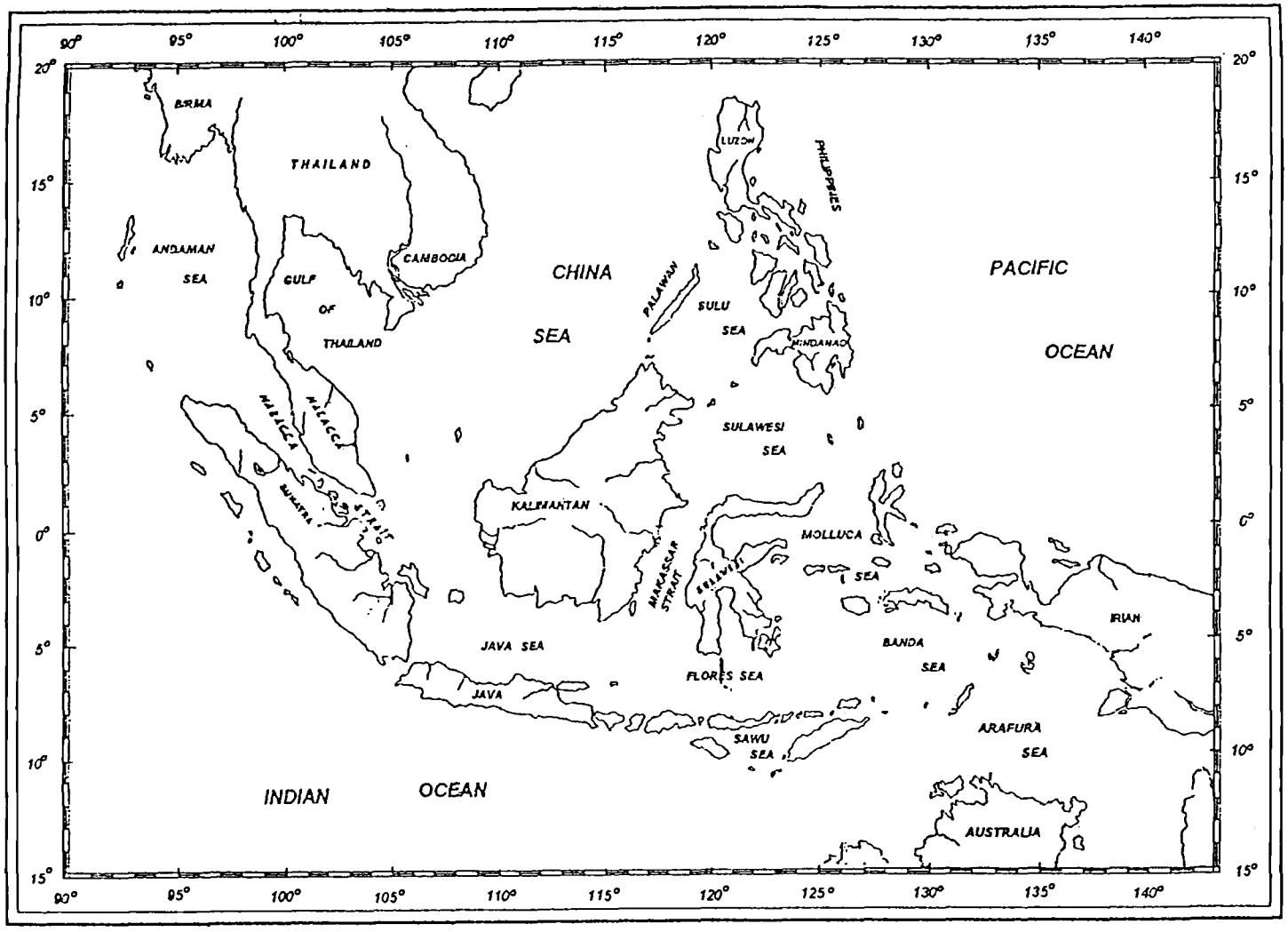


Fig. 1. Indonesia and its adjacent waters.

skipjack, other tunas, and demersal finfish, besides a number of other economically important groups like the sharks and rays, crustaceans, molluscs, sea cucumbers, turtles, seaweeds, etc.

The status of fisheries development in Indonesia varies according to the geographical areas and the concentrations of the human population. For example, most of the coastal fisheries resources in east Sumatra, north Java and the Bali Strait have been fully exploited, while the offshore areas in the EEZ are still underexploited. In 1994, the marine fish production was recorded to be 3.1 million mt, of which 2.7 million mt was finfish, 0.2 million mt crustaceans, 0.075 million mt molluscs, and 0.008 million mt others. Among the finfish 1.8 million mt was of pelagics.

THE SPECIES AND THEIR DISTRIBUTION

The Western Pacific ocean is characterised by a greater diversity of fish species than the eastern Pacific. As part of the Western Pacific region, the Indonesian waters are inhabited by a large number of species of marine and freshwater fish. The small pelagic species are restricted to the coastal waters and the continental shelves of Sunda in the west and Sahul in the east of Indonesia. The Indonesian pelagic fisheries comprise different taxonomic groups of pan-tropical distribution. Principally, the Indonesian small pelagics could be classified into several orders: (1) the herring-like Elopiformes and Clupeiformes, (2) Atheriniformes including the flyingfishes or exocoetids, (3) the small, mesopelagic and bathypelagic fishes belonging to the Myctophiformes in the Banda Sea, (4) the perch-like Perciformes mostly constituted by the carangid jacks and trevallies, and (5) the scombroid mackerels. One of the characteristics of the small pelagics of the Java Sea is their dominance by the clupeoids, carangoids and scombroids, which are benthopelagic, and hence frequently captured in demersal trawls (Widodo, 1976).

Clupeoids

In addition to the sardinellas, a number of commercially important clupeoids belonging to six families exist in the Indonesian waters. Out of these six families, three belong to the order Elopiformes. They are the tenpounders (Elopidae), tarpons (Megalopidae) and ladyfishes (Albulidae). The other three families which belong to order Clupeiformes include the predatory wolfherrings (Chirocentridae) sardines, shads and gizzard shads (Clupeidae) and anchovies, (Engraulidae). The species belonging to the these families, their local or common names, English names, distribution and behaviour are listed below.

1. Elopidae

Elops machnata (Tenpounders): Inhabits the coastal waters of east Sumatra and the Malacca Strait. Sometimes, they enter the brackishwater environments at sizes of less than 50 cm. They are rather less active and feed on benthic organisms. Common size 40-60 cm.

2. ***Megalopidae***

Megalops cyprinoides (bulan-bulan; Indo-Pacific tarpon): Inhabits the coastal waters of Sumatra, Java, Kalimantan and Irian Jaya. Common size 20-30 cm.

3. ***Albuloidae***

Albula vulpes (bandeng cururot; ladyfish): Inhabits the continental shelf of the Sunda Shelf in the west and the Sahul Shelf in the east.

4. ***Chirocentridae***

Chirocentrus dorab (golok golok; dorab wolfherring): Inhabits the coastal waters; pelagic. Common size 30-50 cm.

5. ***Clupeidae***

Anodontostoma chacunda (selanget; chacunda gizzard shad): Inhabits coastal waters; pelagic. Common size 15- 0 cm.

Herklotsichthys punctatus (spotted herring): Inhabits coastal waters and moves in shoals. Common size 10-15 cm.

Dussumieria acuta (Japuh; rainbow sardine): Inhabits coastal waters and moves in shoals; pelagic. Common size 10-15 cm.

Hilsa kelee (mata belo; kelee shad): Inhabits coastal waters; pelagic, not abundant. Common size 15-22 cm.

H. (Tenualosa) macrura (terubuk; longtail shad): Inhabits coastal waters, estuaries and rivers of east Sumatra coast, Riau Province; pelagic. Common size 15-25 cm.

H. toli(toli shad): Inhabits coastal waters, estuaries and rivers.; pelagic. Common size 30-40 cm.

Ilisha pristigastroides (Java ilisha): Inhabits estuaries and rivers; benthopelagic. Restrictively distributed throughout Java, Sumatra and Kalimantan. Common size 25-35 cm.

I. elongata (elongate ilisha): Inhabits coastal waters; not abundant; benthopelagic. Common size 25-35 cm.

I. melastoma (Indian ilisha): Inhabits coastal waters; not abundant; benthopelagic. Restrictively distributed throughout north Java coast. Common size 12-18 cm.

I. megaloptera (bigeye ilisha): Inhabits coastal waters; not abundant. Common size 16-22 cm.

Nematolosa nasus (Bloch's gizzard-shad): Inhabits coastal waters; pelagic. Common size 12-16 cm.

Opisthopterus tardoore (tardoore): Inhabits coastal waters; not abundant; pelagic. Common size 16-22 cm.

Pellona ditchela (Indian pellona): Inhabits coastal waters; pelagic. Common size 12-16 cm.

Sardinella lemuru (lemuru; Bali lemuru): Restrictively distributed in the Bali Strait and its adjacent waters. Common size 13-17 cm.

S. fimbriata (tembang tanjan; fringescale sardinella): Inhabits coastal waters; pelagic. Common size 10-15 cm.

S. brachysoma (tembang perempuan; deepbody sardinella): Inhabits coastal waters; pelagic. Common size 12-16 cm.

S. gibbosa (tembang tanjan; goldstripe sardinella): Inhabits coastal waters; pelagic. Common size 12-18 cm.

S. albella (tembang anjan; white sardinella): Inhabits coastal waters; pelagic. Common size 5-10 cm.

Sardinella (*Amblygaster*) *sirm* (siro; spotted sardinella): Inhabits coastal waters; pelagic. Common size 15-20 cm.

S.(A). leiogaster (smootbelly sardinella): Inhabits coastal waters; pelagic. Common size 15-25 cm.

6. ***Engraulidae***

Stolephorus heterolobus (kenaren; shorthead anchovy): Inhabits coastal and neritic waters; pelagic. Common size 8-12 cm.

S. commersoni (bilis; Commerson's anchovy): Inhabits continental shelves; pelagic. Common size 8-14 cm.

S. indicus (teri; Indian anchovy): Inhabits continental shelves; pelagic. Common size 12-16 cm.

S. tri (teri; spined anchovy): Inhabits near river mouths; pelagic. Common size 8-12 cm.

S. buccaneeri (teri; Buccaneer anchovy): Inhabits coastal waters; pelagic. Common size 7-9 cm.

S. bataviensis (teri; Batavian anchovy): Inhabits coastal and neritic waters; pelagic. Common size 7-11 cm.

Coilia dussumieri (daun bambu; gold-spotted grenadier anchovy): Inhabits coastal waters; benthopelagic. Common size 13-17 cm.

Setipinna taty (daun bambu; hairfin anchovy): Inhabits estuaries and coastal waters; benthopelagic. Common size 14-17 cm.

S. melanochir (daun bambu sirip hitam; dusky hairfin anchovy): Inhabits estuaries and coastal waters; benthopelagic. Common size 17-20 cm.

Thrissina baelama (Baelama anchovy): Inhabits coastal waters; pelagic. Common size 9-13 cm.

T. mystax (moustached thryssa): Inhabits coastal waters; pelagic. Common size 15-22 cm.

Thryssa setirostris (long jaw thryssa): Inhabits coastal waters; benthopelagic. Common size 12-16 cm.

T. malabarica (Malabar thryssa): Inhabits estuaries and coastal waters; benthopelagic. Common size 16-19 cm.

Exocoetids

Exocoetid flyingfish are relatively abundant and constitute a fishery of regional significance especially in the Makassar Strait of the South Sulawesi Province. Egg masses of *Cypsilurus,* a local exocoetid of Makassar Strait, are collected for sale using palm fronds in the spawning grounds.

Carangoids

Many species of Carangidae occur in the continental shelves including the coastal waters of Indonesia. Among them, the scads, jacks, and trevallies are quite prominent.

1. ***Carangidae***

Scomberoides commersonianus (talang-talang; talang queenfish): Inhabits coastal and neritic waters upto the edge of the continental shelf.

Trachinotus blochii (snubnose pompano): Inhabits shallow coastal, coral and rocky waters; benthopelagic.

Ulua mentalis (cale-cale trevally): Inhabits shallow coastal areas; benthopelagic.

Seriolina nigrofasciata (black-banded trevally): Inhabits coastal areas;benthopelagic.

Selaroides leptolepis (selar kuning; yellow stripe trevally): Inhabits shallow coastal areas; benthopelagic.

Selar crumenophthalmus (bentong; bigeye scad): Inhabits coastal areas down to 80 m depth; benthopelagic.

S. boops (como; oxeye scad): Inhabits coastal areas coral and rocky reefs; benthopelagic.

Megalaspis cordyla (tetengkek; hardtail scads): Inhabits coastal waters down to 60 m depth; pelagic.

Gnathanodon speciosus (golden toothless trevally): Inhabits shallow coastal waters, coral and rocky reefs; benthopelagic.

Elagatis bipinnulatus (sunglir; rainbow runner): Inhabits coral and rocky reefs of coastal waters; pelagic.

Decapterus russelli (layang; Russell's scad): Inhabits coastal waters and offshore continental shelves; pelagic.

D. macrosoma, (deles; layang scad): Inhabits continental shelves; pelagic.

D. kurroides (momar merah; red tail scad): Inhabits more oceanic eastern Indonesian waters; pelagic.

D. macarellus (momar putih; macarellus scad): Inhabits ore oceanic eastern Indonesian waters; pelagic.

Caranx tille (tille jack): Inhabits shallow waters of coral and rocky reefs; benthopelagic.

C. sexfasciatus (dusky jack): Inhabits shallow waters of coral rocky reefs; benthopelagic.

C. melampygus (bluefin jack): Inhabits coral and rocky reefs; benthopelagic.

C. ignobilis (yellowfin jack): Inhabits coral and rocky reefs; benthopelagic.

Carangoides malabaricus (Malabar cavalla): Inhabits coastal waters, coral and rocky reefs; benthopelagic.

C. ciliaris (longfin cavalla): Inhabits shallow coastal waters and coral and rocky reefs; benthopelagic.

C. chrysophrys (longnose cavalla): Inhabits shallow coastal waters down to 60 m depth benthopelagic.

Atropus atropus (kuweh trevally): Inhabits coastal waters; benthopelagic.

Alepes melanoptera (blackfin crevalle): Inhabits coastal waters; benthopelagic.

A djeddaba (Djeddaba crevalle): Inhabits coastal waters; benthopelagic.

Alectis indicus (threadfin trevally): Inhabits coastal waters; benthopelagic.

Scombroids

The scombroid mackerels (*Rastrelliger* spp) occur throughout the Indonesian waters and constitute the dominant catch of small pelagics along with the scads and the sardinellas.

1. *Scombridae*

Rastrelliger brachysoma (kembung; short-bodied mackerel): Forms large schools in coastal waters; pelagic.

R. kanagurta (banyar; Indian mackerel): Often forms large schools; pelagic.

R. faughni(Inland or Faugh's mackerel): Inhabits coastal waters; pelagic.

BIOLOGICAL BEHAVIOUR

Clupeiformes are typically shoaling fish inhabiting the inshore continental shelves. The shoals may occur in the surface, midwater or near the bottom. Although they are basically pelagic, they may also be benthopelagic in certain seasons or hours of the day. Therefore, it is rather difficult to separate them into pelagic and benthopelagic fish. Clupeids and engraulids very frequently occur in demersal trawl catches in Indonesia. Several species of *Ilisha, Pellona, Ophisthonema, Opisthopterus, Sardinella, and Stolephorus* dominate the tropical demersal catches.

Among the clupeids, the anadromous *Hilsa (Tenualosa) macrura* (*terubuk*) and *Anadontostoma chacunda* belong to the river ascending shads. Most of the 20 species of whitebaits (*Stolephorus*) are coastal shoaling fish. Some of them (e.g., *S.commersoni* and *S. indicus*)enter the brackishwaters occasionally. The strictly coastal and neritic species include *S. heterolobus* and *S. bataviensis. S. tri* is most abundant near river mouths and enters brackishwaters more frequently.

Most of the carangids and scombroids inhabit the coastal waters and are very prominent in the pelagic fisheries of Indonesia. The round scads (*D. russelli* and *D. macrosoma*) occur abundantly in the island chains of the Java Sea, from Karimun Java in the west to Samber Gelap and Lumu-lumu in the Makassar strait and Kangean islands in the east throughout the year, with peak fishing during the rainy season and very poor fishing during the dry season. The smaller scombroids, are less diverse, but of greater fisheries importance than the carangids. *Rastrelliger* forms a very important fishery among the small pelagics.

THE FISHERIES

Methods of Fishing

The fishermen of Indonesia use a number of pelagic gears such as the seines of the payang type (Danishseine), lampara, beachseine and purseseine. In its simplest form, the seine is a net wall consisting of two wings and a section to hold the catch (the bunt or bag), more or less in the centre or on the side. The payang type seine is in vogue since long in Indonesia. Most of the payang and lampara are concentrated in the north coast of Java and Bali Strait, while the rest are scattered in the south of Kalimantan and around Sulawesi, Sumbawa and Lombok Islands. Their fishing grounds are restricted to the coastal waters and the operations take place on a daily basis. The purseseine was introduced in the Java Sea in the early 1970s. The purseseiner fleet increased steadily in both number and the size of the vessels and their operations extended from the traditional grounds in the Java Sea to the Makassar Strait in the east and the South China Sea in the northwest. Most of the fleet are based in the north coast of Java in the major fisheries harbours of Tegal, Pekalongan and Juwana. Purseseiners are the major craft used in the fisheries for the small pelagics in the Java Sea and they land their catches in the above ports. Traditionally the Indonesian fishermen use rumpon as a fish aggregating device for pelagic fishing with payang and purseseine. In addition, they also use the light of paraffin pressure lamps and of electric lamps in combination with the rumpon. Once the fish are landed, they are auctioned and sold to various traders for processing, distribution and marketing.

Purseseine fleet

The purseseine fleet operating in the Indonesian waters especially in the Java Sea, can conveniently be divided into three groups: (1) large purseseiners with inboard engines, (2) small to medium purseseiners with inboard engines and (3) mini purseseiners with outboard engines. In general, the size of the vessels influences their operational tactics and strategies.

(1) *Large purseseiners*: Typically, the large purseseiners are 18 to 30 meters in length, powered with at least a 100 HP inboard engine. Most vessels of this size have fishhold capacity of 50 to 80 mt and stay at sea for 15 to 40 days. They fish not only in the waters of the Java Sea, but also in the Makassar Strait and the Indonesian South China Sea.

(2) *Small to medium purseseiners*: Usually, the small to medium purseseiners fishing in the Java Sea are 15 to 20 meters in length with inboard engines of 35 to 150 HP, carrying capacity of 20 to 25 mt and maximum endurance of 15 days.

(3) Mini purseseiners: Generally the mini purseseiners are 10 to 18 meters length, they use a long shaft outboard engine placed laterally or posteriorly. Their carrying capacity is 1 to 2 mt and their endurances 1 to 3 days. They operate mainly along the Java coast, southeast of Kalimantan and along the coasts of North and Central Sulawesi Provinces facing the Tomini Bay. Their fishing grounds are located in the coastal waters close to their bases.

(4) Other fishing gears: The payang (Danish seine), lampara and beachseines use smaller powered or unpowered boats. They used to be numerous, but since recently they have been diminishing in number due to their modification into more effective mini purseseines. A number of minor fishing gears, e.g., bagan, are also used for the engraulid anchovy fishery both for livebaits and for consumption.

Trends in catches and catch per unit of effort

Catch and effort data facilitate monitoring of fish abundance, but the cpue may often be insensitive to the changes in the abundance of the small shoaling pelagics. The traditional stock assessment methods rely on certain assumptions, which often do not hold good in the case of the small shoaling pelagic stocks. For example, the Verhulst-Pearl type models assume the carrying capacity that determines the maximum (or unexploited) stock size to be a constant. They also assume the effects of the environment on the stock (by effecting reproduction, food supply, larval survival, growth, recruitment, etc.) to be constant or generate a random noise in most population dynamic models. The other models are relevant to single species and assume constant catchability.

The annual fluctuations in catch varied according to species groups. In the decade between 1983 and 1992, the scads ranged from 92 000 mt in 1983 to 196 000 mt in 1992, with peaks in 1985 (173 000 mt) and 1991 (213 000 mt). The mackerels varied from 96 000 mt in 1983 to 177 000 mt in 1992 while the flat sardinellas varied from 105 000 mt in 1983 to 134 000 mt in 1980, before reaching an asymptotic value of about 140 000 mt since 1980. The catch of the round sardinellas decreased from 91 000 mt in 1983 to 51 000 mt in 1986, but regained to 145 000 mt in 1991, before marginally going down to 137 000 mt in 1992. The anchovy catch remained constant at about 105 000 mt from 1983 to 1986, but increased to 137 000 mt in 1991 (Fig. 2). The variations in the other small pelagics during 1983 to 1992 were less marked than those of the dominant ones (Table 1).

The Pekalongan fishing harbour is the most prominent in terms of the weight and the value of the small pelagic fish landed in Indonesia. While the landings of the small pelagics in this harbour reach over 350 to 400 mt per day, the landings in Juwana (both are in north Java) average only about 100 mt per day. In the first decade of the purseseine fishery in the Java Sea, the catches used to be landed in the five major fisheries harbours along the north Central Java Province coast, i.e.,

Tegal, Pekalongan, Batang, Juwana and Rembang. However, over the ten years from 1983 to 1992, the landings in Pekalongan almost doubled from 45 100 mt in 1983 to 86 000 mt in 1992 while in Tegal the landings increased slightly from 10 000 to 16 000 mt. At the same time Pemalang and Batang became insignificant while Juwana became more and more important since 1984, with a landing of 6 400 mt in 1984 to 47 300 mt in 1992 (Fig.3; Table 2). 90 to 95% of the total landings were composed of six predominant commercial categories, i.e., layang (scads), banyar (mackerels), lemuru (round sardinellas), tanjan (flat sardinellas), bentong (bigeye scad) and selar (trevallies) (Table 3; Fig.4).

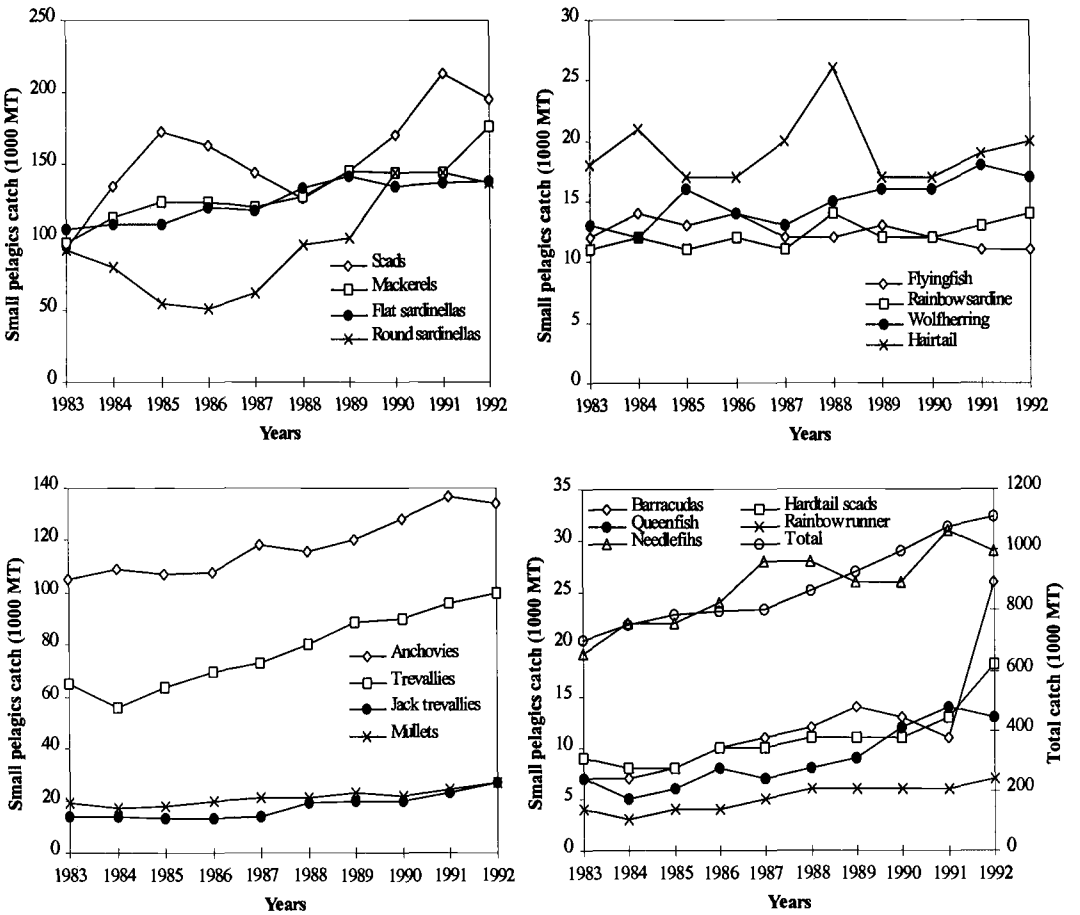


Figure 2. Annual landings of the dominant small pelagics during 1983-1992.

There are three possible relationships between catch per unit effort (CPUE) and abundance: Hyperstability where the CPUE stays high as abundance drops; proportionality where the cpue is proportional to abundance; and, hyperdeflection where the cpue drops much faster than abundance. In almost any fisheries where search is highly efficient, effort concentrates in the areas where fish are most abundant, and where the fish remain concentrated inspite of declining abundance. Purseseining, aided by FADs and lights to concentrate and locate the schools of

small pelagics, could be expected to result in hyperstability. Hyperstability is one of the best and worst features of the small pelagics fisheries. The fishermen do not suffer decreases in the CPUE with decrease in abundance, but the manager is quite concerned with the problems of hyperstability. Therefore, the stocks of the small shoaling pelagics such as the sardines, anchovies, mackerels and horse mackerels are highly variable, and difficult to assess and manage. Some of the major fishery collapses in the world have been ascribed to hyperstability.

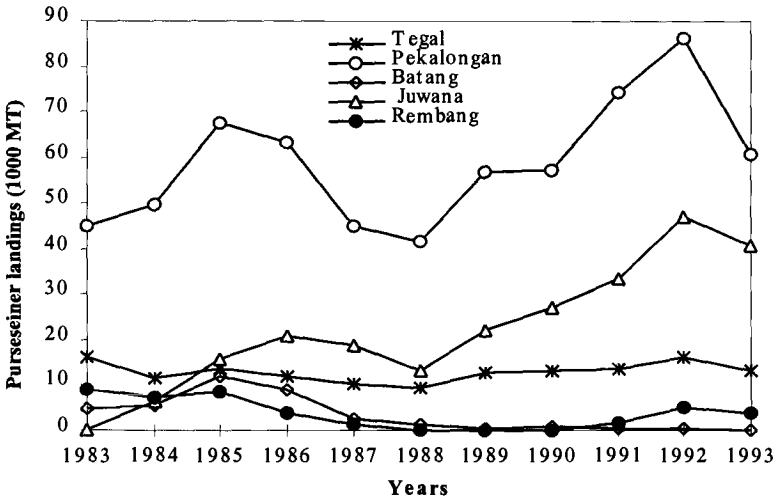


Figure 3. Big purseseiner landing of small pelagics in the fishing ports of Tegal, Pekalongan, Batang, Juwana and Rembang during 1983-1992.

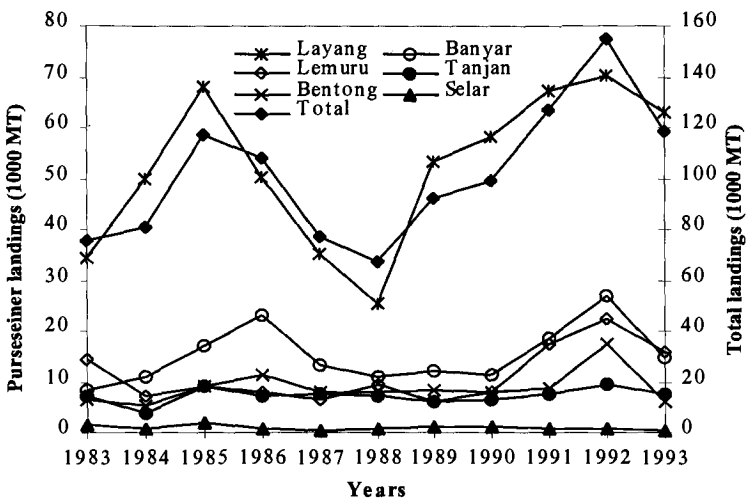


Figure 4. Annual landings of six major categories of small pelagics by big purseseiners in the Java Sea during 1983-1992.

The usefulness of catch and effort data for monitoring abundance could be tested by examining whether the catchability coefficient varied with stock abundance. The annual CPUE for the dominant fishing gears used in the small pelagic fisheries are presented in Table 4 (the number of fishing gears were treated as unit effort). The purseseine effort increased by 54% from 4 500 units in 1983 to 6 900 units in 1994. So far the CPUE for this gear also tended to increase from the 56 mt/ unit gear/year in 1983 to 70 mt/unit gear/year in 1992. For the payang including lampara also the cpue increased from 10 mt/unit gear/year in 1983 to 13 mt/unit gear/year in 1992. The CPUE of the Danishseine varied between 2 mt/unit gear/year and 10 mt/unit gear/year (Fig.5). In general, there were no dramatic changes in the cpue of the main fishing gears for the small pelagics in Indonesia as a whole. So long as the effort remains unevenly distributed in the Indonesian waters, it is quite possible that some areas are exploited so extensively that the cpue may not indicate any clear picture of the impact of fishing.

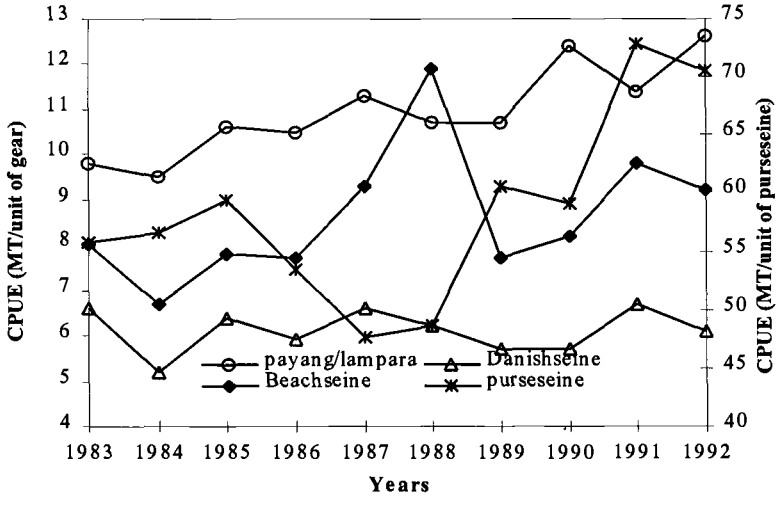


Figure 5. Annual catch per unit of effort of several dominant gears (purseseine, payang/lampara, Danishseine and beachseine) during 1983-1992.

Processing, marketing and disposition of catch

The national fish landings are composed of the small pelagic species (48%), bottom finfish (21%), skipjack, other tuna and other large pelagics (17%), coral seerfish (1%), shrimp (7%), molluscs (2%), other aquatic animals and seaweeds (4%). In general, the economic status of the small pelagic fisheries is determined by local demand for various fish products (in fresh/iced, dried/salted, pindang boiled salted and smoked conditions) in Sumatra, Kalimantan, Sulawesi and chiefly Java. In 1992, 32% of the total catch was processed as dried salted, 6% as pindang boiled, salted, 6% as frozen, 3% as smoked, 2% as fermented products such as belacan, peda and sauce and the rest as canned and as fish meal (Table 5). It is worthy to note that since 1992 two species of scads (*Decapterus macarellus* and

D.russelli) of eastern Sulawesi waters and of Banda Sea are being exported in frozen form to Japan and used as bait in the longline fishery.

The landings in the Pekalongan fisheries harbour (the largest in Indonesia) are divided roughly at 70% and 30% between fresh and salted fish onboard. The processing sector is dominated by traders producing dried salted fish for distant markets as well as for exports to Sri Lanka and Pakistan. There is also a substantially large industry for the pindang boiled salted fish, besides numerous traders involved in fresh fish distribution to distant markets. The landings in the Juwana fisheries harbour (second largest) are divided roughly at 60% and 40% between fresh and salted fish onboard. The processing industry is dominated by the pindang boiled salted fish produced from fresh fish of medium quality while the prime quality fish are sold to fresh fish traders who sell them in the premium Jakarta markets. The fish salted onboard are destined for drying, while those of the poorest quality are converted into fish meal. The landings at Tegal (third big fishing harbour) are relatively small (about 50 to 70mt /day). The processing activities concentrate on dried salted fish for the distant markets in Java and Sumatra. The pindang boiled salted product from all the above three landing sites is particularly popular in central and east Java Provinces, whereas the more heavily salted pindang are sold further west. Jakarta seems to act as a center of attraction for good quality fresh fish while dried salted fish are consumed mainly inland and the most distant markets oustside Java.

In general, marketing of fresh fish and pindang of the fresh small pelagic fish landed in north Java accounts for nearly 75% while a variety of products made by local small scale traders accounts for the remaining 25%. Only small quantities are used as baits in the bottom longline fishery for demersal finfish. Badly spoilt fish and those damaged by poor handling onboard are used for fishmeal production for use in the areas concerned, especially in Batang, a former big landing site close to Pekalongan.

Role of the fishery in food strategy

Indonesian fisheries play a vital national role as a strategic food source. Eventhough fish contribute only 20% of the global requirements of animal protein they supply more than 60% of the total animal protein intake in Indonesia. The average fish consumption has gradually grown from 10.0 kg/capita/ year in 1968 to 14.24 kg in 1981, 15.12 kg in 1988 and 15.9 kg in 1991 and projected to be 16.78 kg in 1994. This consumption level is low, compared to the other countries in the region such as Thailand, Malaysia, Singapore, South Korea, Taiwan and Japan; the rate of increase in consumption is also slow at about 2% annually in recent years.

Since most of the small pelagics landings are consumed domestically, they contribute significantly to the supply of fish protein to the people. The total fish production increased from 1.16 million t in 1968 to 3.54 million mt in 1992. The demand for fish has been estimated by the World Bank to be 4.0 million mt by the year 2000 and 6.0 million mt by 2010. Obviously immediate steps need to be taken to bridge the gaps.

THE BIOLOGICAL AND ENVIRONMENTAL PARAMETERS

Physical environment of the small pelagics

Globally, the tropical ocean includes almost 50% of the total area of all open waters and 30% of the total continental shelf areas, but accounts for only about 16% of the world fish production (Longhurst and Pauly, 1987). Indonesian small pelagic fisheries, like many other tropical fisheries, pose several problems in the understanding of their biological, ecological and physiological characteristics as well as their management. The small pelagics of Indonesia inhabit mostly the continental shelf which is estimated to be 0.49 million km^2 . This area extends from the Sunda Shelf of the South China Sea to the southeast through the Java and Flores Seas, and after an interruption by the deep basin of the Banda Sea, continues into the Sahul Shelf of Northern Australia. The central part of the Sunda Shelf is less than 100 m, but in the southeast, between Sumatra and Kalimantan, the Sunda Shelf is only 10 to 40 m deep. The Sumatra, Java and the south and west coast of Kalimantan border the Sunda Shelf. On the other hand, the lesser Sunda Islands, Sulawesi and Irian Java stand geographically separate from the Sunda Shelf, with their own, much narrower shelf.

The watermasses of the Java Sea are typically of the shallow waters of the continental shelf. Eventhough no major river drains into this shallow sea, its surface water has a salinity of 30 to 32‰.The region of lowest salinity is limited to the islands of Java and Kalimantan, depending on the monsoon regime (Wyrtki, 1961; Soegiarto and Birowo, 1975). The reversal of the monsoon currents is very conspicuous in the Indonesian waters. During the northerly monsoon the South Equatorial Current of the Western Pacific feeds into this circulation through all the east-west passages in the Indonesian archipelago. On the other hand, in August, the southerly monsoon induces strong upwelling along the southern coast of Java and Sumatra (Wyrtki, 1961). The South Equatorial Current of the Indian Ocean brings up nutrient-rich water along the south Java coast and in the Bali Strait, which support an exclusively isolated population of the Bali *lemuru, Sardinella lemuru* (Dwiponggo, 1972; Merta, 1992). During the same period, surface currents from the Flores Sea and the Makassar Strait flow westward into the Java Sea causing upwelling which results in high surface salinities during June and July.

Food and feeding habits

Many species of fish utilize a wide range of food items according to their availability. Little is known about the larval and juvenile diets of many species of fish. The information available on the adult diet of a number of small pelagic species in Indonesia is given in Table 6. The members of the families Elopidae, Megalopidae and Albulidae (Elopiforme) are carnivores and highly active fish predators. *Elops*, however, feeds on benthic organisms. Among the three families of Clupeiformes the members of Chirocentridae are predatory, while those of Clupeidae and Engraulidae are small microphagous fish. There is a change in the diet between phytoplankton and zooplankton depending on the size of the fish. All the genera of Clupeiformes (except *Chirocentrus*) which are classified as predators,

zooplanktivores, herbivores or omnivores are capable of feeding on both phytoplankton and zooplankton. Species of *Ilisha* and *Opisthopterus*, and to some extent *Coilia* are the most common small predatory clupeids. However, a vast majority of clupeoids, particularly the species of *Sardinella, Herklotsichthys, Dussumieria, Setipinna* and *Stolephorus*, feed mostly on zooplankton.

The exocoetid flyingfish (*Cypsilurus*) and the halfbeaks (Belonidae) feed on the macroplankton comprising copepods, larval decapods, molluscs as well as fish larvae. The carangids are diurnally active. The jacks (*Caranx*) are highly predatory while the scads (*Decapterus*), selar (*Selar*) and pompanos (*Trachinotus*) are less predatory.

Species of *Rastrelliger* occur throughout the continental shelves of Indonesia. They feed on macroplankton ranging from small planktonic organisms to pelagic penaeids, fish larvae and juveniles. However, *R.brachysoma* utilizes smaller planktonic items than the *R.kanagurta*.

Biological and population parameters

Limited research capability, availability of relatively few fisheries scientists and a general absence of long historical data on catch, effort and age/size composition of fish have impeded the studies on the biological and population parameters of the small pelagic fish populations in Indonesia. Estimates of growth parameters of some small pelagic species were carried out by analysing length frequency data. The growth, mortality and other parameters of *Decapterus russelli, D.macrosoma, Sardinella sirm, Rastrelliger kanagurta, Selar crumenophthalmus*, and *Selaroides leptolepis* are shown in Table 7.

Reproduction

The limited information available on the maturity , fecundity, and spawning of the small pelagics in the Indonesian waters is outlined here.

Maturity: The onset of maturation is indicated by the rapid development of the gonads, which almost fill the bodycavity, at the ripe stage. The size at first maturity of *D. russelli* is 15.2 cm and 16.1 cm, for male and female respectively, *D. macrosoma* 14.8 cm for male and 15.5 cm for female (Widodo, 1989; 1991), *S.sirm* 18.8 cm for male and 21.0 cm for female (Widodo et. al., 1993), *S. crumenophthalmus* 20.0 cm and 18.0 cm for male and female respectively (Widodo *et. al.*, 1993), *S.gibbosa* 14.7 cm (Atmadja *et. al.*, 1995) and *R.kanagurta* 21.4 cm (Nurhakim, 1993).

Fecundity: Fecundity refers to the number of eggs being readied for the next spawning by a female fish. In this review, fecundity refers to total fecundity, namely, the number of eggs laid during the lifetime of the female. In the Java Sea the fecundity of *S .sirm* is 67 000 to 343 000 eggs, *D.russelli* 29 000 to 49 000 eggs, *D. macrosoma* 69 000 to 106 000 eggs, *S. crumenophthatmus* 42 000 to 48 400 eggs, *R. kanagurta* 82 000 to 134 000 eggs, and *R. brachysoma* 36 000 to 74

000 eggs (Atmadja et. al., 1995). In the Bali Strait, the fecundity of *S. lemuru* is 25 000 to 40 000 eggs; (Merta, 1992), while in the Ambon waters, the fecundity of *Stolephorus heterolobus* is 2 000 to 9 000 eggs, and *S. devisi* 900 to 2 000 eggs (Sumadiharga, 1993) (Table 6).

Spawning: Spawning of tropical fish is often more protracted with one or two peak periods each year. The peak spawning of *D. russelli* in the Java Sea occurs in April/May and August/September, but the spawning of *D. macrosoma* is protracted over several months with peaks in August/September (Widodo, 1988 a & b). In Ambon waters *D. russelli* and *D. macarellus* spawn during April/May to August/September (Andamari and Zubaidi, 1994). In the Java Sea, *S. crumenophthalmus* spawns from April to November, *S .sirm* from February to June (Atmadja et al., 1995), and *R.kanagurta* from February/March to October/November (Nurhakim, 1993). In Bali Strait *Sardinella lemuru* spawns in June/July (Merta, 1992) (Table 6).

MANAGEMENT

Objectives and practices

The objectives of fisheries development are varied, and can be inconsistent but generally include economics, food production and social considerations of which the first two constitute the principal objectives of the Indonesian current 6th five year plan for the period 1993 to 1998. In general, management measures for fisheries include the manipulation of the fisheries resources, subsectors and infrastructures (Larkin et. al., 1984). The manipulation of the fisheries subsectors is usually intended to control fishing effort and the size of fish captured. Among the many possible effort regulations that may be designed to limit the catch to a certain level, those which seem potentially effective in the small pelagic fisheries in Indonesia are the restrictions on the number and capacity of the vessels. The control on the number of vessels may be accomplished by taxes or license fees, while the size and the capacity of the vessels are naturally controlled by the shell owners of most of the major fish landing sites for the small pelagics so that no bigger vessels can enter there.

In the case of the small pelagic fisheries, the generally linear relationship between fishing mortality and fishing effort (as expressed by $F=fq$, where f is effort and q is the coefficient of proportionality or catchability) may be violated by:(i) the variations in the areas inhabited by the stocks, (ii) the heterogeneity of fish distribution within the areas, and (iii) increases in the seiner and skipper skill. Consequently, a management strategy using control on fishing effort to achieve an F_{opt} seems difficult to implement. However, it does not prevent the use of fishing effort management to control fisheries for some other objectives. Closed areas and seasons are relatively easy to enforce and they could be used to control fishing effort as well as the sizes of fish caught. Control of mesh size as a management measure, is often difficult to enforce. Besides, the price that fishermen have to pay for new nets of legal mesh size may not always be acceptable. Mesh size is important to the seiner skipper in order to avoid gilling fish. A mesh that is too

small presents only minor problems, especially when dealing with light fishing which takes a mixed catch of small pelagic fish. Consequently, the enforcement of mesh size regulations is often hard to implement.

In the multispecies small pelagic fisheries, generally, the productivity of individual species fluctuates sharply over a period of several years, while the productivity of the whole fishery remains rather stable. This phenomenon has been observed in the case of the Indonesian small pelagic fisheries also. Therefore, it might be more appropriate to use the total catch of small pelagics rather than the individual catches as the basis for management.

In order to secure the best economic value of fish caught, quality must be ensured right from capture to the consumer. The development of ports handling and processing facilities and improvement of fish-holds onboard the vessels, certainly help add value to the catches and expand the markets for fish products.

Socioeconomically, the small pelagic fisheries have played an important role in providing job opportunities and means of livelihood in Indonesia. Each big purseseiner in the Java Sea can employ 40 to 50 crew onboard while the small ones can employ 10 to 15 crew onboard. In view of the current lack of alternative employment opportunities outside the fishery, management involving the retirement of crew from the fishery is unjustified and probably nonenforceable. Consequently, the creation of new alternatives by the manipulation of the fishery infrastructure could be a constructive supplement or alternative to other management measures.

Quite often assessments based on historical data reveal great uncertainties about sustainable yields, optimum effort levels, effects of various stock enhancement measures, etc. The strategies for dealing with uncertainties in the management of dynamic systems over time include: evolutionary adaptive or trial-and-error adaptive, and active adaptive policies (Hilborn and Walters, 1992). The passive adaptive strategy could be considered optimum when uncertainties are not large. However, it may cause the system to be entrapped into a narrow behaviour. For example, the stock size and yield presumed to be optima, without any data to help decide whether the optima are close to reality. The second policy (evolutionary or trial-and-error adaptive) simply tries a variety of alternative strategies, that hopefully will accumulate experience about which one is best. The third strategy (active adaptive) tries to build up a range of alternative models which are consistent with the historical experience and help determine a policy offering some balance between the losses in short-term yield and in long-term overexploitation. In general, adaptive strategies involve a great deal of effort in stock assessment and modelling. Since stock assessment requires reliable data, improvement in data and methodology is the only means of improving assessment and scientific advice for the sound management of the fishery. In this regard, a number of monitoring, control and surveillance (MCS) activities are being carried out by the Indonesian Directorate General of Fisheries (DGF) in coordination with the institutions involved in fisheries surveillance. Considerable improvements have been made on the quantity and the quality of personnel and infrastructure and in the MCS methodologies and legal aspects of fisheries management. Linkages with the fishermen, other stake-

holders in marine fisheries and institutions controlling environmental quality have been strengthened. Besides government responsibility in management, community control and management of traditional fishing in areas like Sasi in Seram and other areas in Maluku waters are being encouraged in order to actively involve the community in the long-term sustainability of the stocks.

Rules and regulations

The Indonesian fisheries regulations include a number of Acts passed by the parliament (e.g., the Indonesian waters, management of living environment, Indonesian EEZ and fisheries), Presidential decrees (e.g., trawl ban, development of mariculture and water management and conservation) and ministerial decrees (e.g., total allowable catch in the Indonesian EEZ, fishing license, forbidding fishing in coastal waters less than 10 m depth and mangrove areas, closed areas/seasons, etc).

Purseseining was introduced in the Java Sea by the Research Institute for Marine Fisheries through a well known fisherman (Mr. H. Djadjubri) of Batang, in the early 1970s, and it spread quickly to the Bali Strait since 1974 (Merta, 1992). The purseseine fishery got accelerated by the trawl ban which forced the modification of a number of trawlers into purseseiners. As a result the stocks of small pelagics in these two areas have suffered from intensive exploitation, and need to be managed well.

CONCLUSION AND RECOMMENDATIONS

It is difficult to provide realistic estimates of the potential yield of small pelagic resources in the Indonesian waters based on the available database. The small shoaling pelagic stocks which mainly comprise the sardines, anchovies , horse mackerels, and mackerels are not amenable generally to the population dynamic models, thus making their assessment and management particularly difficult and uncertain. Their management becomes difficult because of the changes in the catchability coefficient with stock abundance, as a result of which stock abundance and fishing mortality are difficult to determine from routine effort data.

Accordingly, rational exploitation seems to be the best approach to reduce the potential risk of collapse. This will require that the maximum level of fishing is set below the estimated level required to achieve the maximum equilibrium yield. The fishery should be carefully monitored on the basis of the routine catch and effort data and by independent estimates of abundance through acoustic surveys, where possible.

The approaches to small pelagic fisheries management in Indonesia need to be both resource oriented as well as people oriented so as to fulfill the objectives of resource conservation, production of maximum biological yields and the welfare of the fishermen and their families by improving their standard of living. Management should take into consideration the problems of multispecies stocks, limits of biological yields, optimum effort (costs) and employment, and also address the difficulties arising from the general lack of conventional data, appropriate

institutions, infrastructure and law enforcement. Since there are several drawbacks in implementing measures such as the individual transferable quota system, the traditional methods like the control of fishing effort should be considered. Effort control includes the number, size and engine power of the fleet and also the limitation of light power used in fish aggregations. These measures should be enforced through licensing and taxing the existing and new vessels.

Most of the approaches are oriented to experimental or active adaptive management with moderate changes in fishing effort, which could be monitored and evaluated, prior to attempting other alternatives. In other words, management should be prepared to take early and strong enough actions at the first signs of stock depletion and collapse (reduced distribution range, low recruitment, change in species composition, change in age or size composition of the catches, catch rate decrease, increased catchability, etc.).

Acknowledgements

I wish to express my gratitude to Purwito Martosubroto for encouraging me to write this review, and to Jean Rene Durand, Michael Potier, Subhat Nurhakim and Bambang Sadhotomo of the Java Sea Pelagic Fishery Assessment Project (a tripartite collaboration among Indonesia Agency for Agriculture Research and Development, French ORSTOM and the European Community) for allowing me to use their data on the small pelagics of Java Sea. Thanks are also due to Budi Iskandar for setting out the figures, tables and appendices and to Sudjianto for typing the manuscript.

REFERENCES

Andamari, R., and T. Zubaidi. 1994. Some aspects of reproductive biology of *Decapterus macarellus* in Banda Island, Maluku, Research Institute for Marine Fisheries, Ambon (unpublished).

Atmadja, S.B., B. Sadhotomo, and Suwarso. 1995. Reproduction of main small pelagic species in the Java Sea, p 69-84. In M. Otier and S. Nurhakim (eds) BIODYEX (Biology, Population Dynamics and Exploitation of the Small Pelagic of the Java Sea), PELFISH Project, Jakarta. Workshop on Biology, Population Dynamics and Exploitation of the Java Sea Small Pelagic Fish Resources, Jakarta, 21-25 March, 1994 (in press).

Boely, T., M. Potier, S. Nurhakim, S. Banon, Suwarso, and T. Hariati. 1987. Compilation of the data on the big purseseiners fishery in the Java Sea 1976-1985. ORSTOM- BP PL, Jakarta, Indonesia.

Dwiponggo, A., 1972. Perikanan dan penelitian pendahuluan kecepatan pertumbuhan lemuru (*S.longiceps*) di Muncar, Selat Bali (in Bahasa Indonesia with abstract in English). LPPL 1/72-PL.021/72:117-144.

Dwiponggo, A., T. Hariati, B. Suherman, A.L. Palomares, and D. Pauly, 1986. Growth, mortality and recruitment of commercially important fishes and penaeid shrimps in Indonesia waters. ICLARM Tech. Rep.17:91 p.

Larkin, P.A., *et al.* 1984. Strategies for multispecies management (Group Report), p.287-301. In R.M. May (ed), Exploitation of marine communities.Dahlem onferenzen, Berlin. 367p.

Longhurst, A.R., and D. Pauly. 1987. Ecology of tropical oceans. Acad Press., Inc. New York. 407 p.

Merta, I.G.S., 1992. Population dynamics of "ikan lemuru", *Sardinella lemuru* Bleeker 1853 (Pisces: Clupeidae) in the Bali Straits and its management alternative. Dissertation of doctorate degree, Bogor Agriculture University, Bogor, Indonesia (In Bahasa Indonesia). 201p.

Nurhakim, S., 1993. Biologie et dynamique du BANYAR *Rastrelliger kanagurta* These Teleosteen Scombridae) dans Ia pecheries des grands senneurs en mer de Java. These a l'universite de Bretagne Occidental, France. 106p.

Sadhotomo, B., and S.B. Atmadja. 1985. On the growth of some small pelagic fishes landed by purse seiners at Pekalongan and Tegal between May 1984 to August 1984 (in Bahasa Indonesia with abstract in English). J.Mar. Fish. Res., 33:53-60.

Soegiarto, A., and S. Birowo. 1975. "Atlas Oseanologi Perairan Indonesia dan Sekitarnya," Vol.1 and 2. Lembaga Oseanologi Nasional (in Bahasa Indonesia with abstract in English), Jakarta.

Sudjastani, T., 1994. Population dynamics of chub mackerel in the Java Sea. Mar. Fish. Res. Rep., 7:30-64.

Sudrajat, A., and D. Nugroho. 1983. Study on the biology of yellow-stripe trevally, *Selaroides leptolepis* (Cuv. & Val.) in the Sunda Shelf waters (in Bahasa Indonesia with abstract in English), Jakarta, Indonesia. Mar. Fish. Res. Rep., 29: 79-88.

Suwarso, 1993. Length-weight relationship of the main pelagic fishes of the Java Sea, (STD 10) Java Sea Pelagic Fishery Assessment Project, Jakarta.

Suwarso, B., Sudhotoma and S.B.Atmadja. 1995. Growth parameters and condition factor of the main pelagic species in the Java Sea, p 85-96. In M.Potier and S.Nurhakim (eds) BIODYEX (Biology), Population Dynamics and Exploitation of the Small Pelagic of the Java Sea), PELFISH Project, Jakarta.

Weber, W., 1976. The influence of hydrographical factors on the spawning time of tropical fish. p. 269-281. In K.Tiews (ed.) Fisheries resources and their management in Southeast Asia, German Found for Int.Dev. Fed. Bd. Fish. and FAO.

Widodo, J., 1976. A checklist of fishes collected by R/V Mutiara IV from November 1974 to November 1975. Mar. Fish. Res. Rep. Spec. Rep. Contrib. of Dem. Fish Pro., 1:47-77.

Widodo, J., 1988a Population dynamics and management of "ikan layang", scads mackerel, *Decapterus* spp. (Pisces: Carangidae) in the Java Sea. PhD dissertation. School of Fisheries, University of Washington, Seattle, USA, 150p.

Widodo, J., 1988b, Population biology of Russel's scads (*Decapterus russelli*) in the Java Sea, Indonesia, p. 308-323. In Venema, S.C., J.M. Christensen and D. Pauly (eds), Contribution to tropical fisheries biology. FAO Fish. Rep. 389: 519p.

Widodo, J., 1989. Reproductive biology and harvesting strategy of Indian scads, *Decapterus russelli* (Rupell. 1830) (Pisces Carangidae) of Java Sea. J.Mar. Fish. Res., 53: 89-96.

Widodo, J., 1991. Maturity and spawning of shortfin scads (*Decapterus macrosoma*), (Carangidae) of the Java Sea. Asian Fish. Sci., 4: 245-352.

Widodo, J. Suwarso and R. Basuki. 1993. Preliminary study on the biology and fishery of spotted sardine, *Amblygaster sirm* (Clupeidae) in the Java Sea (in Bahasa , Indonesia with abstract in English). J. Mar.Fish. Res., 72: 21-31.

Wyrtki, K., 1961. Physical oceanography of the southeast Asian waters. NAGA Rep. 2, 195p.

Table 1. Variations in the catch of the dominant small pelagics during 1983 to 1992.

(x1000 mt)

Species	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Scads	92	135	173	163	145	127	146	171	213	196
Mackerels	96	114	125	124	121	128	146	145	144	177
Flat sardinellas	105	109	109	21	118	134	142	135	137	139
Round sardinellas	91	79	54	51	62	95	99	144	145	137
Anchovies	105	109	107	108	118	116	120	128	137	134
Trevallies	65	56	64	70	73	80	89	90	96	100
Jack trevallies	14	14	13	13	14	19	20	20	23	27
Mullets	19	17	18	20	21	21	23	22	24	27
Flying fish	12	14	13	14	12	12	13	12	11	11
Rainbow sardine	11	12	11	12	11	14	12	12	13	14
Wolfherring	13	12	16	14	13	15	16	16	18	17
Hairtail	18	21	17	17	20	26	17	17	19	20
Barracudas	7	7	8	10	11	12	14	13	11	26
Hardtail scad	9	8	8	10	10	11	11	11	13	18
Queenfish	7	5	6	8	7	8	9	12	14	13
Rainbow runner	4	3	4	4	5	6	6	6	6	7
Needlefish	19	22	22	24	28	28	26	26	31	29
Total	**700**	**749**	**784**	**797**	**802**	**867**	**925**	**996**	**1073**	**1109**

Table 2. Landings of small pelagics by big purseseiners in the major fisheries harbours of north Java from 1983 to 1993.

(x1000 mt)

Harbour	Tegal	Pekalongan	Batang	Juwana	Rembang
1983	16.1	45.1	4.7	0.0	9.1
1984	11.5	49.8	5.5	6.4	7.1
1985	13.5	67.6	11.9	15.7	8.6
1986	11.7	63.3	8.8	20.6	3.8
1987	10.1	45.1	2.4	18.5	1.2
1988	9.2	41.4	1.4	13.3	0.0
1989	12.6	56.8	0.6	22.2	0.0
1990	13.0	57.5	1.0	27.0	0.0
1991	13.7	74.3	0.6	33.4	1.7
1992	16.0	86.0	0.5	47.3	5.1
1993	13.1	60.8	0.0	40.8	3.7

Source: Boely *et al.*, 1987; Potier *et al.*, 1991 (STD 5,6,7); 1992 (STD 8,9); 193 (STD 16); 1994 (STD 19).

Table 3. Annual landings of the main commercial categories of small pelagic landed by big purseseiners in the north Java coast from 1983 to 1992.

(x1000 tons)

Year	Total	Layang	Banyar	Lemuru	Tanjan	Bentong	Selar
1983	75.3	34.5	8.3	14.2	7.2	6.4	1.4
1984	80.4	49.8	10.8	7.0	3.9	5.4	0.6
1985	117.3	67.9	17.1	9.0	8.9	8.9	2.0
1986	108.1	50.1	23.0	7.8	7.3	11.5	0.7
1987	77.2	35.0	13.2	6.5	7.4	7.8	0.3
1988	66.8	25.2	10.9	9.4	7.0	7.8	0.9
1989	92.2	53.3	12.1	6.0	5.9	8.2	1.0
1990	98.6	58.2	11.3	7.9	6.6	7.9	1.0
1991	126.9	67.2	18.6	17.5	7.6	8.7	0.9
1992	155.0	70.3	26.8	22.2	9.3	17.2	0.9
1993	118.5	63.0	14.6	16.9	7.7	5.9	0.3

(Sources: Boely et.al., 1987; Potier et al., 1991(STD 5,6,7); 1992 (STD 8,9); 1993 (STD 16); 1994 (STD 19).

Table 4. Annual catch, per unit effort in respect of some dominant fishing gears of small pelagic fisheries in Indonesia during 1983-1992 (Y=yield in mt; f=number of gear units; cpue=y/f=mt/unit year).

YEAR	PURSESEINE			PAYANG/LAMPARA		
	Y	f	CPUE	Y	f	CPUE
1983	250834	4495	55.8	132552	13571	9.8
1984	283066	5005	56.6	142581	15034	9.5
1985	303905	5113	59.4	142026	13378	10.6
1986	307777	5762	53.4	152782	14617	10.5
1987	305814	6426	47.6	162542	14358	11.3
1988	297108	6114	48.6	180545	16818	10.7
1989	378505	6253	60.5	186364	17399	10.7
1990	395857	6715	59.0	198764	15980	12.4
1991	441135	6053	72.9	206127	18116	11.4
1992	441135	6929	70.5	206098	16362	12.6
Year	DANISHSEINE			BEACHSEINE		
	Y	f	CPUE	Y	f	CPUE
1983	19882	2999	6.6	62885	7823	8.0
1984	19529	3779	5.2	60206	8958	6.7
1985	19683	3080	6.4	69366	8948	7.8
1986	15401	2598	5.9	75363	9740	7.7
1987	16054	2438	6.6	90839	9765	9.3
1988	18959	3043	6.2	120080	10065	11.9
1989	17608	3098	5.7	86694	11318	7.7
1990	22172	3900	5.7	85729	10430	8.2
1991	26161	3926	6.7	102853	10499	9.8
1992	22394	3652	6.1	94966	10278	9.2

Table 5. Disposition of marine fishery products during 1983-92.

(1000 mt).

Disposition	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**
Fresh	782	854	879	929	1061	1188	1230	1266	1323	1326
Dried salted	540	561	637	665	627	667	660	683	746	850
Boiled salted	104	121	122	125	120	84	118	121	134	157
Belacan	43	33	41	39	45	52	55	57	53	52
Peda	8	11	7	15	8	7	14	14	12	13
Sauce	0	0.1	0.5	1	2	1	0.3	1	1	1
Smoked	77	45	44	53	55	43	45	52	61	77
Others	35	16	17	20	17	16	16	21	18	18
Frozen	60	46	59	67	65	82	85	109	122	150
Canned	17	17	8	6	13	12	28	26	33	22
Fish meal	14	9	6	3	4	17	20	20	34	27
Total	**1683**	**1713**	**1819**	**1923**	**2017**	**2170**	**2272**	**2370**	**2538**	**2692**

Table 6. Physical environment, food and feeding habits and reproduction of small pelagics in Indonesian waters.

Fish Group	Physical Environment	Food and Feeding Habits	Reproduction
Elopiformes	Continental shelves, sometimes entering brackishwater	Highly active predator; also feed on benthic organisms.	Leptocephalus larvae
Elopidae	Coastal waters of Malacca, Strait, sometimes entering brackishwater	Carnivorus adults; also feed on benthic organisms	
Megalopidae	Coastal waters of Sumatera, Java, Kalimantan and Iriyan Jaya	---------idem-------	
Albuloidae	Continental shelves of Sunda and Sahul	---------idem-------	
Clupeiformes	Continental shelves; very frequently enter brackishwater; some are anadromous; coastal, but tolerant of low salinity; not all species are euryhaline	Usually microphagous on planktonic food, but include zooplankton feeders, omnivores and predators also.	
Chirocentridae	Continental shelves	Predators	
Clupeidae	Continental shelves; shoaling fish; *Hilsa macrura* and *H.ilisha* are anadromus.	Microphagous as well as zooplankton (copepods) feeders.	Partial spawners. *A sirm*: fecundity 67,000-343,000 eggs; length at first maturity 18.8 cm & 20.1 cm for male & female respectively; spawning extends from February to June. *S.lemuru*: spawns in June-July in Bali Strait; fecundity 25,000 to 40,000 eggs.
Engraulidae	Continental shelves (coastal and neritic); some enter brackish-water	Microphagous, as well zooplankton feeders	*Stolephorus heterolobus*: fecundity 2,000 to 9,000 eggs. *S.devisi*: 900 to 2,000 eggs (In Ambon)

Table 6. continuation.

Fish Group	Physical Environment	Food and Feeding Habits	Reproduction
Atheriniformes	Neritic	Predators. Diets comprise macroplankton (copepods, larval decapods, molluscs. salps,siphonophore, larvae and small fish.	Deposit their eggs on demersal solid substrates.
Exocoetidae	Neritic		
Belonidae	Neritic	Macroplankton.	
Perciformes	Continental shelves including coastal waters.		
Carangidae	Neritic	Diurnally active. Strong predators include jacks and trevallies (Caranx). Less active predators include *Decapterus* and *Selar*. Roundscads feed almost entirely on zooplankton (copepods and crustaceans)	Spawning season of *D.russelli* in Java Sea extends from April to June *D.macrosoma* spawns from May to October/December. Fecundity of *D.dusselli is* 29,000 to 49,000 eggs, *D.macrosoma* 68,000 to 106,000 eggs, and *Selar crumenophthalmus* 42,000 to 484,000 eggs; partial spawners. Spawning season from April to November. In Ambon waters *D.russelli* and *D.macarellus* spawn in April/ May to August/ September
Scombridae	Continental shelves *Rastrelliger kanagu-rta* is relatively offshore (>32%) *R.brachysoma* and *R.faughni* are more neritic.	*Rastrelliger* are eletic feeders and omnivorous; primarily micro-and macrophagous.	*R.kanagurta:* fecundity 82 000 to 134.000 eggs; size at first maturity 21.2 cm and 23.0 cm for female and male respectively; Spawning season from February/ March to October *R.brachysoma*: fecundity 36,000 to 74,000 eggs.

Table 7. Biological and population parameters (length in cm; others on annual basis) of six major small pelagic fish in the Java Sea (D.r=*D. russelli*, D.m = *D. macrosoma*, S.s = *S. sirm*, R.k = *R. kanagurta*, S.c = S. *crumerophthalmus*, S.l = S. *leptolepis).*

Species	Parameters							L-W relation ($W=aL^b$)	
	Lα	K	I_c	Z	M	F	F/Z= E	a	b
D.r	25.9-27.0 25.5-26.6 24.7-28.3	0.95-1.20 0.7-1.1 0.39-0.50	11.82 20.72 14.8	3.73-8.21 0.96-2.24	1.79-2.18 0.65-1.19	1.65-6.18 0.31-0.96	0.48- 0.75 0.57	0.0106	2.962[3)]
D.m	25.40 23.1-24.4 25.6	0.98 0.73-0.87 1.05[4)]	16.6 16.3	6.19 3.13-8.71	1.86 0.62-1.73	4.33 2.51-2.90	0.70[1)] 1.45- 0.83	0.0104 0.0034	2.938[3)] 3.442[10)]
S.s	25.80 20.5-23.3 25.2 23.0	1.15 1.3-2.8 1.18 0.96	18.75	5.80	2.06	3.74	0.65[1)]	 0.0112 0.0061	 3.078[6)] 3.280[10)]
R.k	25.80 26.22 23.9	1.63 0.65 2.78	18.77 18.00	 5.08 4.0	 2.58 1.0	 2.50 3.0	 0.49[1)] 0.75	0.0064 0.0093 0.0064	3.167[5)] 3.190[8)] 3.3065[10)]
S.c	25.90 25.8-26.7 26.9	1.25 0.6-0.8[2)] 1.35	17.90	5.56	2.17	3.39	0.61[1)]	0.0144 0.0074	3.1017[7)] 3.334[10)]
S.l	22.0 18.6	1.20 0.19	9.88	5.75	2.21	3.54	0.62	0.0104	3.0429[10]

1) Dwiponggo *et al.* (1986), 2) Suwarso *et al.* (1995), 3) Widodo (1988 a &b), 4) Sandhotomo and Atmadja (1985), 5) Nurhakim (1993), 6) Widodo *et al.* (1993), 7) Widodo *et al.* (1993), 8) Sudjastani (1994), 9) Sudrajat and Nugroho (1983), 10) Suwarso (1993).
These parameters could be used as inputs in the assessment of stocks and yields in respect of the populations dealt with in Table 7.

REVIEW OF THE SMALL PELAGIC RESOURCES AND THEIR FISHERIES IN JAPAN

by

Tokio Wada
National Research Institute of Fisheries Science
2-12-4, Fukuura, Kanazawa-ku, Yokohama, Japan 236

Abstract

The catch of the small pelagics fluctuated between 0.6 million mt and 6 million mt during 1912 to 1994. The catches of the Japanese sardine, Japanese anchovy and Jack mackerel severely fluctuated. Large and medium purseseiners contributed 51% to 73 % to the small pelagic landings during 1985 to 1994. More than 90% of the sardine catch and about 50% of the mackerels are used as feed in fish culture or processed into fishmeal and fish oil. The methods employed to assess the stock abundance are briefly discussed in the paper. All the major fisheries are subjected to licensing system. Japan has introduced a management system based on the total allowable catch which is apportioned through individual quotas.

INTRODUCTION

The small pelagic fishes have been an important source of protein for the Japanese people. They are comsumed as perishable or various types of processed human foods, as food for aquacluture and livestock, as fertilizers for agriculture, and as materials of industrial products, such as fishmeal and oil. Therefore, stock fluctuations of these fishes have affected not only fisheries which directly catch the fishes, but also the related industries. In recent years, the collapse of the Japanese sardine stock has given a big shock to the related fisheries and industries. Stock fluctuations in the small pelagics are closely related to the global ocean climate changes (Lluch-Belda *et al.*, 1989; Bakun, 1996), and the influence of fisheries on the fluctuations has not been so large. Developed fisheries in recent years, however, tended to easily overexploit the stock when its abundance was low. In Japan, the management policy for the small pelagic fisheries has essentially been through effort control. However, with the ratification of the United Nations Convention on the Law of the Sea in 1996, the Japanese government has newly introduced a management system based on total allowable catch (TAC) for fisheries. The stocks of and the fisheries for the small pelagic fishes around Japan have been well described in a review by Chikuni (1985). There are many reports on stock fluctuations and ecological changes in respect of the Japanese sardine (e.g., Kuroda 1991; Wada *et al.*, 1995; Watanabe *et al.*, 1995; 1996). Therefore, this paper focuses on a brief review of the Japanese fisheries for the small pelagics including their utilization in recent years, the present management system based on TAC and the present status of stock assessment for setting the TAC.

THE MAJOR SMALL PELAGIC RESOURCES

The major small pelagic fishes distributed around Japan and exploited by the domestic fisheries include the Japanese sardine (*Sardinops melanostictus*), Japanese anchovy (*Engraulis japonicus*), round herring (*Etrumeus teres*), chub mackerel (*Scomber japonicus*), spotted mackerel (*Scomber australasicus*), jack mackerel (*Trachurus japonicus*), scads (*Decapterus spp.*), Pacific saury (*Cololabis saira*) and Pacific herring (*Clupea pallasi*). The sum of the catches of these species fluctuated from 0.6 million mt to 6 million mt, accounting for 2% to 58 % of the total catch of marine fisheries in Japan (Fig. 1). Among these species, the Japanese sardine, Japanese anchovy, chub mackerel and Pacific saury are especially important because of the size of their catches. On the other hand, the annual catches of round herring, spotted mackerel and scads are relatively low and stable. The annual catches of Pacific herring in Hokkaido and northern Honshu have been high in the latter half of the 19th century and peaked to 1 million mt in 1897. Through the early half of the 20th century, however, the catches decreased rapidly, but after the 1960's, they tumbled to a seriously low level.

DISTRIBUTION AND MIGRATION

The spawning grounds of the Japanese sardine, Japanese anchovy, chub mackerel and Pacific saury, which have relatively high population abundance, occur in the coastal to the offshore waters off the southwestern Japan. The feeding grounds are located in the waters off the northeastern Japan including the northern part of the Japan Sea and the southern part of the Okhotsk Sea. They migrate between the spawning and the feeding grounds seasonally. The range of the migration changes with their population abundance. The changes are remarkable in the Pacific Ocean.

The Japanese sardine in the Pacific Ocean (the Pacific population) show large changes in their migration pattern in accordance with their abundance (Wada and Kashiwai, 1991; Kuroda, 1991). If the abundance is high, the immatures and the adults expand their disribution to the central part of the north Pacific. The fishing grounds also expand to the waters off Hokkaido to Kuril Islands. The major spawning grounds shift from the coastal waters off the southwestern Japan to the offshore waters off the southern Kyushu and to the main stream of the Kuroshio Current. On the other hand, in the low abundance period, the northern limit of the feeding grounds retreats to the waters off the northern Honshu. The fishing grounds off Hokkaido disappear, and the main spawning grounds retreat to the coastal waters.

The round herring, spotted mackerel and scads which have relatively low population abundance, distribute in the coastal to the offshore waters off the southwestern Japan, and their migration ranges are relatively small. In the past, almost all the herrings caught in the Japanese waters were the spawning adults of the Hokkaido-Sakalin stock. However, with the stock decline through the 20th century, the spawning grounds of the stock around Hokkaido have almost disappeared. The present targets of the herring fisheries in northern Japan are the immature fishes which come from the small spawning grounds in Sakalin, and the small local populations spawning along the coasts and in the blackshi lakes around Hokkaido.

FISHERIES AND UTILIZATION

Trends in catches

Figure 2 shows the longterm changes in the species composition of the catches of major small pelagic fishes around Japan from 1912 to 1994, while Table 1 gives the annual catches of the major five species in the last decade (1985-1994), excluding the Pacific herring. The Japanese sardine show two significant catch periods in the 1930's and 1980's, but very low catches in the 1960's. The catch increased remarkablly since 1973, recording a historical high of 4.5 million mt in 1988. After the peak, the catch decreased rapidly with the stock decline by the successive recruitment failures from 1988 to 1991. The estimated catches in 1995 and 1996 were 660 000 mt and 300 000 mt, respectively.

The annual catches of the Japanese anchovy were 300 000 mt to 400 000 mt in the 1960's. The catch decreased in the 1970's and varied from 140 000 mt to 220 000 mt in the 1980's. Since 1988, the catch increased with the recovery of the stock and kept a high level at about 300 000 mt, excluding 1993 and 1994.

The catch of the mackerels is the sum of the catches of the chub mackerel and the spotted mackerel, where the former is the most predominent. The catch increased in the 1960's and kept a high level of over 1 million mt in the 1970's. It decreased through the 1980's and dropped to a bottom of 255 000 mt in 1991. In recent years, the catch recovered and reached 600 000 mt each in 1993 and 1994, but consisted almost of the immature fish of age 0 to 2 years. The stock biomass is still very low, especially in the Pcific Ocean.

The catch of the jack mackerel was high at about 500 000 mt in the 1960's. It decreased throughout the 1970's and dropped to a minimum of 54 000 mt in 1980. However, it increased again after the latter half of the 1980's and recovered to over 300 000 mt in the 1990's.

The annual catch of the Pacific saury increased to 600 000 mt in the 1950's with the introduction of a new fishing gear, the stick-held dipnet, but decreased in the 1960's and fluctuated from 100 000 mt to 400 000 mt in the 1970's. It gradually increased after 1981 and kept a relatively high level of 260 000 mt to 300 000 mt in the 1990's.

It has been pointed out that the sardine populations vary inversely with the anchovy populations in temperate waters (Liuch-Belda *et al.*, 1989). Fig. 2 clearly shows that there is a species alternation among the major small pelagics in the following sequence: the mackerels (chub mackerel and spotted mackerel, Group A) were replaced by the Japanese sardine (Group B); the sardine were replaced by a group of Japanese anchovy, jack mackerel and Pacific saury (Group C); and the three species in group C were replaced by the mackerels. Matsuda *et al.*, (1991; 1992) proposed an interspecific competition model for groups A, B, and C as a hypothesis for the species replacement. If species A causes a decline in the population of B, B causes a decline in C, and C causes a decline in A. The model predicts that the abundance of these three groups fluctuates forever and dominates in a cyclic order.

The annual catches of the round herring and scads have been relatively low and stable, ranging from 30 000 mt to 68 000 mt and 48 000 mt to 109 000 mt respectively in the last decade (1985-1994). As regards the spotted mackerel, the annual catch is not separated from the catch of the chub mackerel in the statistics, but not so large as mentioned above, yielding annually only 50 000 mt to 100 000 mt in the last decade.

Major fisheries for small pelagics

Table 2 shows the average composition of the catch by the type of fisheries from 1985 to 1994. Large and medium type purseseines constitute the most major fishing gears for the Japanese sardine, mackerels and jack mackerel, accounting for 51% to 73 % of total catches of these species. In the case of the Japanese anchovy, the small and medium type purseseine fisheries and boatseine fisheries accounted for 33% and 29 % respectively of the catches. Among the small pelagics the anchovy are the smallest in fishable size and their fishing grounds are usually located in the coastal waters. Therefore, the relatively small scale fisheries are appropriate for the anchovy. On the other hand, almost 99% of the Pacific saury was caught by the stick-held dipnet fishery, which is one of the liftnet fisheries with fish attracting lamps.

An operation unit of the medium and large type purseseine fishery consists of a netting boat, one or two searching or fish attracting boats and two to three carrier boats. Among the different size classes of netting boats, 50 to 99 gross mt and >100 gross mt boats are the most frequent. In the last decade (1985-1994), the Japanese sardine occupied 43% to 83% of the total catch of the medium and large type purseseine fishery. The number of operation units and fishing trips gradually decreased through the last decade. In 1994, they recorded 63% and 51% respectively. In spite of such a decline in the fishing effort, the CPUE (catch per trip) decreased with the decline of sardine population. The CPUE in 1994 came down to 63% of the peak of 279 mt per trip in 1988 (Table 3).

Processing and marketing

Since the pelagic fishes distributed around Japan show large fluctuations in their population abundance and catch, the style of utilization changes with the stock abundance and catch. Table 4 gives the percentage of landings by types of utilization and fish species in 1994 when the catch level of sardine was still high, and the catches of other species were in historical middle levels. More than 90% the of sardine catch was used as food for fish aquaculture or processed to fishmeal and fishoil. The proportion consumed as perishable human foods and food products was very small. In respect of the mackerels and jack mackerel, the proportions consumed as human foods were larger than that of the sardine. But about half the landings of these fishes were used as feed for fish cluture. On the contrary, about 40% of saury was consumed as perishable human foods and another 40% as food products.

The late larvae and early juveniles of the sardine and anchovy smaller than about 35mm in total length, are one of the traditional foods called *shirasu* in Japan. The *shirasu* are caught by small boatseines and round haulnets in the coastal waters along the southwestern Japan, where the catch in the last decade ranged from 60 000 mt to 100 000 mt.

Export and import

In the international trade of fisheries products, items, amounts and the balance of export and import reflect the changes in the catches globally. Table 5 shows the details of the export and import of the products of small pelagics from 1985 to 1994 in Japan. In the last decade (1985-1994), Japan exported chilled and frozen sardine, mackerels and saury, and also canned sardine and mackerels to Asia and African countries. Fish meal and fish oil mainly made from sardine are also important export products. The amount of these products exported gradually decreased with the decline in the catches of the sardine and mackerels. On the other hand, the import of chilled and frozen Atlantic mackerel (*Scomber scombrus*) after 1985 increased with the decrease in the mackerel catch around Japan. The import of fishmeal from Chili and Peru, where the anchovy stock has recovered in recent years, has also increased to cover the decrease in domestic production.

FISHERIES MANAGEMENT SYSTEM FOR THE SMALL PELAGIC FISHRIES

Fisheries license system

Historically Japan carried out fisheries management by restricting fishing effort or fishing practices. In the present legal system, almost all the major fisheries are categorized as licensed fisheries, requiring a license or recognition from the administrative organizations for fishing. Issuing the license means an administrative action to lift the prohibition in a specific case for the generally prohibited fishery in view of the imperative need for the conservation of the fishery resources and adjustment of fisheries. The licensed fishery is divided into two types: the "Minister licensed fishery", which is licensed or recognized by the Minister of Agriculture, Forestry and Fisheries based on the provisions of the Fisheries Law. The other is the "Governor licensed fishery", which requires the license or recognition from the Governor of the Prefecture according to the regulations of the prefectures. In the licensed fisheries, various regulations are attached as the conditions for the license or recognition.

Input control in the fisheries for the small pelagics

The medium and large type purseseine fishery belongs to the Minister licensed fishery. Under the present regulation system of this fishery, the operation area around Japan is divided into eight blocks. The number of license, number of vessels in an operation unit, actual fishing area and fishing season are restricted by each block. The stick-held dipnet fishery for the Pacific saury using a vessel more than 10 gross mt is conducted under the recognition of the Minister. This fishery is the only fishery permitted to catch saury in the north Pacific off Japan. With the recognition, the number of vessels, open day of fishing season and total power of fish attracting lamps are regulated.

The small and medium type purseseine fishery and boatseine fishery are the governor licensed fishery. Almost all the vessels are 5 to 40 gross mt size. The number of license, fishing area and fishing season are restricted by prefecture in the waters under the prefectural jurisdiction.

These restrictions have been focused on the adjustment of the operations among the fisheries overlapping the fishing grounds and the target species. Therefore, the function of adjusting the fishing effort corresponding the stock level, has not operated well enough. The fishing effort and the CPUE decreased to 51% and 63 % of the peak values, respectively, with the rapid decline in the sardine population. However, only 84 % of the license was cut down in this period, decreasing it from 330 in 1985 to 278 in 1994.

Outline of TAC system as an output control

Introduction of TAC system: Japan ratified the United Nations Convention on The Law of The Sea in 1996. With the ratification, Japan establishes its economic jurisdiction over the 200 miles exclusive economic zone (EEZ), and begins a new fisheries management system based on TAC in the EEZ, in addition to the previous management system by fisheries license. The target species for management by the TAC in 1997 are the Japanese sardine, mackerels (chub mackerel and spotted mackerel), jack mackerel, Pacific saury, walleye pollock (*Theragra chalcogrammus*) and snow crab (*Chionoecetes opilio*). The TACs for the chub mackerel and spotted mackerel are combined and a common TAC set for the mackerels. The two species are not separated in the catch statistics as the external differences are very slight and it is difficult to separate them on the vessels and landing port. The Japanese common squid (*Todarodes pacificus*) will be added to the target from 1998.

Setting and Allocating TAC:The process of TAC setting and its allocation to fisheries is as follows:

A. With cooperation from the prefectural research organizations, the government research institutions assess the target stocks, calculate the allowable biological catches (ABCs), and then recommend the ABCs to the government as the scientific basis for the TAC.

B. In consultation with the representatives of the fishermen, and in consideration of the situation of the fisheries concerned, the government sets the annual TAC by stocks, based on the ABCs.

C. In consultation with the prefectural governments, and in consideration of the results of the catches by fishery, the government allocates the TAC to the Minister licensed fisheries concerned, fisheries for foreign countries and Governor licensed fisheries in each prefecture. The TACs allocated to the Governor licensed fisheries in each prefecture are managed by the prefectural government.

Management of TAC: In the new legal system established with the ratification of the United Nations Convention on the Law of the Sea, the national and prefectural governments are able to allocate the TAC to the individual fisherman (i.e., Individual Quota (IQ) system). However, in order to adjust the new TAC system with the previous management system by fisheries license, both level of the government administration adopt the open access system among the licensed fishermen concerned, as a managing method of TAC.

STOCK ASSESSMENT AND ABC CALCULATION

Estimating abundance

The present methods of estimating abundance and biological reference points (BRPs) for the ABC calculation of the major pelagics in Japan are summarized in Table 6. Some biological and population parameters are also listed. Virtual population analysis (VPA) including Pope's (1972) cohort analysis is a common method for the abundance estimation in respect of the sardine, mackerel and jack mackerel which have relatively long life spans. Age is usually determined by scale reading. In many cases, the natural mortality coefficients (M) are estimated by some statistical relationships between M and life span (λ) of target species. Tanaka (1960) suggested the following formula, $M=2.5/\lambda$ and Kawai (1987) proposed the following relationship, $M>2/\lambda$.

Detailed catch and effort data for stick-held dipnet fishery for the Pacific saury are available. In addition, the catchability coefficient of stick-held dipnet was estimated from the changes in the relative abundance with the shifting of the fishing grounds (Matsumiya and Tanaka, 1976). Therefore, the saury biomass in fishing grounds is simply calculated by dividing the catch by the rate of exploitation. The rate of exploitation is given as the product of the catchability coefficient and the overall fishing effort. Test sampling by drifting gillnets shows occasional dense schools of the saury outside the fishing grounds. The total biomass is estimated from the relative abundance based on the test sampling inside and outside the fishing grounds.

In the southern Pacific stock of the Japanese sardine occurring in the Pacific waters along the southern Japan, the spawning biomass is estimated from the annual egg production. In this method, the total fecundity of a female in a spawning season is calculated by the size distribution of the oocytes in the gonad. The number of oocytes in the final development stage and the number of peaks in the ova size distribution are recognized as batch fecundity and the number of spawning in a season, respectively. If we know the age composition of the spawning biomass and the relative fecundity of a female by age, the total egg production could be divided by age, and the survival rate between two successive ages could be calculated. The advantage of this type of method is its independence from the fishery data. The daily egg production method (DEPM, Lasker [ed.], 1985) is more appropriate for estimating the spawning biomass of fish. However, it has not yet been conducted in Japan.

Biomass measurement by acoustic surveys has been tried for the Japanese sardine and other small pelagics in the feeding and spawning grounds. In the 1980's when the sardine population was at a high level, acoustic survey was useful for assessing the available stock abundance of sardine in the fishing grounds off Hokkaido before the fishing season (Wada, 1994). In many cases, however, the estimates of biomass sometime quite differ from the estimates by other methods such as the VPA.

BRPs and ABC calculation

Outline of BRPs: The purpose of fisheries management is to avoid overfishing and to achieve the MSY. In general, there are two types of overfishing, recruitment overfishing

and growth overfishing. To avoid recruitment overfishing is more essential to keep the stock level. In the fisheries management before the 1980's, the F_{msy} based on the surplus production model and the F_{max} and $F_{0.1}$ based on the yield per recruitment (YPR) model have been conventionally used as the biological reference points (BRPs) for calculating the ABC. The YPR model does not consider the changes in the spawning and recruitment relationship, while growth and recruitment are not distinguished in the surplus production model. Therefore, the BRPs based on these models are not enough for the purpose of avoiding recruitment overfishing. On the other hand, the spawning per recruitment (SPR) analysis has been focused as a method to determine the appropriate exploitation level, enough to avoid recruitment overfishing (Goodyear, 1993). The details of BRPs are well documented by Caddy and Mahon (1995) in the FAO Fisheries Technical Paper No.347.

Concept of management by SPR: For the persistence of a fish population, fishing should not reduce the spawning per recruitment (SPR) below a threshold level that is necessary for replacement. If we can adjust the SPR as a reciprocal of the recruitment per unit of spawning (RPS) estimated from the spawning and recruitment relationship, the successive generations of the population will replace each other on average (Sissenwine and Shephard, 1987; Mace and Sissenwine, 1993). The value of SPR is usually expressed as a percentage (%SPR) to the value of SPR which is expected when there is no fishing ($SPR_{F=0}$). $F_{\%SPR}$ is the fishing mortality coefficient corresponding with a %SPR.

BRPs and ABC calculation in Japan: The present objective of fisheries management based on the calculation of ABC for fixing the TAC of the target species is to achieve the MSY level and to keep the present level of target stock abundance. In the case of fluctuating populations, the average MSY level should be recognized from the average stock abundance and the average fishing mortality coefficient, as determined by the BRP method. In almost all the cases of ABC calculations, the $F_{\%SPR}$ values are used as BRP (Table 6). The $F_{\%SPR}$ corresponding to the median of RPS in the longterm will be a target reference point for achieving the MSY level, and the $F_{\%SPR}$ corresponding to the median of RPS in recent years will be a BRP to keep the present stock level. In the case of the chub mackerel in the northern part of the Pacific waters (the Pacific substock), 40%SPR will be appropriate as a long range target for sustaining the population (Wada *et al.*, 1996). In those cases where the recent recruitment levels are high and there is no danger of recruitment overfishing, $F_{0.1}$ is also adapted for avoiding growth overfishing (e.g., chub mackerel in East China Sea and Japan Sea). In the case of the Pacific saury, F=M is used as BRP because of the short lifespan.

CONCLUSIONS AND RECOMMENDATIONS

An inevitable problem of the TAC system by open access is the discard of small-sized or immature fishes. In the Pacific stock of the chub mackerel, the recent catches were biased towards the immature fishes of age 0 to 2 years, resulting in very deleterious influence on the recovery of the stock (Matsuda *et al.*, 1992; Wada *et al.*, 1996). The TAC system may improve the situation. The ITQ system will be a good solution to this problem. Under this system, it will be expected that the fishermen schedule the fishing operations with the migration and growth of fishes, and avoid the unnecessary competition among them.

If the species alternation among the small pelagics is an inherent nature of the community of the small pelagics, to concentrate fishing on the present dominant species, is a reasonable management policy arising from the competition model. Based on the species composition of catches (Fig. 2), it is evident that after the decline in the Japanese sardine, the populations of the Japanese anchovy, jack mackerel and Pacific saury have become dominant up to the present. The present fishery license system, however, does not permit the purse seine fishery to catch the saury. This is the reason why the purseseine fishery still fishes the chub mackerel stock even at its low level. To use the pelagic fish stocks totally and reasonably, it will be necessary to lighten the regulation of the target species for a specific fishery.

One of the difficulties of fisheries management for the small pelagic fishes is the uncertainty of population fluctuations. The SPR analysis supposes an equilibrium condition between the egg production of parents in a year and the total egg production from the cohorts provided by the adults. However, it considers the issues of stock fluctuations, and is a better means of determining the BRPs for the small pelagic stocks.

REFERENCES

Bakun, A. 1996. Patterns in the ocean. Calf. Sea Grant/CIB, San Diego, U.S.A. 323p.

Caddy, J.F. and R. Mahon. 1995. Reference points for fisheries management. FAO Fish.Tech. Pap., No.347: 83p.

Chikuni, S. 1985. The fish resources of the northwest Pacific. FAO Fish. Tech. Pap., No.266: 190p.

Goodyear, C.P. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. pp. 67-82. In: Smith, S.J., J.J. Hunt, and D. Rivard [ed.]. Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci., 120.

Kawai, T. 1987. A study on variability of marine teleost resources from a viewpoint of comparative ecology. Bull. Tokai Reg. Fish. Res. Lab. 122:49-127.

Kuroda, K. 1991. Studies on the recruitment process focussing on the early life history of the Japanese sardine, *Sardinops melanostictus* (Schlegel). Bull. Natl. Res. Inst. Fish. Sci. 3: 25-278.

Lasker, R. [ed.]. 1985. An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*. NOAA Tech. Rep. 36: 99p.

Lluch-Belda, D., R.J.M. Crawford, T. Kawasaki, A.D. MacCall, R.H. Parrish, R.A. Schwartzlose, and P.E. Smith. 1989. World wide fluctuations of sardine and anchovy stocks: the regime problem. S. Afr. J. Mar. Sci. 8: 195-205.

Mace, P.M. and M.P. Sissenwine. 1993. How much spawning per recruit is enough? pp. 101-118. In: Smith, S.J., J.J. Hunt, and D. Rivard [ed.]. Risk evaluation andbiological reference points for fisheries management. Can. Spec. Publ. Fish.Aquat. Sci., 120.

Matsuda, H., T. Wada, Y. Takeuchi, and Y. Matsumiya. 1991. Alternative models for species replacement of pelagic fishes. Res. Pop. Ecol., 33: 41-56.

Matsuda, H., T. Wada, Y. Takeuchi, and Y. Matsumiya. 1992. Model analysis of theeffect of environmental fluctuation on the species replacement pattern of pelagic fishes under interspecific competition. Res. Pop. Ecol., 34: 309-319.

Matsuda, H., T. Kishida, and T. Kidachi. 1992. Optimal harvesting policy for chub mackerel (*Scomber japonicus*) in Japan under a fluctuating environment.Can. J. Fish.aquat. Sci. 49: 1796-1800.

Matsumiya, Y. and S. Tanaka. 1976. Dynamics of the saury population in the Pacific Ocean off northern Japan-II, Estimation of the catchability coeffcient q with the shift of fishing ground. Bull. Japn. Soc. Sci. Fish. 42: 943-952.

Pope, J.G. 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Int. Comm. Northwest Atlantic Fish. Res. Bull. 9: 65-74.

Sissenwine, M.P. and J.G. Shepherd. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci., 44: 913-918.

Tanaka, S. 1960. Studies on the dynamics and management of fish populations. Bull.Tokai Reg. Fish. Res. Lab. 28: 1-200.

Wada, T. 1994. Acoustic survey of sardine. Bull. Japan. Soc. Fish. Sci. 60: 807-808.

Wada, T. and M. Kashiwai.1991. Changes in growth and feeding ground with fluctuation in stock abundance. pp. 181-190. In: Kawasaki, T., S. Tanaka, and Y.Toba [ed.]. Long-term variability of pelagic fish populations and theirenvironments.Pergamon Press, London.

Wada, T., T. Matsubara, Y. Matsumiya, and N. Koizumi. 1995. Influence of environment on stock fluctuations of Japanese sardine, *Sardinops melanostictus*.pp. 387-394. In: Beamish, R.J. [ed.]. Climate change and northern fish populations. Can. Spec. Publ. Fish. Aquat. Sci. 121.

Wada, T., C. Sato, and Y. Matsumiya. 1996. Fisheries management for the Pacific stock of chub mackerel, *Scomber japonicus*, based on spawning per recruit analysis.Bull. Japn. Soc. Fish. Oceanogr. 60: 363-371.

Watanabe, Y., H. Zenitani, and R. Kimura. 1995. Population decline of the Japanese sardine *Sardinops melanostictus* owing to recruitment failure. Can. J. Fish. Aquat. Sci. 52: 1609-1616.

Watanabe, Y., H. Zenitani, and R. Kimura. 1996. Offshore expansion of spawning of the Japanese sardine,_*Sardinops melanostictus*, and its implication for egg and larval survival.Can. J. Fish. Aquat. Sci. 53: 55-61.

Table 1. Annual catches of major small pelagic fishes around Japan from 1985 to 1994.

(Unit: tons)

Year	Japanese Sardine	Japanese Anchovy	Jack Mackerel	Mackerels	Pacific Saury
1985	3,866,128	205,824	152,929	772,699	245,944
1986	4,209,518	220,870	110,491	944,809	217,229
1987	4,316,526	140,509	181,422	701,406	197,084
1988	4,488,411	177,492	227,770	648,559	291,575
1989	4,098,989	182,258	181,456	527,486	246,821
1990	3,678,229	311,427	221,974	273,006	308,271
1991	3,010,498	328,870	223,005	255,165	303,567
1992	2,223,766	300,892	223,412	269,153	265,884
1993	1,713,687	194,511	311,949	664,682	277,461
1994	1,188,848	188,034	323,130	633,354	261,587
Average	**3,283,960**	**225,069**	**216,054**	**569,032**	**261,542**

Source: Japanes Yearbook of Fisheries Statistics.

Table 2. Average composition (%) of catch by type of fisheries and by fish species from 1985 to 1994.

Type of Fishery/Fish Species	Japanese Sardine	Japanese Anchovy	Jack Mackerel and Scads	Mackerels	Pacific Saury
Large and Medium type purseseine	73.0	26.0	51.4	70.2	-
Medium type and other small purseseine	19.2	33.1	32.3	17.9	-
Boat seine	0.8	28.6	0.2	-	-
Set net	6.0	8.4	8.2	3.9	1.2
Stick-held dip net and other lift nets	0.4	2.7	3.2	3.7	98.5
Trawl	-	-	1.0	-	-
Others	0.6	1.2	3.7	4.3	0.3
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Source: Japanese Yearbook of Fisheries Statistics.

Table 3. Changes in catch, effort, and CPUE of large and medium type purseseine from 1985 to 1994.

Year	Number of Fishing Units Operated Size (gross tons) of Netting Boat				Number of trips	Catches by Fish Species (tons)			CPUE Catch per Trip
	Total	<50	50~100	100≤		Total	Japanese Sardine	Japanese Sardine (%)	
1985	210	6	77	127	14,563	3,462,060	2,683,964	77.5	238
1986	202	5	72	125	15,307	4,061,898	3,161,918	77.8	265
1987	201	7	68	126	14,529	3,920,646	3,268 030	83.4	270
1988	203	8	73	122	14,577	4,064,071	3,355,545	82.6	279
1989	208	8	70	130	14,177	3,589,977	2,974,546	82.9	253
1990	198	6	68	124	12,141	3,319,080	2,726,707	82.2	273
1991	183	3	65	115	11,392	2, 804,754	2,240,377	79.9	246
1992	167	1	63	103	10,140	2,026,108	1,527 510	75.4	200
1993	155	1	59	95	8,579	1,825,157	1,071,796	58.7	213
1994	132	2	50	80	7,739	1,350,460	584,106	43.3	175
Average	**186**	**5**	**67**	**115**	**12,314**	**3,042,421**	**2,359,450**	**74.4**	**241**

Source: Japanese Yearbook of Fisheries Statistics.

Table 4. Percentage of landings by style of utilization and fish species in Japan in 1994.

Style of utilization	Japanese Sardine	Jack Mackerel	Mackerel	PacificSaury
Perishable Foods	3.4	29.1	15.8	40.3
Fish Paste and Fish Paste Products	1.2	1.2	0.0	0.0
Canned Foods	2.3	0.1	8.1	4.5
Other Processed Food Products	3.8	26.4	19.5	33.0
Fish Oil and Fertilizers	19.4	0.1	2.1	6.6
Fish Culture or Bait	69.8	43.2	54.4	15.6
Total	**100.0**	**100.0**	**100.0**	**100.0**

Average of landings by style and by species at 33 major ports.
Source: Japanese Yearbook of Fisheries Statistics.

Table 5. Export and import of products of small pelagic fishes in Japan from 1985 to 1994.

Products	Fresh, Frozen and Chilled Fish			Canned Foods		Fish Oil	Fish Meal
	Japanese Sardine	Mackerels	Pacific Saury	Japanese Sardine	Mackerels		
Export							
1985	no data	12,538	19,150	69,207	59,144	249,969	157,438
1986	no data	no data	18,753	55,930	38,599	225,201	167,192
1987	no data	18,732	17,449	38,812	31,806	157,453	216,593
1988	99 237	14,434	19,226	20,639	28,539	347,453	212,645
1989	128,472	22,728	31,867	22,244	28,465	186,515	223,859
1990	83,309	11,147	44,991	17,015	19,100	216,858	147,471
1991	79,348	4,227	37,677	15,885	13,968	115,679	113,444
1992	56,428	7,188	67,162	12,632	12,131	44,939	44,441
1993	47,781	23,550	61,177	10,569	11,199	13,315	40,614
1994	42,098	21,803	40,586	9,344	8,908	4,192	20,696
Import							
1985	-	29,432	-	-	-	7,724	78,551
1986	-	no data	-	-	-	7,629	157,807
1987	-	no data	-	-	-	7,175	183,767
1988	-	39,328	-	-	-	7,383	226,976
1989	-	60,679	-	-	-	3,382	166,536
1990	-	70,754	-	-	-	3,043	226,372
1991	-	194,064	-	-	-	5,192	282,015
1992	-	137,270	-	-	-	8,809	330,686
1993	-	207,708	-	-	-	15,321	301,872
1994	-	175,218	-	-	-	45,470	379,456

Source: Annual Statistics of Trade by the Ministry of Finance of Japan.

Table 6. Methods for estimating stock abundance, BRPs, life spans, and natural mortality coefficient of major small pelagic fishes by distribution area or sub-stock.

Species	Area or Sub-Stock	Methods for Abundance Estimation	BRPs	Life Span (years)	Natural Mortality Coefficient
Japanese sardine	Pacific-North	VPA	F%SPR	6-8	0.4
	Pacific-South	Total Egg/Fecundity	1/3 of abundance	6-8	0.4
	Japan Sea/East China Sea	VPA	F%SPR	6-8	0.4
Chub mackerel	Pacific-North	VPA	F%SPR	6-8	0.4
	Pacific-South	VPA	F%SPR	6-8	0.4
	Japan Sea/East China Sea	VPA	F%SPR	6-8	0.35
Jack mackerel	Pacific	VPA	F%SPR	4-6	0.5
	Japan Sea/East China Sea	VPA	F%SPR	4-6	0.5
Pacific saury	Northwest Pacific	Catch/Exploitation Rate	F=M	1.2-1.5	1.7-2.0

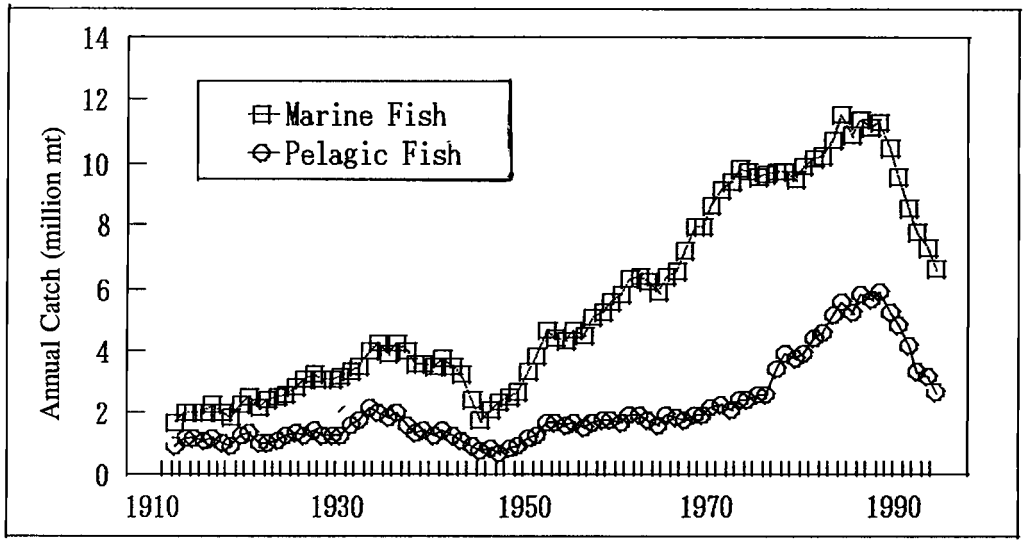


Fig. 1. Trends of catch of total marine fish and of major small pelagics around Japan from 1912-1994.

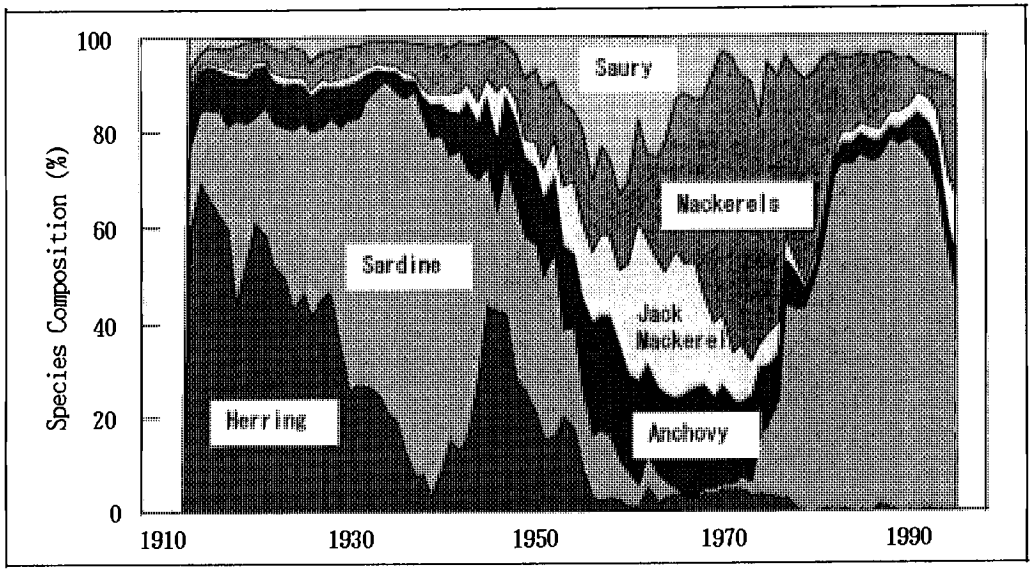


Fig. 2. Long term changes in species composition of major small pelagic fishes around Japan from 1912-1994. Mackerels includes chub and spotted mackerel.

SMALL PELAGIC FISH RESOURCES AND THEIR FISHERIES IN MALAYSIA

by

Phaik-Ean Chee
Fisheries Research Institute
11960 Batu Maung, Penang, Malaysia.

Abstract

Pelagic fish contribute to about one-third of the total marine production in Malaysia. Landings of pelagic fish in Malaysia were recorded at 326,955 tonnes in 1994. The fisheries for the small pelagics are supported by only a few major species of which the mackerels of the genus Rastrelliger are of historical and current importance. The fisheries for the small pelagics developed from the use of traditional fishing gears like driftnets to the use of different types of the fish purseseine. The fishery is most developed in the coastal areas off the west coast of Peninsular Malaysia where the trawl now harvests a substantial portion of the small pelagic fish. The same stocks of small pelagic fish resources could also be exploited by the neighbouring countries.

INTRODUCTION

Pelagic fish, which contributed to the bulk of the catch during the period before the introduction of the trawl into Peninsular Malaysia (Yap, 1976), still contribute to a significant portion of the total marine landings in Malaysia. Pelagic fish contribute to one-third of the total marine production in Malaysia (Fig.1; Table 1). Although the fisheries for the small pelagics are so important, they are supported by only a few major families and are exploited traditionally by the fish purseseine and driftnet. The trawl has, however, emerged as a major gear in the efficient exploitation of the pelagic fisheries in Malaysia. On the west coast of Peninsular Malaysia, the mackerels of the genus *Rastrelliger* contributed to the development of the fishery and still remain the mainstay of the marine fisheries. In the other states of Malaysia, a mix of other small pelagic fish belonging to different families, support the fishery. The development of the fisheries for the small pelagics was most rapid on the west coast of Peninsular Malaysia where the fishermen were fast to adopt and adapt the introduced fishing gear and technology to harvest fish. However, in recent years, with the encouragement given for the development offshore fishing in the Malaysian exclusive economic zone (EEZ) fishing activities have increased steadily in the South China Sea area off the east coast of Peninsular Malaysia, Sarawak and Sabah.

DISTRIBUTION OF SMALL PELAGICS

The small pelagic fish are generally distributed in the shallow coastal waters of the continental shelf areas. These shallow shelf areas, often less than 100 m deep, form the traditional and main fishing grounds for the small pelagics in Malaysia. Off the coast of Sarawak, depths exceed 1 000 m just 60nm to 120nm

offshore, while off the east coast of Sabah, the depth of water exceeds 1 000 m within 18 nm from the shore. These deepsea areas offer good potential for the development of the fishery for the tunas and other pelagics (Chee, 1989).

There appears to exist significant spatial differences in the distribution of pelagic fish schools off Peninsular Malaysia. Fish school densities are higher in the coastal areas compared to the areas further offshore (Aglen *et al.*, 1981; Edi-Muljadi *et al.*, 1984). Small pelagic fish also show seasonal inshore-offshore migration in relation to the monsoon in Peninsular Malaysia. During the period of the northeast monsoon from November to March when the sea is turbulent, pelagic and semipelagic fish undertake offshore migration and dispersion. In contrast to this, there appears to be an inshore movement of small and semipelagic fish into the coastal areas during the calm off-monsoon period from April to October (Anon., 1987a).

Information on the distribution, fishing and spawning grounds, concentration, abundance and possible migration patterns of certain commercial fish groups in Southeast Asia is given in Chullasorn and Martosubroto (1986) and Longhurst and Pauly (1987).

THE FISHERY FOR THE SMALL PELAGICS

The main gear for fishing the small pelagics used to be the fish purseseine. There are three major types of fish purseseines in use. The traditional fish purseseine is operated at night by scouting for free-swimming schools. Night purseseining is also traditionally practised in conjunction with fish aggregation by coconut leaf lures and small lamps. The use of coconut leaf lures as fish aggregating devices (FADs) also enabled day fishing. In the mid-eighties, however, spotlights mounted on the wheel-houses of purseseiners, were introduced as FADs. The use of spotlights in conjunction with purseseining increased the efficiency of the fish purseseine, but decreased its selectivity, thereby enabling increasing quantities of bycatch to be aggregated and caught. The sizes of certain species aggregated and caught by these purseseiners operating in conjunction with spotlights, were smaller than those caught by the purseseiners operating without spotlights or in conjunction with coconut leaf lures as fish aggregating devices (Chee, 1992). When spotlights were first introduced, the purseseiners performed well and high catch rates were recorded. Currently all purseseiners on the west coast use spotlights for aggregating fish in combination with the other traditional methods of fish aggregation or scouting for free-swimming schools.

Driftnets of varying lengths and mesh sizes also catch substantial quantities of pelagic fish mostly in inshore areas of less than 12nm from the shoreline, in Peninsular Malaysia, Sarawak and Sabah. The fish purseseine, however, still remains one of the most important fishing gears for the pelagic fish in Malaysia.

In the last two decades, the growth of the fleet for the high opening bottom trawls has led to the efficient exploitation of the small pelagic fish by this gear in addition to the demersal species. Increasing quantities of pelagic fish in particular

the Indo-Pacific and the Indian mackerels of the genus *Rastrelliger*, have been caught by the trawl along the west coast of Peninsular Malaysia. In 1970, purseseines landed 99% of *Rastrelliger* along the west coast of Peninsular Malaysia. This dropped to 81% in 1980, 37% in 1990, and further down to 23% in 1994. On the contrary, the landings of *Rastrelliger* by trawls had steadily increased from < 1% of the total mackerels landed in 1970 to 13%, 30% and 29% in 1980, 1990 and 1994 respectively on the west coast. The driftnets (including the trammelnets) have been landing increasing quantities of *Rastrelliger*, especially after 1987 (Fig.2).

A few families dominate the small pelagic fisheries in Malaysia. These include the Scombridae, Carangidae, Clupeidae and Engraulidae. The small pelagic fisheries of the west coast of Peninsular Malaysia developed through fishing for *Rastrelliger* (Yap, 1976), which still constitute the backbone of the fishery for the small pelagics today, contributing 6% to the total marine landings on the west coast. If the current fishing intensity persists, conflicts may arise between the purseseiner and the trawler fleets fishing for the same stocks of *Rastrelliger* on the west coast of Peninsular Malaysia. A similar situation already exists in the Gulf of Thailand.

Two main species of *Rastrelliger*, i.e., *R. brachysoma* and *R. kanagurta* are exploited by the fishery. *R. faughni* is also present, but only in small quantities. From the observations conducted in Perak on the west coast of Peninsular Malaysia, it was estimated that *R. brachysoma* contributed (84% by trawl, 12% by fish purseseine and 52% by driftnet) to the total *Rastrelliger* caught between 1993 and 1995. The remaining 16% (14% by trawl and 2% by fish purseseine) was *R. kanagurta*. Substantial quantities of *R. brachysoma* are caught by driftnets off the west coast of Peninsular Malaysia. Thus, the *Rastrelliger* fishery is supported largely by *R. brachysoma,* a more coastal species compared to *R. kanagurta*.

The other small pelagic fish that contribute to the fishery of the west coast of Peninsular Malaysia are a mix of scads (*Atule mate, Selar, Alepes*), roundscads (*Decapterus*), sardines and round herrings (*Sardinella and Dussumieria*), hardtail scad (*Megalaspis cordyla*) and the small tuna (mainly *Euthynnus affinis, Auxis thazard* and *Thunnus tonggol*) (Fig. 4).

On the east coast of Peninsular Malaysia, the fishery for the small pelagics is supported by three major groups of fish, namely, the Indian mackerel (*R. kanagurta*), scads (*Atule mate, Alepes*, *Selar* and *Selaroides leptolepis*) and roundscads (*Decapterus*). Small tunas (*T. tonggol, E. affinis and A. thazard*) are also an important group of small pelagics (Fig.5). The fish purseseine is the major gear for *Rastrelliger*, landing between 70% and 80% of the total, while the trawls catch only < 10% of the total (Fig.3). Most of the *Rastrelliger* caught off the east coast of Peninsular Malaysia is *R. kanagurta* mixed with small quantities of *R. faughni* . Off the coasts of the states of Sarawak and Sabah, the fishery for the small pelagics is also supported largely by *Rastrelliger, Decapterus, Selar* scads, *Sardinella* and small tunas. The fishery is supported by a mix of species, but not dominated by *Rastrelliger* as seen on the west coast of Peninsular Malaysia (Figs 6 and 7). The small pelagics, fished by the purseseine and driftnet are more developed in Sabah than in Sarawak.

The anchovies of the genus *Stolephorus,* are the main engraulids, fished selectively by the anchovy purseseine. The anchovy fishery is most developed off the west coast of Peninsular Malaysia, and is indeed, a very valuable fishery.

TRENDS IN CATCHES

Landings of pelagic fish increased steadily from below 100 000 mt in 1970 to reach 240 000 mt in 1981, and after a brief period of depression attained 326 955 tonnes in 1994 (Fig.1). Of this total, nearly equal amounts of 117 087 mt and 116 063 mt, came from the west and the east coasts of Peninsular Malaysia respectively, while 78 846 mt came from Sabah and only 14 959 mtonnes from Sarawak. The total marine landings recorded 1 065 585 mt in 1994. Although records of the landings of pelagic fish in Sabah and Labuan were not available before 1988, the figures available after 1988 reflect impressive development of fisheries further offshore. However, the pelagic fisheries appear to be least developed off Sarawak.

The main species of pelagic fish landed on the west coast belong to *Rastrelliger*. In the South China Sea area off the east coast of Peninsular Malaysia, Sarawak, Sabah and Labuan where the dominance of *Rastrelliger* is not so distinct, a few other important species contribute to the landings.

Landings of trash fish by fish purseseines on the west coast of Peninsular Malaysia increased from below 1 000 mt before 1986 to over 2 000 mt annually after 1986 (Table 2). The period around 1986 saw the introduction of spotlights as FADs in the purseseine fishery of this area. This increase in the trash component was contributed in part by the increase in the bycatch of fish purseseiners using spotlights. Previous to this, fish purseseines generally caught small quantities of trash as bycatch. A comparison of catch rates and species of fish caught by the different categories of purseseines was made by Chee (1992). Bycatch is expected to be higher when spotlights are used for the aggregation of fish in the inshore areas.

PROCESSING AND MARKETING

Bulk of the small pelagic fish caught is consumed fresh. While most of the fish are sold in the local markets, some fish are packed in ice and exported to neighbouring countries like Singapore, Thailand and Brunei. Small quantities are frozen for export.

Over the last decade there has been increased utilization of low-valued fish for the production of value-added fish and fish-based products like *surimi*, fish cakes, fish fingers, fish balls and fish crackers. Certain small pelagic fish are preferred for the production of selected products. For example fish cakes, fish fingers and fish balls are made from the round herrings (*Dussumieria*) and sardines (*Sardinella*) to yield a springy texture. Top quality fish crackers are made from the wolf herring (*Chirocentrus*) while the sardines are used to produce cheaper fish cracker.

Some small pelagic fish, particularly the Indo-Pacific mackerel (*R. brachysoma*) are boiled or steamed and sold in trays during periods of glut. Many pelagic fish are salted, dried and sold locally. Almost all the anchovies caught in Malaysia are boiled in brine and sold in the dried and salted form.

While the production of value-added products from low-valued fish reduces wastage of fish, much debate has arisen over the use of fish as feed for aquaculture operations. With the fast development of fish culture in ponds and in floating cages, much of the bycatch of fishing vessels including the small pelagics (notably *Decapterus*) are sold as feed for these culture operations (Chee, 1996). Even the Indo-Pacific mackerel are used as direct feed in fish culture during periods of glut when the ex-vessel price of this fish drops. In the past, much of the surplus catch of the Indo-Pacific mackerel used to be reduced into fish meal. Other alternative ways of utilizing the Indo-pacific mackerel are being devised. The general disposition of marine fish landings in Peninsular Malaysia, shown in Table 3 does not furnish any information regarding the raw material (e.g., small pelagics) of the products listed.

BIOLOGICAL AND POPULATION PARAMETERS

Chong and Chua (1974) reported that the spawning season of *R. brachysoma* extends from October to December annually. However, from maturity studies using gonadosomatic indices (GSI), conducted by the Fisheries Research Institute, Penang, it was found that *R. brachysoma* sampled on the west coast of Peninsular Malaysia exhibited two main spawning peaks in a year, although mature fish could be sampled throughout the year. Mature *R. kanagurta* were also sampled throughout the year, but the GSI peaked in August/September. The spawning season of *R. kanagurta* extended from October/November to April, while Chee (1978) reported that spawning extended from May to January. Batch spawning that occurs over extended periods as observed in *Rastrelliger,* is quite typical of many tropical fish species where ova maturation is asynchronous.

Table 4 provides a partial list of studies on the biological and population parameters of some small pelagic fish in Malaysia. More complete compilations of biological information of fishes in the Southeast Asian region can be found in Ingles and Pauly (1984) and Chullasorn and Martosubroto (1986). These parameters could be used in stock assessments, which form an important basis for the formulation and implementation of proper management strategies.

FISHERIES MANAGEMENT

The legal framework for the management of marine fisheries resources in Malaysia is embodied in the Fisheries Act 1985. Fishing zones have been allocated to commercial and traditional fishing gears under the Fisheries Licensing Policy 1981. Commercial gears like the trawl and the fish purseseine are allowed to operate beyond 5nm from the shore, while only the traditional fishing gears and the anchovy purseseine are allowed to fish within the 5 nm belt. This zonation also serves to protect the productive inshore areas within which are located some of the important fish breeding and nursery areas. Critical habitats such as the seagrass

beds and coral reefs are located within this 5nm belt which is fringed by stretches of mangrove forests on the landward side along certain parts of the coastline. The value of mangroves and their importance in sustaining coastal ecosystems have generated much concern in Malaysian fisheries (Macnae, 1974; Sasekumar and Chong, 1987; Chong, 1996). Certain groups of islands have been gazetted as Marine Parks in Malaysia. These parks are natural reefs and are essentially closed areas to all forms of fishing activities within a 2 km radius. Currently there are 38 Marine Parks in Malaysia. Legally, fishing vessels bigger than 40 GRT have to fish beyond the 12nm from the shoreline.

The main management measure being strictly enforced is the control of fishing effort through strict license limitation of fishing vessels and fishing gear. Though licensing does limit the number of fishing vessels and gears allowed to operate , it does not control the increase in the overall fishing power and efficiency of the fishing vessels and the fishing gears. Over the years, the total number of fish purseseines has not shown any significant increase (Table 5). However, purseseining has improved considerably in qualitative terms through the introduction of colour echo sounders and sonar, new navigational aids like GPS (Geographical positioning systems) and FADs like spotlights. The use of spotlights as FADs has facilitated the exploitation of a wide range of species, thereby making the fish purseseine less selective. To control the use of spotlights in coastal waters and to reduce user-conflicts, fish purseseiners, irrespective of GRT, are allowed to aggregate fish using spotlights only beyond the 12nm from the shore. Only a 30kw generator is permitted to power the spotlights onboard.

Small pelagic fish undertake short-distance migration, which seems to be influenced by environmental parameters like sea surface temperature, currents, salinity and productivity. A hypothetical migratory path of *R. brachysoma* off the west coast of Peninsular Malaysia and Thailand was proposed (Anon., 1987b) based on limited results from a joint Malaysia/Thailand tagging project. Preliminary results from this project show that the stocks of *R. brachysoma* are shared by Malaysia and Thailand. Chullasorn and Martosubroto (1986) also discussed short-distance migration within countries as well as transboundary migration of certain species. This information stresses the need for collaborative work to support improved management measures for these transboundary stocks that are shared by neighbouring countries.

Regional collaborative studies and workshops were initiated in the past by the South China Sea Fisheries Development and Coordination Programme (Anon., 1976), Southeast Asian Fisheries Development Center (Anon., 1981; Anon., 1995, Anon.,1996) and the Bay of Bengal Programme (Anon., 1987b) to contribute to the better management of the shared stocks in the region. Collaborative studies on the effects of interaction between fisheries harvesting the same stocks in different geographical areas should be planned and implemented on a sustained basis.

CONCLUSIONS AND RECOMMENDATIONS

1. The migratory nature of the small pelagic fish stocks calls for their assessment on a regional basis in line with the FAO Code of Conduct for Responsible Fisheries, where it becomes the responsibility of every country concerned to effectively manage and conserve fisheries resources.

2. There is urgent need to set up data banks and exchange data on the small pelagic fisheries for the purposes of stock assessment and management at the national and regional levels.

3. There is need to standardize and calibrate fishing effort for the assessment of small pelagic fish stocks.

REFERENCES

Aglen, A., L.Foyn, O.R. Godo, S.Myklevall, O.J. Ostvedt, 1981. Surveys of the marine fish resources of Peninsular Malaysia, June-July 1980. Reports on surveys with R/V "DR.FRIDTJOF NANSEN", Institute of Marine Research, Bergen, Norway.

Anonymous, 1976. Report of the Workshop on the Fishery Resources of the Malacca Strait - Part II. SCS/Gen/76/6, South China Sea Fisheries Development and Coordinating Programme, Manila, Philippines.

Anonymous, 1981. Report on the Seminar on Stock Assessment of Pelagic Resources with Emphasis on Shared Stocks. Southeast Asian Fisheries Development Centre, Bangkok, Thailand.

Anonymous, 1987a. Deep-sea Fisheries Resources Survey within the Malaysian Exclusive Economic Zone, Final Report: Volume 2 Book 1, Department of Fisheries Malaysia, Kuala Lumpur, Malaysia.

Anonymous, 1987b. Investigations on the Mackerel and Scad Resources of the Malacca Straits, BOBP/REP/39, RAS/81/051, Bay of Bengal Programme, Colombo, Sri Lanka.

Anonymous, 1995. Report on the Regional Workshop on Data Collection and Management Related to Shared Stocks in the Southeast Asian Region. Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center, Kuala Terennganu, Malaysia.

Anonymous, 1996. Report of the Second Regional Workshop on Shared Stocks in the South China Sea Area. Marine Fishery Resources Development and Management Department, Southeast Asian Fisheries Development Center, Kuala Terennganu, Malaysia.

Biusing, E.R., 1994. Population dynamics and biology of mackerel resources (genus *Rastrelliger* sp., family Scombridae) along the west coast of Sabah, Malaysia. In: Almah, A., M.Mazlan and S.Mustafa (eds.). Proceedings of the Seminar onMarine Fisheries Resources of Sabah, Ko-Nelayan and Faculty of Science & Natural Resources, Universiti Kebangsaan Malaysia, Kota Kinabalu, Sabah.

Chee, P.E., 1978. The reproductive pattern of *Rastrelliger kanagurta*. Proceedings of the Second Annual Seminar, Malaysian Society of Marine Sciences, 33-42.

Chee, P.E., 1989. Tuna Fisheries Resource and Development. Paper presented at Seminar on Deepsea Fisheries Resources within the Malaysian Exclusive Economic Zone, 20 May 1989, Kuala Lumpur, Malaysia.

Chee, P.E., 1992. Purse Seining with Lights as Fish Aggregating Devices. In:Ho, Y.W., M.K.Vidyadaran, A.Norhani, M.R.Jainudeen and B.Abd. Rani. Proceedings of the National IRPA (Intensification of Research Priority Areas) Seminar, Ministry of Science, Technology & Environment Malaysia, Kuala Lumpur, Malaysia.

Chee, P.E., 1996. A Review of the Bycatch and Discards in the Fisheries of Southeast Asia. Paper presented at the Technical Consultation on Reduction of Wastage in Fisheries, 28 October - 1 November 1996, Tokyo, Japan.

Chong, V.C., 1996. The prawn-mangrove connection - fact or fallacy? In: Suzuki, M., S. Hayase and S.Kawahara (eds.). Proceedings of the Seminar on Sustainable Utilization of Coastal Ecosystems for Agriculture, Forestry and Fisheries in Developing Regions. Japan International Research Center for Agricultural Sciences (JIRCAS), Ministry of Agriculture, Forestry and Fisheries, Japan, pp 3-20.

Chong, B.J. and C.W.Chua, 1974. Growth, age determination and spawning of ikan kembung, *Rastrelliger neglectus* (Van Kempen) in the northern Straits of Malacca. Mal. Agric. J. 49:344-356.

Chullasorn, S and P.Martosubroto, 1986. Distribution and important biological features of coastal fish resources in Southeast Asia. FAO Fisheries Technical Paper 278, FAO, Rome, Italy.

Edi-Muljadi, A., H.L. Chai, S.Selvanathan and Y. Abdul-Hamid, 1984. Acoustic survey of pelagic fish resources in the waters off the east coast of Peninsular Malaysia. Fisheries Bulletin No.28, Department of Fisheries, Ministry of Agriculture, Malaysia.

Ingles, J. and D. Pauly, 1984. An Atlas of the Growth, Mortality and Recruitment of Philippine Fishes. ICLARM Technical Reports 13, 127 p. Institute of Fisheries Development and Research, College of Fisheries, University of the Philippines in the Visayas, Quezon City, Philippines and International Center for Living Aquatic Resources Management, Manila, Philippines.

Longhurst, and D. Pauly, 1987.Ecology of Tropical Oceans. Academic Press Inc., U..S.A. 407 p.

Macnae, W., 1974. Mangrove forests and fisheries. FAO/UNDP Fishery Programme. Indian Ocean Fishery Commission IOFC/DEV/74/34. 35 p.

Mansor, M.I., 1987. On the status of the Rastrelliger and Decapterus fisheries of the west coast of Peninsular Malaysia in 1984-1985. In: Anonymous, 1987. Investigations on the Mackerel and Scad Resources of the Malacca Straits, BOBP/REP/39, RAS/81/051, Bay of Bengal Programme, Colombo, Sri Lanka. p.81-100.

Sasekumar, A. and V.C. Chong, 1987. Mangroves and prawns: Further perspectives In: Sasekumar, A., S.M.Phang and E.L.Chong (eds).Towards Conserving Malaysia's Marine Heritage. Proceedings of the Tenth Annual Seminar of the Malaysian Society of Marine Sciences. pp 10-15.

Yap, C.L., 1976. Fishery Policies and Development with Special Reference to the West Coast of Peninsular Malaysia from the Early 1900s. *Kajian Ekonomi Malaysia* 13(1&2): 7-15.

Table 1. Pelagic fish and total marine production in Malaysia.

Pelagic fish landings (tonnes)					Total pelagic (tonnes)	Total marine (tonnes)	Percent of Total
Year	West Coast	East Coast	Sarawak	Sabah & Labuan			
1970	59532	29735	6390	-	95657	339418	28
1971	60178	33027	5449	-	98654	364292	27
1972	31297	45459	4278	-	81034	354808	23
1973	47696	40579	6812	-	95087	440913	22
1974	47862	58766	7298	-	113926	523944	22
1975	37440	49386	16703	-	103529	472441	22
1976	49851	49996	15035	-	114882	514881	22
1977	59725	65269	12151	-	137145	616147	22
1978	71790	80971	15061	-	167822	682510	25
1979	79518	76314	13654	-	169486	693398	24
1980	103241	76537	12657	-	192435	733668	26
1981	90843	135129	13714	-	239686	755358	32
1982	104810	80634	13931	-	199375	676463	29
1983	121262	102907	13887	-	238056	724994	33
1984	120804	81010	14374	-	216188	600472	36
1985	96610	90762	14146	-	201518	574355	35
1986	72949	60506	15713	-	149168	561967	27
1987	117799	127145	9108	-	254052	859008	30
1988	92871	104971	12312	17675	227829	825631	28
1989	89444	95098	16480	16421	217443	882492	25
1990	106297	97956	17496	15969	237718	951307	25
1991	78230	113556	17689	53724	263199	911933	29
1992	93365	101090	16366	79449	290270	1023516	28
1993	83738	128491	17667	81302	311198	1047350	30
1994	117087	116063	14959	78846	326955	1065585	31

Table 2. Landings of trash fish by fish purseseines on the west coast of Peninsular Malaysia.

Year	Landings (tonnes)
1982	768
1983	665
1984	727
1985	588
1986	4,541
1987	6,471
1988	4,064
1989	5,358
1990	3,580
1991	2,959
1992	3,312
1993	4,815
1994	3,183

Source: Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia.

Table 3. Disposition of marine fish landings (tonnes) in Peninsular Malaysia.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fresh	289,118	281,804	445,069	395,346	472,046	515,868	634,772	619,590	503,827	514,868
For freezing	9,393	11,396	11,386	11,780	5,295	7,138	2,701	6,808	2,363	1,255
For curing:	42,157	39,162	63,937	69,391	47,825	49,706	8,935	23,562	31,600	29,797
Dried/ Salted/ Smoked Steamed/ Boiled	9,181	2,803	5,335	942	14	6,878	493	-	-	670
Fermented	13,617	12,757	13,694	14,657	13,774	19,034	8,245	11,640	21,552	25,655
Others	8,435	2,360	16,373	16,331	9,392	15,792	3,762	19,004	10,752	10,427
For reduction	87,468	91,669	174,480	176,038	163,551	172,076	39,968	49,540	178,860	184,256
Others	3,492	4,425	10,291	9,964	34,987	33,411	10,711	37,388	42,664	18,151
Total	462,861	446,376	740,565	694,449	746,884	819,903	709,587	767,532	791,618	785,079

Source: Annual Fisheries Statistics, Department of Fisheries, Ministry of Agriculture, Malaysia.

Table 4. Biological and population parameters of selected pelagic fish in Malaysia.

Species	L α (mm)	K	M	Z	Area	Gear	Reference
Rastrelliger kanagurta	297	1.19	1.97	6.90	Perlis	Purseseine	Mansor 1987
Rastrelliger kanagurta	290	1.21	2.01	8.14	Penang	Purseseine	Mansor 1987
Rastrelliger kanagurta	357	0.73	1.41	6.69	Sabah	Purseseine	Biusing 1994
Rastrelliger brachysoma	196-201	0.36-0.44			Kedah	Purseseine	Chong & Chua 1994
Rastrelliger brachysoma	240	1.04	1.92	10.21	Kedah		Mansor 1987
Rastrelliger brachysoma	260	0.6	1.31	7.9	Perak	Purseseine	Mansor 1987
Rastrelliger brachysoma	250	0.82	1.62	6.79	Perak	Trawl	Mansor 1997
Rastrelliger brachysoma	242	0.52	1.22	3.43	Selangor	Purseseine	Mansor 1987
Rastrelliger brachysoma	240	1.02	1.89	7.15	Selangor	Trawl	Mansor 1987
Rastrelliger brachysoma	338	0.64	1.31	5.30	Sabah	Purseseine	Biusing 1994
Decapterus russelli	270	1.01	1.82	9.56	Perlis	Purseseine	Mansor 1987
Decapterus russelli	240	0.81	1.63	3.67	Penang	Purseseine	Mansor 1987

Table 5. Number of fish purseseines estimated to be in operation in Peninsular Malaysia.

Year	West Coast	East Coast
1978	195	178
1979	236	190
1980	241	208
1981	301	279
1982	343	236
1983	325	233
1984	361	247
1985	377	241
1986	251	209
1987	320	347
1988	318	312
1989	217	431
1990	202	248
1991	226	318
1992	172	287
1993	204	318
1994	194	295

Source: Annual Fisheries Statistics, Department of Fisheries, Malaysia.

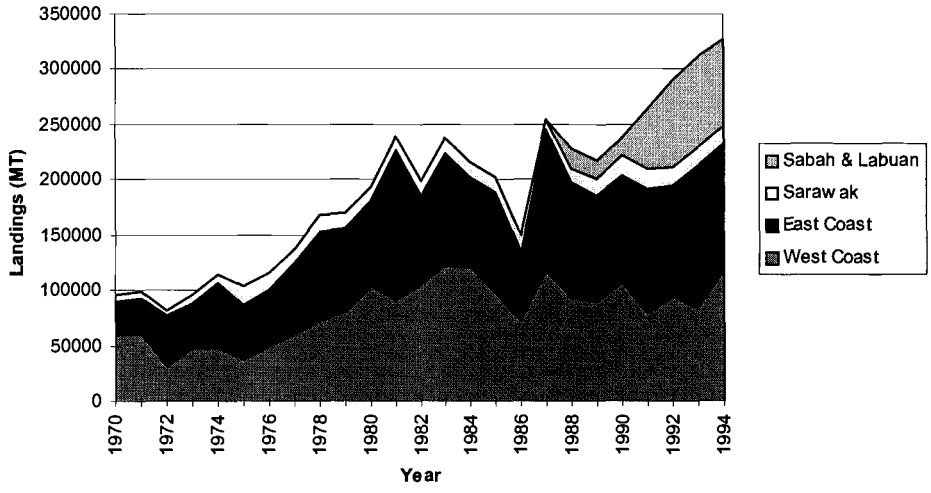


Figure 1. Landings of pelagic fish in Malaysia.

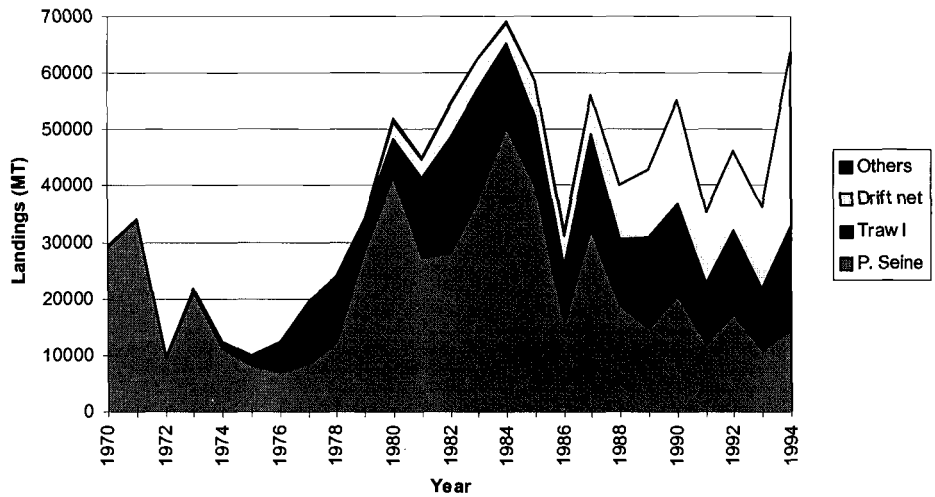


Figure 2. Landings of Rastelliger by fishing gear - West coast peninsular Malaysia.

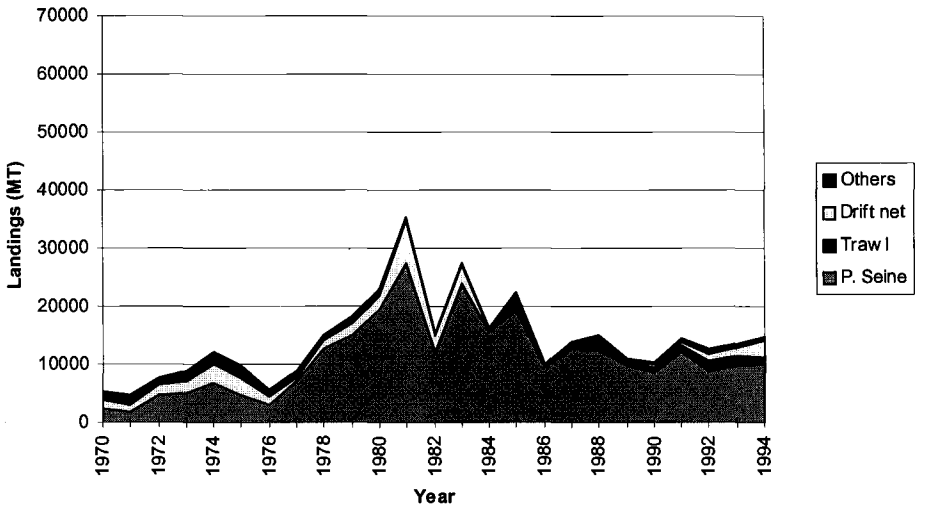


Figure 3. Landings of Rastrelliger by fishing gear - East coast Peninsular Malaysia.

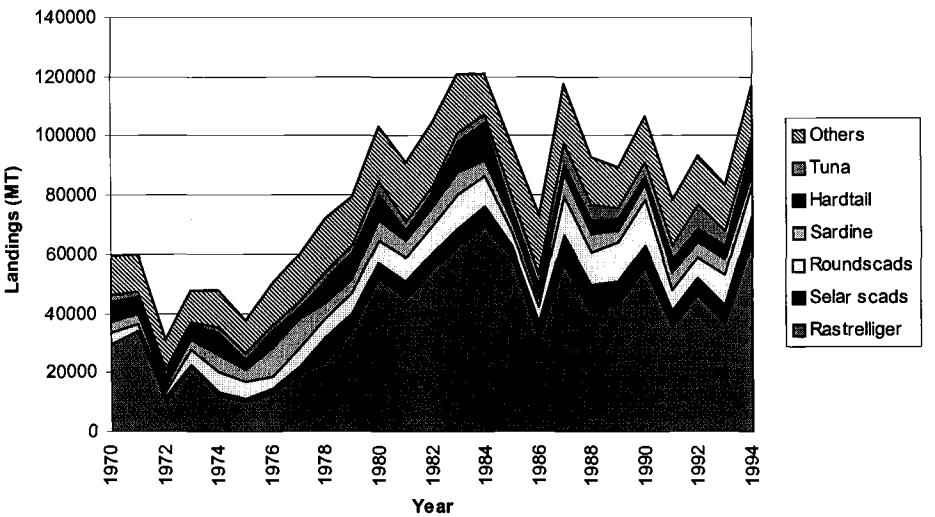


Figure 4. Landings of pelagic fish - West coast Peninsular Malaysia.

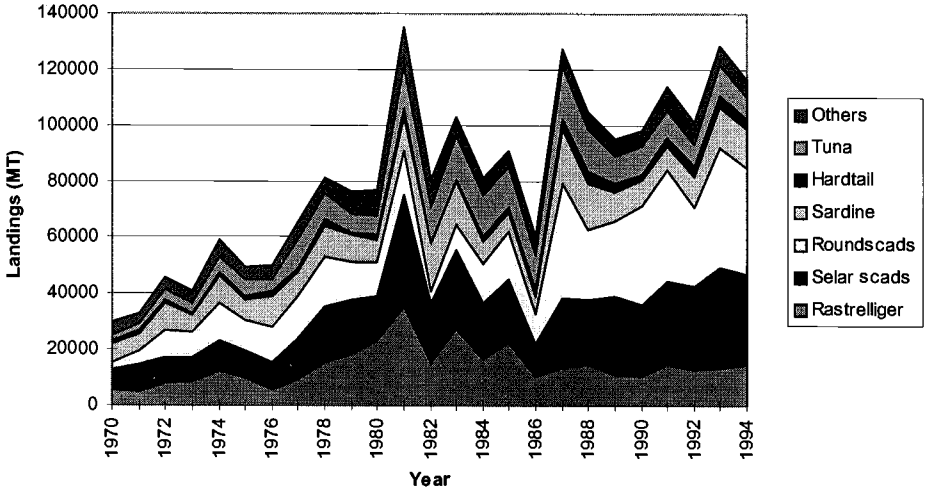


Figure 5. Landings of pelagic fish - East coast Peninsular Malaysia.

REVIEW OF THE PHILIPPINE SMALL PELAGIC RESOURCES AND THEIR FISHERIES

by

Rosita R. Calvelo
Bureau of Fisheries and Aquatic Resources
Department of Agriculture and Food, Arcadia Building
Quezen City, Metro Manila 3008, Philippines

Abstract

The average annual production of the small pelagics was 83 000 mt from the municipal fisheries and 715 000 mt from the commercial fisheries during 1984-1995. The purseseines contributed 58.8% to the landings, followed by the ringnets (19.6%). Information on the seasonality in the catches and the biological characteristics of the major species are provided in the paper. The small pelagics, which are heavily exploited, are marketed worldwide from the Philippines as dried, smoked, salted and brined products. Serious attention needs to be paid for their management for which a few options are suggested in the paper.

INTRODUCTION

The Philippines has been ranked as the 12th among the largest fishing nations during 1993. The total fish production for 1995 was 2.78 million mton valued at P 83.84 billion (US$ 3.22 billion), which included 0.98 million mt (34%) valued at P 23.73 billion by the commercial marine fisheries subsector, 0.78 million mt (29%) valued at P 24.33 billion by the municipal marine fisheries, 0.82 million mt (30%) valued at P 33.33 billion by aquaculture and 0.20 million mt (7.4%) valued at P 2.45 billion by inland fisheries (Table 1). About one million or 5% of the country's labour force are dependent on fishing as a means of their livelihood. The largest share of the labour force in the fisheries sector is contributed by the municipal fisheries (68%; 675 677), followed by aquaculture (26%; 258 480) and commercial marine fisheries (6%; 56 715). Fish consumption in the Philippines is high but varies by region, ranging from 30 kg to 40 kg per capita per year, which is about 50 to 70% of the total animal protein consumed by the Filipinos (NSCB, 1992).

In the Philippines, the small pelagics are caught by both the commercial and the municipal artisanal fishing gears and mostly consumed fresh or processed (dried, smoked and fermented as food condiment products), especially by the low income population and those living below the poverty line. However, some species of small pelagics are utilized for canning. A number of evaluations and asessments conducted so far indicate that the small pelagic resources are overexploited in the Philippines, and hence warrant effective management to sustain the production to meet: (1) the present protein requirements of the 70 million population and their future needs (BAS, 1995; NSCB, 1995) and (2) the export needs of the Philippine economy. This paper presents the overall status of the small pelagic resources, their

fisheries, biological characteristics and options for their management in the Philippines.

THE RESOURCES AND THEIR DISTRIBUTION

Dalzell and Ganaden (1987) used the term "small pelagic fishes" as an arbitrary classification of a diverse group of fishes that share a common habitat, which is the upper surface layer of the water column, usually within the continental shelf, not exceeding 200 m in depth. The species comprising the Philippine catch of small pelagics as discussed in this paper, belong to 13 families namely, Scombridae, Carangidae, Clupeidae, Engraulidae, Chirocentridae, Trichiuridae, Sphyraenidae, Stromateidae, Exocoetidae; Mugilidae, Coryphaenidae, Rachycentridae and Caesionidae.

Fishing Grounds

The important fishing grounds for the small pelagics are located between Luzon and the southern coast of Mindanao (Fig. 1; Dalzell and Ganaden, 1987; SCSP, 1976; 1977; 1978). The Sulu Sea, which includes the West Sulu Sea, South Sulu Sea, East Sulu Sea and the Cuyo Pass, is the most productive basin with rich fishing grounds for the pelagics in the Philippines because of upwelling (Ronquillo, 1974). The Sulu Sea yields considerable catches of mackerels and sardines, but the main fishing grounds for the mackerels exist in the Visayan Sea where the sardine rank second. The Moro Gulf and the Tayabas Bay which yield significant catches of anchovies are ranked next to the Visayan Sea in fish production while the Bohol Sea, Lamon Bay and the Batangas coast are ranked successively below the Tayabas Bay. The catch of small pelagics from these major fishing grounds indicate only a slight increase during 1991 to 1995 (Table 2).

THE FISHERIES

The Philippine marine fisheries resources are typical of the Central Indo-West Pacific region and characterized by a generally high species diversity comprising about 2 400 species. Based on the gross tonnage of the fishing vessels marine fisheries in the Philippines are divisible into commercial and municipal fisheries. Vessels of three gross tonnage and above are grouped under commercial or offshore fisheries while the motorized or nonmotorized boats of less than three gross tonnage are treated under municipal, smallscale/artisanal or nearshore fisheries. The commercial fisheries operate starting from a distance of 15 km from the shore upto the outer limit of the EEZ, and also in the international waters in accordance with the rules of the law of the sea. The municipal fisheries operate in the municipal waters extending to a distance of 15 km from the shore, as embodied in the Local Government Code.

The Philippine Fisheries Statistics published by the Bureau of Fisheries and Aquatic Resources (BFAR) included 50 fishing grounds consisiting of bays, gulf, seas, etc. up to the 1970s. Subsequently, these fishing grounds were grouped into 24 statistical areas (Fig. 2) through the initiative of the South China Sea Programme

(SCSP) and later by the Food and Agriculture Organization (FAO). The data presented here were taken from the BFAR municipal and commercial catch statistics for 1984 to 1987 and from the Bureau of Agricultural Statistics (BAS) for 1988 to 1995 (BAS,1991; 1995; BFAR, 1987; NSCB, 1992; 1995).

Annual production

During the period 1984 to 1995, the annual production of small pelagics from the municipal fisheries ranged from 340 601 mt to 453 090 mt. The average annual production, which was 402 809 mt, accounted for 43.37% to 53.01% (average 51.29%) of the total municipal catch (Table 3). During the same period the commercial fisheries landed much higher catches of the small pelagics which ranged from 340 613 mt to 667 301 mt (mean = 499 626 mt), accounting for 66.53% to 76.25% (mean = 72.04%) of the total commercial catches (Table 4).

Commercial fishing vessels

Throughout the 5-year period of 1991 to 1995 seven major commercial gears ranked constantly high in terms of their efficiency in the exploitation of the small pelagics (Table 5). On an average, the purseseine ranked first with 361 957 mt (58.8%), followed by the ringnet with 123 299 mt (19.64%), bagnet with 55 397 mt (8.91%), trawl with 39 480 mt (6.47%), Danishseine with 20 574 mt (3.30%), gillnet with 2 632 mt (0.42%) and round haulseine with 1 776 mt (0.30%). The catch of ringnet surpassed the bagnet catch and was double the trawl catch, which was also quite significant because of the use of high opening trawls (Borja, 1975). The increase in the purseseine and ringnet catches is due to the use of the payaos fish aggregating device (FAD) since the late 1970s (Calvelo, 1992) and the increase in the number of ringnet units in response to the better catches of both tunas and small pelagics around the payaos (Aprieto, 1982; Floyd and Pauly, 1984).

One of the principal gears used by Dalzell and Ganaden (1987) in the analysis of the small pelagic commercial catches is the muro-ami, which employes swimmers of about 200 to 300 young boys, to scare the fish by pounding the coral reef. As a result there has been a massive distruction of the coral reefs (Dalzell and Ganaden, 1987), and hence this gear was declared as illegal and banned under the Fisheries Administrative Order (FAO) No. 163. The Danishseine (locally known as hulbot-hulbot or buli-buli) is intended for demersal fisheries, but exploits the small pelagics as well, as it has been slightly modified with scareline and an iron ring which encircles the codend. It is dragged or towed during operation like the trawl, and used nationwide widely in both municipal and commercial fisheries since the mid 1980s, but there is no record of the total number of units in operation.

PROCESSING AND MARKETING

Besides the regular local trade, the small pelagics are marketed worldwide as dried, smoked, salted or brined products, particularly in the leading markets of Japan, Hongkong, United Kingdom, Germany, Korea, Canada, France, South Africa and Taiwan. The small pelagics exported by the Philippines from 1986 to

1991 ranged from 520 872 kg to 2 262 002 kg, valued at P 20 549 234 to P 104 549 092 respectively. Processed products of sardines, herrings, mackerels and anchovies form the mainstay of the exports of small pelagics (Tables 6). The oil-processed products of small pelagics decreased by more than half from 1994 to 1995 in terms of both quantity (kg) and value (P) (Table 7). Despite this, the overall marine products exports improved by 2.2% from 1994 to 1995 on account of shrimps and tuna (BFAR, 1996). There is no particular record of the volume and value of roundscads exported, as they are lumped with other frozen fish in the BFAR statistics. The roundscads are canned (sardine type) and marketed widely throughout the Philippines, like the mackerel and sardines. The fusiliers and bigeyed scad are processed dried and marketed internally. The current retail price of small pelagics is indicated in Table 8a. The small pelagics are also processed as fish meal, especially if they are small-sized and/or no longer fresh.

GEOGRAPHY AND CLIMATE

The Philippines, located between the latitudes of 21° 25'N and 4° 23'N and longitudes of 116 ° 00'E and 127 ° 00'E, is bounded by the Pacific Ocean on the east, the Celebes Sea and the Bornean waters on the south and the China Sea on the west and the north (Fig.3). Comprising more than 7 100 islands, the Philippines has a coastline of about 17 500 kilometers and a limited area of about 18.46 million ha of continental shelf which varies in width from about 1.6 km to 69 km where most of the commercial fisheries are concentrated (Ronquillo, 1974). An area of about 44 096.5 km^2 is covered by coral reefs within the 20 to 40 m depths (Gomez *et al.*, 1981).

The temperature and rainfall are characteristically of the tropical monsoon type, comprising the southeast monsoon (June to October), the northeast monsoon (November to March) and the trade wind season (April to May) (Ronquillo, 1974). The averagae surface temperature is 27.3°C in the areas as far north as the 23° N and 28.2°C in the areas up to the 19° N of the Philippines (Dalzell and Ganaden, 1987). The temperature decreases by 0.03° C/m depth from the sea surface to the 100m depth. The thermocline is formed between the depths of 100m and 300m with a sudden drop in temperature to 12 to 15°C, followed by only a slight temperature decrease below the thermocline level. There is very little salinity variation with season or depth in the areas away from the eastern and western side of the Philippines, but marked variations have been observed along the west coast of the archipelago during the southwest monsoon. The Malampaya Sound, west of the Palawan Is., is characterised by wide seasonal variations in the surface salinity, which ranges from 28.2 to 34.6 ppt., with a mean of 32.1 ppt. and the lowest in October at the time of peak rainfall.

BIOLOGY OF SMALL PELAGICS

Roundscads

The species of roundscads found in the Philippine waters are *Decapterus macrosoma*, *D. maruadsi*, *D. macarellus*, *D. russelli* and *D. kurroides*. They are caught in depths ranging from 40 m to 200 m. Like the tunas, the roundscads are

circumtropical inhabiting the outer neritic and the contiguous oceanic regimes (Yesaki, 1983). The spawning period of *D. macrosoma* and *D. russelli* is protracted, extending from December to March in the Palawan waters and December to April or May in the Manila Bay (Tiews *et al.*, 1970). In the Lamon Bay, particularly around the Calagua Is. about 50% of *D. macrosoma* and *D. maruadsi* are found to be in the immature and maturing stages. There is also a dense population of fry (3.5 cm TL) in the Bay during the southwest monsoon (Calvelo *et al.*, 1987). The maturity of the fish and the occurrence of the larvae observed in the Lamon Bay and its approaches during April 1967 (Magnusson, 1973) suggest spawning in this area a few months ahead. In the Moro Gulf, maturing and mature *D. macarellus* in IV to VI stages of maturity were found in fish ranging from 10.5 cm to 40.0 cm lengths. The sex ratios of the roundscads differ by species and by areas. In the Manila Bay, the males of *D. russelli* and the females of *D. macrosoma* were dominant over the other sex, but the males and females of both the species were equally represented in the Palawan waters (Tiews *et al.* 1970 a). In the Camotes Sea, the male to female ratio was 1.05:1.0 for *D. russelli*, but the females dominated the other stocks, as seen from the female to male ratio of 1.2:1.0 for *D. macrosoma* and 1.8:1.0 for *D. maruadsi* (Calvelo, 1992) and 1.8: 1.0 for *D. macarellus* in Moro Gulf (Calvelo, 1992; 1997). The fecundity of *D. macrosoma* ranged from 67 900 to 106 200 eggs and of *D. russelli* from 28 700 to 48 000 egg (Tiews *et al.*, 1970 a).

While *D. macrosoma* feed typically on zooplankton, *D. russelli* prey on small fish. Both the species are known to consume *Stolephorus* eggs (Tiews *et al.*, 1970 a & b). In the Moro Gulf *D. macarellus* feed predominently on fishes and crustaceans.

The life span of *D. maruadsi* is 4.2 years (Corpus *et al.*, 1972), of *D. russelli* 2.8 years and of *D. macrosoma* 3.2 years (Ingles and Pauly, 1984). The mean length at first capture for *D. macrosoma* is 12.9 cm and for *D. russelli* 4.5 cm for the ringnet catch in the Camotes Sea (Jabat and Dalzell, 1988). The length-weight relationship for *D. macrosoma* was computed to be $W=0.005639\ L^{3.159}$ and for *D. russelli* $W=0.0099771\ L^{3.015}$ indicating isometric growth in both the species.

According to Tiews *et al.* (1970a), the roundscads avoid salinity of less than 30 ppt, and their distribution is strongly influenced by the density of zooplankton. They observed that the roundscads, particularly *D. russelli*, changed their habit from pelagic to demersal, during their spawning season.

Mackerels

The mackerels, which are epipelagic, inhabiting both the inshore and offshore waters, include *Rastrelliger brachysoma, R. kanagurta, R. faughni, Scomber japonicus* and *S. australasicus* in the Philippine waters. While *R. brachysoma* are more inshore in distribution, *R. kanagurta* and *R. faughni* tend to be more offshore in distribution. *S. japonicus* and *S. australasicus*, which are subtropical and warn temperate in distribution (Dalzell *et al.*, 1990) occur in the

Philippine waters only very seasonally. The mackerel populations of the southern Sulu Sea and the northern Palawan waters seem to be contiguous with those of the northern Celebes Sea and the west coast of Borneo (FAO, 1985). The degree of mixing of *Rastrelliger* populations from the adjacent waters into the Philippines has not yet been determined.

R. brachysoma feed principally on the microplankton while *R. kanagurta* prefer the macroplankton such as the larvae of shrimps and fishes. The mackerels seem to spawn in much deeper waters as fully ripe fish are not found in the commercial catches. The fecundity of *R. brachysoma* from the Manila Bay has been estimated to be 11 300 to 119 300 eggs for fishes ranging from 16 cm to 22 cm TL (Tan, 1970). The life span of *R. brachysoma* and *R. kanagurta* has been estimated to be 1.5 to 2 years (Ingles and Pauly, 1984; Dalzell and Ganaden, 1987).

Anchovies

It is not known whether there are different stocks of the various species of *Stolephorus* inhabiting the Philippine waters. *S. heterolobus, S. devisi* and *S. punctifer* breed throughout the year, with peak spawning activity during the northeast monsoon season from October to March (Tiews *et al.*, 1970b). The mature males and females are common during the period of transition from the northeast monsoon to the southwest monsoon (April to July) and from the southwest monsoon to the northeast monsoon (October to December). The average life span of the stolephorids is generally 1 to 2 years, but *S. indicus*, the largest in the genus reach up to 3 years (Tiews et *al.*, 1970b; Ingles and Pauly, 1984; Dalzell and Ganaden, 1987).

Bigeyed scad

There are two species of bigeye scad in the Philippines, *Selar boops* and *S. crumenophthalmus*. The habitat of *S. boops* ranges from the shallow coastal reefs and sandy areas to the offshore grounds. They feed on small fishes and invertebrates. *S. crumenophthalmus* are migratory between the shallow murky inshore reefs and sandy flats and the clear offshore waters. They feed on small fishes, crustaceans, gastropods and foraminiferans; however, the juveniles prefer benthic forms (Schroeder, 1984). The longevity of *S. crumenophthalmus* is about a 2.5 years (Ingles and Pauly, 1984).

Sardines

Information on their distribution in the Philippines suggests wide range of salinity tolerance by the various species of the sardines (Herre, 1953). The sardine stocks of the southern Visayan Sea and the Bohol Sea seem to be contiguous with those of Sulu Sea and Celebes Sea (FAO, 1985). Similar to the stocks of the anchovies and the roundherrings in the Philippines, very little is known about the idendity and the biology of the sardines. The life span of the sardines, in general, appears to be 2 to 3 years, and probably up to 4 years. In the Camotes Sea,

Sardinella longiceps, ranging from 11.5 cm to 19.5 cm length were found to be immature and in the male to female ratio of 1.1:1.2 (Bognot, unpublished).

Roundherrings

Very little is known about the biology of the roundherrings in the Philippines although they form a significant part of the catches of the clupeids. Examination of the otoliths suggests that they attain 13 cm to 14 cm in the first year of life and the estimated life span is about 2 to 3 years (Dalzell and Ganaden, 1987).

Fusiliers

The fusiliers include the species of *Caesio* and *Pterocaesio*, which form the largest component of reef fish biomass. They are midwater schooling fish, which swim actively across the reefs, feeding on the plankton (Schroeder, 1984). The life span of *Pterocaesio pisang* is estimated to be 2 to 3 years.

Small tunas

The small tunas in the Philippines are composed mainly of two species of *Auxis, A. thazard* (frigate tuna) and *A. rochei* (bullet tuna) and *Euthynnus affinis* (kawa-kawa or eastern little tuna). The other species of small tunas, namely, *Thunnus tonggol* (longtail tuna) and *Sarda orientailis* (oriental bonito) are occasionally landed, but included with the other species of tunas. Very few studies have been conducted on the biology of the Philippine small tunas. Through the tuna sampling established by the FAO/UNDP/IPTP in the Philippines from 1980 to 1991, considerable data on the length measurements of these species have been generated. The size ranges of the small tunas sampled from the tuna ringnet catches at different landing centres from 1985 to 1987 shown in Table 8b (Arce and Gonzales, 1995) indicate no significant differences through the years, suggesting continuous recruitment into the fishery. In the Camotes Sea the modal size of 21 cm suggests that the *A. rochei* fishery to be of 1 to 2-year old fish. *A rochei* reach 17 cm, 29 cm, 35cm and 42 cm (FL) at the age of 1 to 4 years, respectively (Jabat and Dalzell, 1988). In the Batangas Bay, the spawning of *A. rochei* occurs in March, May and July and November to December (Arce, 1987). The male to female ratio is 1.2: 1.0 and the length-weight relationship is $4.529 \times 10^{-3} L^{3.36}$ (Yesaki, 1983). The larvae of tunas including that of the little tuna and other fishes are distributed in the Ragay Gulf, Burias and the Ticao Pass (Abusso, 1988).

Dolphinfish

Pelagic and demersal fishes, dominated by juvenile pelagics (50%) and deepsea spiny rayed fishes (Percomorphi) form the food of the dolphinfish. Cephalopods and crustaceans constitute only a minor portion of the diet. As the tunas, the dolphinfishes are voracious and appear to be nonselective, feeding on any available living organism (Ronquillo, 1953).

Other scads

The trawl catches of carangids from the Visayan Sea indicate differences in the depth distribution of various species. *Caranx kalla, C. djedaba* and *C.malabaricus* are caught in depths ranging from 20 m to 80 m; *Megalaspis cordyla* at 20 m to 50 m and 110 m to 140 m; and *Selaroides leptolepis* at 20 m to 50 m. Trawl catch of *S. leptolepis* ranges in size from 3.5 cm to 18.5 cm (TL) in a polymodal distribution. Those of 3.5 to 6.0 cm size are caught in July, October, and January to March, while those of 15.0 to 18.5 cm are caught from July to March (based on 1976-77 surveys). *S. leptolepis* of 3 to 18 cm size are caught mainly by gillnets set at 15 m depth in the mouth of the Manila Bay and nominally by other major gears operated inside the bay. Smaller sized fish are caught in February and March. Catches of *S. leptolepis* in the Visayan Sea and in the Manila Bay are composed of immature, maturing and mature individuals. Mature males and females range from 12.5 cm (TL) upwards. The male to female sex ratio in the Visayan Sea is 1.08:1.0 and in the Manila Bay 1.09:1.0. The length-weight relation for both sexes is $W=0.00630L^{3.19}$ for the Visayan Sea and $W=0.0278L^{2.699}$ for the Manila Bay.

Bombayduck

Harpodon nehereus are encountered in the catches from the central Visayas, but they are more abundant in the FAO Area 51 (Western Indian Ocean) within their general geographical distribution extending from the east coast of Africa to the Western Pacific, but limited only to some coastal waters and estuaries. Specimens of *H. micochir*, taken for the first time, off the Lubang Island at 448 m to 484 m depths indicate this fish to be mesopelagic (De la Paz, 1988).

POPULATION PARAMETERS

The growth parameters, estimated from the length frequency data, using ELEFAN II and the mortality parameters are presented in Table 9 (Corpuz *et al,* 1972; Dalzel, 1987; Dalzell *et al.,* 1990; 1991; Lavapie-Gonzales, 1987 a & b). The recruitment patterns generated from the length frequency analysis by ELEFAN II are illustrated in Fig. 4.

Recruitment of *D. macrosoma* and *D. russelli* into the fishery takes place during January to April when the fish attain lengths of 10 to 20 cm towards the end of their first year of life (Tiews *et al.*, 1970a; Ingles and Pauly, 1984). However, there are two peaks in the recruitment into the Camotes Sea ringnet fishery, perhaps associated with the two major monsoon periods, every year. In the case of the mackerels recruitment pattern varies from area to area, even within the same species, but is generally unimodal or bimodal (Dalzell and Ganaden, 1987). Two recruitment pulses seem to be typical of many Philippine fishes. These pulses are asymmetrical in size and occur during the different monsoons which seem to determine the pattern of recruitment and the spawning seasonality (Fig.4; Dalzell and Ganaden, 1987).

Biological information is not available for the other groups of small pelagics and hence there is need for collaborative research on a regional basis.

SEASONALITY IN CATCHES

The seasonal variations in the production of the different small pelagics, averaged for the period 1980 to 1986, were obtained from the Navotas fish port complex, where almost 70% of the catch of small pelagics from the major fishing grounds are landed (Calvelo, 1972; Dalzell and Ganaden, 1987; Fig. 5). Besides the purseseine and ringnet catches and CPUE by month are furnished for the Moro Gulf for 1993 and 1994 for the roundscads and tunas in Tables 10 and 11.

Catches of the roundscads peak during the summer months, but decline gradually towards the following months in the Navotas fish port complex. The same pattern has been observed in the ringnet fishery for the roundscads in the Camotes Sea and the Moro Gulf (Arce and Gonzales, 1995; Caliente, 1984). However, in the Lamon Bay of the Calagua Is. peak catches occur during the southwest monsoon season from June to August (Calvelo *et al.*, 1991; Ronquillo, 1973).

Catches of the bigeye scad, anchovies and roundherrings reach their peaks during the latter half of the year, with minimum landings between March and May. The landings of the sardines increase after April, with peak during July followed by a decline during the latter half of the year. A similar pattern has been observed in the trawler landings of the sardines in the San Miguel Bay (Vakily, 1982). The two species of mackerels exihibit different peaks in their catches. *R. kanagurta* catches attain the lowest levels during December and January, a major peak during March and a minor peak during May to July. There are three distinct peaks in the catches of *R. brachysoma*, which occur during February, June and October. The two peaks in the production of the fusiliers occur during February to April and July to October and the lowest production during June to January.

A. rochei are abundant in the Camotes Sea during the summer months with a secondary peak in October. In contrast, *A. thazard* are least abundant during May to July and most abundant towards the end of the year up to January (Jabat and Dalzell, 1988). As in the case of the eastern little tuna, the frigate and bullet tunas also do not show any distinct seasonality as they are always found in the catches of ringnets and purseseines in the Moro Gulf (based on monthly observations made during 1993 and 1994).

The peak fishing seasons for the small pelagics by fishing gears and by fishing grounds, as determined by a recent study conducted by Trinidad *et al.* (1993) are outlined below:

1. Sardines and mackerels: peak season is from January to April for the surface gillnet fishery in the Tayabas Bay, San Pedro Bay and Maqueda Bay.

2. Anchovies, sardines and mackerels: peak season is from January to April for the bagnet fishery in the East Sulu Sea, Tayabas Bay, Manila Bay (approaches) and Ragay Gulf.

3. Anchovies, sardines, mackerels, roundherrings and roundscads: peak season is from November to April for the round haulseine fishery in the Tayabas Bay and Ragay Gulf.

4. Sardines, mackerels and herrings: peak season is from February to June for the purseseine fishery in the Camotes Sea, Bohol Strait, Visayan Sea, Mindoro waters and Palawan waters.

5. Mackerels, sardines, roundscads and other carangoids: peak season is from October to May for the purseseine fishery in the South and East Sulu Sea, Visayan Sea and Camotes Sea.

6. Sardines: peak season is from January to May for the encircling gillnet fishery in the Ragay Gulf.

7. Sardines, anchovies and other small pelagics: peak season is from June to December for the beachseine fishery in the Visayan Sea.

FISHERIES MANAGEMENT

Development issues

During the 1920s and the 1930s, the Japanese fishermen introduced into the Philippines the beam trawl, a commercial fishing gear known as utase. This gear used to be operated by the combined power of the sail and the engine. Commercial trawling was expanded after World War II when viable trawling grounds were located under the Philippine Fishery Programme of the Fish and Wildlife Service, together with the continuous induction of innovative net designs, net materials and engines into the fishing fleets. There are five types of commercial fishing vessels operating in the Philippine small pelagic fisheries (Dalzell *et al.*, 1991; Table 12). The carrier vessels serve the ringnetters, trawlers, and purseseiners, transporting fish ashore and bringing water and other provisions to the crew of the fleets, thereby relieving the mother vessels of the need to frequent the homeports and maximizing fishing time.

Together with the development of the purseseines and the ringnets, the payaw fish aggregating devices (FADs), anchored in floating rafts, were also developed, resulting in the maximization of the small pelagic catches. The payaw, which evolved from a simple construction of bamboo and palm fronds, has been in use in the Philippines municipal fisheries. Since long (Murdy, 1980). There are no regulations governing the deployment of the payaws, which are estimated to be about 5 000 to 10 000 units along the Philippine coast at present. In the southern Mindanao, the payaws deployed in the deep waters of the Moro Gulf and the Celebes Sea are built from welded steel tubes and anchored in depths of up to 5 000

m. These structures cost about P 72 500 (US$ 3 600) each, of which about 80% is the cost of the ropes (Dalzell *et al.*, 1991). Concurrent with the growth of the purseseines, ringnets and payaws, the several antiquated municipal gears which were in wide use as early as the 16th century, have also been developed and improved considerably. In the course of these technological changes, the small scale fishermen from the southeast coast of Cebu were relocated to the northwest coast of Cebu due to the overfishing of the flyingfish stocks during the 1930s (Dalzell *et al.*, 1991). The growth of the fishing industry in terms of the number of fishing units and people engaged in the municipal and commercial sectors has generated considerable fishing pressure resulting in the steady increase in production and profit, but negative impacts are likely to follow, if the Philippine fisheries are not properly managed.

Overfishing problems

Since the Philippine marine fisheries, like in the other Southeast Asian countries, are characteristically a multigear system operating on multispecies stocks, assessment of the effect of fishing on the small pelagic stocks, is rather difficult. The problem is further aggravated by the fact that the gears exploiting the small pelagics are of different sizes and the boats use engines of different horsepower. In spite of these difficulties, time series data on the catch and fishing effort data could be constructed by Dalzell *et al.* (1991) for the period between 1948 and 1986, using the standardized total annual adjusted fleet horsepower for the fleet size (Table 12) and the annual catch (Fig. 6). The small pelagic catches increased rapidly with the rapid increase in the fishing effort particularly since the mid 1960s, but did not continue to rise after the early 1970s. The overall trend in the catch per unit of effort from 1948 to the present suggests a continuing decline(Fig. 6). Using the Fox model, Dalzell *et al.* (1991) were able to show how the catches leveled off and declined with the continuous increase in the fishing effort after reaching the point of the MSY on a national basis during the mid 1970s (Fig.7). The ratio of fishing mortality (F) to natural mortality (M), could also be used as an index of measuring how heavily a stock is fished (Dalzell and Ganaden, 1987). The optimum level of fishing effort is achieved when fishing mortality approaches natural mortality, $F\ opt_1 = M$; however, approximately 40% of natural mortality has also been proposed as optimum fishing mortality $F\ opt_2 = 0.4M$ (as quoted by Dalzell and Ganaden, 1987). Various studies indicate more or less similar estimates of mortality for the roundscads and many other small pelagics (Calvelo and Dalzell, 1987; Dalzell and Ganaden, 1987; Ingles and Pauly, 1984). In most cases, the F and M ratios have been found to be much higher than the $F\ opt_1$ particularly in the case of some stocks of stolephorid anchovies and the roundscads stock (Fig. 9), indicating heavy exploitation.

Management issues

The importance of fisheries to the Philippines economy is so great that the current issues of overexploitation cannot be ignored. The major issues which include reduction in the catches and income, rising conflicts among the fishermen and habitat degradation, are being addressed by the national administration, with appropriate assistance from the FAO (Pollock, 1996).

The problems of overexploitation and related issues are being dealt with through a 5-year management programme called the Fishery Sector Programme (FSP), funded by the Asian Development Bank (ADB) and the Overseas Economic Cooperation Fund (OECF), and implemented in the 12 priority bays of the country during 1990 to 1995. This was the maiden management programme of the government to address the problems of the fisheries sector, which consists essentially of the large and small pelagic fisheries. In the coastal fisheries sector, the programme addressed the issues of enhancement, environmental rehabilitation, control of destructive fishing activities and improved law enforcement through a community-based management regime. The local officials were assisted in framing a basic municipal fishery ordinance, providing for the management of the resources of the bays. Initially, a Bay Management Council (BMC) was formed to oversee the formulation and implementation of a Coastal Resources Management Plan (CRMP) of each of the bays. The CRMP dealt with the problems of rehabilitation of the environment and the resources, as well as the identification of alternative livelihood projects, which could be agriculture, mini-enterprise or mariculture. A monitoring, Control and Surveillance System (MCSS) was initiated as a management tool for the coastal areas, the offshore areas and the other areas within EEZ. This system is being piloted in the areas where the stakeholders have pledged their support. Besides, several Fisheries Administrative Orders (FAOs) are under active consideration for implementation. They include (i) a moratorium on the issue of commercial fishing boat license (CFBL) for new fishing vessels except for large fleets that will operate in the EEZ, (ii) increase in the mesh size of nets from 2 cm to 4 cm, and (iii) encouragement to the larger commercial fishing fleets to fish offshore or enter into joint-venture with other countries for expanding their operations. The several options and the possible outcomes specific to the small pelagic fisheries, are illustrated in Fig. 10 (Dalzell et *al.* 1991).

CONCLUSIONS AND RECOMMENDATIONS

The small pelagic fisheries of the Philippines are being heavily exploited, and hence, serious attention needs to be paid on their management to improve the catches and income to the fishermen, and to sustain the stocks and ensure the food security. Therefore, the following management options are recommended for urgent action and implementation:

1. reducing the catches of juveniles in order to increase production;
2. reducing or limiting the fishing effort;
3. increasing the mesh size of fishing nets;
4. enforcing the laws for protecting the coral reefs and mangroves;
5. protecting the spawning grounds;
6. maintaining and protecting the remaining productive marine habitats;
7. generating reliable and up-to-date catch and effort data, which are basic to management; and

8. enforcing the suggested resource rents to generate funds for increasing the R & D appropriations.

REFERENCES

Abuso, Z.V., 1988. Occurrence and distribution of larval tunas in Ragay Gulf, Burias Pass and Waters north of Samar. Indo-Pacific Tuna Dev. Mgt. Programme, *IPTP/88/GEN/15:* 164-179.

Aprieto, V.L., 1982. Philippine tuna fishing management. *Fish Res. J. Philipp.* 7(1): 38-50

Arce, F.M., 1987. The *Auxis spp.* fisheries of Batangas, Philippines. Indo-Pacific Tuna Dev. Mgt. Programme, *IPTP/88/GEN/12*: 137-144.

Arce, F., and C. Gonzales. 1995. The fisheries and biology of roundscads, mackerel and neritic tunas in the Philippines. A paper presented at the second regional workshop on shared stocks in the South China Sea area sponsored by SEAFDEC Marine Fishery Resources Development Management Programme (MFRDMP), Kuala Terenggana, Malaysia, 18-20 July 1995.

BAS, 1991. Fisheries Statistics, Bureau of Agricultural Statistics, Quezon City, 1988-1991.

BAS, 1995. Fisheries Statistics, Bureau of Agricultural Statistics, Quezon City, 1988-1995.

BFAR, 1987. Bureau of Fisheries and Aquatic Resources, Philippines. Fisherries Statistics. Quezon City, Metro Manila 1984-1987.

BFAR, 1996. Bureau of Fishereis and Aquatic Resources. Philippine Fisheries Profile 1995. 47 pp.

Bognot, E.C., (MS. Unpublished) Study on the Biology of Sardines (*Sardinella* spp.) in Camotes Sea.

Borja, P.C., 1975. On the ability of the otter trawls to catch pelagic fish in fish in Manila Bay. *Phil. Jour. Fish., Vol. 10 & 12*: 39-56.

Cabanban, A.G., 1984. Some aspects of the biology of (Bleeker 1985) (Pisces Caesionidae) in Centeral Visayas. University of the Philippines, MS thesis, 69 p.

Caliente, A., 1984. Aspect of the biology and fishery of redtail roundscad (*Decapterus russelli*) in the coastal waters of Western, Leyte. MS Thesis. College of Fisheries, U.P. Visayas, Iloilo City.

Calvelo R., and P. Dalzell, 1987. A review of the recent status of exploited stocks of roundscads in the Philippines. *(IPFC/87/Symp./IV/Inf./9)*.

Calvelo R., S. Ganaden and L. Tuazon.. 1991. Relative abundance of fish caught by bagnet around Calagua Island (Lamon Bay) with notes on their biology. *Phil. Jour. Fish. 22*, 49-67.

Calvelo, R.C., 1992. Synopsis of biological and related data on the Philippine roundscads. *Phil. Jour. Fish., Vol. 23*: 51-80

Calvelo, R.C., 1997. Assessment and biology of white-lipped roundscads (*Decapterus macarellus*) in Moro Gulf. MS. Unpublished.

Corpuz., A., J. Seager and V. Sambilay, 1972. Population parameters of commercially important fishes in the Philippine Waters. Department of Marine Fisheries, Univ. of the Philippines in the Visayas. *Tech. Rep. No. 6*:99 pp.

Corpuz, A., J. Saeger and V. Sambilay, Jr., 1985. Population parameters of commercially important fishes in the Philippine Waters. Technical Reports of the Department of Marine Fisheries No. 6, College of Fisheries UPV, Diliman Quezon City.

Dalzell, P., and R. Ganaden. 1987. A review of the fisheries for small pelagic fishes in Philippine waters. Bureau of Fisheries and Aquatic Resources, *Tech. Pap. Ser. Vol.X No.1*:58 p.

Dalzell, P., 1987. The overfishing of small pelagics fish stocks in the Philippines *(IPFC/87/Symp./IV/Inf./8)*.

Dalzell, P., P. Corpuz, F. Arce and R. Ganaden, 1990. Phillippine small pelagic fisheries and their managment. *Aquaculture and Fisheries Management 1990*, 27: 77-94.

Dalzell, P., P. Corpuz and R. Ganaden, 1991. The characteristic of Philippine small pelagic fisheries and options for management.

De la Paz, R.M., 1988. Deep Sea Fishes. In Proceedings of the Seminar-Workshop on the Status of Fisheries-related Oceanography Researches in the Philippines. 29 August 1988 at BFAR, Quezon City.

FAO, 1985. Report of the FAO/SEAFDEC Workshop on Shared Stocks in South East Asia, FAO Fish Rep. 337, 97 p.

Floyd, J.M., and D. Pauly. 1984. Smaller size tuna in and around the Philippines-can fish aggregating devices be blamed? INFOFISH Marketing Digest 5/84; 25-27.

Gomez, E.D., A.C. Alcala and A.C. San Diego. 1981. Status of the Philippine coral reefs - 1981, Proceedings of the fourth international coral reef symposium, 1: 245-282.

Gonzales, F. 1991. Growth, mortality and recruitment of *Decapterus kurroides* in Davae Gulf, Philippines. *Fishbyte, 9* (2) 6-9.

Guanco, M., 1991. Growth and mortality of Indian mackerel, *Rastrelliger kanagurta* (Scombridae) in the Visayan Sea, Central Philippines. *Fishbyte, 9*(2):13-15.

Herre, A.W., 1953. Checklist of Philippine fishes. Res. Rep. 20. *LIS Fish and Wildlife Service, Washington, D.C.* 977 p.

Ingles, J., and D. Pauly. 1984. An atlas of the growth mortality and recruitment of Philippine fishes. International Center for Living Aquatic Resources Management, Manila, Philippines. *ICLARM Tech. Rep. 13.*

Jabat, M. and P. Dalzell.1988. Preliminary stock assessment of the Danao ringnet fishery for bullet tunas and small pelagic fishes in the Camotes Sea, Central Visayas, Philippines. *BFAR Tech. Pap. Ser.. 11*(1):34pp.

Lavapie-Gonazales. F. 1987a. Growth, mortality and recruitment of Philippine fishes. International Center for Living Aquatic Resources Management, Manila, Philippines. *ICLARM Tech. Rep. 13.*

Lavapie-Gonzales, F. 1987b. Growth, mortality and recruitment of *Decapterus kurroides* in Davao Gulf, Philippines. *Fishbyte.* 9 (2):6-9.

Magnussion, S.E., O.Tan and R.M. Legasto. 1973. Zooplankton distribution and abundance in Lamon Bay and its approaches. *Phil. Jour. Fish., 11 (1 & 2)* : 73-85.

Murdy, E.O. ,1980. The commercial harvesting of tuna attracting payaos: A possible boon for small-scale fishermen. *ICLARM Newsl.3 (1);* 10-13.

NSCB, 1992. 1992 Philippine Statistical Yearbook. National Statistic Coordinating Board, Manila.

NSCB, 1995. 1995 Philippine Statistical Yearbook. National Statistic Coordinating Board, Manila.

Pollock, B., 1996. Fisheries management in the Philippines: A brief review. Paper contribution during the 2nd National Fisheries Workshop. February 1996. Puerto Azul, Cavite 16 pp.

Ronquillo, I.A., 1953. Food habits of tunas and dolphin based upon the examination of their stomach content. *Phil. J. Fish. 2*:71-83.

Gomez, E.D., A.C. Alcala and A.C. San Diego. 1981. Status of the Philippine coral reefs - 1981, Proceedings of the fourth international coral reef symposium, 1: 245-282.

Gonzales, F. 1991. Growth, mortality and recruitment of *Decapterus kurroides* in Davae Gulf, Philippines. *Fishbyte, 9* (2) 6-9.

Guanco, M., 1991. Growth and mortality of Indian mackerel, *Rastrelliger kanagurta* (Scombridae) in the Visayan Sea, Central Philippines. *Fishbyte, 9(2)*:13-15.

Herre, A.W., 1953. Checklist of Philippine fishes. Res. Rep. 20. *LIS Fish and Wildlife Service, Washington, D.C.* 977 p.

Ingles, J., and D. Pauly. 1984. An atlas of the growth mortality and recruitment of Philippine fishes. International Center for Living Aquatic Resources Management, Manila, Philippines. *ICLARM Tech. Rep. 13.*

Jabat, M., and P. Dalzell, 1988. Preliminary stock assessment of the Danao ringnet fishery for bullet tunas and small pelagic fishes in the Camotes Sea, Central Visayas, Philippines. *BFAR Tech. Pap. Ser. 11*(1):34pp.

Lavapie-Gonazales, F., 1987a. Growth, mortality and recruitment of Philippine fishes. International Center for Living Aquatic Resources Management, Manila, Philippines. *ICLARM Tech. Rep. 13.*

Lavapie-Gonzales, F., 1987b. Growth, mortality and recruitment of *Decapterus kurroides* in Davao Gulf, Philippines. *Fishbyte.* 9 (2):6-9.

Magnussion, S.E., O.Tan and R.M. Legasto. 1973. Zooplankton distribution and abundance in Lamon Bay and its approaches. *Phil. Jour. Fish., 11 (1 & 2)* : 73-85.

Murdy, E.O., 1980. The commercial harvesting of tuna attracting payaos: A possible boon for small-scale fishermen. *ICLARM Newsl.3 (1);* 10-13.

NSCB, 1992. 1992 Philippine Statistical Yearbook. National Statistic Coordinating Board, Manila.

NSCB, 1995. 1995 Philippine Statistical Yearbook. National Statistic Coordinating Board, Manila.

Pollock, B., 1996. Fisheries management in the Philippines: A brief review. Paper contribution during the 2nd National Fisheries Workshop. February 1996. Puerto Azul, Cavite 16 pp.

Ronquillo, I.A., 1953. Food habits of tunas and dolphin based upon the examination of their stomach content. *Phil. J. Fish. 2*:71-83.

Table 1. Quantity and value of fish production by sector in the Philippines during 1985 to 1995.

Year	Commercial Marine Fisheries	Municipal Marine Fisheries	Inland Fisheries	Aquaculture	Total
1985	512	785	260	495	2052
1986	546	807	265	471	2089
1987	591	816	245	561	2213
1988	600	838	232	600	2270
1989	637	883	222	629	2371
1990	701	895	237	671	1504
1991	760	914	233	692	2599
1992	805	855	230	736	2626
1993	845	803	227	772	2647
1994	885	787	223	791	2686
1995	980	780	200	820	2780
Value (P million)					
1985	7857	12796	1920	8724	31297
1986	9248	14611	2640	10823	37331
1987	9821	12217	1891	11421	37350
1988	10272	14693	1940	15213	42118
1989	11033	16182	2206	15673	45094
1990	12411	16736	2564	20466	52177
1991	15245	19614	2519	22656	60034
1992	16801	19444	3212	25986	65443
1993	18365	20118	2067	30508	71058
1994	21130	22327	2492	35280	81229
1995	23730	24330	2450	33330	83840

Source: Fishery Statistics 1985-1995, Bureau of Agricultural Statistics.

Table 2. Share of the principal fishing grounds in the catches (in mt) of the Philippines during 1991/92.

Species	West Sulu Sea	South Sulu Sea	Visayan Sea	Moro Gulf	Lamon Bay	East Sulu Sea	Ciyo Pass	Tayabas Bay	Batangas Coast	Bohol Sea	Others	Total
1991												
Roundscad	2,250	54,638	34,765	16,535	5,024	6,285	3,760	4,199	808	6,100	112,596	246,960
Sardines	2,357	10,737	59,662	884	669	550	530	1,146	154	1,127	17,608	95,424
Anchovies	840	1,940	900	813	896	498	1,070	7,040	32	16	10,252	24,297
Mackerel	1,048	8,907	12,414	902	545	1,042	424	1,465	10	1,320	22,725	50,802
Bigeyed scad	410	3,428	2,534	722	544	88	169	432	24	501	5,499	14,351
Roundherring	7	964	445	1	161	40	1,070	76	26	-	-	2,790
Fusilier	27	25	141	4	12	17	15	19	17	2	5,206	5,485
Total	6,936	80,639	110,861	19,861	7,851	8,520	7,038	14,377	1,071	9,066	173,886	440,109
%	1.58	18.33	25.19	4.51	1.78	1.94	1.69	3.27	0.24	2.06	39.51	100
1992												
Round scad	2,712	76,408	31,529	36,990	10,988	7,535	1,687	5,326	942	6,889	93,031	274,037
Sardines	2,442	22,642	56,861	3,491	487	2,928	466	325	158	6,617	28,570	124,987
Anchovies	957	842	1,612	2,658	925	367	969	6,413	406	334	7,763	23,246
Mackerel	337	9,662	9,775	3,708	612	1,171	116	2,135	80	598	10,659	38,853
Bigeyed scad	278	4,416	2,431	2,688	527	128	60	25	15	334	5,013	15,915
Roundherring	95	4,547	2,250	54,638	34,765	16,536	5,024	6,285	3,760	4,199	808	6,100
Fusilier	8	35	32	177	22	8	3	850	-	28	6,272	7,435
Total	6,829	118,552	102,677	55,178	13,684	12,152	3,328	15,389	1,624	14,800	151,711	495,924
%	1.38	23.91	20.70	11.13	2.76	2.45	0.67	3.10	0.33	2.98	30.59	100

Source: Fishery Statistics 1991-1992, Bureau of Agricultureal Statistics

Table 3. Annual production of small pelagics in the Philippines in relation to total production in tons during 1984 to 1993.

Year	Municipal Fishery (mt)			Commercial Fishery (mt)		
	Total production	Small pelagics		Total production	Small pelagics	
		Production	% share		Production	%share
1984	789,975	243,322	30.80	513,335	250.664	48.83
1985	785,382	223,748	28,49	511,987	245,281	47.91
1986	807,361	215,646	26.71	546,230	277,076	50.73
1987	815,878	281.880	34.55	591,192	313,215	52.98
1988	838,195	247,496	29.53	599,995	321,342	53.56
1989	882,626	253,675	28.74	637,138	365,045	57.29
1990	894,866	262,166	29.30	700,564	415,454	59.30
1991	913,765	259.067	28.35	759,815	438,372	57.69
1992	854,360	424,556	28.39	804,866	494,805	61,47
1993	803,274	222,496	27,70	845,431	529,593	62.64
Average	838,568	245,205	29.26	651,055	365,085	55.24

Source: BFAR Fisheries Statistics for (1984 - 1987) and Bureau of Agricultural Statistics for 1984-993.

Table 4. Contribution of major commercial fishing gears to the small pelagic catches (in mt) during 1994/95.

Species	Trawl	Purse seine	Ringnet	Bagnet	Round haul seine	Danish seine	Other gears	Total	Percentage (%)
1994									
Roundscads	4,827	135,767	38,864	25,187	594	4,659	361	210,259	
Sardines	6,030	109,955	45,892	15,784	994	1,853	1,593	182,101	35.60
Anchovies	4,313	2,036	8,377	10.872	98	215	308	26,219	5.13
Mackerel	3,788	25,136	10,323	1,185	123	6,938	259	47,752	9.34
Big-eyed scad	1,036	8,773	8,216	979	32	947	670	20,653	4.04
Round herring	1,888	12,805	3,346	603	1	180	203	19,026	3.72
Fusilier	5,060	15	2	17	-	192	171	5,457	1.07
Total	26,942	294,487	115,020	54.627	1,842	14,984	3,565	511,467	100
1995									
Roundscads	5,140	165,820	31,622	27,505	-	6,108	796	236,991	43.82
Sardines	11,386	121,244	31,854	21,445	28	2,653	3,024	191,634	35.44
Anchovies	3,393	1,283	6,875	14,114	1,206	424	2,313	29,608	5.48
Mackerel	2,748	19,522	4,709	2,778	100	7,175	607	37,639	6.96
Big-eyed scad	571	8,918	5,367	794	4	1,451	2,808	19,910	3.68
Round herring	1,628	11,891	3,466	994	-	289	4	18,282	3.38
Fusilier	75	6,005	29	7	-	94	508	6,718	1.24
Total	24,951	334,683	82,922	67.634	1,338	18,194	10,060	540,782	100.00
%	4.61	61.89	15.52	12.51	0.25	3.36	1.86		100
%	5.27	57.58	22.49	10.68	0.36	2.93	0.70		100

(Source: Bureau of Agricultural Statistics for 1994/95.

Table 5. Contribution of major commercial fishing gears of the small pelagic catches (in mt) during 1991 - 1995.

	Fishing Gears						
Year	Trawls	Purseseine	Ringnet	Bagnet	Round haulseine	Danish seine	Other gears
1991	35,336	310,259	42,085	37,647	3,493	4,869	6,292
1992	34,689	348,354	50,369	42,944	2,010	5,606	11,952
1993	31,405	335,362	93,575	46,158	173	14,206	9,475
1994	26,942	294,487	115,020	54,627	1,842	14,984	3,565
1995	24,951	334,683	82,922	67,634	1,338	18,194	10,060
Average	30,665	324,629	76,994	49,802	1,771	11,572	8,269
%	6.09	64.45	15,29	9.89	0.35	2.30	1.64

Source: Bureau of Agricultural Statistics for 1991 to 1995.

Table 6. Export of processed products of small pelagics from the Philippine during 1986 to 1991.

Year	1986		1987		1988	
Commodity	Q(kg)	V(p)	Q(kg)	V(p)	Q(kg)	V(p)
1. Dried , salted or in brine; smoked (whether or not cooked before or duirng smoking)						
1.1 Anchovies (dried, slated or in brine)	44,852	2,370,949	91,605	3,092,689	147,092	7,913,631
1.2 Herrings (dried, slated or in bring)	133,216	6,548,125	144,852	6,286,302	190,651	9,546,499
1.3Mackerels (dried slated or in brine)	34,473	1,670,872	58,531	2,578,475	76,335	3,387,484
1.4 Sardines (dried, slated in brine)	9,987	441,793	24,787	1,179,723	8,215	375,367
1.5. Herrings, smoked	39,693	1,969,280	60,587	2,880,028	69,521	3,269,9580
1.6 Sardines, smoked	7,829	361,498	12,378	590,580	5,905	276,590
2. Prepared or preserved						
2.1 Anchovies, prepared or preserved in airtight container	2,783	199,084	8,776	604,914	9,406	647,034
2.2 Mackerels, prepare or preserved in airtight container	33,182	642,517	10,252	505,416	2,264	80,469
2.3 Sardines, prepared or preserved in airtight container	47,696	1,367,352	191,877	5,921,957	236,344	8,916,378
2.4 Herrings prepared or preserved in airtight container			306	18,748	144	624
2.5 Anchovies (fish paste in airtight container)	167,161	7,348,713	193,804	8,092,318	151,073	8,560,852
Total	520,872	20,549,234	797,755	23,666,924	896,820	72,404,508

Table 6 cont'd

Year	1989		1990		1991	
Commodity	Q(kg)	V(p)	Q(kg)	V(p)	Q(kg)	V(p)
1. Dried , salted or in brine; smoked (whether or not cooked before or duirng smoking)						
1.1 Anchovies (dried, slated or in brine)	75,309	3,415,364	101,704	5,372,118	165,712	8,844,761
1.2 Herrings (dried, slated or in bring)	150,101	7,712,996	108,238	6,619,618	114,103	7,853,430
1.3Mackerels (dried slated or in brine)	52,169	2,651,568	43,647	2,744,224	42,281	2,958,406
1.4 Sardines (dried, slated in brine)	17,124	994,401	5,792	342,736	12,352	790,097
1.5. Herrings, smoked	39,219	2,056,388	28,140	1,640,498	29,170	1,889,014
1.6 Sardines, smoked	3,175	154,796	2,185	118,103	4,061	257,362
2. Prepared or preserved						
2.1 Anchovies, prepared or preserved in airtight container	20.031	1,411,239	8,631	910,237	18,049	1,701,279
2.2 Mackerels, prepare or preserved in airtight container	18,898	639,891	269,107	10,058,668	120,293	4,675,385
2.3 Sardines, prepared or preserved in airtight container	342,368	13,877,710	403,721	18,832,745	1,547,887	65,040,682
2.4 Herrings prepared or preserved in airtight container						
2.5 Anchovies (fish paste in airtight container)	99.074	4,567,502	137,699	6,997,390	208,093	10,538,676
Total	817,468	37,481,828	1,108,864	53,636,337	2,262,002	104,549,092

Table 7. Small pelagics processed in oil (in whole, piece or unminced).

Year	1994		1995	
Species	Kg	Value(P)	Kg	Value(P)
Sardine	2,732,970	88,350,963	1,286,371	49,156,309
Mackerel	772,757	25,226,799	33,152	1, 837 ,945
Anchovies	9,643	704, 914	131,159	7 ,978, 150
Herring	740	135,327	899	162,665
Total	**3 ,516,110**	**114, 418, 003**	**1,451,581**	**59,135, 069**

Table 8a. The current retail price (in P) of small pelagics per kg weight in Metro Manila markets.

Small pelagics	Fresh	Dried salted	Canned	Canned	Canned	Bottled in condiment
Sardines	60	160 P7.50/can of 11.5 g	P16.80/can of 425 g	-	-	-
Mackerel	80	160	P 6.90/can of 155 g	P16.00/ can of 425 g	-	-
Round scads	60	150	-	-	-	-
Anchovies	60	140	-	-	P6.75/bottle of 350 ml fish sauce. P26.00/bottle 230 g fish paste	P17.95/litre of fish sauce. P 36.00/340 g of fish paste
Bigeyed scad	150	-	-	-	-	-
Herring	140	-	-	-	-	-
Fusilier	100	120	-	-	-	-

Table 8b. Size ranges (in cm) of small tunas caught in the Philippines during 1985 to 1987.

Species	1985	1986	1987	Area
Auxis thazard	21-39	21-39	12-44	Labuan, Zamboanga
Auxis rochei	11-39	21-30	12-34	Labuan, Zamboanga
Euthynnus affinis	21-49	21-48	11-54	Labuan, Zamboanga
Auxis thazard	14-29	20-33	24-38	Opol, Misamis Oriental
Auxis rochei	15-29	16-29	20-23	Opol, Misamis Oriental
Auxis thazard	20-43	13-28	-	Sta. Cruz, Davao
Auxis rochei	17-29	10-20	-	Sta. Cruz, Davao
Auxis thazard	18-37	20-31	17-37	General Santos City
Auxis rochei	17-28	19-27	16-37	General Santos City
Euthynnus affinis	16-31	20-25	18-29	General Santos City

Table 9. Growth and mortality parameters in respect of the small pelagics in the Philippines.

Family/Species	Location	Loo	K	Lmax	tmax	O'	M	References
CLUPEIDAE								
Sardinella melanura	Palawan	22.5	0.70	21	4.1,	2.55	1.53	Ingles and Pauly (1984)
Sardinella sirm	Palawan	27.3	0.86	25	2.96	2,81	1.66	Ingles and Pauly (1984)
Sardinella longiceps	Manila Bay	21.0	1.10	18	1.93	2.69	2.10	Ingles and Pauly (1984)
Sardinella fimbriata	Manila Bay	18.0	0.70	17	3.15	2.36	1.63	Ingles and Pauly (1984)
Sardinella fimbriata	Palawan	22.0	1.15	19	1.88	2.75	2.42	Ingles and Pauly (1984)
Sardinella fimbriata	Philippines	14.0	1.60			2.50	3.00	Ronquillo (1960)
Dussumiera acuta	Ragay Gulf	21.0	1.05	18	1.0	2.67	1.97	Corpuz *et. al* (1985)
CAESIONIDAE								
Pterocaesio pisang	Philippines	17.6	1.14	15	1.82	1.82	2.15	Cabanban (1984)
Pterocaesio pisang	Philippines	17.5	0.97	15	2.20	2.20	2.15	Cabanban (1984)
CARANGIDAE								
Decapterus macrosoma	Camotes Sea	25.0	0.88			2.74	1.73	Jabat and Dalzell (1988)
Decapterus macrosoma	Manila Bay	31.5	0.65	28.0	3.63	2.81	1.33	Ingles and Pauly (1984)
Decapterus macrosoma	Manila Bay	31.5	0.71	28.0	3.32	2.85	1.41	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	27.0	0.90	25.0	3.10	2.82	1.72	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	26.8	0.71	25.0	4.04	2.71	1.47	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	26.5	1.00	25.0	3.04	2.85	1.85	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	27.8	0.83	25.0	2.50	2.81	1.61	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	33.0	0.50	31.0	5.92	2.74	1.10	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	27.5	1.25	21.0	1.30	2.88	2.12	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	25.0	1.20	20.0	1.50	2.88	2.12	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	25.5	0.85	22.0	2.20	2.74	1.68	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	25.50	0.80	22.0	2.20	2.72	1.62	Ingles and Pauly (1984)
Decapterus macrosoma	Palawan	33.0	0.65	30.0	3.90	2.85	1.31	Ingles and Pauly (1984)

Table 9 cont'd

Family/Species	Location	Loo	K	Lmax	tmax	O'	M	References
CARANGIDAE								
Decapterus macrosoma	Palawan	30.0	0.74	27.0	3.30	2.82	1.47	Ingles and Pauly (1984)
Decapterus macrosoma	Samar Sea	23.0	1.25	22.0		2.82	2.19	Corpus et. al. (1985)
Decapterus macrosoma	Ragay Gulf	25.5	1.26	23.0		2.91	2.12	Corpus et. al. (1985)
Decapterus maruadsi	Burias Pass	27.7	0.82	22.0		2.63	1.67	Corpus et. al. (1985)
Decapterus maruadsi	Samar Sea	23.55	0.81	23.0		2.65	1.64	Corpus et. al. (1985)
Decapterus maruadsi	Ragay Sea	23.5	0.52	22.0		2.46	1.22	Corpus et. al. (1985)
Decapterus kurroides	Davao Gulf	25.0	0.80			2.39	1.62	Gonzales (1991)
Decapterus russelli	Manila Bay	27.0	0.80	23.0	2.60	2.77	1.59	Ingles and Pauly (1984)
Decapterus russelli	Manila Bay	30.0	0.54	26.0	4.00	2.69	1.19	Ingles and Pauly (1984)
Decapterus russelli	Manila Bay	26.9	0.69	24.0	3.40	2.70	1.44	Ingles and Pauly (1984)
Decapterus russelli	Manila Bay	26.0	0.73	24.0	3.80	2.69	1.51	Ingles and Pauly (1984)
Decapterus russelli	Manila Bay	33.0	0.45	28.0	4.54	2.69	1.51	Ingles and Pauly (1984)
Decapterus russelli	Manila Bay	33.0	0.45	28.0	4.54	2.69	1.03	Ingles and Pauly (1984)
Decapterus russelli	Camotes Sea	33.7	0.36			2.61	0.89	Jabat and Dalzell (1988)
Selar crumenophtalmus	Manila Bay	36.5	0.89	34.0	3.2	3.07	1.57	Ingles and Pauly (1984)
ENGRAULIDAE								
Stolephorus punctifer	Manila Bay	10.1	1.10	9.0	2.2	2.05	2.55	Ingles and Pauly (1984)
Stolephorus punctifer	Manila Bay	10.6	1.85	9.2	1.2	2.32	3.53	Ingles and Pauly (1984
Stolephorus punctifer	Manila Bay	9.2	1.15	8.0	2.0	1.99	2.69	Ingles and Pauly (1984
Stolephorus indicus	Manila Bay	16.3	1.42	15.0	1.8	2.58	2.67	Ingles and Pauly (1984
Stolephorus indicus	Manila Bay	15.7	1.08	15.0	2.9	2.43	2.23	Ingles and Pauly (1984
Stolephorus indicus	Ragay Gulf	14.5	1.30				2.55	Corpuz et. al (1985)
Stolephorus heterolobus	Manila Bay	12.1	1.60	11.0	2.4	2.09	2.29	Ingles and Pauly (1984)
Stolephorus heterolobus	Manila Bay	11.4	0.95	11.0	2.4	2.09	2.29	Ingles and Pauly (1984)
Stolephorus commersoni	Manila Bay	11.3	0.96	10.0	2.3	2.09	2.28	Ingles and Pauly (1984)
Stolephorus tri	Ragay Gulf	14.5	1.30				2.55	Corpuz et. al (1985)
Stolephorus tri	Samar Sea	14.5	1.30				2.55	Corpuz et. al (1985)

Table 9 cont'd

Family/Species	Location	Loo	K	Lmax	tmax	O'	M	References
SCOMBRIDAE								
Rastrelliger brachysoma	Samar Sea	24.5	1.28	22.0	1.7	2.89	2.17	Corpuz et al. (1985)
Rastrelliger brachysoma	Samar Sea	25.0	1.30	23.0	2.1	2.91	2.32	Corpuz et al. (1985)
Rastrelliger brachysoma	Samar Sea	25.5	1.45	23.0	1.7	2.97	2.19	Corpuz et al. (1985)
Rastrelliger brachysoma	Manila Bay	34.0	1.10	30.0	2.1	3.10	1.84	Ingles and Pauly (1984)
Rastrelliger brachysoma	Samar Sea	25.0	1.60	22.0	1.4	3.00	2.56	Ingles and Pauly (1984)
Rastrelliger brachysoma	Manila Bay (1958-60)	34.0	0.98					BFAR files (unpublished)
Rastrelliger brachysoma	Visayan Sea (1983)	34.0	0.98					BFAR files (unpublished)
Rastrelliger brachysoma	Visayan Sea (1984)	32.5	1.20					BFAR files (unpublished)
Rastrelliger brachysoma	Samar Sea (1984)	29.75	1.30					BFAR files (unpublished)
Rastrelliger brachysoma	Leyte Gulf (1985)	34.0	0.98					BFAR files (unpublished)
Rastrelliger faughni	Camotes Sea	25.9	1.45			299	2.44	Jabat and Dalzell (1988)
Rastrelliger kanagurta	Illana Bay (1984)	39.0	0.72			3.04		BFAR files (unpublished)
Rastrelliger kanagurta	Guimaras Strait (1985)	27.8	1.65			3.10		BFAR files (unpublished)
Rastrelliger kanagurta	Samar Sea (1984)	26.5	1.60			3.05		BFAR files (unpublished)
Rastrelliger kanagurta	Visayan Sea (1984)	37.0	0.70			2.98		BFAR files (unpublished)
Rastrelliger kanagurta	Visayan Sea (1983)	29.5	1.50			3.12		BFAR files (unpublished)
Rastrelliger kanagurta	Visayan Sea (1983 87)	38.0	0.80			3.06		Guanco (1991)
Rastrelliger kanagurta	Samar Sea	27.5	1.30	25.0	2.0	2.99	2.11	Corpuz et al (1985)
Rastrelliger kanagurta	Samar Sea	28.0	1.31	26.0	2.0	3.01	2.13	Corpuz et al (1985)
Rastrelliger kanagurta	Palwan water	28.0	1.55	25.0	1.5	3.08	2.43	Ingles and Pauly (1984)
Rastrelliger kanagurta	Camotes Sea	25.5	1.50			2.99	2.45	Jabat and Dalzell (1988)

Table 10. Purseseine catches and catch per unit effort for the Moro Gulf by month during 1993 and 1994.

MONTH and YEAR	ROUNDSCAD		FRIGATE TUNA		BULLET TUNA		KAWAKAWA		ALL SPECIES	
	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)
January 1993	0.4	-	9.7	0.4	-	-	-	-	49.2	1.8
February	112.2	1.9	49.7	0.8	74.9	1.3	26.0	0.4	386.1	6.5
March	52.7	0.8	35.1	0.5	91.5	1.3	16.0	0.2	366.0	5.3
April	50.0	0.8	24.3	0.4	211.6	3.5	2.8	0.1	482.2	8.0
May	151.0	0.2	147.7	0.2	140.3	0.2	4.1	-	29641.1	45.5
June	23.9	0.6	16.1	0.4	-	-	-	-	322.4	8.1
July	7.8	0.1	12.L2	0.2	20.2	0.4	2.7	0.1	262.1	4.9
August	11.5	0.1	10.9	0.1	87.3	0.9	14.2	0.1	755.5	7.4
September	43.2	0.3	71.1	0.6	98.6	0.8	55.8	0.4	807.2	6.3
October	4.4	0.1	47.9	0.6	95.9	1.5	27.9	0.4	519.9	7.9
November	8.6	0.1	47.9	0.7	26.3	0.4	9.7	0.1	464.5	6.8
December	6.6	0.1	10.5	0.2	20.6	0.4	4.7	0.1	372.0	6.5
TOTAL	472.2	0.5	477.0	0.4	867.2	0.9	163.8	0.2	34428.2	11.4
January '94	50.4	0.5	57.3	0.6	15.4	0.2	3.4	-	662.0	6.4
February	6.4	0.1	22.6	0.4	33.5	0.6	4.3	0.1	284.5	5.3
March	3.5	0.1	9.4	0.4	14.6	0.6	1.9	0.1	117.4	4.7
April	5.4	0.2	20.9	0.9	12.6	0.5	4.0	0.2	202.3	8.3
May	16.8	0.4	10.3	0.2	8.2	0.2	1.2	-	186.7	3.9
June	39.2	0.5	59.9	0.8	90.6	1.2	6.5	0.1	447.7	5.9
July	57.2	0.6	40.8	0.4	39.1	0.4	26.4	0.3	628.7	6.2
August	57.3	0.4	40.8	0.3	8.9	0.1	40.8	0.3	628.5	4.5
September	7.9	0.2	30.0	0.8	7.2	0.2	27.0	0.7	179.6	4.9
October	7.7	0.4	16.1	0.8	7.2	0.2	27.0	0.7	179.6	4.9
November	0.5	-	12.7	0.3	13.9	0.4	2.5	0.1	85.7	2.3
December	3.9	0.1	32.5	0.6	28.0	0.5	10.7	0.2	267.0	5.1
TOTAL	256.2	0.3	353.4	0.5	274.9	0.4	32.8	0.2	3805.7	5.4

(Preliminary data from the tuna catch , monitored under PTRP, (unpublished). * Raised catch from sample boat total catches using % coverage and % days sampled ** Catch per unit effort derived only from the individual vessels sampled

Table 11. Ringnet catches and catch per unit effort for the Moro Gulf by month during 1993 and 1994.

MONTH and YEAR	ROUNDSCAD		FRIGATE TUNA		BULLET TUNA		KAWAKAWA		ALL SPECIES	
	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)	Total* catch (mt)	CPUE** (mt/trip day)
January 1993	55.7	0.5	97.0	0.8	168.6	1.4	46.0	0.4	1082.5	8.9
February	-	-	166.3	0.8	255.5	1.3	37.7	0.2	840.2	4.2
March	68.1	0.3	241.1	0.9	272.5	1.0	21.9	0.1	1547.4	5.7
April	35.2	0.2	83.8	0.5	13.4	0.1	2.5	-	667.9	3.8
May	32.4	0.1	84.6	0.3	213.0	0.6	36.5	0.1	1039.1	3.0
June	12.7	-	96.4	0.3	128.1	0.4	40.7	0.1	949.4	3.2
July	166.5	0.4	89.9	0.2	148.1	0.4	0.5	-	2387.9	6.3
August	42.6	0.2	76.7	0.3	241.7	0.9	21.2	0.1	1145.0	4.3
September	19.8	0.1	112.8	0.8	155.0	1.1	57.9	0.4	1353.4	9.8
October	216.7	0.6	167.5	0.5	193.9	0.5	35.1	0.1	2212.8	6.2
November	40.4	0.3	103.7	0.5	62.2	0.3	4.3	-	1167.2	5.7
December	94.4	0.7	134.6	1.0	156.6	1.2	9.3	0.1	1245.8	9.3
TOTAL	814.3	0.3	1454.2	0.5	2008.4	0.7	313.5	0.1	15638.6	5.7
January '94	63.9	0.6	55.4	0.5	46.8	0.5	4.9	0.1	783.6	7.6
February	45.1	0.2	217.4	0.9	122.2	0.5	22.5	0.1	1373.2	5.4
March	27.1	0.1	132.7	0.5	255.0	0.9	16.6	0.1	1514.7	5.2
April	117.1	0.5	109.3	0.5	172.7	0.8	4.1	-	960.7	4.4
May	130.7	0.5	227.1	0.9	119.3	0.5	9.3	-	1660.0	6.6
June	239.2	1.3	303.5	1.7	290.6	1.6	36.8	0.2	1844.0	10.2
July	108.1	0.4	147.8	0.5	235.4	0.8	6.7	-	1453.5	4.8
August	212.1	1.2	148.0	0.8	189.8	1.1	34.2	0.2	2718.8	15.1
September	480.8	1.3	266.4	0.7	853.6	2.2	28.0	0.1	2708.5	7.1
October	268.7	0.6	235.1	0.5	974.6	2.1	30.6	0.1	3084.2	6.6
November	160.2	0.6	172.9	0.6	904.1	3.4	28.3	0.1	2268.5	8.5
December	62.4	0.2	160.2	0.6	429.1	1.6	21.3	0.1	18003.8	6.6
TOTAL	1915.6	0.6	2175.8	0.7	4593.1	1.4	243.1	0.1	22174.0	7.3

Preliminary data from tuna catch, monitored under PTRP, (unpublished). * Raised catch from sample boat total catches using coverage and days sampled.
** Catch per unit effort derived only from the individual vessels sampled.

Table 12. The number of vessels from the five principal commercial fleets exploiting the small pelagics and the carrier vessels from 1948 to 1986.

Year	Purse seine	Basnig	Otter trawler	Ringnet-ter	Muro-ami	Total	Carrier vessel	Grand Total
1948	9	168	15	no data	9	201	no data	201
1949	10	242	58	-	2	312	--	312
1950	16	333	129	-	2	480	-	480
1951	26	502	190	-	2	718	-	718
1952	35	648	234	-	1	918	-	918
1953	29	643	227	-	5	904	-	904
1954	49	653	309	-	3	969	-	969
1955	38	670	301	-	10	1,019	-	1,019
1956	76	574	313	-	21	904	-	904
1957	65	540	283	-	22	969	-	969
1958	57	733	349	-	31	1,170	-	1,170
1959	77	717	423	-	33	1,250	-	1,250
1960	79	673	445	-	47	1,244	-	1,244
1961	75	680	462	-	48	1,265	-	1,265
1962	89	742	490	-	46	1,367	-	1,367
1963	109	892	513	-	48	1,562	-	1,562
1964	152	841	494	-	42	1,529	36	1,565
1965	168	1,009	578	-	79	1,834	99	1,933
1966	226	1,006	596	-	47	1,875	159	2,034
1967	176	1,002	593	-	37	1,808	190	1,988
1968	196	883	653	-	25	1,732	175	1,907
1969	223	796	667	-	24	1,710	217	1,927
1970	215	858	653	-	26	1,752	193	1,945
1971	265	743	652	-	37	1,697	258	1,955
1972	320	650	690	-	39	1,699	290	1,989
1973	470	791	794	-	37	2,092	155	2,247
1974	280	584	767	-	37	1,668	297	1,965
1975	313	713	763	58	35	1,882	278	2,160
1976	342	656	786	58	36	1,878	268	2.146
1977	280	504	684	61	34	1,563	241	1,804
1978	331	639	769	150	5	1,894	269	2,163
1979	408	641	877	143	41	2,110	260	2,370
1980	412	624	848	158	7	2,049	346	2,395
1981	450	552	764	222	45	2.033	415	2,448
1982	516	603	829	269	39	2,256	496	2,752
1983	403	573	932	310	43	2,261	516	2,777
1984	318	652	884	394	37	2,285	521	2,806
1985	306	602	763	418	37	2,126	513	2,639
1986	280	565	702	404	34	1,985	465	2,450

Source: Dalzell *et. al.*, 1991.

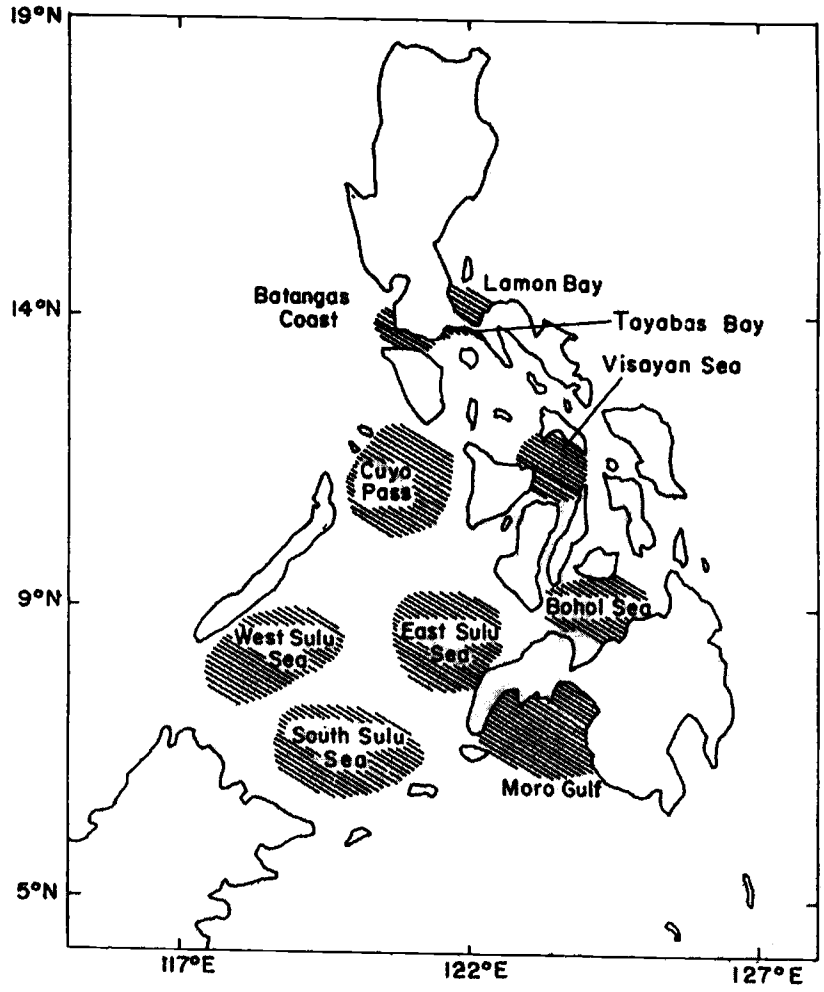


Fig. 1. The major fishing grounds for small pelagic fisheries.

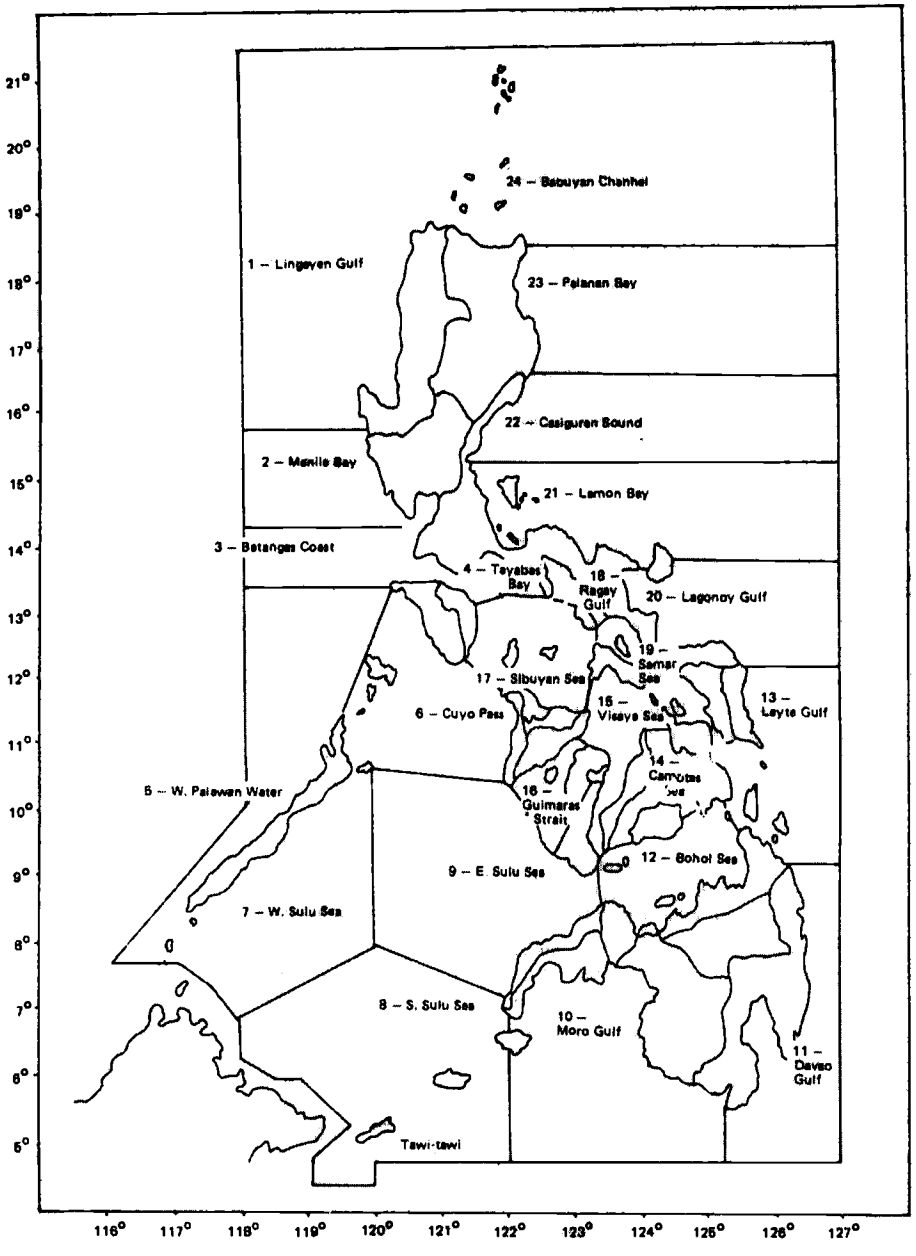


Fig. 2. Map of the Philippines showing the 24 statistical fishing areas.

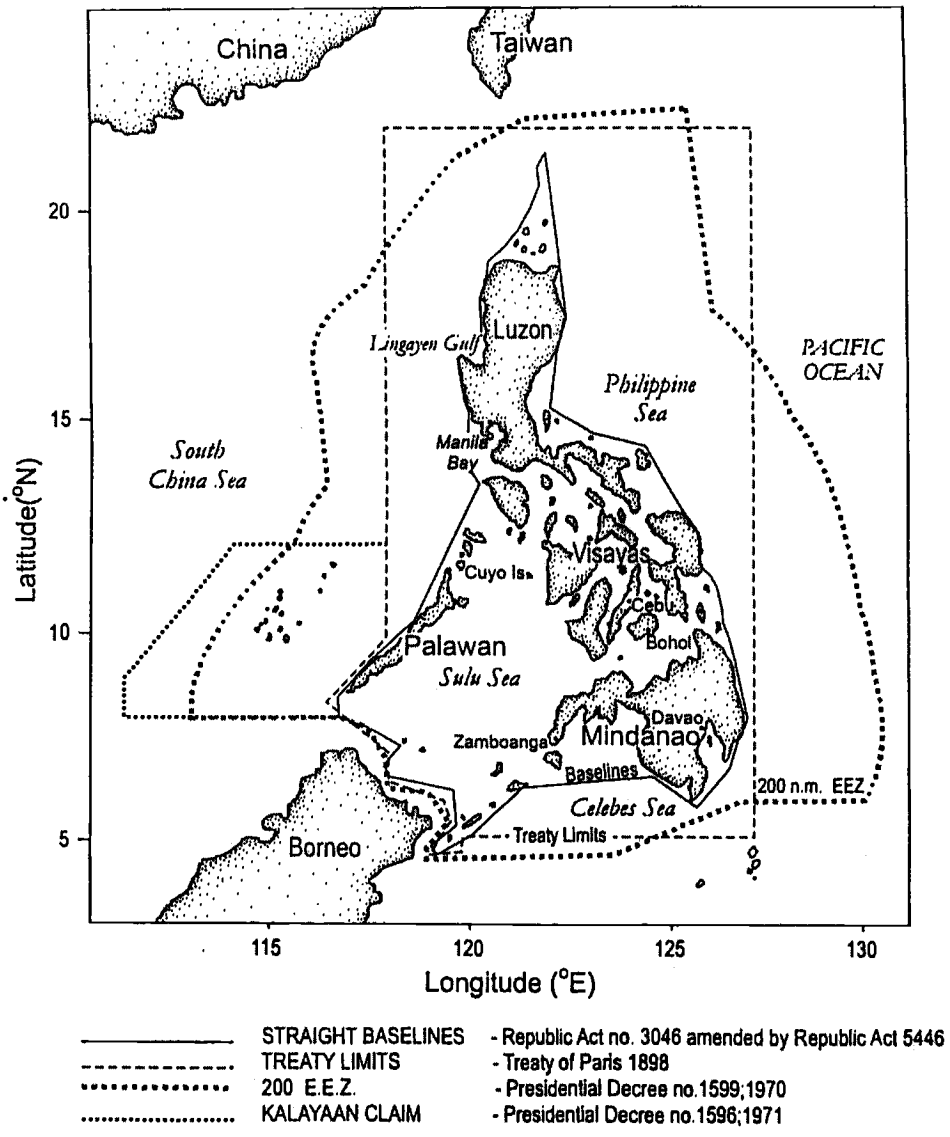


Fig. 3. Marine jurisdictional boundaries of the Republic of the Philippines.

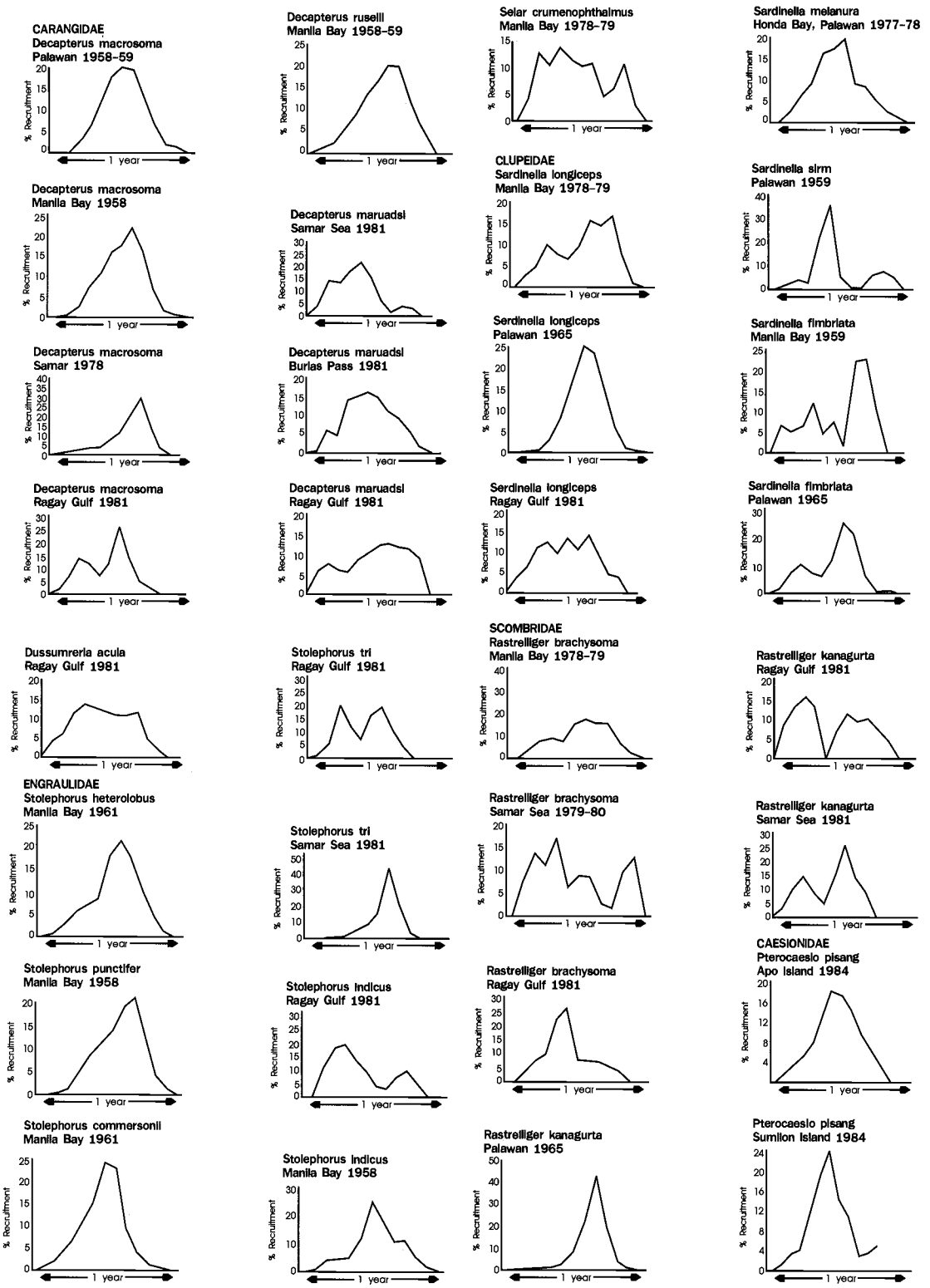


Fig.4 : Recruitment patterns generated from length frequency data by ELEFAN II for various species of small pelagic fish from different locations in the Philippines. Source : Dalzell and Ganaden (1987a)

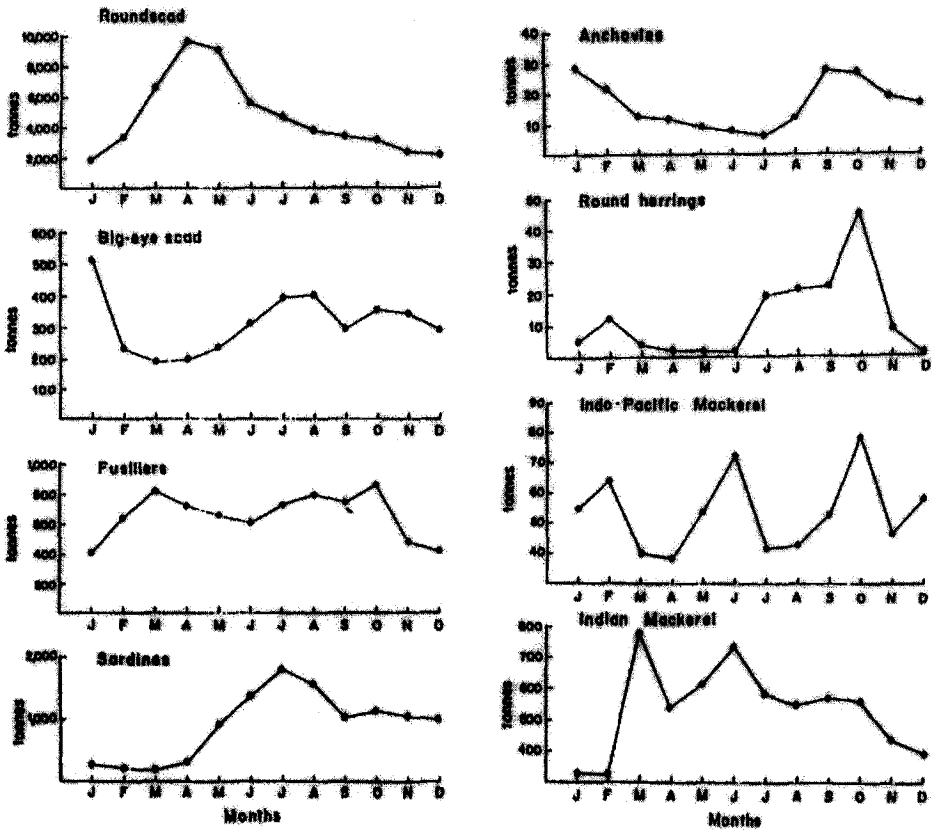


Fig. 4a. Mean monthly landings of the seven principal small pelagic fish species at Navotas Fish Port Complex estimated from landing data, 1980-1086. Source: Dalzell and Ganaden (1987).

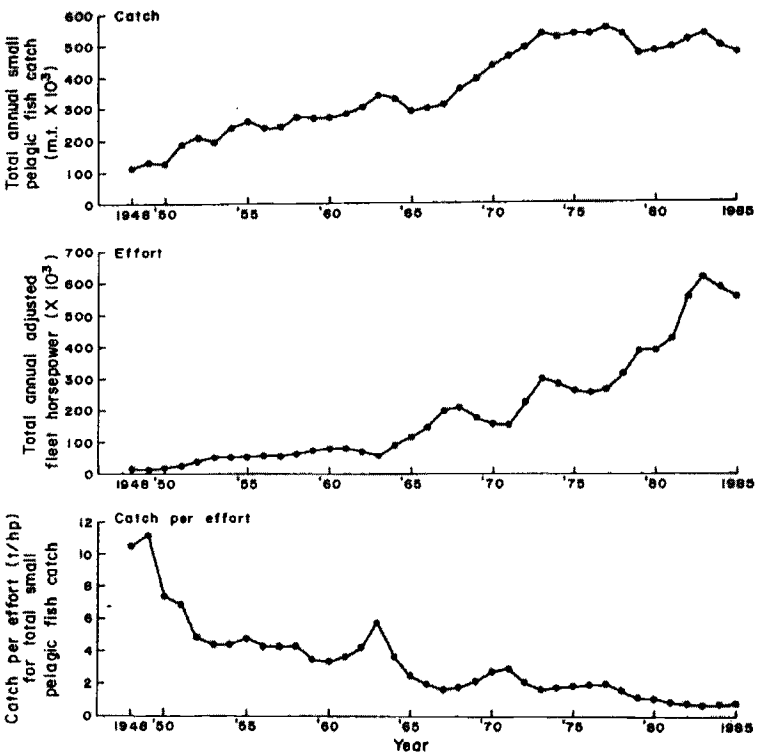


Fig. 5. Time series of total small pelagic catch, fishing effort and catch per effort 1948 to 1986.
Source: Dalzell *et. al.* (1991).

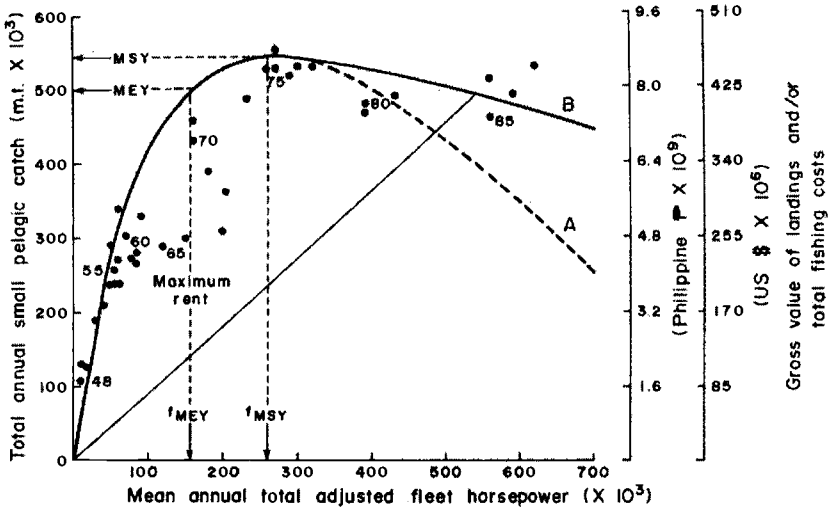


Fig. 5a. Total annual small pelagic catch versus mean annual fleet horsepower. Curve A is the Fox surplus production model fitted by conventional means; Curve B represents another interpretation of data. The fMEY and MEY are based on the assumption that the fishery achieved economic equilibrium between 1981 and 1985. Equation of the line fitted to the 1948 to 1985 points:

$$y = x\, e^{1.751} - 3.89310^{-6x}$$

The 1986 data point was added without calculating the curve.
Source: Dalzell *et. al.* (1981).

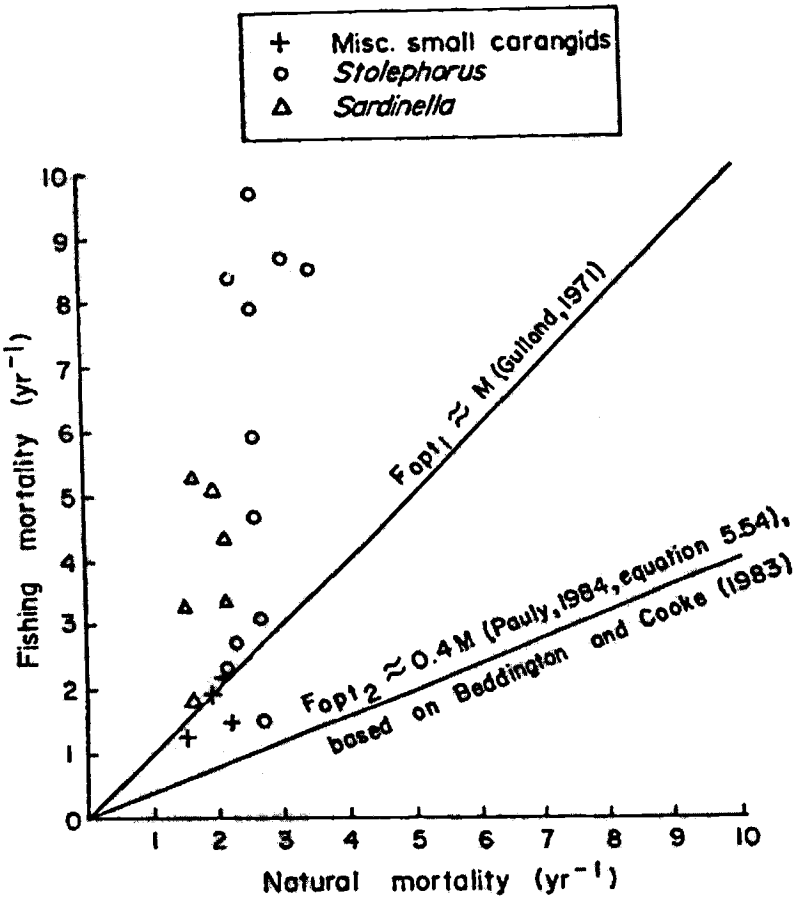


Fig. 6. Relationship between apparent fishing mortality and natural mortality in small pelagic fish stock of the Philippines.
Source: Dalzell and Ganaden (1987).

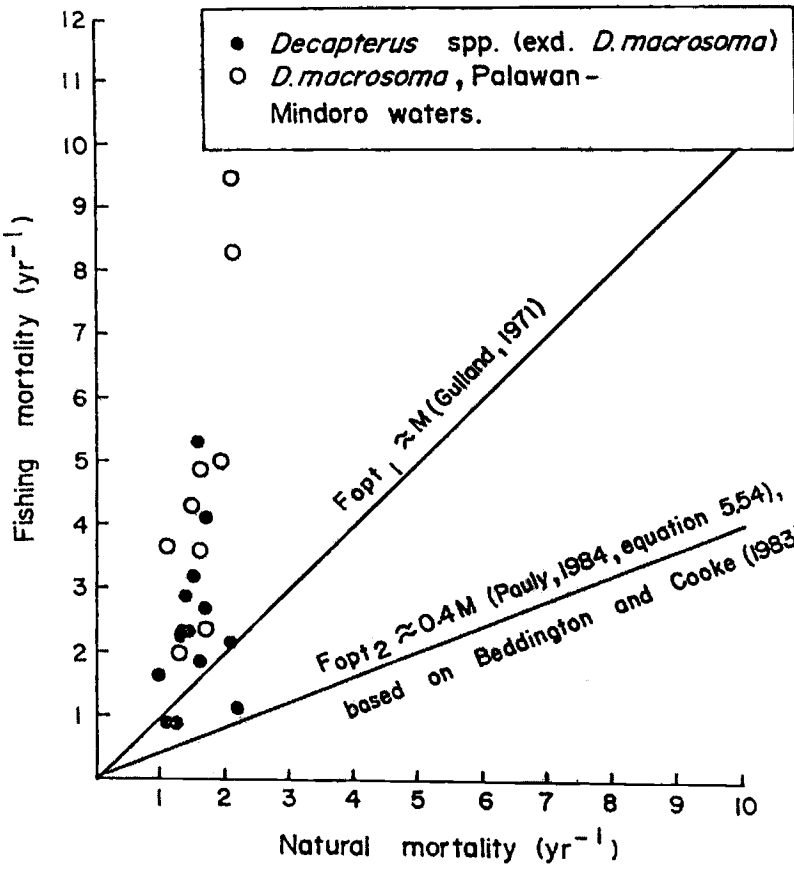


Fig. 7. Plot of apparent fishing mortality on natural mortality for Philippine stocks of round scads (*Decapterus spp.*).
Source: Calvelo and Dalzell (1987).

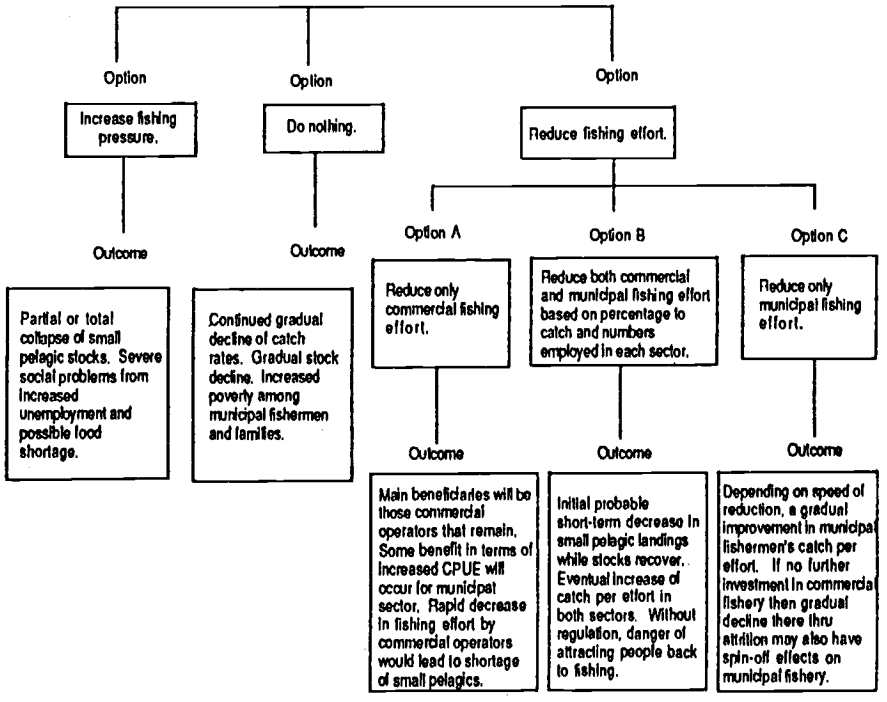


Fig. 8. Management options for Philippine small pelagic fisheries.
Source: Dalzell *et. al.* (1991).

Review of the Small Pelagic Fisheries of Sri Lanka

by

Pauline Dayaratne
National Aquatic Resources Research and Development Agency, Colombo 15, Sri Lanka

Abstract

In Sri Lanka, the small pelagics contribute around 40% to the coastal fish production. The present estimated production of the small pelagics is about 65 000 mt with the estimated maximum potential of about 95 000 mt. The main fishing gears used in the fishery include the small meshed gillnets, beahseines and purseseines.

The small pelagics are generally distributed in the coastal and estuarine waters, with only a few species, like Amblygaster sirm and flyingfish extending their distribution to the offshore waters. Age, growth and mortality have been estimated from length frequency data and daily growth rings on otoliths for some of the most commercially important species.

Fisheries management is carried out by the Department of Fisheries and Aquatic Resources Development on the basis of Fisheries Ordinance of 1940 and the Fisheries and Aquatic Resources Act No. 2 of 1996. The involvement of the communities in the management of fisheries is taken cared by the fisheries cooperative societies.

INTRODUCTION

An Island situated in the Indian Ocean to the south of India, between the latitudes of 6 to 10 degrees north and the longitudes of 80 to 82 degrees east, Sri Lanka has a coatline of 1760 km, and exclusive economic zone (declared in 1978) of about 517 000 km^2 including 28 000 km^2 of continental shelf which is narrow, with average and maximum widths of 25 km and 45 km respectively. The productivity of the coastal waters is limited due to the lack of significant upwellings and the narrow continental shelf. Marine fishing is carried out all around the Island, but most of the production comes from the coastal waters, which accounted for 161 500 mt (74%) of the total catch of 221 500 mt in 1995. No separate statistics is available for the small pelagic catch, but the statistics from the Ministry of Fisheries & Aquatic Resources indicates 95% of the shoreseine catches and 70% of the category "others" to be small pelagics. Accordingly, the small pelagic catch in 1995 was estimated to be around 65 000 mt, which was about 40% of the total coastal fish catch in the Island. Almost the entire small pelagic catch is consumed locally, especially by the low income groups as the price is generally lower than that of the large pelagics and the demersals. 85% to 95% of the small pelagic catch is consumed in the fresh form while the remaining 10% to 15% is dried and sold. A significant number of fisherwomen from the northwest and west coasts are engaged in postharvest activities of small pelagic fisheries, such as sorting the catch (from the gillnets and beachseines) and drying and marketing the products.

FISHERIES FOR SMALL PELAGICS

The beachseines operated by the large log raft (paru) and the gillnets of natural fibres operated by the small log raft and dugout canoes contributed significantly to the catch of small pelagics in the past. The small pelagic fisheries sector benefited considerably from the motorisation of artisanal fishing vessels and the introduction of synthetic nylon nets for gillnetting. Subsidies encouraged the coastal fishermen adopt gillnet fishing, resulting in a significant increase in the production of small pelagics from about 35 000 mt in 1967-68 to 76 000 mt in 1981. Since then there has been a continuous increase, which peaked at 90 000 mt in 1983. The production, however, dropped to around 70 000 mt in 1984-85 after the civil disturbances in the northern and eastern parts of the country, and stabilised around 65 000 mt during the decade of 1985-95 (Table 1). More than 45% of the small pelagics comes from the areas where the continental shelf is wide and the productivity higher than the other regions (Table 2; Fig. 1).

Table 1. Coastal fish production by species or groups (in mt) during 1985-1995.

Species or groups	1985	1986	1987	1988	1989	1990
King mackerel	3475	3575	3698	3842	3899	3314
Carangids	8096	8327	8616	8952	9085	7722
Skipjack	12118	12463	12896	13398	13597	12237
Yellowfin tuna	6716	6907	7147	7426	7536	6406
Other blood fish	6298	6477	6702	6963	7066	6359
Sharks	6341	6521	6748	7011	7115	6404
Skates	8772	9022	9335	9699	9843	8859
Rockfish	7012	7211	7462	7753	7863	6688
Shoreseinecatches*	27682	28471	29460	30608	31064	27958
Prawns	4192	4311	4461	4635	4704	4469
Lobsters	592	608	629	654	663	629
Others*	48972	50374	52124	54158	54976	43087
TOTAL	140266	144266	149278	155099	157411	134132

Species or groups	1991	1992	1993	1994	1995
King mackerel	3916	3524	3369	3200	2993
Carangids	8975	8526	8378	8000	6910
Skipjack	16690	18359	19316	20475	23548
Yellowfin tuna	10664	11730	11981	13180	12050
Other blood fish	9325	10258	10681	11215	17642
Sharks	8640	9072	9446	9100	9381
Skates	9720	9234	9615	10400	4636
Rockfish	8658	9870	10277	10585	7088
Shoreseinecatches*	33426	35097	37379	38870	49785
Prawns	5176	6470	6737	4000	4000
Lobsters	789	828	862	1000	400
Others*	43172	40200	41859	41475	23067
TOTAL	159151	163168	169900	171500	161500

* 95% of the shore seine catches and 70% of the 'others' consist of small pelagics - MFAR.
Source: Ministry of fisheries & Aquatic Resources.

Table 2. Coastal fish production by districts (in metric tons) during 1985-1995.

DFEO Division	1985	1986	1987	1988	1989	1990
Colombo	1676	2087	2208	2294	2328	2183
Negombo	20625	21221	21551	22214	22524	17428
Chillaw	13986	14386	15220	15812	16047	15052
Puttalam	21528	21239	22471	23347	23695	22089
Kalutara	5319	5965	6311	6557	6654	6241
Galle	11622	11550	12220	12696	12885	12087
Matara	10125	9700	10263	10663	10821	10150
Tangalle	10196	10252	10847	11269	11436	10727
Mannar	8246	8246	8567	8694	8694	6299
Mullativu	3426	3669	3669	3812	3868	2868
Trincomalee	9258	10336	10336	10739	10899	8223
Batticaloa	3256	3256	3256	3382	3432	3218
Kalmunai	7228	8584	8584	8918	9050	6489
Jaffna	13775	13775	13775	14702	15078	11078
Total	140266	144266	149278	155099	157411	134132

DFEO Division	1991	1992	1993	1994	1995
Colombo	2561	2625	2250	1923	2152
Negombo	19371	21405	22277	25634	28570
Chillaw	17351	19217	20198	21308	21554
Puttalam	23431	24017	24867	23732	27028
Kalutara	8621	8837	9368	9703	9903
Galle	13429	13765	14173	14386	15309
Matara	12597	12975	13823	14375	14809
Tangalle	12086	13295	14427	15204	15499
Mannar	8782	6225	6300	*	*
Mullativu	3141	1967	950	*	*
Trincomalee	11412	13048	14250	14565	8739
Batticaloa	8745	9371	9750	*	*
Kalmunai	9261	10344	11150	*	*
Jaffna	8363	6077	6117	*7934	*4577
Total	159151	163168	169900	171500	161500

* For 1994 and 1995 fish production of all these DFEO Divisions were grouped together as production from the Northern Province which is given in this table under Jaffna.

Source: Ministry of Fisheries & Aquatic Resources Development.

The main fishing gears used in the exploitation of the small pelagics include the beachseines and the small meshed gillnets. The beachseine operates within a very limited range from the shore, while the small meshed gillnets operated by the traditional motorised and nonmotorised craft and the 17-18' fibre reinforced plastic (FRP) boats with outboard engines, exploit the inshore grounds. Since the early 1980s, 3.5 mt size purseseiners with inboard engines also became popular along the southwest coast for the exploitation of the small pelagics. In 1992 the fishing fleet in

Sri Lanka consisted of around 25 600 vessels of which 14 000 (56%) were nonmotorised (Table 3). Majority of the nonmotorised craft, motorised traditional craft and the FRP boats with outboard motors are used in the small pelagic fisheries, particularly in gillnet and handline operations throughout the year or seasonally. Since recently the use of combination gears such as the small meshed gillnets for the small pelagics and the handlines for the demersals is becoming increasingly popular, particularly along the west coast, because of better economic performance of such combination fisheries.

Table 3. Composition of the operating fishing craft in Sri Lanka (1992).

	Unmotorised	Motorised
1. Traditional craft		
1.1 Dugout canoes with	7678	840
outrigger	455	909
1.2 Dugout canoes without	1072	-
outrigger	5172	
Beachseine craft		
Others		
Subtotal	14377	1749
2. Introduced craft		
2.1 17-23 ft (FRP) boats	-	7004
2.2 28-32 ft (3.5-4 ton) boats	-	2044
2.3 Over 32 ft boats	-	415
Subtotal		9463
Total	14377	11212
Percentage	56.2%	43.8%
Grand total	25,589	

Source: Ministry of Fisheries & Aquatic Resources Development.

Beachseine fishery

The beachseine fishery was the highest single contributor to the total Island fish production before the motorisation of the fishing industry. During 1953 and 1954 it accounted for about 13 000 mt, which was 40% of the fish production in the country (Canagarathnam and Medcof, 1956), but subsequently its importance decreased with the emergence of new techniques of exploitation (Weerakoon, 1965). Beachseining is carried out all around Sri Lanka (Fig. 2) in relatively calm waters seasonally, depending on the exposure of the fishing areas to the monsoon: during October to April along the westcoast and April to September along the east coast. Therefore, most beachseine owners and their crew migrate from the west to the east coast during the southwest monsoon. Usually 40 to 60 men are involved in one beachseine operation; depending on the location, the area of operation is limited to a narrow belt of one to two kilometers from the shore.

The earliest record of beachseining in Sri Lanka is that of Pearson (1922), while the first record of its fishery is that of Canagarathnam and Medcof (1956) followed by Canagaratnam (1965), reporting the existence of 3 600 beachseines throughout the Island, but only a fraction of them operating on any particular day. However, by 1983-84, the number of beachseines declined to 1 500, yielding about 10 000 mt of small pelagics (Anon., 1984). The catch rates of beachseine operations

through the successive periods from 1953 to 1993 are given in Table 4. As the beachseines depend on the availability of fish schools in the nearshore waters, which in turn depend on various oceanographic parameters such as the currents, there is a wide variation in their catch rates, both seasonally as well as geographically. Catch rates varying from 4 lb to 1910 lb per operation during 1953-54 were recorded by Canagaratnam and Medcof (1956), 216 lb to 1798 lb per operation during 1964-65 by Canagaratnam (1965) and 177 lb to 336 lb per operation during 1983-86 by Karunasinghe (1986). The annual fish production from beachseines alone increased from 13 000 mt during 1952-54 to 29 000 mt during 1961-63. Towards 1961-63, however, the annual total marine fish rpoduction increased to 92 000 mt as a result of the motorisation of the traditional fishing craft and the introduction of motorised fibreglass boats, but the contribution of the beachseines dropped to 30% during 1961-63 (Canagaratnam, 1965). With the increasing use of other fishing gears, particularly the small meshed gillnets targeting the small pelagic stocks, the beachseine production dropped to 5 to 10% during 1982-84 (Anon., 1984). However, the total beachseine production during this period remained around 12 000 mt to 13 000 mt , indicating no significant reduction from the 1961-63 level.

Table 4. Beachseine catch rates through the successive periods from 1953 to 1993.

			Average catch rate in kg.	
Source	**Period**	**Area**	**Catch/ haul**	**Catch/manhour**
Canagaratnam & Medcof (1956)	1953 - 1954	West Northeast Northwest	64.9 413.6 83.0	0.6 3.7 0.6
Canagaratnam (1965)	1964 - 1965	South West Northwest North East	131.8 817.3 388.6 139.6 436.4	1.6 2.4 3.6 2.6 3.1
Karunasinghe (1986)	1983 - 1986	Southwest West	336.1 177.4	1.3 0.7
Weerasooriya (1986)	1985	South	296.3	-
Dayaratne & Sivakumaran (1994)	1991 - 1993	Southwest	45.0	0.3
Fernando & Dayaratne (1994)	1992 - 1993	Northwest	210.5	1.8

Source: Ministry of Fisheries & Aquatic Resources Development.

The number of species in a beachseine catch is generally high, with about a dozen species well represented, and more than 90% of the catch consisting of small pelagics. The clupeids such as the herrings, sardines and anchovies are the most common in the catch, followed by the carangids like the scads, Indian mackerel and silverbellies. Although the species compositoin varies from one place to another, it is always dominated by the above groups. *Sardinella* species constituted the bulk of

the beachseine catch in Moratuwa in the 1960s (Canagarathnam, 1965), but the silverbellies became dominant in the early 1980s (Karunasinghe, 1986). In recent years the anchovies (*Stolephorus spp.*) have become dominant along the southwest coast, accounting for half the catch (Dayaratne and Sivakumaran, 1994).

Small mesh gillnet fishery

The use of small mesh gillnets in the small pelagic fisheries became popular after the advent of motorisation of artisanal fishing boats, enabling their operation in fairly distant grounds for schools that were not accessible to the traditional beachseine operations. With the introduction of FRP boats with outboard engines in the 1970s, gillnetting with nylon nets became a popular method for exploiting the small pelagics. Although successful trials were carriedout, the use of monofilament gillnets in the small pelagic fisheries did not become popular (Pajot, 1977a). Around 80% of the small pelagic production in the mid 1980s came from the small mesh gillnets (Karunasinghe and Dayaratne, 1986), which are now commonly operated all around the Island by the nonmotorised traditional craft, nonmotorised FRP dugout canoes, motorised traditional craft and 17-23 ft FRP boats with outboard motors (Fig. 2). Despite the development efforts during the last decade, the indigenous traditional craft is still predominant, continuing to play an important role in the small pelagic fisheries (Table 3). The type and the number of craft involved in the small mesh gillnet fishery vary according to areas. The 17-23 ft FRP boats are used in this fishery along the northwest and west coasts, whereas the nonmotorised traditional craft, nonmotorised FRP craft, motorised traditional craft and a few 17-23 ft FRP boats are used along the southwest coast (Karunasinghe and Fonseka, 1985). While the nonmotorised traditional craft is quite popular along the south coast, the 17-23 ft FRP boats are used only in certain localities in the south.

In almost all the areas, the mesh sizes used in the small mesh gillnet fishery vary according to the seasonal variations in the availability and abundance of different species of fish. The mesh size ranging from 1 1/8" to 1 1/2" is the most commonly used in the sardine fishery and other clupeids of the size range of 8 to 24 cm total length; 4/8" to 9/10" mesh is common along the northwest, west and southwest coasts, mainly for the anchovies (*Stolephorus spp.*), fishery and other small engraulids and clupeids of the size range of 3 to 10 cm; mesh of 1 1/4" to 2" sizes is used in the northwest, west and southwest coasts for the relatively larger small pelagics such as the Indian mackerel, sabrefish (*Chirocentrus dorab*), barracudas (*Sphyraena spp.*) etc. The number of net pieces used in a small mesh gillnet fishery varies from 4 to 30, depending on the craft type (Table 5). Generally the nonmotorised craft carries 4 to 14 pieces of nets, the motorised traditional craft 8 to 24 pieces and the FRP boats 12 to 30 pieces each (Dayaratne, 1985 b). The height of these nets often varies according to the areas of operation; in the south, where the continental shelf is very narrow and the inshore waters relatively deeper the height is twice that used in the other areas (Karunasinghe and Fonseka, 1985) (Table 5).

The catch rate of the motorised craft is generally more than double that of a nonmotorised craft operated in the same area. It also varies seasonally as well as geographically. The areas influenced by the monsoons experience peak fishing for the small pelagics towards the end of the monsoon season. The catch rates of the

small mesh gillnets are usually higher in the northwest and west coasts than in the other areas (data is not available for the north). The high catch rates (154 kg/boat/day) for the FRP boats operating in the northwest indicate the relatively high productivity in the shelf extending over a large area. The catch rates of the small mesh gillnet fishery remained more or less the same over the past decade except in the northwest (Chilaw), which experienced a slight increase and the west (Negombo) which suffered a significant decrease (Table 6; Karunasinghe and Fonseka, 1986).

Table 5. Summary of small mesh gillnet operations.

Area	Type(s) of craft	Maximum # recorded daily	Mesh size range(s)	No. of pieces of net	Effective netwidth (fathoms)	Depth of fishing (fathoms)	No. of fishing trips/boat/day
Far South	NM oru M oru FRP boats	487 63	 1 1/8" - 1 1/4"	6-14 8-24 12-30	4 3/8 - 7	10-15 10-15 10-35	1
South	NM oru M oru FRP boats	395 185	 1 1/8" - 1 1/4"	6-14 8-24 12-30	4 3/8 - 7	10-15 10-15 15-35	1
Southwest	NM oru FRP oru M oru FRP boats	 568 47	4/8" - 1" 4/8" - 1" 1 1/8" - 1 1/4" 1 3/4" - 2"	4-8 4-8 6-12 8-16	 2 5/8 - 3 1/2	3-5 3-5 10-15 15-35	1-2
West	FRP boats	700	4/8" - 1 1/2"	14-24	3 1/2	8-18	1-2
Northwest	FRP boats	556	4/8" - 1 1/2"	14-24	3 1/2	8-18	1

Source: Karunasinghe and Fonseka, 1985; NM oru = nonmotorised wooden oru; M oru = motorised oru; FRP oru = nonmotorised FRP oru; FRP boats = 17-23' FRP boats.

The efficiency of the motorised craft is always higher than that of the nonmotorised craft used for the same fishery.

Around 30 species of fish have been identified from the catches of the small meshed gillnet fishery. The clupeids form more than 85% of the catches in the northwest, west and far south, 70% in the south and 35% in the southwest. The engraulids are as important as the clupeids in the southwest. Among the clupeids, *Amblygaster sirm* (*Sardinella sirm*), *Sardinella albella*, *Sardinella gibbosa*, *Pellona ditchella* and *Dussumieria acuta* are the dominant (Table 7; Dayaratne, 1984; Karunasinghe and Fonseka, 1986).

Table 6. Catch rates in the small meshed gillnet fishery.

Source	Study Period	Area	Craft Type	Catch rates in kg/boat/day
Dayaratne (1984)	1978 - 1980	West	FRP	52.7
Dayaratne (1984)	1978 - 1980	Northwest	FRP	68.7
Karunasinghe & Fonseka (1985)	1983 - 1984	Far south	NM	12.3
			M*	24.2
		South	NM	8.9
			M*	9.7
		Southwest	NM	9.7
			M*	19.0
		West	M*	42.4
		Northwest	M*	153.7
Karunasinghe & Dayaratne (1986)	1985	Far south	M*	19.4
		South	M*	17.9
		Southwest	NM	8.6
		West	M	8.6
			FRP	34.7
		Northwest	FRP	78.7
Dayaratne & Karunasinghe (1992)	1989 - 1990	Far south	NM	15.5
			M	22.3
			FRP	27.0
		South	NM	7.9
			M	16.0
			FRP	19.1
		Southwest	NM	8.5
			FRP	31.0
		West	FRP	38.5
		Northwest	FRP	179.5
Dayaratne & Sivakumaran (1994)	1992 - 1993	Southwest	NM	15.6
			FRP	18.9
Jayawardena & Dayaratne (1994)	1991 - 1993	Northwest	FRP	19.9
Fernando & Dayaratne (1994)	1992 - 1994	Northwest	NM	11.4
			FRP	25.2

NM=nonmotorised craft; M=motorised craft; FRP=fibre reinforced plastic; *M=includes motorised traditional craft and FRP boats.

The small mesh (30 to 50 mm) gillnet fishery at Kandakuliya (a major fish landing site) in the northwest coast employs FRP boats with 15 to 25 H.P engines, which operate upto the 60m depth range. Although about 700 boats operated during 1991, the fleet reduced to 500 boats during 1993. The fishery recorded catch rates of 22 kg/boat/day during 1991 and 18 kg/boat/day during 1993. Clupeids, mainly *A. sirm*

and *A.clupeoides*, constitute around 72% of the catch. The total production was estimated to be 2 008 mt and 1 617 mt during 1991-92 and 1992-93 respectively (Jayawardane and Dayaratne, 1994).

Table 7. Species composition (%) of the FRP boat small meshed gillnet fishery along the northwest, west, southwest and south coasts.

Species or species group	1995	1996
Amblygaster sirm	54.6	28.6
Sardinella gibbosa	24.9	21.3
Sardinella albella	11.7	15.0
Stolephorus spp.	0.9	8.6
Thryssa spp.	1.3	2.9
Dussumieria spp.	0.4	2.8
Decapterus spp.	1.1	3.9
Others	5.1	16.9

Source: Karunasinghe and Dayaratne, 1997.

Gillnets of two categories of mesh sizes: 28 to 45 mm and 50 to 64 mm (stretched mesh)(operated by nonmotorised outrigger canoes (6.7 to 7.4 m length) and 18 ft FRP boats) are used for the sardines and the mackerels respectively along the south coast of Sri Lanka (Dayaratne and Sivakumaran, 1994). The catch rate is high (about 50 kg/operation)at the start of the southwest monsoon in May, and the average catch rate about 25 to 30 kg per operation, but the fishing operations remain suspended during most part of the monsoon season due to rough sea conditions. Regional differences in the species composition of the catches are conspicuous, for example *A.sirm* are caught mainly from Haraspola, but contribute only 15% to the total catch of small pelagics in Sri Lanka; *Stolephorus* species and juveniles of frigate tuna are dominant in the catches at Beruwala.

The gillnet fishery, developed in the recent past off Kandakuliya in the northwestern province, targets mainly the flyingfish stocks, using 5 to 5.5 m FRP boats fitted with 25 to 40 HP engines. About 50 pieces (1500 mesh long and 110 mesh wide) of small mesh gillnets of 29 to 48 mm stretched mesh, constitute one unit. The fishery is seasonal, carried out from October to April by the fishermen migrating from the west coast, with about 50 boats per day realising catch rates of 110 kg/boat/day (1991-92) to 155 kg/boat/day(1992-93) and total catch of 1 246 mt during 1991-92 and 1 724 mt during 1992-93. About 9 species are caught, but *Hirundichthys oxycephalus* contribute around half the catch (Jayawardane and Dayaratne, 1994).

Purseseine fishery

Until the early 1980s, the small pelagic fisheries in Sri Lanka used to be carried out mainly by beachseines and small mesh gillnets. During the period 1972-1976, the UNDP/FAO project on fisheries development carried out experimental

fishing for the small pelagics with purseseines. This experiment paved the way for a modest purseseine fishery for the small pelagics in the southwest coast using the existing craft. In the early 1980s, there were only two purseseiners, but the fleet increased to 69 units in 1990. This development, however, led to many instances of conflicts between the purseseine fishermen and those operating small mesh gillnetters and beachseiners. As a result, regulations requiring permits, and restriction of purseseining to areas, beyond 7 to 12 miles from the coast depending on the coastal district, were introduced.

The purseseiner is a 3.5 t craft and the net 200 m long and 50 m height, with mesh size of 9/10" and 5/8" in the body and the bunt respectively. Surface lamps of 1500 watts are used to attract the small pelagic fish. Although the regulations limit the fishing operations to beyond 7 miles, fishing along the southwest coast is usually carried out at a distance of around 3 to 4 km from the coast where the depth range is 35 to 60 m (Dayaratne and Sivakumaran, 1994). In the beginning of commercial fishing (1985-86) the average catch rate was 185.7 kg/fishing operation (Dayaratne, 1991); but it declined to 52 kg/operation during 1991-93 (Table 8; Dayaratne and Sivakumaran, 1994).

The fishery targets mainly the sardines particularly along the southwest coast. Around 48% of the catch consists of *Sardinella sirm* followed by squids (24%) and scads (7%). The Indian mackerel, redbait and silverbellies are also caught, but to a less extent (Dayaratne, 1991). The redbait were significant in the experimental operations carried out during 1973-1974 along the west coast (Joseph, 1975). Clupeids constitute the dominant component in the catches in all the areas. No separate statistics is available for the production of small pelagics by different fisheries as all the inshore catches are grouped together in the National Statistics. However, studies carried out on the purseseine fishery in the southwest coast indicate the average annual catch of small pelagics to be 615 mt (Dayaratne and Sivakumaran, 1994).

Other fisheries

In Sri Lanka, the small pelagics are exploited by other fisheries also, but no statistics is available to indicate the magnitude and composition of the catch. These fisheries include the ringnet fishery, the seasonally operated encircling gillnet fishery, trammelnet fishery in the lagoons, stilt fishery in the south, handlining and trolling, castnet fishery in the shallow lagoon areas and fish aggregating device (FAD) - based fishery. The large mesh ringnet fishery is carried out along the southwest, south and east coasts, mainly for the medium pelagics like the frigate tuna and bullet tuna, while the small mesh (1 1/8"-1 1/2") ringnets are operated occasionally in the south, southwest and east coasts, mainly for the sardines, (*S.sirm*) and the halfbeaks (Hemiramphidae).

Table 8. Catch rates (kg) per operation in purseseine operations

Experimental fishing				**Craft type**
Source period	Pajot (1977) (1972-1976)	Joseph (1974) (1972-1973)	Joseph(1975) (1973-1974)	10.8 m 11 mt boats
NNE	1200	1925	838	
NE	721	941	710	
E	433	140	467	
NNW	-	750	-	
NW	757	300	-	
W	420	339	441	
SW	368	210	413	
S	256	325	-	
Commercial fishing				
Source period	Dayaratne (1991) (1985-1986)	Dayaratne (1991) (1986-1987)	Dayaratne & Sivakumaran (1994)* (1991-1993)	8.5-9.8 m 3.5 mt boats
SW	185.7	94.1	52.0	

The encircling gillnets (called kattudel, when operated in the sea and vallachchal when operated in the lagoon) are operated seasonally in the west coast off the Negombo area and in the lagoons of Chilaw and Puttalam, essentiall for the sardines (*Sardinella longiceps and S.gibossa*). In Negombo these nets are operated from FRP boats in the sea during the daytime from October to April. The catches are landed in extremely fresh condition. A traditional encircling gillnet fishery operates in the Puttalam and Chilaw lagoons. This fishery is carried out by large dugout canoes iln the Puttalam lagoon with high catch rates (83 kg/operation) compared to other fisheries in the estuary (Alwis and Dayaratne, 1992).

In stilt fishing, the fishermen operate a rod & line sitting on a stick. This traditional fishery, which is unique to Sri Lanka, is limited only to certain locations in the southern coastal waters, where it exploits mainly the small pelagics like *Herklostichthys punctatus* and scads. The threats to the sustainability of this fishery have been described by Nagodawitharana (1994).

Trolling and handlining are carried out in the southwest and east coasts for the medium pelagics such as the frigate tuna, bullet tuna and kawakawa and the large pelagics such as the seerfish. However, when the schools of the small pelagics such as the scads make seasonal migrations towards the coast, they are taken by these gears in the bays in the south.

The FADs are not used on any commercial scale in the small pelagics fishery in Sri Lanka, but several experiments have been carried out in the mid 1980s by the FAO/BOBP with low cost inshore FADs, which caught large quantities of dolphinfish (*Coryphaena hippurus*) and rainbow runner (*Elagatis bippinulatus*) (Weerasooriya, 1987). These species, which usually do not contribute much to the catches in the other fisheries, are underutilized, and could be exploited by deploying inshore FADs. Since recently, the NARA is deploying FADs at the continental shelf break for exploiting the large pelagics.

SPECIES AND DISTRIBUTION

Out of about 120 species of small pelagics identified from the coastal waters of Sri Lanka (Munro, 1955), around 40 species are considered as economically important as they are generally well represented in the commercial fisheries. The small pelagics are generally distributed in the coastal and estuarine waters although a few species like A. *sirm* and flyingfish (*Hirundichthys spp.*) have extended their distribution to the offshore waters as well. The density of the small pelagics is the highest along the northwest and northeast coasts of Sri Lanka (Pajot, 1977 a; Fig. 3). Sardines (*S.jussieu, S.longiceps, S.fimbriata and S. (A)sirm*) dominate all the areas, but 50% of the catches comes from the northern part and 40 to 50% from the other areas. *S(A) sirm* dominate the eastern side more than the other areas. The carangids are very prominant in the catches from the northeast areas, but poorly represented in the catches from the west and south coasts. Among the scads, *Decapterus russelli*, *Selar mate* and *Selar crumenophthalmus* are dominant.

Ecogram recordings of fish carried out by the R/V Dr. Fridtjof Nansen during August to September 1978, April to June 1979 and January - February 1980 indicate the highest biomass of 25 000 mt in the Pedro Bank followed by 20 000 mt in the northwest coast and 15 000 mt in the Hambantota Bank (Fig. 4). High concentrations of small pelagics of about 10 000 mt of standing stock occur in the area between Negombo and Chilaw on the west coast; but the biomass is rather low in the area between Trincomalee and Mullativu. The small pelagics of the northwest coast consist mainly of the small scads, Indian mackerel and small trevellies. The recordings in the Pedro Bank consist mainly of the small scads, distributed mostly in the outer Bank. On the basis of the estimated average biomass of 10 000 mt during the 3 coverages, the shortlived nature of the small pelagics and the exploitation level of 50 000 mt at the time of the R/V Dr.Fridtjof Nansen servey, the FAO/ADB (1988) Fisheries Sector study estimated the maximum potential of the small pelagics in the region to be 75 000 mt around the island, excluding the unsurveyed northern part. The survey conducted in waters less than 10 m deep include both commercial and noncommercial pelagics, and assumed that the exclusion of the grounds in less than 10 m depth balanced out the inclusion of the noncommercial pelagics in the surveyed areas. Hence, the potential in the unsurveyed area in the north was considered to be 20 000 mt (peak production level in 1981) and the total maximum potential to be 95 000 mt in 1981when the small pelagic production reached a peak of 76 128 mt. However, the production gap of about 19 000 mt should be viewed very cautiously, and the exploitation kept at the 1981 level, till a reassessment is made based on accurate methods (FAO/ADB, 1988). The distribution of the small pelagics by depths is evident from the catches of the small mesh gillnets made at different depths (Table 9). *S(A). sirm* are distributed in relatively deeper waters (>26 m) with *S. gibbosa* and *S. albella* distributed at 12 to 26 m depths. Most of the other small pelagics such as *S. albella, Thrissocles spp., Leiognathus spp.* and *Stolephorus spp.* are distributed in shallow waters in <12 m.

The difference in the geographical distribution of small pelagics as evident from the comparison of the species composition of the catches of the gillnet fishery (Karunasinge & Dayaratne, 1986), could be attributed to the relatively wide shelf in the northwest and west and very narrow shelf in the south. *S.(A) sirm, R. kanagurta, Decaperus spp.* and *Loligo spp.* are distributed in relatively deeper waters, as evident from the purseseine catches from Hikkaduwa and Ambalangoda areas (Dayaratne, 1991). The appearance of *R. kanagurta,* and *Decapterus spp.* in the purseseine catches only in certain months indicates possible migration towards the shore from the offshore or deeper waters (Dayanatne, 1991; Dayaratne and Sivakumaran, 1994). In the small mesh gillnet fishery taking place along the northwest, west, southwest and south coasts of Sri Lanka, the sardines are still predominant in all the areas except Kalutara where *Stolephorus spp.* and *Leiognathus spp.* dominate (Dayaratne and Karunasinghe, 1992). Experimental fishing with purseseines and lamparanets for the small pelagics indicates that the redbait (*Dipterygonotus leucogrammicus*) are distributed in the southwest, west and east coasts (Joseph, 1973). The small carangids are more abundant on the east coast (Joseph, 1975). *S.(A) sirm* and *S.(A).clupeoides* contribute more than 80% to the gillnet fishery in the waters upto 60 m deep along the northwest (Jayawardene and Dayaratne, 1994). Nine out of 15 species of flyingfish recorded from Sri Lankan

waters (Jinadasa, 1972) occur in the catches of the seasonal gillnet fishery operating in the offshore waters of the northwest Sri Lanka. They are known to undertake seasonal migration to the nearshore, especially of Trincomalee on the east coast, where *Hirundichthys coromandelensis* dominate the catches. However, for Sri Lanka as a whole, *Hirundichthys oxycephalus* are the most abundant contributing 46% to the catches. Such distinct seasonal migration is undertaken by other small pelagics such as the squids (*Loligo* spp.) also to Trincomalee in the east and to Dondra and Galle in the south (Perera, 1975).

Table 9. Species composition (%) of catches taken by small mesh gillnets at different depths.

	Depth (m)			
Species	**12**	**12-20**	**20-26**	**26**
Sardinella sirm	-	6.4	51.4	91.2
S. gibbosa	4.6	36.6	28.6	7.6
S.albella	27.5	38.1	3.8	-
Other *Sardinella* spp.	-	-	2.3	-
Kowala coval	21.9	1.2	-	-
Anchoviella spp.	4.5	3.6	-	-
Leiognathus spp.	18.9	5.6	-	-
Thrissocles spp.	-	3.0	1.7	-
Spyraena spp.	2.1	2.6	12.4	1.2
Other spp.	20.5	2.9	-	-

Source: Dayaratne, 1985 b.

FISH PROCESSING AND MARKETING

Most of the marine fish catches in Sri Lanka, particularly the small pelagics are landed in fresh form as the fishery is carried out in the nearshore waters within a short duration of a few hours. The catches of the small pelagics are removed from the gillnets after landing. The beachseine catches are generally sold on the beach itself. Processing is undertaken due to lack of transport facilities, inadequate ice supplies in glut seasons, high demand for certain items of dried fish and the need to convert spoilt fish into a consumable form. Sundrying after dressing and salting is the most common method of processing. The small pelagics are usally brined for 24 h and dried for a day. The other forms of processing include pickling (jadi making) and smoking. Pickling of small pelagics, particularly the sardines, once prevalent along the western and southern coasts of Sri Lanka on a small scale, has declined in importance. Smoking has never been practised on a wider scale in Sri Lanka. In 1989 around 12 000 mt of dryfish has been produced (Table 10). The small pelagics form more than 60% of the dryfish production of which more than 80% come from Jaffna, Mullative and Puttalam districts. The lack of drying space and the nonavailability of sheltered storage space, lack of brining facilities (cement tanks or other containers to keep fish after salting) are the common bottlenecks faced by the processors. Spoilage of dry fish is frequent due to inadequate drying, insect and other pest attack, use of unclean water, and low quality salt and improper stacking

(Karunanayaka and Abhayaratne, 1988). In the western and southern areas, the products are disposed in bulk to the traders, within one month of their production, on strict cash terms to the highest bidders. Irregular visits of traders to the production centres and fluctuating demands pose some problems to the processors (Karunanayaka and Abhayaratne, 1988). Fish marketing is handled largely by the private traders as the government does not control their activities, instead encourage them to enter this trade in order to strengthen competition and reduce the margin accruing to the middlemen at the expense of the producer and the consumer. The Ministry of Fisheries intends to assist the fisheries cooperatives to undertake marketing while the banking system is actively helping the traders to strengthen their marketing facilities with insulated and refrigerated trucks. The government regulates marketing through the Ceylon Fisheries Cooperation to help the producer during

Table 10. Dryfish production (in tons) by groups during 1980 to 1989

Variety	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
King mackerel	159	266	231	199	56	99	23	25	26	28
Carangids	1091	1400	1418	1129	213	379	125	137	144	155
Bloodfish[1]	31	106	94	95	101	179	777	855	898	969
Shark, skate	1522	2889	3582	2879	359	639	177	195	205	221
Rockfish[2]	1935	1023	1357	1092	666	1185	1776	1954	2052	2216
Shoreseine groups[3]	3867	4873	4720	4037	3335	5933	4051	4456	4678	5052
Others	90	90	95	101	348	620	2823	3105	3260	3523
Total	8695	10647	11497	9532	5078	9034	9752	10727	11263	12164

Source: Ministry of Fisheries & Aquatic Resources. (1. Tuna and tuna-like fishes; 2. Demersal breams, snappers, emperors, etc.; 3. Indian mackerel, herring, sardines, sprats, etc.).

gluts and the consumer during deficits. The distribution of marine fish shows 3 distinct patterns: (i) there is a highly localised distribution network pivoting on each landing centre; (ii) the assemblers and wholesalers at the landing centre link with the intermediate market wholesalers, who in turn distribute the fish to the consumers through other retailers; and (iii) the linkage of almost all major landing centres with the St. John's market in Colombo; the redistribution function of the St. John's market supercedes that of any other terminal markets in the country (Fig. 5; Karunanayaka and Abhayaratne, 1988).

FISHING POPULATION

Surveys conducted by the Ministry of Fisheries and Aquatic Resources in 1989 indicated a total of 98,444 active fishermen supporting a fishing population of 412 200 living in 87 808 households located in 1 050 villages in the marine fisheries sector (Table 11). The ancillary industries employed 18 500 personnel

including 7 900 in marketing and 8 300 in processing and other activities such as boat building, net making, ice making etc. There is no separate statistics of fishermen engaged exclusively in the coastal fisheries or in the small pelagic fisheries. However, the marine fishing fleet is composed mainly of craft types engaged in the small pelagic fisheries. Considering the type of craft and the number of fishermen working in each craft type, about 70 000 active fishermen seem to be engaged in the small pelagic fisheries. 62.6% of Sri Lankan's population live in the five coastal provinces where about 4% of the total is of the fishing population (Table 11). The highest concentration of marine fisheries is found in the northern and eastern provinces, where the fishing population forms more than 10% of the total population. The density of fishermen is the highest in the coastal District Fisheries Extension Officer (DFEO) areas of Jaffna, Batticaloa, Kalmunai, Chilaw, Negombo and Trincomalee (Table 12). About 25% of the fishing population in the marine sector is represented by the active fishermen, 79% of the coastal fishermen depend on fishing as the sole source of income, 15% as the main source of income and 6% as the secondary source of income (Table 13).

Table 11. Fishing populations in the coastal provinces.

Coastal Provinces	Total population (x 1000)	Marine fishing population	Percentage of total population
1.Western	4404	48530	1.1
2.Southern	2074	46918	2.26
3.Northern	1185	143664	12.10
4.Eastern	1252	125965	10.06
5.Northwestern	1998	47123	2.36
Total (5 coastal provinces)	10918	412200	3.78
All 9 provinces in Sri Lanka	17433	412200	2.36

Source: Fisheries Survey 1989, Ministry of Fisheries & Aquatic Resources.

Table 12. Marine fishermen and fishing population in DFEO areas.

DFEO areas	Fishing population	Number of fishermen
Colombo	6577	1610
Negombo	29226	7419
Chilaw	29302	7173
Puttalam	17821	4539
Kalutara	12727	3157
Galle	14813	3590
Matara	18213	4426
Tangalle	13892	3354
Mannar	24252	5684
Mullativu	13286	3183
Trincomalee	28456	6502
Batticaloa	55292	12843
Kalmunai	42217	9022
Jaffna	106126	25942
Total	412200	98444

Source: Fisheries Survey 1989, Ministry of Fisheries & Aquatic Resources.

Table 13. Dependence fishermen on fishing as a source of income.

	Number of fishermen		Fishing as source of income					
	Marine	Total	Sole source		Main source		Secondary source	
Province			No.	(%)	No.	(%)	No.	(%)
Western	12186	12862	10522	(81.8)	1654	(12.9)	686	(5.3)
Southern	11370	13309	11990	(86.3)	967	(7.3)	852	(6.4)
Northern	34809	35979	27369	(76.0)	6933	(19.3)	1677	(4.7)
Eastern	28367	30089	22657	(75.3)	5812	(19.3)	1620	(5.4)
Northwestern	11712	13469	11582	(86.0)	790	(5.9)	1097	(8.1)
Total (5 coastal provinces)	98444	05708	83620	(79.1)	16156	(15.3)	5932	(5.6)
Country total (9 provinces)	98444	111335	86240	(77.5)	16962	(15.2)	8133	(7.3)

Source: Fisheries Survey 1989, Ministry of Fisheries Aquatic Resources.

ECONOMIC ROLE OF MARINE FISHERIES

Currently the fisheries sector contributes a moderate 1.9% only to the gross domestic product (GDP) of the Island, yet it is important to the economy in terms of employment, foreign exchange earnings and protein supply. In 1989, 120 000 persons were engaged in fishing and fishery related activities, accounting for 2% of the total employed population. In the current decade export earnings from the sector

increased steadily, reaching Rs3 656 million in 1995, which is 1.6% of the total export earnings of the country (Table 14). Fish contribute approximately 60% to the animal protein intake and about 15% to the total protein consumption in Sri Lanka which traditionally prefers fish to other animal products. Domestic fish production has always been insufficient to meet the local demand, resulting in substantial import requirements. The strong growth in local fish production combined with the removal of restrictions on imports has led to an increase in the per capita consumption of fish from 10.5 kg in 1972 to 18.1 kg in 1988.

No information is available on the contribution of the small pelagic fisheries to the economy of Sri Lanka. However, the production of small pelagics, estimated at 65 000 mt which is 40% of the total marine fish production, is the most important component in the marine fisheries sector. The small pelagics are generally not exported.

SMALL PELAGIC FISHERIES

Population dynamics and stock assessment of some commercially important small pelagics have been accorded greater importance in fisheries research, and the results obtained are summarized below.

1. Age and growth

The age and growth of *Sardinella sirm, Sardinella gibbossa, Sardinella albella* and *Sardinella longiceps* determined by using the primary growth rings in the otoliths revealed: (a) the existence of daily growth rings in the otoliths of *S. sirm* and (b) relatively fast growth of all the four sardine species (Dayaratne and Gjosaeter, 1986). *S.sirm* grow at the rate of 1.9 mm/day during the first 50 days, 0.9 mm/day during the next 50 days, 0.4 mm/day from the 100th day to the 200th day and 0.2 mm/day during the subsequent days. *S. gibbosa* grow at a considerably slower rate of 0.9, 0.7 and 0.4 mm/day for the periods 0-50, 50-100 and 100-200 days respectively. *S. albella* grow still slower, at the rates of 0.8, 0.5 and 0.3 mm/day for the same periods. The growth rate of *S. longiceps* is the same as that of *S. gibbosa*. The relative growth indicated by the parameter K of the von Bertalanffys growth equation, is the highest in *S. sirm* and *S. gibbosa*, low in *S. longiceps* and the lowest in *S. albella* (Table 14). The growth parameters of *S.sirm* sampled from gillnet catches in Negombo, based on the length frequency data have been found to be: annual K = 0.93 and 0.95; L ∞ = 24.75cm and 24.8cm for 1980-81 and 1983-84 respectively (Siddeek *e. al., 1985*). The west coast samples of *S. sirm* indicated the annual K to be 2.19 and the L ∞ = 24.2 cm (Jayasuria, 1989). However, in another study of *S. sirm* based on the west coast length frequency data considerable

Table 14. Volume(tons) and value (x 10^6 Rs)of exports of fish and fish products during 1990 to 1995

	1990		1991		1992		1993		1994		1995	
	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE	VOLUME	VALUE
Prawns	1855.27	485.86	942.64	454.60	1246.25	613.09	1426.44	806.08	2300.8	1650.4	2780.5	2153.1
Lobsters	164.62	50.00	187.77	139.60	153.96	125.14	311.57	209.21	364.2	257.6	283.3	259.7
Crabs	-	-	322.89	39.28	533.33	66.91	516.33	82.22	908.6	168.2	898.2	181.4
Beche de mer	36.47	27.13	18.53	14.40	24.51	36.56	37.33	25.63	91.9	69.3	247.6	148.2
Ornamental fish	153.75	68.11	98.03	40.66	246.27	142.93	290.68	204.91	382.7	247.6	331.2	273.3
Chank and other shells	821.44	174.64	70.22	22.85	93.08	12.30	121.89	19.87	235.7	33.8	745.9	41.3
Shark fins	1.42	13.28	182.24	108.62	89.55	135.16	58.60	98.93	81.2	110.4	126.9	162.8
Molluscs					138.93	42.73	134.31	47.61	112.6	48.7	51.3	16.3
Fish maws	78.25	28.85	5.07	29.31	3.76	0.58	1.75	0.82	0.7	0.2	1.3	1.7
Frozen fish	51.38	35.13	0.56	5.78	1130.04	116.14	2900.74	625.07	2706.9	702.3	1978.5	413.5
Fat & oil of fish					55.10	12.37	45.56	21.79	8.7	3.3	12.3	4.2
TOTAL	3162.60	883.00	1827.95	855.10	3734.78	1303.91	5895.40	2144.09	7193.9	3291.7	7457.1	3655.5

Source: Customs Department.

Table 15. Growth parameters of *Sardinella* spp.

Species	Method used	Growth parameters		
		K (Year)	La (cm)	T_0 (Year)
S. sirm	Direct length/age data	2.38	22.8	-0.083
	Back-calculated data	3.74	22.0	0.063
	Length frequency data	3.5	23.0	--
S. gibbosa	Direct length/age data	4.4	12.98	0.039
	Back-calculate data	3.4	14.1	-0.016
S. albella	Direct length/age data	5.43	12.2	0.233
	Back-calculate data	2.03	13.8	-0.01
S. longiceps	Direct Length/age data	2.79	16.3	-0.025
	Back-calculate data	5.62	14.5	-0.027

Source: Dayaratne and Gjosaeter, 1986.

difference has been noticed: the annual K was 1.1, 1.2 and 1.48 and the L ∞ 25.0 cm, 24.9 cm and 25.8 cm for 1984-85, 1985-86 and 1986-87 respectively (Karunasinghe and Wijeratne, 1991 a); length-based estimates of growth parameters of *S.sirm* for southern coastal waters were found to be: annual K = 0.95 and L ∞ = 23.8 cm (Karunasinghe, 1986). Length frequency samples of *S. sirm* taken from the purseseine fisheries in the southwest coast indicate the annual K to be 2.15, 2.06 and 1.93 and L∞ to be 22.50 cm, 22.75 cm and 23.50 cm for 1985, 1986 and 1987 respectively (Dayaratne, 1990a). Length-based estimates of growth parameters of *S. gibbosa* collected from the western coastal waters were found to be: annual K = 2.2 and L ∞ = 17.0 cm. (Dayaratne, 1986 b).

Primary growth rings in the otoliths of some clupeids, assumed to be daily rings were used for determining their age (Dayaratne, 1989). The growth parameters of the anchovy *S. heterolobus* were estimated from the length-at-age data determined from the daily growth rings on the otoliths. The annual K of 4.02 and L∞ 8.62 cm for the direct length-at-age data and K 3.9 and L∞ 8.74 cm for the back-calculated length-at-age data indicate this anchovy to be fast growing with a life span of only 9 months (Dayaratne, 1990 b).

Dussumieria acuta and *Ilisha melanostoma* seem to grow similar to *Sardinella spp.*, attaining a length of about 14 cm and 11 cm respectively in the first year of life. While *Escualosa thoracata* reach a size of about 9 cm in the first year, *Opisthopterus tardoore* grow faster to a size of about 8 cm in 4 months. Daily growth rings in the otoliths indicate the length of the milkfish (*Chanos chanos*) to be 8 cm in 3 months after hatching (Dayaratne, 1988 b). The length-based ELEFAN and LFSA computer packages were also applied on the pooled length frequency data, collected from the purseseine, gillnet and beachseine fisheries for determining the growth parameters of five species of small pelagics (Table 16; Dayaratne and Sivakumaran, 1994).

Table 16. The growth parameters of five species of small pelagics.

Species	Growth parameters	
	K per year	La (cm)
Sardinella sirm	1.3	24.6
Auxis thazard	1.4	45.0
Decapterus macarellus	0.8	41.2
Selar Crumenophthalmes	0.5	34.8
Rastrelliger kanagurta	1.7	36.0

2. Maturity and spawning

Based on the birthdates (back-calculated from the daily growth increment-based age estimates), combined with the distribution of four gonadial maturity stages, the spawning season of four *Sardinella spp.* was determined (Dayaratne, 1984). The spawning season of *S. sirm* is protracted with a peak from April to June; *S. albella* spawn twice a year, with a major spawning from February to April and a minor spawning in October to December; during the major spawning season all the fish are mature in March and the spent fish appear in April; *S. gibbosa* also spawn twice a year, the first from May to July and the next in December (Dayaratne, 1984). Gonadal Index (GI) of seven different maturity stages of *S. sirm* indicates the value to be the highest at stage VI and during February and May when spawning takes place (Karunasinghe, 1990). The size of *S. sirm* at 50% maturity is 15.0 cm for the females and 15.9 cm for the males corresponding to an age of 10.2 months and 11.5 months respectively. The fecundity of *S. sirm* varies from 55 000 to 95 000 eggs in fish of 16.0 cm to 20.0 cm length (Karunasinghe, 1990). Backcalculated birthdates based on dailing growth rings in the otoliths, combined with the known spawning seasons for different locations, confirm two spawnings per year in the case of *D. acuta*, *I. melanostoma* and *O. tardoore* (Dayaratne, 1989). *C. chanos* spawn from March to May (Dayaratne, 1988 b). Based on their spawning migration, sex ratio and gonadal index, the flyingfish *Hirundichthys spp.* have been found to spawn along the eastern coast of Sri Lanka (Jinadasa, 1972).

3. Length-Weight relationship

The length-weight relationship of *S. sirm* indicates slight difference between the males and the females (Karunasinghe, 1990), while that of *S. gibbosa* given below, shows significant differences between the males, female and the juveniles (Dayaratne, 1986 b).

Male : Log W = 2.46 Log L - 1.05 (r = 0.9; n = 131)
Female : Log W = 2.58 Log L - 1.62 (r = 0.92; n = 71)
Juvenile : Log W = 2.31 Log L - 129 (r = 0.89; n = 47)

The length-weight relationship of the flyingfish *H. coromandelensis* has been estimated to be (Jinadasa, 1972),

Male : Log W = 0.01034 + 2.1227 X Log L
Female : Log W = 0.0807 + 2.8126 X Log L

4. Morphometric characteristics

Morphometric characteristics of *S. sirm* in the Negombo and Chilaw areas reveal that the same stock is fished by the small meshed gillnets in the Negombo and Chilaw areas (Dayaratne, 1986 a; Karunasinghe, 1990).

5. Mortality and exploitation rates

The annual total mortality coefficient (Z), natural mortality coefficient (M) and fishing mortality coefficient (F) for *S. sirm* from the west coast were estimated to be 4.12, 2.12 and 2.0 respectively (Dayaratne, 1985 a; 1990), while the yield-per-recruit analysis showed that maximum yield-per-recruit could be obtained at a fishing mortality of 4 to 5 and about 80% of the maximum yield-per-recruit at a fishing mortality of 2. However, the gillnet fishery samples of *S. sirm* from Negombo indicated significantly lower values of Z, F,M and E (Table 17; Siddeek *et al.*, 1985), as was the case with another west coast study which indicated Z to be 2.75, M 1.3, F 1.45 and E 0.527 (Karunasinghe and Wijeratne, 1991 a). Estimates of M = 3.07, F = 1.97 and Z = 5.20 for the *S. sirm* stock from the southwest coast imply fast turnover of biomass, allowing fishing pressure to be maintained at relatively high levels while the mean E = 0.47 suggests that the maximum yield-per-recruit could be obtained at a high E of 0.80 (Dayaratne, 1990 a). A relatively lower exploitation rate of 0.31 was estimated for the *S. sirm* stock from the southern coastal waters (Karunasinghe, 1986). Mortality estimates for five small pelagics made by using the pooled length frequency data pertaining to the purseseine, gillnet and beachseine fisheries indicate underexploitation of certain stocks (Table 18; Dayaratne and Sivakumaran, 1994).

Table 17. Mortality parameters for *S. sirm* stock from Negombo

Period	Total mortality Z	Fishing mortality F	Natural mortality M	Exploitation rate E
1980-1981	2.39	0.96	1.43	0.40
1983-1984	3.07	1.64	1.43	0.53

Table 18. Mortality estimates for five small pelagics exploited by purseseine, gillnet and beachseine fisheries.

Species	Natural mortality	Fishing mortality	Exploitation rate
S. sirm	2.24	0.99	0.30
A. thazard	1.98	2.61	0.57
D. macarellus	1.41	2.38	0.63
S. crumenophthalmus	1.09	0.51	0.32
R. kanagurta	2.4	1.59	0.40

6. Length at first capture and recruitment pattern

The age at first capture of *S. sirm* is 0.4 year and 0.5 year in the catches of the gillnets of 28 mm and 30 mm mesh size respectively, operating in the west coast (Dayaratne, 1985 a). While the mean length at first capture for the west coast gillnet fishery is 16.17 cm and the length at 25% and 75% probability of capture 14.5 cm and 17.9 cm respectively (Karunasinghe and Wijeratne, 1991 a). The length at 50% capture (L_{50}) for *S. sirm* caught in the purseseine fishery is 19.1 cm corresponding to the age of about 11 months (Dayaratne, 1990a). The mean lengths at first capture caught in the west coast beachseine, purseseine and gillnet fisheries for *S. sirm* have been estimated to be 3.9 cm, 20.2 cm and 19.5 cm respectively, for *O. macrelles* 10.1 cm, 29.5 cm and 27.6 cm respectively and for *R. kanakurta* 6.9 cm, 11.0 cm and 21.7 cm respectively. The mean length at first capture for *S. crumenopthalmus* caught in purseseines and gillnets is 11.2 cm and 22.3 cm respectively and for *A thazard* caught in comparatively large meshed gill nets and ringnets 23.7 cm and 25.6 cm respectively (Dayaratne and Sivakumaran 1994).

Recruitment to the *S. sirm* stocks takes place in two peaks per year, seperated by a period of 3 months (Karunasinghe and Wijeratne, 1991 a; Dayaratne, 1989). The same pattern has been observed in the stocks of *Nematalosa nasus, L. splendens* and *H. oxycephalus* also, with one major and one minor recruitments per year, seperated by a few months (Dayaratne *et al.*, 1994).

7. Gear selectivity

By the method of comparing the length frequencies of fish caught by gillnets of 2.5 cm to 3.8 cm mesh from the west coast and by using the fish length-girth relationship method, the selection factor for *S. sirm* has been estimated to be 5.53 and 5.48 respectively, and the gillnet selection range 12.9 cm to 23.3 cm (Dayaratne, 1988a).

Since the mean selection length has been found to be less than 16 cm for gillnets of 2.31 cm and 2.56 cm mesh, it is necessary to limit the use of these mesh sizes to maintain the size at first capture at 16 cm (Karunasinghe and Wijeratne, 1991 b).

8. Species interaction

Although the small pelagics are distributed mostly within the inshore waters and their fisheries have distinct depth ranges, there seems to exist a direct relation between the different gears and the small pelagics that they exploit in most of the areas. The most common small pelagic species, *S. sirm*, are caught mainly by the small meshed gillnets throughout the coast, but are also caught in the beachseines along the northwest, south and east coasts and dominate the purseseine catches in the southwest. The juveniles of *S. sirm* appear in the beachseine catches taken from the west and southwest coasts in certain months. *S. gibbosa, S. albella and S. longiceps* are common in the catches of small meshed gillnets, beachseines and encircling gillnets, operated along the northwest, west and southwest coasts. Many species of whitebait anchovies are caught in the beachseines and the small meshed gillnets, operated throughout the coast. The scad mackerals and the Indian mackerels are common in the catches of the main fishing gears such as the beachseines, small meshed gillnets and purseseines. They are also caught in the handlines, stilt fishing (in the south) and ringnets.

ENVIRONMENTAL IMPACTS ON THE FISHERIES RESOURCES

1. Man-made perturbations

34% of the total population in Sri Lanka live in the coastal region, where fishing, tourism and agriculture constitute the major economic activities. The increase in these activities and the migration of people to the coastal region, are already threatening the coastal ecosystem, particularly the critical habitats such as the coral reefs, estuaries, lagoons and mangroves, which are vital for the sustainability of the coastal fish stocks. The mangroves are cut for timber and fuel wood, and the habitat converted into aquaculture sites or human settlements while the coral reefs are mined for lime; destructive fishing is resorted to in certain areas. Coastal pollution arises mainly from engine oil wastes from shipping and fishing craft and the discharge of industrial and domestic effluents. A major international shipping lane, five miles off the southern and the southwestern coasts, is the route for over 5 000 tankers every year, posing risks of accidental spills. Ballast discharges in and around the ports add to coastal pollution, causing frequent tar balls on the southwest beaches. Most industrial wastes in Sri Lanka are not treated before their discharge into the rivers, lagoons and sea. Runoffs with agrochemicals draining into the rivers, estuaries and lagoons, ultimately disperse into the sea and affect the marine organisms. The major sources of industrial pollution include the Valachchenai and the Embilipitya paper factories which discharge large quantities of wastes into the Batticaloa lagoon and the Walawe Ganga estuary respectively and a large number of tanneries and other industrial plants, which discharge their wastes into the Kelani Ganga estuary. The sandy beaches and the contiguous coral reefs of Sri Lanka are of great tourist attraction, resulting in more than 75% of the graded hotels located along the coast. Unplanned tourism development in some areas has resulted in pollution, destruction of habitats and migration of fishermen from their traditional fish landing sites. Currently Sri Lanka lays great stress on integrated coastal resource management and the NARA has launched various multidiciplinary

research programmes for the coastal and estuarine ecosystems, where teams of fisheries biologists, ecologists, environmentalists, oceanographers, aquaculturists and socioeconomists, together carry out investigations to help address the various management issues.

2. Oceanographic influences

The distribution and abundance of the small pelagics in the coastal waters of Sri Lanka are influenced by the monsoon rains and winds. The high catch rates of all the small pelagics from the west coast during the southwest monsoon period, are due to the rich nutrients and plankton resulting from the monsoon processes and rains (Karunasinghe, 1990) and the monsoon currents, and the northward migration of some sardine species along the west coast (Dayaratne, 1984). The seasonal inshore migration of some species such as the scad mackerel into the shallow bays and estuaries in the south is related to the changes in the current pattern. The possibility of transoceanic mixing of the populations of the small pelagics through the monsoon currents has been demonstrated recently (Karunasinghe, 1996).

ASSESSMENT OF SMALL PELAGIC RESOURCES

The yield from the small pelagic fisheries operating along the northwest, west and south coasts of Sri Lanka was analysed under an Asian Development Bank Technical Assistance project, by means of the Schaefer and Fox surplus production models (fitted to the time series data for 1979 to 1993 on annual catch and effort) and the Thompson and Bell single species assessment technique (based on growth and mortality parameters) for *S. sirm* which comprise about 60% of the landings. The surplus production model indicates that the present yields are very close to the maximum, and no sustained increase would result by increasing the effort ((Figs 6 and 7), rather, the yield would decrease, along with catch rates. The Thompson and Bell method shows a slight increase in the yield of *S. sirm* by only another 3 555 mt by doubling in the effort (Figs 6 and 7). Considering that *S. sirm* form 60% of the small pelagics catches, all the small pelagics proportionate to 3 555 mt *S. sirm* should be 5 733 mt, which could be achieved only at a much reduced catch rate, i.e., 43% less than the maximum and the consequential profit reduction to the individual fishermen, in the event of doubling the effort.

FISHERIES MANAGEMENT

Sri Lanka carries out fisheries management through sections 20 and 33 of the Fisheries Ordinance of 1940, which empowers the Ministry of Fisheries to frame regulations for fisheries management. Several regulations have been framed for particular areas or for the entire nation, such as the beachseine regulation (1984) and the purseseine regulation (1987), which limit the number and type of craft, the size and mesh of the gear and the areas of operation. Although there has been substantial developments in fisheries, leading to the increase in production from 40 000 mt in the 1940s to 200 000 mt in 1995, the Fisheries Ordinance of 1940 could not adequatly meet the demands of this development, and hence, the Fisheries and Aquatic Resources Act No.2 of 1996 was enacted. This new Act consisting of 10

sections lays greater emphasis on management and sustainable development through the application of various conservation measures: (a) licensing of all major fishing operations, (b) declaration of areas for fisheries management, and (c) conservation of fisheries and aquatic resources. Enhanced fines and jail terms have been included for any violation of the provisions to ensure strict compliance, for which the Department of Fisheries and Aquatic Resources Development has established a separate division for fisheries management in 1991, and this division has been strengthened further by the UNDP Marine Fisheries Management Project functioning since 1992. Traditional management measures such as the Territorial User Right Fisheries (TURF) where the rights are held privately by individuals are already in existence in several fisheries including the stakenet, beachseine and stilt fisheries (in the south),with very effective management procedures. Some form of community TURF also seems to have operated in the past, but in spite of strong territorial feelings still prevalent in many communities, community control over access to fishing areas is fast weakening.

The Fisheries Sector Study of the FAO/ADB (1988) made the following observations and recommendations on the marine fisheries management situation in Sri Lanka.

Observations

1. Conditions of free and open access prevail in almost all fisheries, particularly on the west coast.

2. Overall, the coastal fisheries show signs of approaching the limits of sustainability.

3. The existing fishing capacity in terms of boats and gears is sufficient enough for exploiting all the available coastal stocks up to their sustainable limits.

4. Technological innovations, such as mechanical purseseining, have contributed to increasing competition and conflicts among fishermen.

Recommendations

1. Adoption of management objectives to achieve: (i) maximum social and economic benefits, (ii) sustainability of the resources, (iii) equity in the ownership of the means of production and (iv) parity in income and distribution.

2. Greater effort to generate bioeconomic and socioeconomic data.

3. Establishment of a central management and enforcement authority to implement measures to regulate fishing effort.

4. Involvement of fishermen and fishing communities in the preparation, adjustment and enforcement of management measures within the limits of centrally regulated overall fishing effort.

5. Education of the public to generate political supports for fisheries management.

The sector study, while pointing out the weaknesses in the enforcement of the existing rules and regulations governing fisheries management in Sri Lanka, emphasised the need for clearly separating the public services responsible for enforcement from the other fisheries services. At present, the District Fishery Extension Officers (DFEO) provide a variety of services to the fishermen, in addition to enforcing the fisheries regulations.

Public awareness

Public awareness campaigns on fisheries management have already been initiated by various institutes that have direct or indirect responsibilities in managing the fisheries resources in Sri Lanka. The management unit of the Department of Fisheries and Aquatic Resources has taken initiatives to educate the fisheries inspectors on various aspects of fisheries management through the training programmes organised by the National Institute of Fisheries Training (NIFT). The National Aquatic Resources Research and Development Agency (NARA) has been engaged in conducting seminars and workshops to the members of the fishing communities to pass down the research findings, particularly those relating to fisheries management. Several workshops have been held on the management of lobster fisheries in the south and the use of small mesh in gillnets, purseseines and ringnets. The need for integrated management in fisheries has been emphasised by the Coastal Resources Management Project (CRMP) in Sri Lanka. Attempts have been made to draw up Special Area Management Plans (SAMP) to manage the resources in particular geographical areas. SAMPs for the Hikkaduwa marine sanctuary and the Rekawa lagoon are under preparation by the CRMP. The fishing communities in these areas have been actively engaged in the planning process and several public awareness campaigns have been carried out during the process.

Community-based management

The open access nature of fisheries has frustrated the attempts to manage fisheries by entry limitation and other centrally imposed regulations, and hence, the government is encouraging the establishment of fishermen cooperatives at the village level in order to promote a self regulatory approach to management and conservation. Community-based fisheries management system has been in existence in Sri Lanka for quite some time (Atapattu and Dayaratne, 1992). The rotational beachseine fishery in the western and southern provinces, the stakenet fishery in the Negombo lagoon in the western province, the trawl fishery in the northwestern province and the fish kraall (jakottu) fishing in the Madu Ganga estuary in the southern province are some of the community-based management systems that exist in Sri Lanka. Where there is a strong cooperative movement, it is possible to introduce and operate a community-based approach successfully (Fernando, 1994).

In Sri Lanka, fisheries cooperative societies have registered remarkable growth, increasing from 540 societies with a membership of 26 400 in 1989 to 769 with a membership of 86 966 in 1993 at the annual growth rate of 57%. The factors required for community-based fisheries management are quite favourable in these cooperative societies (Fernando, 1994), but they have no legislative powers since the existing ordinance is highly centralised, with no provision for community-based management. However, steps have been taken to include such provisions in section 31 of the new draft Fisheries and Aquatic Resources Act.

Need for regional management

There is not much evidence to prove that the small pelagic resources around Sri Lanka are shared by the neighbouring countries, except that: (i) the same species of small pelagics are found in nearly all the countries of the region, (ii) the flyingfish fishery along the east and northwest coasts of Sri Lanka seems to originate from the Coromandel coast of India, and (iii) the Indian oil sardine fishery along the northwest coast of Sri Lanka appear to originate from the Indian southwest coast. Collaborative research is necessary to confirm these assumptions and to investigate the important species for their biology and fisheries on a regional basis.

DISCUSSION

The small pelagics are important in the Sri Lankan fisheries economy as they contribute around 40% to the coastal fish production. The stocks of sardines that dominate the catches of the small pelagics have been assessed and the gaps between the maximum sustainable yield and the present yield, determined. The *S. sirm* stock is being exploited optimally along the west coast, but poorly along the southwest and west coasts. Optimally, uncontrolled increase in the fishing effort for the small pelagics has led to considerable decrease in the catch rates particularly along the west coast, and any further increase in effort might result in only a marginal increase in the absolute yield, but the catch rates would decline further, making fishing operations nonprofitable. The squids, Indian mackerel, scad mackerel and halfbeaks are not exploited significantly as there are no exclusive fisheries for these stocks, which currently contribute only incidental catches to other fisheries. The potential of these stocks need to be assessed and suitable craft and gear identified for their exploitation. The concentration of fishing effort along the west coast is due mainly to the civil disturbances along the north and the east coasts, resulting in the influx of refugee fishermen from the north and the east to the northwest coast and partly due to the southwest monsoon turbulance preventing the migration of the beachseine fishermen from the west coast to the east coast. There has been a significant increase in the use of efficient fishing gear such as the purseseines, ringnets, encircling gillnets and nylonnet codends in the beachseines in the recent past, resulting in several fishing conflicts between their owners and the traditional fishermen. Therefore, the Ministry of Fisheries and Aquatic Resources established the Management Unit in the Department of Fisheries and Aquatic Resources to address these management problems. The research needed for this purpose is undertaken by the National Aquatic Resources Research and Development Agency, and more management oriental research programmes are being carried out at

present. Biosocioeconomic approach has been found to be appropriate to managing fisheries, particularly the small scale fisheries as it requires to consider the socioeconomic issues of the fisherfolk in connection with the bioeconomic situation of the fishery in question. The active involvement of the fishing communities in fisheries management has become increasingly important as otherwise management has always tended to fail.

Acknowledgements

I wish to express my sincere thanks to Miss. C. Perera of the Marine Biological Resources Division, National Aquatic Resources Research and Development Agency, for the computer assistance given to me during the preparation of this report.

REFERENCES

Alwis, M.M., and Dayaratne, P., 1992. Present status of the fishery for finfish and shellfish resources of Puttalam estuary, in the north western province of Sri Lanka. Paper presented at the 3rd Asian Fisheries Forum, Oct. 1992, Singapore.

Atapattu, A., and P. Dayaratne, 1992. Case studies on Community Based approaches in Resource Management in Sri Lanka. Paper presented at the Expert Consultation on the Development of Community Based coastal Fisheries Management Systems for Asia and the pacific June 1992, Kobe, Japan.

Canagaratnam, P., and J.C. Medcof, 1956. Ceylon's Beach Seine Fishery. Bull. of Fish. Res. Stn. Vol. 4.

Dayaratne, P., 1984. Fisheries Biology of small pelagic fish in the west coast of Sri Lanka. Ph.D. Thesis, University of Bergen, Norway.

Dayaratne, P., 1985a. Status of the sardine stocks on the west coast of Sri Lanka. J. Nat. Aq. Res. Ag. Sri Lan. 32, (1 & 2) : 147-150.

Dayaratne, P., 1985b. Some observations on small-meshed gillnet fishery in Negombo and Chilaw. J. Nat. Aq. Res. Ag. Sri Lan. 32 (1 & 2) : 66-81.

Dayaratne, P., 1986a. Identification of sardine stocks (*Amblygaster sirm*) in Negombo and Chilaw areas by using morphometric characters. J. Nat. Res. Ag. Sri Lanka (Unpublished).

Dayaratne, P., 1986b. Some observations on the fishery and biology of *Sardinella gibbosa*. J. Nat. Res. Ag. Sri. Lan. (Unpublished).

Dayaratne, P., 1988a. Gillnet selectivity of *Amblygaster sirm*. Asian Fisheries Science 2 (1988): 71-82.

Dayaratne, P., 1988b. Age and growth of milkfish (*Chanos chanos*) by using daily growth rings. J. Inland Fish. Sri Lanka, 4: 3-10.

Dayaratne, P., 1989. Primary growth rings in otoliths of some clupeids from Sri Lanka. Asian Fisheries Science, 2 : 255-264.

Dayaratne, P., 1990a. An assessment of *Amblygaster sirm* (Walbaum) stocks in the south west coast of Sri Lanka. In: Hirano, R. and I. Hanyo, editors. Proceedings of the Second Asian Fisheries Forum, 17-22 April, 1989, Tokyo, Japan.

Dayaratne, P., 1990b. Age and growth estimates of *Stolephorus heterolobus* (Ruppell) by using the daily growth rings in the otoliths in Hirano R. and I. Hanyo, editors. Proceedings of the Second Asian Fisheries Forum, 1: 17-22 April, 1989, Tokyo, Japan.

Dayaratne, P., 1991. Preliminary observations of the purseseine fishery in the south west coast of Sri Lanka. Vidyo. J. Sc. Vol.3.

Dayaratne, P ., M.Alwis, A.Jayawardena, and A. Gunaratne, 1994. Assessment of some fish stocks in the Puttalam/Mundal Estuarine System and associated coastal waters (Unpublished).

Dayaratne, P., and J. Gjosaeter,1986. Age and growth of four *Sardinella spp.* from Sri Lanka. Fish. Res., 4:1 - 33.

Dayaratne, P., and W.P.N. Karunasinghe, 1992. Coastal fishery resources utilization by the small-meshed gillnet fishery along the west and south coast of Sri Lanka. Paper presented at the 3rd Asian Fisheries Forum, Oct. 1992. Singapore.

Dayaratne, P., and K.P. Sivakumaran, 1994. Bio-Socio-Economics of fishing for small pelagics along the south west coast of Sri Lanka. BOBP/WP/96.

FAO/ADB, 1988. Sri Lanka Fisheries Sector Study. Report of the FAO/ADB Cooperate Programme, FAO, Rome.

Fernando, K.H.C., 1994. Prospects for developing community-based fishery management in Sri Lanka. Sri Lanka/FAO National workshop on Development of Community based Fishery Management System, Colombo, Sri Lanka. Oct. 1994.

Fernando, T., and P. Dayaratne, 1994. Small mesh gillnet fisheries from Udappuwa to Mampuri along the North-western coastal belt of Sri Lanka (Unpublished).

Jayasuria, P.M.A., 1989. Some aspects of the biology and population dynamics of *Amblygaster sirm* from the west coast of Sri Lanka. J. Natn. Sci. Coun. Sri Lanka 17(1):53-66.

Jayawardene, A., and P. Dayaratne, 1994a. A preliminary analysis of the small-mesh gillnet fishery in the Kalpitiya peninsula and the fishing Island off Kalpitiya in the North-west coast of Sri Lanka (Unpublished).

Jayawardene, A., and P. Dayaratne, 1994b. Preliminary analysis of the flying fish fishery in Kandakuliya on the North-western coastal waters of Sri Lanka (Unpublished).

Jinadasa, J., 1972. Bioeconomics of the flying fish *Hirundichthys coromandelenses*.M.Sc. Thesis, Vidyodaya University of Ceylon, Jan. 1972.

Joseph, B.D.L., 1973. Preliminary Report on Experimental fishing with purse seine and lampara nets for small pelagic fish varieties around Sri Lanka. Bull. Fish. Res. Stn. Cey., Vol. 25.

Joseph, B.D.L., 1975. Purseseining for small pelagic fish around Sri Lanka. Bull. Fish. Res. Stn. Cey., Vol. 26.

Karunasinghe, W.P.N., 1986. Fishery and length based population studies of *Amblygaster sirm* (Walbaum) from the southern coastal waters of Sri Lanka. Proc. of the 42nd Annu. Session of the Sri Lanka Asso. for the Advnc. of Sci. (Abst), 229 pp.

Karunasinghe W.P.N., 1990. Some aspects of biology and fishery of trenched sardine *Amblygaster sirm* (Pisces: Clupeidae) from the coastal waters around Negombo, Sri Lanka. M.Phil. Thesis. University of Kelaniya, Sri Lanka.

Karunasinghe, W.P.N., 1996. Population variability and inter-relationships of five species of mullet (Pisces: Mugilidae). Ph.D Thesis, Macquarie University, Sydney, Australia.

Karunasinghe, N., and P. Dayaratne, 1986. Small pelagic fisheries on west and south coasts of Sri Lanka. J. Nat. Res. Ag. Sri Lan. (Unpublished).

Karunasinghe, W.P.N., and P. Dayaratne, 1997. Species composition and abundance in the small meshed gillnet fishery carried out during 1995/1996 period. Paper presented at the 3rd Annual Sessions of the Sri Lanka Association for Fisheries and Aquatic Resources, Colombo, Sri Lanka, June 1997.

Karunasinghe, W.P.N., and M. Fonseka, 1985. A preliminary analysis of small mesh gillnet fishery in the inshore waters of Sri Lanka. J. Nat. Aq. Res. Ag. Sri Lanka, 32:34-45.

Karunasinghe, W.P.N., and M.J.S. Wijeratne, 1991a. Population dynamics of trenched sardine *Amblygaster sirm* (Clupeidae) in the western coastal waters of Sri Lanka. Asian Fish. Sci. 329-334.

Karunasinghe, W.P.N., and M.J.S. Wijeratne, 1991b. Selectivity estimates for *Amblygaster sirm* (clupeidae) in the small-meshed gillnet fishery on the west coast of Sri Lanka. Fisheries Research 10: 199-205.

Karunanayaka, M.M., and M.D.C. Abhayaratne, 1988. Fish marketing in Sri Lanka. A study of market operation and consumer behaviour. Report of a project undertaken jointly by the National Aquatic Resources Agency and the University of Sri Jayawardena Pura.

Munro I.S.R., 1955. The marine and fresh water fishes of Ceylon published for Department of External Affairs, Canberra, Australia.

Nagodawitharana, M.T.K., 1994. Community based Fishery Management Practices Case study on Stilt Fishery in Kathaluwa and Ahangama. Sri Lanka/FAO National workshop on Development of Community-Based Fishery Management System; Colombo, Sri Lanka. Oct. 1994.

Pajot, G., 1977a. Small mesh monofilament and multifilament (PA Nylon): Experimental Gillnetting. UNDP/Sri Lanka Fishery Development Project SRL/72/051.

Pajot, G., 1977b. Exploratory fishing for live bait and commercially important small pelagic species. UNDP/Sri Lanka fishing development project SRL/72/051.

Pearson J. 1922. Fishing appliances of Ceylon. Bull. of the Ceylon Fisheries, (3): 76-77.

Siddeek, M.S.M., L. Joseph, P.M.A. Jayasuriya and W.P.N. Karunasinghe, 1985. A preliminary analysis of length frequency data of *Amblygaster sirm* from Negombo, Sri Lanka using ELEFAN programs. J.Nat. Aq. Res. Ag. Sri Lan. 31:46-56.

Weerakoon A.C.D., 1965. Ceylon Fisheries Past & Future. The Development of Ceylon's Fisheries (symposium), pp 248-250.

Weerasooriya, K.T., 1986. Report on experiment beach seine with nylon netting wings NARA Report (Unpublished).

Weerasooriya, K.T., 1987. Experience with Fish Aggregating Devices of Sri Lanka. BOBP/WP/54, pp. 23.

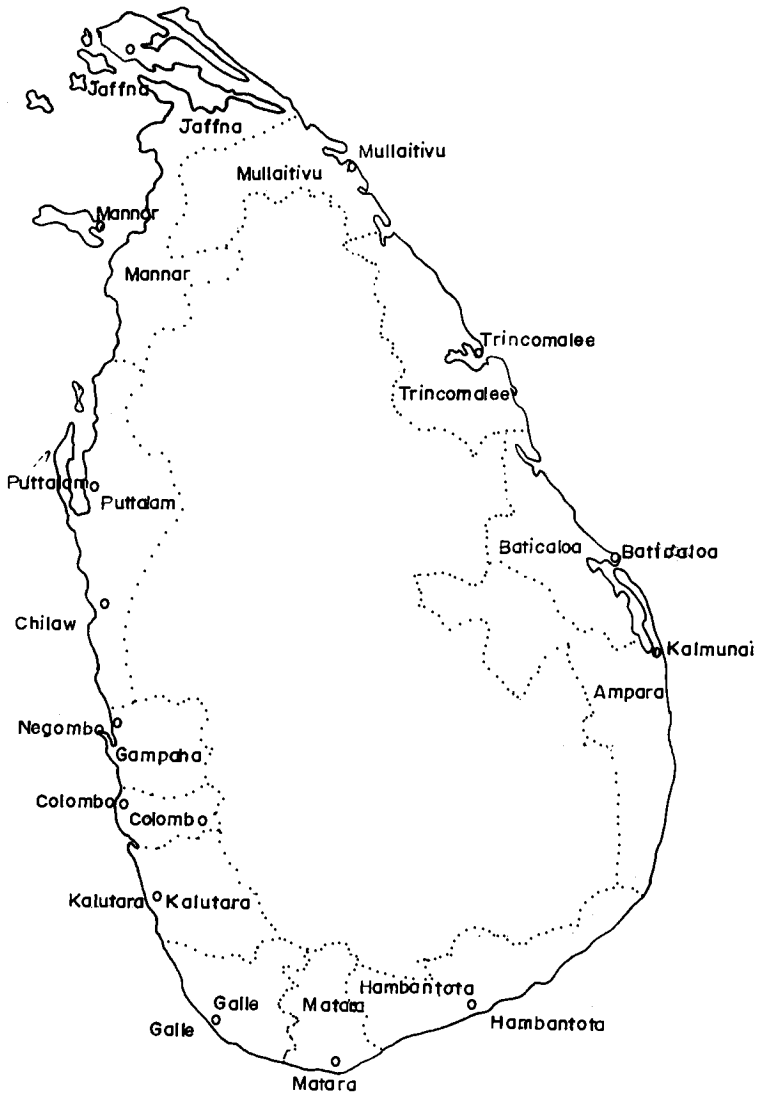


Fig. 1. Map of Sri Lanka showing Coastal District Fisheries Extension Office Areas.

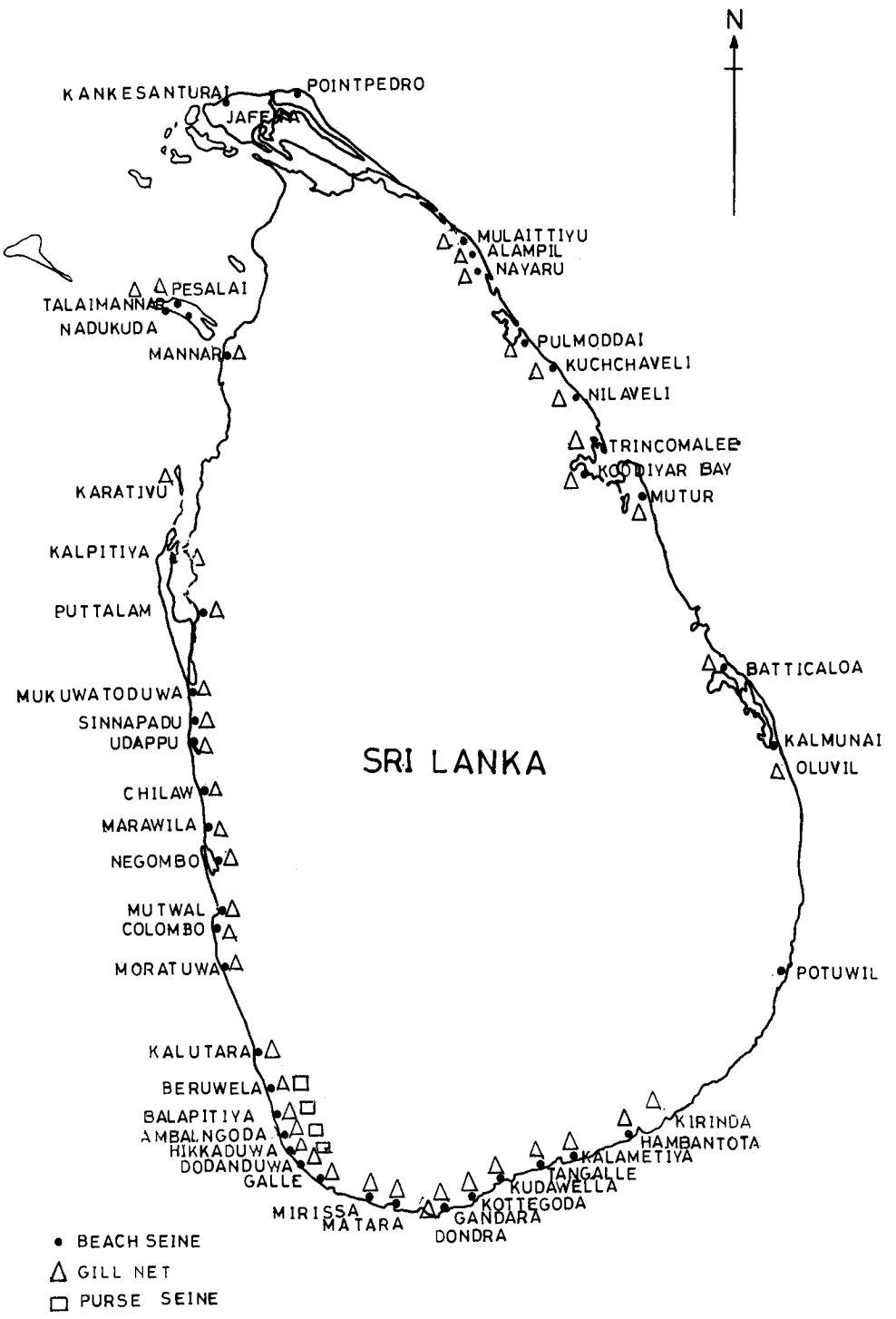


Fig. 2. Small pelagic fish landing sites along the coast of Sri Lanka.

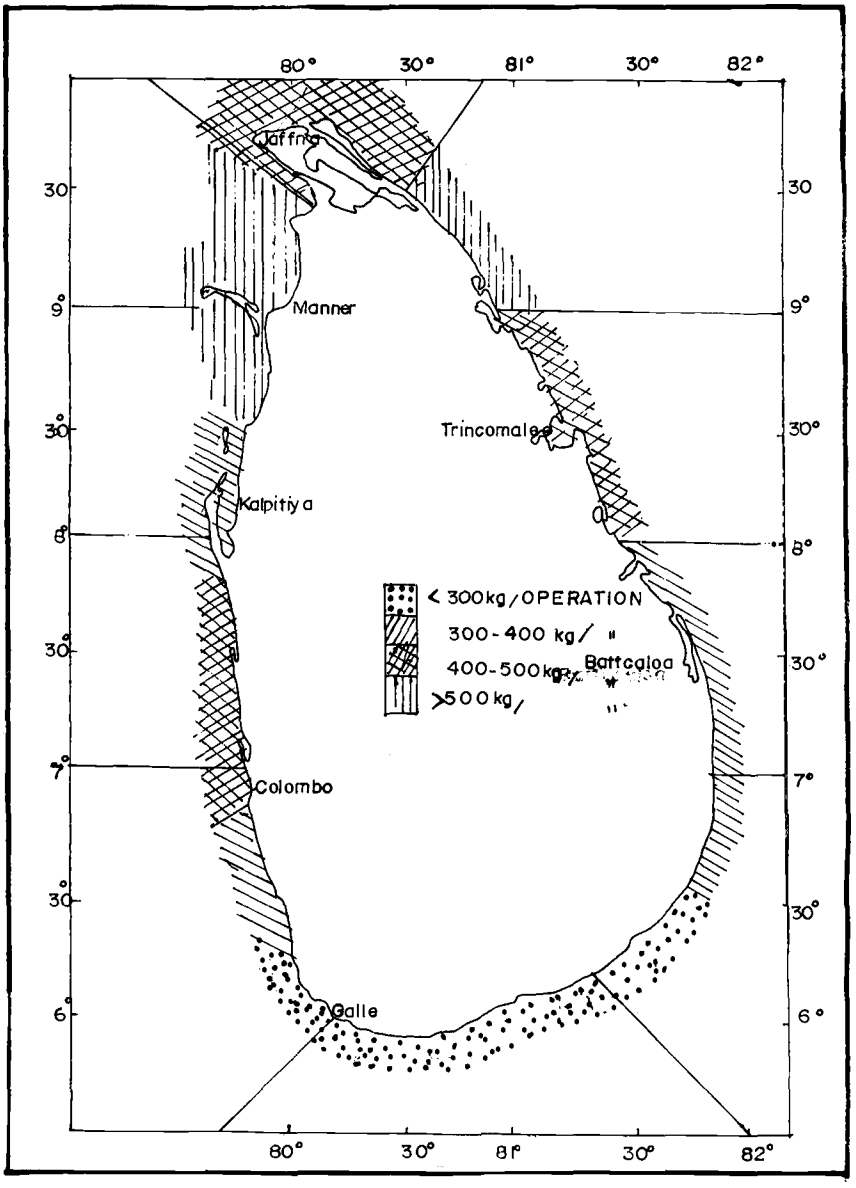


Fig. 3. The relative density pattern for small pelagic fish aroung Sri Lanka.

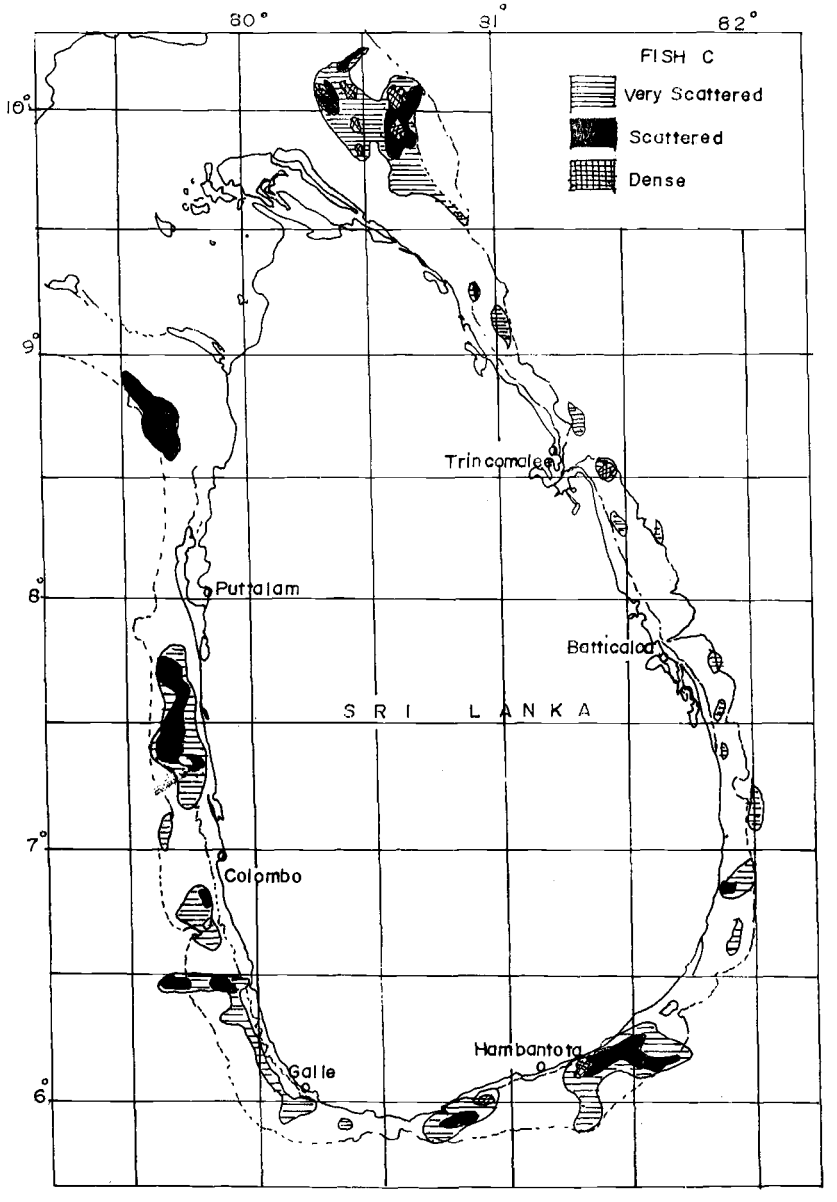
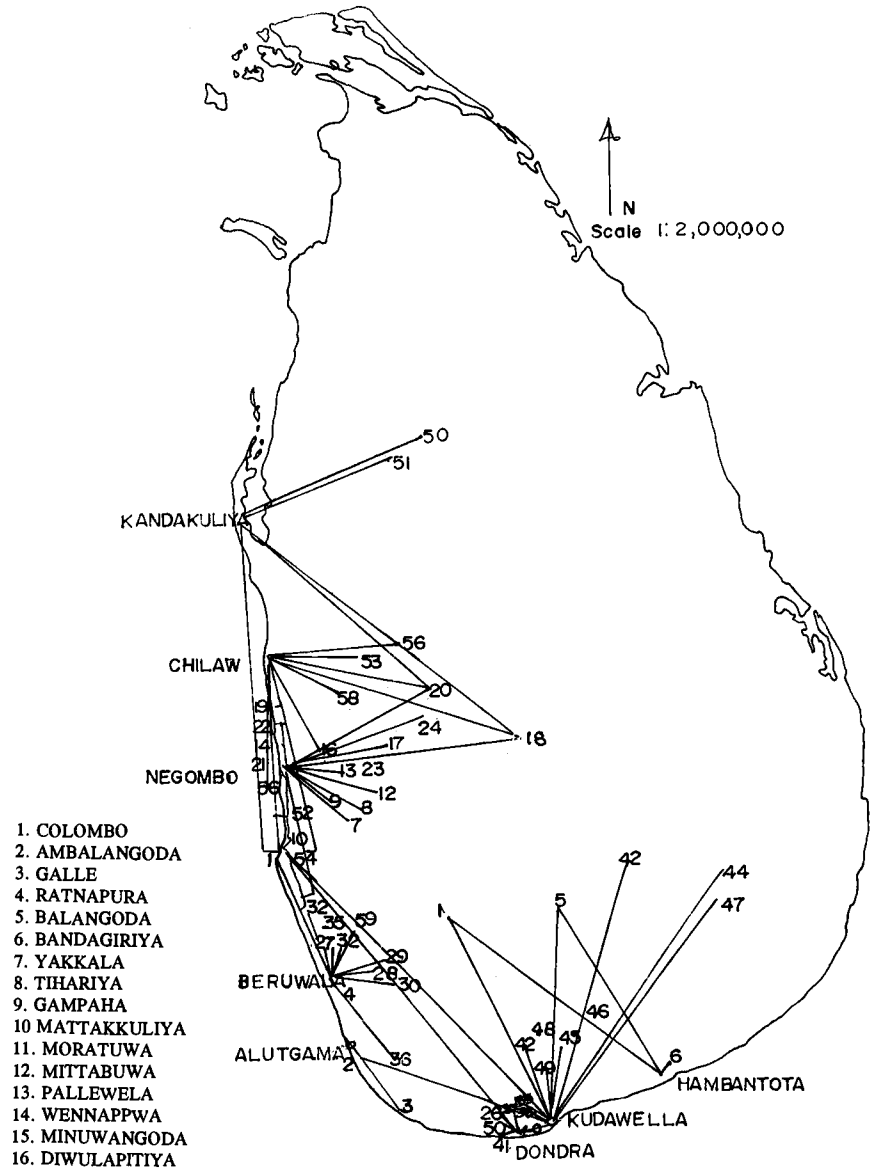


Fig. 4. Distribution of small pelagics based on the echo intensity recordings.
Source: Blinheim and Foyn (1980).



1. COLOMBO
2. AMBALANGODA
3. GALLE
4. RATNAPURA
5. BALANGODA
6. BANDAGIRIYA
7. YAKKALA
8. TIHARIYA
9. GAMPAHA
10 MATTAKKULIYA
11. MORATUWA
12. MITTABUWA
13. PALLEWELA
14. WENNAPPWA
15. MINUWANGODA
16. DIWULAPITIYA
17. WEYANDODA
18. KANDY
19. MARAWILA
20. KURNEGALA
21. KOCHCHIKADE
22. KATUNERIYA
23. MIRGAMA
24. POLGAHAWELA
25. YATIYANA
26. AKURESSA
27. KALUTARA
28. MATUGAMA
29. AGALAWATTA
30. MEEGAHATENNA
31. PANADURA
32. BANDARAGAMA
33. HORANA
34. ALUTGAMA
35. NAGODA
36. ALPITIYA
37. BELLIATTA
38. RADAMPALA
39. GATAMANNA
40, DEDUWALA
41. MATARA
42. BANDARAWELA
43. URUBOKKA
44. MONARAGALA
45. MIDDENIYA
46. EMBILIPITIYA
47. OKKAMPITIYA
48. KATUWANA
49. WALASMULLA
50 ANURADHHAPURA
51. NOCHCHIYAGAMA
52. JA-ELA
53. WELLAMPITIYA
54. SEEDWA
55. WARIYAPOLA
56. MADAMPE
57. KULIYAPITIYA
58. MEEGASARA

Fig. 5. Distribution of wet fish from selected processing centers.
Source: Karunanayaka and Abhayaratne (1988).

REVIEW OF THE SMALL PELAGIC RESOURCES AND THEIR FISHERIES IN THE GULF OF THAILAND

by

Somsak Chullasorn
Marine Fisheries Division, Department of Fisheries
Ministry of Agriculture, Bangkok 10900, Thailand

Abstract

The landings of the small pelagics increased from 62 950 mt in 1971 to 614 814 mt in 1994. The increase was due to increase in the number and efficiency of purseseiners and increase in the catches of round scads, sardines, anchovies, mackerels and coastal tunas. In 1994, mackerels (122 958 mt), sardines (123 700 mt), anchovies (97 343 mt) and coastal tunas (99 811 mt) dominated the landings. The small pelagics are utilized mostly in fresh and steamed form for domestic consumption. Information on the biological characteristics of major species has been provided in the paper. Almost all the pelagic stocks in the Gulf of Thailand are being fully exploited and few stocks are subjected to overfishing. A few options to effectively implementing management measures have been suggested.

INTRODUCTION

The Gulf of Thailand extends northwest from the southern part of the South China Sea, covering a coastline of 1875 km in length and an area of approximately 350 000 km^2. It is bordered by the coast of Thailand, Kampuchea and Vietnam on the east, by the coast of Thailand on the north and west and by the line drawn from the Thai-Malaysian border to the tip of Cape Camau of Vietnam on the south. The mean depth of the Gulf is approximately 45 m and the maximum depth 80 m in the central basin (Fig. 1). The Gulf of Thailand is considered to be one of the most productive areas of the world with a high level of primary production and abundant fisheries resources, which are typical of the Indo-Pacific fauna. The marine fish fauna in the Thai waters include 1 347 species belonging to 141 families. They consist of 618 species of economic importance, 350 species of aquarium fish and 379 species of trash fish. The demersal fish fauna exhibit the greatest species diversity and a high degree of species intermixing, so that no single species or group of species is normally predominant in the catch. The pelagic fish fauna are less diverse and less intermixed. The fisheries resources in the Gulf are currently exploited by at least 150 types of fishing gears (Okawara *et al.*, 1986). Each type of gear, however simple or specialised , catches more than one species of fish.

RESOURCES AND THEIR DISTRIBUTION

Pelagic fish dwell and feed at the surface or in the water column in schools in waters of temperature ranging from 26^0 to 30^{0}C. The fishing grounds of pelagics are generally of muddy-sandy bottom and associated with rich biomass of plankton. The coastal small pelagics frequently inhabit the nutrient-rich inshore neritic waters, while the large pelagics inhabit the offshore neritic and oceanic waters. The

shallow-water fishing grounds are highly productive and account for much of the Gulf's total pelagic catch. The small pelagics are exploited mostly with shallow-water purse seines (i.e., Thai, Chinese and luring purse seines), surface and midwater gillnets, liftnets and other surrounding nets.

The commercially important pelagics classified by the Thai Department of Fisheries, include 48 species of Carangidae, 30 species of Engraulidae, 28 species of Clupeidae, 19 species of Scombridae and 14 species of Mugilidae (Sukhavisidth, 1996). Their importance depends on the magnitude of the catch, the wholesale value as well as the export potential. There are 17 economically important species or groups of species of pelagics included in the Thai fisheries statistics (Fig. 2). Among them, the most common small pelagics of substantial catch and value are the Indo-Pacific mackerel, Indian mackerel, sardines, anchovies, round scads, bigeye scad and trevallies. The information on the distribution, fishing grounds, abundance, spawning grounds and migratory pattern of the important small pelagics in the Gulf of Thailand is shown in Figs 3 to 12.

Mackerels

The five species of mackerels occurring in the Gulf of Thailand are the Indo-Pacific mackerel (*Rastrelliger neglectus*), Indian mackerel (*R. kanagurta*), Faughn's mackerel (*R. faughni*), shortbody mackerel (*R. brachysoma*) and slender mackerel (*Rastrelliger sp.* 1) (Sukhavisidth, 1996). *R. neglectus* and *R. brachysoma* are abundant in the coastal waters, while the other species are distributed more in the offshore waters throughout the Gulf. The mackerels are caught mainly by the purse seines, encircling gillnets and occasionally by paired trawls. These five species of mackerels are combined in the Thai fishery statistics as coastal mackerel (*R. neglectus* and *R. brachysoma*) and offshore mackerel (*R. kanagurta*, *R. faughni* and *R. sp.* 1). Their fishing grounds extend widely from the inshore to the central part of the Gulf (Figs 3 to 5).

Sardines

The sardines found in the Gulf of Thailand belong to *Sardinella* spp., *Amblygaster* spp., *Dussumieria* spp. and *Herklotsichthys* spp. Among them the goldstriped sardine (*Sardinella gibbosa*), fringescale sardine (*S. fimbriata*) and spotted sardine (*Sardinella* (*Amblygaster*) *sirm*) are the most common. However, they are grouped together in the Thai fisheries statistics as sardines (*Sardinella* spp.). Sardines are widely distributed throughout the Gulf with high concentration in the coastal areas (Fig. 6). They are caught mainly by the purse seines, encircling gillnets and drift gillnets.

Anchovies

The anchovies in the Gulf belong to the species of *Coilia, Setipinna, Thryssa*, *Thrissina* and *Stolephorus*. Among them, *Stolephorus* spp. that comprise 12 species are the most abundant.. The shorthead anchovy (*Stolephorus hetrerolobus* /*Encrasicholina heteroloba*; Whitehead *et al.*, 1988) and the Indian

anchovy (*S. indicus*) are commercially important and very abundant in the nearshore waters (Fig. 7). The anchovies are exploited by small-meshed purse seines, liftnets, set bagnets, pushnets, trawls and bamboo stake trap.

Round scads

The round scads found in the Gulf of Thailand are represented by eight species of *Decapterus*, the most common being 1) *D. dayi, D. killiche* and *D. macrosoma*. According to Thai taxonomists, *D. maruadsi* once believed to be an important round scad in the Gulf of Thailand, is found only in Japanese waters. The round scads are widely distributed in the offshore waters, but very intense in the central part of the Gulf (Fig.8). They are mainly caught by purse seines, especially the luring purse seines. The catches of all species of round scads are treated together as *Decapterus spp.* in the fisheries statistics.

Bigeye scad

The bigeye scad (*Selar crumenophthalmus*) are abundant and widely distributed in the offshore waters as the round scads. They are caught together with the round scads in purse seines and also in trawls. Due to the rapid increase in the catch of bigeye scad corresponding with the development of luring purseseine fisheries, they are treated separately in the fisheries statistics since 1980, and the research effort on the various aspects of bigeye scad considerably increased.

Other carangids

The other carangids are composed of 39 species belonging to *Atule, Carangoides, Scomberoides, Selar* and *Selaroides*. They are important in terms of the quantities landed and treated together as other carangids in fisheries statistics due to the difficulties in the field identification of the various species. Therefore, the research carried out so far on this group has remained quite limited except *Atule mate* (yellowtail scad), yellow stripe scad (*Selaroides leptolepis*) and hardtail scad (*Megalaspis cordyla*).

Coastal tunas

The coastal tunas in the Gulf Thailand include mostly the longtail tuna (*Thunnus tonggol*), kawakawa (*Euthynnus affinis*) and frigate tuna (*Auxis thazard*). They are abundant and are widely distributed in the Gulf. When the demersal fish production had declined, the Thai fishermen turned to pelagic fisheries by using seine nets with lights for attracting fish school. The development of pelagic fishery together with the development of canning industry since the 1980s has considerably expanded the market for the tunas. Stimulated by the strong demand for the tuna canning industries, which developed rapidly in the recent years, fishing for the coastal tunas, has become one of the imporatnt activities in Thailand.

THE FISHERIES

In the past, the pelagic fisheries resources used to be exploited only in the inshore waters of the Gulf with very simple fishing gears such as the bamboo stake traps and set bagnets. Around 1925, the Chinese purseseine, introduced into Thailand for the Indo-Pacific mackerel, gained popularity among the Thai fishermen. This gear was subsequently modified into the Thai purseseine which is much larger in size and widely used in the pelagic fisheries in the coastal areas. Since the early 1960s, marine fisheries developed and expanded rapidly, as a result of the modification of fishing gears and technologies, venture of fishing fleets into new fishing grounds, improvement of fishing vessels and development of supporting facilities and infrastructures. The remarkable development of pelagic fisheries since the 1970s was due to the development of luring purse seines, discovery of the round scads fishing grounds in the central part of the Gulf in 1973, development of light luring fishing techniques to catch small pelagics since 1978, development of large purse seines for coastal tunas and hardtail scad in deeper waters since 1982 and the development of anchovy fisheries with light luring since 1983. The total annual catch of pelagics during the period 1971 to 1994 ranged from 63 000 to 676 000 mt (Table 1). Although the annual catch increased rapidly from 1971 to 1977, it declined until 1980, but improved substantially again peaking at 676 000 mt in 1992, followed by a slight decrease in 1993. The sharp increase in the catch of the pelagics from 1971 to 1977 was due to the rapid increase in the catch of the round scads and sardines by the increase in the number of luring purse seines (Table 2). The increasing trend after 1980 was due to the recovery of the Indo-Pacific mackerel stock and the development of the fisheries for the anchovies and coastal tunas by the increase in the number of anchovy purse seines and regular purse seines (Table 2).

Among the 17 species and groups of species of pelagics appearing in the fisheries statistics, 6 species and groups of species of small pelagics are considered important and have been studied for their biological characteristics and the state of the stocks, the results of which are summarized below.

Indo-Pacific mackerel (*Rastrelliger brachysoma*/*R. neglectus*)

The Indo-Pacific mackerel or chub mackerel are one of the most economically important pelagics in the Gulf of Thailand. The main fishing grounds are located in the coastal areas, especially between the Cholburi and Surattani provinces, which provide approximately 80 percent of the total catch taken from the Gulf. During 1971 to 1994 the annual catch from the Gulf ranged from 26 129 mt in 1977 to 99 638 mt in 1984. The maximum sustainable yield (MSY) was about 104 000 mt for a fishing effort of about 146 000 Thai purseseine fishing days (purseseiner days) (Tantisawetrat, 1994). Evidently the Indo-Pacific mackerel is being fully exploited in the Gulf of Thailand since 1984. The increase in fishing effort beyond the optimum of 146 000 purseseiner days is inadvisable.

Indian mackerel (*Rastrelliger kanagurta*)

The fishery for the Indian mackerel has been remarkable since 1973 due to the expansion of the luring purseseine fishery to further offshore. The catch increased substantially from 12 690 mt in 1983, after which, it somewhat fluctuated, showing a slightly decreasing tendency. The maximum sustainable yield for the areas II, III and VI in the west coast of the Gulf of Thailand was estimated. The virtual population analysis and surplus production model indicated the MSY to be 32 866 mt and 32 533 mt respectively for an optimum fishing effort of 112 500 for luring purseseine days (Tantisawetrat, 1996). No definite sign of overfishing has been observed yet. However, the mesh size of the luring purseseine should be enlarged to 3 cm from the present 2.5 cm so that the present catch of small sized mackerel in substantial quantities could be reduced and the annual yield increased by about 20 percent.

Sardines (*Sardinella spp.*)

The sardines are caught mainly by the purseseine, particularly the luring purseseine, in both coastal and offshore areas. Similar to the Indian mackerel, they are landed in large quantities since 1973. The catch peaked at 203 364 mt in 1977, but steadily declined to the low of 68 447 mt in 1985, followed by nearly stable catch of about 110 000 to 140 000 mt per annum. Since 1983, the number of purse seines increased steadily, but the production of sardines did not increase concurrently. The maximum sustainable yield of sardines in the Gulf of Thailand is estimated to be around 104 000 mt for an optimum fishing effort of about 190 000 luring purseseine days. Obviously the fishing effort expanded on the sardine fishery was beyond the optimum since 1988. Therefore, the fishery showed signs of overfishing; it is recommended that the fishing effort be reduced by about 14 percent in order to revive the sardine stocks.

Round scads (*Decapterus spp.*)

The marked development of the purseseine fishery in Thailand resulted since 1973 from the discovery of new fishing grounds in the middle of the Gulf of Thailand, particularly for the round scads, which are caught mainly by the luring purseseine, using bunches of coconut fronds as the lure. The gear is operated daytime in grounds of 30-50 m depth. The catch increased from 660 mt in 1972 to 12 690 mt in the very next year, and continued to increase steadily to reach the maximum of 129 800 mt in 1977, and decreased year after year to yield only about 20 000 to 40 000 mt per year over the past 15 years. The round scads were heavily exploited in the short period between 1972 and 1977, depleted since 1977 up to the present. Although the number of luring purse seines increased from 505 units in 1977 to 730 units in 1981-1982, the production of round scads was extremely low throughout after the high catch taken during 1977-1978.

Anchovies (*Stolephorus spp.*)

Anchovies are widely distributed in the inshore waters. Although 12 species are found in the Gulf of Thailand, the most dominant species is *Stolephorus heterolobus* (/ *Encrasicholina heteroloba*) which constitutes about 87 percent of the total anchovy catch. The principal fishing gear used for the anchovy fishery is the small-meshed purseseine (or anchovy purse seine), but pushnet, bamboo stake trap and luring liftnet are also used to some extent. The anchovy purseseine is operated both during day and night time. The catch of anchovies increased remarkably after 1981 due to the development of light fishing technique for attracting fish schools at night. Fishing operations extended further offshore resulting in a considerable increase in the catch from about 10 000 to 20 000 mt per year to 103 101 mt in 1985 and 110 000 to 120 000 mt per year over the last 5 years. The maximum sustainable yield of anchovies in the Gulf is estimated to be around 104 000 mt. This would mean that the anchovy resources are heavily exploited since 1985, and hence, increase in fishing effort has to be carefully controlled.

Bigeye scad (*Selar crumenophthalmus*)

After the development of the luring purseseine fishery, together with its expansion into the grounds further offshore, the bigeye scad catch increased considerably from 15 000 mt in 1980 to the peak of 37 080 mt in 1994. Based on the data for the period 1979 to 1988, the maximum sustainable yield of the bigeye was estimated as 18 500 mt for the optimum fishing effort of 125 000 luring purseseine fishing days (Isara, 1994).

Coastal tunas (*Thunnus tonggol, Euthynnus affinis* and *Auxis thazard*)

Prior to the 1980's, the catches of the coastal tunas in the Gulf of Thailand were relatively low at 3 298-19 929 mt. By employing purseseiners, this fishery rapidly developed after 1982, supported by the strong demand from the canning industries. Furthermore, new larger fishing boats installed with freezers were built for fishing for longer periods in the highseas. The catch increased from 39 368 mt in 1982 to 157 163 mt in 1992, which was also the outcome of promoting fisheries outside the Thai waters through joint ventures or fisheries agreements with neighbouring countries, and the exploration for new fishing grounds. The maximum sustainable yield for coastal tunas was estimated from the yield curve established from the relationship between the total catch and fishing effort. The estimated potential yield was 86 000 mt (Chuenpun, 1996).

Growth of small pelagic fisheries

The development of pelagic fisheries in the Gulf began in 1973 and attained remarkable growth, resulting in a fourfold increase in the catch from 141 608 mt in 1973 to 614 814 mt in 1994. Almost all the stocks of the pelagics are subjected to full exploitation and some stocks such as the round scads have been depleted beyond recovery compared to the Indo-Pacific mackerel, because of lack of proper management measures. The luring devices use bunches of coconut fronds soaked in the sea during the daytime and lights at night. These devices increased the fishing

efficiency to the greatest extent possible. Moreover, the big purseseiners have been modernized with colour echosounders or sonars (for fish school detection), power saving devices (e.g., purseline winch & power block that enable the boats to reduce the manpower), radar, wireless communication equipments, satellite navigation and refrigerator units. These developments enabled the extension of the fishing grounds to longer distances and the operations to longer periods. These activities have the potential to deplete the stocks faster. However, as the pelagic resources in the Gulf are multispecies, the fishermen change their targets from heavily exploited stocks to others with good potential, without much difficulty. Therefore, the problems of resource depletion among the the pelagics are not so serious in the Gulf.

Utilization

The marine capture fisheries in Thailand operate from 37 major fishing ports and several hundred fishing villages along the Gulf. In 1994 the marine capture fishery production accounted for 89 percent of the total marine fishery production of 3.15 million mt, valued at 77 299 million Baht. The various forms of utilization of marine fishery products include fresh consumption (14.5%), fresh chilled and frozen (26.1%), canned (14.8%), steamed or smoked (0.3%), fish sauce (2.3%), shrimp paste (0.7%), salted (2.9%), dried (2.1%), fish meal (36.1%) and others (0.2%).

The export of fishery products contributes significantly to the national income. Since 1991, fishery products have become the first ranking commodity in Thailand's agricultural products export. In 1993-1994 Thailand emerged as the largest fishery products exporter in the world market. In 1994, 1.215 million mt of fishery products valued at 110 285 million Baht, were exported.

The small pelagics are utilized mostly in fresh and steamed form for domestic consumption; this is particularly so with the Indo-Pacific mackerel, Indian mackerel and trevallies. Large quantities of anchovies are used for producing good quality fish sauce while some portion is boiled and dried. The sardines and round scads are used mostly for canning. Small sardines which form about 42 % of the the total sardine catch and accepted by the canning factories, are used for fish meal production. Small quantities of small pelagics are salted and dried mainly for domestic consumption.

BIOLOGICAL AND ENVIRONMENTAL PARAMETERS

The Gulf of Thailand can be considered as one of the large single marine ecosystems owing to its unique topography and oceanographic and climatic characteristics. It is one of the biologically richest areas in the world because of the high level of nutrients and fish stocks in the coastal waters. However, the environmental conditions of the Gulf have changed markedly in recent times because of very fast economic growth. The most severe problem is the biological overexploitation of fish stocks using excessive fishing effort and destructive fishing gears. Uncontrolled urban and industrial waste discharge, untreated waste water discharge from shrimp farms, habitat destruction and runoff compound the problems of environmental degradation in the Gulf.

Pollution in the Gulf which has become an important environmental issue in Thailand, stems mainly from land-based sources. Out of about 90 000 legally approved factories in Thailand, at least 1 500 factories discharge their waste water through the estuaries to the sea. Marine organisms are fragile and easily vulnerable to pollutants, which may result in changes in their population density and distribution. More than 65 percent of all wastes is of domestic liquid sewage, which is generally discharged raw directly into the coastal waters, where it strongly affects the net ecosystem metabolism. About 60 percent of total phosphorous loading is of anthropogenic origin and occurs within the last 50 km stretch of rivers, where human activities are very intense. As a result, the levels of faecal coliforms and BOD have increased considerably in the coastal areas of the Gulf.

Assessment of the environmental impacts of mariculture in the inner Gulf of Thailand suggests that a portion of nitrate in the inshore waters might derive from shrimp farm discharges, resulting in high primary production and eutrophication. Periodic formation of *Noctiluca* blooms and the subsequent anoxic bottom conditions in the inshore areas that pose high risks to the fishery resources have been attributed to shrimp farm discharges (Suvapepun, 1995). The effluents from shrimp farms in the southern part of the Gulf seem to have affected the water quality as well as the abundance of the pelagic and benthic communities in the adjacent areas in the Gulf.

The data on the important biological features of eight important species of small pelagics in the Gulf of Thailand have been compiled from the research works conducted by the scientists of the Department of Fisheries (Table 3). They include the Indo-Pacific mackerel, Indian mackerel, one sardine, one anchovy, round scad, bigeye scad, hardtail scad and one trevally. The results of the studies given in the table vary greatly according to the periods and areas surveyed as well as the methodologies applied. Therefore, those parameters need to be further examined and updated.

The pelagics have become very important in the commercial fisheries of the Gulf of Thailand since the beginning of organised marine fisheries development up to the present. The Marine Fisheries Division of the Department of Fisheries has initiated detailed studies on many small pelagics during the past 30 years. But the efforts could not cover all the important species as each group comprised many species. Another important shorcoming is the lack of biological data continuously over the long-term mainly because of the nonavailability of proper samples for the studies. Research is however, being intensified to address these issues.

FISHERIES MANAGEMENT

The rapid development and expansion of the pelagic fisheries in the Gulf of Thailand during the last two decades resulted in the intensive exploitation of both nearshore and offshore pelagic stocks. Many groups of small pelagics fish have been subjected to full exploitation while some are being overfished. The prospects of further expansion of marine fisheries in the Gulf seem quite bleak. Scientists have assessed the status of the fishery and have proposed appropriate measures to

conserve, manage and control fishing operations with a view to harmonizing the fishing activities with the actual potential for growth. Without systematic management, monitoring, control, surveillance and rehabilitation, there will be greater conflict in the use of the fisheries resources of the Gulf.

In order to conserve the marine fisheries resources, the Department of Fisheries of Thailand has introduced various management measures through the Fisheries Act of 1901 and its amendments made in 1947 and 1982. The regulations include (1) the determination and enforcement of the optimum sizes and kinds of fishing gears and craft that could be permitted for fishing; (2) prohibitions of the use of certain methods of fishing in certain areas; (3) establishing the spawning and nursing seasons and areas of commercially important marine fish stocks and prohibiting the use of certain fishing gears in these seasons and areas ; (4) mesh size restrictions for purseseining, gillnetting and liftnetting; and (5) limiting the entry of new trawlers by limiting the grant of new licenses.

Under the amended 1947 Fisheries Act, a series of ministerial rules and regulations concerning the conservations of the pelagic resources have been issued. They are briefly described here.

1. Ministerial regulation of 20 July 1972

This regulation prohibits fishing by trawlers and pushnets within a distance of 3,000 m from the shoreline and within a perimeter of 400 m of any stationary fishing gear in the Gulf of Thailand. It serves the purpose of maintaining the productivity of the near-shore waters, where the catches have been found to drop below their potential yield. Moreover, 80% of the total catch used to be small fish, of which at least half were the juveniles of economically important species.

2. Ministerial regulation of 14 February 1983

Night operation of purse seines using light lures and mesh sizes of less than 2.5 cm are banned in the Gulf of Thailand, as the luring lamps attract large quantities of small fish compared to the traditional fishing methods.

3. Ministerial regulation of 28 November 1984

An area of approximately 26,400 km^2 was declared as a conservation zone in the Gulf of Thailand to protect several commercially exploited species of demersal and pelagic fish during their spawning seasons extending from 15 February to 15 May. This regulation prohibits fishing by all types and sizes of trawlers (with the exception of beam trawlers), all types of purseseiners (except the anchovy purseseiners operating during the day time from 15 February to 31 March only) and gillnets of less than 4.7 cm mesh size along the coasts of Prachuap Khirkhan, Chumphon and Surat Thani provinces as well as the Khanom district in the Nakhon Sri Thammarat province in the Gulf of Thailand.

This regulation incorporates the relevant sections of the two previous ministerial regulations for the purpose of banning the fishery for *Rastrelliger* spp. (Pla Too and Pla Lung) during the spawning season. It also incorporates the ministerial regulation of 3 March 1983 for the purpose of closing the spawning and nursery grounds of demersal and pelagic fish. It clearly delineates the areas closed to fishing, but in the case of the demersal and pelagic fisheries, it has lifted the ban on the operation of beam trawlers for shrimps and anchovy purseseiners operating during the day time, in order to alleviate the hardships of the affected fishermen during the closed season. Further, the anchovies do not spawn in the conservation zone during the closed season.

4. Ministerial regulation of 11 April 1985

Conservation measures for protecting the breeding stocks in their spawning and nursery grounds were extended to the Andaman Sea, where an area of approximately 1 800 km^2 at Phangnga and Krabi, was declared as a zone of conservation through closed seasons and/or prohibition of certain fishing gears during 15 April to 15 June. The rules in the relevant ministerial regulation governing gear restrictions in the Gulf of Thailand apply to the conservation zone in the Andaman Sea also.

However, these various regulations, particularly those relating to gear restrictions, closed areas and seasons have not been fully enforced, and some fishermen still operate the prohibited fishing gears illegally in violation of the regulations. In particular, complete enforcement of regulations on the small-scale fishermen is difficult and illegal operations in the inshore areas make resource management difficult. Considering these problems, improvements in fisheries management propose to introduce license limitation, mesh size regulation, light luring devices regulations and zoning system for certain sizes of fishing vessels and fishing methods. Recently, the Department of Fisheries has established a project on artificial reef installations, which serve as physical obstacles to destructive fishing practices and provide habitats for juveniles, which could reach marketable as well as reproductive sizes in these artificial habitats.

CONCLUSIONS AND RECOMMENDATIONS

The rapid development and expansion of pelagic fisheries has resulted in considerable fishing pressure on the fisheries resources in the Gulf of Thailand. Almost all the pelagic stocks are being fully exploited, while some stocks are subjected to overfishing. The current catches are predominently of smaller and low value items as the sardines of which over 40% are small sized and hence used in fish meal production. Undersized sardines are not accepted by the canning factories. This situation is bound to continue if adequate management measures such as licence limitation of fishing effort, mesh size regualtion, fishing efficiency reduction (such as light intensity limitation for luring purseseine), closed areas and seasons during spawning and nursing phases and quota system (limitation of quantity and size of fish) are not implemented effectively through a regime of monitoring, control and surveillance.

There should be appropriate research effort and support to generate the data required for taking proper management decisions. There are still considerable gaps in the knowledge of the biology of many of the fish stocks. Information on the migration, spawning areas, seasons, size at first maturity, life span, food and feeding, growth and mortalities of many species stocks is still quite inadequate. The most important and basic requirement of stock assessment is time series data on catch and effort and the size composition of the catches by species. The reliability of the available time series data is questionable. There are still uncertainties in the identification of some important species of Decapterus, Stolephorus and *Sardinella*. This basic problem needs to be solved urgently so that the Scientists working on stock assessment problems are certain about the species they are dealing with.

REFERENCES

Chuenpun, A. 1996. Coastal tuna resources in the Gulf of Thailand. Stock Assessment Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division (In Thai).

Department of Fisheries. 1973-1984. The Marine Fisheries Statistics 1971-1982 based on the sampling survey. Fisheries Statistics Section, Fisheries Economics and Planning Sub-division, Department of Fisheries (In Thai).

Department of Fisheries. 1985-1994. The Marine Fisheries Statistics 1983-1991 based on the sampling survey. Fisheries Statistics Sub-division, Fisheries Policy and Planning Division, Department of Fisheries (In Thai).

Department of Fisheries. 1995. The Marine Fisheries Statistics 1992 based on the sampling survey. Fisheries Statistics Sub-division, Fisheries Economics Division, Department of Fisheries (In Thai).

Department of Fisheries. 1996. The Marine Fisheries Statistics 1993-1994 based on the sampling survey. Fisheries Statistics and Information Technology Sub-division, Fisheries Economics Divsion, Department of Fisheries (In Thai).

Department of Fisheries. 1973-1984. Thai Fishing Vessels Statistics 1971-1982. Fisheries Statistics Section, Fisheries Economics and Planning Sub-division, Department of Fisheries (In Thai).

Department of Fisheries. 1985-1994. Thai Fishing Vessels Statistics 1983-1991. Fisheries Statistics Sub-division, Fisheries Policy and Planning Division, Department of Fisheries (In Thai).

Department of Fisheries. 1995. Thai Fishing Vessels Statistics 1992. Fisheries Statistics Sub-division, Fisheries Economics Division, Department of Fisheries (In Thai).

Department of Fisheries. 1996. Thai Fishing Vessels Statistics 1993-1994. Fisheries Statistics and Information Technology Sub-division, Fishery Economic Division, Department of Fisheries (In Thai).

Isara, P. 1994. Assessment of big-eyed scad (*Selar crumenophthalmus*) from purseseine in the Gulf of Thailand. Technical paper no. 5/1993, Stock Assessment Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division (In Thai).

Okawara, M., A. Munprasit, Y. Theparoonrat, P. Masthawee and B. Chokesanguan 1986. Fishing gear and methods in Southeast Asia 1. Thailand. Training Department, Southeast Asian Fisheries Development Center, TD/Res/9.

Sukhavisidth, P. 1996. Checklist of marine fishes of Thailand. Technical Paper No. 2/1996. Marine Resources Surveys Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division, Department of Fisheries (In Thai)

Suvapepun, S. 1995. Environmental aspects of responsible fisheries in the Gulf of Thailand. Symposium on Environmental Aspects of Responsible Fisheries, Seoul, Republic of Korea, 15-18 October 1996. APFIC/SYMP/96/CR6.

Tantisawetrat, C. 1994. Status of Indo-Pacific mackerel (*Rastrelliger neglectus*, van Kampen) resource in the Gulf of Thailand. Stock Assessment Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division (In Thai).

Tantisawetrat, C. 1996. Status of Indian mackerel resource and fishery in the Gulf of Thailand. Technical Report No. 4, Stock Assessment Section, Bangkok Marine Fisheries Development Center, Marine Fisheries Division. (In Thai).

Whitehead, P.J.P. G.J. Nelson and T. Wongratana 1988. FAO Species catalogue, clupeoid Fishes of the world. FAO Fish. Syn. (125), (2): 397-398p.

Table 1. Total catch of pelagic fishes caught by main fishing gears in the Gulf of Thailand, 1971-1994.

YEAR	SARDINE	ANCHOVIES	INDO-PACIFIC MACKEREL	INDIAN MACKEREL	ROUND SCADS	BIGEYE SCADS	COASTAL TUNA	KING MACKEREL	HARDTAIL SCAD	OTHER PELAGICS *	TOTAL
1971	2,061	7,173	38,279	5,390	495	0	3,298	150	1,020	5,084	62,950
1972	8,034	12,785	33,367	9,340	660	0	4,135	1,587	867	9,542	80,317
1973	21,705	22,325	41,416	12,690	14,741	0	5,924	3,643	1,903	17,261	141,608
1974	46,274	19,516	34,720	14,003	33,267	0	6,900	2,307	3,342	11,256	171,585
1975	48,957	14,691	58,865	16,349	25,033	768	7,974	5,452	4,289	14,898	197,276
1976	91,819	15,339	49,628	19,012	82,477	72	7,382	6,214	14,388	22,719	309,050
1977	203,364	9,914	26,129	30,261	129,800	0	11,187	8,899	25,492	31,212	476,258
1978	133,614	8,520	42,260	33,703	106,272	0	7,098	6,240	14,334	42,287	394,328
1979	136,338	14,099	82,634	24,754	26,979	0	13,327	7,397	6,286	32,712	344,526
1980	96,362	16,697	47,336	24,858	30,171	15,381	12,525	7,787	11,136	23,856	286,109
1981	129,176	12,095	66,099	17,079	34,403	26,303	19,929	9,702	3,628	20,662	339,076
1982	87,935	23,211	71,220	18,282	32,074	16,185	39,368	6,931	3,796	14,251	313,253
1983	97,705	38,141	60,175	50,574	24,521	21,357	81,931	7,184	18,270	24,937	424,795
1984	83,814	88,804	99,638	29,827	27,475	23,061	69,355	8,099	5,928	21,805	457,806
1985	68,447	103,101	97,852	32,862	25,667	17,174	81,200	8,380	5,608	54,760	495,051
1986	92,527	57,959	88,768	38,803	23,947	18,728	90,225	10,978	17,299	45,623	484,857
1987	83,633	55,466	92,155	36,259	41,838	22,978	96,131	11,924	17,468	42,116	499,968
1988	89,077	66,675	88,822	18,653	14,016	11,931	141,274	12,050	19,765	53,215	515,478
1989	114,310	94,315	92,688	26,498	17,267	12,063	124,899	9,181	19,533	48,691	559,445
1990	90,789	118,727	68,160	20,844	10,676	19,972	156,208	9,153	13,648	49,043	557,220
1991	114,465	110,020	55,186	16,256	22,747	15,451	137,869	6,110	11,937	44,558	534,599
1992	141,422	120,211	88,308	29,337	42,525	21,851	157,163	6,711	17,775	50,601	675,904
1993	112,620	116,648	68,025	33,882	46,186	19,581	106,797	9,568	18,345	52,243	583,895
1994	123,700	97,343	73,727	49,231	38,394	37,080	99,811	8,537	20,532	66,459	614,814

Sources: The Marine Fisheries Statistics base on the Sampling Survey, Department of Fisheries, 1971-1994.

* = False trevally, other trevallies, Silver pomfrets, Black pomfrets, Wolf herrings, Threadfins & Mullets

Table 2. Number of fishing gears registered in the Gulf of Thailand, 1971-1994.

Year	Total	LPS	TPS	CPS	MEN	APS	KMN	PUN	BET	PAT	OBT
1971	5,133	33	328	14	244	42	134	573	613	522	2,203
1972	6,613	1	317	34	254	48	118	1,232	599	698	2,812
1973	8,809	109	337	3	227	66	170	1,470	533	818	3,926
1974	7,598	167	289	2	183	46	120	1,062	343	848	3,593
1975	7,182	195	289	1	187	30	134	933	283	844	3,393
1976	8,530	273	290	2	199	45	135	697	284	814	3,734
1977	10,056	412	135	0	313	14	206	946	423	876	4,532
1978	10,840	510	82	0	358	28	115	1,137	489	804	4,610
1979	13,569	478	64	0	354	43	203	1,394	537	1,120	6,264
1980	16,521	506	96	0	304	28	272	1,639	1,067	1,092	7,182
1981	12,426	602	40	0	256	13	302	881	496	910	5,278
1982	16,756	582	33	0	229	22	196	1,011	711	300	5,921
1973	15,059	556	40	0	141	37	234	941	328	1,180	6,848
1984	13,801	262	362	0	167	53	243	777	196	1,072	6,744
1985	13,691	216	448	0	210	118	254	663	139	1,122	6,104
1986	13,581	254	425	1	196	92	295	579	97	1,060	5,415
1987	13,858	357	474	0	218	47	327	517	46	1,078	5,342
1988	13,286	427	586	0	127	69	398	490	50	1,044	4,997
1989	16,694	453	357	0	109	76	216	1,108	493	1,929	8,830
1990	17,581	333	657	0	100	105	239	1,119	456	1,978	8,686
1991	15,323	282	744	0	88	234	279	768	144	1,822	6,941
1992	13,989	252	657	0	71	228	300	634	51	1,661	6,376
1993	15,141	930	?	0	92	255	198	663	51	1,540	6,242
1994	14,367	890	?	0	99	285	220	543	98	1,508	5,531

Sources : Thai fishing vessels statistics, Department of Fisheries, 1973-1996.
Luring purse seine in 1993-94 = Luring purse seine + Thai purse seine
LPS = Luring purse seine, TPS = Thai purse seine, CPS = Chinese purse seine
MEN =Mackerel encircling gill net, APS =Anchovy purse seine, KMN =King mackerel drift gill
PUN = Push net, BET = Beam trawl, PAT = Pair trawl, OBT = Otter board trawl.

Table 3. Important biological features and parameters of small pelagic fish in the Gulf of Thailand.

Species	Area (country) surveyed	Vertical distribution range (m)	Body size captured		Spawning		Fecundity	Recruitment		Size at first maturity (cm)	Sex ratio (M:F)	Growth (rate or coefficient)	Mortality (coefficient)	Life span (year)	Food organisms	Length-weight relationship
			Mean (cm)	Maximum (cm)	Area	Season(month)		Size (cm)	Season(month)							
FAMILY SCOMBRIDAE *Rastrelliger brachysoma*	Gulf of Thailand	20-40	15.0	20.95 21.5	10-40 mi off Prachuab Surattani	2-4, 6-8	egg = $9x10^{-8}$ $L^{4.8356}$ 20 000-30 000/ batch	10.25	1-3, 7-9	17.5	1:1	z=0.33	z=1.06	2-3	Phyto-planktons, zoo-planktons	W = $0.006138L^{3.215}$ M : W = $0.000005732L^{3.1235}$ F : W = $0.000006578L^{3.1235}$
R. kanagurta	Gulf of Thailand	30-60	16.0	22.9	-	2-4 7-8	200 000	7.5	5-6	18.6	1:1	k=2.76	M=3.75 F=4.973 Z=8.733	2-3	Phyto-, zoo-planktons, diatoms, copepods	M : W = $0.0000001958L^{3.7653}$ F : W = $0.000009454L^{3.0375}$
FAMILY ENGRAULIDAE *Stolephorus heterolobus*	Gulf of Thailand	5-50	4.5	8.89	30 mi off Prachuab Nakorn	3-4, 7-9	2000-4000	2.8-4.0	All around 4-12	5.5-6.0	1:1	k=0.198 k=1.8/ year	Z=13.50 M=3.54	1-1.5	Phyto-planktons	M:W = $2.064x10^{-6}L^{3.2494}$ F:W = $7.089x10^{-6}L^{2.9329}$
FAMILY CARANGIDAE *Decapterus maruadsi*	Gulf of Thailand	30-70	13.2	23.1	Central Gulf	2-3, 7-8	38 000 515 000	5.5 6.5	1-2, 6-8	16.1	1:1.2	K=0.11 1-2 cm/ month	-	2-3	crus-taceans, copepods	W = $0.00005L^{2.811}$
Decapterus macrosoma	Gulf of Thailand	30-60	-	-	-	12-5	-	-	-	16.5	1:0.9	-	-	-	-	-
Atule mate	Gulf of Thailand	15-45	16.0	25.8	30 mi off Chumporn Nakorn	3-4	-	5.5-6.5	1-3, 6-9	-	-	0.8 cm/ k=0.107	-	2-3	-	-
Selar crumenophthalmus	Gulf of Thailand	30-60	20-25	28.4	-	-	-	10.0	-	19.4	1:1.3	k=2.4	Z=9.7 M=3.3 F=6.5	-	-	-
Megalaspis cordyla	Gulf of Thailand	20-50	22.0	28.8	-	12-5, 8-11	-	11.5-10.5	5, 9	-	1:0.8	1.2 cm/ month k=0.2	-	-	Fish, crus-taceans	W = $0.144L^{2.9785}$

Body size refers to total length unless specified as FL: fork length or SL: standard length; sexes are combined unless specified as M: male or F: female.

Table 3. (Cont'd)

Species	Area (country) surveyed	Vertical distribution range (m)	Body size captured		Spawning		Fecundity	Recruitment		Size at first maturity (cm)	Sex ratio (M:F)	Growth (rate or coefficient)	Mortality (coefficient)	Life span (year)	Food organisms	Length-weight relationship
			Mean (cm)	Maximum (cm)	Area	Season(month)		Size (cm)	Season(month)							
FAMILY CLUPEIDAE *Sardinella gibbosa*	Gulf of Thailand	15-40	10.0	18.4	Entire coastal zone	All around 3-4, 7-8	-	8.5	4-8, 12-2	13.3	1:2.3	K=0.33	-	1-2	Phyto-planktons	$W=9.28x10^{-6}L^{3.0047}$
FAMILY CARANGIDAE *Decapterus macrosoma*	Gulf of Thailand	30-60	-	-	-	12-5	-	-	-	16.5	1:0.9	-	-	-	-	-
FAMILY CARANGIDAE *Atule mate*	Gulf of Thailand	15-45	16.0	25.8	30 mi off Chumporn Kakorn	3-4	-	5.5-6.5	1-3, 6-9	-	-	0.8 cm/ k=0.107	-	2-3	-	-
Selar crumenophthalmus	Gulf of Thailand	30-60	20-25	28.4	-	-	-	10.0	-	19.4	1:1.3	k=2.4	Z=9.7 M=3.3 F=6.5	-	-	-
Megalaspis cordyla	Gulf of Thailand	20-50	22.0	28.8	-	12-5, 8-11	-	11.5-10.5	5, 9	-	1:0.8	1.2 cm/ month k=0.2	-	-	Fish, crustaceans	$W = 0.144L^{2.9785}$

Body size refers to total length unless specified as FL: fork length or SL: standard length; sexes are combined unless specified as M: male or F: female.

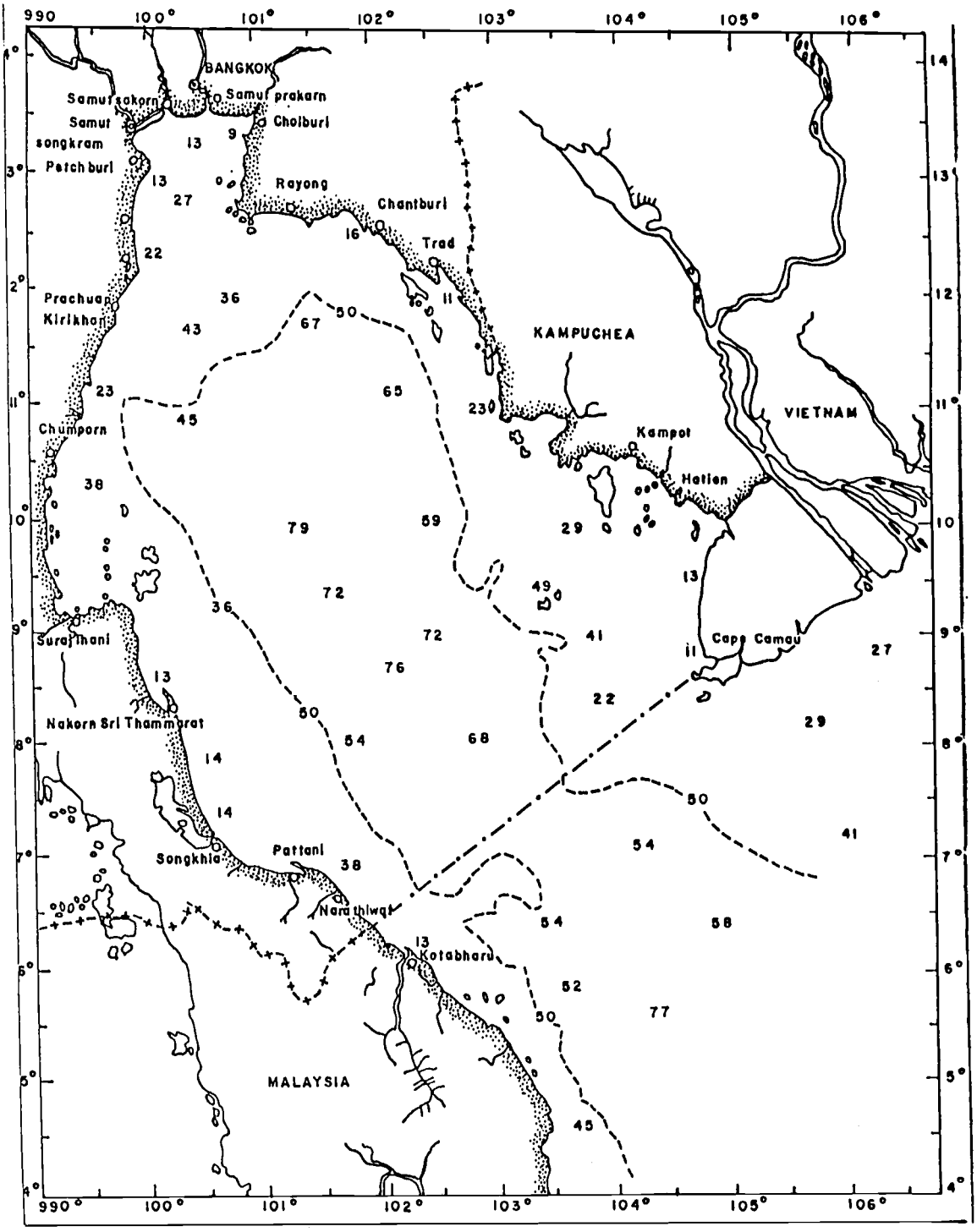


Fig. 1. The Gulf of Thailand.

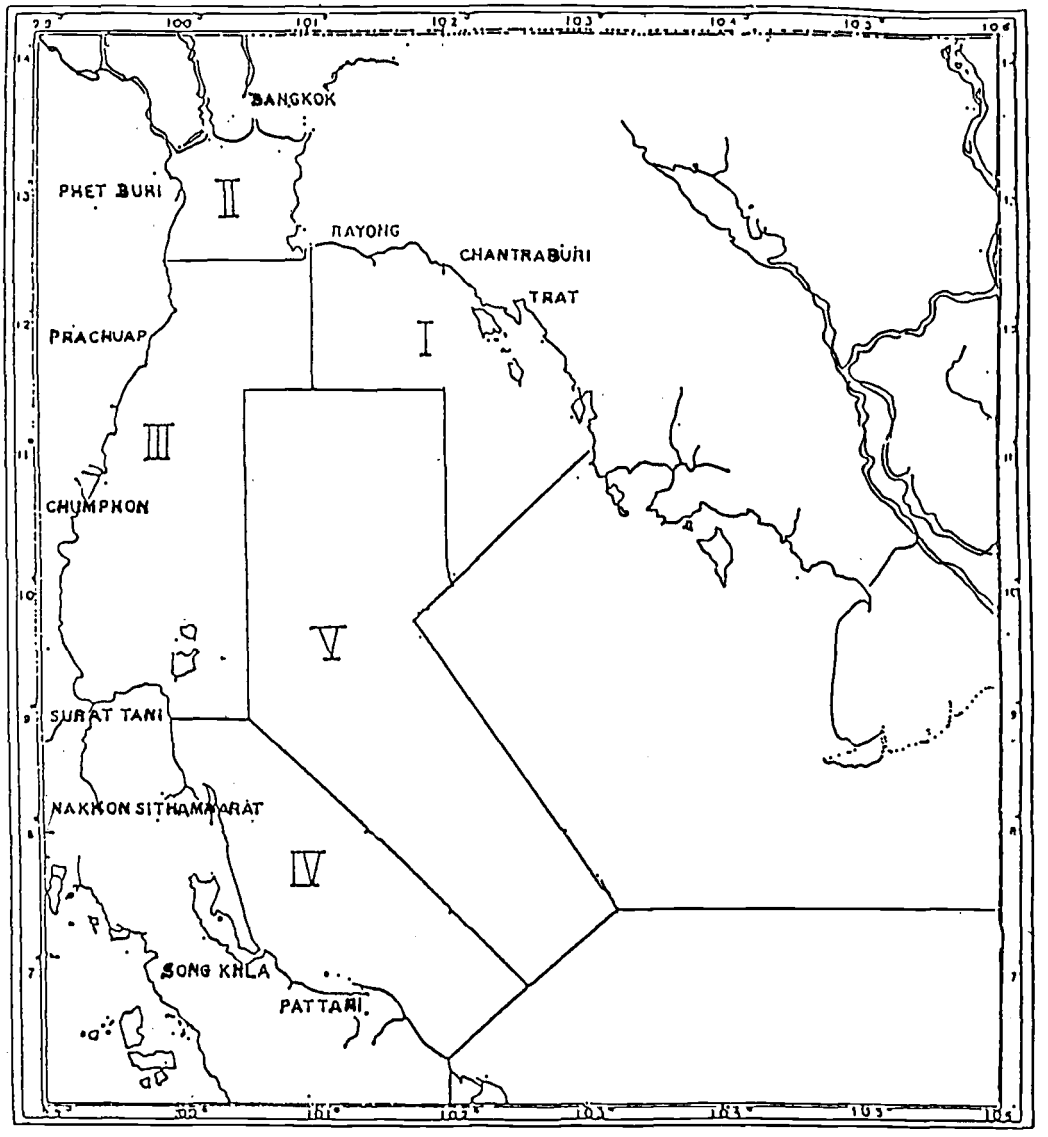


Fig. 2. Map showing the statistical area.

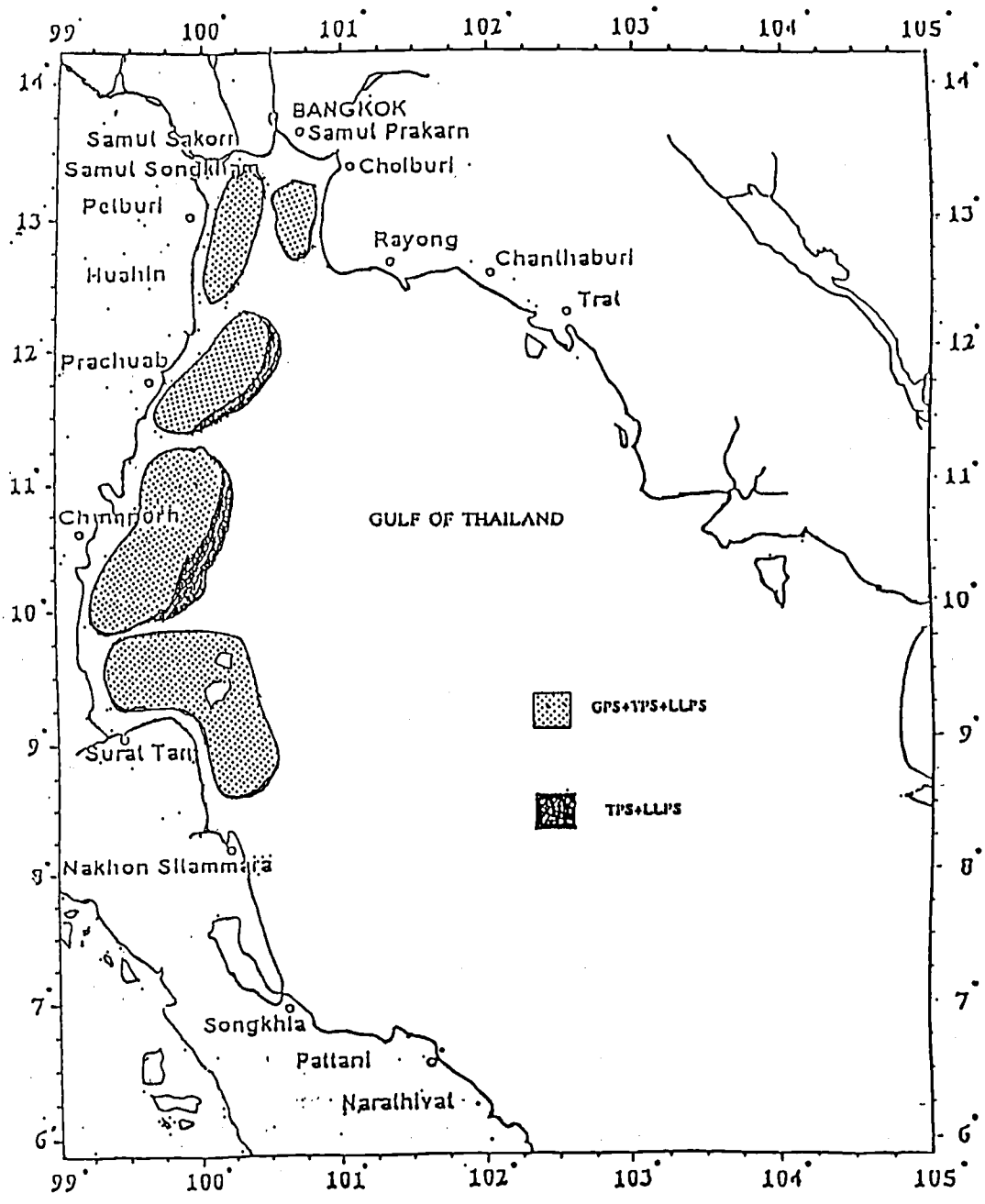


Fig. 3. The main fishing ground of Chub mackerel, R. neglectus in the Gulf of Thailand.

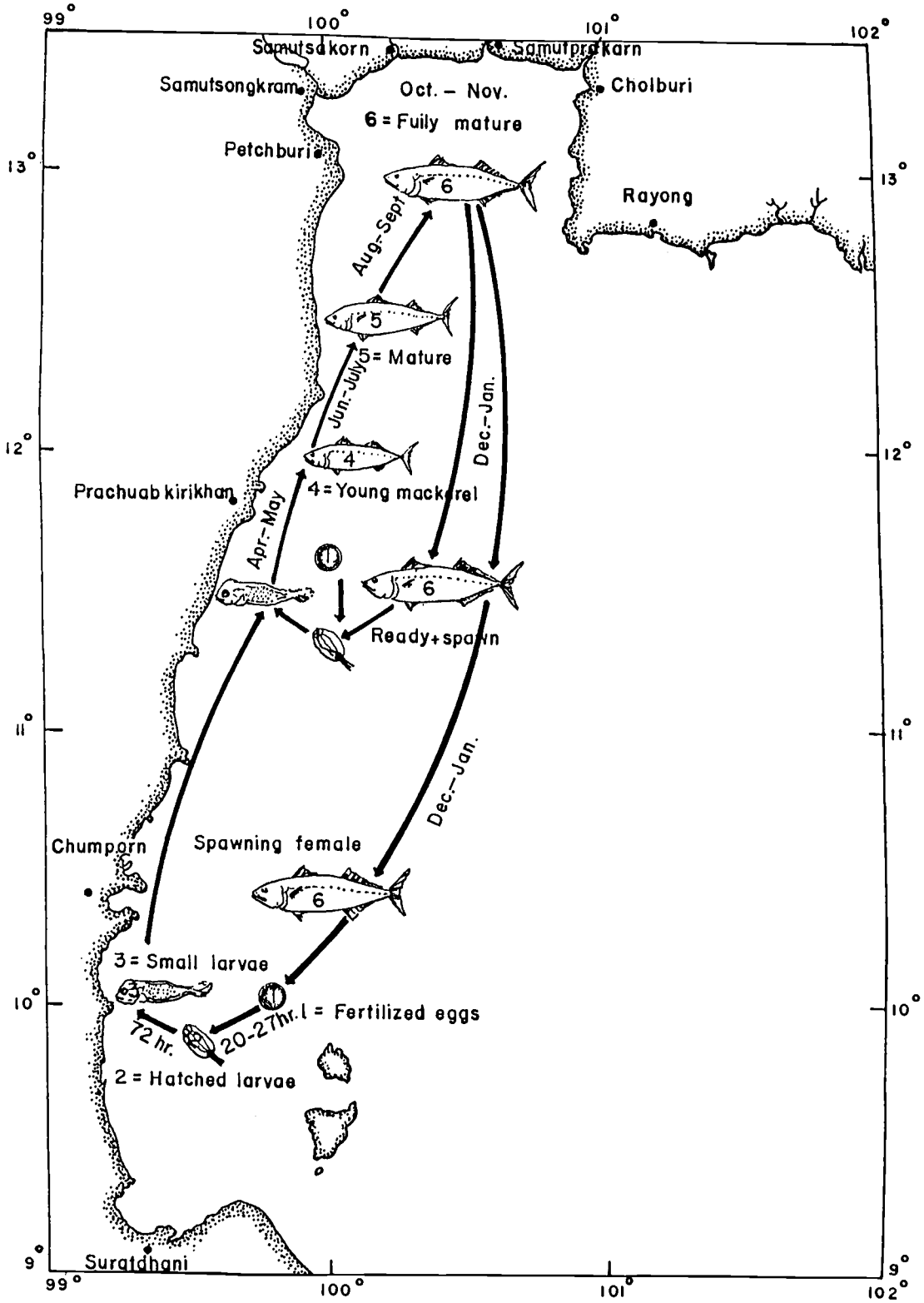


Fig. 4. Life cycle of the Indo-Pacific mackerel in the Gulf of Thailand.

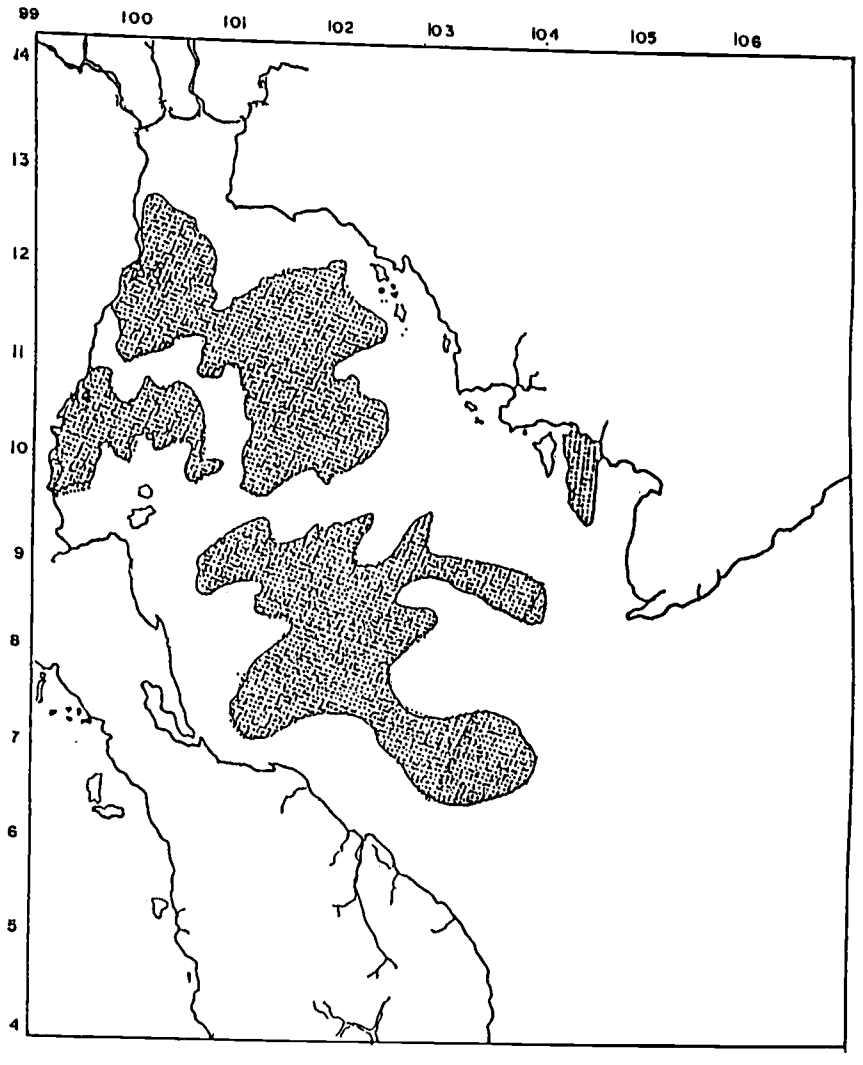


Fig. 5. The main fishing grounds of Indian mackerel in the Gulf of Thailand.

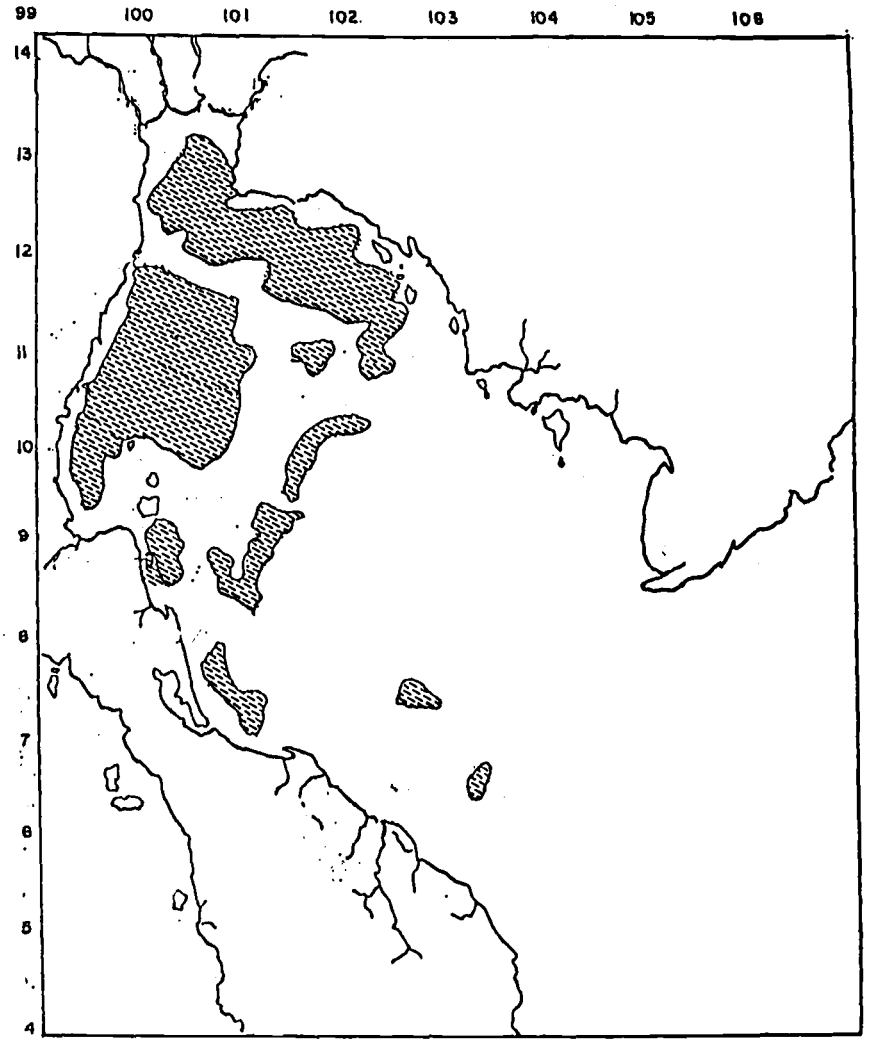


Fig. 6. The main fishing grounds of Sardines in the Gulf of Thailand.

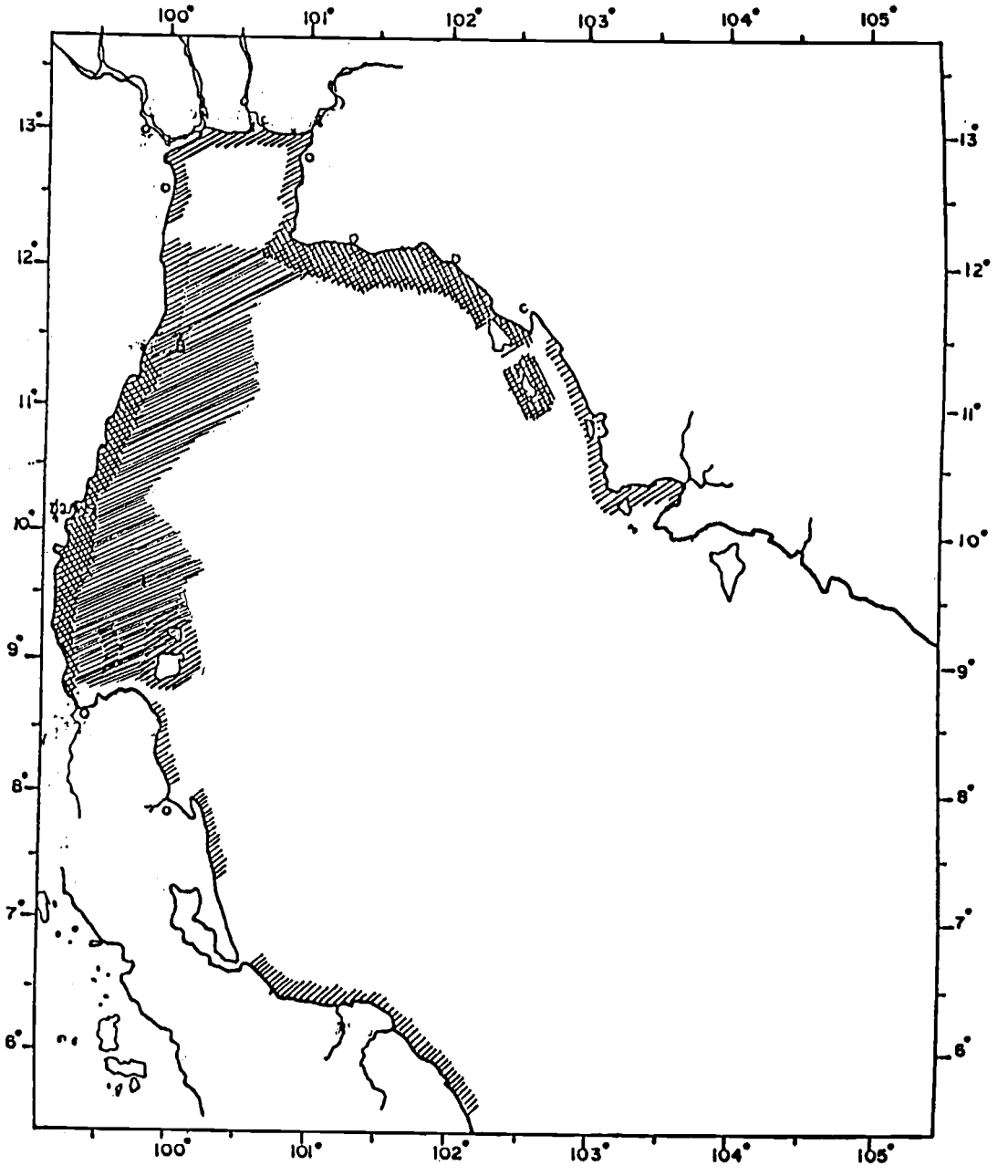


Fig. 7. The main fishing grounds of Anchovies in the Gulf of Thailand.

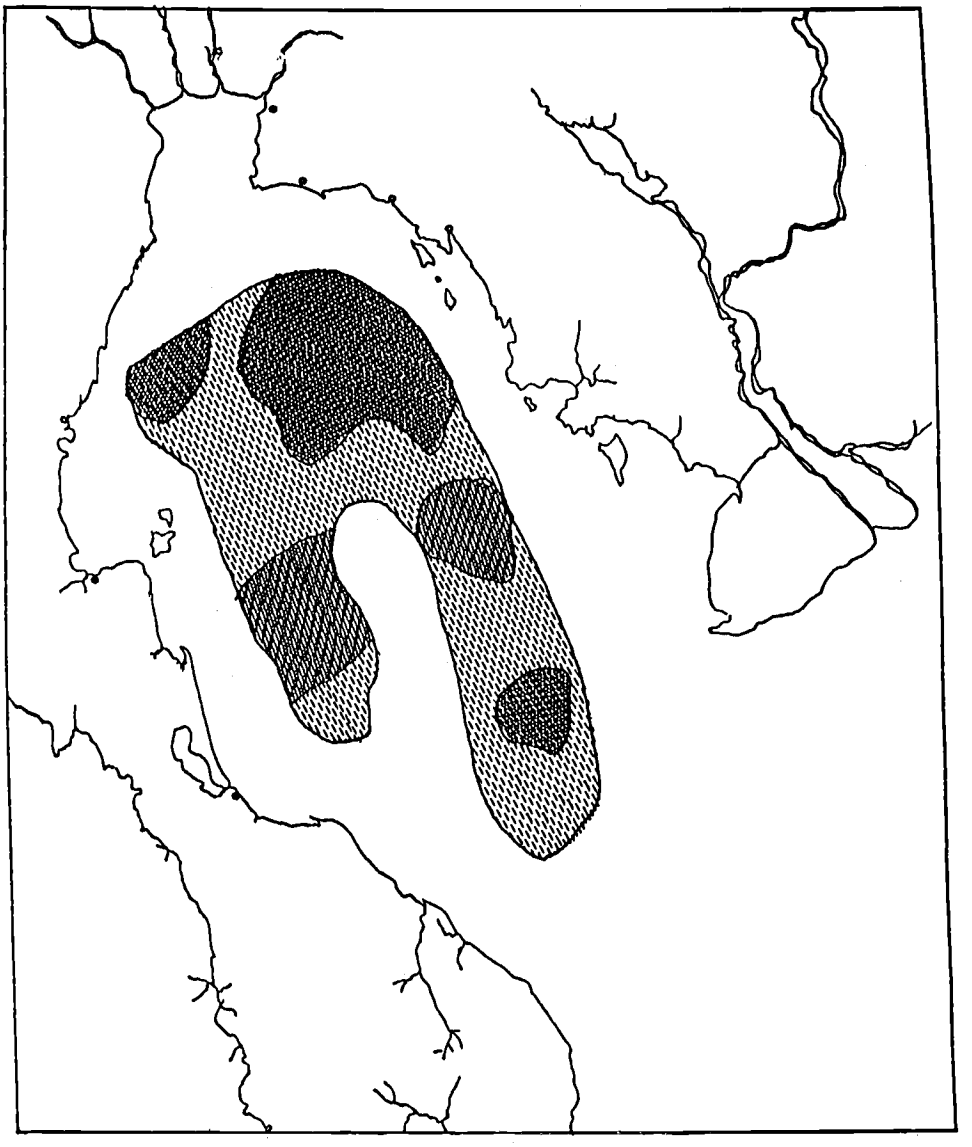


Fig. 8. The main fishing grounds of Round scads in the Gulf of Thailand.

Area of abundance

Area of distribution

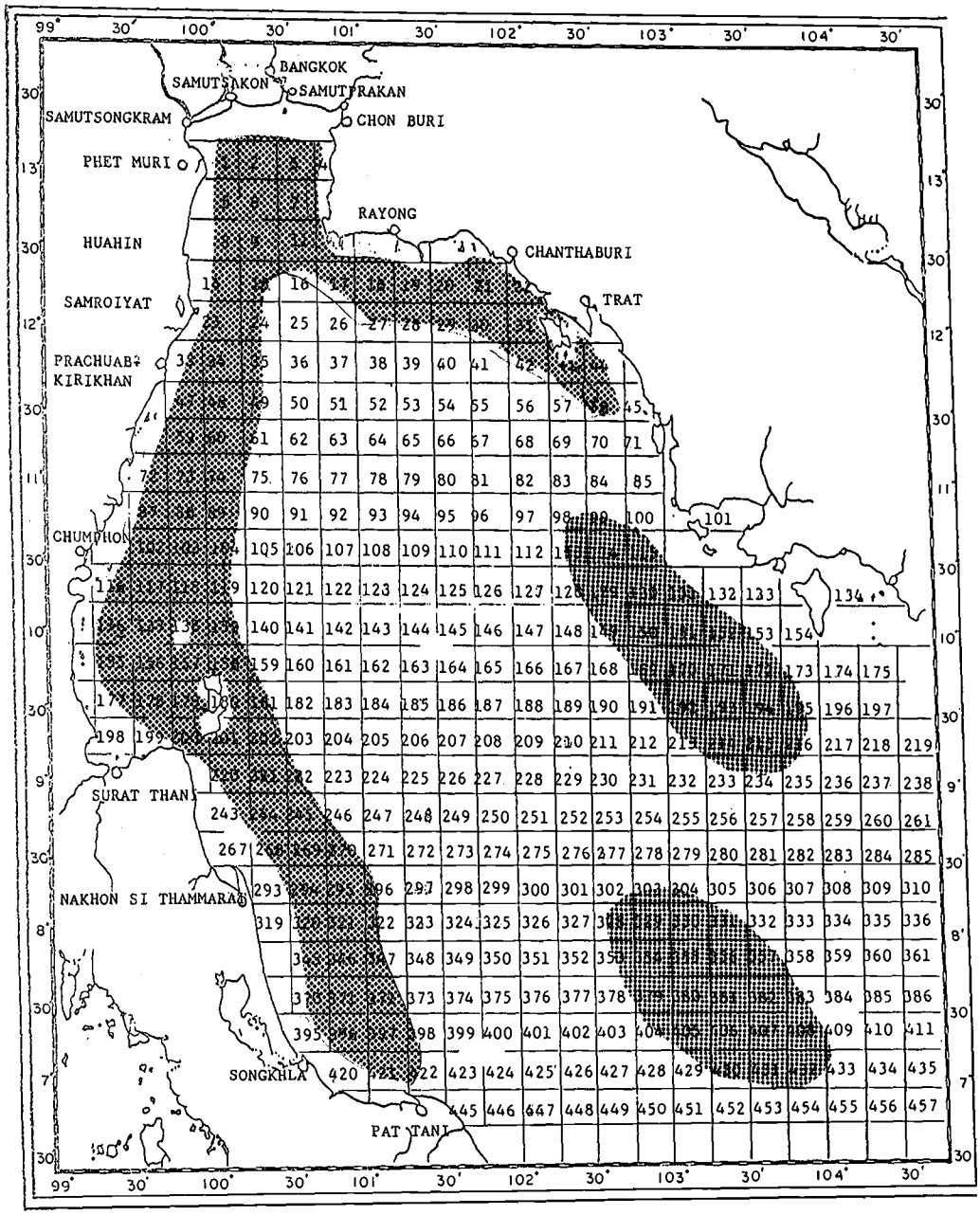


Fig. 9. Map showing the statistical sub-areas and the major fishing grounds of Thai purseseine in the Gulf of Thailand.

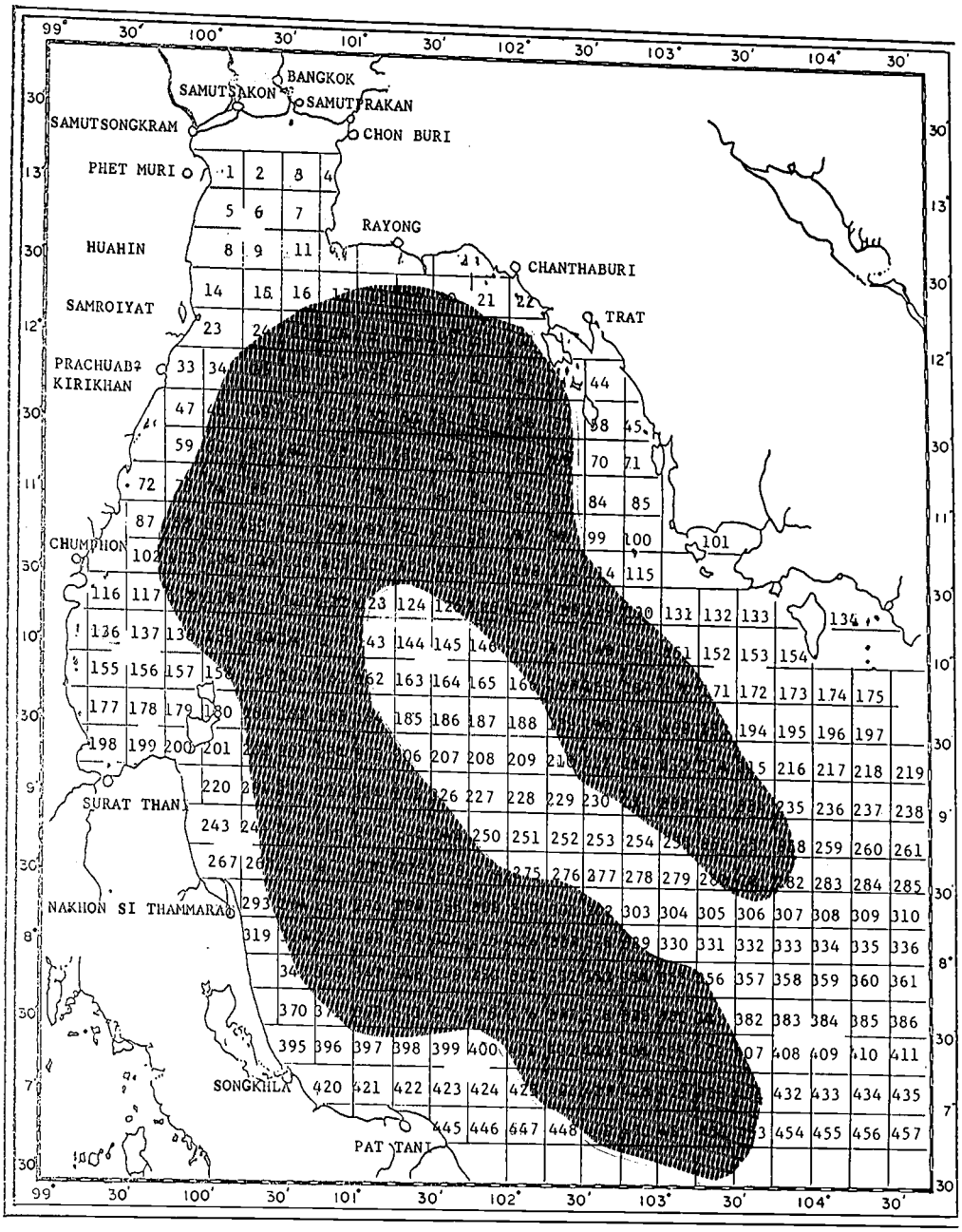


Fig. 10. Map showing the statistical sub-areas and the major fishing grounds of luring purseseine in the Gulf of Thailand.

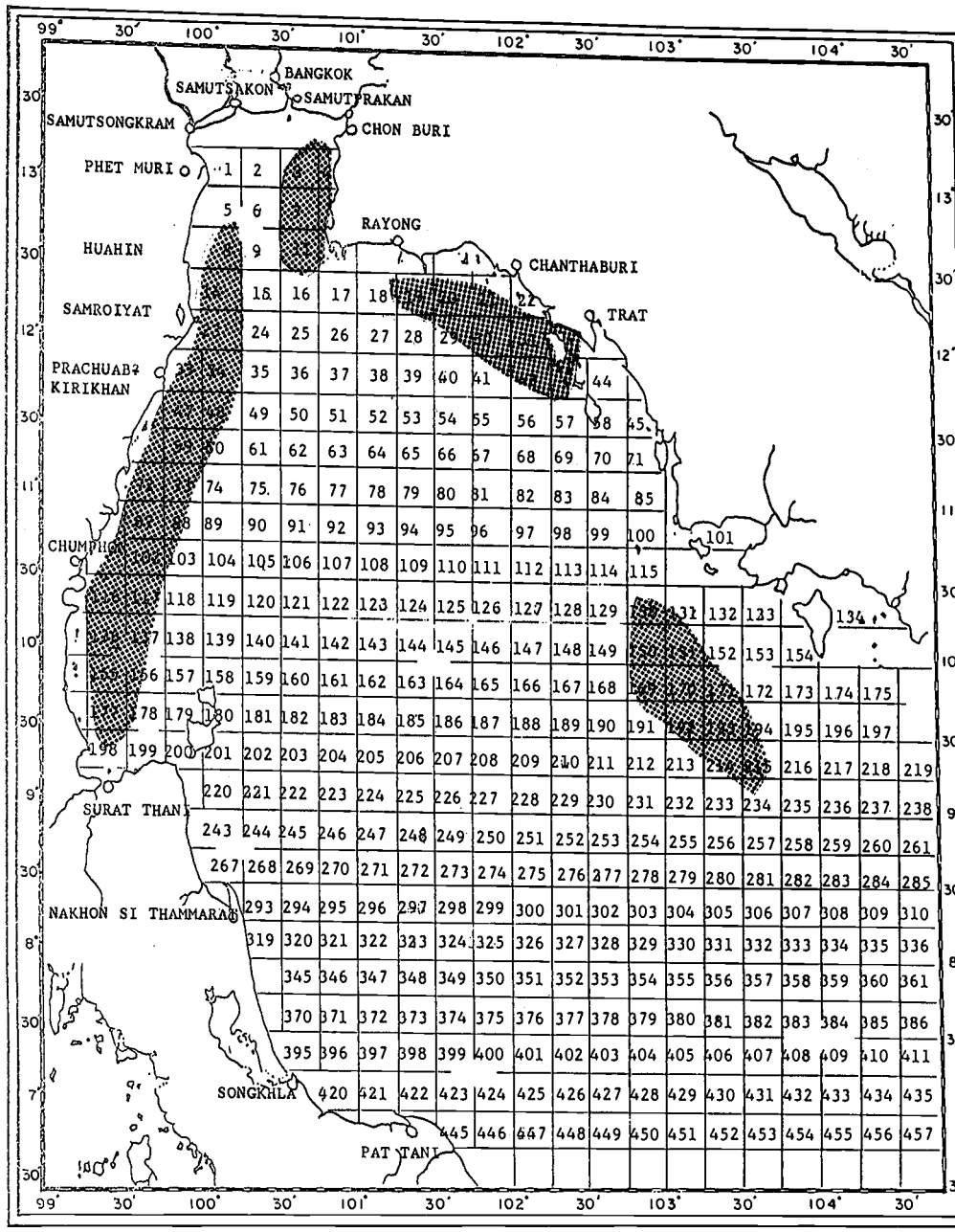


Fig. 11. Map showing the statistical sub-areas and the major fishing grounds of encircling gill net in the Gulf of Thailand.

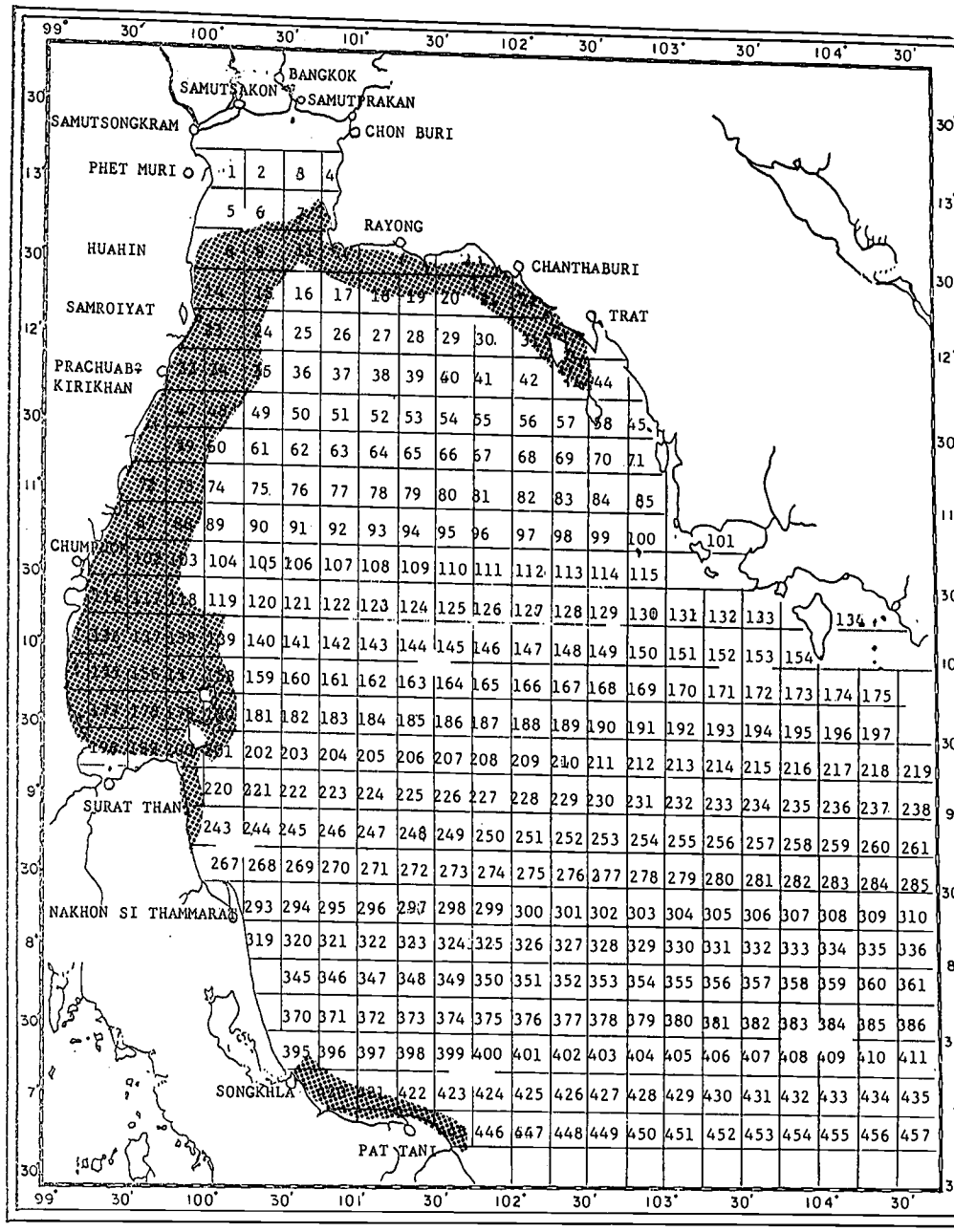


Fig. 12. Map showing the statistical sub-areas and the major fishing grounds of Anchovy purseseine in the Gulf of Thailand.

SMALL PELAGIC FISHERIES IN THE SOUTH CHINA SEA

by

Hiroyuki Yanagawa

Marine Fishery Resources Development and Management Department
Southeast Asian Fisheries Development Center
Fisheries Garden, Chendering,Kuala Lumpur, Malaysia

Abstract

In the South China Sea area, the annual catches of the dominant small pelagics, namely, the round scads (peak landings: 596 000 mt in 1991), selar scads (229 000 mt in 1990), jacks, cavalla and trevallies (147 000 mt in 1993), Indian mackerel (357 000 mt in 1992), Indo-Pacific mackerel (212 000 mt in 1993), Spanish mackerel (114 000 mt in 1993), kawakawa (283 000 mt in 1992), frigate and bullet tunas (128 000 mt in 1992), sardines (716 000 mt in 1993) and anchovies (419 000 mt in 1993) reached the peak in the 1990's. The purseseines was the dominant gear, catching 84/5% of the total round scad, 52.4% of the Indian mackerel and 65.9% of the Indo-Pacific mackerel catches during 1992. The CPUE of the purseseines were highly fluctuating for the dominant groups during 1978-1992. The principal component analysis revealed that the catches of 12 major small pelagics in the area have changed considerably from 1976 to 1993.

INTRODUCTION

The South China Sea is globally one of the most productive areas for marine capture fisheries, which accounts for around 10% of the grand total of world fish catch. This paper describes the catch trends of 12 small pelagic fish species (groups), catch by fishing gears and CPUE values of some selected species (groups) and the status of the small pelagic fisheries in the area analyzed by principal component analysis. Some descriptions in this account have been derived from the Report of the Second Regional Workshop on Shared Stocks in the South China Sea Area published by the SEAFDEC/MFRDMD.

REFERENCES OF DATA EXAMINED

The data required for this study were obtained from the SEAFDEC Fishery Statistical Bulletins for the South China Sea Area from 1976 to 1993 and Catch-effort Statistics for the South China Sea Area from 1978 to 1991, published by the SEAFDEC. The Bulletins cover the South China Sea, which has been designated by the FAO as Fishing Area 71, and the territorial waters of the Andaman Sea belonging to Malaysia and Thailand. The species (groups) for study in this paper are shown in Table 1.

Table 1. Species (groups) list and codes of ISSCAAP (FAO) and SEAFDEC examined in this paper

No	ISSCAAP(FAO)		SEAFDEC		
	Group	Code	Name	Code No.	Family and Scientific name
1	34. Jacks, mullets, sauries, etc.	SDX	1. Round scads	3405	Carangidae-*Decapterus* spp.
		BIS TRY	2. Selar scads	3407	Carangidae - *Selar crumenophthalmus* *Selaroidesleptolepis* (including *Alepes* spp. *Selar* spp.
		HAS	3.Hardtail scad	3408	Carangidae-*Megalaspis cordyla*
2	34. Jacks, mullets, sauries etc.	TRE GLT	4. Jacks, cavalla and trevallies	3406	Carangidae - *Caranx* spp *Gnathanodon speciosus* (including *Alectis* spp., *Atropusatropus,* *Caranx chrysophrys,* *C.malabaricus,* *C. ignobilis)*
3	37. Mackerels	RA G	5. Indian mackerels	3701	Scombridae - *Rastrelliger kanagurta* (including *Rastrelliger faughni*)
		RAB	6. Indo-Pacific mackerel	3702	Scombridae - *Rastrelliger brachysoma*
4	36. Tunas	LOT	7. Longtail tuna	3604	Scombridae - *Thunnus tonggol*
		KA W	8. Eastern little tuna	3606	Scombridae - *Euthynnus affinis*
		FRZ	9.Frigate tuna and bullet tuna	3607	Scombridae - *Auxis hazard, Auxis rochei*
5	35. Sardines, anchovies	SIX	10. Sardines	3501	Clupeidae - *Sardinella* spp.
		STO	11. Anchovies	3503	Engraulidae - *Stolephorus* spp.
6	36. Tunas	COM	12. Narrow-barred king mackerel	3609	Scombridae - *Scomberomorus commerson*

CATCH TRENDS OF SMALL PELAGIC SPECIES GROUPS

Scads

Round scads: The round scads catch in the South China Sea Area (hereafter referred to as Area) recorded 40 5000 mt, accounting for 7.03% of the grand total in 1976 and remained nearly constant in 1977. The catch decreased drastically from 1978 recording only 193 000 mt in 1980 (3.15% of the grand total), but increased steadily from 286 000 mt (4.48%) in 1981 to 446 000 mt (5.56%) in 1987. After a slight decrease from 1988, the catch increased again to 596 000 mt (6.78%) in 1991 and remained constant till 1993 (Fig. 1).

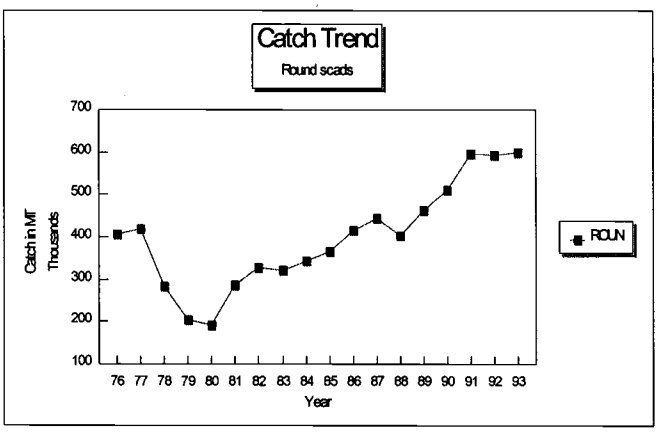


Fig. 1. Catch trend of round scads in the Area from 1976-1993.

Selar scads: The selar scads catch recorded 101 000 mt, accounting for 1.75% of the grand total in 1976 and increased to the peak 229 000 mt (2.69%) in 1990. In between, the catches attained secondary peaks during 1978 to 1981 and during 1983 to 1985 with declines during 1982 and 1986. After the peak in 1990, the catch stabilized 210 000 mt during 1991 to 1993 (Fig. 2).

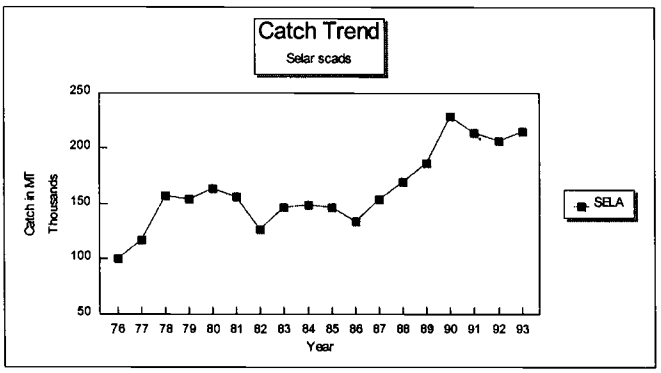


Fig. 2. Catch trend of selar scads in the Area from 1976-1993.

Hardtail scads: The hardtail scad catch increased from 40 000 mt accounting for 0.70% of the grand total in 1976, to 67 000 mt (1.08%) in 1979, but decreased drastically to 43 000 mt (0.67%) in 1981. The catch which was increased dramatically again to 72 000 mt (1.01%) in 1983 followed by a decrease to 57 000 mt (0.84%) in 1985 and increase to a peak of 82 000 mt (1.02%) in 1987. The catch, however, decreased drastically again to 54 000 mt (0.67%) in 1988 and 50 000 mt (0.59%) in 1990, which was followed by an increasing trend again reached 66 000 mt (0.68%) in 1993 (Fig. 3).

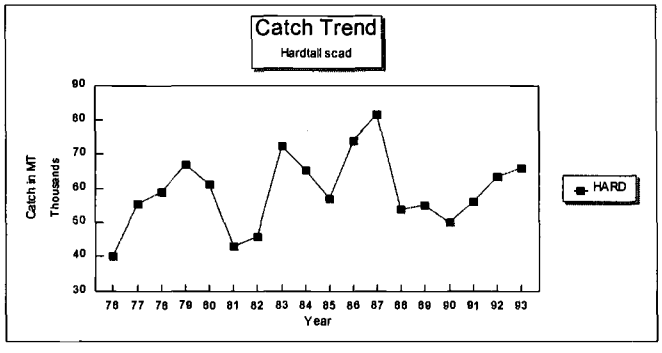


Fig. 3. Catch trend of hardtail scad in the Area from 1976-1993.

Jacks, cavalla and trevallies: The jack, cavalla and trevallies catch in the Area recorded 65 000 mt, accounted for 1.13% of the total in 1976 and increased dramatically to 118 000 mt (1.76%) in 1978. After declining to 83 000 mt (1.05%) in 1982, the catch increased again to 123 000 mt (1.53%) in 1988, and although there was a short decline to 113 000 mt (1.29%) in 1991, it peaked to 147 000 mt (1.51%) in 1993 (Fig.4).

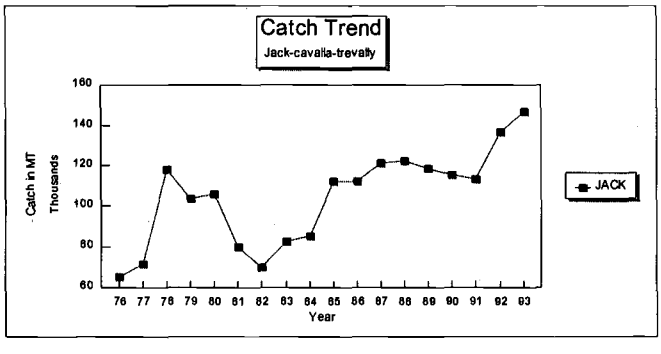


Fig. 4. Catch trend of jacks-cavalla-trevallies in the Area from 1976-1993.

Mackerels

Indian mackerel: The Indian mackerel catch (Fig. 5) recorded 84 000 mt accounting for 1.45% of the grand total in 1976 and increased almost steadily to the maximum of 357 000 mt (3.75%) in 1992. In between, the catch remained nearly constant around (280 000 mt) (3.89%) from 1983 to 1988 (Fig. 5).

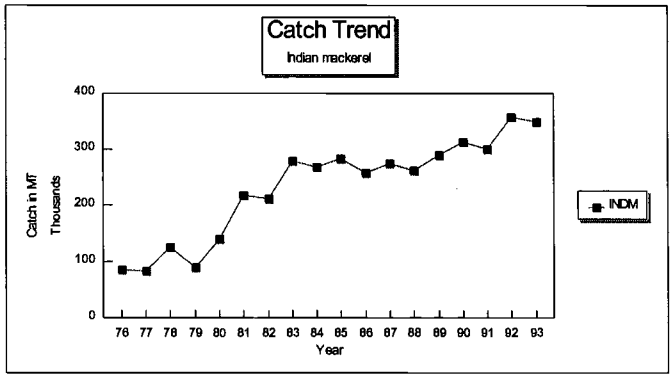


Fig. 5. Catch trend of Indian mackerels in the Area from 1976-1993.

Indo-Pacific mackerel: The Indo-Pacific mackerel catch (Fig. 6) in the Area recorded 156 000 mt accounting for 2.71% of the grand total in 1976, and reached 188 000 mt (3.03%) in 1979 after a slight decrease in 1977. The catch decreased drastically to 92 000 mt (1.43%) in 1981, but increased again to 167 000 mt (2.50%) in 1984, decreased to 144 000 mt (1.97%) in 1986, followed by 164 000 mt (1.86%) in 1991, before peaking at 212 000 mt (2.18%) in 1993 (Fig. 6).

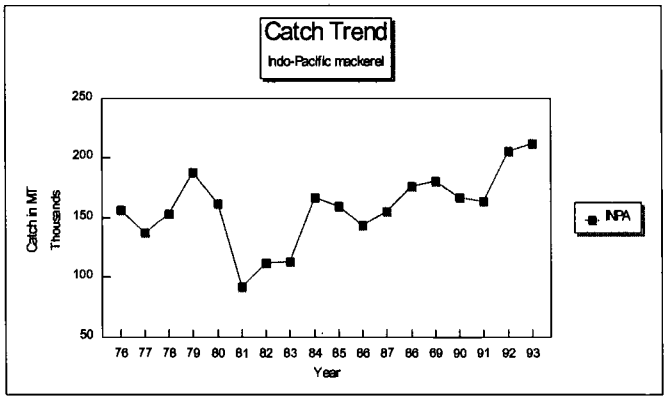


Fig. 6. Catch trend of Indo-Pacific mackerel in the Area from 1976-1993.

Neritic tunas

Longtail tuna: The longtail tuna catch recorded only 74 mt in 1976, but began to increase almost steadily through 13 000 mt accounting for 0.19% of the grand total in 1977, to 73 000 mt (1.02%) in 1983. It remained constant till 1986, but increased dramatically to the peak 123 000 mt (1.44%) in 1990, which was followed by a slight decrease to 100 000 mt (1.03%) in 1993 (Fig. 7).

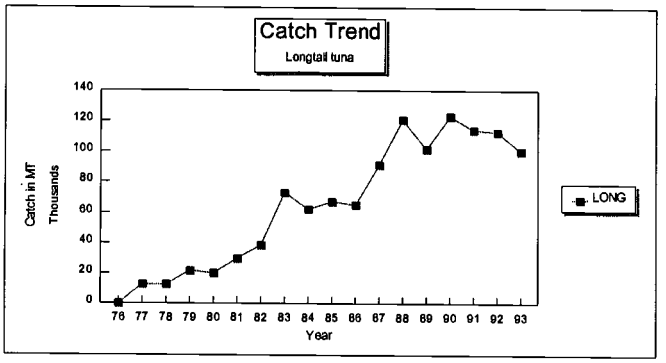


Fig. 7. Catch trend of longtail tuna in the Area from 1976-1993.

Eastern little tuna (kawakawa): The eastern little tuna catch which recorded 99 000 mt, accounting for 1.72% of the grand total in 1976, increased to 132 000 mt (2.01%) in 1977. After a decrease to 91 000 mt (1.47%) in 1979, the catch increased steadily to 197 000 mt (2.75%) in 1983 and the peak 283 000 mt (2.97%) in 1992, remaining more or less constant in 1993, as well (Fig. 8).

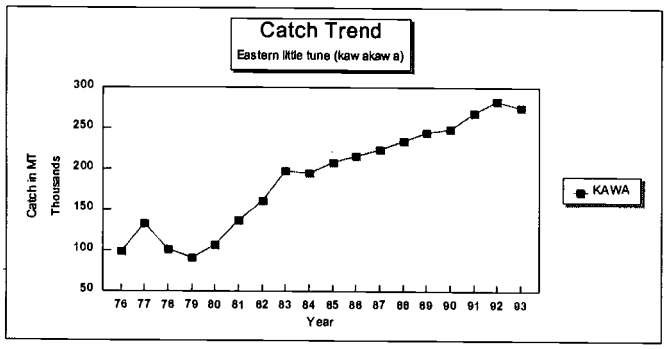


Fig. 8. Catch trend of eastern little tuna (kawakawa) in the Area from 1976-1993.

Frigate and bullet tunas: The catch of the frigate and bullet tunas which recorded only 30 000 mt, accounting for 0.53% of the grand total in 1976 increased dramatically to 76 000 mt (1.15%) in 1977. After a decrease to 51 000 mt (0.76%) in 1978 followed by an increase to 98 000 mt (1.61%) in 1980 and again a decrease to 72 000 mt (1.08%) in 1982, the catch increased steadily to the peak 134 000 mt (1.61%) in 1989. The catch decreased to around 100 000 mt in 1990 and 1991 but rose again to 128 000 mt (1.34%) in 1992, followed by a slight decrease in 1993 (Fig. 9).

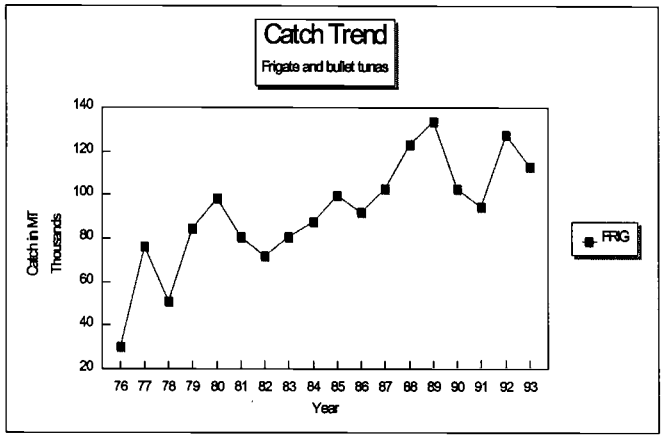


Fig. 9. Catch trend of frigate and bullet tunas in the Area from 1976-1993.

Sardines and anchovies

Sardines: The sardine catch which was 309 000 mt (accounting for 5.35% of the grand total) in 1976, recorded 475 000 mt (7.19%) in 1977, 380 000 mt (6.21%) in 1981, 508 000 mt (7.09%) in 1983, and declined drastically to 253 000 mt (3.80%) in 1984 and 208 000 mt (3.04%) in 1985. However, the catch increased dramatically to 406 000 mt (5.57%) in 1986 and then to 716 000 mt (7.36%) in 1993 (Fig. 10).

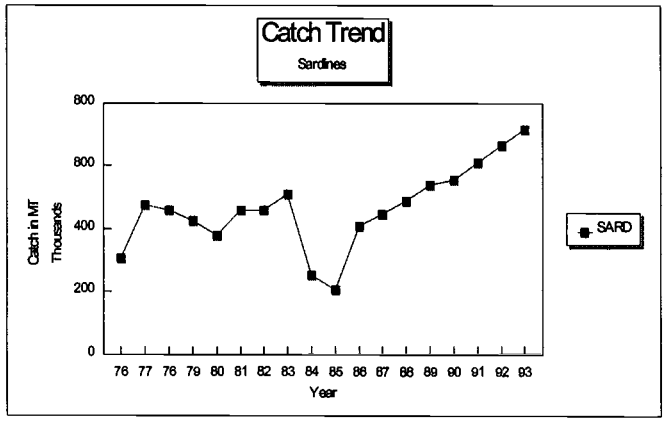


Fig. 10. Catch trend of sardines in the Area from 1976-1993.

Anchovies: The catch of anchovies which was 177 000 mt (accounting for 3.07% of the grand total) in 1976 recorded 154 000 mt (2.33%) in 1977, 234 000 mt (3.49%) in 1978, remained constant till 1981 at around 230 000 mt and increased to 339 000 mt (4.97%) in 1985, and after a decrease to 291 000 mt (3.98%) in 1986, it increased steadily to 419 000 mt (4.40%) in 1992 and 1993 each (Fig. 11).

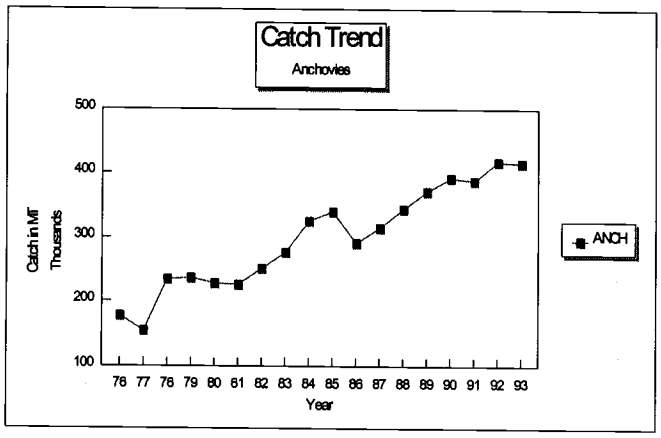


Fig. 11. Catch trend of anchovies in the Area from 1976-1993.

Narrow-barred king mackerel (Spanish mackerel): The narrow-barred king mackerel catch which recorded 62 000 mt (1.08% of the grand total) in 1976 increased to 84 000 mt (1.35%) in 1979, and after some fluctuations i.e., 70 000 mt (1.14%) in 1980; 86 000 mt (1.35%) in 1983; 77 000 mt (1.13%) in 1985, the catch increased to 90 000 mt (1.24%) in 1986, remained constant from 1987 to 1990 and increased again to reach the peak 114 000 mt (1.18%) in 1993 (Fig. 12).

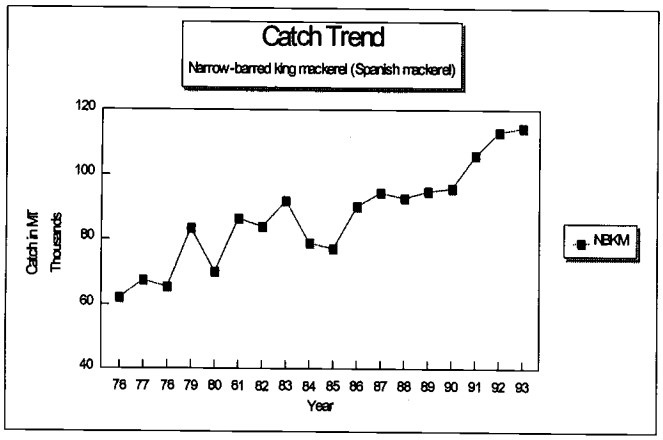


Fig. 12. Catch trend of narrow-barred king mackerel in the Area from 1976-1993.

CATCHES OF SOME SELECTED SPECIES GROUPS BY TYPES OF FISHING GEAR

Round scads

Among the catches by various gears, the purseseine catch of round scads was the most dominant with 253 000 mt (accounting for 77.3% of the total roundscads catch) in 1976. In 1981, the purseseine catch decreased to 126 000 mt (59.4%),

while the catches of other fishing gears increased considerably. For example, the liftnet catch of rounds cads increased significantly to 39 000 mt (18.5%). However, in 1986 the purseseine catch of round scads increased to 150 000 mt (68.1%), the liftnet catch decreased considerably and the trawl catch recorded 23 000 mt (accounting for 10.0% of the roundscads catch), while the gillnet and hooks-and-line catches accounted for 4.9% and 3.5% respectively of the total round scad catch. In 1992, the purseseine catch increased steadily to 332 000 mt (84.5%), followed by the liftnet (31 000 mt; 7.9%) and trawl catches (12 000 mt; 3.0%) (Table 2).

Table 2. Catch (in metric tonnes) of roundscads by type of fishing gear during 1976, 1981, 1986 and 1992 in the Area.

Gear / Year	1976	1981	1986	1992
Purseseine	252,667	126,279	149,858	331,744
Trawl	14,546	21,181	22,873	11,862
Gillnet	1,103	13,569	10,778	6,658
Liftnet	7,129	39,258	27,229	30,832
Hook & line	29	8,716	7,774	5,136
Trap	10,803	1,009	325	176
Others	40,512	2,672	1,249	6,175
Total	326,789	212,684	220,086	392,583

The data were obtained from Malaysia, the Philippines and Thailand.

Indian mackerels

The purseseine catch of the Indian mackerels was the most dominant at 44 000 mt, accounting for 53.0% of the total Indian mackerels catch during 1976, when the trawl catch was 13 000 mt (15.2%) and the gillnet catch 3,600 t (4.3%) only. In 1981, the purseseine catch increased to 80 000 mt (61.5%), followed by gillnet catch (24 000 mt; 18.5%) and the trawl catch (21 000 mt; 15.8%). In 1986, the purseseine catch accounted for over 60% of the Indian mackerels catch of 80 000 mt while the gillnet and trawl catches were almost the same at 16,000 t (13%) each and hook-and-line catch at 6 300 mt (5.0%). In 1992, the purseseine catch was still the most dominant with 94 000 mt, accounting for 52.4% while the gillnet catch increased to 45 000 mt (accounting for 24.9%) followed by the trawl catch of 25 000 mt (13.9%) (Table 3).

Table 3. Catch (in metric tonnes) of Indian mackerels by type of fishing gear during 1976, 1981, 1986 and 1992 in the Area.

Gear / Year	1976	1981	1986	1992
Purseseine	44,386	80,471	79,661	94,231
Trawl	12,759	20,725	15,695	24,989
Gillnet	3,568	24,171	16,775	44,822
Liftnet	933	1,372	3,412	3,278
Hook & line	253	2,663	6,276	6,318
Trap	678	662	1,702	1,017
Others	21,176	734	1,305	5,114
Total	83,753	130,798	124,826	179,769

The data were obtained from Malaysia, the Philippines and Thailand.

Indo-Pacific mackerel

In 1976 the purseseine catch of the Indo-Pacific mackerel was the most dominant with 45 000 mt accounting for 55.5% of the total Indo-Pacific mackerel catch, followed by trawl (12 000 mt; 14.5%) and gillnet (8 600 mt; 4.3%). In 1981 while the purseseine catch remained at 44 000 mt accounting for less than 50% of the total catch of Indo-Pacific mackerel, gillnet catch increased to 28 000 mt (31.0%) and the trawl catch significantly at 12 000 mt (13.3%). In 1986, the purseseine catch increased to 75 000 mt (52.0%), followed by the gillnet catch (42 000 mt; 29.3%) and the trawl catch (15 000 mt; 10.2%). In 1992, the purseseine catch further increased to 101 000 mt (65.9%) but the gillnet catch decreased to 26 000 mt (17.1%) while the trawl catch increased marginally to 18 000 mt (11.6%)

Table 4: Catch (in mt) of Indo-Pacific mackerel by type of fishing gear during 1976, 1981, 1986 and 1992 in the Area.

Gear/Year	1976	1981	1986	1992
Purseseine	44,941	43547	74774	101,043
Trawl	11,735	12,182	14,617	17,844
Gillnet	8,646	28,418	42,093	26,214
Liftnet	2,535	800	770	217
Hook&line	10	1,487	4,859	2,415
Trap	1,333	3,186	5,460	1,997
Others	11,791	2,012	1,189	3,524
Total	80,991	91,632	143,762	153,254

The data were obtained from Malaysia, the Philippines and Thailand.

CATCH PER UNIT EFFORT

Round scads

The CPUE (mt/day) for the purseseine roundscads catch was very high at 0.624 mt/day in 1978, but ranged from 0.095 mt/day (1990) to 0.323 mt/day (1987), subsequently. The CPUE variations were much stronger after 1986 than in the previous years (Fig.13).

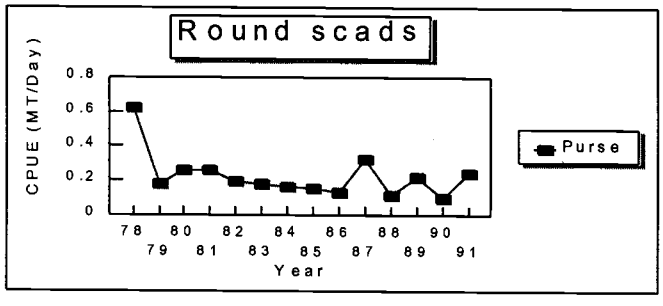


Fig.13. CPUE values for the purseseine roundscads catch from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia, Sabah, Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data was not always available for the same year for the above areas).

Indian mackerels

The CPUE (mt/day) for the catch of Indian mackerels by purseseine that was 0.124 mt/day in 1978, increased dramatically to 0.434 mt/day in 1982. After 1982, the CPUE showed a clear declining trend towards 0.20 mt/day in 1986, followed by repeated ups and downs in the subsequent years (Fig.14).

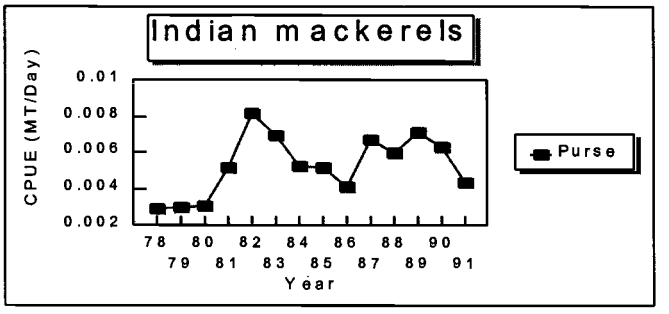


Fig. 14. CPUE values for the purseseine catch of Indian mackerels from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia, Sabah, Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data was not always available for the same year for the above areas).

The CPUE value (mt/day) for the trawl catch of Indian mackerels ranged from 0.0003 mt/day (1978,1979 and 1980) to 0.008 mt/day (1982), with an average of 0.005 mt/day (Fig.15).

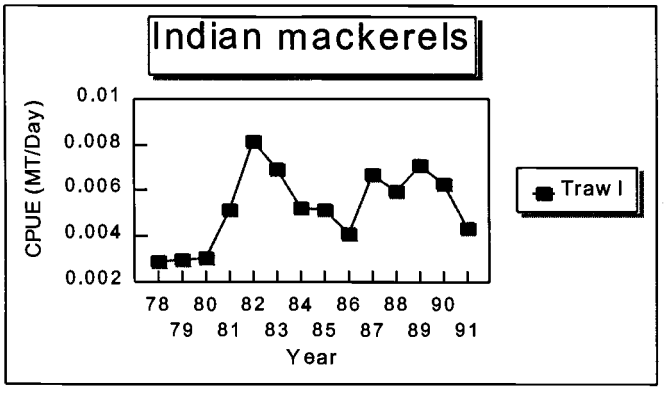


Fig. 15. CPUE values for the trawl catch of Indian mackerels from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia , Sabah, Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data were not always available for the same year for the above areas).

The CPUE value (mt/day) for the drift gillnet catch of Indian mackerels was generally less than 0.003 mt/day, with exceptions of 0.009 mt/day in 1979 and 0.005 mt/day in 1982 (Fig.16).

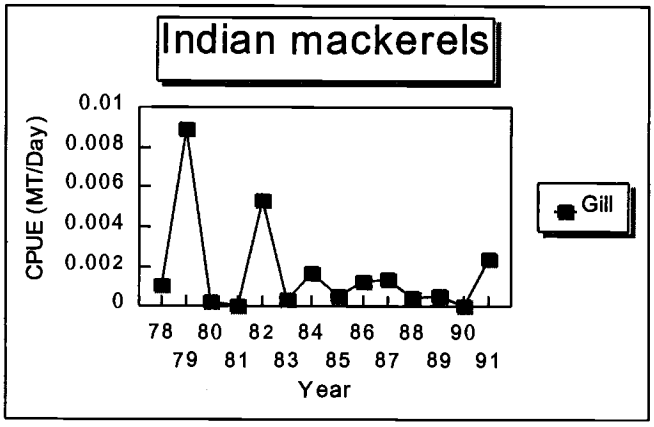


Fig. 16. CPUE values for the drift gillnet catch of Indian mackerels from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia, Sabah, Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data were not always available for the same year for the above areas).

Indo-Pacific mackerel

The CPUE (mt/day) for the catch of Indo-Pacific mackerel by the purseseine fleet increased from 0.078 mt/day in 1978 to 0.337 mt/day in 1985 with some ups and downs in between. After 1985, there was a general decrease towards 0.191 mt/day in 1988 before increasing again to 0.258 mt/day in 1991 (Fig.17).

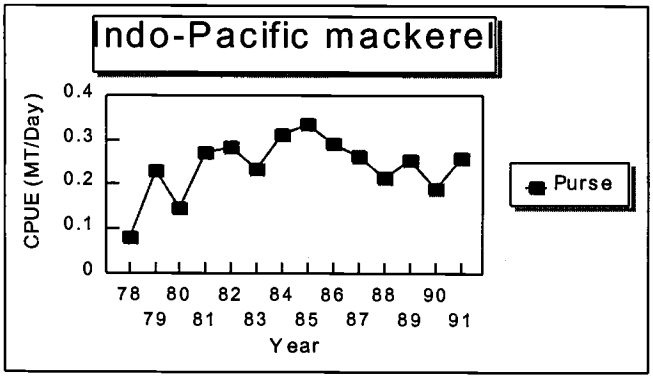


Fig.17. CPUE values for the purseseine catch of Indo-Pacific mackerel from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia, Sabah,Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data were not always available for the same year for the above areas).

The CPUE values for the trawl catch of Indo-Pacific mackerel decreased from about 0.008 mt/day during 1979-81 to 0.003 mt/day in 1983, but increased again to 0.006 mt/day in 1988 and remained constant till 1990 (Fig.18).

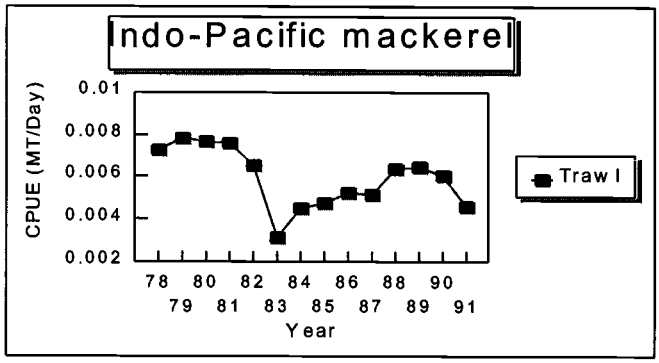


Fig.18. CPUE values for the trawl catch of Indo-Pacific mackerel from 1978-1991 in the Area. (The data were obtained from west and east coasts of Peninsular Malaysia, Sabah, Visayas, Mindanao, Gulf of Thailand and Andaman Sea; the data were not always available for the same year for the above areas).

ANALYSIS OF THE SITUATION OF SMALL PELAGIC FISHERIES IN THE AREA

The catches of 12 small pelagic species (groups) were analyzed by principal component analysis (PCA) (Table 5). The percentages of variance (ratio of contribution) for the first, second and third principal components were found to be 66.3%, 10.2% and 7.9% respectively, while the cumulative percentage from the first to the third components was found to be 84.4%. Thus , about 85% of the information in the total variation is attributable to the first three principal components. Factor loading for each species (group), examined graphically, indicated that all the factor loading were dropped in the circles between the 1.0 and 0.5 factor loading radii. Therefore, the information in respect of all the species (groups) could be well explained by the first and second principal components.

The factor scores of the first and second principal components, plotted in Fig.19, indicate that the cumulative ratio of contribution of the first and second principal components is 76.5%. The catches of anchovies, eastern little tuna (kawakawa), longtail tuna, narrow-barred king mackerel (Spanish mackerel), Indian mackerels, selarscads,frigate and bullet tunas and jacks-cavalla-trevallies are reflected positively. No species (groups) are reflected negatively in the first principal component. The catches of hardtailscad, Indo-Pacific mackerel, jacks-cavalla-trevallies and frigate and bullet tunas are reflected positively in the second principal component while the catches of roundscads, sardines, eastern little tuna (kawakawa), Indian mackerels, narrow-barred king makckerel (Spanish mackerel) and longtail tuna are reflected negatively in the second principal component.

fish species (groups) in the Area.

Component	PC1	PC2	PC3
Eigen value	7,952	1,224	0.951
% of	66,266	10,200	7.928
Cumulative %	66,266	76,466	84,394
Factor loading			
Round scads	0.781	-0.343	0.105
Selar scads	0.861	-0.083	0.280
Hardtail scad	0.320	0.758	-0.360
Jacks-cavalla-trevallies	0.815	0.406	0.249
Indian mackerels	0.889	-0.130	-0.375
Indo-Pacific mackerel	0.611	0.428	0.540
Longtail tuna	0.936	-0.101	-0.196
Eastern little tuna	0.940	-0.148	-0.242
Frigate and bullet tunas	0.823	0.195	-0.108
Sardines	0.684	-0.275	0.343
Anchovies	0.958	-0.005	-0.063
Narrow-barred king mackerel	0.921	-0.122	-0.088

The results of principal component analysis may be summarized as: (1) the 12 small pelagic fisheries in the Area have grown considerably from 1976 to 1993, with some alternation of major species (groups); (2) after 1987, most fisheries can be considered to have reached the well developed state based on the catch trends; (3) three major catch trends could be recognised as shown in Fig.19.

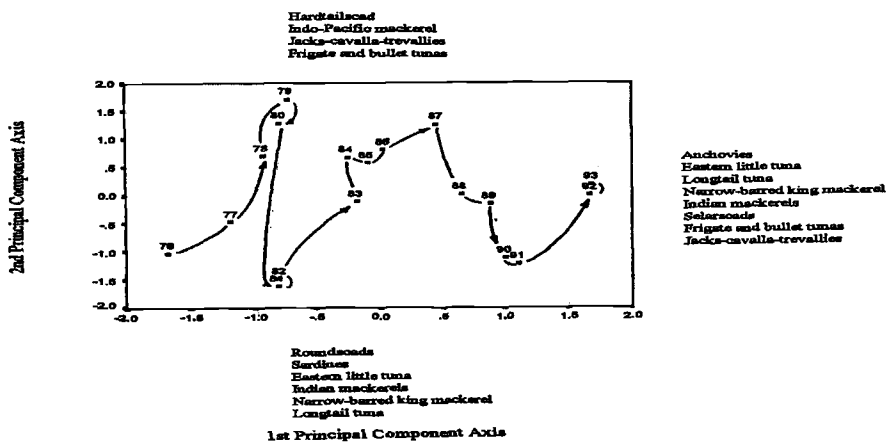


Fig. 19. Yearwise plots of factor scores for the catch of 12 small pelagic fish species (groups) on the first and the second principal components. Each species (group) name is shown as a reflection of each axis.

From the yearwise plots for the 18 years from 1976 to 1993, it is found that the values for the early period (1976 and 1977) are positioned at the negative reflection zone of the first principal component; therefore, the next three years (1978,1979 and 1980) have moved to the positive reflection zone of the second

principal component; and the values for 1981 and 1982 have moved to the negative reflection zone of the second principal component. After 1982, the values for the following years 1984, 1985, 1986 and 1987 have moved again to the positive reflection zone of the second principal component through almost the centre of the axis (1983); the values for the years 1988,1989,1992 and 1993 have moved to the positive reflection zone of the first principal component through the negative reflection zone of the second principal component (1990 and 1991). The principal component analysis indicates alternation of species (groups) of major catches also (Table 6).

Table 6. Summarized alternation of species (groups) of major catches in the Area based on the principal component analysis.

Species	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
Round scads	xx xx	xx xx				xx xx	xx xx	xx xx							xx xx	xx xx		
Selar scads													xx xx	xx xx			xx xx	xx xx
Hard-tails			xx xx	xx xx	xx xx				xx xx	xx xx	xx xx	xx xx						
Jack-c-trev.			xx xx	xx xx	xx xx				xx xx	xx xx	xx xx	xx xx	xx xx	xx xx			xx xx	xx xx
Indian mack.	xx xx	xx xx				xx xx	xx xx	xx xx					xx xx	xx xx	xx xx	xx xx	xx xx	xx xx
Indo-P mack.			xx xx	xx xx	xx xx				xx xx	xx xx	xx xx	xx xx						
Long-tail tuna	xx xx	xx xx				xx xx	xx xx	xx xx					xx xx	xx xx	xx xx	xx xx	xx xx	xx xx
East. litte t	xx xx	xx xx				xx xx	xx xx	xx xx					xx xx	xx xx	xx xx	xx xx	xx xx	xx xx
Frig. bullet			xx xx	xx xx	xx xx				xx xx	xx xx	xx xx	xx xx	xx xx	xx xx			xx xx	xx xx
Sardines	xx xx	xx xx				xx xx	xx xx	xx xx							xx xx	xx xx		
Ancho-vies													xx xx	xx xx			xx xx	xx xx
NBK mack.	xx xx	xx xx				xx xx	xx xx	xx xx					xx xx	xx xx	xx xx	xx xx	xx xx	xx xx

CONCLUSIONS

Based on the analysis of the 12 small pelagic fisheries during 1976 to 1993, the following conclusions could be made.

(1) During the years from 1976 to 1993 the catches of 12 small pelagics showed a generally increasing trend, especially after 1987, with all species (groups) showing higher catches than the 18 year average, except the hardtailscads.

(2) Slight alternations of species (groups) of major catches were observed at two to four years.

(3) The fisheries for the Indian mackerels, eastern little tuna (kawakawa) and narrow -barred king mackerel (Spanish mackerel) were found to be the most stable over the 18 years.

(4) The anchovy fishery progressed steadily , and registering higher growth rate than that of the grand total production.

(5) The fishery for the hardtail scad showed relatively big variations in catch at every two to four year-term.

(6) The roundscads fishery was marked by significant declines, followed by a period of recovery and an increasing trend over the 18 years.

(7) The selar scad fishery did not show a big increase in catches, but it can be considered as one of the stable fisheries.

(8) For the purpose of fisheries management, certain fisheries characterised by similar patterns could be considered as groups, and the interactions among them examined in detail to facilitate better management measures.

SECTION III

FISHERIES ENVIRONMENT IN THE APFIC REGION WITH PARTICULAR EMPHASIS ON THE NORTHERN INDIAN OCEAN

by

V.N. Pillai, M. Devaraj and E.Vivekanandan
Central Marine Fisheries Research Institute
Cochin 682 014, India.

Abstract

The stocks of the small pelagics in the northern Indian Ocean are governed by different environmental factors such as wind pattern, currents, convergence, temperature, salinity, dissolved oxygen and vertical mixing processes. An attempt is made in this paper to correlate these factors with the fisheries for the small pelagics. In the northwest Pacific Ocean, successes or failures of recruitment of pelagic fishes are related to oceanographic factors, especially the direction of Kuroshio current. The information available on these aspects has been briefly reviewed.

INTRODUCTION

The marine ecosystem is a balanced network of biophysicochemical relationships. The limit to the amount of life that a given habitat can support, often referred to as the carrying capacity, is determined by various physicochemical processes, which in turn are determined by the terrestrial, atmospheric and oceanographic processes in operation. The total biomass of all living organisms present in a given area at any one time is referred to as the standing crop. The most important physical and chemical factors that determine the quality and quantity of both the standing crop and the carrying capacity of an ecosystem include temperature, hydrostatic pressure, salinity, density, dissolved oxygen, carbon dioxide, pH and the nutrients such as phosphates, nitrates and silicates. Vertical and horizontal distribution of these properties in the oceans together with the ocean circulation patterns as determined by atmospheric and geographical factors, play a major role in deciding the productivity of the marine ecosystems.

The stocks of small pelagics in the APFIC region are governed by different oceanographic and environmental conditions, which are unique to every area. Some of the major environmental conditions prevailing in the different areas of the APFIC region are given in Table 1.

NORTHERN INDIAN OCEAN

The northern Indian Ocean, which encompasses the northern part of the Western Indian Ocean (Arabian Sea) as well as the northern part of the Eastern Indian Ocean (Bay of Bengal), lies north of the 10°S latitude. The Arabian Sea and the Bay of Bengal are unique in many respects in that they differ drastically from the circulation pattern in similar latitudes in the northern hemisphere of the Atlantic and Pacific Oceans. The northern Indian Ocean, together with its two major bays,

the Arabian Sea and the Bay of Bengal, is landlocked in the north by the Asian continent which separates the northern Indian Ocean from the deep-reaching vertical convection areas of the Arctic seas and the cold climate regions of the northern hemisphere. This geographic separation is a major factor, which determines the oceanographic conditions of the northern Indian Ocean.

Wind pattern

The northern Indian Ocean falls within the monsoon gyre, where the predominant wind direction changes gradually from northeasterly to northwesterly and later to westerly during March to May (Anon., 1966). In June, the direction changes to southwesterly and westerly with increasing velocities and by July, the velocity reaches Beaufort 5 to 7. During June to August, the predominant wind direction is from southwesterly to westerly. By the end of August, the wind velocity decreases and by October-November the wind starts blowing from northwesterly to east northeasterly with comparatively low velocities. Both sea and land breeze are common in this area except during the southwest monsoon (along the Indian west coast) and the northeast monsoon season (along the Indian east coast).

Currents

The broad aspects of the circulation pattern in the Arabian Sea and the Bay of Bengal comprise the monsoon current, the equatorial current and the equatorial countercurrent (Varadachari and Sharma, 1967). The monsoon current is westerly during the northeast monsoon period and easterly during the southwest monsoon period. The north equatorial current is westerly and the equatorial current, easterly. The coastal circulation becomes clockwise during the southwest monsoon season (May to October) and counterclockwise during the northeast monsoon season (October to December). In this broad pattern of current, eddies occur within a current system or between two current systems. During the southwest monsoon season, the northeasterly current is practically nonexistent and the equatorial current and the monsoon current dominate the area. In general, the speed of the current is greater in the Bay of Bengal and the Arabian Sea compared to the equatorial regions of the northern Indian Ocean, except off the central part of the east coast of India, particularly in the months of March and April. The stongest currents are generally found off the Somali coast.

During the southwest monsoon, there is a southerly flow along the Indian west coast, spreading over the entire shelf region. During the change from the southwest monsoon to the winter, the northerly current is established off the shelf. Adjacent to and on the seaward side of the northerly flow is present a southerly current limited to the southerly region. From winter to summer (February to April), the northerly current vanishes and the circulation breaks up into eddies. The southerly current persists in summer though it is limited to a narrow belt. Once again during the southwest monsoon period, this narrow southerly current spreads over the entire shelf. In general, the winter current appears to be stronger than the southwest monsoon current along the west coast of India.

During the southwest monsoon period (May to October), the surface current flows southwards along the west coast of India, thereby causing a lifting of the isolines for the different oceanographic parameters (temperature, salinity, dissolved oxygen and density) near the coast. In order to satisfy the basic theory of particle motion in relation to the Coriolis force, denser subsurface waters from the intermediate, subsurface levels are slowly induced upwards (upwelling) along the continental shelf to occupy the left side of the southerly current (near the coast). This ultimately results in the comparatively denser, colder and low oxygenated subsurface waters reaching the surface levels near the coast. During this season, oxygen deficient waters cover the whole continental shelf area over the bottom.

The southerly current transports the comparatively high-saline Arabian Sea waters southwards along the west coast, though during the rainy season the addition of freshwater from rainfall and river runoff causes a significant lowering of the surface salinity near the coast.

During the northeast monsoon period (November to March), the surface current reverses its direction and turns northerly. The northerly current advects low salinity equatorial waters northwards at the surface levels causing a convergence located between latitudes 10°N and 12°N where the high-saline Arabian Sea water sinks below the less-saline equatorial waters. The effects of winter cooling at the surface levels along the convergence zone lead to the process of sinking. During the winter season (January-February), the surface mixed layer covers most of the shelf. For the coastal areas south of Bombay on the northwest coast of India, the resultant speed of the current is reported to be more than 20 km/day during the southwest monsoon period (Banse, 1968). From November to January, a northward flowing current is observed. This drift appears to be shallow and seems to have little influence on the waters below the thermocline (Wyrtki, 1973).

The seasonal reversal of wind causes a corresponding change in the flow of the surface waters in the Bay of Bengal. During the SW monsoon season, there is a clockwise circulation noticed in the central Bay. The northerly flow is close to the central Indian continental shelf where the speed reaches 3 to 5 knots. During the NE monsoon, the surface circulation becomes anticlockwise with lesser speeds.

The currents along the west coast of India have a distinct annual cycle. The current turns equatorward in February, gets stronger with time and is most energetic during July and August. Thereafter it decreases in strength, vanishes and reverses its direction by October-November and flows away from the equator during November to January (Madhupratap *et al.*, 1994). In June, there is a shallow (75 m to 100 m deep) equatorward surface current, below which there are downwelling indications of a poleward undercurrent hugging the continental slope carrying low saline waters in the SW Bay of Bengal (Shetye *et al.*, 1990). Both the currents weaken towards the north upto the 15° latitude and cease to be noticeable at about the 20° latitude. The width of the surface current is about 150 km and the bottom 50 km. The winds during this period vary between WNW near the southern end of the Indian coast to WSW near the northern end. The longshore component of the wind stress is generally equatorward. Therefore, the coastal circulation of the

west coast of India during the SW monsoon is dynamically similar to the wind driven eastern boundary currents found elsewhere in the oceans (Shetye *et al.*, 1990). Though this is true during the SW monsoon, the monthly mean longshore component of wind is comparatively very low between February and May (Shetye and Shenoi, 1988). Numerical experiments suggest early remote-forced upwelling in this area resulting from Kelvin waves originating in the Bay of Bengal (McCreary *et al.*, 1993).

During the NE monsoon, there is a poleward surface coastal current along the west coast of India, along a stretch which is 400 km wide near the southern end and approximately 200 m deep, carrying low saline equatorial surface water. This current is driven by a longshore pressure gradient which overwhelms the influence of the winds during the season (Shetye *et. al.*, 1991). Part of the driving force for these currents also comes from the Kelvin waves triggered by the collapse of the winds along the east coast of India as the SW monsoon withdraws and the NE monsoon sets in.

Convergence zone

The existence of convergence zone in the SE and NE Arabian Sea is evident from the horizontal salinity gradients observed during the period from January to March (Figs. 1 to 3). In 1973, salinity gradients indicated a zone of convergence between the Calicut section in the south and the Kasaragod section in the north, a distance of 150 km (Pillai, 1982; Fig. 1). In 1974, the sea surface salinity increased from 33 ppt to 35 ppt from the Karwar section in the south to the Ratnagiri section in the north, suggesting the existence of a convergence zone over a distance of 220 km. This salinity difference was less pronounced in 1975.

The variations in the sea surface salinity suggest that the convergence zone exhibits seasonal variations, spreading northwards with the intensity of the northward flow, which carries equatorial waters towards the northern latitudes (Darbyshire, 1967). During the southwest monsoon season, the salinity distribution at the surface level is not indicative of the convergence zone, mainly due to the effect of rainfall and river runoff.

Temperature

The monthly mean sea surface temperature in the southeastern and the central eastern Arabian Sea (1973 to 1978) shows large variations in space and time (Table 2; Pillai, 1982). In general, the sea surface temperature is comparatively low during January and February and from July to October (the lowest of 21.1°C in August off Cape Comorin in the southern tip of India) while it is relatively high along the different sections during May (the maximum of 30.2° C off Karwar on the middle of the southwest coast of India). The high values are associated with the summer season, just prior to the onset of the southwest monsoon. A steady increase in the highest monthly mean temperature (1973 to 1978) from the south to the north is noticed between Cape Comorin and Karwar (28.7°C to 30.2°C). The low values are noticed during January and February and during the peak upwelling season (July

to October). The lowest values are observed in those areas where the intensity of upwelling is comparatively high (between Cape Comorin and Kasaragod).

The mean depth of the top of the thermocline reveals large variations from season to season (Table 3; Pillai, 1982). The top of the thermocline is the deepest during the period from December to February and the top reaches the surface layers during June to September (south of Cochin on the southwest coast of India) and October-November (north of Cochin). Off Tuticorin in the Gulf of Mannar on the southeast coast (immediately contiguous to the southwest coast), the vertical oscillation of the top of thermocline ranges from 32 m (June to September) to 78 m (December to February).

Off the southwest coast of Africa, the thermocline, in general, is shallow during the summer, deep during the spring and deepest during the winter (Duncun, 1964). The vertical time sections of seawater temperature for the sections representing the southwest tip of India (Cape Comorin and Quilon; Fig. 4), the central southwest coast of India (Cochin and Kasaragod; Fig. 5) and the northern southwest coast of India (Karwar and Ratnagiri; Fig. 6) clearly bring out the variations in the vertical movement of the various isotherms in space and time. The net vertical movement has been estimated from the oscillations of the 23°C isotherm, which exhibits the maximum movement on the vertical plane (Table 4). A comparison of the mean upward movement of the isotherm (1973 to 1978) indicates the maximum (110 m) off Quilon and minimum (79 m) off Cape Comorin. In certain years (e.g., 1977 July), the isotherm reaches the very surface off Quilon as well as Cape Comorin (Pillai, 1982; Figs 4 to 11)).

Salinity

The monthly mean sea surface salinity (1973 to 1978) in the southeastern and the central eastern Arabian Sea indicates two peaks, one during May-June before the onset of the southwest monsoon and another during September-October immediately after the southwest monsoon (Table 5; Pillai, 1982). The lowest values are associated with the monsoon rains and river run-off, which show a lot of variations from one area to another in different years. The monthly mean surface salinity varies from 32.5 ppt to 36.1 ppt. The salinity maximum characteristic of the tropical oceans is found at depths of 100 m to 150 m during the northeast monsoon and 30 m to 50 m during the southwest monsoon. The variations in salinity are characteristic of the surface layers above the salinity maximum layer. The surface salinity is the highest at the Karwar and Ratnagiri sections during May/June (35.6 ppt to 36.1 ppt). Comparatively low saline waters (33.0 ppt) occupy the surface at Cape Comorin in December when the equatorial surface waters advect northwards (Figs 1 to 3). The lowering of salinity during December and January in the Palk Bay and the Gulf of Mannar is attributed to the southerly current along the east coast of India. During these months, the surface salinity increases steadily from 33.0 ppt off Cape Comorin to 35.1 ppt off Karwar and Ratnagiri. The maxima, occurring comparatively late in the southern sections, are associated mainly with the advection of the high saline Arabian Sea water in the southerly flow and the presence of high salinity bottom water brought upward to the surface layer in the

areas where upwelling is active. The minima occur first in the southern region and progressively move northwards following the trends in the monsoon rainfall and the development of the northerly flow (Pillai, 1982).

In general, the sections north of Kasaragod exhibit comparatively higher salinity conditions than the southern sections. At greater depths between 100 m and 500 m, there is a decreasing trend in the salinity values, north to south. In the sections off Quilon and Cape Comorin, this feature is observed as a salinity maximum at the depth of the thermocline. Here, the northern Arabian Sea corresponds to the subtropical zone of high salinity. The salinity maximum at the depth of the thermocline represents an intrusion of high saline water from the subtropical high salinity zone towards the equatorial zone below the less saline surface layer. It is quite likely that the comparatively high saline north Arabian Sea waters are spreading southwards slowly losing their high saline characteristics. This is in agreement with the general circulation in the upper layers in the tropical and subtropical waters. The salinity maximum associated with the main thermocline probably represents an intrusion of high saline waters below the less saline surface layers towards the equator.

Dissolved oxygen

The major disadvantage of the landlocked condition of the northern Indian Ocean and its separation from the cold climate regions is that the subsurface watermasses of the two northern bays could not be replenished with the oxygen rich deep circulation originating from the Arctic Seas, unlike in the Pacific and the Atlantic Oceans. Instead, the oxygen deficient high salinity surface waters of the Red Sea and the Persian Gulf sinking to the bottom, enter the northern Arabian Sea in the winter at a depth of 800 m and 300 m through the Gulf of Aden and the Gulf of Oman, respectively. These two watermasses together with the high salinity subsurface watermasses of the Arabian Sea that have sunk to about the upper level of the thermocline around 100 m at a temperature gradient of 22° to 26°C consequent upon intense summer evaporation, constitute what is termed the North Indian High Salinity Oxygen Minimum Intermediate Water (NIHSOMIW). With an almost uniform salinity vertically, the NIHSOMIW occupies a depth range of about 100 m to 300 m from the surface to about 1200 m in the entire monsoon gyre down to 10°S latitude.

Explorations by ORV *Sagar Kanya* along the west of 60°E meridian between the 4°N and 6°S latitudes indicated considerable difference in the dissolved oxygen content in the upper 200 m. Warm and nutrient rich water with low oxygen occurs along the 60°E meridian in contrast to the cool and relatively nutrient deficient water with high oxygen to the west of it; in addition, warm waters with high nutrients and low DO occur in the north and relatively cold water with low nutrients and high DO occur in the south. The Arabian Sea component of the NIHSOMIW (with subsurface salinity maximum in the upper thermocline) first turns south and then east with the SW monsoon surface current, penetrating the region south of Sri Lanka and flowing eastwards across the entire width of the ocean, ultimately spreading through the entire monsoon gyre north of 10°S. The Red Sea and the

Persian Gulf components of the NIHSOMIW, spreading east with the SW monsoon surface current, fill the entire Bay of Bengal including the region west of Sumatra below a depth of 300 m (Wyrtki, 1973). The northern Indian Ocean has been recognised as the largest region with the lowest oxygen concentration in the entire open world oceans (Dietrich, 1973).

It is remarkable that the lower and the upper depth limits of the shallow water and deep water fish concentrations are outside the depth ranges (300 m to 1200 m) of the oxygen minimum layers in the Gulf of Oman and off the Somali coast. Both these areas are located within or very close to the major upwelling zones, where, however, the pelagic fishery stocks are far less than the expected levels for the levels of primary production taking place there. Most of the primary production is lost to the bottom in the form of dead organic matter, which through particulate feeders, support the substantial deepsea mesopelagic fishery resources.

The dissolved oxygen content of the surface layers of the SE and central eastern Arabian Sea shows large variations in space and time (Pillai, 1994). In most of the sections, a good correlation exists between the thermocline top and the oxycline. By May, the oxygen deficient waters begin to penetrate the shelf slowly. The upward tilting of the isolines of oxygen and the relative position of the oxycline are indicated in the vertical time sections for the southern region (Quilon; Fig. 12) and the central/northern region (Karwar; Fig. 13) of the southwest coast of India. By June-July, the oxygen deficient waters penetrate below the thermocline and cover the entire bottom of the shelf. In August, the oxycline becomes very shallow and in the areas of upwelling the low oxygen intermediate water reaches the very surface. The oxygen deficient water remains on the shelf until October, especially in the areas where upwelling is intense. By December, once again, the shelf waters become well aerated. The mean monthly sea surface values (1972 to 1978) range from 5.35 ml 0_2 to 1.10 ml 0_2 per liter (Table 6). Off the shelf, there is a well developed oxycline which is found approximately at the same depth as the thermocline. Below the oxycline, in general, the oxygen concentrations are higher in the southern sections than in the northern sections. Off Ratnagiri, the oxygen depleted intermediate waters reach the surface levels. In general, the concentration of dissolved oxygen at the surface levels during the upwelling season increases towards the northern sections corresponding to the decrease in the intensity of upwelling beyond Karwar. The period when the oxygen deficient waters remain in the continental shelf is longer in the northern region off Karwar than in the southern region. Off Karwar, the period is nearly 6 months compared to nearly 2 months off Quilon.

Vertical mixing processes: upwelling, sinking and their impacts on the Malabar upwelling system (southwest coast of India)

Upwellings are of great significance to biological productivity because of the high fertility they cause in the euphotic zone. Coastal upwellings occur mostly along the western coasts of the continents as exemplified by the coasts of Peru, California, northwest and southwest Africa, west coast of India etc. Exceptions to this pattern are found along the northeastern African coast, Somali coast, east coast of Arabia,

east coast of India etc. Localised upwellings are found around the areas of divergences. Whereever upwelling is influenced by the monsoon wind system and accompanying currents, the phenomenon is more seasonal. In the coastal upwelling areas, sediments rich in organic matter are found. Attempts have also been made to chart the upwelling areas by mapping phosphatic deposits (Dragesund, 1970). The economic benefits of upwelling are mainly due to the large concentrations of commercially important fishes in these areas. Most of these resources consist of clupeoid fishes with short food chains and their predators like the tunas.

The best example of a highly productive upwelling area is the coast of Peru with its huge catches of anchovies. Other important productive upwelling areas are the southwest African coast with its rich fisheries for the pilchard and the Californian coast with its sardines. The major pelagic fishery resources of India like the Indian oil sardine, the Indian mackerel and the whitebaits inhabit the SW and SE coasts where regular seasonal upwelling is prevalent. It is estimated that the upwelling areas of the world constitute only a little over 0.1% of the ocean surface, but contribute about half of the world's fish supply.

Upwelling occurs in varying intensities along the west and east coasts of India, corresponding with the SW monsoon. The onset of the SW monsoon generates the Somali current, resulting in a general clockwise circulation in the Arabian Sea, which in turn develops into a relatively strong southerly current along the west coast of India. The comparatively cold, low-oxygenated and denser water from the subsurface is slowly brought upwards along the continental shelf, very near the coast. The depth at which the upward sloping motion of the subsurface watermass begins is dependent on the velocity, direction and duration of the prevailing wind system in a specific area, the bottom topography, the prevailing current system at the surface and the vertical stability of the water column. The speed of the ascending motion would also depend on the continuance of the favourable factors with more or less the same intensity. Along the west coast, upwelling sets earlier in the south and progressively shifts to the north. The process commences in the deeper waters as early as February and the effect reaches the coastal surface waters by May (Banse, 1968; Sharma, 1968) to July and continues through August to early September in the south and October in the north. The strong southerly flow with the coast on the left side induces the upward motion of the subsurface water near the coast. The winds, blowing with the northerly component parallel to the coast till April, help the process to intensify. The thermocline climbs up during the upwelling season and reaches the surface in June or July. There is no system of wind generated upwelling during the SW monsoon period along the west coast of India, where the dense bottom waters approach the surface because of the immediate interplay of the current with the tilting of the sea surface and thermocline (Darbyshire, 1967). Upwelling occurring around the Lakshadweep islands during November/December is attributed to the divergence of current systems in the vicinity of the islands (Rao and Jayaraman, 1966; Pillai and Perumal, 1975). Off Cochin, upwelling starts by mid August, establishes by late September and ends by mid October (Ramamirtham and Jayaraman, 1960). However, none of these processes may be directly applicable to the SW coast of India as a whole (Pillai, 1982).

Along the east coast of India, prior to the commencement of the SW monsoon (April), the southerly winds blow parallel to the coast. The coastal currents, flowing northerly throughout the coast are favourable to the development of upwelling along the east coast. In the northern hemisphere, a wind blowing parallel to the sea coast with the coastline to its left, or an offshore wind, will favour the process of upwelling. The prevailing current system and not the wind is regarded as the main cause generating and maintaining upwelling (Banse, 1968). Even if a uniform current velocity is considered all along the coast, the rise of dense, deep water will be stronger in the north farther away from the equator.

The peak in the zooplankton biomass normally follows the peak periods of upwelling along the SW coast of India (Fig. 14 to 19). The time lag is dependent on the incoming radiation and the inorganic nutrients in the upwelled waters to promote phytoplankton production. The time lag increases when the monsoon rains continue with a cloudy sky, thereby reducing the incoming solar radiation, while the nutrient content would depend on the depth from which the upwelled water originates and the time taken by the watermass to reach the surface. This interval varies from year to year and also from place to place (Pillai, 1982). The zooplankton biomass in the Cochin section is at its maximum during July-August and minimum during November and March (1976 to 1978). It is comparatively high in the areas of intense upwelling, as for example, in the sector between Kasaragod and Karwar. That the biomass in this sector during July-August, 1978 was two times higher than that during July-August, 1977, suggests considerable annual variations. In the Quilon and Cape Comorin sections however, the plankton biomass does not indicate a proportionate increase with the high intensity of upwelling during 1977 (Figs 14 & 15). The sea bottom of the narrow continental shelf between Quilon and Cape Comorin is mostly rocky, in contrast to the region north of Quilon where it is mostly muddy. During upwelling, the oxygen minimum layer (0.5 ml/l) emerges from 100 m to 150 m depth to the surface, especially in the areas between Quilon and Kasaragod. As a result, some fish populations move into the shallow surface waters while the others move offshore, away from the centre of strong upwelling. At times, the rate of upwelling suddenly intensifies, slowing down the replenishment of oxygen through surface aeration and wind mixing. Bulk of the pelagic populations comprising the Indian mackerel, oil sardine and whitebaits avoid temporarily the areas of intense upwelling and tend to concentrate into dense schools close to the surface and the coast in the nearshore grounds, affording good catches.

Sinking is characterised by the downward movement of comparatively denser surface layer. Winter cooling and surface evaporation increase the density of the surface layers, thereby promoting sinking. Converging current systems also facilitate sinking, provided there is appreciable difference in the density characteristics of the two current systems. Sinking brings the well aerated surface waters to the bottom, as a result of which, the pelagic fish populations disperse over a vast area of the shelf. Along the SW coast of India, sinking of the offshore waters (coastal convergence) occurs over the shelf from September to January and a well defined isothermal layer of about 75 m to 100 m thickness is present along the west coast (Ramamirtham and Jayaraman, 1960; Sharma, 1966; Pillai, 1982). Sinking is

active along the entire SW coast between Cape Comorin and Ratnagiri between September and February, starting much earlier in the south from Cape Comorin to Quilon; it begins during September along the Cochin to Kasaragod sector and October or November further north from Karwar to Ratnagiri; comes to an end earlier (January) in the south and later in the north (March) of the SW coast. Sinking is closely associated with the cessation of upwelling, and more or less follows the same trend from south to north along the SW coast. The vertical oscillation of the 23°C isotherm which shows the maximum movement on the vertical plane is taken as an indicator of the process of sinking. An approximate estimation of the velocity of sinking at the various sections (1974) indicates that the velocities range from 79 cm to 139.5 cm/day. The maximum velocity of 139.5 cm/day is observed off Kasaragod and the minimum of 79 cm/day off Ratnagiri. As in the case of upwelling, the sinking velocities also show large variations from year to year and also from one area to another (Table 7; Fig.20; Pillai, 1982).

The period of peak sinking activity along the SW coast (October to March) coincides with the peak fishing season for the oil sardine and mackerel fisheries. The warming of the upwelled cooler surface layer by the northerly warm equatorial current provides the conditions necessary for the small pelagic fisheries during peak sinking (October to February). In December, the surface isothermal layer resulting from sinking (convergence) in the shelf is about 75 m to 100 m thick along the west coast of India (Ramamirtham and Jayaraman, 1960). Convergence facilitates the concentration of zooplankton, which in turn results in the formation of dense schools of the small pelagics such as the oil sardine, mackerel and whitebaits which feed predominantly on the zooplankton (Hela and Laevastu, 1970; Noble, 1972). The northerly migration of the whitebaits starts from the central Gulf of Mannar by early November. The dissolved oxygen concentration is comparatively high in the northerly current of the postmonsoon season (October-November) along the SW coast. The gradual rise in the sea surface temperature coupled with higher DO concentration during this season enriches zooplankton production, followed by proportionately high whitebait biomass. By December, the whitebaits spread almost all along the SW coast between Tuticorin in the Gulf of Mannar and Ratnagiri on the northern tip of the SW coast (Arabian Sea). During the southward and northward migrations of the whitebaits, the respective surface currents prevailing during these migrations favour the passive transport (floating and drifting). The rich phytoplankton and zooplankton biomass during the sinking season provides them the required food. The catches of the oil sardine and mackerel are maximum during sinking in the winter season when the northerly drift prevails along the SW coast.

Along the west coast of India, the phytoplankton bloom is rich during the SW monsoon off the Trivandrum coast from January onwards and reaches the peak in May, but further north, off Calicut and northwards, the peak is attained in July-August, thereby indicating the commencement of upwelling in the subsurface layer much earlier, even when the current is northerly along the west coast; from September onwards, the phytoplankton bloom vanishes, indicating the cessation of upwelling from thereon (Subramonyan, 1973).

The average primary productivity of the west coast of India, within the surface and 50 m depth in terms of carbon production beneath a square meter of the sea surface is 1.19 gC/m ^{2}/day (Nair *et al.*, 1973; Table 8). This is equivalent to an annual gross production of 434 gC/m^2/year which is quite high compared to several other areas of the world (Table 9). The productivity is higher along the coast than along the edge of the shelf and the least outside the shelf. In the shelf area beyond the 50 m isobath, the mean primary production is only 0.43 gC/m^2/day, which indicates an annual net production of only 25 gC/m^2/year. Based on these values, it was estimated that 1 200 000 mt of fish could be harvested from the area within the 50 m isobath of the west coast (Nair *et al.*, 1973). This figure is about the same as the present annual yield of 1.2 million mt from the west coast. The primary production in the different states and depth zones of the southeastern Arabian Sea area (Nair *et al.*, 1973) is furnished in Table 10.

In the main upwelling area of the west coast, between Kasaragod and Quilon, the peak of zooplankton occurs in July-August with another peak from October to December. The latter period is also the peak for the northern region between Karwar and Ratnagiri. In the Gulf of Mannar, the highest zooplankton production occurs in July and again in November-December. There is good correlation between upwelling (evident from the upward movement of the 23°C isotherm and the 1 ml/l O_2 isoline) and zooplankton biomass at Cape Comorin (1973 to 1975), Quilon (1973 to 1975), Cochin (1973 to 1978), Kasaragod (1973-1975), Karwar (1973 to 1975) and Ratnagiri (1973 to 1975) (Figs 14 to 19; Pillai, 1982). The ichthyoplankton is abundant between May and September, with peak in July to September, moderate abundance in October and November and low adundance during December to April. The sardine larvae are found all year round, but mostly between June and August. The main spawning ground is located between the 8° and 10° 30'N latitudes in the middle and outer shelf in a 10 to 15 nautical miles band, 20 nautical miles offshore (40 m to 80 m). Moderate spawning activity of sardines takes place south of Quilon on the southwest coast and the southeast coast off Tuticorin in the Gulf of Mannar. The Indian mackerel seem to have an extended spawning season than the oil sardine. High density of mackerel larvae is found in April, July, August and November, but neither eggs nor larvae are found in January, March and December. The main spawning ground is believed to be between 8° and 15°N latitudes in a 10 nautical miles belt (mostly between 55 m and 100 m depths), with most of the larvae occurring off Cochin and Karwar. The major part of the whitebait ichthyoplankton is found between April and August in the surface waters above the depth of 20 m to 60 m. Peak spawning occurs in the central area between Quilon and Kasaragod (7° 30' to 11°N) during May to July and in the south between Quilon and Cape Comorin during October-November.

The average zooplankton biomass in the midshelf for the southeastern Arabian Sea (Table 11 for 1971 to 1978) and the abundance of zooplankton along the southwest coast during the monsoon period (for 1971 to 1975) indicate a recurring pattern in the zooplankton distribution and abundance in the shelf waters. In general, the period from July to September is found to be the peak season for plankton production, with a fairly uniform concentration of plankton beyond the nearshore waters all along the coast. Thereafter until December, a shoreward shift

in the concentration is evident, especially in the south. At the same time, the continuous distribution breaks up, becomes patchy and the overall abundance is greatly reduced to the lowest level in January and February. The biological cycle is clearly influenced by the process of upwelling especially in the central and southern region (Figs. 21 to 23). Studies made onboard FORV *Sagar Sampada* during the period 1984 to 1994 also confirm the above findings.

There have been attempts in the past to correlate the oil sardine and mackerel fisheries with rainfall. Normally, bulk of the oil sardine catch is landed following the period of heavy rainfall during the SW monsoon season. However, the oil sardine catch at Ullal near Mangalore in the SW coast was found to be the lowest (52 mt) during 1963-64 when rainfall was the heaviest (306.5 cm). The catches were better during 1965-66 and 1966-67 (283.7 mt and 385.6 mt, respectively) when the annual rainfall was comparatively low (274.1 cm and 283.6 cm, respectively). An inverse relation exists between the annual rainfall and the mackerel catches off Calicut on the SW coast (Pradhan and Reddy, 1962). High temperature and salinity affect the mackerel fishery adversely. The mackerel season in the north Kanara district on the SW coast coincides with the transition from the low salinity and temperature conditions of the SW monsoon to the high salinity and warmer conditions of the summer (Ramamurthy, 1965).

Sea level can be an indicator of upwelling (Longhurst and Wooster, 1990). The variations in the oil sardine abundance relate well with sea level, which is a good index of upwelling at Cochin while the monsoon rainfall is a good indicator of recruitment success. The invasion of the continental shelf by the oceanic oxygen poor waters during the Malabar upwelling tends to exclude the oil sardine stock from the coastal waters where the plankton blooms are most intense. Therefore, unlike that of the Indian mackerel, the spawning strategy of the Indian oil sardine places its recruitment at risk as evident from the statistical relationship between sardine recruitment failure and unusually early, remotely forced upwelling. The abundance of the oil sardine along the Malabar coast (Indian SW coast) is highly variable in the decadal scale. The 0-year group recruitment into the fishery begins towards the end of the summer monsoon (SW monsoon) when the sea level indicates remotely forced upwelling (caused by the geostrophic upsloping of the isopleths towards the coast) rather than the wind driven upwelling that occurs during the monsoon. Unusually early remote forcing appears to inhibit subsequent recruitment, perhaps through the exclusion of the spawning fish from the neritic zone by the oxygen deficient upwelled water (Longhurst and Wooster, 1990). The oil sardine and the Indian mackerel synchronise their spawning with the productive conditions of the SW monsoon seasons (Madhupratap *et al.*, 1994). Sea level anomaly shows that the levels have been low during 1940 to 1947, high during 1948 to 1957, higher during 1958 to 1964 and fluctuating thereafter. By comparison, the sardine catches have been found to be poor during 1941 to 1949 (<5 000 mt per year), moderate during 1950 to 1956 and high from 1957 onwards. Between 1900 and 1940, the oil sardine catches have been generally low, whereas the Indian mackerel fishery has had very poor seasons. There was no correlation between the sea level and the oil sardine or Indian mackerel landings during 1960 to 1990. In 1963, for example, when the oil sardine catches fell below 100 000 mt, the sea level in April,

1962-63 was not low. The very low oil sardine landings in the 1940s and the earlier years seem to have been caused by a combination of factors while the increase in the recent years could be due to mechanised fishing and the use of synthetic gear material. The argument that the late arrival of the SW monsoon causes low oil sardine catches does not appear tenable. Years with very less rainfall in the recent past (1965, 1966, 1972, 1979, 1982, 1985, 1987) also did not particularly affect the oil sardine fishery (Madhupratap *et al.*, 1994). The presence of a correlation does not imply cause and effect. The correlation holds good for a few years and then breaks down.

Three factors seem to dominate the processes controlling the oil sardine and other major fisheries in the SW coast of India (Madhupratap *et al.*, 1994):

(i) Wind driven upwelling, which is an annual feature, brings up not only the nutrients to the euphotic zone triggering the production of plankton, it also upslopes the cool low oxygen layer towards the surface and coast, forcing the fish stocks into the thin oxygen rich surface layer close to the SW coast.

(ii) Early remote forced upwelling during February to May (much before the wind-induced upwelling) is caused by the effect of the Coriolis force on the Gulf of Aden-Gulf of Oman surface watermass of low oxygen. This watermass sinks and pervades throughout the northern Indian Ocean, north of 10°S latitude. The emergence of this watermass towards the sea surface causes the early appearance of the stocks in the surface layer, and any interannual variability pattern in the upwelling will reflect in the movement and abundance of the stocks.

(iii) River runoff contributes, through the enrichment of the coastal waters and the microbial loop, to the development of high zooplankton populations.

Once the monsoon and upwelling progress northward during June to September, the stocks of larvae and juveniles benefit significantly from the rich plankton, and hence, any mismatch between the time of spawning and the peak plankton production (through a break in the monsoon and upwelling) could be detrimental to recruitment. Studies undertaken onboard FORV *Sagar Sampada* during the peak of the SW monsoon in July, 1991 and July, 1992 confirm that upwelling can be positive or negative depending on the nutrient level, which determines the magnitude of plankton productivity (Pillai, 1994). The plankton blooms occur after a certain duration from the time of upwelling away from the areas occupied by the upwelled water due to the following factors (Pillai, 1994):

(a) Quantum of inorganic nutrients in the upwelled water: Nutrients, especially phosphates, determine chlorophyll production, and hence, even in areas with cloud-free skies, upwelling may not result in a high enough phytoplankton production without adequate quantity of nutrients. Nutrients in the upwelled water depend on the origin and velocity of upwelling, i.e., the time taken by the upwelled water to reach the surface layer from the depths it originates as evident from the observations made for Quilon and Cape Comorin sections (in 1977) where inspite of higher upwelling velocities, the zooplankton biomass does not indicate a proportionate

increase during the months following peak upwelling, due to the shallow shelf of mostly rocks. This is in sharp contrast to the conditions in the Cochin and Kasaragod sections which indicate proportionate increase in the zooplankton biomass, following the peak upwelling season, due to the deeper and muddy shelf (Figs 14 to 19). Cochin shelf does not reveal a monsoon maximum for chlorophyll-a in certain seasons due to the late onset or scanty monsoon and exhibits positive correlation of phosphates with chlrophyll-a as seen in 1987 and 1988 (Balachandran *et al.*,1989).

(b) Incoming radiation: Since upwelling along the SW coast of India synchronises with the cloudy SW monsoon, sufficient light does not reach the sea surface to promote photosynthetic activity.

(c) Velocity of surface currents: Very often higher zooplankton biomass is observed away from the point where the upwelled water reaches the surface layer, and the biomass varies from year to year as the upwelled water is carried away by the wind induced surface currents, which show minor changes in their velocity directions, both in space and time (Pillai, 1994).

The wind driven offshore transport off Cape Comorin at the southern extremity of India reveals that the strong westerly monsoon winds are tangential to the land mass and drive a very strong offshore Ekmann transport. This strong upwelling signal would tend to propagate northwards along the Indian coast through the coastally trapped wave mechanism. In such a case, while seeking an index of inter-annual variability in upwelling in this area, one should perhaps look at the coastal upwelling index off Cape Comorin (Bakun, 1993). The seasonal upwelling effects along the southwest coast of India are a propagated response to the wind driven offshore Ekmann transport occurring some distance to the south off Cape Comorin. In such a case, fish are benefitting from an upwelling cycle that peaks in June. This propagating upwelling signal continues to be substantial from July through October (Bakun, 1993). This also happens to be the period of the year when spawning activity of the Indian oil sardine is most prevalent (Longhurst and Wooster, 1990).

The turbulent mixing index near Cape Comorin, where this upwelling would have its wind generated origin, is substantial during most of this period. By the time the Somali current reaches the southwest coast of India, the flow is much less intense and has developed a more diffuse, meandering tendency (Wyrtki, 1971) characteristic of the eastern ocean coastal upwelling systems. Thus, the Indian oil sardine which support the Western Indian Ocean's one of the largest pelagic fisheries, spawn in relatively mild offshore transport and wind driven turbulence regimes of a tropical coastal upwelling system. Such spawning during the upwelling seasons is a recurrent pattern noted in other eastern ocean, low latitude pelagic fish stocks (Roy *et al.*, 1992).

Upwellings in other regions of Indian Ocean

(i) *Somali coastal upwelling*: This appears by far the most intense seasonal scale upwelling occurring in the world. The wind induced upwelling component during June to August appears to be far stronger than what occurs in the most intense upwelling zones (Bakun, 1993). The driving force behind this exceptional upwelling is a tropospheric wind current called "Findlater Jet", which extends northwestward from the coast of Somalia cutting diagonally across the Arabian Sea.

(ii) *Upwelling off Oman*: The extension of the "Findlater Jet" into the northern part of the Arabian Sea influences the coastal region of the Arabian peninsula off Oman. Eventhough the mean position of the axis of the Jet is located about 500 km off the Oman coast, substantial wind levels associated with the feature do extend to the continental boundary where they produce very high offshore Ekmann transport and associated coastal upwelling.

(iii) *Coastal upwelling within the Gulf of Aden*: Inside the Gulf of Aden, the wind is easterly for most of the year producing offshore Ekmann transport favourable for coastal upwelling off the southern coast of the gulf. However, during the SW monsoon, with the prevailing southwesterlies, the wind driven Ekmann transport is directed towards the southern coast during June, July and August.

(iv) *Upwelling off Madagascar*: The coastal upwelling that may occur off southern Madagascar is apparently accompanied by quite high levels of wind induced turbulent mixing. Off the southern coast of the island, the easterly trade winds produce offshore Ekmann transport throughout the year with a peak in late winter.

(v) *Upwelling off Tanzania and northern Mozambique*: The large coastal area off the Sofala Bank of Mozambique looks most promising as a reproductive habitat for small pelagic fishes. Since this area is a coastal bight located downstream of a zone of wind driven offshore transport of surface waters, it has many characteristics of the most common type of sardine spawning habitat. In this area, the coastal topography shelters the interior of the bight from strong wind induced mixing and the enclosed gyral circulation helps to retain the pelagic eggs and larvae.

In fact, the configuration of the Sofala Bight is very similar to that of the southeastern Brazilian Bight of the eastern tropical south America which has supported a major sardine fishery for many years. The annual sardine landings initially grew rapidly to a peak of 228 000 mt in 1973 and then declined to a level of 120 000 mt to 140 000 mt (Saccardo, 1983), which was maintained till 1986. The major differences are that in the Brazilian case, there is a definite local upwelling centre where the surface characteristics of an upwelling zone are clearly apparent just upstream (equatorward) of the bight. Even so, the seasonal cycles of chlorophyll look rather similar with two bight areas. This leads one at least to suspect that a significant small pelagic fish component could find acceptable spawning habitat within the Sofala Bight, perhaps in waters too shallow for detection by large acoustic survey vessels. Further south, in the Maputo Bay along

the Natal coast, the characteristic wind mixing values rising to well above 250 m^3 S^3 appears to favour successful spawning of substantial coastal pelagic populations.

NORTHWEST PACIFIC OCEAN

The northwest Pacific Ocean is a region where intensive efforts have been made to relate the environmental factors and the variations in fisheries, especially to find out the causes for the rises and collapses of the Japanese sardine. The continental shelf around Japan is narrow except in the West China Sea and hence, the abundance of demersal fishes is rather small. On the contrary, pelagic fishes are abundant due to the oceanographic conditions. The Kuroshio warm current approaches Japan from the south and flows eastward along the southern coast of Japan and meets the Oyashio current which comes down from the north. Frontal zones and mixing zones are formed in the areas where the currents meet. It is becoming increasingly clear that the pelagic fish stocks are variable depending on the changes in the oceanographic conditions. Particularly, successes or failures of recruitment due to changes in the oceanographic factors determine variations in the entire stock (Tanaka, 1983).

The important pelagic species such as the Japanese sardine, anchovy, round herring, mackerels and saury are plankton feeders and are under the influence of the Kuroshio current. These warm water fishes generally spawn in coastal waters inside the Kuroshio current off southwestern Japan in winter and spring. Larval fish are transported eastward or northward by the Kuroshio current and feed on abundant food and grow rapidly in the coastal waters of northern Japan or in frontal or mixing zones in the offshore waters in summer and autumn. Depending on the presence or absence of the cold watermass in the Pacific off central or western Japan, the Kuroshio often changes its route. The change in route is a turning point on the distribution and movement of fish shoals and mortality in early life stages which cause changes in stock size (Watanabe, 1982). For the sharp decline in the sardine stock in the 1940s, Nakai (1949) explained that the Kuroshio began meandering in and after 1934, and left the coast in the middle of the 1940s, reaching southward following the appearance of a large cold watermass which changed the normal route of the Kuroshio. This resulted in the drifting of the larvae from the main spawning ground to far offshore waters which was unfavourable for the larvae. The larvae were reported to die of starvation, causing severe reduction in recruitment. The major reason for the spurt in the landings in the 1980s was due to very successful spawning by the Ashizuri subpopulation of the sardine which as a result migrated into the Japanese waters in substantial numbers. The spawning ground extended to a very vast area during those years. The meandering of the Kuroshio disappeared in the southwestern region and the eggs and larvae were entrained favourably in a counterclockwise direction into the Kuroshio current leading to recruitment success.(Matsushita *et al.*, 1989) considered that the recruitment potential of pelagic fish is significantly influenced by inshore-offshore dispersal. As the pelagic eggs and larvae have limited motility, their fate is influenced by the physical movement of water. If the drift is towards a favourable area, recruitment becomes successful. From the repeated studies on the Japanese sardine, the following dispersal patterns of eggs and larvae, which determine the

status of the stock, are discernable: (i) If spawning occurs in the coastal waters, the survival of the larvae is better and a significant stock size ensured. (ii) If spawning occurs in the upstream regions of the Kuroshio current, the larvae are transported and dispersed widely, which is an adaptation for the expansion of the stock. In other words, the shift of the main spawning grounds to the upstream regions of the Kuroshio could be beneficial in increasing the stock. (iii) On the other hand, if the current is not favourable, the eggs and larvae spawned in the coastal waters could be shifted to unfavourable offshore areas leading to a decrease in the stock.

Kondon (1988) proposed a theory that the dominant yearclass of sardine is formed only when three conditions, (i) the spawning frequency of adult sardines, (ii) the distribution area of copepod nauplii which form the first bait for the larvae of sardines, and (iii) the change in the path of the Kuroshio current are satisfied concurrently. In other words, the transition of the path of the current from meander to straight runs, or from straight runs to meander are the vital considerations.

The changes in the direction and meander of the Kuroshio current and the consequent change in the stock of the sardines are largely influenced by the environmental changes affecting the Pacific Ocean or the global environmental changes in general. The changes in the stock of the sardines are analogous, in phase, with those of the stocks of the far eastern sardines, i.e., the Californian sardines and the Chilean sardines (Kawasaki, 1982). Significant correlations between the Japanese, Californian, northwest Atlantic and Humboldt systems support the hypothesis that the sardines in these regions are influenced simultaneously by trans-oceanic climatic linkages operating on a wider scale (Crawford *et al.,* 1989). The transpacific linkages were less apparent for the chub mackerels and the anchovies, indicating that the sardines are the most susceptible to global climatic changes. An explanation with some empirical support is that the changes in the sea temperature, possibly influenced by solar radiation and air temperature, cause large changes in the extent of the habitat suitable for the sardines. Kawasaki and Omori (1988) suggested that the variations in the solar radiation lead to variations in primary production, and therefore, in the availability of suitable food items to the sardines. Crawford, *et al.* (1989) observed that solar radiation was positively related to air temperature two years later and the air temperature in turn was related to the SST of the same year in the north Atlantic, and to the SST of two years earlier in the north Pacific. The two year lag between influences of solar radiation on the north Pacific and north Atlantic Oceans is of interest in that it reflects the similar significant lag between the catches of sardine off Japan and England.

DISCUSSION

Comparative studies of fish reproductive habitats have tended to identify a fundamental "triad" (Bakun, 1996) of 3 major classes of processes that combine to yield favourable reproductive habitats for coastal pelagic fishes: (i) Enrichment (upwelling, mixing etc), (ii) concentration (convergence, frontal formation, water column stability, ergoclines etc), and iii) processes favouring retention within appropriate habitats.

The importance of enrichment processes is quite widely understood as evident from the detailed surveys of the regional upwelling systems, described above. Perhaps less widely appreciated is the importance of the concentration processes. For very small organisms such as the fish larvae and other important components of the planktonic food web, seawater represents a viscous fluid; a major energy expenditure may be necessary just to move from one food particle to another. Thus, large amounts of energy needed for the rapid growth, required for the quick passage through the various size related levels of intense predation that pervade the ocean environment, may be expended in feeding activity. Consequently, the availability of processes, whereby food particles are concentrated tends to be vital. This is probably a major reason why various types of interfaces or ergoclines (Legendre and Demers, 1985) tend to be sites of enhanced biological activity in the ocean. The interfaces tend either to maintain or to be maintained by the mechanisms of concentration (Bakun, 1996). Ocean fronts are obvious examples. An innate attraction to drifting objects serves to position the fish within the zones of enhanced biological activity and correspondingly improved feeding conditions (Bakun, 1993; 1996). Conversely, turbulence is a dispersive process, and so, acts counter to the concentration processes. Thus intense turbulent mixing events have appeared to be detrimental to larval survival by disrupting local food concentrations (Lasker, 1978; 1981a; b; Peterman and Bradford, 1987; Wroblewski and Richmond, 1987).

The third factor in the "triad" is retention. Life cycles of marine organisms tend to include at least one stage of passive larval drift. Thus, in a dispersive fluid medium, the loss of early life stages from the population habitat may represent serious wastage of reproductive resources. Consequently, fish populations tend to spawn in locations and seasons that minimize such losses (Parrish *et al.*, 1981; Sinclair, 1988). Interspection of the optimal environmental window in terms of the "fundamental triad" of enrichment, concentration and retention appears to be straightforward. The control on the "low wind" side can be explained as a lack of sufficient enrichment of the trophic system by either wind induced upwelling or mixing. The control on the "high wind" side could be a combination of the adverse impacts on the retention element of the triad due to the resulting excessive offshore transport and on the concentration element due to intense turbulent mixing which could: (i) disperse the concentration of appropriately sized nutritious food particles; (ii) inhibit basic photosynthetic production by mixing phytoplankton cells beyond their "eutical depth"; and, (iii) impair a larva's ability to physically capture prey. While the fish may feed well as relatively strong swimming filter feeding adults due to the particularly high primary productivity of these systems, survival of their early stages may be severely limited by the other two triad elements (Bakun, 1996).

However, Bakun (1993) noted that there were no known changes in marine climate that corresponded with the biological record. He concluded that the environmental changes could have influenced directly the very large fluctuations in the sardine stocks, but might have acted instead on the structure of the ecosystems. As an example of possible ecosystem change influencing sardine abundance, he drew attention to the increased abundance of sardines off Japan in the 1980s coinciding with the collapse of a very large stock of oceanic squids under heavy fishing in the same region. The squids are voracious predators of sardines and their

collapse is not attributed to environmental change. Hence, it may be difficult to assess the climatic impact on the ecosystem as a whole.

REFERENCES

Anon., 1966. Climatological tables of observatories of India. *India Meteorological Dept.*, 1-470.

Bakun, A., 1993. The California current, Benguela current and southwesterm Atlantic ecosystems: A comparative approach to identifying factors regulating biomass yields. In: K. Sharma, L.M. Alexander, and B. Gold, (eds) Large marine ecosystems-stress, mitigation and sustainability, American Assn for the Advancement of Science, Washington, p.199-224.

Bakun, A., 1996. Patterns in the ocean: Ocean processes and marine population dynamics. Univ.California Sea Grant, California, 323 pp.

Balachandran, V.K., M.S. Rajagopalan, and V.K. Pillai, 1989. Chlorophyll-a and phaeo pigment as indices of biological productivity in the inshore waters off Cochin. *Indian J. Fish.*, 30(3):45-79.

Banse, K., 1968. Hydrography of the Arabian sea shelf of India and effects on demersal fishes. *Deepsea Research*, 15(1):45-79.

Crawford. R.J.M., L.G. Undertill, L.V. Shannon, D. Lluchbelda, W.R. Steyfried, and C.A. Villacastiv-Herrero. 1989. An empirical investigation of transoceanic linkages between areas of high abundance of sardine. In: T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguchi (eds). Longterm variability of pelagic fish populations and their environment. *Proc. of International Symposium Sendai, Japan*, Pegamon Press, Oxford, pp. 319-332.

Darbyshire, M., 1967. The surface waters off the coast of Kerala, Southwest India. *J.Mar.Biol.Assn.* U.K., 39: 637-658.

Dietrich, G., 1973. Physikalische and chemische daten nach beobachtungen des forschugschiffes "Meteor" in Indischen Ozean 1964/65.

Dragesund, O., 1970. Factors influencing year class strength of Norwegian spawning herring (*Clupea harengus*. Linn). Fish. Dir. Skr. Ser. Harsunders, 15: 381-450.

Duncun, C.P., 1964. Seasonal occurrence of thermoclines off the southwest cape 1955-1961. *Invest. Rep. Div. Fish. Univ. S.Afri.*, 50: 1-15.

Hela, I., and T. Laevastu, 1970. Fisheries oceanography. Fishing News (Boobs) Ltd., London.

Kawasaki, T., 1982. Problems in evaluating the productivity of fishery resources. *Bull. Jap. Soc. Fish. Ocean.*, 42: 75-77.

Kawasaki, T., and M. Omori. 1988. Fluctuations in the three major sardine stocks in the Pacific and the global trend in temperature. In: T. Wyatt and M.G. Larranata (eds). Longterm changes in marine fish populations. *Inst. de Invest. Marines de vigo*, Vigo, pp 37-53.

Kondon, K., 1988. Grasping the trend of pelagic fish stock - with raw material for the relationship between the longterm change in the stock of sardines and oceanographic conditions. In: Fisheries and research of fisheries and oceanography in the 21st century. Society of Fisheries Oceanography, 178-184.

Lasker, R., 1978. The relation between oceanographic conditions and larval anchovy food in the California current: Identification of the factors leading to recruitment failure. *Rapp. P-V Reun.Cons. Int. Explor. Mer.*, 173:212-230.

Lasker, R., 1981a. Factors contributing to variable recruitment of the northern anchovy (*Engraulis mordax)* in the California current: contrasting years 1975 through 1978. *Rapp.P.-V Reun. Cons.Int. Explor. Mer.*, 178: 375-388.

Lasker, R., 1981b. The role of a stable ocean in larval fish survival and subsequent recruitment. In: R.Lasker (ed) Marine fish larvae: morphology, ecology and relation to fisheries. Univ. Washington Press, Seattle. 131 p.

Legendre, L., and S. Demers, 1985 Auxillary energy, ergoclines and aquatic biological production. Naturaliste can., 112: 5-14.

Longhurst, A.R., and W.S. Wooster, 1990. Abundance of oil sardine (*Sardinella longiceps*) and upwelling on the southwest coast of India. *Can. J.Aquatic Sci.*, 47: 2407-2419.

Madhupratap, M., S.R. Shetye, K.N.V. Nair, and P.S. Nair, 1994. Oil sardine and Indian mackerel: their fishery problems and coastal oceanography. Curr. Sci., 66(5): 340-348.

Matsushita, K., T. Sugimoto, and M. Shimizu, 1989. Possible importance of inshore-offshore physical dispersal for prevailing pelagic fish recruitment potential. In: T. Kawasaki, S. Tanaka, Y. Toba and A. Taniguche (eds). Long term variability of pelagic fish populations and their environment. *Proc. of International Symposium, Sendai, Japan*, Pergamon Press, Oxford, pp. 101-108.

Nair, P.V.R., S. Samuel, K.J. Joseph, and V.K. Balachandran. 1973. Primary production and potential fishery resources in the seas around India. Proc. Symp. on Living resources of the seas around India, *CMFRI Spl. Publ.*, 184-198.

Nakai, Z., 1949. Why cannot the sardine be caught? *Suisan kikan*, 2: 92-101.

Noble, A., 1972. Surfaco temperature and its relation to the duration of mackerel fishery at Karwar. *Indian J.Fish.*, 39(3, 4):119-124.

Parrish, R.H., C.S. Nelson, and A. Bakun.1981. Transport mechanisms and reproductive success of fishes in the California current. *Biol Oceanogr.* ,1: 175-203.

Peterman, R.M., and M.J. Bradford, 1987. Wind speed and mortality rate of a marine fish, the northern anchovy (*Engraulis mordax*). *Science,* 235:354-356.

Pillai, V.N., 1982. Physical characteristics of the coastal waters off the SW coast of India with an attempt to study the possible relationship with sardine, mackerel and anchovy fisheries, Ph.D. thesis, Cochin University, India.

Pillai, V.N., 1994. Possible relationship between the process of upwelling and zooplankton biomass in the shelf waters along the southwest coast of India. *J.Mar. Biol. Assn.India* (in press)

Pillai, V.N., and M.C. Perumal, 1975. A note on tuna fishery around Agatti Island (Lakshadweep) in relation to hydrographic conditions leading to the phenomenon of upwelling. *Curr. Sci.,* 1: 17-18.

Pradhan, L.B., and C.V.G. Reddy, 1962. Fluctuations in mackerel landings at Calicut in relation to hydrographical factors. *Indian J.Fish.*, 9(1): 100-209.

Ramamirtham, C.P., and R. Jayaraman, 1960. Hydrographic features of the continental shelf waters off Cochin during the years 1958 and 1959. *J. Mar.Biol.Assn.India*, 2(2): 199-207.

Ramamurthy, S., 1965. Studies on the plankton of the north Kanara coast in relation to pelagic fishery. *J.Mar.Biol.Assn.India*, 7(1): 127-149.

Rao, L.V.G., and R. Jayaraman, 1966. Upwelling in the Minicoy region of Arabian Sea. *Curr.Sci* 35(15):378-380.

Roy, C., P. Cury, and S. Kifani, 1992. Pelagic fish reproductive stocks and reproductive strategy in upwelling areas: environmental compromises. In: A.I.L. Payne, K.H. Brink, K.H.Manu and R.Hilborn (eds) Benguela trophic functioning. *S.Afr.J.Mar.Sci.*, 12 p.

Saccardo, S.A., 1983. Biologia disparibilidad de sardina (*Sardinella brasiliensis*) en la costa suderte del Brasil. In: G.D.Sharp and J.Csirke (eds) Proceedings of the expert consultation to examine changes in abundance and species composition of neritic fish resources. *FAO Fish. Rep.*, 291: 12-24 p.

Sharma, G.S., 1966. Thermocline as an indicator of upwelling. *J. Mar. Biol. Assn. India*, 8(1):8-19.

Sharma, G.S., 1968. Seasonal variation of some hydrographic properties of the shelf waters off the west coast of India. *Bull. Nat. Inst. Sci.* India, 38: 263-276.

Shetye, S.R., and S.S.C.Shenoi. 1988. Seasonal cycle of surface circulation in the coastal north Indian Oceans. *Proc. Indian Acad. Sci.*, 97:53-62.

Shetye, S.R, A.D. Gouveia, S.S.C. Shenoi, D. Sundar, G.S. Michael, A.M. Almeida, and KJ. Santanam. 1990. Hydrography and circulation off the west coast of India during the southwest monsoon 1987. *J.Mar. Res.*, 48: 359-378.

Shetye, S.R., A.D. Gouveia, S.S.C. Shenoi, G.S. Michael, D. Sundar, A.M. Almeida, and K. Santanam. 1991. *Deep Sea Res.*, 38(12): 1517-1529.

Sinclair, M., 1988. Marine populations. An essay on population regulation and speciation.Washington Sea Grant Program, 252 p.

Subramonyan, R.,1973. Hydrography and plankton as indicators of marine resources. Proc. Symp. on Living resources of the seas around India, *CMFRI .Spl.Publ.*, 101-115.

Tanaka, S., 1983. Variation of pelagic stocks in waters around Japan. *FAO Fish. Rep.*, 91(2): 17-36.

Varadachari, V.V.R., and G.S. Sharma, 1967. Circulation of the waters in the north Indian Ocean. *J.Indian Geophys.*, 4(2):61-73.

Watanabe, T., 1982. Survival of Japanese sardine at early stages of life. *Izv. Tikhookean Nauchno Issled. Inst. Rybn. Khoz. Okeanogr.*, 105:92-107.

Wroblewski, J.J., and J.C. Richmond. 1987. The non-linear response of plankton to wind-mixing events: implications for larval survival of northern anchovy. *J.Plankton Res.*, 9:103-123.

Wyrtki, K., 1971. Oceanographic atlas of the International Indian Ocean Expedition. National Science Foundation, Washington, D.C., 531p.

Wyrtki, K., 1973. Physical oceanography of the Indian Ocean. In: Zeitzschel T.(ed) Biology of the Indian Ocean. Chapman and Hall, London, 18-36p.

Table 1. Major environmental factors influencing fisheries in the APFIC area.

Area	Factors
I. Western Indian Ocean	(i) Tropical monsoon regime; (ii) conspicuous effect of southwest monsoon current (iii) seasonal upwelling and areas of high productivity
II. Eastern Indian Ocean	(i) Tropical monsoon regime; (ii) severe cyclonic weather conditions during northeast monsoon in the northern part; (iii) heavy freshwater runoff in the northern part
1. Western Australian Sea	(i) Seasonal occurrence of southward flow of Leeuwin current along the shelf break; (ii) wind-driven coastal currents reverse direction seasonally
III. Northwest Pacific Ocean	(i) Warm, tropical watermass in the south; cold, subarctic watermass in the north; and convergence of the two in the central part; (ii) formation of numerous eddies
1. Okhotsk Sea	(i) Formation of cold, counterclockwise gyre; (ii)heavy ice cover and vertical mixing in winter
2. Japan Sea	(i) Formation of a warm water and a cold water current without convergence
3. Yellow Sea & East China Sea	(i) Strong and warm monsoon current from the South China Sea towards the Yellow Sea in the north and through the East China Sea during summer; (ii) equally strong cold current in the reverse direction during winter
IV. Western Central Pacific Ocean	
1. Java Sea	(i) Tropical monsoon regime; (ii) strong south equatorial current during the southeast monsoon brings nutrient rich water; (iii) strong upwelling along the south Java Sea and Sumatra in August
2.South China Sea	(i) Tropical monsoon regime; (ii) high discharge of nutrient rich freshwater from rivers
3. Philippine Sea	(i) Tropical monsoon regime; (ii) the north Pacific equatorial current dominates; (iii) a giant eddy dominates on the eastern side

Table 2. Monthly mean sea surface temperature values (°C) at the different sections along the southwest coast of India during 1973-1978 (Pillai, 1982).

Month	Cape Comorin	Quilon	Cochin	Kasaragod	Karwar	Ratnagiri
January	27.73	28.26	28.07	27.56	27.09	27.04
February	26.96	27.88	28.28	28.02	27.65	26.50
March	28.67	29.12	29.39	29.21	28.39	28.77
April	28.73	29.82	30.01	29.70	29.46	27.83
May	27.23	28.24	29.05	29.46	30.15	30.03
June	26.10	27.42	27.70	28.28	28.65	29.55
July	24.87	24.96	25.04	27.09	26.64	27.84
August	21.13	24.58	24.11	23.17	24.71	27.99
September	-	24.26	23.57	21.78	25.57	27.56
October	25.31	25.98	27.18	27.01	23.86	27.78
November	27.98	28.20	28.05	26.68	27.35	28.26
December	27.09	28.47	28.12	28.56	27.94	27.05

Table 3. Mean depths of the top of the thermocline at the different oceanographic sections along the southeast and southwest coast of India during 1973-1978 (Pillai, 1982).

Section	Shallowest (m)	Period	Deepest (m)	Period
Ratnagiri	11	Oct.-Nov.	39	Dec-Feb.
Karwar	10	Oct.-Nov.	61	-do-
Kasaragod	13	Jan. to Sept.	56	-do-
Cochin	10	-do-	61	-do-
Quilon	16	-do-	66	-do-
Cape Comorin	20	-do-	63	-do-
Tuticorin(SE)	32	-do-	78	-do-

Table 4. Position of the 23°C isotherm (sectionwise/yearwise) within the areas of observation along the southwest coast of India during 1973 to 1978 (Pillai, 1982).

Section	1973		1974		1975		1976		1977		1078	
	Max.	Min.	Max.	Min	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Cape Comorin	Mar.	Jul.	Feb.	Oct.	Feb.	Jul.	Feb.	Jul.	Feb.	Jul.	Feb.	Jul.
Depth(m)	110	57	140	43	120	45	115	42	115	0	115	53
Quilon	Jan.	Jul.	Feb.	Oct.	Feb.	Sept.	Feb.	Aug.	Feb	Jul.	Feb.	Jul.
Depth(m)	115	20	140	23	132	15	127	15	127	0	127	32
Cochin	Jan.	Aug.	Jan.	Aug.	Feb.	Sept.	Feb.	Aug.	Mar.	Jul.	Jan.	Jul.
Depth(m)	110	17	130	16	113	17	124	16	110	7	112	24
Kasaragod	Feb.	Aug.	Jan.	Aug.	Mar.	Aug.	Jan.	Aug.	Jan.	Jul.	Jan.	Aug.
Depth(m)	128	27	110	32	122	30	144	17	144	27	144	27
Karwar	Feb.	Sep.	Jan.	Nov.	Mar.	Oct.	Jan.	Aug.	Jan.	Sep.	Jan.	Oct.
Depth(m)	128	16	120	34	138	35	134	48	134	22	134	15
Ratnagiri	Feb.	Nov.	Jan.	Nov.	Feb.	Oct.	-	-	Feb.	Sep.	Feb.	Oct.
Depth(m)	125	50	122	56	170	45	-	-	170	70	170	70

Table 5. Monthly mean sea surface salinity values (ppt) at the different sections along the southwest coast of India during 1973 to 1978 (Pillai, 1982).

Month	Cape Comorin	Quilon	Cochin	Kasaragod	Karwar	Ratnagiri
January	34.51	34.09	33.70	32.71	32.90	-
February	33.91	33.34	33.66	34.43	35.62	35.46
March	34.21	34.03	34.33	34.16	33.84	34.90
April	33.79	34.69	34.31	34.64	35.13	35.63
May	34.95	34.90	35.11	35.55	36.12	36.02
June	34.71	35.23	35.21	34.64	35.60	35.83
July	34.93	34.66	34.63	35.07	34.41	35.14
August	34.99	34.70	34.43	34.94	34.89	34.81
September	-	34.97	35.22	35.29	35.32	35.63
October	35.26	35.34	34.77	34.71	35.26	34.78
November	34.35	34.66	34.67	34.53	35.45	35.19
December	33.03	33.69	32.50	34.20	35.08	35.08

Table 6. Monthly mean sea surface dissolved oxygen values ml/l) at the different sections along the southwest coast of India during 1973-1978 (Pillai, 1982).

Month	Cape Comorin	Quilon	Cochin	Kasaragod	Karwar	Ratnagiri
January	4.61	4.64	4.91	4.65	3.00	4.33
February	4.91	4.97	4.82	4.90	4.89	4.61
March	4.54	4.52	4.64	4.40	4.61	4.79
April	4.67	4.50	4.58	4.23	4.63	4.62
May	3.91	4.46	4.71	4.65	4.69	4.61
June	4.26	4.23	4.22	4.43	4.44	5.02
July	4.03	3.75	3.71	3.15	3.73	4.33
August	2.30	3.72	3.83	2.14	3.32	4.54
September	-	-	2.46	1.10	5.35	4.30
October	4.20	4.22	3.34	4.43	1.39	4.53
November	4.55	4.76	4.60	3.88	4.00	4.67
December	4.64	4.56	4.62	4.98	4.97	5.04

Table 7. Sinking intensity based on the vertical movement (m) of 23°C along the southwest coast of India during 1973 to 1978 (Pillai, 1982).

Section	Year	Period From	To	Duration (days)	Downward movement From	To	Vertical distance	Speed (cm/day)
Cape Comorin	1973	Jul.	Jan.	193	57	140	83	43.0
	1974	Oct.	Jan.	96	125	125	82	85.4
Quilon	1973	Jul.	Jan.	195	20	140	120	61.5
	1974	Sep.	Jan.	123	23	140	117	95.1
	1975	Aug.	Feb.	185	21	80	59	31.9
Cochin	1973	Sep.	Jan.	125	17	140	123	98.4
	1974	Aug.	Jan.	142	16	150	134	94.4
	1975	Sep.	Jan.	134	17	150	133	99.3
	1976	Aug.	Apr.	262	18	115	97	37.0
Kasaragod	1973	Aug.	Mar.	224	24	119	95	42.4
	1974	Sep.	Dec.	86	30	150	120	139.5
	1975	Sep.	Dec.	182	35	90	65	35.7
	1976	Aug.	Nov.	93	19	108	89	95.7
Karwar	1973	Oct.	Mar.	151	47	133	86	57.7
	1974	Oct.	Jan.	93	34	150	116	124.7
	1975	Oct.	Jan.	92	35	130	95	103.3
Ratnagiri	1973	Nov.	Mar.	119	45	133	88	73.0
	1974	Oct.	Feb.	119	56	150	94	79.0

Table 8. Daily primary production at some stations along the west coast of India expressed as grams carbon fixed beneath a square metre of sea surface (within 50 metres depth) (Nair *et. al.*, 1973).

Date	Latitude	Position	Longitude	Depth in metres	Production $gC/m^2/day$
05/06/1965	8° 00'		77° 20'	38	2.09
15/12/1965	13° 25'		75° 10'	40	0.95
16/12/1965		Karwar Bay		7	1.39
03/02/1966	9° 40'		76° 00'	40	0.18
06/09/1966	9° 00'		76° 28'	25	1.24
07/08/1967	14° 08'		74° 18'	30	0.61
06/09/1967	9° 52'		76° 10'	18	2.37
07/09/1967	9° 20'		76° 51	50	1.18
07/09/1967	8° 42'		76°35'	35	1.26
09/09/1967	7° 45'		77° 19'	50	0.48
09/09/1967	7° 45'		78° 00'	47	1.43
20/07/1968	8° 53'		76° 21'	50	1.12
21/07/1968	10° 29'		75° 51'	37	0.89
22/07/1968	11° 19'		75°36'	28	1.34
24/07/1968	12° 08'		74°58'	37	2.45

Table 9. Annual primary productivity (gross) in a few marine localities as grams carbon per square metre of sea surface (Nair *et. al.*, 1973).

Locality	Production
Barents Sea	170 - 330
English channel	60 - 98
Georges Bank	309
North Sea	57 - 82
Long Island Sound	470
Off Hawai (open ocean)	21
Off Hawai (inshore)	123
Turtle grass bed (Florida)	4650
Hawaiian coral reef	2900
Shelf waters of New York	
Shallow coastal region	160
Continental slope	100
North Central Sargasso Sea	78
Gulf of Mannar(inshore within 10m depth)	745
Temperate oceans	100 to 150
Equator	110 to 146
Barren tropical oceans	50
West coast of India (within 50m depth)	434
East coast of India(continental shelf)	230

Table 10. Summary of primary production values for different zones along the west coast of India in gC/m^2/day (Nair *et. al.* 1973).

States	Upto 50m depth			50 to 200m depth			> 200m depth		
	No.of stns	Total	Average	No.of stns	Total	Average	No.of stns	Total	Average
Kanyakumari district.	3	4.00	1.33	5	1.49	0.37	6	1.08	0.18
Kerala	10	12.17	1.22	13	3.20	0.25	22	3.80	0.17
Karnataka	6	6.50	1.08	4	0.77	0.19	3	0.84	0.28
Maharashtra	-	-	-	2	0.23	0.12	-	-	-
	19	22.67	1.19	24	5.69	0.23	31	5.72	0.18

Table 11. Plankton biomass values (ml/m^3) in the mid shelf off the southwest coast of India (3rd station from the coast) in space and time (Source: PFP records); H-Highest monthly average; L-Lowest monthly average.

Section	1971	1972	1973	1974	1975	1976	1977	1978
Ratnagiri	H.--	0.87(Aug.)	0.66(Aug.)	3.58(Aug)	0.43(Oct.)	0.83(May)	0.83(Dec.)	-
	L--	0.35(Dec.)	0.13(Jun.)	0.04(Apr.)	0.14(May)	-	0.13(Jul.)	0.33(Jun.)
Karwar	H1.44(Oct.)	1.75(Sep.)	1.10(Nov.)	1.02(Aug.)	0.31(Jun.)	1.87(Aug.)	0.73(Dec.)	1.02(Jun.)
	L--	0.01(Dec.)	0.28(Mar.)	0.04(Mar.)	0.16(Oct.)	0.12(Apr.)	0.22(Jul.)	
Kasargod	H0.55(Sep.)	0.93(Jul.)	0.73(Jun.)	2.72(Dec.)	0.5(Oct.)	0.19(Jul.)	-	-
	L.0.20(Nov.)	0.02(Dec.)	0.06(Nov.)	0.10(Jan.)	0.11(Apr.)	0.06(Apr.)		
Cochin	H1.25(Sep.)	4.85(Sep.)	1.20(Jul.)	1.70(Feb.)	0.88(Sep.)	0.34(Aug.)	0.69(Jul.)	1.05(Julk.)
	L0.07(Oct.)	0.06(Jul.)	0.14(Jan.)	0.03(Sep.)	0.03(Mar.)	0.12(Apr.)	0.09(Mar.)	0.08(Jan.)
Quilon	H1.25(Sep.)	4.85(Sep.)	1.20(Jul.)	1.70(Feb.)	0.88(Sep.)	0.34(Aug.)	0.69(Jul.)	1.05(Jul.)
	L0.07(Oct.)	0.06(Jul.)	0.14(Jan.)	0.03(Sep.)	0.03(Mar.)	0.12(Apr.)	0.09(Mar)	0.08(Jan.)
CapeComorin	H-	-	1.6(Aug.)	0.63(Oct.)	1.62(Nov.)	0.34(Nov.)	0.93(Jul.)	0.43(Jul.)
	L-	-	1.21(Jan.)	0.20(Apr.)	0.09(Mar.)	0.19(Jun.)	0.06(Nov.)	-

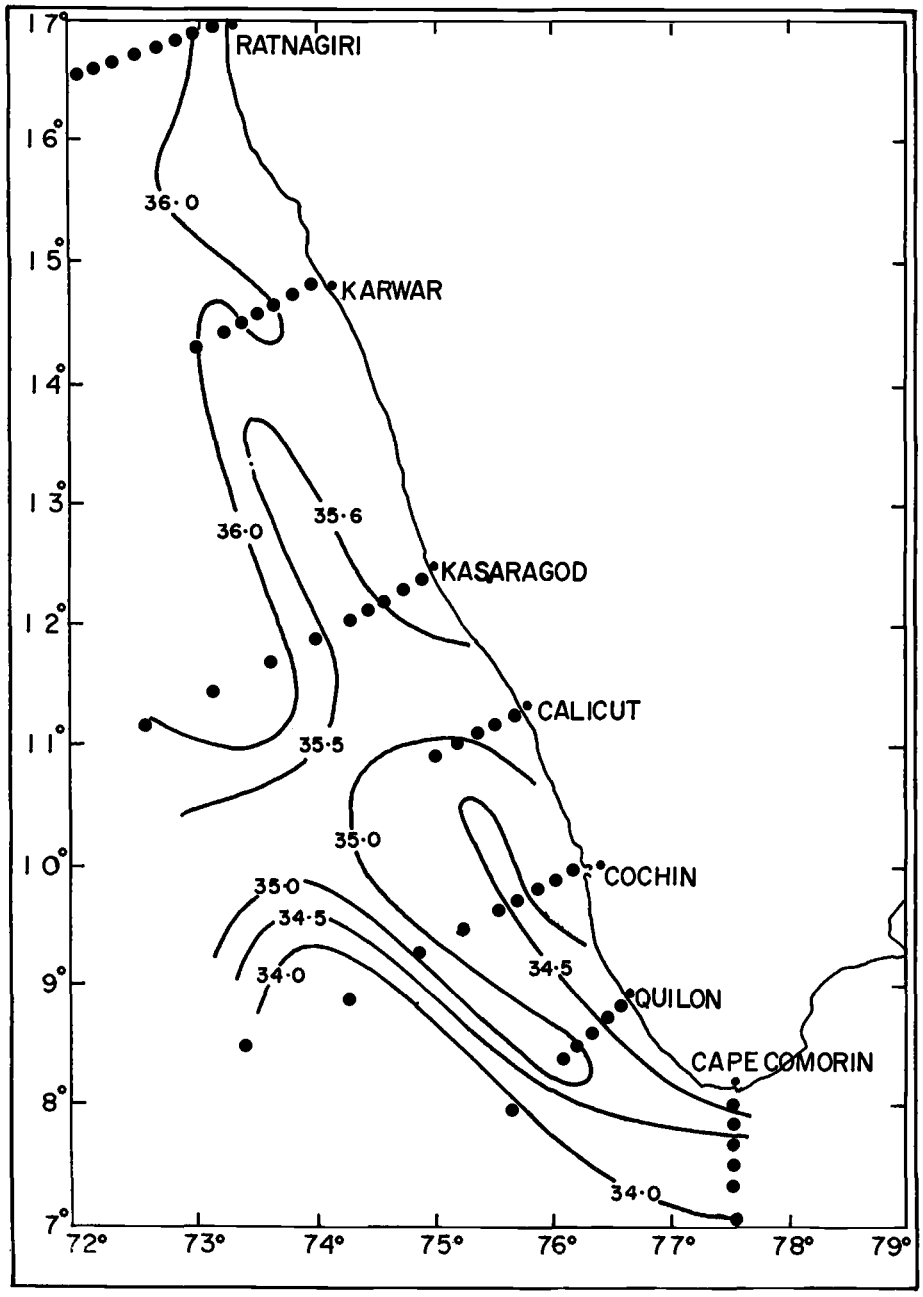


Fig. 1. Horizontal distribution of sea surface salinity along the SW coast of India during January to March 1973.

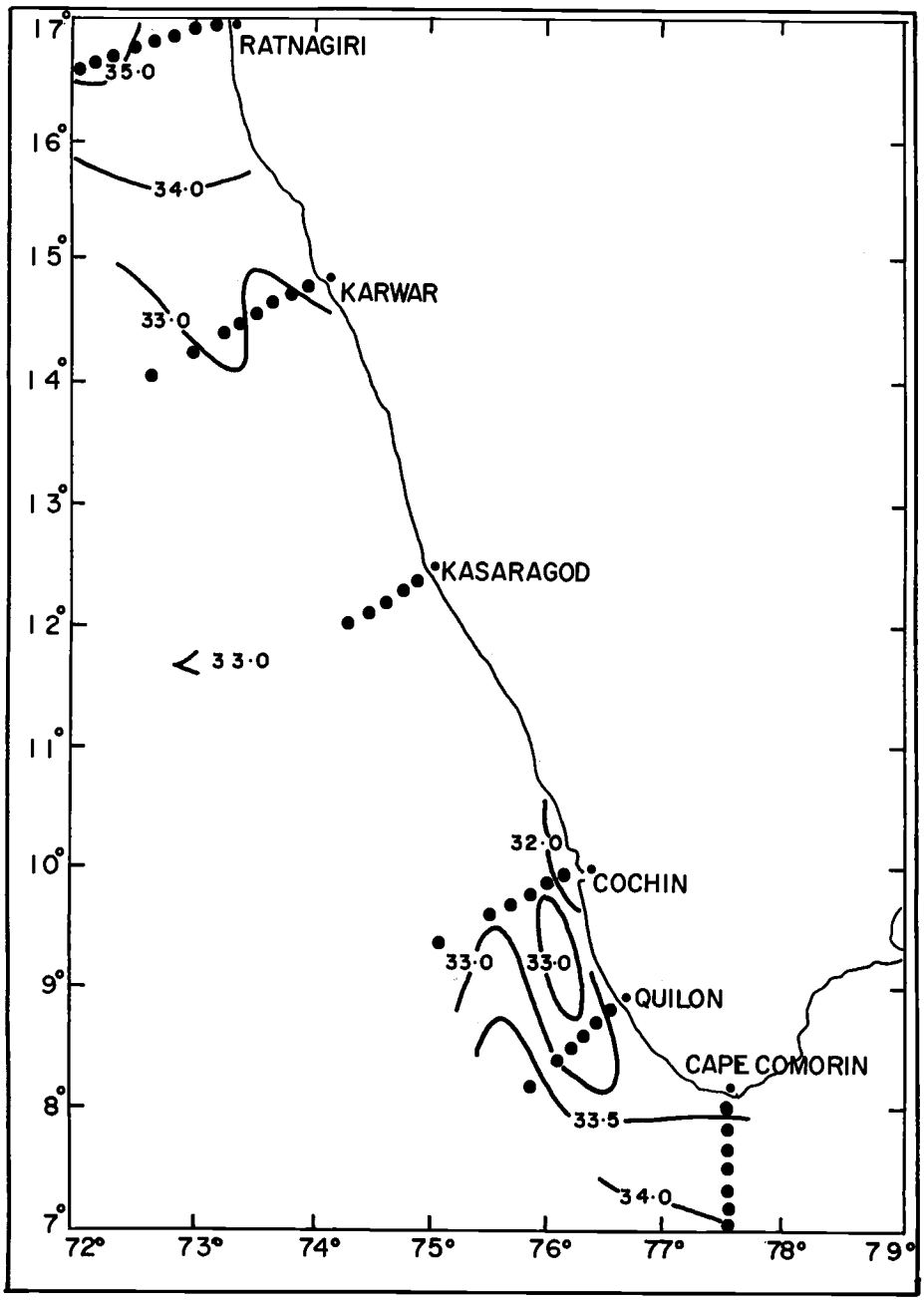


Fig. 2. Horizontal distribution of sea surface salinity along the SW coast of India during January to March 1974.

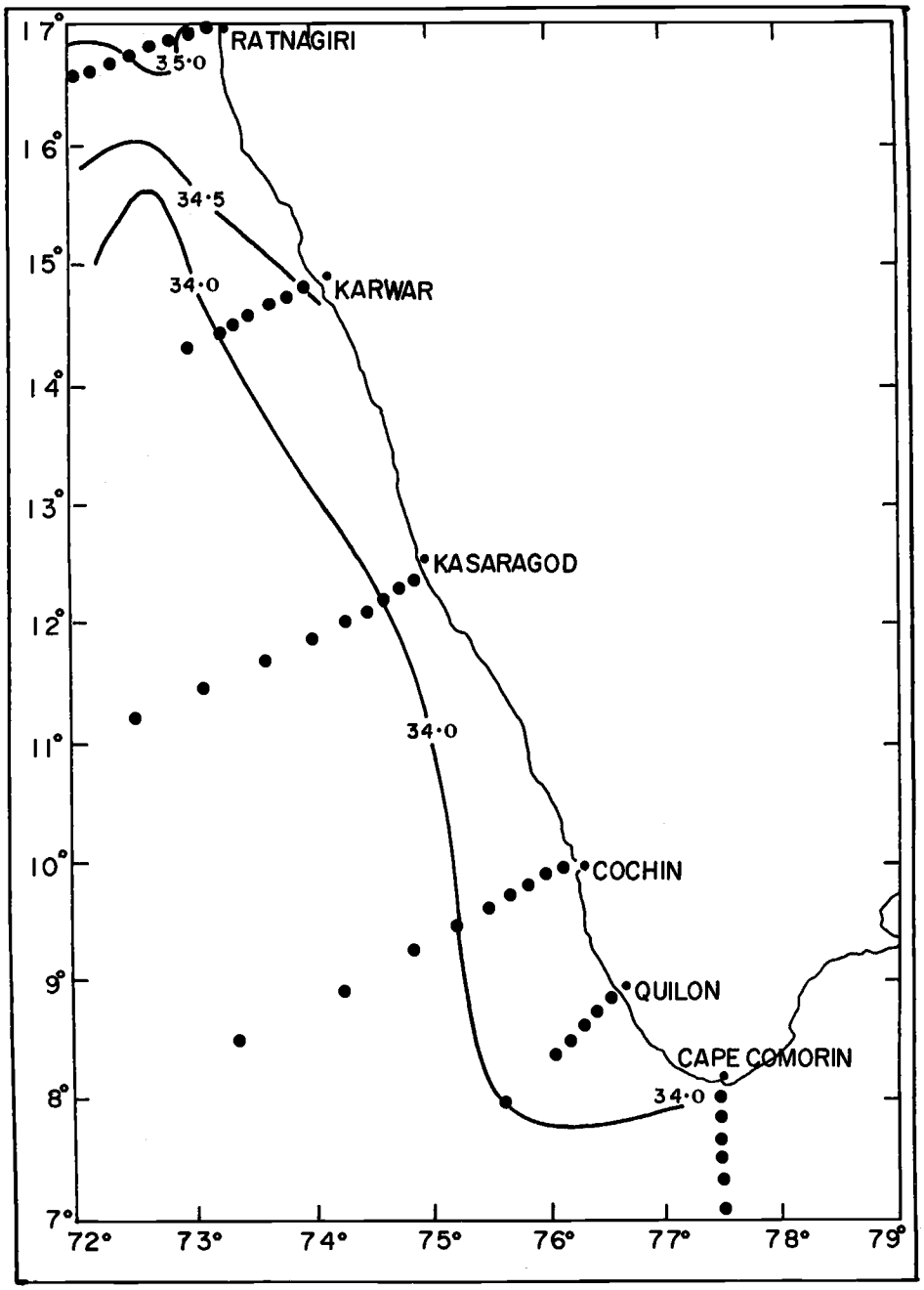


Fig. 3. Horizontal distribution of sea surface salinity along the SW coast of India during January to March 1975.

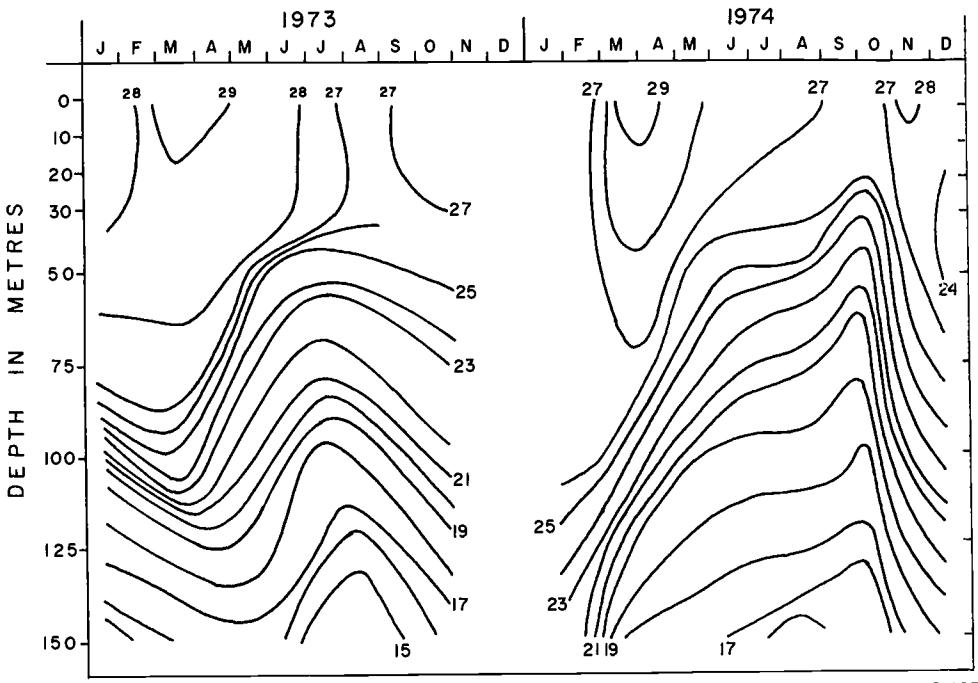


Fig. 4. Vertical time section for seawater temperature off Cape Comorin during 1973 and 1974.

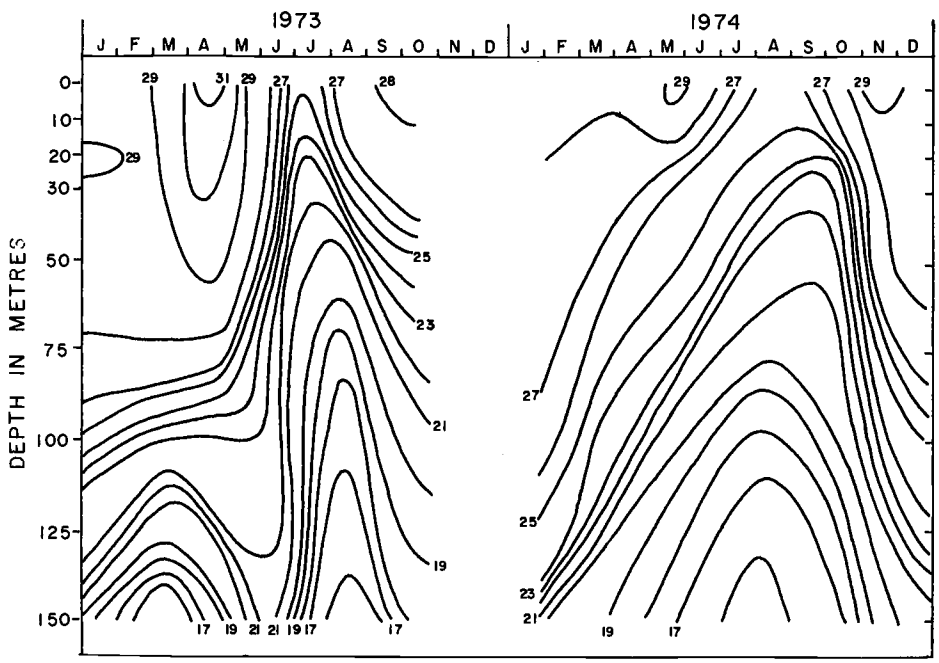


Fig. 5. Vertical time section for seawater temperature off Quilon during 1973 and 1974.

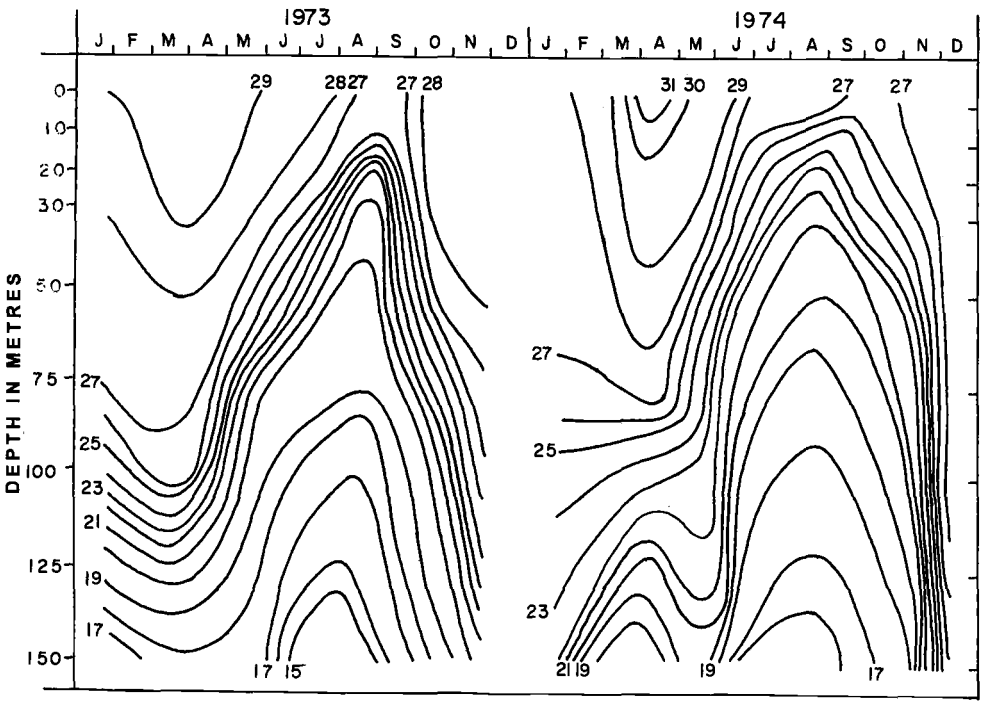


Fig. 6. Vertical time section for seawater temperature off Cochin during 1973 and 1974.

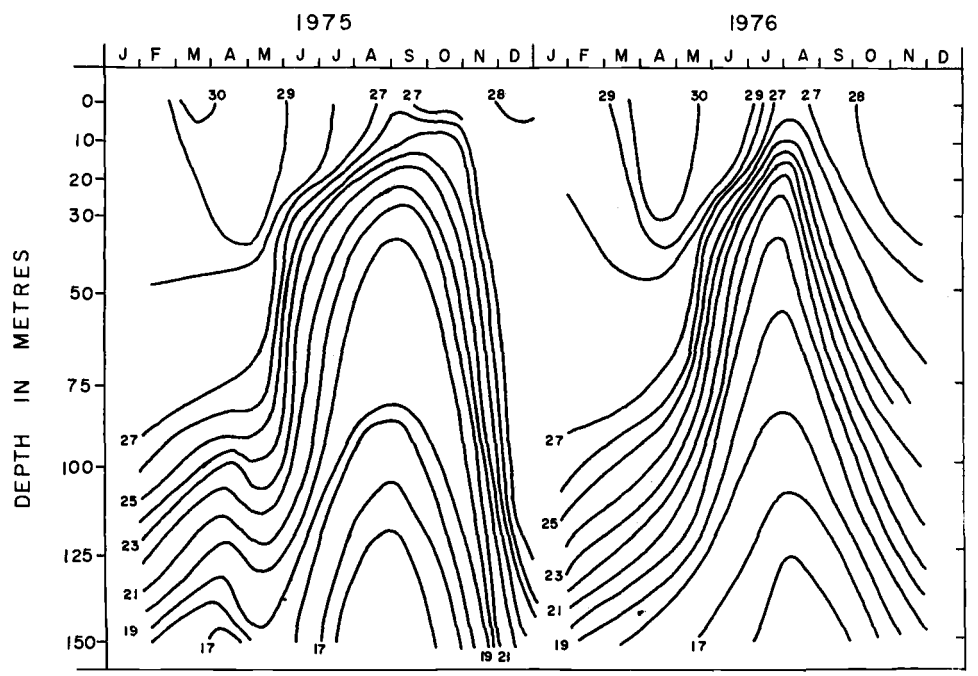


Fig. 7. Vertical time section for seawater temperature off Cochin during 1975 and 1976.

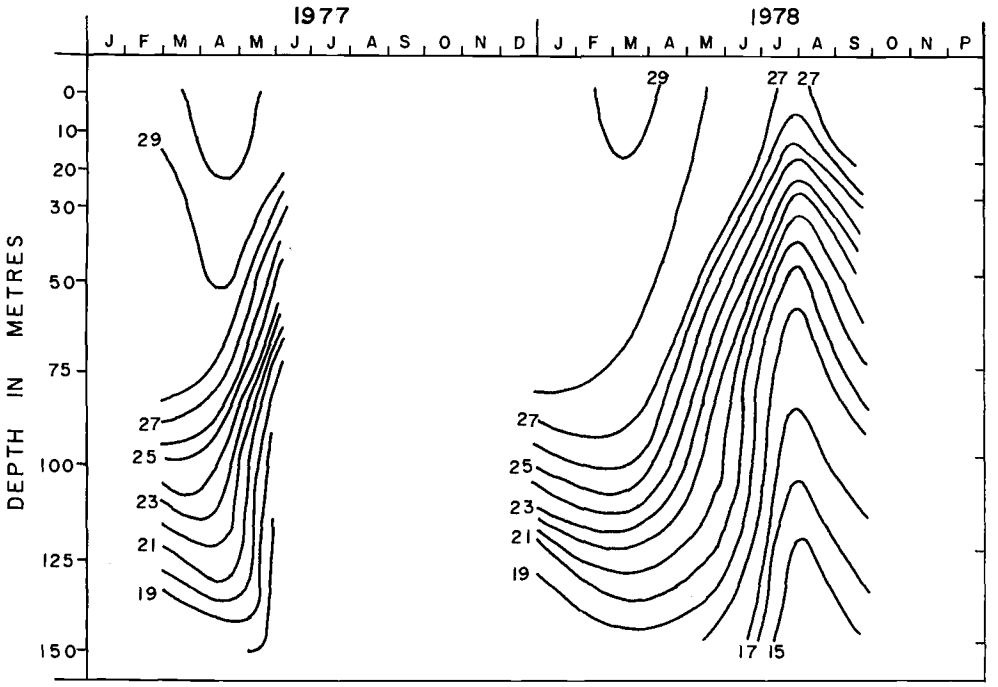


Fig. 8. Vertical time section for seawater temperature off Cochin during 1977 and 1978.

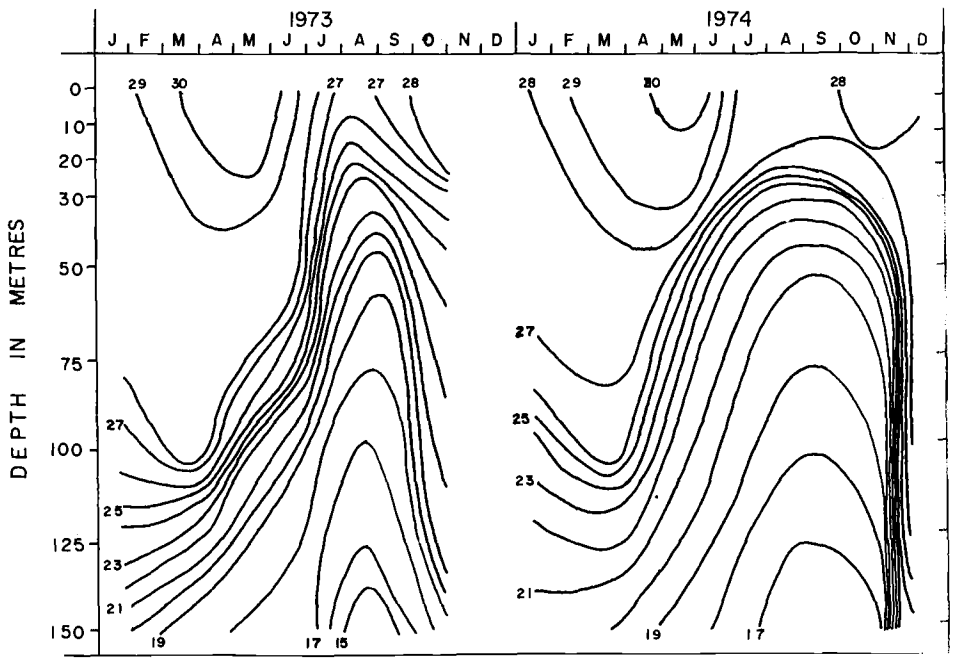


Fig. 9. Vertical time section for seawater temperature off Kasaragod during 1973 and 1974.

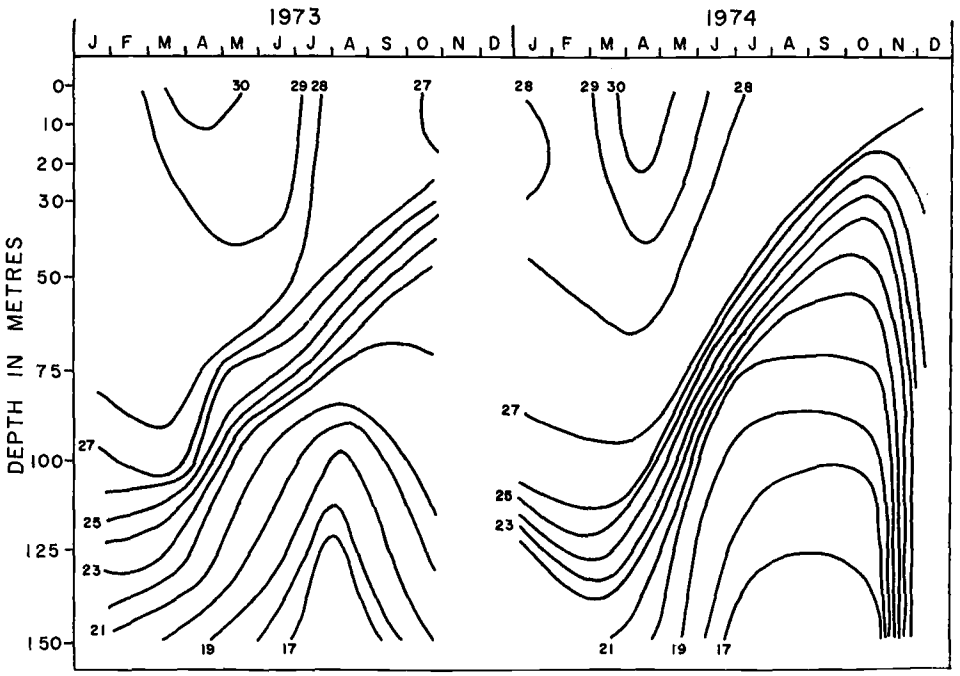


Fig. 10. Vertical time section for seawater temperature off Karwar during 1973 and 1974.

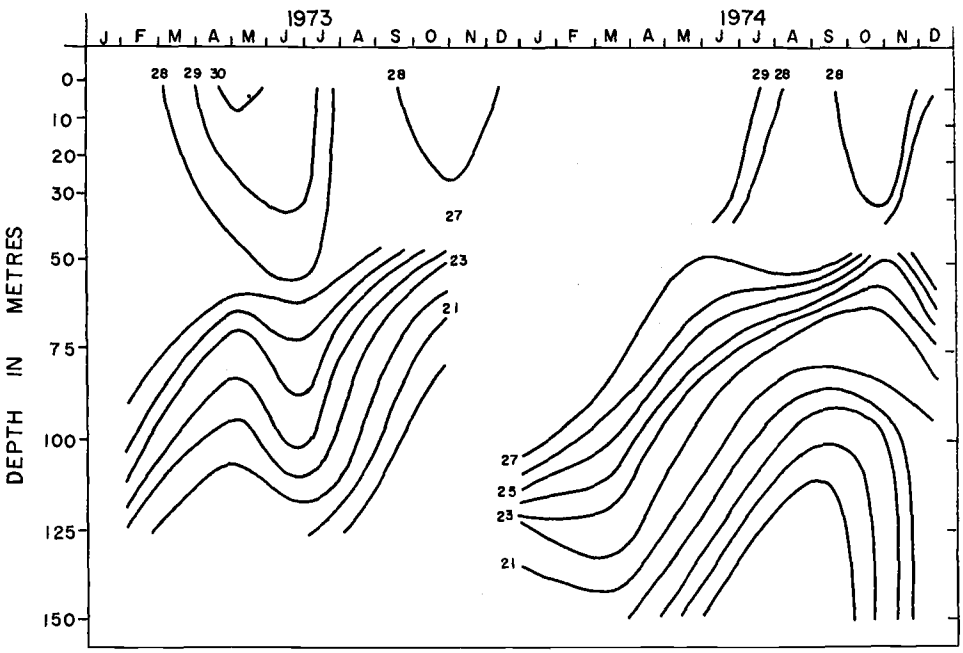


Fig. 11. Vertical time section for seawater temperature off Ratnagiri during 1973 and 1974.

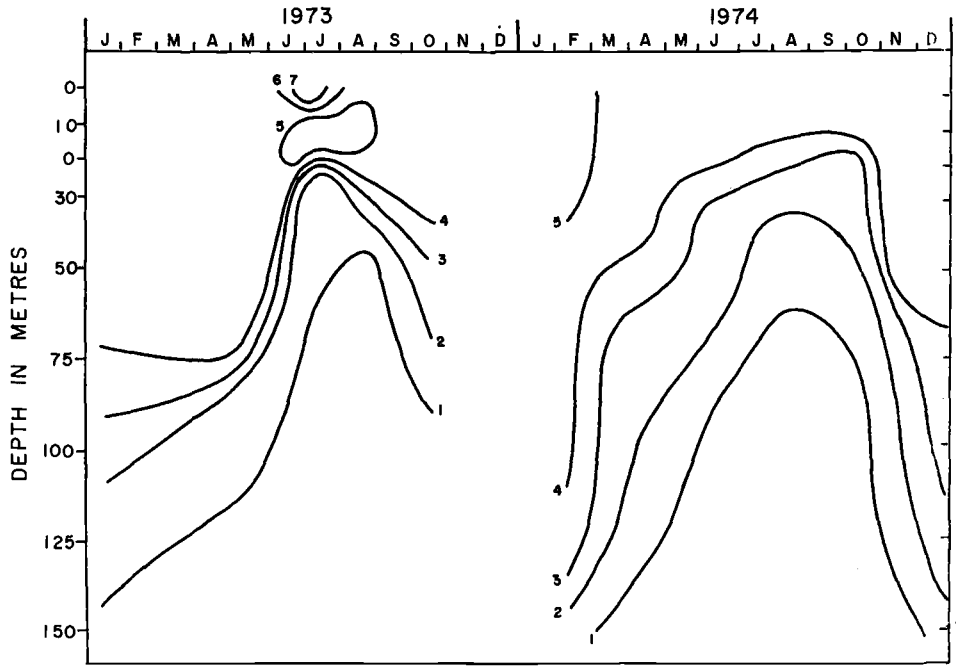


Fig. 12. Vertical time section for dissolved oxyen off Quilon during 1973 and 1974.

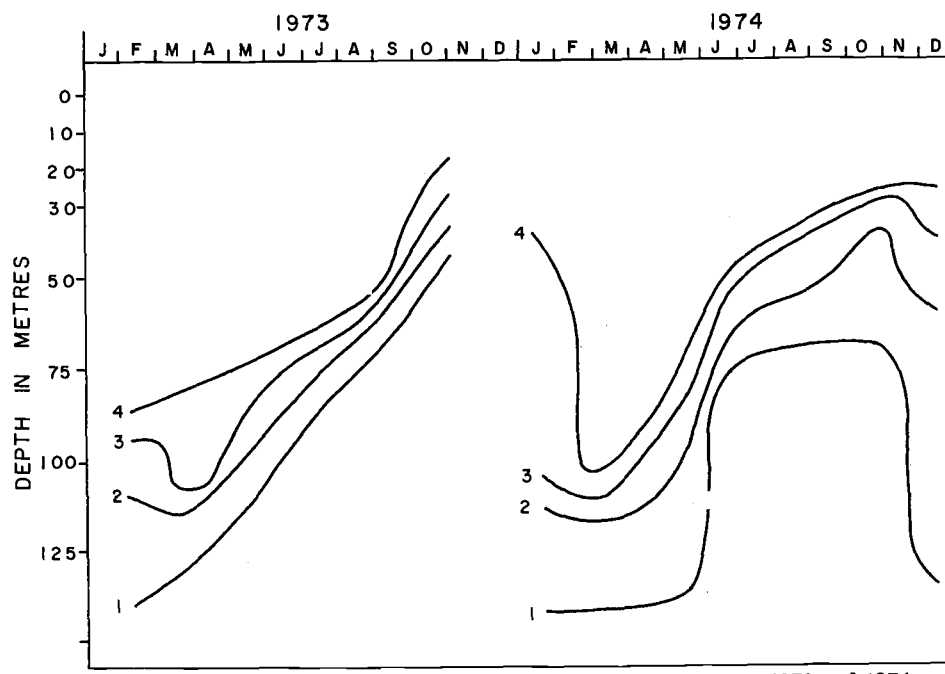


Fig. 13. Vertical time section for dissolved oxyen off Karwar during 1973 and 1974.

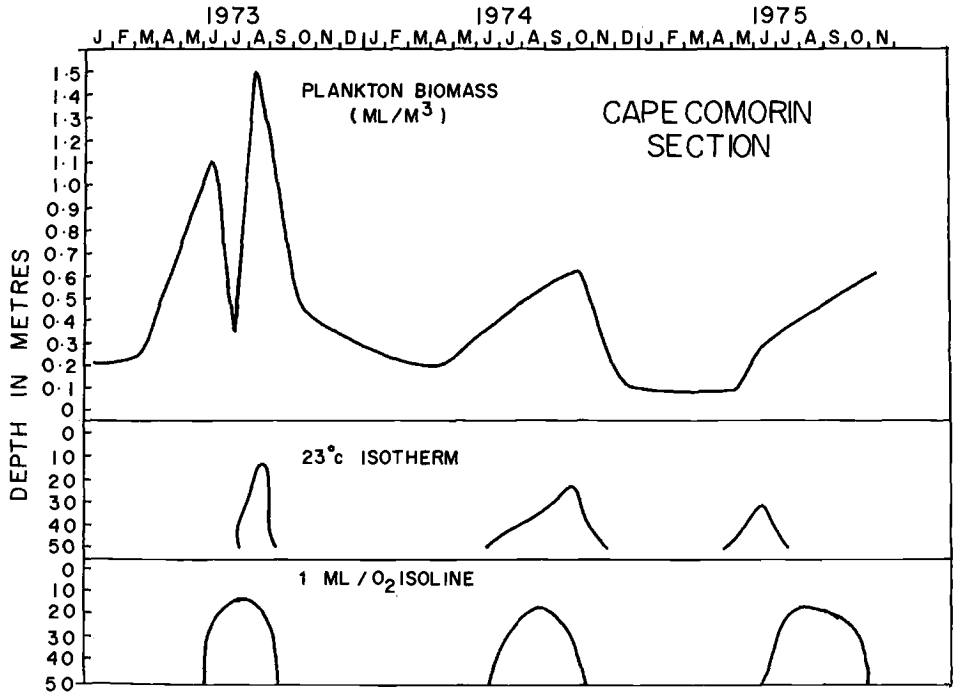


Fig. 14. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Cape Comorin during 1973-1975.

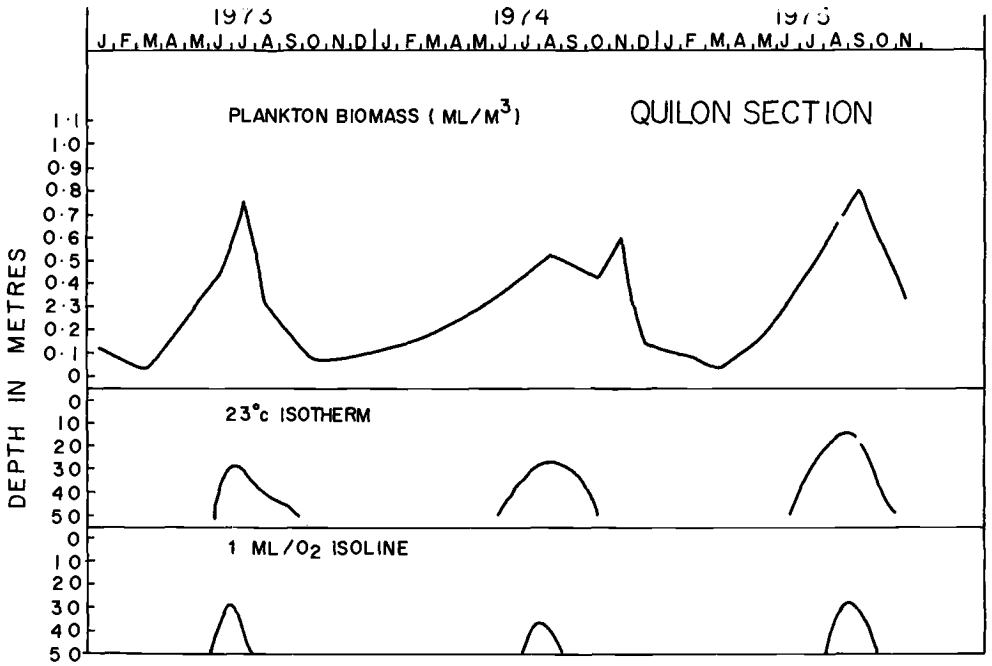


Fig. 15. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Quilon during 1973-1975.

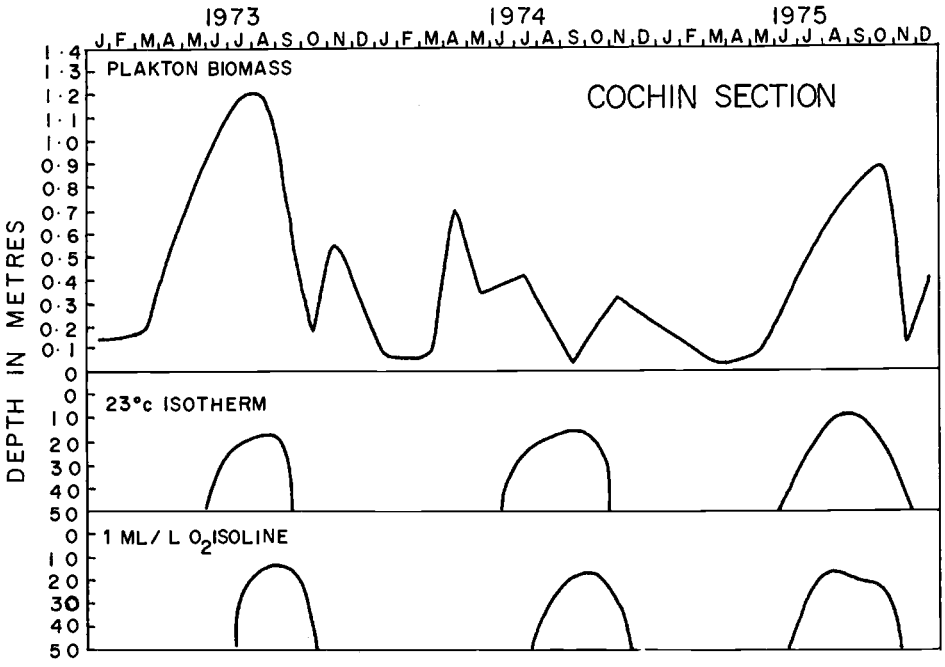


Fig. 16. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Cochin during 1973-1975.

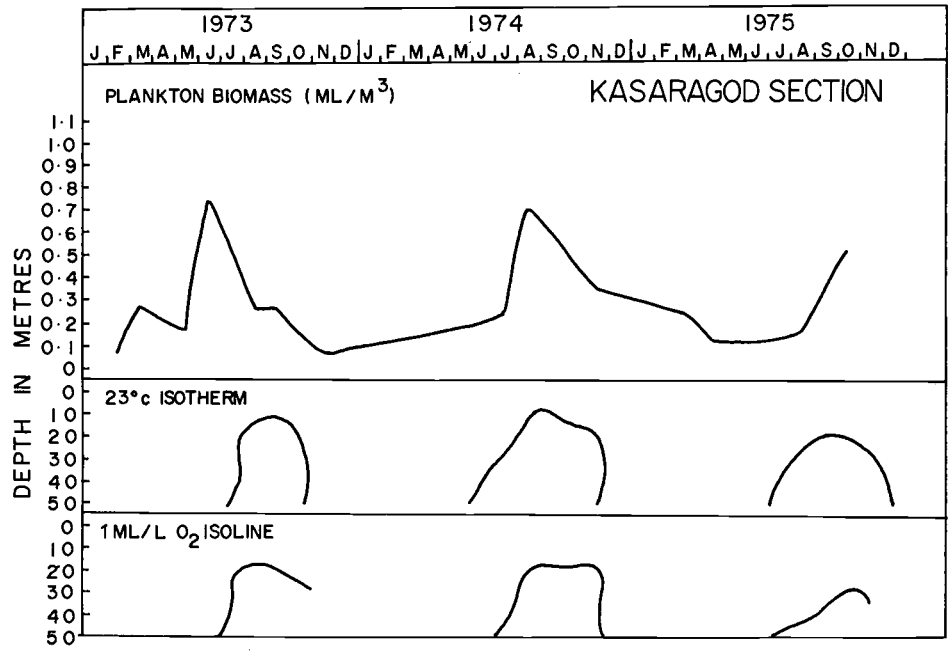


Fig. 17. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Kasaragod during 1973-1975.

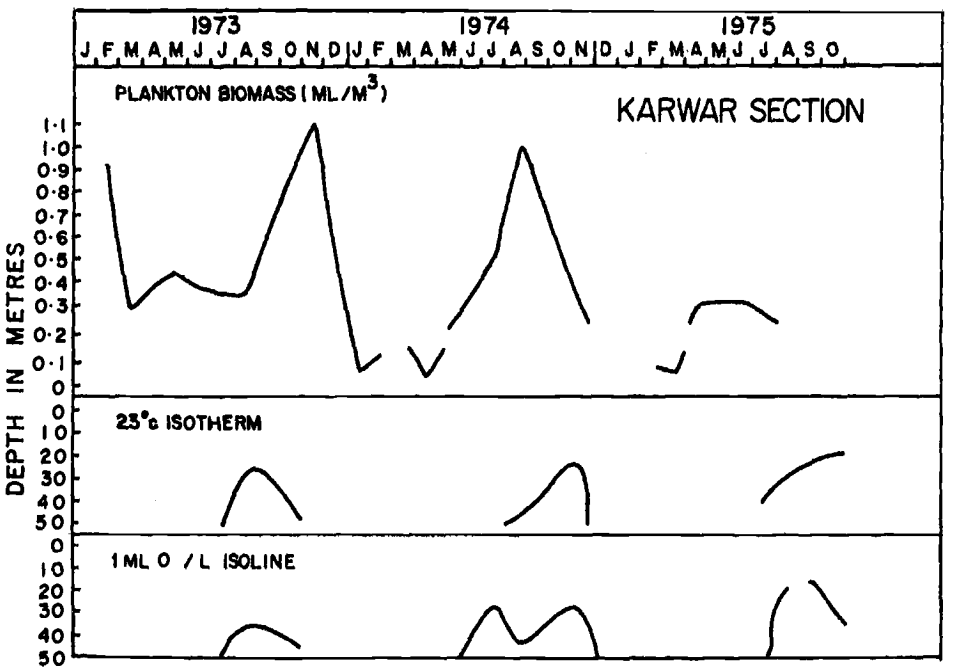


Fig. 18. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Karwar during 1973-1975.

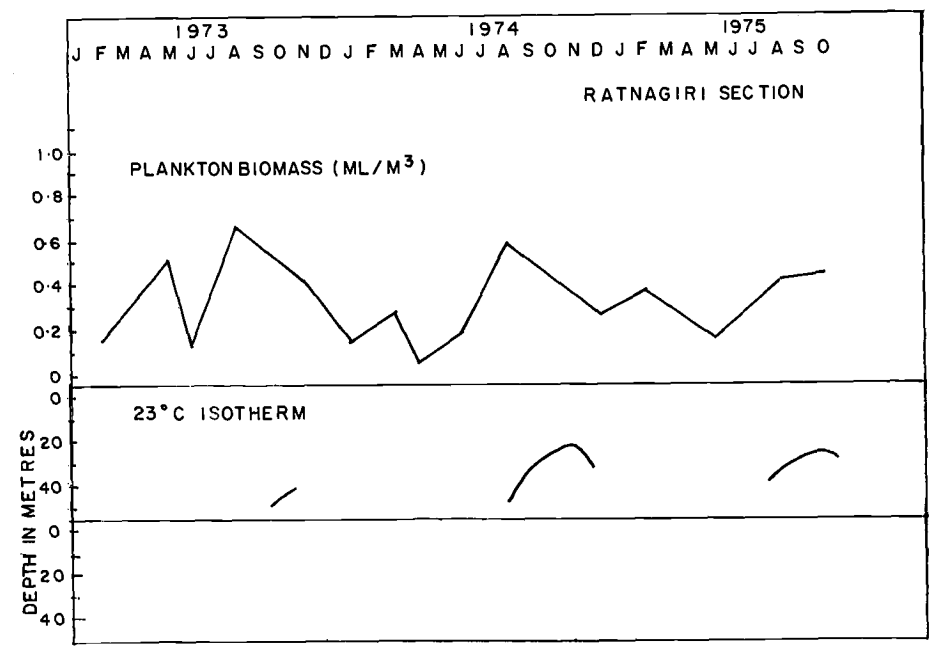


Fig. 19. Relationship between upwelling (in terms of vertical oscillation of 1 ml/l oxygen isoline and 23^{0}C isotherm) and zooplankton biomass off Ratnagiri during 1973-1975.

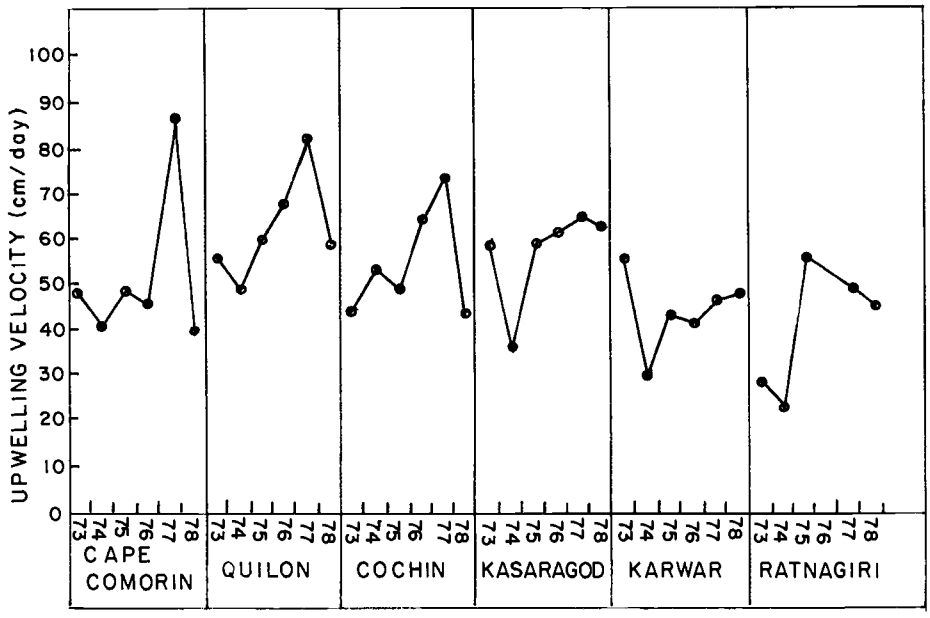


Fig. 20. Diagramatic representation of upwelling velocity (cm/day) off different locations along the SW coast of India during 1973 to 1978.

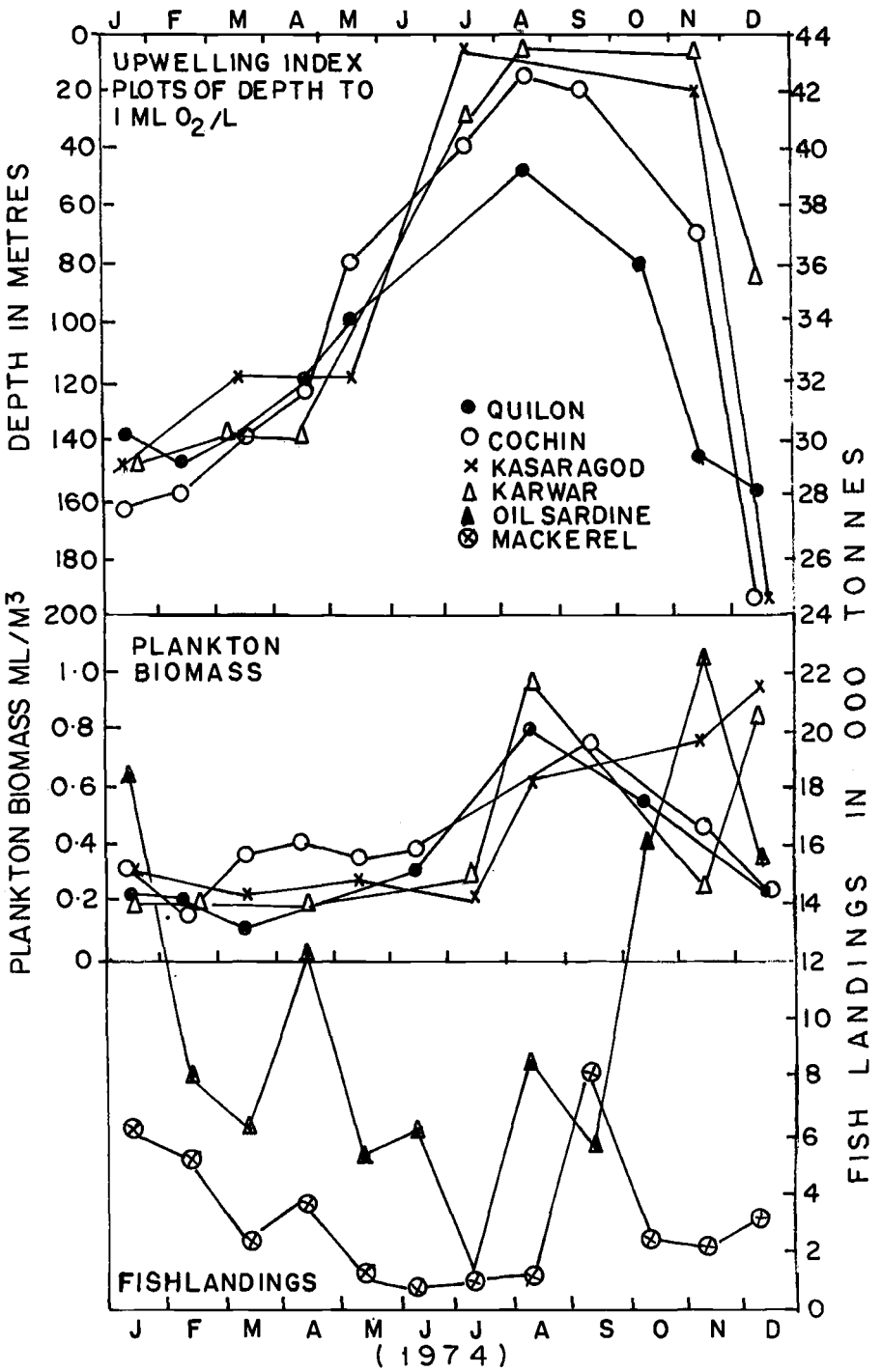


Fig. 22. Relationship between upwelling, zooplankton biomass and landings of oil sardine and Indian mackerel during 1974.

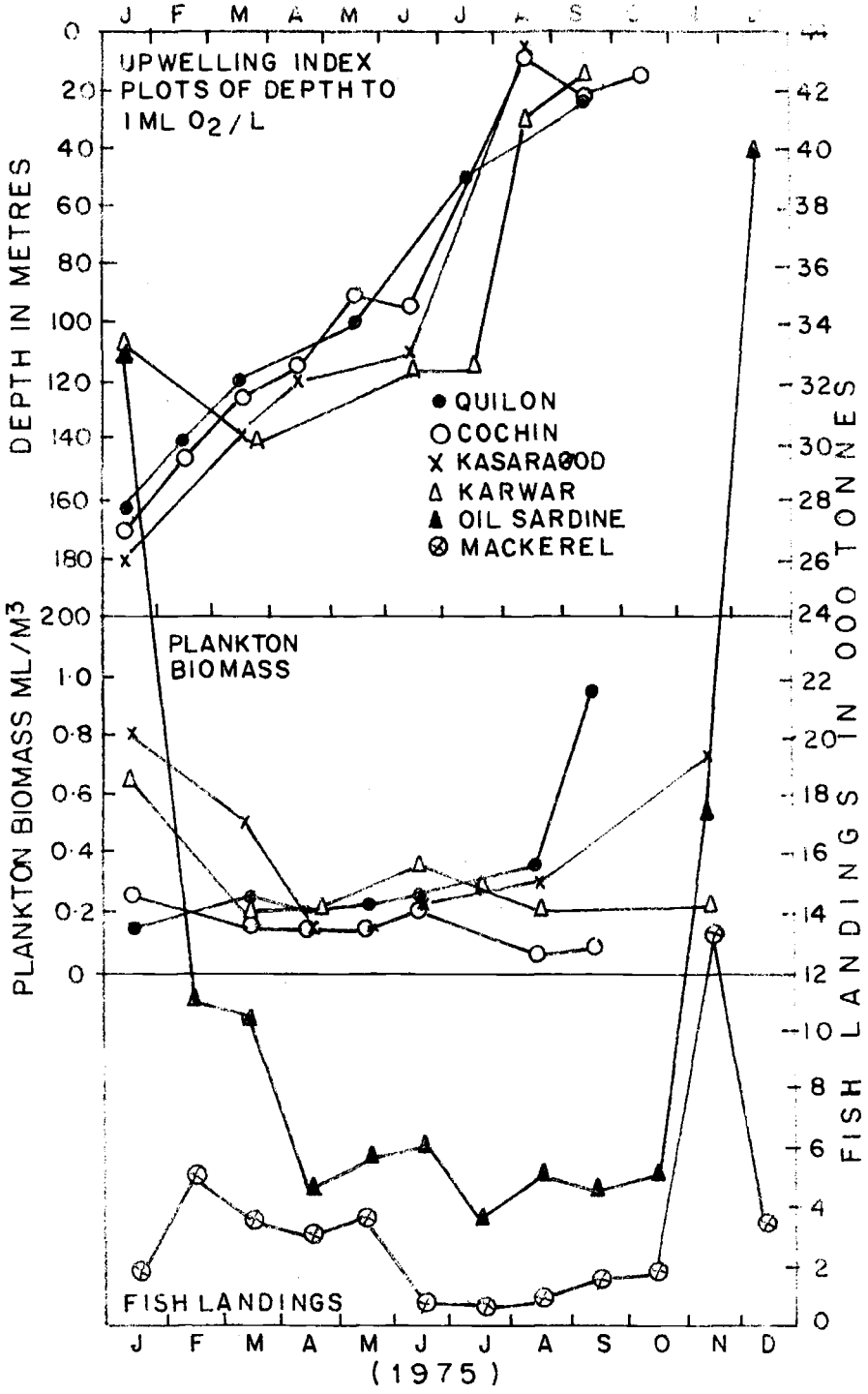


Fig. 23. Relationship between upwelling, zooplankton biomass and landings of oil sardine and Indian mackerel during 1975.

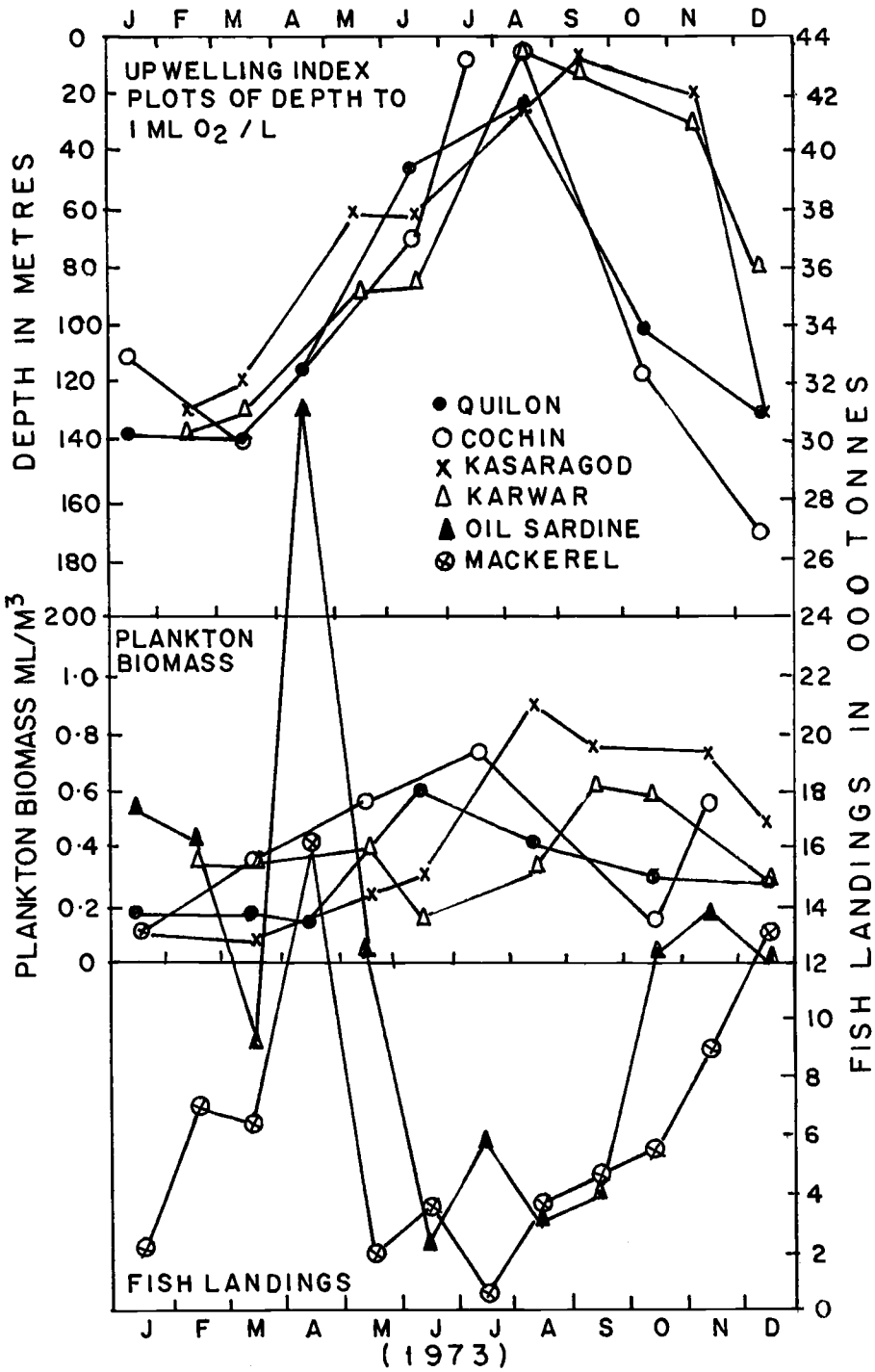


Fig. 21. Relationship between upwelling, zooplankton biomass and landings of oil sardine and Indian mackerel during 1973.

STOCK ASSESSMENT IMPLICATIONS AND MANAGEMENT OPTIONS FOR THE SMALL PELAGICS IN THE APFIC REGION

by

M. Srinath and M. Devaraj
Central Marine Fisheries Research Institute
Cochin 682014, India

Abstract

Problems in stock assessment and management of the exploited fish stocks, especially the pelagic fish stocks, are reviewed. The theoretical and practical constraints in the application of the assessment techniques and production modelling with reference to the small pelagics are indicated. Appropriate approaches to pelagic fish stock assessment and management are outlined.

INTRODUCTION

The great stocks of the sardines, anchovies, and other small pelagics account for about one third of the world's yield of marine fish and are of key economic importance to many nations. Production of these stocks depends on a delicate balance between the physical ocean processes and the pattern (or magnitude) of exploitation. When environmental conditions in the ocean are optimal, strong year classes result and the populations grow rapidly. Under such situations, a well managed fishery could yield significant catches. Many present day populations of small pelagics display a complex pattern of vital rates, indicating the adaptations of the sub-populations to the local habitat conditions. Some sub-populations are tiny with a maximum biomass of only less than 20 000 mt while the others reach millions of mt. These sub-populations experience different environmental conditions and are natural models of how marine populations react to environmental changes. No group of marine populations is better suited for examining the linkages between the physical forces and the population dynamics and structure than the small pelagics because of their worldwide distribution, long time series in abundance and the wealth of information on their ecology and dynamics. During the last two decades, several pelagic fish stocks have been reduced to very low levels and there have been structural changes in the exploited pelagic fish stock assemblage. Many attempts have been made to understand the dynamics of the small pelagics through mathematical modelling of the fishery dependent and fishery independent factors.

PRODUCTION MODELLING

Modelling functions as a research tool that provides a basis for hypothesis testing by putting field measurements into a common framework. Such a framework is necessary to summarize the accumulated information, provide the linkage between historical data sets, retrospective studies and field process studies, and develop predictions regarding the effects of changes in the factors that govern the dynamics of the system. The use of mathematical models in fisheries work was established in the late 1950's by Beverton and Holt (1957). Building on this

cornerstone, many fishery scientists, statisticians and mathematicians progressively developed various mathematical models, which helped understand the system better. We would focus here primarily on the use of some of the most commonly used models in fisheries within a management oriented framework and their role in providing information for the decision making process. The application of mathematical models to assess fish stocks is the core of resource evaluation activity. The quantitative models help predict the effects of different management options(or policies) on the fisheries systems. Gulland (1974) categorized the main questions faced by the fishery managers as follows.

(a) How big is the resource and how many fish could be caught each year while maintaining the stock for the future ?

(b) Given the potential catch, how should this be used for the greatest benefit of the country ?

(c) What actions need to be taken to achieve these objectives ?

In fish stock assessment, there are two types of models that are employed to study the dynamics of the fish stocks. One is the micro or analytical models (or methods) and the other the macro or global (surplus production) models. Models that could be solved in closed form mathematically are analytical models. For such models, a general solution applicable to all the situations the models represent, could be obtained. In the analytical models, we take into consideration the various components that affect the stock, namely, growth, mortality, size or age at first capture etc. In the macro models, we deal with only the observable inputs (say, fishing effort) and the actual ouputs (yield in weight) from a given population. The main features which attract the fishery biologist to use these models are: (i) they are simple models, (ii) the data requirements are limited, and (iii) there is high enough computational ease in estimating the model parameters.

Surplus Production Models

The most commonly used models in fisheries management are the various surplus production models such as those proposed by Schaefer (1954) or Fox (1970). Notwithstanding their original assumptions which apply strictly to the single species systems, these models have served as management tools in many fisheries. Numerous authors have shown that these models tend to overestimate both the MSY and the fMSY. Schaefer (1954) assumed that the specific rate of natural growth f(B) was a decreasing function of the biomass B and the relationship to be linear, and derived a simple relationship between the catch per unit effort (CPUE) and the fishing effort, from which, the reference points for management could be estimated. Research on surplus production models is mainly devoted to: (1) model formulation, (2) parameter estimation, (3) extension to multispecies or multifleet fisheries, and (4) the introduction of environmental information.

Schnute (1977) recast the Schaefer's model into a stochastic dynamic model. Because random errors were shown explicitly, the parameter estimation for the

model was dictated by the least squares condition. The model was converted into a form directly applicable to a data stream of annual fishing effort and catches. The new version was also stochastic. Equations were given for predicting the next year's catch. Agnello and Anderson (1977), Pope (1980) and Prager(1994) proposed theoretical extensions of the Schaefer model.

Tsoa *et al.* (1985) genaralised the conventional Schaefer model to permit the estimation of the unconstrained Cobb-Douglas production function for a fishery in the absence of population data.

Roff (1983) proposed a simple auto-regressive model and compared it with the Deriso delay differential model and Schnute's version of the Schaefer model. He found that for the demersal fish stocks, this model was found to fit the data better. He could not, however, ascribe any biological significance to the model.

Alagaraja (1984) proposed a simple model in which the differences in the catches of successive years are depicted as functions of the previous year's catch and termed it as the relative response model (RRM). A suitable relationship needs to be worked out depending on the data. The simplest form is $C_{t+1} = a + b\ C_t$, which is nothing but the auto-regressive model of order 1.

Srinath (1992) dealt with some problems associated with fitting the surplus production models to unsuitable data. He contended that purely empirical models would fit the data better than the conventional surplus production models and proposed an empirical relationship between catch and effort.

In a critical review of the surplus production models, Laloe (1995) observed that: (1) the precision of some parameter estimators appeared to be good, but the strong asymmetry of the confidence intervals and the large impact of the choice of a given formula on a given formula, went against his observation of high precision of parameter estimators; (2) fishing effort standardization did not necessarily lead to useful results for management; (3) the observation error estimators gave better results though they could not be advocated as the only approach; (4) the possible progress in the use of the surplus production models was more likely to concern the quality of questions that should be observed than the response to the usual questions; and (5) the surplus production models should be used in a framework in order to give representations of fisheries, taking into account "expert knowledge" as well as a much greater set of information.

Ludwig (1981) pointed out that if random fluctuations were taken into consideration, the assessment of management strategies became more complicated. While improving the alternative harvesting strategies for the three laws of population dynamics, namely, the Beverton & Holt model, the logistic model and the Pella-Tomlinson model, it has been found that the results of the harvesting strategies change with the noise level in the population and also depend on the type of the model used.

It is well known in the exploited fish populations that the estimates of the stock size and the catch (or yield) are subject to errors, which are caused both by fishery dependent and fishery independent factors. In this context, Prager (1994) pointed out that, because process errors were propagated forward in time, it would seem that time series fisheries models (e.g., production models), should include correction for process errors, so that the system could be modeled as correctly as possible.

Analytical Models

One of the earliest analytical models developed with a management framework was that by Beverton and Holt (1957). They developed a mathematical model relating the yield per recruit with the fishing mortality and age at first capture. Reference points for management were determined from the model, based on effort regulation or mesh regulation. The F_{max} criterion propounded by them for a given age at first capture denotes the maximum of the yield per recruit on the yield per recruit curve. Their formulation was based on the assumptions that there was knife-edge selection and the fishing mortality remained constant during the exploited phase. The early theory of population dynamics of exploited fish stocks emphasized the significance of the calculation of F_{max} (the maximum level of fishing mortality for a given size at first capture) which maximizes the average yield from each recruit entering the fishery. This was one of the earliest benchmarks for fisheries management, but suffered from a number of failures.

The yield per recruit analysis suggested by Beverton and Holt (1957) suffered many criticisms. The Y/R does not take into account the effect of exploitation on the proportion of mature fish in the population. Generally, F_{max} is greater than F_{MSY} and continued exploitation at this level could lead to the depletion of the spawning stock and affect adversely recruitment. Another criticism often made about the Y/R analysis was that the yield contour surface had always the same shape. The best long-term strategy suggested by the curve will not be valid if the stock suffered recruitment failure which was often the case with the pelagic stocks. Failures in recruitment, when the spawning stock has been reduced to low levels, have been observed for several pelagic fish stocks. However, because of the larger variability in recruitment at all stock levels, it is rather difficult to predict at what stock level the recruitment failure will occur.

The sharp increase in fishing mortality and the decrease in stock size occurring before the sharp decrease in recruitment to the exploited stock (caused by reduced spawning stock) could be discovered. This means that if there is no correlation between catch per unit effort and stock size and no direct estimates are available of stock size or recruitment, the dangerous situation would not be detected, before the estimates of poor year class are available. Virtual population analysis (VPA) (Pope, 1972; Jones, 1984) is another analytical tool which has been widely used for the assessment of fish stocks over the last two decades. The method certainly gives good estimates of stock size and recruitment if good data of catch in numbers by age (or length) are available. Tuning the VPA by choosing that terminal F which gives similar variations in F to those in the fishing effort during the last

years may be a valid method in the case of the demersal stocks or even in pelagic stocks to a certain extent, if it is assumed that the stock is in a rather stable equilibrium. However, when the stock is decreasing due to overexploitation and /or decreasing recruitment, the method may yield disastrous results. Multispecies and multifleet versions of the VPA have also been attempted. Research is now underway to develop a comprehensive multispecies VPA.

REFERENCE POINTS FOR MANAGEMENT

The reference points used in fisheries management are largely the outcomes from the biometric or econometric models. These criteria for management are obtained from global or analytical formulations of the exploited fish stocks. The former models take into account the information on the fishing effort and the total yield only, and the reference points are derived from an appropriate mathematical relationship between the yield and the effort. The latter approach takes into account the processes of growth, reproduction and mortality and explains the yield as a function of these processes. Another approach is to estimate the stock-recruitment relationship and thereby indicate the fate of the fishery based on the variations in the recruitment in relation to the spawning stock. In recent times, the VPA or the length cohort analysis, has been increasingly used in fish stock assessment. These are nothing but some variants to the classical analytical models.

The criterion for the management of fisheries has generally been based on the maximum sustainable yield (MSY), the optimum yield (OY) or the maximum economic yield (MEY). The MSY has been defined in various ways. Technically, it is defined as the peak of the surplus production curve. It has also been interpreted as the point of maximum surplus production on the stock-recruitment curve. However, it is most commonly understood as the maximum constant yield that can be harvested year after year. The OY is more general than the MSY. Here, the overall objective includes considerations of societal benefits, rural upliftment, employment, foreign exchange etc. However, the development of the management regimes based on such multiple objectives has rarely been attempted and especially in the case of the small pelagics, because the ecosystem management and the constraints on the environmental parameters add another but complex dimension to the problem. The MEY is termed as the realization of maximum revenue and the economist's alternative to the MSY.

The models used in the estimation of the MSY were originally equilibrium models, which implied that the catch represented by the production curve was the outcome of the corresponding standard effort applied for the years, necessary for reaching the equilibrium (Beddington and May, 1977). These models ignore the real biological processes which actually generate the biomass and the time lag involved in building the required biomass. When the age structure of the population is changing rapidly, a single functional form of the biomass may not be valid.

The analytical models such as the VPA or the cohort analysis(or more recently the MSVPA) incorporating growth and mortality rates, age at first capture, etc., are widely used in the ICES areas. However, the data required to estimate the

age-structure of the exploited fish population are not available for many tropical stocks and most of these stocks are still being assessed using low precision approaches based on sparse or inaccurate data.

MANAGEMENT AND STOCK ASSESSMENT PROBLEMS

Resources management are constrained by the lack of knowledge or the uncertainty about the fluctuations in stock size and recruitment and also the factors (biotic or abiotic or both) which affect the yearclass strength. Reliable estimation of the stock size is central to any fisheries regulation regime. In some fisheries, effort regulation is implemented instead of the catch quotas. This will be successful only if fishing mortality is strongly correlated to the fishing effort and is not significantly dependent on stock size. If the catchablility is inversely related to the stock size , the regulation of the pelagic fish stocks on the basis of fishing effort would be futile and may be counterproductive (Ultang, 1980). In the absence of knowledge about the relationship between fishing mortality and fishing effort, the alternative is to manage the fishery through the application of catch quotas. However, the problem here is how to estimate the total allowable catch. Ultang (1980) enumerated the following extra problems connected with the assessment and management of short lived pelagic stocks.

1. Stock sizes and catches depend almost completely on one or two year classes. It is not possible to build up a "buffer stock" to make the stock and the assessment less dependent on varying yearclass strength.

2. When estimates of yearclass strength are available from catch data, the yearclass is often already out of the fishery.

3. The usefulness of virtual population analysis in obtaining estimates of stock size, fishing mortality and recruitment in previous years is rather limited because of the short time a yearclass is in the fishery. This makes the estimates critically dependent on the input fishing mortality on the oldest age group and on the assumed value of natural mortality which is highly uncertain.

4. The time available for making a survey estimate of yearclass strength before the yearclass comes into the fishery is usually short and often has to rely on only one estimate without any additional check on it.

5. Because of the high natural mortality, any surplus which is not taken in one year will not be available to the fishery in the next year, even to a minor extent. Therefore, the consequences of excessive restrictions on the fishery are quite different for short-lived from long-lived species.

The major constraint to the application of catch-effort methods in the assessment of the small pelagics, especially in the tropical countries, is the complex multigear and multispecies fishery systems, where the exploitation of the small pelagics is dominated by the traditional gears. If the fishery operates with traditional

gears limited to a small area, the estimated changes in abundance may not be representative of the total stock.

The appropriate type of production model for a particular fishery could be known only after overfishing has occurred and the total effort that provides the MSY has been exceeded. A more rational interpretation of the MSY for a stock, subjected to wide variations in recruitment, would be the yield which could be removed in perpetuity from the resource with an accepted low probability of endangering it (Sissenwine, 1978). From theoretical considerations, Beddington and May (1977) noted that once the Fmsy has been exceeded , the stocks will fluctuate more severely and their return time to equilibrium will increase markedly. The problem becomes more complex when the fluctuations in the stock are characterized by density-dependence and long-term cyclic or irregular variations. In the context of a general framework , where the evaluation of the resource is not the unique objective, the surplus production models may, however,be very flexible tools for fishery analysis with low parameter requirements (Laloe, 1995). The F_{max} was one of the earliest benchmarks for fisheries management, but as referred to earlier, suffered a number of failures. Another reference point is the approximate MSY which is generalized as $x.M.B_0$ based on the natural mortality rate (M), with the values of x relating to the stock characteristics. Patterson(1992) found that only low values of x not exceeding 0.33 were sustainable for several stocks of small pelagics. This approach could be used for setting "Precautionary Reference Points"(Caddy and Mahon, 1995). Caddy and Csirke (1983) expressed yield as a function of Z(total instantaneous rate of mortality), which could be used to estimate Zmbp at which the maximum biological production (MBP) could be obtained.

The target reference points could also be derived from the stock-recruitment relationship or from an extension of the yield per recruit analysis, which incorporated age/size at maturity in calculating the spawning stock biomass per recruit. Due to considerable variations in the recruitment, more often than not, it was extremely difficult to obtain statistically significant stock-recruitment relationship or spawning stock -recruitment relationship. In all S-R relationships, the spawning biomass corresponding to the maximum surplus production (B_{msp}), occurs at some level between high and low stock size (Ricker, 1975). Thus, it is possible to estimate theoretically the F_{msp} that would allow the B_{msp} to survive and reproduce in that year. Because of the problems in parameterising the stock-recruitment relationship, it is rather difficult to arrive at an appropriate mathematical model. Evans and Rice(1988) proposed an ingenious method of describing the stock - recruitment relationship without the mediation of a functional relationship. They followed the Markovian chain principles and suggested strategies for short-term and long-term prediction of recruitment.

Management measures may be envisaged as either input controls or output controls. In the former, the management strategies are based on the limitation of the fleet size, mesh size, license or closed seasons. In the latter case, restrictions are imposed on the composition of the catch and the size of fish or the total allowable catch quotas. Management options from these controls could be profitably combined when stocks show indications of overexploitation. These measures are expected to

be effective in the small pelagic fisheries where the fleet size and characteristics such as the gear type could be properly monitored. However, this requires the political will and social awareness about the need for conserving and sustaining the small pelagic stocks which are the major source of livelihood of traditional and small artisanal sector. Constant catch quotas for highly fluctuating stocks such as the pelagic stocks could result in varying rates of exploitation (Sissenwine, 1978). Unless it is set at a very low level, there is likelihood of overexploitation in the years of low abundance. Variable catch quotas tend to lag behind the actual variations in recruitment by one or several years. This may result in the loss of good year classes in certain years.

A number of studies have revealed the regulation of the level of fishing effort to be more advantageous than that based on the catch quotas (Hanneson, 1993). Beddington and May (1977) noted that with a constant management strategy, environmental perturbations would cause more serious departures from equilibrium conditions than when a constant effort strategy was followed. Reeves (1974) found that under recruitment variations, an effort limit produced higher catch rates than a fixed catch quota. A constant effort strategy requires that fishing effort be controlled to that corresponding to a target F value. However , it was felt that the catchability would increase due to learning by the fishermen and increase in the fishing power. Another disadvantage which would lead to a disequilibrium state, especially in the case of the pelagic stocks, is due to the increase in the catchability at low stock sizes, thus impairing the assumption of direct proportionality of the fishing mortality with the fishing effort. In the light of the recent failures of quota controls in obtaining sustainable yields from most of the so called well managed fisheries, managing the fishery through effort control warrants a critical reexamination.

According to Freon *et al.* (1992), the conventional surplus production models are not suitable for certain stocks because fishing effort variations explain only a small fraction of the total variability of the annual production and the CPUE. Often the residual variability originates from the influence of the environmental phenomena, will affect the abundance or the catchability coefficient. They developed algorithms to improve the accuracy of the conventional models by inserting the environmental models in them and built an interactive expert system software CLIMPROD for choosing and adjusting a global production model which accounts for changes in the environmental factors. One of the major constraints in the application of the surplus production models for the assessment of the pelagic stocks is the variations in the catchability coefficient(q). The high incidence of collapse amongst the small shoaling pelagic fisheries besides their high vulnerability to unrestrained fishing has been attributed to density dependence of the catchability coefficient (Csirke,1988). The assumption $F=qf$ is central to most of the fish stock assessment models in fisheries research. Here, q is assumed to be constant and independent of stock abundance. The proportionality between F and f may be violated by variability in the area inhabited by the stock, distribution of the stock and also the harvesting power of the fishing vessels. The significant feature of pelagic fish stocks which may affect q is their schooling behaviour. The relationship between F and f depends on how the effort is measured, and for stock assessment

purposes, the problem is whether it is possible to find a proper measure of effort which is proportional to the fishing mortality. Assuming no correlation between effort and the yearclass abundance, it was shown that $q = k.N^{-b}$ The relation may be most easily interpreted when N is defined as the mean stock size during the year or fishing season, instead of the stock size in the beginning of the year. In this case $C = F.N = q.f.N = k.f.N^{1-b}$. If b=0, then C/f is proportional to N, and if, b = 1, then C is proportional to f and the catch per unit effort is constant. For intermediate values of b, there will be some decrease in the catch per unit effort with decreasing stock size, but it will not be proportional. MacCall (1976) reported that for the Californian Pacific sardine fishery , the catchability coefficient increased with the decrease in the stock size.

According to May (1992), the chaotic behaviour of the systems could be due to density dependence. Thus, nonconformity of the data with the theoretical surplus production model does not necessarily mean any negation of the model as such, but warrants critical examination of the trend in the data and the underlying processes that contribute to long-term and short-term variations. Thus, there is an urgent need to re-orient the research in pelagic fish stock assessment through a critical study of the pelagic fish systems in their entirety rather than exploring nonexistent simple catch-effort relationship. In otherwords, research should address the problem incorporating both the fishery dependent and fishery independent factors in the production model. It is high time that we examine the variations in the catchability coefficients for most of the hitherto overexploited fish stocks and evolve a suitable management option based on a meaningful model taking into consideration the biophysical parameters.

Evidence is mounting that the ecosystems supporting small pelagic fish populations undergo productivity changes of decadal frequencies which are expressed, *inter alia*, by "regime shifts" of clupeoid populations. The causal mechanisms need identification, perhaps using new methods for the analysis of time series of phytoplankton, zooplankton, fish, and physical data. Considerable difficulties remain in predicting the effects on the resources of short-term (seasonal) and long-term (interannual to decadal) variations in the marine environment. There is thus a need to assess the relationship between these variations and the long-term global changes. A variety of models ranging from energy budget models of key species to the physical models of regional circulation and mixing dynamics are required. Especially valuable are the models that bridge the interface between biology and physics. The unsatisfactory performance of the existing fisheries models and the derived management options therefrom warrant critical review and change in the management of fisheries using appropriate reference points for managing fisheries. Stochastic modelling approach in which the model inputs and results are given as a range of possible realizations which account for the natural randomness needs to be followed for highly variable stocks such as the small pelagics. This type of approach requires that significant amount of reliable data be available so that the acceptable confidence levels could be obtained for model predictions.

Devaraj and Vivekanandan (this volume) gave a comparative account of the small pelagic fisheries in the APFIC region. They dealt with not only the status of the exploited small pelagics, but also the various management measures that were adopted by the respective countries. The account clearly indicated that the stock assessment techniques and production modelling procedures remain more or less uniform across the countries of the region. Although it is well recognized that the stock assessment of the exploited small pelagics defies direct solutions, the assessment of these stocks continues to be carried out by the traditional population dynamics exercises (mostly valid for the demersal stocks) for want of better or more suitable alternatives. The methodologies for the estimation of the parameters for growth and mortality rates are common to both the pelagics and the demersal stocks. These parameters are increasingly being estimated using the length composition data because of the obvious difficulties in the age determination of the tropical small pelagics. Till now there seems to be no consensus on the validity of the length based estimation procedures for estimating the growth and mortality parameters. There is thus an urgent need to standardize the procedures and propose appropriate methodologies for parametric estimation. Another daunting task that confronts the fishery biologist assessing the stocks is the definition and quantification of effective effort in multispecies and multifleet systems.

All the methods of stock assessment and model formulations presuppose that the data are relevant, properly validated and reflect the reality. In the tropical developing countries, the data required for stock assessment and fishery management emanate from the commercial fish landings. There are only very few (or no) fishery surveys conducted from onboard research vessels. The method or mode of data collection varies from country to country. No study has yet been taken to evaluate the sampling procedures that are followed to collect the relevant data for fish stock assessment and management. There should be concerted effort and cooperation among all the countries of the APFIC region to address these vital issues. There should also be effort to develop a strong database on the small pelagics of the region incorporating all the factors that cause variations in the exploited stocks and thus enable the development of GIS-based management decisions.

REFERENCES

Agnelo, R.J, and L.G. Anderson. 1977. Production relationships among the interrelated fisheries. In: *Economic Impacts of Extended Fisheries Jurisdiction.* Ed. Lee. G. Anderson. Ann. Arbor. Science Publishers Inc., 428p.

Beverton, R.J.H., and S.J. Holt. 1957. On the dynamics of exploited fish populations. *Fish.Invest.Minist.Agric.Fish.Food.G.B.(2 Sea Fish)* 19: 533p.

Caddy, J.F, and J. Csirke. 1983. Approximations to sustainable yield for exploited and unexploited stocks. Oceanogr. Tropic. 18(1): 3-15p.

Caddy, J.F., and Mahon, R., 1995. Reference points for fisheries management. FAO Fisheries Technical Paper, No. 347, Rome, Italy, 1995. 83p.

Csirke, J., 1988. Small shoaling pelagic fish stocks. In: Gulland, T.A. (ed). Fish Population Dynamics. John Willey, 271-400p.

Evans ,G.T., and J.C. Rice, 1988. Predicting recruitment from stock size without a mediation of a functional relations. J. C.I.E.M. 44: 111-122p.

Freon, P; C. Mullon, and G. Pichon, 1992. CLIMPROD: Experimental interactive software for choosing and fitting surplus production models including environmental variables. FAO computerized Information Series (Fisheries) No. 5, Rome, Italy, 82p.

Fox, W.W., 1970. An exponential surplus yields model for optimizing exploited fish population. *Trans. Am. Fish. Soc.* 99: 80-88p.

Gulland, J.A., 1974. Guidelines for fishery management. *Indian Ocean Fishery Commission.* Rome. FAO/UNDP, ICFC/DEV/74/36: 84p

Hanneson, R., 1993. Strategies for stabilization. Constant catch or constant fishing effort? pp 665-682 in: Kruse, G; D.M. Eggers, R.J. Marasco, C. Pautzke and T.J. Quinn II [ed.]. Proceeding of the International Symposium on Management Strategies for Exploited Fish Populations. Alaska Sea Grant College Program. Report No 93 -02. University of Alaska. Fairbanks.

Jones, R., 1984. Assessing the effects of changes in exploitation pattern using length compositon data (with notes on VPA and cohort analysis). FAO Fish. Tech. Paper No. 256: 118p.

Laloe, F., 1995. Should surplus productions models be fishery description tools rather than biological models? *Aquat. Living Resour.* 8: 1-16p.

Ludwig, D., 1981. Harvesting strategies for a randomly fluctuating population. *J. CIEM.* 39: 168-174p.

MacCall, A.D., 1976. Density dependence of catchability coefficient in the California Pacific sardine *Sardinops sagax caerulea* purse seine fishery. Calif co.op Oceanic Fish Invest. Rep 18. 136-148p.

May, R., 1992. The chaotic rhythms of life In: The New Scientist Guide to Chaos. Ed. Nina Hall Penguin Books: 223p.

Patterson, K., 1992. Fisheries for small pelagic species: an empirical approach to management targets. Rev. Fish. Biol. Fish. 2: 321- 338p.

Prager, M.H., 1994. A suite of extensions to a non equilibrium surplus production model. *Fish. Bull.* 92: 374-389p.

Pope, J.G., 1972. An investigation of the accuracy of virtual population analysis using cohort analysis. Res. Bull. ICNAF (9): 65-74p.

Pope, J.G., 1980. Assessment of multispecies resources. In, Selected lectures from the CIDA/FAO/CECAF Seminar on fishery resource evaluation. FAO/TF/INT 180(C) Can. Suppl. 166p.

Reeves, J.E., 1974. Comparisons of long term yields from catch quotas and effort quotas under conditions of variable recruitment. ICNAF Res Doc. 74/31 16pp(Mimeo).

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Board.Can.* 191: 382p

Roff, D.A., 1983. Analysis of catch -effort data, comparison of three methods. *Fish. Aquat. Sci.* 40: 1496-1506p.

Schaefer, M.B., 1954. Some aspects of the dynamics of population important to the management of the commercial marine fisheries. *Bull. IATTC* 1: 26-56p.

Schaefer, M.B. ,1957. A study of the dynamics of the fishery for Yellowfin tuna in the Eastern Tropical Pacific Ocean. *Bull. IATTC* 2: 247-285p.

Schnute, J., 1977. Improved estimates from the Schaefer production model. *Can.J. Fish. Aquat. Sci.* 42. 42: 414-419p.

Sissenwine, M.P., 1978. Is MSY an adequate foundation for optimum yield? Fisheries 3 (6): 22-24p.

Srinath, M., 1992. Catch-effort relationship in Pacific Bigeye tuna fishery. *Naga* Vol 15. No. 1 : 29-30p.

Tsoa, E, W.E. Schrank, and N. Roy. 1985. Generalizing fisheries models: an extension of Schaefer's analysis. *Can.J. Fish. Aquat. Sci.* 42: 44-50p.

Ultang, O., 1980. Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach to assessment and management. Rapp. P.V. Reun. CIEM. 177: 489-504p.

REGIONAL COOPERATION FOR MANAGING MARINE FISH STOCKS IN THE APFIC REGION

by

M. Devaraj and E. Vivekanandan
Central Marine Fisheries Research Institute
Cochin 682014, India

Abstract

For effective management of straddling fish stocks, regional cooperation of the participating countries is required. Formation of regional fisheries forums and intergovernmental consultative machinery's is very vital. The functions of the existing regional bodies and the factors which should form the basis for effective management of fish stocks are discussed.

INTRODUCTION

The production of small pelagics, in general, has increased in the APFIC region during the past 4 decades. Technological advancements in fishing craft and gears (for e.g., in India, Thailand and China), the discovery of new fishing grounds (for e.g., in the Gulf of Thailand) and the increase in the number and efficiency of fishing fleet in all the member countries during the past 4 decades are the major reasons for the increase in the landings. However, barring Japan and Australia, the fishery has developed without effective national and international management policies in the region. Most of the member countries have now realized that the stocks of many small pelagics are on the decline and hence are taking serious steps to assess and overcome the hurdles in implementing fisheries management. It is being increasingly realized that for the management of the marine fisheries resources, international cooperation through regional organizations has a particularly important role to play. Management of marine fish stocks, especially the straddling stocks, is necessary at the regional level, that is at a scale greater than national, but less than global in scope. The concept of a region, long applied by geographers to the terrestrial portions of the earth, is now applicable to the oceans (Hayashi, 1995). Management action on a transboundary stock taken by only one country on a part of its life cycle without cooperation of other parties involved in the exploitation of that stock would be futile, resulting in eventual depletion of that stock (Anon., 1996).

IMPORTANCE GIVEN TO REGIONAL COOPERATION IN RIO DECLARATION

Considering that the traditional concept of MSY is no longer adequate in any one particular geographical area, especially for the straddling stocks, the Rio Declaration of the United Nations Conference on Environment and Development (UNCED) adopted an agreement on precautionary approach to apply widely, both in the areas of national jurisdiction and the high seas. The agreement: (i) requires the

coastal countries and other countries fishing in the highseas to cooperate for the purpose of achieving compatible conservation and management measures in respect of the stocks concerned, (ii) stresses the biological unity and other biological characteristics of the stocks and the relationships between the distribution of the stocks, their fisheries and the geographical particularities of the region concerned; (iii) requires the coastal countries and other countries fishing in the adjacent highseas to inform each other of the areas under their national jurisdiction and for the highseas, respectively; (iv) stresses the need to make every effort to enter into provisional arrangements of particular nature (Hayashi, 1995), which could be made by the countries either directly or through regional organizations; and (v) attaches great importance to the role of regional fisheries conservation and management organisations. Where a competent regional organization already exists, the countries concerned shall cooperate by becoming members of such organizations and/or by agreeing to apply the management measures established by such organizations. Only those states which become members shall have access to the fisheries resources of the region. With respect to the regions where no such organization exists, the agreement obliges relevant countries to cooperate and establish such an organization and participate in its work.

REGIONALIZATION OF MARINE AREAS

Regionalizing the oceans is not a new idea; the Pacific, Atlantic and Indian Oceans are large geographic areas recognized as distinct marine regions for centuries. The concept of small regions or subregions of the oceans such as the South China Sea, Gulf of Thailand and Bay of Bengal is gaining considerable importance from the point of view of managing the fisheries resources. However, it is somewhat difficult to delineate the regions precisely as there is no characteristic homogeneity within any region. Inspite of this difficulty, management of marine fisheries resources calls for close cooperation among the countries of a region, which are analogous in many respects (Morgan, 1994). The Third United Nations Conference on the Law of the Sea (UNCLOS III) believes that it is not necessary, and further, it is inconvenient, to make efforts to define a region very precisely. Any kind of cooperation developed by the concerned countries in a given part of the ocean is regional, without considering whether the marine area involved in cooperation has features that justify regarding it as a region (Vallega, 1994). The areas in the APFIC region, for instance, vary greatly in physical and environmental conditions. The region encompasses typical tropical, temperate and near-polar areas. The littoral and island countries in the South Asian region are generally characterized by very high population density, low to very low per capita income, vast hinterlands that generate substantial agricultural production, extensive freshwater and brackish water resources with significant aquaculture potential and increasing industrial growth. On the other hand, the oil producing countries around the Persian Gulf are generally characterized by very high per capita income and availability of only a restricted hiterland for agricultural production, but very high growth of oil-based industries. A third category is the highly industrial countries such as Japan and Korea. In addition to these differences in the economic status of the countries in the APFIC region, there are also diversities in political philosophy, governmental set up, ethnicity, culture, religion and food habits between the

countries. It is against these national and regional settings, one has to look for the prospects of fostering regional cooperation between the member countries for the development and management of fisheries in both the inshore and offshore areas of their exclusive economic zones.

FACTORS TO BE CONSIDERED FOR REGIONAL COOPERATION

Notwithstanding its undoubted advantages, the development of marine regional cooperation is a complex and difficult process. It is essential to view regional cooperation in marine fisheries in the wider context of the entire economy, and in relation to the priority ratings given by the member countries. The need for regional cooperation for economic objectives is being increasingly felt all over the world, particularly by the third world; however, the problems of bilateral or regional nature hinder rapid progress inspite of national aspirations towards this cause. Several countries which are not members of any regional organization, are not bound by the code of conduct for fishing. There is an increasing trend by fishing vessels evading management regimes by reflagging their vessels to flags of the countries which are not members of an international fisheries organization (Anon., 1993). This means that they can continue fishing in the areas beyond the EEZ without having to comply with the regulations set by the international bodies for their members. Hence, the viability of the entire system of conservation is being threatened. Management at regional level, to be effective, will have to be political, and tangible support among the participating countries is required. Land-based cooperation is a prerequisite for marine oriented regionalism. The state of affairs in the APFIC region to foster regional cooperation for marine fisheries are discussed below.

(i) The fish stocks, which are being shared between countries, need to be identified together with their stock areas. Determination of migratory routes and patterns, spawning season and frequency and stock abundance is very vital for the management of shared stocks. However, information on these aspects is lacking or inadequate in respect of many of the stocks. The FAO/SEAFDEC workshop on shared stocks has identified 40 stocks as being shared by two or more countries in the Southeast Asia (Anon., 1985). Devaraj and Vivekanandan (1997; this volume) have provided a list of probable shared stocks in the other areas within the APFIC region. It is important that a complete list of stocks that are shared by two or more countries in the APFIC region is prepared.

(ii) There is an urgent need to integrate national research efforts into a cooperative programme for the assessment of major stocks exploited by the member countries in the APFIC region to determine the total allowable catch (TAC) which may be shared by the concerned countries on an equitable basis. Every maritime country should undertake cooperative research and investigations with the neighbouring countries in the areas of common interest. Research institutions in marine fisheries and oceanography in these countries should be fully equipped to handle this task. Once the TAC is determined for the EEZ and the international waters of each marine region, there should be appropriate national and regional strategies for realising the target yields.

(iii) Whereas adequate capabilities exist in several countries in the APFIC region to generate optimum yields from the territorial seas, capabilities of many countries are inadequate for areas beyond the territorial seas. This has resulted in poaching close to or within the territorial seas. Apparently, the poaching vessels do not have the knowledge of abundance of the resources. The future of the development of high seas fisheries in the region would depend on the identification of resources of high enough abundance for commercial operations. Hence, there is need for proper assessment of the profitability of exploiting the high seas resources prior to the commencement of commercial fishing ventures.

(iv) Commercial fishing ventures should consider the possibility of regional joint ventures between countries possessing the fishery resources, but lacking in capital and technology and those possessing surplus fleet capacity. In all the proposals for joint ventures, intra regional tie-ups should be preferred to tie-ups with countries from outside the region.

(v) The immediate challenge arising from the agreements on regional cooperation is the surveillance of the economic zones for the protection of the resources, for which many of the countries do not possess the requisite capabilities. Therefore, it may be worthwhile to pool and share whatever national facilities exist for offshore surveillance and protection on a common basis, and share the cost on an equitable basis. It would be advisable to take into consideration the facilities available among the participating countries and evolve a suitable operational arrangement within the regional framework.

(vi) Another important area where cooperation could be of great help is in respect of post-harvest technology and marketing among the APFIC countries. The post-harvest and marketing strategies have developed in 3 distinct ways in the APFIC region (Devaraj and Vivekanandan, 1997; this volume). In India and Sri Lanka, the small pelagics are consumed mostly in fresh condition or sundried and there is scope for these countries to develop suitable post-harvest technologies for the production of value added fish and fish-based products. On the other hand, the Southeast Asian Countries have developed a number of value added products from the small pelagics. In the third category, Australia and Japan use a large portion of the small pelagics as fish meal. It is essential that all these countries coordinate with each other and launch upon joint programmes within the region to convert the low value species into value added products for direct human consumption by making use of the available expertise.

(vii) Establishment of priorities as well as the urgency of the needs is essential if limited resources in terms of funding, staff and facilities have to be used to the greatest advantage. The logical step is to provide access to the needy countries, under procedural arrangements with those possessing the competence. Funding seems to be a major constraint for the implementation of identified opportunities, and this applies to both national governments and international agencies. Although certain basic funding can be met from within the normal national budgetary processes, there may be extraneous costs, usually involving

foreign exchange, which present particular funding constraints at the national level.

Therefore, cooperation in such important supporting services like banking will be a prerequisite to sustain not only fisheries development, but the regional economy as well. A regional investment bank may be expected to play a major role in financing small and medium projects of mutual interest in all economic spheres including fisheries. It is suggested that the formation of a regional bank may be initiated with an initial capital, which could go up subsequently through subscriptions from extra-regional sources as in the case of the Asia Development Bank. A regional investment institution will have a better credit rating, and may thus be in a position to make bond issues or arrange syndicated loans from international capital markets on better terms than that from the national entities. In any event, an investment corporation would be a useful instrument for giving ideas for regional cooperation a concrete bankable form (Mukerjee, 1980). Until such time when a regional banking institution is established, supportive international aid agencies could assist by providing funding or topping up money to cover areas of financial deficit. An ongoing need for supportive funding in fisheries is clearly seen by the Eastern Indian Ocean and Western Central Pacific countries. Therefore, withdrawal or non-availability of such funding will seriously jeopardize current cooperative efforts within fisheries, and will undoubtedly slow down the development process as a whole unless replaced by alternative input arrangements such as a regional bank.

INTERNATIONAL ORGANIZATIONS IN THE APFIC REGION

For identifying the important opportunity areas (a few of which have been outlined above) and for implementing the identified programmes, a suitable machinery comprising the representatives of all the participating countries has to be established. The machinery's role should include primarily: (i) mechanisms for the identification of projects in which all the member countries would participate and those in which cooperation could be bilateral or trilateral; (ii) formulation and implementation of projects; and (iii) funding arrangements. For the purpose of project identification, the machinery could request the member countries to prepare twin and complementary lists which identify the needs and their priority on the one hand and competence on the other.

Besides the research, development and management network in the individual countries, there are several international organizations in the APFIC region which assist and coordinate national and international programmes in fisheries development, promote regional research activities and examine management problems. These organizations include the APFIC for the entire Asia-Pacific region; the Indian Ocean Fishery Commission (IOFC) and the Indian Ocean Tuna Commission for the Western and Eastern Indian Ocean; the Bay of Bengal Programme for the Eastern Indian Ocean; the Fisheries Forum Agency (FFA), the Southeast Asian Fisheries Development Center (SEAFDEC), the International Center for Living Aquatic Resources Management (ICLARM) and the South Pacific Commission (SPC). Although there is no regional fisheries organization in the Northwest Pacific, various bilateral agreements exists. PICES is the forum for communication among fishery scientists from the whole North Pacific. All these

promotional bodies play only advisory roles, and do not have any regulatory powers.

For the effective implementation of any integrated and coordinated policy on regional cooperation, an intergovernmental consultative machinery is important in addition to the international bodies. This machinery will have to meet periodically to formulate, establish and supervise the implementation of the policy guidelines. Such consultative organizations and regional fisheries forums could jointly coordinate regional multilateral and bilateral programmes and thereby eliminate wasteful duplication by national and international institutions (Kwiatkowska, 1990). At present, the Southeast Asian and other areas in the Indian Ocean are provided with the possibility of realizing such consultative and coordinating functions, including fisheries through collaborative activities within the framework of the Indian Ocean Marine Affairs Cooperation Conference (IOMAC), which is an organization functioning outside the United Nations system. Other areas in the APFIC region lack such intergovernmental consultative organizations. The overall concept of the IOMAC in implementing an integrated ocean policy (including the living resources) is identified in the following five major stages (Kwiatkowska, 1990): (i) Promoting awareness, assessment and plan, (ii) training, (iii) establishment of organizations, (iv) basic institutional support, and (v) direct country support. In the wider and nonhomogeneous regions such as the Indian Ocean, the ultimate achievement of the objectives is expected to occur first in the subregions and subsequently on a longer perspective in the entire region.

In addition to the international bodies and intergovernmental machinery's, there are several intergovernmental agreements within the region. (i) Following the joint venture fishery arrangements in the development area between Thailand, Malaysia and Indonesia under the new Economic Triangle, or IMT-GT (Indonesian-Malaysian-Thailand Growth Triangle) Project, which covers the northern Malacca Strait, increased catches in the area are expected. (ii) The excess fleets of Thailand exploit the waters of the neighbouring countries through various bilateral agreements. (iii) Within the terms of an Australian-Indonesian memorandum of understanding, the Indonesian fishermen continue to operate in an offshore area adjacent to the Kimberly coast (the most eastern part of the Indian Ocean). (iv) Indonesia provides fishing access to foreign fleets 18 km off the archipelago primarily in the South China Sea and on the Pacific side. (v) Fishermen from Japan and New Zealand have been granted fishing rights in the Australian waters through bilateral agreements. (vi) As the stock of the southern bluefin tuna is limited and heavily exploited, a regional initiative involving Japan, Australia and New Zealand in the joint management of this stock has been established. (vii) With the termination of the Indo-Pacific Tuna Programme (IPTP), the cooperation in tuna fisheries between the member countries will be accommodated within the framework of the Indian Ocean Tuna Commission (IOTC) which covers all the countries bordering the Indian Ocean and the non-coastal countries fishing in the Indian Ocean (Anon., 1995). (viii) France, Spain, Taiwan, Republic of Korea and Japan exploit tuna and tuna-like fishes in the Western Indian Ocean. (ix) In the Persian Gulf, special committees have been set up for the management of fish stocks, particularly the Indian Ocean tuna. (x) Among the Northwest Pacific

countries, 5 bilateral fishery agreements currently exist through which management of the shared stocks is partially conducted (Anon., 1992). (xi) India relied on a system of licensing international vessels on charter and on joint venture basis in the 1980s and the 1990s, but could not make much headway due to internal resentment.

Many of the international bodies and intergovernmental agreements mentioned above have a number of characteristics required for a regional organization and hence are in a position to help their member countries implement some of the management programmes. These organizations can transform into a regional fisheries forum where the roles played by the member countries could be coordinated.

As there are several regional bodies which would result in heavy expenditure on establishment and possible duplication of effort, it was agreed in 1972 by the International Coordination Committee of the IOFC that proliferation and duplication of international bodies was undesirable (Anon., 1972). Hence, serious consideration should be made by the countries in the region as to whether a new regional forum should be developed or the existing bodies enhanced (Anon., 1996). However, all the countries are not members of the same organization. Furthermore, many of these organizations and participating countries are facing financial crunch and hence forced to observe austerity. Taking these problems into account and noting that a number of countries in the region do not prefer, at this stage, to consider setting up a new regional mechanism or upgrading an existing mechanism, the FAO proposed (i) strengthening the activities of the APFIC and (ii) establishment of a joint secretariat working/party with a view to reinforcing technical cooperation among the concerned organizations (Anon., 1996).

POSSIBLE METHODS OF IMPLEMENTING REGIONAL COOPERATION

The following principles and guidelines should be taken into account by the regional fisheries forum while examining the changing needs for international collaboration and for charting the roles of the member countries (Marashi, 1996): (i) Objectives of international cooperation should include contribution from all the parties involved on the basis of their experience and capacity, leading to the enhancement of national capabilities and transfer of technology. (ii) Cooperative research efforts and technical cooperation should have clearly identified objectives, responsibilities and deadlines. (iii) Central collection and analysis of data from all fleets fishing a common resource. (iv) Adequate financial resources, other resources and technical support should be provided to support regional bodies. There is thus an urgent need to mobilize much greater funds for regional cooperation. As soon as possible, developing countries should increase their participation and commitment to the technical support of such bodies as well as take full responsibility for the management. (v) Where appropriate, closer collaboration should be established between the FAO regional fisheries bodies and projects on the one hand and regional economic groupings and organizations concerned with fisheries on the other.

By and large, many developing countries in the APFIC region lack the expertise in integrated fisheries policy making and management. Regional organizations can play an important role in overcoming the drawbacks of the developing countries. The implementation of various national fisheries management schemes will be expensive, but the costs and implementation can be reduced substantially through suitable regional cooperative effort (Anon., 1996). These include the conduct of cooperative management research on fish stocks particularly those that are commonly exploited and the development of suitable stock assessment techniques applicable to the multigear, multispecies situation. Regional cooperation can play an important role in the transfer of technologies commonly required by the countries in the region, human resources development and capacity building for proper management and development of fisheries. Realising the nature of distribution of the resources, the high cost of their management and the technological capability that is required, the report by the Commonwealth Expert Study Group on Maritime Policies which was set up by the Commonwealth Heads of Governments of Asia Pacific region concluded that regional cooperation is the most viable method for achieving the optimum potential benefits of the oceans.

REFERENCES

Anon., 1972. Proceedings of the 15th session of Indo-Pacific Fisheries Council. FAO Report (1972): 76 pp.

Anon., 1985. Report of the FAO/SEAFDEC workshop on shared stocks in southeast Asia. FAO Fish. Rep., 337: 97 pp.

Anon., 1992. Review of the state of world fishery resources. Part 1. Marine resources. FAO Fish. Circa., 710: 114 pp.

Anon., 1993. Marine fisheries and the law of the sea: a decade of change. FAO Fish. Circa., 853: 66 pp.

Anon., 1995. Review of the state of world fishery resources: marine fisheries. FAO Fish. Circa., 884: 105 pp.

Anon., 1996. APFIC and the sustainable development of southeast Asian fisheries. RAP Publ., 11: 51 pp.

Devaraj, M., and E. Vivekanandan. 1997. A comparative account of the small pelagic resources in the APFIC region (this volume)

Hayashi, M., 1995. The 1995 agreement on the conservation and management of straddling and highly migratory fish stocks: significance for the Law of the Sea Convention. Ocean & Coastal Management, 29: 51-69pp.

Kwiatkowska, B., 1990. Institutional marine affairs cooperation in developing state regions. Marine Policy, 14: 385-420pp.

Marashi, S.H., 1996. Summary information on the role of international fishery and other bodies with regard to the conservation and management of living resources of the high seas. FAO Fish. Circa., 908: 104 pp.

Morgan, J.R., 1994. The marine region. Ocean & Coastal Management, 24: 51-70.

Mukerjee, D., 1980. Cooperation among ASEAN, sudden movement forward. Times of India, Nov 17, 1980pp.

Vallega, A., 1994. The regional scale of ocean management and marine region building. Ocean & Coastal Management, 24: 17-37pp.

ASIA-PACIFIC FISHERY COMMISSION
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC