SCIENTIFIC COOPERATION TO SUPPORT RESPONSIBLE FISHERIES IN THE ADRIATIC SEA

MiPAF

Food and Agriculture Organization of the United Nations

Italian Ministry of Agriculture and Forestry Policies

Adriamed

GCP/RER/010/ITA

The Biology and Stock Assessment of *Merluccius merluccius* (L.) in the Adriatic Sea: an Historical Review by Geographical Management Units

Paper presented at the GFCM-SAC Working Group on Demersal Species

Tunis, 13th-16 th March 2001

GCP/RER/010/ITA/OP-03 Termoli (Italy), March 2001

The biology and stock assessment of *Merluccius merluccius* (L.) in the Adriatic Sea: an historical review by geographical management units*

NICOLA UNGARO[1], NEDO VRGOC[2], PIERO MANNINI[3]

ADRIAMED Project

[1] Laboratory of Marine Biology (Bari, Italy)
[2] Institute of Oceanography and Fisheries (Split, Croatia),
[3] FAO-Adriamed Project (Termoli, Italy)

Abstract

The hake (Merluccius merluccius) *is one of the main commercial and heavily exploited species of the demersal fishery of the coastal countries in the Adriatic Sea. This paper aims to critically review the existing information on the population dynamics and stock assessment of this resource. It is highlighted that, despite the fact that most of the research would indicate very high levels of fishery exploitation of the species for a long time, apparently fishery production has not experienced major crisis over the years. Some of the possible reasons behind this contradiction, which should be taken into account for future research, are discussed. Some programmes also relevant to the hake under implementation at basin level by the FAO-Adriamed Project are reported.*

Introduction

The hake is one of the most studied demersal species in the Adriatic Sea, partly due to its substantial impact (due to the species abundance and economic value) on fishery activities in the basin. Annual hake landings in the Adriatic were estimated at 2000-4000 tons during the eighties-nineties according to the General Fisheries Commission for the Mediterranean (GFCM) statistics, and the species resulted the most abundant within the "demersal group" (percentage larger than 16% in the last fifty years, as reported by Jukic *et al*., in press). In general Italian landings did not show a well-defined trend, a positive trend could be observed in the eastern Adriatic where demersal fishery appeared to have developed quickly during the 1990s (Mannini & Massa, 2000). However since the relatively high landing figure of 1993, a marked decrease during the last four years (1994-1997) can be observed.

Biological, ecological and distributional studies have been published in the last century since the fifties, and "basic" information on the species biology in the Adriatic was reported in the papers by Matta (1954), Ghirardelli (1959), Karlovac (1959) and Zupanovic (1961). Other papers on biology and ecology were published between 1965 and 1976 (Karlovac, 1965; Piccinetti & Piccinetti Manfrin, 1971a, 1971b; Jukic, 1972; Froglia, 1973; Jardas, 1976), and in the same years first studies on the population dynamics were available (Zupanovic, 1968; Levi & Giannetti, 1972).

* This paper was conceived as a follow-up to the Adriamed Working Groups on Shared Demersal and Small Pelagic Fishery Resources meeting held in Bari (February 2001), where regional experts from Albania (FRI, Dürres; FD, Tirana), Croatia (IOF, Split), Italy (LBMB, Bari; IRPEM, Ancona; LMBF, Fano; ICRAM, Chioggia) and Slovenia (NIB, Ljubliana) agreed upon the suitability of producing such a paper and requested the authors to prepare it.

The eighties were the years of "population dynamics", "stock assessment" and resource-fishery interactions in the Adriatic and various papers developed these subjects together with biological features (Jukic & Piccinetti, 1981; Flamigni, 1984; Jukic & Arneri, 1984; Bello e*t al*., 1986; Giovanardi *et al*., 1986; Jukic & Piccinetti, 1987a, 1987b; Alegria Hernandez et al., 1982; Zupanovic & Jardas, 1986; Alegria Hernandez & Jukic, 1988; Zupanovic & Jardas, 1989).

Some of the topics mentioned (both biology and stock assessment) were also developed during the nineties (Alegria Hernandez & Jukic, 1990; Alegria Hernandez & Jukic, 1992; Ungaro *et al*., 1993; Ungaro *et al*., 1996; Ungaro & Marano, 1996; Ardizzone, 1998), in the same period new papers on time-series approach were published (Piccinetti & Piccinetti Manfrin, 1994; Marano *et al*., 1994; Manfrin *et al*., 1998; Marano *et al*., 1998a, 1998b; Ungaro *et al*., 1998). Moreover, some information on the multi-gear exploitation of the hake resource in the Adriatic was reported (De Zio *et al*., 1998), as well as the reproposal of the importance of nursery areas (Frattini & Paolini, 1995). In the end, new mapping techniques (*i.e.* GIS) allowed recent analysis on the distribution pattern of the resource in the basin, but only at national level (Italian waters up to the limit of international waters) (Ardizzone & Corsi, 1997; Ardizzone *et al*., 1999).

Despite the large amount of information, the published papers have a "local outline" (with few exceptions) and they referred to particular areas (Northern, Central or Southern Adriatic) mostly within national borders or international waters limits.

In recent years the GFCM promoted discussion on the definition and delimitation of the Management Units within the Mediterranean. With regard to the Adriatic Sea, two Geographical Management Units (henceforth M.U.) were proposed during the 24th GFCM session (Alicante, 7-15 July 1999) and at the GFCM-SAC (Scientific Advisory Committee) Working Group on Management Units (Alicante, 23-25 January 2001); the first Adriatic M.U. covers the whole extension of the Northern and Central Adriatic Sea, the second one the whole extension of the Southern part (Adriamed, 2001).

The main purpose of the present paper is to review the literature available on the hake resource on the basis of the above-mentioned M.U. and also to indicate some of the research programmes relevant to the Adriatic hake which are being implemented within the FAO-Adriamed Regional Project framework.

Review of bibliographic data

This section includes some published results on hake biological features (growth, reproduction, feeding), population dynamics, stock assessment and time-series studies.

1. Management Unit 37.2.1.a (Northern and Central Adriatic)

1.1 Biological features

Growth. Growth parameters reported values are: $L\infty$ = 85 cm, K = 0.12 yr^{-1} (Jukic & Piccinetti, 1981; Flamigni, 1984). Other papers reported age per length values also (Tab. 1) (Zupanovic, 1968; Jukic & Piccinetti, 1981; Flamigni, 1984). The information reported refers to combined sexes, but a differential growth by sex was underlined in some papers (Jardas, 1976).

Table 1. *M. merluccius*: age per length estimations in the Northern and Central Adriatic Sea.

Age (years)	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***
TL (cm)	9-19	19-26	28-33	35-39	40	44	49	57

Reproduction. Most papers report a long spawning period during the year (Karlovac, 1965; Zupanovic, 1968; Jukic & Piccinetti, 1981). Length-at-maturity was recorded at 20-30 cm (TL) and 26-33 cm (TL), for males and females respectively (Zupanovic, 1961; 1968; Jukic & Piccinetti, 1981).

Feeding. Hake feeds mostly on fish (> 60% of prey items) and crustaceans (>15%) as a general rule; the percentage of preyed fish increases with hake length, while crustaceans mostly occur in the stomach of hakes smaller than 16 cm (Karlovac, 1959; Zupanovic, 1968; Piccinetti & Piccinetti Manfrin, 1971a; Jukic, 1972; Froglia, 1973; Jardas, 1976).

1.2 Population dynamics, stock assessment and time-series studies.

Most of the studies referred to the analysis of the catches from trawlers (landings and mostly scientific surveys) (Zupanovic, 1968; Jukic & Piccinetti, 1981; Flamigni, 1984; Jukic & Arneri, 1984; Giovanardi *et al*., 1986; Jukic & Piccinetti, 1987a, 1987b; Alegria Hernandez et al., 1982; Zupanovic & Jardas, 1986; Alegria Hernandez & Jukic, 1988; Zupanovic & Jardas, 1989; Alegria Hernandez & Jukic, 1990; Alegria Hernandez & Jukic, 1992; Piccinetti & Piccinetti Manfrin, 1994; Manfrin *et al*., 1998). All the papers identified the depth range 100-200 m as an area characterised by a concentration of juveniles. Length distributions also appeared to be quite similar over a long-time period (thirty years) (see the paper from Zupanovic, 1968, and the paper from Manfrin *et al*., 1998), and most of the catches were represented by specimens lesser than 20 cm TL (Zupanovic & Jardas, 1986).

With regard to abundance indices, Jukic & Arneri (1983), reported a CPUE (kg/trawling hour) maximum value of 6 kg/h during the years 1948-49, while it was around 3 kg/h in the year 1982. Jukic & Piccinetti (1981) reported a value of 6 kg/h during the years 1972-73, and similar values were also found during the nineties (Manfrin *et al*., 1998). A maximum production (MSY) of 3000-4000 tons/year was estimated for the basin during the years 1972-73 (Jukic & Piccinetti, 1981).

Natural mortality estimates ranged mostly between 0.2 and 0.3 yr^{-1}, while total mortality (Z) referenced values, calculated by means of catch curve and Heincke methods, were higher than 0.8 yr^{-1} in most assessment (Zupanovic, 1968; Jukic & Piccinetti, 1981; Flamigni, 1984; Giovanardi *et al*., 1986; Jukic & Piccinetti, 1987a, 1987b; Alegria Hernandez & Jukic, 1990; Alegria Hernandez & Jukic, 1992). Results from global models underlined hake stock overexploitation since from sixties (Levi & Giannetti, 1972; Alegria Hernandez *et al*., 1982).

Recent time-series studies carried out in the western part of the M.U. (Piccinetti & Piccinetti Manfrin, 1994; Manfrin *et al*., 1998) showed an apparent increasing trend in survey catch rates from 1985 to 1995 and a decreasing trend during the last two years (Fig. 1), but small quantitative variations with respect to previously published data. The catches were mostly represented by specimens lesser than 20 cm TL in all the surveys, and the shape of length distributions remained quite stable during the full time-period considered (Fig. 2).

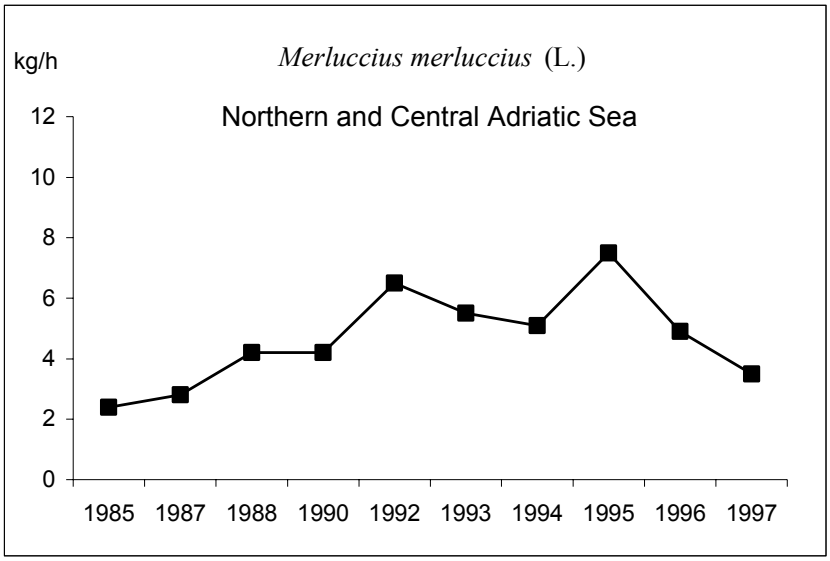

Figure 1. Catch rates (kg/h) per year from trawl surveys 1985-1997 in the Northern and Central Adriatic Sea (data from Manfrin *et al*., 1998).

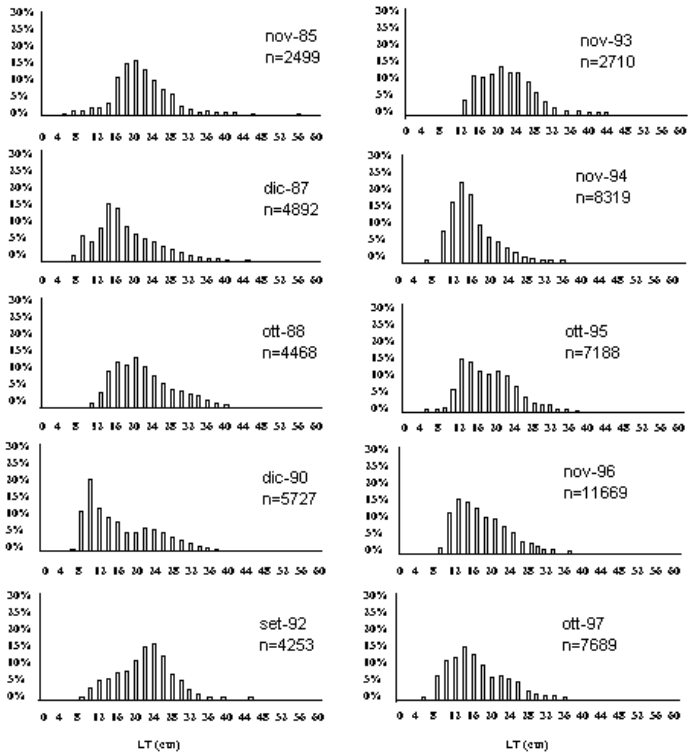

Figure 2. Length-frequency distributions per year of *M. merluccius* from seasonal (Autumn) trawl-surveys 1985-1997 in the Northern and Central Adriatic Sea (modified from Manfrin *et al*., 1998).

2.2 Management Unit 37.2.2.b (Southern Adriatic)

2.1 Biological features

Growth. Growth parameters have been reported for the females ($L\infty$ = 82.6 cm, K = 0.13 yr^{-1}) and combined sexes ($L\infty$ = 75.7 cm, K = 0.15 yr^{-1}), and a differential growth by sex was underlined (Ungaro *et al*., 1993; Ungaro & Marano, 1996).

Reproduction. A long spawning period during the year was determined, with peaks during summer and winter (Ungaro *et al*., 1993). Length-at-maturity was found at 25-30 cm total length (lower size for males, higher for females) (Ungaro *et al*., 1993).

Feeding. Hake feeds mostly on fish and crustaceans (> 80% of prey items) as a general rule; the percentage of preyed fish increases with hake length, while crustaceans mostly occur in the stomach of the hakes smaller than 15 cm (Ungaro *et al*., 1993).

2.2.1 Population dynamics, stock assessment and time-series studies

Most of the studies referred to the analysis of the catches from trawlers (mostly scientific surveys) (Bello *et al*., 1986; Ungaro *et al*., 1993; Marano *et al*., 1994; Ungaro *et al*., 1996; Ungaro & Marano, 1996; Marano *et al*., 1998a, 1998b; Ungaro *et al*., 1998). As far as length distribution is concerned, published papers mostly reported specimens in the size-range up to 20 cm TL, as reported for the previous M.U.

CPUE values ranged from 1.4 to 9.9 kg/h during the time-period 1985-1997 (Marano *et al*., 1998a). Mortality estimates have values (M =0.3 yr^{-1} and Z =1-1.7 yr^{-1}) comparable with the results of the Northern and Central Adriatic (Ungaro *et al*., 1993); a high exploitation rate resulted from the application of Thompson & Bell model (Ungaro & Marano, 1996).

The paper from De Zio *et al*. (1998) showed the catch size structure from the bottom long-line fishery (Fig. 3) and underlined the differences in comparison with trawl-survey catches (Fig. 2 and 5).

Recent time-series studies carried out in the western part of the M.U. (Marano *et al*., 1994; Marano *et al*., 1998a) showed an apparent increasing trend in survey catch rates from 1985 to 1993 and a decreasing trend from 1994 to 1997 (Fig. 4). The catches were mostly represented by specimens of less than 20 cm TL in all the surveys, and the shape of length distributions remained quite stable during the full time-period considered (Fig. 5). Trend analysis was carried out, both considering a “classic” approach (Marano *et al*., 1998b) and Arima models (Ungaro *et al*., 1998), and no significant trend was found.

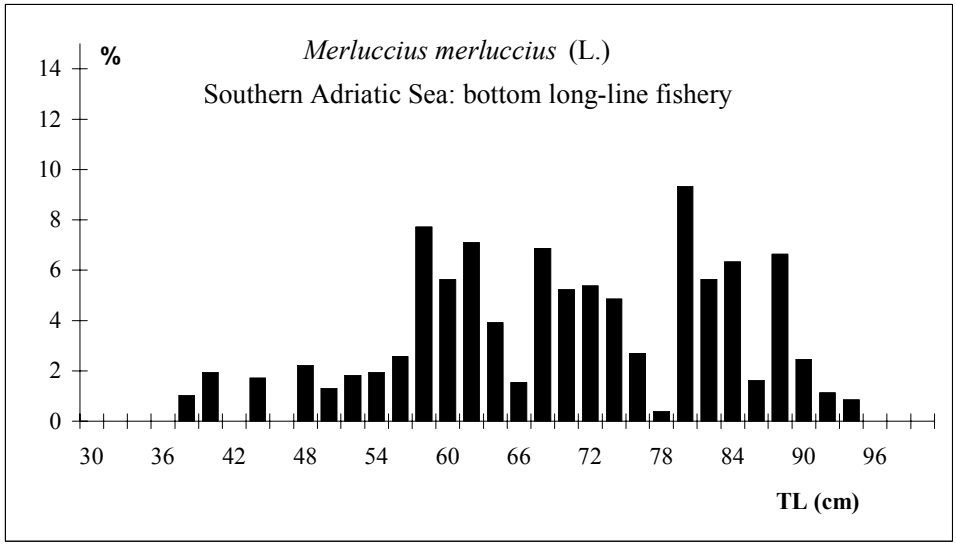

Figure 3. Length-frequency distributions of *M. merluccius* from bottom long-line fishery in the Southern Adriatic Sea (modified from De Zio *et al*., 1998).

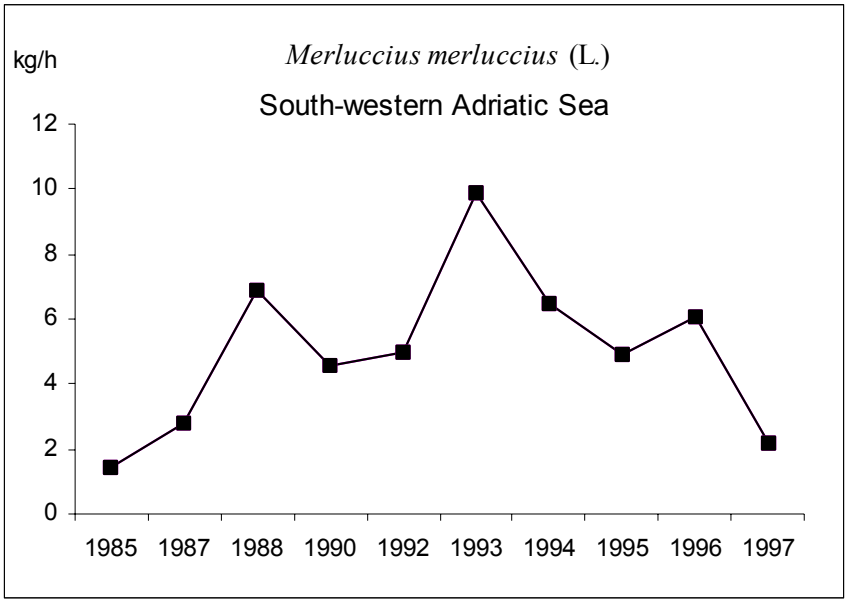

Figure 4. Catch rates (kg/h) per year from seasonal trawl-surveys 1985-1997 in the Southern Adriatic Sea (data from Marano *et al*., 1998a).

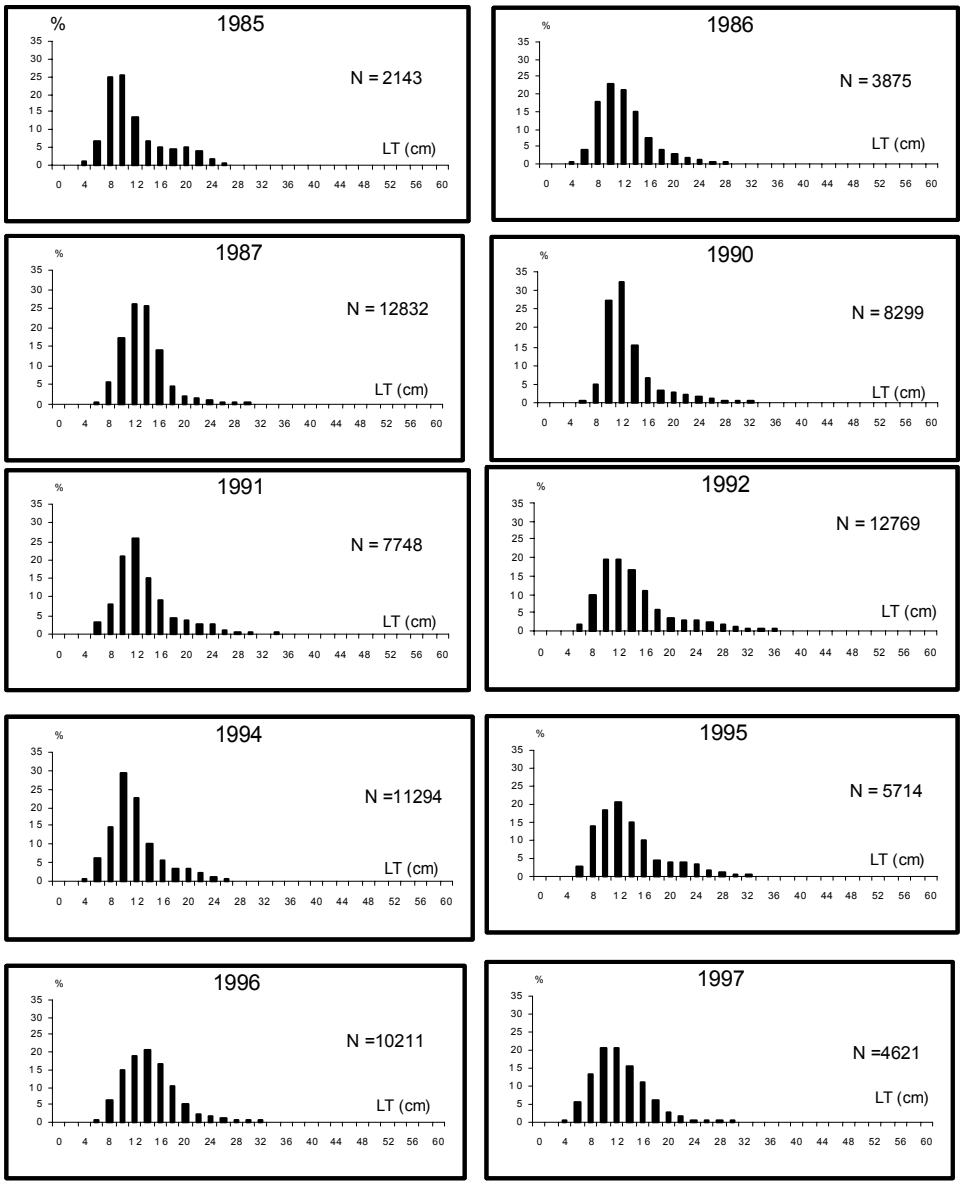

Figure 5. Length-frequency distributions per year of *M. merluccius* from seasonal (Autumn) trawl-surveys 1985-1997 in the Southern Adriatic Sea (data from Marano *et al*., 1998a).

On-going research projects implemented by Adriamed

In line with the Adriamed Project's main aim of supporting and strengthening scientific cooperation to foster joint fishery research and managememt at regional level, the experts collaborating within the Project framework have identified research priorities concerning shared demersal fishery resources of the Adriatic Sea. This is expected to improve the information available on the Adriatic Sea resources, to make available an up-to-date scientific database and to facilitate scientific cooperation in data collection, sharing and analysing. Consequently, research programmes are being elaborated and implementation is planned with the Project's assistance.

- ***International bottom trawl survey in the Adriatic Sea***. This programme consists in the execution of joint groundfish appraisal survey in late summer/autumn 2001 covering the whole Adriatic through the execution of hauls along the eastern part (Albanian, Croatian and Slovenian waters) to be integrated with the routine Italian bottom trawl survey programme. The main objective will be the spatial and temporal improvement of stock monitoring and assessment.
- ***Identification of management options for the Pomo/Jabuka Pit critical habitat***. This programme focuses on the study of the fishery resource dynamics and assessment of the Pomo/Jabuka Pit critical area, in order to identify appropriate management options (and if necessary research needs). *Ad hoc* group of scientists with particular knowledge of the Pomo/Jabuka Pit ecology and fishery productivity will be organised.
- ***Identification of biological unit of Adriatic Sea shared stocks based on genetic stock structure analysis***. This programme consists in the analysis of the genetic stock unit of target species, by means of DNA marker variation analysis.
- ***Regional training on fishery resources appraisal and joint stock assessment exercise***. This programme consists in the organisation of activities targeted to the enhancement of professional skills and strengthening of scientific co-operation in the Adriatic, through co-operative analysis of the available scientific information on shared stocks.

Discussion and Conclusions

In the Adriatic the "scientific heritage" of more than fifty years of fishery research is available, and it is probably one of the most important in the Mediterranean. The review of the bibliographic references underlines the following features:

1) The size composition from current and late 1940s trawl surveys showed juveniles as the main component of the catch (Fig. 6). However, it is uncertain whether the difference in the occurrence in the catch of larger size hake (>25cm) is due to sampling (e.g. trawl efficiency and selectivity) or to changes in the structure of the sampled population. It may be worth noting that as long ago as the 18th century Moller pointed out the high occurrence of juvenile hake in trawl catches (Moller, 1775, in Zupanovic & Jardas, 1986).
2) Abundance indices from the catches (kg/h, data from trawl-surveys) did not indicate any clear trend, but showed quite large fluctuations over a long-time period. Reported statistical landing data mostly agreed with this tendency (Mannini & Massa, 2000).
3) Indices of exploitation, such as Z, F and E, were found to have high values for the last thirty years. Global and analytical models gave similar indications.

The discrepancy between the high estimated values of exploitation parameters and the fishery performance in terms of yield over most of the years may be noted, and some of the possible reasons could be summarised as follows:

- the length structure of stock is strongly related to the trawl gear selectivity. In the Adriatic the authorised mesh-size of commercial trawl-nets has ranged between 30 and 40 mm since the fifties, so the length at first capture (50%) is around 10-12 cm (much smaller with respect to maturity length) and juveniles are the main component of the commercial catch (N.U., pers. obs.). The catchability of large specimens is low with respect to the trawl net, while other gears (bottom long-line) mostly collect them. So, most of the available length structures only represent fractions of the hake population.
- Most growth parameter estimates are probably biased due to the sampling procedures and subsequent data are unlikely to be fully representative of the population at sea (see previous comment).
- Mortality estimates are probably biased. Natural mortality values are affected by estimation methods and feel the effect of "constant assumption", which may be particularly relevant for the juveniles, while Z values from catch-curve were overestimated because of the analysed length-age distributions (trawl surveys). Consequently, the resulting F is necessarily overestimated since F = Z-M.
- Application of global and analytical models (Beverton & Holt, Thompson & Bell, etc.) with the parameters mentioned could give a misleading information.

Aside from any controversy, Adriatic trawl fishery mostly targeted on the juvenile fraction of the hake population but the same population remains apparently stable. Could it be attributed to the "refugium concept" (Caddy, 1993)? The hake population compensated for the decrease of other predators (Jukic *et al*., in press)? And, most importantly, how sustainable is the fishing pressure on juveniles?

We can try to solve both these questions by using different stock assessment approaches (Abella *et al*., 1997) and by means of studies referring to the recruitment (e.g. ad hoc trawl surveys), focussing on the nursery/spawning areas in the Adriatic (i.e. Pomo/Jabuka Pit) and also monitoring the hake catch from other gears (i.e. bottom long-line). Moreover, the comparison and integration of the essential fishery-independant data (trawl survey) with fishery-dependant data (commercial catch) would greatly contribute to the improvement of the information available for stock assessment purposes. It is widely recognised that it is important to take into account in an appropriate manner all available information for the assessment of fishery resources. Currently, efforts are being made through Adriamed to list, integrate and cooperatively utilize the present and past information on the Adriatic Sea fishery resources available in the region.

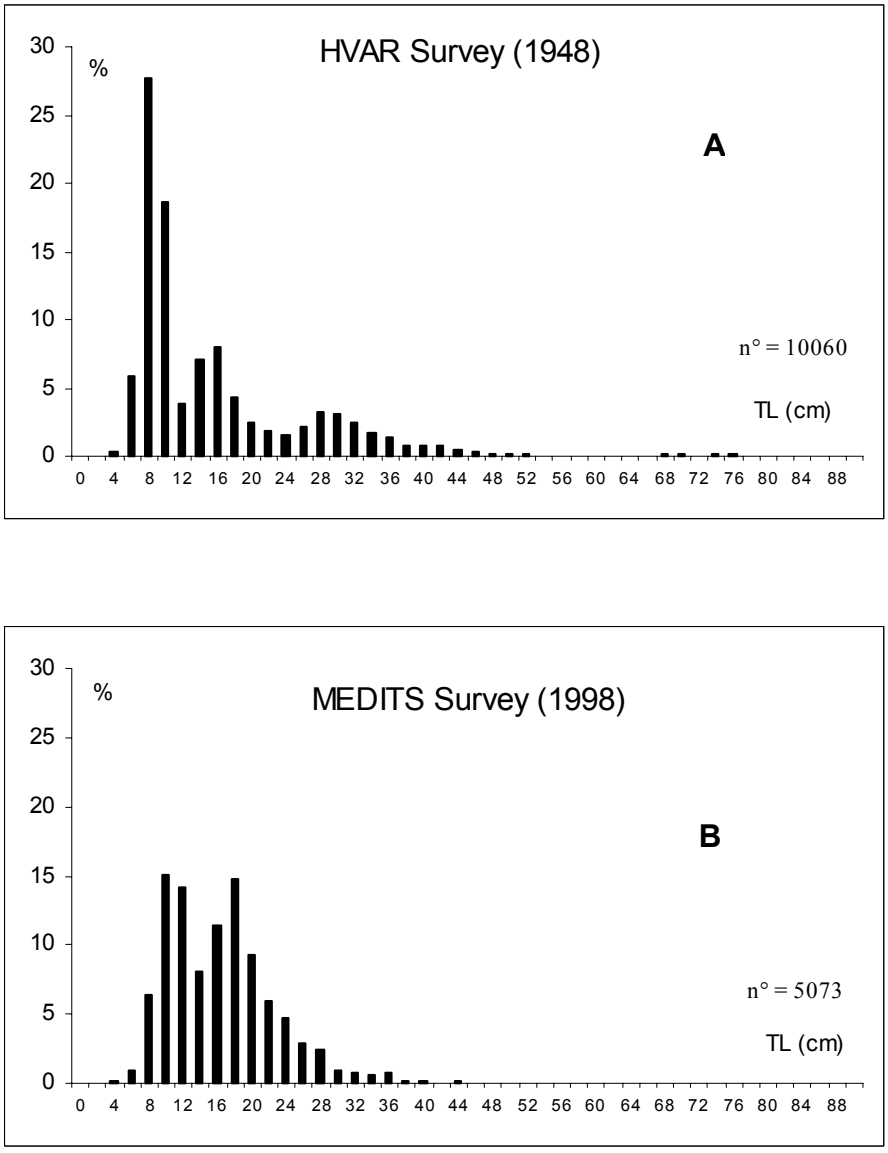

Figure 6. Length distributions of *M. merluccius* from two trawl-surveys carried out at fifty years period in the same Adriatic area and season (spring-summer) (A = Hvar Survey, 1948; B = Medits Survey, 1998).

Acknowledgements

The assistance of Roberto Gramolini and Fabio Massa in the preparation of this document is gratefully acknowledged.

References

Abella A.J., Caddy J.F., Serena F. – 1997 – Do natural mortality and availability decline with age? An alternative yield paradigm for juvenile fisheries, illustrated by the hake *Merluccius merluccius* fishery in the Mediterranean. *Aquat. Living Resour*., **10**: 257-269.

Adriamed – 2001 – The geographical management units of the Adriatic Sea. *Paper presented at GFCM-SAC Working Group on Management Units (Alicante, 23-25 January 2001).*

Alegria Hernandez V., Granic B., Jukic S. – 1982 - The protection of the hake (*Merluccius merluccius* L.) in the Adriatic Sea by regulation of the level of exploitation. *Acta Adriatica*, **23**(1-2): 431-440.

Alegria Hernandez V., Jukic S. – 1988 – Stock-recruitment relationship for the hake (*Merluccius merluccius* L.) from the open middle Adriatic – Jabuka Pit. *FAO Fish. Rep*., **394**: 137-141.

Alegria Hernandez V., Jukic S. – 1992 - Abundance dynamics of the hake (*Merluccius merluccius* L.) from the middle Adriatic sea. *Bull. Inst. Océanogr. Monaco*, **11**(n° spécial): 151-161

Alegria Hernandez V., Jukic S. – 1990 - Some aspects of biology and population dynamics of the hake (*Merluccius merluccius*) from the Adriatic sea. *Rapp. Comm. int. Mer Médit*., **32** (1): 265.

Ardizzone G. D. – 1998 – Un tentativo di valutazione delle condizioni di *Merluccius merluccius* e *Mullus barbatus* nei mari italiani. *Biol. Mar. Medit*., **5** (2): 151-168.

Ardizzone G. D., Corsi F. (Eds) – 1997 – Cartography of the italian demersal resources. Experimental trawl surveys (1985-1987). *Biol. Mar. Medit*., **4**(2): 479 pp.

Ardizzone G. D., Corsi F., Agnesi S. (EDS) – 1999 – Atlante delle Risorse Ittiche Demersali Italiane Triennio 1994-1996. Ministero per le Politiche Agricole. Roma, 1999.

Bello G., Marano G., Rizzi E., Jukic S., Piccinetti C. - 1986 – Preliminary survey on the Adriatic hake, *Merluccius merluccius* (L.) within the demersal resources assessment programme, spring 1985 survey. *FAO Fish. Rep.***, 345**: 200 – 204.

Caddy J.F. – 1993 – Some future perspectives for assessment and management of Mediterranean fisheries. *Sci. Mar*., **57**: 121-130.

De Zio V., Ungaro N., Vlora A., Strippoli G. – 1998 - Lo stock di nasello del Basso Adriatico: struttura demografica e rendimenti di pesca della frazione catturata con palangaro di fondo. *Biol. Mar. Medit*., **5** (2): 128-135.

Flamigni C. - 1984 – Preliminary utilization of trawl survey data for hake (*Merluccius merluccius* L.) population dynamics in the Adriatic sea. *FAO Fish. Rep*., **290**: 109 – 115.

Frattini C., Paolini M. – 1995 - Ruolo delle acque profonde nel medio Adriatico quale nursery per *Merluccius merluccius* (L.). *Biol. Mar. Medit*., **2** (2): 281-286.

Froglia C. – 1973 – Osservazioni sull'alimentazione del merluzzo (*Merluccius merluccius* L.) del medio Adriatico. *Atti V Congr. Soc. It. Biol. Mar., Edit. Salentina*: 327-341.

Ghirardelli E. – 1959 – Contribution to the knowledge of the biology of the hake (*Merluccius merluccius* L.) in the Middle Adriatic. *Proc. Gen. Fish. Coun. Medit*., **5**: 489-494.

Giovanardi O., Rizzoli M., Jukic S. - 1986 – Preliminary consideration on the fishery management of the hake (*Merluccius merluccius* L.) stock in the Adriatic sea. *FAO Fish. Rep*., **345**: 71 – 77.

Jardas I. – 1976 – Contribution to the knowledge of the biology of hake in the Adriatic Sea. *Rev. Trav. Inst. Peches marit*., **40** (3/4): 615-618.

Jukic S. – 1972 – Ishrana oslica (*Merluccius merluccius*), bukve (*Boops boops*), trlje (*Mullus barbatus*) i arbuna (*Pagellus erythrinus*) u Kastelanskom zaljevu. *Acta Adriatica*, **14**(4): 1-40.

Jukic S., Arneri E. - 1984 – Distribution of hake *(Merluccius merluccius* L.), stripped mullet (*Mullus barbatus* L.) and pandora (*Pagellus erythrynus* L.) in Adriatic sea. *FAO Fish. Rep*., **290**: 85 – 91.

Jukic S., Piccinetti C. - 1981 – Quantitative and qualitative characteristics of demersal resources in the Adriatic sea with some population dynamic estimates. *FAO Fish. Rep.,* **253**: 73 – 91.

Jukic S., Piccinetti C. – 1987a – Biological and economic aspects of mesh size regulation in the multispecies demersal fishery of the Adriatic sea. *Acta Adriatica,* **28** (1 – 2): 199 – 219.

Jukic S., Piccinetti C. – 1987b – Contribution to the knowledge on the short and long-term effects of the application of 40 mm codend mesh size in Adriatic trawl fishery-eastern Adriatic coast. *FAO Fish. Rep.,* **394**: 282 – 290.

Jukic-Peladic S., Vrgoc N., Krstulovic-Sifner S., Piccinetti C., Piccinetti-Manfrin G. , Marano G., Ungaro N. – in press - Long-term changes in demersal resources of the Adriatic Sea: comparison between trawl surveys carried out in 1948 and 1998. *Fish. Res.*

Karlovac J. – 1965 – Contribution a la connaissance de l'ecologie du merlu *Merluccius merluccius* L. dans le stade planctonique de sa vie en Adriatique. *Rapp. Reun. Comm. Int. Explor. Scient. Mer. Meditt*., **18**: 461-464.

Karlovac O. – 1959 – On the feeding of the hake (*Merluccius merluccius* L.) of the Adriatic Sea. *Proc. Gen. Fish. Coun. Medit*., **5**: 333-339.

Levi D., Giannetti G. – 1972 - Analisi sullo stato di sfruttamento di una popolazione ittica mediante un modello matematico di cattura e sforzo. *Quad. Lab. Tecnol. Pesca*, **1**(4): 101-114.

Manfrin G., Paolini M., Piccinetti C. – 1998 – Le risorse demersali dell'Alto e Medio Adriatico. *Biol. Mar. Medit*., **5** (3)**:** 96-108.

Marano G., De Zio V., Pastorelli A.M., Rizzi E., Ungaro N., Vaccarella R. - 1994 – Considerazioni sullo stato di sfruttamento delle risorse demersali (basso Adriatico). *Biol. Mar. Medit*., **1**(2): 89-94.

Marano G., Ungaro N., Marano C.A., Marsan R. – 1998a - La ricerca sulle risorse demersali del bacino Adriatico sud-occidentale (anni 1985-97): sintesi dei risultati. *Biol. Mar. Medit*., **5** (3)**:** 109-119.

Marano G., Ungaro N., Marzano M.C., Marsan R. – 1998b - Le Risorse Demersali dell'Adriatico pugliese: analisi di una serie storica ('85-'95) relativa ai dati di cattura e demografia degli stock. *Biol. Mar. Medit*., **5** (2): 52-67.

Mannini P., Massa F. – 2000 - Brief overview of Adriatic fisheries landing trends (1972-97). In: F. Massa and P. Mannini (eds), Report of the First Meeting of the Adriamed Coordination Committee. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-01: 31-49.

Matta F. – 1954 – Il merluzzo del Mediterraneo. Nota II. *Boll. Pesca*, **IX** (1): 5-29.

Piccinetti C., Piccinetti Manfrin G. – 1971a – Osservazioni sull'alimentazione del merluzzo (*Merluccius merluccius* L.) in Alto e Medio Adriatico. *Note Lab. Biol. Mar. e Pesca Fano*, **IV**: 41-64.

Piccinetti C., Piccinetti Manfrin G. – 1971b – Osservazioni sulla media vertebrale dei merluzzi dell'Alto e Medio Adriatico. *Note Lab. Biol. Mar. e Pesca Fano*, **IV**: 65-84.

Piccinetti C., Piccinetti Manfrin G. - 1994 – Considerazioni sullo stato di sfruttamento delle risorse demersali (alto e medio Adriatico). *Biol. Mar. Medit*., **1**(2): 77 – 87.

Ungaro N., Marano C.A., D'uggento A. - 1998 - Relazioni tra specie demersali del bacino adriatico sud-occidentale: analisi statistica di serie storiche. *Biol. Mar. Medit*., **5** (1): 196-202.

Ungaro N., Marano G. - 1996 - Considerations on the hake stock of the South-Western Adriatic Sea. *FAO Fish. Rep*., **533** (Suppl.): 97-100.

Ungaro N., Marano G., Marsan R. - 1996 - The use of the swept area method for the estimate of biomass: a first attempt relative to three demersal finfishes (hake, red mullet, four spotted megrim) in South-Western Adriatic Sea. *FAO Fish. Rep*., **533** (Suppl.): 101-104.

Ungaro N., Rizzi E., Marano G. - 1993 - Note sulla biologia e pesca di *Merluccius merluccius* (L.) nell'Adriatico pugliese. *Biologia Marina*, **1**: 329-334.

Zupanovic S. – 1961 – Contribution to the knowledge of the biology of the hake (*Merluccius merluccius* L.) in the Middle Adriatic. *Proc. Gen. Fish. Coun. Medit*., **6**: 145-150.

Zupanovic S. – 1968 – Study of hake (*Merluccius merluccius* L.) biology and population dynamics in the Central Adriatic. *Rev. Gen. Fish. Counc. Medit*., **32**: 5-24.

Zupanovic S., Jardas I. – 1986 – A contribution to the study of biology and population dynamics of the Adriatic hake. *Acta Adriatica*, **27**(1-2) : 97-146.

Zupanovic S., Jardas I. – 1989 - Fauna i flora Jadrana. *Jabucka kotlina, I i II dio. Logos, Split*, 526 pp.