FAO Fisheries Circular No. 958 FIRM/C958
ISSN 0429-9329

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Food
and
Agriculture
Organization
of
the
United
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PRELIMINARY ASSESSMENT FOR THE SHRIMP FISHERIES OF THE NEGOMBO LAGOON (SRI LANKA)

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2000

PREPARATION OF THIS DOCUMENT

This paper is one of the scientific papers produced by the UNDP/FAO Marine Fisheries Management Project in Sri Lanka (SRL/91/022). The project is the first national executed project in fisheries in the country funded by UNDP while FAO provided a consultant as Fisheries Management Advisor, Mr. Michael Sanders. The paper is a result of a good co-operative work between the consultant and the counterparts provided by the Government of Sri Lanka. Not only the scientific work that the paper offers is of importance, but it is the scientific advice generated by this work that forms the basis for the development of management plan for fisheries in the Negombo Lagoon. This kind of work which is directly related to the process of development of fisheries management plan is still meagre in developing countries and thus it is of importance to publish it in the FAO Circular to enable wide distribution. The project received technical backstopping from Mr. P. Martosubroto from the Marine Resources Service (FIRM) of the FAO Fisheries Department.

Sanders, M.; Jayawardena, A.; Ediriweera, S.
Preliminary assessment for the shrimp fisheries of the Negombo Lagoon (Sri Lanka).
FAO Fisheries Circular. No. 958. Rome, FAO. 2000. 98p.

ABSTRACT

The Negombo Lagoon has an area of 3 164 hectares and is situated some 40 km north of Colombo. It is part of a much larger Muthurawajawela Marsh-Negombo Lagoon coastal wetland. Apart from at the single narrow opening to the sea at its northern end, the water depth within the lagoon is less than 2 m. Six principal gears are used for catching shrimp inside the lagoon. Trammel nets are the most common, which along with cast nets are operated across the central portion of the lagoon. Stake nets are used immediately inside the entrance. Around the perimeter, lagoon seines (drag nets) and brush pile are the common gears. Fyke nets are also used at the southern end of the lagoon. Outside the lagoon, non-mechanized shrimp trawlers are operated north of the entrance, while mechanized shrimp trawlers are used 5 - 10 km to the south. The estimated catch from all gears operated inside the lagoon in 1997 was 613 t of shrimp and 1 044 t of others (mostly fish). The production from trawlers operated outside the lagoon was 270 t of shrimp and 239 t of others. Fourteen species of shrimp were identified, with six of these being major contributors to the catches. *Penaeus indicus* and to a lesser extent, *P. semisulcatus* were the most important in the trammel net and cast net catches. *P. indicus* was also the main species from brush piles. The stake nets set at the entrance caught mainly *Metapenaeus dobsoni* and *M. moyebi*. The latter were the major component of the catches with lagoon seines. The other important species caught in the lagoon was *M. elegans*. The main species in the trawl catches were *M. dobsoni* and *Parapenaeopsis coromandelica*. The former was the only major contributor to both the lagoon and outside catches. *P. indicus* and *P. semisulcatus* were relatively scarce in the trawl catches. Estimates of the growth and mortality parameters for each species are provided. Cash flow analyses are also reported in respect to base case fishing units for each gear type. The report includes a mathematical modeling of the fishery, undertaken in order to investigate likely outcomes from changes in the fishery inputs, particularly the consequences to catch weights and CPUEs from applying different fishing efforts. Also included is a discussion of the management implications along with a set of recommendations.

FOREWORD

This study of the fisheries of the Negombo Lagoon, and the associated trawl fisheries conducted outside the lagoon, was done as a component of the UNDP funded Marine Fisheries Management Project (SRL/91/022). The project was executed through the Ministry of Fisheries and Aquatic Resources Development (MFARD) with support from FAO. It sought to establish a mechanism for the management of fisheries, to strengthen the capabilities of the field staff in fisheries management, and to promote the participation of the fishing communities as major entities in the formulation and implementation of management. The project's many activities have included drafting a management plan for the Negombo Lagoon fisheries, which has now been approved for implementation. The plan envisages the lagoon as a Fisheries Management Area (as defined in the Fisheries Act), provides for the establishment of management infrastructure, and empowers the local communities to engage in fisheries co-management.

As an adjunct to the management plan, this study was undertaken to determine both the biological and financial performance of the lagoon and nearby shrimp fisheries. It demonstrates an approach to assessing performance, and the benefit from having inputs from both fishery biologists and economists. The task was highly ambitious due to the complexity of the fisheries, involving a multitude of species, gears and fishing locations. The remaining and substantial challenge is to utilise the findings, together with local knowledge and experience, to ensure that the fisheries are maintained, and continue to provide substantial employment and financial benefit. The achievement of these objectives will require the successful implementation of the fisheries management plan, and strong community participation in management. Future performance will also continue to be linked to the success of the surrounding economy. Fortunately, the fishermen of Negombo already have a good appreciation of the strategies and potential benefits. The stake net fishery at the entrance to the lagoon is a fine and long-standing example of community based fisheries management.

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ACKNOWLEDGEMENTS

The collection of detailed catch and effort data for the lagoon fisheries, was undertaken by Mr. D. Bandula (Fisheries Inspector). Supplementary catch and effort data were collected by Mr. H. Perera and Mr. M. Gunawardane (Research Assistants, NARA). The persons locally engaged in the sampling of catches and the recording of biological data were Mr. Leslie Fernando, Mr. Stanley Joseph, Mr. Aruna Sampath, and Mr. Susantha Nandimal. At different times, their work was supervised by Mr. R. Wickremasinghe (FI Negombo), Mr. Nishantha Ranasinghe, Mr. M. Fernando, and Mrs. W. Ekanayake (DFAR HQ). Financial control was exercised through Mr. D. Disanayake (District Fisheries Extension Officer). All these persons contributed substantially to the success of the study.

Contents

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Fishing Gears and Methods

Fishing inside the lagoon involves the use of eight principal gear types. Except for gill nets and hand lines, these gears are used mainly to catch shrimp. The most common gears are trammel nets. These along with cast nets are operated across the central portion of the lagoon. Stake nets are operated immediately inside the entrance at the northern end. These are set at night during the outgoing tide, and target species aggregated at the entrance and migrating to sea. The gears used in the shallower waters are lagoon seines and brush pile. Brush piles are dead tree branches, each encompassing an area of 5 – 10 m in diameter. The fish and shrimp aggregate within the branches, and are periodically removed with surrounding nets. The other gear used in the lagoon for catching shrimp are fyke nets. These are set at the southern end adjacent to the marsh. Outside the lagoon, there are non-mechanised shrimp trawlers operated north of the entrance, and mechanised shrimp trawlers operated 5 - 10 km to the south. Apart from the latter, all craft are of traditional design. Fishing from mechanised craft is prohibited within the lagoon.

Catches, Fishing Efforts, and Catch Values

The estimated catch from all gears in 1997 was 2 258 t (whole weight), comprised of 883 t of shrimp and 1 375 t of others (mostly fish). The contribution from the lagoon was 613 t of shrimp and 1 136 t of others. The single most productive gear was trammel nets. These caught 304 t of shrimp and 1 044 t of others. The production from trawlers operated outside the lagoon was 270 t of shrimp and 239 t of others. The fishing efforts expended within the lagoon totalled 312 638 landings and 1 642 952 fishing hours. The former indicates almost 1 000 landings per day. The combined effort with trawls was 24 660 landings and 168 479 fishing hours. The monthly catches per unit effort (CPUE) indicated that spring and autumn were the most productive seasons for shrimp. The CPUEs for the non-shrimp species show much less seasonality. The value of the catches (at the landing sites) for all gears was estimated as Rs 154 million (equiv. $US 2.5 million). The contribution from the gears used in the lagoon was Rs 114 million. About two-thirds of these amounts were from the shrimp components.

Species and Sizes of Shrimp in the Catches

Fourteen species of shrimp were identified. Six of these were major contributors to the catches. The most important in the trammel net and cast net catches were *P. indicus* and to a lesser extent *P. semisulcatus*. *P. indicus* was also the main species caught from brush piles. The stake nets set at the entrance caught mainly *M. dobsoni* and *M. moyebi*. The latter were a major component of the catches from lagoon seines. The other important species caught inside the lagoon was *M. elegans*. This and *M. moyebi* are able to complete their life cycles within lagoon environments. Very few were found in the catches from outside. The main species in the trawl catches were *M. dobsoni* and *Pa. coromandelica*. The latter is a wholly marine species. *M. dobsoni* was the only major contributor to both the lagoon and outside catches. *P. indicus* and *P. semisulcatus* were relatively scarce in the trawl catches. The sizes of the shrimp caught differed substantially between gears. The smaller sizes were from the lagoon seines and brush pile, and larger sizes from the trammel nets, cast nets, and trawls. The stake nets produced mostly small and intermediate sizes.

Growth and Mortality of Shrimp

Analyses were undertaken to establish the mathematical relationships between each of carapace length and age, carapace length and total weight, and carapace length and total length. The rates of growth at 'mid-length' were estimated to be approaching 1 mm/week (carapace length) for *P. indicus* and *P. semisulcatus*, about 0.6 mm/week for *M. dobsoni*, *M. elegans* and *Pa. coromandelica*, and about 0.4 mm/week for *M. moyebi*. *P. indicus* and *P. semisulcatus* were shown to attain much larger maximum sizes than the other four species, with *M. moyebi* being the smallest. Females invariably grew larger than males. Most of the shrimp caught in the lagoon were aged from several months to about one year, and between about 6 and 14 months for those caught outside. It was concluded for the main species that two cohorts enter the fisheries each year, from separate spawning in spring and autumn. It was presumed that these were linked to the spring and autumn rainy seasons. Analyses were undertaken to determine the adult natural mortality rates, and the mathematical relationships between natural mortality and age. The findings were consistent with the maximum age for all species being about 2 years. Slightly lower adult mortalities were estimated for the larger species, and for females. The major cause of natural mortality was presumed to be predation.

Investments, Fishing Costs, and Remunerations

Cash flow analyses were undertaken in respect to hypothetical base case fishing units. These utilised data collected during interviews with fishermen-owners. Estimates of the investment (in craft and gear) required to replace existing units with new items ranged between Rs 25 000 for brush pile and lagoon seine units to about Rs 320 000 for a mechanised trawl unit. Fishing costs were found to be low, except for mechanised trawlers for which engine fuel was a major item. Investment in craft and gear, repairs and maintenance, and payments to crew were the main items of cost. Daily trip costs (other than the payments to crew) and annual administrative charges (eg. craft registration and fishing operations licence) were generally negligible. No craft were insured. Few owners had borrowed, and roughly an equal number had received government subsidies to meet the costs of craft and gear. Crews were invariably paid a share of the catch value less other (ie. non-labour) trip costs. The estimated monthly remunerations per crew were found to be remarkably similar for all gears, and ranged from Rs 4 500 – 6 000. The monthly remunerations to fishermen-owners for their labour and investment were estimated as between about Rs 5 000 – 13 000 (after subtracting depreciation). The upper value relates to operating a mechanised trawler (for which a relatively large investment is required). The lower value approximates the remunerations to be expected, from operating either a trammel net, cast net, or brush pile unit. This is little different from the estimated remunerations per crew.

Mathematical Model of the Fisheries

A model was formulated to investigate the likely outcomes from changes in the fisheries inputs, particularly the consequences to catch weights and CPUEs from applying different fishing efforts. The model was structured to accommodate eight gear types and the six main shrimp species. The required inputs included the fishing efforts, the parameters describing growth and natural mortality, catchability coefficients, selection/recruitment ogives, and recruitment numbers. The last three of these inputs were estimated internally from the model. The chosen values were those for which the estimated and observed length frequencies, associated with inputting the contemporary fishing efforts, were in closest agreement. The outputs estimated from the model were the annual catch numbers, catch weights, CPUEs, and catch length frequencies. A substantial shortcoming of the model, the absence of 'spatial separation' for those stock components migrating to different locations, was understood and accommodated within the interpretation of the findings. A future task will be to include the 'spatial separation'. This is likely to require the collection of additional data, so as to clarify the migration behaviour for each species.

Applications of the Model

Three hypothetical scenarios were examined. In the first scenario the fishing effort with stake nets was varied while the efforts for the other gears were maintained at the contemporary levels. The results indicated that substantially increased catches were likely, from increased stake net effort. In reality, there is very little scope for increased effort, as the suitable sites (for stake nets) at the entrance of the lagoon are already fully utilised. Reducing the stake net effort produced near proportional reductions in stake net catch, associated with very marginally increased CPUEs (in the trawl fisheries). In the second scenario, the fishing effort with trammel nets was varied. The estimated decrease in trammel net CPUEs from increased effort was judged as likely to be unacceptable. The loss of catch from reduced effort was found to be greater than the increase in catch from the other gears. The results as such provide no justification for deliberate change in the trammel net effort. In the third scenario, the combined fishing efforts for the trawl fisheries were varied. The findings indicated that the potential to increase the mechanised trawler catch is negligible (other than from gaining access to previously fished ground off Colombo, which is presently denied for security reasons). There seems some scope to increase the catch from non-mechanised trawlers, although this would be associated with substantial reduction in the already modest CPUEs.

Implication for Future Management

It was concluded that the fisheries are performing satisfactorily at the present levels of fishing effort. This is in the sense that the opportunities for employment appear fully utilised. Attempts to expand the fisheries would cause reduced remuneration levels, which are already low to modest. The integrated character of the fisheries (eg. different gears being targeted at different species and sizes) confers stability and should be preserved. Another beneficial characteristic to be maintained is the generally low fishing costs, in large part the consequence of the traditional crafts and methods used. As the scope to increase catches or employment seems negligible, the priorities for management will continue to be social harmony and an appropriate sharing of the benefits. The community based management being applied successfully in the stake net fishery, provides a useful blueprint upon which the management of the other fisheries might be based. Beneficial outcomes are most likely to be achieved with the communities fully incorporated within the management process. These views are reflected within the recent changes to fisheries legislation, and in the shortly to be implemented fisheries management plan for the Negombo Lagoon.

Recommendations

1. The 'open access' character of the fisheries (other than the stake net fishery) means that the present CPUEs and hence remunerations to the fishermen are insecure. They would be reduced from their present modest levels in the event of an increase in the number of fishermen and craft. While an influx is not believed to be imminent, it is nevertheless <u>recommended</u> that the ability to control the number of fishing units be established at the earliest. Furthermore, that this control be exercised through co-management arrangements that include the local fishing communities as major participating entities.

2. The present management regime prohibits the use of motorised craft within the lagoon for the purpose of fishing. It also prohibits the use of certain fishing gears and methods that are damaging to the lagoon environment. There is a separation of the trawler fleets operating outside the lagoon: the non-mechanised trawlers being engaged north of the entrance, while the mechanised trawlers are confined to grounds well to the south. These measures all serve to preserve harmony and an appropriate sharing of the fisheries resources. It is recommended that the measures be continued.

3. The fisheries are characterised by low costs of fishing (other than the mechanised trawl fishery for which there are fuel costs). This is highly important in preserving acceptable remuneration levels. It is recommended that attempts to introduce new technologies or increased quantities of gear per fishing operation that might ultimately lead to reduced remunerations be avoided. Some trammel net fishermen have sought to enhance their share by increasing the number of nets used. This acts to reduce the catches of the other fishermen, unless they also use more nets. In order to avoid an unnecessary spiralling of gear usage and hence costs, it is recommended to limit the quantity of trammel nets able to be used from a craft during a fishing operation.

4. Although not investigated during this study, the future performance of the fisheries is highly vulnerable to changes in the environment within the lagoon. The lagoon is a shallow, largely enclosed water-body, surrounded by urban development, and industrial encroachment. It is recommended that extreme care be taken to preserve and where necessary enhance the fisheries values of the lagoon environment. Particularly sensitive elements in respect to the potential impact on fisheries, will be the mangroves, sea-grass beds, sediment and pollution levels, loss of waters through reclamation, water depth at the entrance, and diversion of water flows. Any damaging effects from fishing activities themselves should also be avoided.

5. Including the fishing communities as major participants in the management process will presumably be reflected by greater adherence to management measures. It will remain necessary nevertheless that an effective monitoring and enforcement presence exist, hence it is recommended that the local enforcement capability be reviewed. Improvement might be achieved by re-defining the duties of the existing Fisheries Inspectors (FI), who presently are almost solely engaged in extension and social welfare activities. The alternative approach would be to establish a small group of dedicated enforcement staff operating directly from the District Fisheries Extension Office (DFEO).

6. Concerning future research, there is a need for additional studies to both confirm and improve on the present findings. An important reason why ‘spatial separation’ was not included in the fisheries model, was incomplete knowledge about migration for each of the shrimp species. It is recommended that a substantial shrimp tagging study be implemented. This should seek to determine, for example, the extent of migration between the two trawling grounds, the proportions of the shrimp leaving the lagoon which migrate to each ground, and the proportions which delay leaving the lagoon (until the next rainy season).

INTRODUCTION

General

This study of the fisheries of the Negombo Lagoon was done as a component of the UNDP funded Marine Fisheries Management Project (SRL/91/022), executed through the Ministry of Fisheries and Aquatic Resources Development (MFARD) with support from FAO. Its objectives were to assess the present performance of the fisheries, the extent by which performance might be improved (or safeguarded), and to demonstrate assessment methods. As shrimp are the principal target species, some of which are known to migrate to the sea, it was judged necessary to also study the linked trawl fisheries operated outside but adjacent to the lagoon. The study was commenced in January 1997. Data on the species and sizes being caught, catch weights, fishing efforts, fish prices and fishing costs were collected over the following 14 months. Use was made of the existing staff capabilities within each of the Department of Fisheries and Aquatic Resources Development (DFARD), and the National Aquatic Resources and Development Agency (NARA). It was also necessary to recruit a small team of persons selected from the fishing communities, to undertake that part of the work associated with the sampling of catches. This was administered from the District Fisheries Extension Office (DFEO) in Negombo.

Negombo Lagoon

The Negombo Lagoon, situated some 40 km north of Colombo and with an area of 3 164 hectare, is part of a much larger Muthurawajawela Marsh-Negombo Lagoon coastal wetland. The connection to the sea is by a single narrow opening at its northern end. Other than at the entrance, the water within the lagoon is less than 2 m in depth. There is dispersed freshwater input through the marsh at the southern end, particularly during the rainy seasons centred around each of April and October. Multiple uses of the lagoon and surrounds include fishing, aquaculture, agriculture, tourism, trade and shipping. The large town of Negombo is at the northern end adjacent to the entrance. Most of the lagoon perimeter is fringed by habitation. During the past several decades there has been visible degradation of the lagoon environment. This is well documented in the Conservation Management Plan (WCP, 1994). It has occurred from inadequately planned settlement, industrial and municipal pollution, intensification of fishing, deforestation, and general habitat destruction. There are eight principal fishing gears used within the lagoon, of which six are important for the capture of shrimp. In addition, both non-mechanised and mechanised shrimp trawlers are operated outside the lagoon. Summary descriptions for these gears and methods are given below. They are based largely on the information given in Fishing Craft and Gear of Sri Lanka (DFAR, 1995). A general depiction of the fishing locations in respect to each of the gears is shown in Figure 1.

Fishing Gears and Methods

<u>Stake Nets:</u> The use of stake nets (*kattudel)* occurs immediately inside the entrance. These are set during the night on the out-going tide, and targeted at the shrimp aggregated inside the entrance, as well as shrimp migrating to the sea for spawning. There are some 62 sites (legally designated) suitable for the placement of stake nets. The nets can only be operated in channels of about 3 to 4 m in depth. Two men are usually required to install and operate a stake net. Nine or ten mangrove sticks of 4 to 6 metres length are fixed into the lagoon bed. The wings of the net (each about 20 m in length) are fixed in an upright position onto these sticks. Then a cod-end of conical shape (15 to 18 m in length) is fitted at the apex

between the wings. After the net is installed, a kerosene lantern is suspended from a separate stick attached to the craft anchored adjacent to the cod-end. The light from the lantern acts to attract shrimp and fish to the vicinity of the net. The use of stake nets is subject to 'community-based management'. This includes the stake net societies administrating the allocation of sites amongst their member fishermen.

Fyke Nets: The fyke nets (*muttugam dela* and *udugam dela*) used at the southern end of the lagoon, are little different from the stake nets used at the entrance. They are also operated from very early morning and principally targeted at shrimp. The placement of the nets is with the wings opening towards the mangroves. In order to reduce the catch of very small shrimp, the mesh sizes used in the wings and cod-end are generally larger than in stake nets. When used to catch fish, a different higher opening cod-end is attached between the wings. Fishermen using fyke nets are usually also engaged in other types of fishing. The nets are sometimes operated by fishermen working alone, although mostly there are two fishermen working together.

Trammel Nets: The lagoon fishery that attracts the largest number of fishermen involves the use of trammel (*disco)* nets. They operate with small lagoon craft (*oru*) or log rafts (*theppan*), up to 4 m in length. Propulsion is by poling. Up to 30 net pieces are operated by a single fisherman. Much less commonly, two fishermen may operate a larger quantity of gear. The net pieces are about 20 m in length, with mesh sizes of 25 – 30 mm in the inner panel, and 130 – 150 mm in the outer panels. The nets extend from the water surface to the lagoon bed. They are laid across the tide, with one end anchored by a 1 – 2 kg stone. The other end is attached to the craft anchored by a pole driven into the lagoon bed The nets are set throughout the central area of the lagoon. This is done in the very early morning, with the catches being landed at around 10 or 11 A.M. the same day. The fish and shrimp are removed from the nets at about hourly intervals. The shrimp are generally large and hence valuable, although only a small proportion of the catches by number and weight.

Cast Nets: Cast nets are also used principally across the central area of the lagoon, and targeted at the larger shrimp. They may be operated at night, in association with light attraction by kerosene lantern, or during daytime. Their use is much more seasonal than for the other gears. The method requires substantial physical exertion by the fishermen, and is not sufficiently remunerative other than when shrimp are abundant. The cast nets able to be used from craft are about 5 – 6 m in length (measured from the apex). The hauling lines are about 3 – 6 m in length. After being thrown, the net sinks to the bottom, and is then slowly hauled to the surface by a cord attached to the apex. The net progressively 'collapses' while being hauled, due to the weight of the lead sinkers around the circumference, with the catch remaining entangled in its folds. The skill required of these fisherman, is to cast the net so that it covers as large an area of the lagoon bottom as possible.

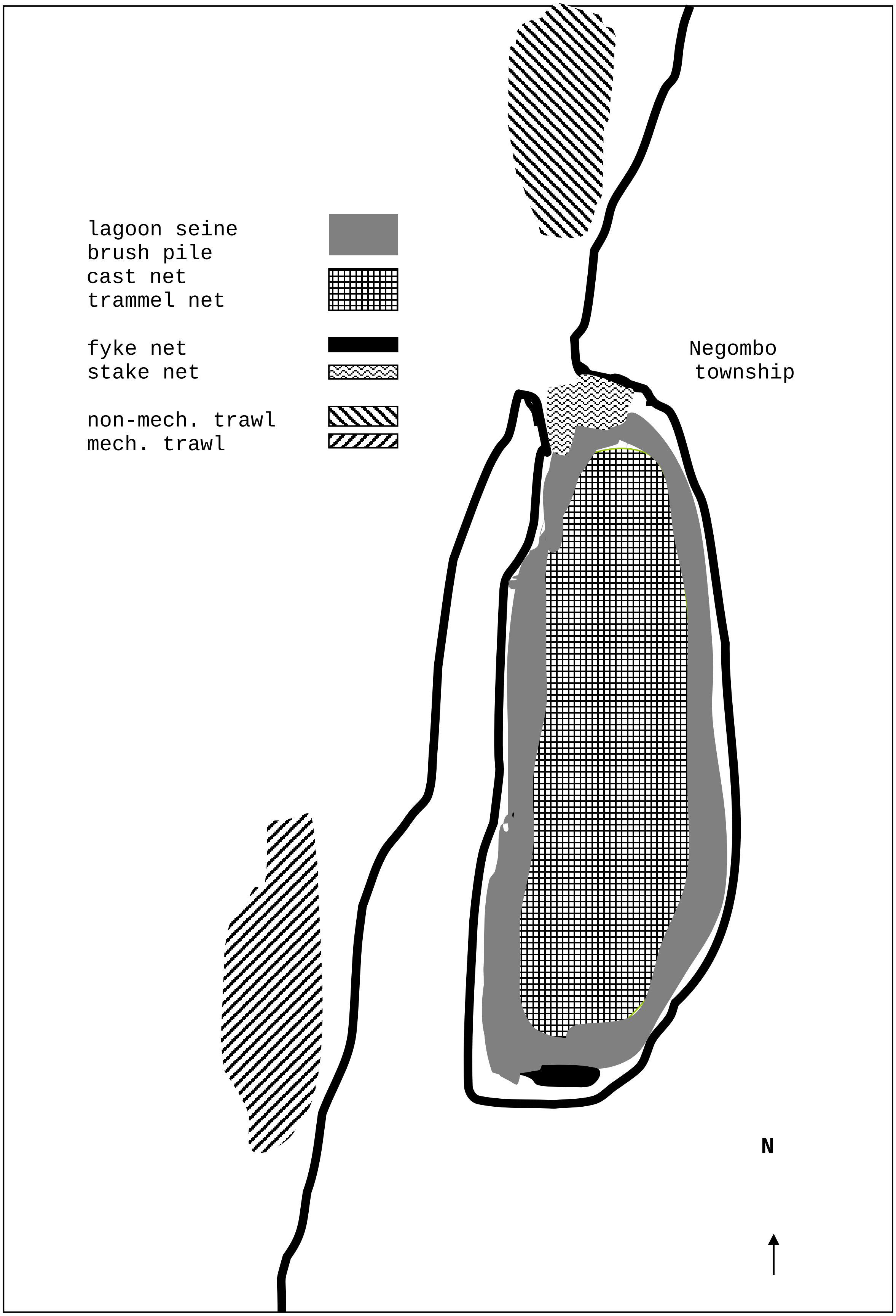
Lagoon Seines: The lagoon seine (*gawana dela)* is another physically demanding gear used in the lagoon. They are operated seasonally in the shallower depths of 1 – 1.5 m adjacent to the shoreline, and are targeted at concentrations of small shrimp. Two fishermen, one at each end, are required to drag the net while wading, usually in the same direction as the tidal current. The net is about 40 – 50 m in length and 4 – 5 m in depth. Floats are attached to the headrope, and lead sinkers to the bottom rope. Each fisherman ties the end of the bottom rope to one leg. Fishing is undertaken during daylight. The net is dragged about 40 – 50 m. during each encircling operation. The canoe is also dragged by one of the fishermen. A third fisherman is sometimes involved, in which case they will all take turns in dragging the net. The lagoon seine is perceived as a highly productive gear, but sometimes criticised for its damaging effect when used over sea-grass beds.

<u>Brush Pile</u>: The other gear operated in shallow depths is the surrounding net (*mas athu*) used in association with brush pile (*kottu*). The latter are dead branches embedded in the lagoon bottom, covering a surface area of about 5 - 10 m in diameter. At intervals of about 30 days, each brush pile is encircled with a surrounding net attached to about 12 – 15 poles fixed to the lagoon bed. All the branches of the brush pile are then removed, after which the area within the net is progressively reduced, so as to confine the catch and allow its removal. About 3 – 4 hours are required to dismantle a brush pile and complete a surrounding net operation. The typical length of a surrounding net is 40 – 50 m. Re-establishing the brush pile occurs during the same or next day. A fisherman will usually operate only a few brush pile (1 – 5) while engaging in other types of fishing. Some fishermen operate a larger number, up to 20 – 25 brush pile.

<u>Non-mechanised Trawlers</u>: The use of non-mechanised trawlers occurs outside the lagoon, to a distance of 5 km north of the entrance. They are operated during day-time in waters up to 12 m depth, from craft of traditional design, fitted with outrigger and sail, and manned by 4 persons. The nets are towed under sail power; rarely the crew may row when there is insufficient wind speed. The net is shaped like a long narrow cone, with a small cod-end about 1 m in length, and a larger body of about 7 m. No floats are used for the head-rope. There are lead sinkers placed at intervals along the foot-rope, and heavy stones of 30 – 35 kg attached at each end. The net on each side is connected to the towing ropes by bridles, of about 4.5 m to the stones, and a shorter length to the head-rope. The towing of a net takes about 1 hr, after which it is manually hauled. The direction of the craft is then reversed (without turning) and the net returned to the water. There are about 4 - 6 trawls during a fishing day.

<u>Mechanised Trawlers</u>: The mechanised trawlers are operated from the Hendala Canal on grounds commencing about 5 km south of the entrance. They are prevented by regulations from fishing on the same grounds as the non-mechanised trawlers. The craft are of the 3.5 t type, 28 ft in length, and of reasonably modern design. They are powered by inboard diesel engines of 25 – 40 HP. The net is towed from thick bamboo poles, extended as booms either side of the craft. The fishing operations and net design are otherwise similar to those with the non-mechanised trawlers. The nets are larger, with a cod-end of about 2.5 m in length, and a body of about 12 – 15 m. Floats are attached to the head-rope, lead sinkers at intervals to the foot-rope, and 30 – 35 kg stones at each end. The nets are recovered manually. While some craft are used throughout the year, the operations of most are confined to about 5 months centred on June/July. Up to two-thirds of the boats may be idle in some months. A few may be used in catching fish with other gears.

Figure 1: Fishing locations by gear type.



CATCH WEIGHTS AND FISHING EFFORTS

Introduction

The findings reported here are from two separate data collection activities. In respect to each of the gears used in the lagoon other than stake nets, catch and effort data were collected for a sample of landings (usually six or seven), on each of two days per month, at each of five landing sites. The total numbers of landings by gear type were also recorded for these days. The sites had previously been chosen as representative of the landing sites generally within the lagoon. In was assumed that fishing took place on 24 days in each month. It was also necessary to know the numbers of craft operating at the five sample sites (185 craft), and at all landing sites (1 151 craft). These values were obtained from a frame survey undertaken in September 1997. Utilising all these data, the catches and efforts for the sample landings were raised in a series of steps, to obtain estimates for the month by gear type.

In respect to the use of stake nets and trawls, catch and effort data were collected in respect to a selection of landings (from a few to as many as 20) on each of 2 – 4 days per month. The catch values and number of crew (including skipper) were also recorded. The landings were sufficiently localised to allow determination of the total number of craft engaged on the sample days. At the time of the frame survey in September 1997, there were 154 stake net craft, 135 non-mechanised trawlers, and 95 mechanised trawlers. In the process of raising to obtain monthly estimates for each gear type, it was assumed that fishing occurred on 30 days each month in the case of stake net fishing, and on 25 days each month for the trawlers. The estimates obtained for both the monthly and annual catch weights, fishing efforts and CPUEs, separately in respect to all gear types, are given in Tables 1 to 11.

Catches, Efforts and CPUEs

The annual catch from all gears was determined as 2 258 t. This was comprised of 883 t of shrimp and 1 375 t of others (mostly fish). The contribution from the lagoon was 613 t of shrimp and 1 136 t of others. The single most productive gear type was the trammel net. These produced 304 t of shrimp (mostly *P. indicus*) and 1 044 t of others. The production from trawlers operated outside the lagoon was 270 t of shrimp and 239 t of others. The fishing effort expended within the lagoon totalled 312 638 landings and 1 642 952 fishing hours. The former represents roughly one thousand landings per day. Two thirds of this effort was from trammel nets. The effort expended by the trammel net fishermen amounted to 228 736 landings and 1 110 311 fishing hours. They generally used about 30 net pieces during each fishing day. The combined effort with trawlers was 24 660 landings and 168 479 fishing hours.

The 'all species' CPUEs estimated for trammel nets and cast nets were around 5 kg/landing or 0.9 kg/fishing hour. These are the gears operated by fishermen working alone. The CPUEs for the remaining gears were substantially higher; roughly two times higher for lagoon seines, 4 times higher for trawls, and six times higher for stake nets. These gears require more fishermen to be engaged. Lagoon seines and stake nets require the involvement of two persons, while the crew on a trawler is normally 4 persons. Using these values gives CPUEs/fisherman which are about the same for each gear, other than stake nets, which are 3 times higher. In a sense, the latter is an exact 'compensation' for the stake net fishermen, whose access to the fishing sites is restricted (by the rules of the stake net societies) to every third night.

Seasonality was reflected by the trends in the monthly CPUEs. In the case of shrimp, the spring and autumn months were the most productive, particularly the latter. This can be seen most clearly in the CPUEs for trammel nets, cast nets, lagoon seines, stake nets, and non-mechanised trawls. The CPUEs for the non-shrimp species indicate much less seasonality. There was a greater use of cast nets in spring and autumn, whereas for most other gears, the monthly efforts were generally constant throughout the year. This would suggest that fishing with cast nets is generally profitable, compared with other gears, only during the months when the shrimp are abundant. A virtue of trammel nets is that they are also highly effective in catching fish, which helps to maintain acceptable remuneration levels during the off-seasons for shrimp. The use of mechanised trawlers was largely confined to a single most productive period, centred around June and July.

Discussion

These catches and efforts are the most comprehensive so far reported for the Negombo Lagoon. They are nevertheless not without error. The catch weights are not from actual weighings, but are approximations from visual examination by the enumerators at the landing sites. The information on fishing efforts was from questioning the fishermen at the time of landing, and hence reliant on the ingenuity and integrity of the interviewees. In some months, the less used gears were poorly represented amongst the sampled landings. Also, in the short time during which the catches were available for examination, it was not always possible to achieve a fully comprehensive identification of all the species. Notwithstanding, it can be reported that the fishermen appeared always fully cooperative, and the enumerators were well trained and committed.

Table 1: Annual catch weight, fishing effort, and CPUEs.

	Lagoon Seine	Brush Pile	Cast Net	Trammel Net	Gill Net	Hand Line	Fyke Net	Stake Net	Non-Mech. Trawl	Mech. Trawl	All Gears
Catch Weights (kg)											
P. indicus	9 653	1 190	42 374	246 764	2 012	--	43	35 454	3 475	4 513	345 477
P. semisulcatus	1 781	198	2 492	28 097	43	--	--	15 001	103	14	47 729
P. monodon	355	274	2 368	23 040	1 562	--	15	793	421	433	29 262
P. merguiensis	--	--	--	--	--	--	--	2 063	1 299	1 415	4 777
Small shrimp spp.	14 374	164	10 777	5 790	1 277	--	6 769	158 091	181 639	76 577	455 458
sub-total	26 163	1 827	58 011	303 690	4 894	--	6 828	211 402	186 938	82 951	882 703
Others (mostly fish)	40 096	42 236	29 403	740 773	153 377	27 620	5 537	97 011	134 621	104 429	1 375 103
total	66 259	44 063	87 414	1 044 464	158 271	27 620	12 365	308 413	321 559	187 380	2 257 806
Effort (hr)	45 805	39 395	108 166	1 110 311	224 510	32 927	17 942	63 897	119 604	48 875	1 811 431
Effort (landings)	5 438	6 757	15 693	228 736	35 285	5 919	3 688	11 123	17 204	7 456	337 298
Av. hours/landing	8.4	5.8	6.9	4.9	6.4	5.6	4.9	5.7	7.0	6.6	5.4
CPUE (kg/landing)											
P. indicus	1.77	0.18	2.70	1.08	0.06	--	0.01	3.19	0.20	0.61	
P. semisulcatus	0.33	0.03	0.16	0.12	0.00	--	--	1.35	0.01	0.00	
P. monodon	0.06	0.04	0.15	0.10	0.04	--	0.00	0.07	0.02	0.06	
P. merguiensis	--	--	--	--	--	--	--	0.18	0.08	0.19	
Small shrimp spp.	2.64	0.02	0.69	0.03	0.04	--	1.84	14.21	10.56	10.27	
sub-total	4.81	0.27	3.70	1.33	0.14	--	1.85	19.01	10.87	11.12	
Others (mostly fish)	7.37	6.25	1.87	3.24	4.35	4.67	1.50	8.72	7.82	14.01	
total	12.18	6.52	5.57	4.57	4.49	4.67	3.35	27.73	18.69	25.13	
CPUE (kg/hr)											
P. indicus	0.211	0.030	0.392	0.222	0.009	--	0.002	0.555	0.029	0.092	
P. semisulcatus	0.039	0.005	0.023	0.025	0.000	--	0.000	0.235	0.001	0.000	
P. monodon	0.008	0.007	0.022	0.021	0.007	--	0.001	0.012	0.004	0.009	
P. merguiensis	--	--	--	--	--	--	--	0.032	0.011	0.029	
small shrimp spp.	0.314	0.004	0.100	0.005	0.006	--	0.377	2.474	1.519	1.567	
sub-total	0.572	0.046	0.537	.0.273	0.022	--	0.380	3.309	1.563	1.697	
others (mostly fish)	0.875	1.072	0.272	0.667	0.683	0.839	0.309	1.518	1.126	2.137	
total	1.447	1.118	0.808	0.941	0.705	0.839	0.689	4.827	2.689	3.834	

Table 2: Monthly catch weight and fishing effort for lagoon seines.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	896	995	612	246	194	--	60	664	50	1 680	3 285	971	9 653	548	291
P. semisulcatus	582	166	157	22	26	--	--	133	299	187	187	22	1 781	1 211	1 181
P. monodon	--	83	157	86	4	--	7	--	--	--	19	--	355	--	34
small shrimp spp.	--	--	--	--	403	871	896	199	5 089	1 643	4 489	784	14 374	1 211	4 500
sub-total	1 478	1 244	926	355	627	871	963	995	5 438	3 509	7 979	1 777	26 163	2 970	6 005
others (mostly fish)	187	622	1 390	2 150	2 497	8 181	2 370	995	4 809	6 589	6 617	3 688	40 096	5 649	6 810
total	1 665	1 866	2 316	2 505	3 124	9 052	3 333	1 991	10 247	10 098	14 596	5 465	66 259	8 619	12 815
Effort (hr)	597	747	2 650	2 333	2 699	2 769	2 912	1 618	6 626	8 726	8 493	5 637	45 805	8 461	7 999
Effort (landings)	75	83	299	299	299	373	299	166	747	933	1 120	747	5 438	995	1 027
Av. hours/landing	8.00	9.00	8.88	7.81	9.04	7.42	9.75	9.75	8.88	9.35	7.58	7.55	8.42	8.50	7.79
CPUE (kg/landing)															
P. indicus	12.00	12.00	2.050	0.825	0.650	--	0.200	4.000	0.067	1.800	2.933	1.300	1.775	0.550	0.283
P. semisulcatus	7.80	2.00	0.525	0.075	0.088	--	--	0.800	0.400	0.200	0.167	0.030	0.327	1.217	1.150
P. monodon	--	1.00	0.525	0.288	0.013	--	0.025	--	--	--	0.017	--	0.065	--	0.033
small shrimp spp.	--	--	--	--	1.350	2.333	3.000	1.200	6.817	1.760	4.008	1.050	2.643	1.217	4.383
others (mostly fish)	2.50	7.50	4.655	7.200	8.363	21.917	7.935	6.000	6.442	7.060	5.908	4.940	7.374	5.675	6.633
total	22.30	22.50	7.755	8.388	10.463	24.250	11.160	12.000	13.725	10.820	13.033	7.320	12.185	8.658	12.483
CPUE (kg/hr)															
P. indicus	1.500	1.333	0.231	0.106	0.072	--	0.021	0.410	0.008	0.193	0.387	0.172	0.211	0.065	0.036
P. semisulcatus	0.975	0.222	0.059	0.010	0.010	--	--	0.082	0.045	0.021	0.022	0.004	0.039	0.143	0.148
P. monodon	--	0.111	0.059	0.037	0.001	--	0.003	--	--	--	0.002	--	0.008	--	0.004
small shrimp spp.	--	--	--	--	0.149	0.315	0.308	0.123	0.768	0.188	0.529	0.139	0.314	0.143	0.563
others (mostly fish)	0.313	0.833	0.525	0.922	0.925	2.955	0.814	0.615	0.726	0.755	0.779	0.654	0.875	0.668	0.851
total	2.788	2.500	0.874	1.074	1.158	3.270	1.145	1.231	1.546	1.157	1.719	0.970	1.447	1.019	1.602

Table 3: Monthly catch weight and fishing effort for brush pile.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	329	242	--	31	28	105	30	--	--	39	101	286	1 190	174	--
P. semisulcatus	45	69	--	37	--	--	--	--	--	47	--	--	198	--	--
P. monodon	30	90	--	12	--	22	--	29	--	16	50	25	274	610	--
small shrimp spp.	--	21	--	--	129	15	--	--	--	--	--	--	164	--	--
sub-total	403	422	--	81	157	142	30	29	--	101	151	311	1 827	784	--
others (mostly fish)	4 360	2 272	814	3 341	1 652	4 263	2 449	5 241	4 651	4 176	5 073	3 945	42 236	12 369	4 130
total	4 763	2 693	814	3 422	1 809	4 405	2 479	5 270	4 651	4 277	5 224	4 256	44 063	13 153	4 130
Effort (hr)	3 210	2 420	784	4 231	2 352	3 210	2 352	3 702	4 181	5 288	4 368	3 297	39 395	9 146	3 360
Effort (landings)	597	415	299	747	448	597	448	581	523	933	672	498	6 757	1 161	560
Av. hours/landing	5.38	5.83	2.63	5.67	5.25	5.38	5.25	6.38	8.00	5.67	6.50	6.63	5.83	7.88	6.00
Av. aggreg. days	??	??	??	32.3	31.0	32.3	27.5	??	33.0	??	35.0	30.5	31.7	39.0	35.5
CPUE (kg/landing)															
P. indicus	0.550	0583	--	0.042	0.063	0.175	0.067	--	--	0.042	0.150	0.575	0.176	0.150	--
P. semisulcatus	0.075	0.167	--	0.050	--	--	--	--	--	0.050	--	--	0.029	--	--
P. monodon	0.050	0.217	--	0.017	--	0.038	--	0.050	--	0.017	0.075	0.050	0.041	0.525	--
small shrimp spp.	--	0.050	--	--	0.288	0.025	--	--	--	--	--	--	0.024	--	--
others (mostly fish)	7.300	5.477	2.725	4.475	3.688	7.138	5.467	9.025	8.900	4.475	7.550	7.925	6.251	10.650	7.375
total	7.975	6.493	2.725	4.583	4.038	7.375	5.533	9.075	8.900	4.583	7.775	8.550	6.521	11.325	7.375
CPUE (kg/hr)															
P. indicus	0.102	0.100	--	0.007	0.012	0.033	0.013	--	--	0.007	0.023	0.087	0.030	0.019	--
P. semisulcatus	0.014	0.029	--	0.009	--	--	--	--	--	0.009	--	--	0.005	--	--
P. monodon	0.009	0.037	--	0.003	--	0.007	--	0.008	--	0.003	0.012	0.008	0.007	0.067	--
small shrimp spp.	--	0.009	--	--	0.055	0.005	--	--	--	--	--	--	0.004	--	--
others (mostly fish)	1.358	0.939	1.038	0.790	0.702	1.328	1.041	1.416	1.113	0.790	1.162	1.196	1.072	1.352	1.229
total	1.484	1.113	1.038	0.809	0.769	1.372	1.054	1.424	1.113	0.809	1.196	1.291	1.118	1.438	1.229

Table 4: Monthly catch weight and fishing effort for cast nets.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	5 142	3 472	944	--	9	--	34	37	2 710	3 388	26 389	249	42 374	944	84
P. semisulcatus	2 273	--	17	--	--	--	11	12	62	77	39	--	2 492	647	--
P. monodon	244	523	1 494	--	--	--	--	--	--	--	108	--	2 368	124	--
small shrimp spp.	3 248	3 173	1 425	851	--	78	22	25	--	--	1 955	--	10 777	216	--
sub-total	10 907	7 167	3 881	851	9	78	67	75	2 772	3 465	28 490	249	58 011	1 930	84
others (mostly fish)	5 738	3 621	5 152	1 321	924	526	258	286	719	898	7 721	2 240	29 403	3 397	322
total	16 644	10 788	9 032	2 173	933	605	325	361	3 490	4 363	36 211	2 489	87 414	5 327	406
Effort (hr)	17 727	14 372	10 973	2 576	1 866	1 176	1 232	1 369	5 338	6 673	38 850	6 014	108 166	14 289	1 540
Effort (landings)	2 165	2 240	1 717	448	373	224	224	249	821	1 027	5 375	830	15 693	2 157	280
Av. hours/landing	8.19	6.42	6.39	5.75	5.00	5.25	5.50	5.50	6.50	6.50	7.23	7.25	6.89	6.63	5.50
CPUE (kg/landing)															
P. indicus	2.375	1.550	0.550	--	0.025	--	0.150	0.150	3.300	3.300	4.909	0.300	2.700	0.438	0.300
P. semisulcatus	1.050	--	0.010	--	--	--	0.050	0.050	0.075	0.075	0.007	--	0.159	0.300	--
P. monodon	0.113	0.233	0.870	--	--	--	--	--	--	--	0.020	--	0.151	0.058	--
small shrimp spp.	1.500	1.417	0.830	1.900	--	0.350	0.100	0.100	--	--	0.364	--	0.687	0.100	--
others (mostly fish)	2.650	1.617	3.000	2.950	2.475	2.350	1.150	1.150	0.875	0.875	1.436	2.700	1.874	1.575	1.150
total	7.688	4.817	5.260	4.850	2.500	2.700	1.450	1.450	4.250	4.250	6.736	3.000	5.570	2.470	1.450
CPUE (kg/hr)															
P. indicus	0.290	0.242	0.086	--	0.005	--	0.027	0.027	0.508	0.508	0.679	0.041	0.392	0.066	0.055
P. semisulcatus	0.128	--	0.002	--	--	--	0.009	0.009	0.012	0.012	0.001	--	0.023	0.045	--
P. monodon	0.014	0.036	0.136	--	--	--	--	--	--	--	0.003	--	0.022	0.009	--
small shrimp spp.	0.183	0.221	0.130	0.330	--	0.067	0.018	0.018	--	--	0.050	--	0.100	0.015	--
others (mostly fish)	0.324	0.252	0.469	0.513	0.495	0.448	0.209	0.209	0.135	0.135	0.199	0.372	0.272	0.238	0.209
total	0.939	0.751	0.823	0.843	0.500	0.514	0.264	0.264	0.654	0.654	0.932	0.414	0.808	0.373	0.264

Table 5: Monthly catch weight and fishing effort for trammel nets.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	25 127	26 289	21 681	4 620	1 606	659	907	31 215	9 194	41 346	61 448	22 673	246 764	5 981	2 404
P. semisulcatus	14 519	4 071	1 141	508	152	94	52	280	3 129	1 973	752	1 427	28 097	11 134	7 026
P. monodon	375	9 131	10 774	904	279	53	72	247	229	225	272	478	23 040	986	1 084
small shrimp spp.	1 846	921	835	193	952	294	129	112	149	--	358	--	5 790	--	464
sub-total	41 867	40 411	34 432	6 224	2 989	1 101	1 160	31 854	12 701	43 544	62 830	24 577	303 690	18 101	10 977
others (mostly fish)	74 273	66 841	66 470	47 408	57 134	73 624	75 438	55 148	67 540	44 805	57 896	54 198	740 773	69 807	55 948
total	116 140	107 252	100 902	53 632	60 123	74 725	76 597	87 002	80 241	88 349	120 726	78 775	1 044 464	87 908	66 926
Effort (hr)	95 125	87 503	95 285	76 102	82 975	81 530	107 717	117 090	91 807	93 006	88 090	94 083	1 110 311	106 077	92 903
Effort (landings)	21 278	22 066	21 577	15 231	16 500	15 305	15 977	20 739	19 187	20 718	19 337	20 822	228 736	21 817	19 971
Av. hours/landing	4.47	3.97	4.42	5.00	5.03	5.33	6.74	5.65	4.78	4.49	4.56	4.52	4.85	4.86	4.65
Av. number of nets	27.6	25.5	28.2	21.8	23.1	21.8	19.8	33.9	26.9	32.1	34.1	33.6	27.0	33.0	29.8
CPUE (kg/landing)															
P. indicus	1.181	1.191	1.005	0.303	0.097	0.043	0.057	1.505	0.479	1.996	3.178	1.089	1.079	0.274	0.120
P. semisulcatus	0.682	0.184	0.053	0.033	0.009	0.006	0.003	0.014	0.163	0.095	0.039	0.069	0.123	0.510	0.352
P. monodon	0.018	0.414	0.499	0.059	0.017	0.003	0.005	0.012	0.012	0.011	0.014	0.023	0.101	0.045	0.054
small shrimp spp.	0.087	0.042	0.039	0.013	0.058	0.019	0.008	0.005	0.008	0.000	0.019	0.000	0.025	0.000	0.023
others (mostly fish)	3.491	3.029	3.081	3.113	3.463	4.810	4.722	2.659	3.520	2.163	2.994	2.603	3.239	3.200	2.801
total	5.458	4.861	4.676	3.521	3.644	4.882	4.794	4.195	4.182	4.264	6.243	3.783	4.566	4.029	3.351
CPUE (kg/hr)															
P. indicus	0.264	0.300	0.228	0.061	0.019	0.008	0.008	0.267	0.100	0.445	0.698	0.241	0.222	0.056	0.026
P. semisulcatus	0.153	0.047	0.012	0.007	0.002	0.001	0.000	0.002	0.034	0.021	0.009	0.015	0.025	0.105	0.076
P. monodon	0.004	0.104	0.113	0.012	0.003	0.001	0.001	0.002	0.002	0.002	0.003	0.005	0.021	0.009	0.012
small shrimp spp.	0.019	0.011	0.009	0.003	0.011	0.004	0.001	0.001	0.002	0.000	0.004	0.000	0.005	0.000	0.005
others (mostly fish)	0.781	0.764	0.698	0.623	0.689	0.903	0.700	0.471	0.736	0.482	0.657	0.576	0.667	0.658	0.602
total	1.221	1.226	1.059	0.705	0.725	0.917	0.711	0.743	0.874	0.950	1.370	0.837	0.941	0.829	0.720

Table 6: Monthly catch weight and fishing effort for gill nets.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	--	--	157	45	--	45	1 384	382	--	--	--	--		--	--
P. semisulcatus	--	--	--	--	--	13	29	--	--	--	--	--		--	--
P. monodon	776	--	601	--	--	90	65	31	--	--	--	--		--	--
small shrimp spp.	--	--	1 254	--	--	22	--	--	--	--	--	--		--	--
sub-total	776	--	2 012	45	--	170	1 478	412	--	--	--	--		--	--
others (mostly fish)	9 415	19 145	10 442	14 559	19 745	29 117	17 263	5 873	14 332	4 970	3 897	4 619	153 377	8 171	2 352
total	10 191	19 145	12 454	14 603	19 745	29 287	18 741	6 285	14 332	4 970	3 897	4 619	153 377	8 171	2 352
Effort (hr)	9 220	14 963	14 241	29 565	27 912	37 516	32 865	16 218	20 360	9 332	5 935	6 381	224 510	9 644	5 459
Effort (landings)	1 941	3 069	2 613	4 480	5 226	5 823	5 301	1 908	2 016	933	896	1 078	35 285	1 659	840
Av. hours/landing	4.75	4.88	5.45	6.60	5.34	6.44	6.20	8.50	10.10	10.00	6.63	5.92	6.36	5.81	6.50
Av. number of nets	10.0	12.3	10.0	13.4	19.5	17.4	22.3	14.8	11.8	4.0	8.5	10.3	15.7	10.5	6.0
CPUE (kg/landing)															
P. indicus	--	--	0.060	0.010	--	0.008	0.261	0.200	--	--	--	--	0.057	--	--
P. semisulcatus	--	--	--	--	--	0.002	0.006	--	--	--	--	--	0.001	--	--
P. monodon	0.400	--	0.230	--	--	0.015	0.012	0.016	--	--	--	--	0.044	--	--
small shrimp spp.	--	--	0.480	--	--	0.004	--	--	--	--	--	--	0.036	--	--
others (mostly fish)	4.850	6.238	3.996	3.250	3.778	5.000	3.257	3.078	7.110	5.325	4.350	4.283	4.347	4.925	2.800
total	5.250	6.238	4.766	3.260	3.778	5.029	3.536	3.294	7.110	5.325	4.350	4.283	4.486	4.925	2.800
CPUE (kg/hr)															
P. indicus	--	--	0.011	0.002	--	0.001	0.042	0.024	--	--	--	--	0.009	--	--
P. semisulcatus	--	--	--	--	--	--	0.001	--	--	--	--	--	--	--	--
P. monodon	0.084	--	0.042	--	--	0.002	0.002	0.002	--	--	--	--	0.007	--	--
small shrimp spp.	--	--	0.088	--	--	0.001	--	--	--	--	--	--	0.006	--	--
others (mostly fish)	1.021	1.279	0.733	0.492	0.707	0.776	0.525	0.362	0.704	0.533	0.657	0.724	0.683	0.847	0.431
total	1.105	1.279	0.874	0.494	0.707	0.781	0.570	0.388	0.704	0.533	0.657	0.724	0.705	0.847	0.431

Table 7: Monthly catch weight and fishing effort for hand lines.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
small shrimp spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
sub-total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
others (mostly fish)	1 762	1 626	672	1 762	1 463	672	2 217	1 008	10 554	756	2 117	3 011	27 620	5 740	2 408
total	1 762	1 626	672	1 762	1 463	672	2 217	1 008	10 554	756	2 117	3 011	27 620	5 740	2 408
Effort (hr)	2 837	2 323	1 120	2 837	2 090	1 120	4 106	1 866	5 823	1 400	3 920	3 484	32 927	7 466	3 780
Effort (landings)	597	581	224	597	523	224	821	249	896	187	523	498	5 919	664	560
Av. hours/landing	4.75	4.00	5.00	4.75	4.00	5.00	5.00	7.50	6.50	7.50	7.50	7.00	5.56	11.25	6.75
CPUE (kg/landing)															
P. indicus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
small shrimp spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
others (mostly fish)	2.950	2.800	3.000	2.950	2.800	3.000	2.700	4.050	11.780	4.050	4.050	6.050	4.666	8.650	4.300
total	2.950	2.800	3.000	2.950	2.800	3.000	2.700	4.050	11.780	4.050	4.050	6.050	4.666	8.650	4.300
CPUE (kg/hr)															
P. indicus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
small shrimp spp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
others (mostly fish)	0.621	0.700	0.600	0.621	0.700	0.600	0.540	0.540	1.812	0.540	0.540	0.864	0.839	0.769	0.637
total	0.621	0.700	0.600	0.621	0.700	0.600	0.540	0.540	1.812	0.540	0.540	0.864	0.839	0.769	0.637

Table 8: Monthly catch weight and fishing effort for fyke nets.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan'98	Feb
Catch Weights (kg)															
P. indicus	10	22	2	9	--	--	--	--	--	--	--	--	43	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	3	7	1	4	--	--	--	--	--	--	--	--	15	--	--
small shrimp spp.	53	119	182	1 029	427	225	638	714	748	573	606	1 457	6 769	1 042	403
sub-total	67	148	184	1 043	427	225	638	714	748	573	606	1 457	6 828	1 042	403
others (mostly fish)	34	76	78	444	167	240	95	588	508	671	981	1 654	5 537	1 709	790
total	101	224	262	1 487	593	465	732	1 301	1 255	1 244	1 588	3 111	12 365	2 752	1 193
Effort (hr)	133	296	250	1 417	1 133	1 275	1 381	1 679	1 677	2 063	2 625	4 012	17 942	1 866	2 034
Effort (landings)	33	74	50	283	267	300	283	315	383	458	500	741	3 688	481	438
Av. hours/landing	4.00	4.00	5.00	5.00	4.25	4.25	4.88	5.33	4.38	4.50	5.25	5.42	4.86	3.88	4.65
CPUE (kg/landing)															
P. indicus	0.300	0.300	0.033	0.033	--	--	--	--	--	--	--	--	0.012	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	0.100	0.100	0.013	0.013	--	--	--	--	--	--	--	--	0.004	--	--
small shrimp spp.	1.600	1.600	3.633	3.633	1.600	0.750	2.250	2.267	1.950	1.250	1.213	1.967	1.835	2.165	0.920
others (mostly fish)	1.030	1.030	1.567	1.567	0.625	0.800	0.335	1.867	1.325	1.465	1.963	2.233	1.501	3.550	1.806
total	3.030	3.030	5.247	5.247	2.225	1.550	2.585	4.133	3.275	2.715	3.175	4.200	3.353	5.715	2.726
CPUE (kg/hr)															
P. indicus	0.075	0.075	0.007	0.007	--	--	--	--	--	--	--	--	0.002	--	--
P. semisulcatus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P. monodon	0.025	0.025	0.003	0.003	--	--	--	--	--	--	--	--	0.001	--	--
small shrimp spp.	0.400	0.400	0.727	0.727	0.376	0.176	0.462	0.425	0.446	0.278	0.231	0.363	0.377	0.559	0.198
others (mostly fish)	0.258	0.258	0.313	0.313	0.147	0.188	0.069	0.350	0.303	0.326	0.374	0.412	0.309	0.916	0.388
total	0.758	0.758	1.049	1.049	0.524	0.365	0.530	0.775	0.749	0.603	0.605	0.775	0.689	1.475	0586

Table 9: Monthly catch weight and fishing effort for stake nets.

	Jan'97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Jan	Feb
Catch Weights (kg)															
P. indicus	798	1 435	--	1 739	1 297	1 193	1 161	3 048	2 444	17 577	4 424	339	35 454	546	1 030
P. semisulcatus	4 374	2 750	3 666	1 475	929	37	39	190	1 202	221	13	106	15 001	911	1 952
P. monodon	--	109	9	225	210	102	48	29	--	27	15	21	793	15	82
P. merguiensis	--	--	--	--	1 270	--	--	--	--	--	--	793	2 063	--	--
small shrimp spp.	5 064	12 769	3 407	17 354	10 773	28 844	6 706	13 098	10 745	35 393	11 539	2 400	158 091	11 524	17 991
sub-total	10 236	17 062	7 081	20 792	14 478	30 176	7 954	16 364	14 390	53 217	15 992	3 660	211 402	12 996	21 055
others (mostly fish)	16 622	6 022	3 478	12 406	17 907	10 308	3 180	3 773	13 559	4 939	2 122	2 697	97 011	2 341	2 943
total	26 857	23 083	10 559	33 198	32 385	40 484	11 135	20 137	27 950	58 156	18 114	6 357	308 413	15 337	23 997
Effort (hr)	4 890	2 688	1 854	6 055	6 623	7 659	4 794	5 646	6 108	8 460	5 984	3 138	63 897	6 165	5 765
Effort (landings)	840	615	690	1 035	1 110	1 200	750	975	1 050	1 350	938	570	11 123	990	940
Av. hours/landing	5.8	4.4	2.7	5.9	6.0	6.4	6.4	5.8	5.8	6.3	6.4	5.5	5.7	6.2	6.1
Av. crew/craft	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	2.0	2.0	1.9	2.0	2.0	2.0
Catch Value (Rs'000)	1 367	1 779	744	1 790	1 497	2 495	751	1 517	1 829	4 773	1 628	431	20 601	1 263	2 048
Av. Price (Rs/kg)	50.9	77.1	70.5	53.9	46.2	61.6	67.5	75.3	65.5	82.1	89.9	67.8	66.8	82.3	85.4
CPUE (kg/landing)															
P. indicus	0.95	2.33	--	1.68	1.17	0.99	1.55	3.13	2.33	13.02	4.72	0.60	3.19	0.55	1.10
P. semisulcatus	5.21	4.47	5.31	1.42	0.84	0.03	0.05	0.20	1.14	0.16	0.01	0.19	1.35	0.92	2.08
P. monodon	--	0.18	0.01	0.22	0.19	0.08	0.06	0.03	--	0.02	0.02	0.04	0.07	0.02	0.09
P. merguiensis	--	--	--	--	1.14	--	--	--	--	--	--	1.39	0.18	--	--
small shrimp spp.	6.03	20.76	4.94	16.77	9.71	24.04	8.94	13.43	10.23	26.22	12.31	4.21	14.21	11.64	19.14
sub-total	12.18	27.74	10.26	20.09	13.04	25.15	10.61	16.78	13.71	39.42	17.06	6.42	19.01	13.13	22.40
others (mostly fish)	19.79	9.79	5.04	11.99	16.13	8.59	4.24	3.87	12.91	3.66	2.26	4.73	8.72	2.37	3.13
total	31.97	37.53	15.30	32.07	29.18	33.74	14.85	20.65	26.62	43.08	19.32	11.15	27.73	15.49	25.53
CPUE (kg/hr)															
P. indicus	0.16	0.53	--	0.29	0.20	0.16	0.24	0.54	0.40	2.08	0.74	0.11	0.56	0.09	0.18
P. semisulcatus	0.89	1.02	1.98	0.24	0.14	0.01	0.01	0.03	0.20	0.03	0.00	0.03	0.24	0.15	0.34
P. monodon	--	0.04	0.01	0.04	0.03	0.01	0.01	0.00	--	0.00	0.00	0.01	0.01	0.00	0.01
P. merguiensis	--	--	--	--	0.19	--	--	--	--	--	--	0.25	0.03	--	--
small shrimp spp.	1.04	4.75	1.84	2.87	1.63	3.77	1.40	2.32	1.76	4.18	1.93	0.76	2.47	1.87	3.12
sub-total	2.09	6.35	3.82	3.43	2.19	3.94	1.66	2.90	2.36	6.29	2.67	1.17	3.31	2.11	3.65
others (mostly fish)	3.40	2.24	1.87	2.05	2.70	1.35	0.66	0.67	2.22	0.58	0.6	0.86	1.52	0.38	0.51
total	5.49	8.59	5.69	5.48	4.89	5.29	2.32	3.57	4.58	6.87	3.03	2.03	4.83	2.49	4.16

Table 10: Monthly catch weight and fishing effort for non-mechanised trawls

	Mar'97	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Year
Catch Weights (kg)													
P. indicus	363	206	143	143	282	160	146	516	622	390	225	279	3 475
P. semisulcatus	20	27	--	--	--	--	8	35	3	3	1	5	103
P. monodon	40	38	25	10	56	28	34	103	45	8	14	20	421
P. merguiensis	37	41	23	16	133	133	282	334	89	81	105	27	1 299
small shrimp spp.	10 355	5 800	3 394	9 480	16 996	7 405	11 441	30 421	9 616	9 019	45 647	22 065	181 639
sub-total	10 815	6 111	3 586	9 649	17 467	7 727	11 911	31 409	10 375	9 501	45 991	22 396	186 938
others (mostly fish)	17 576	5 762	3 446	8 694	15 303	12 330	6 819	22 308	6 434	7 494	16 502	11 955	134 621
total	28 391	11 874	7 032	18 343	32 770	20 057	18 730	53 717	16 808	16 994	62 493	34 351	321 559
Effort (hr)	8 547	7 201	3 116	8 470	11 600	12 213	7 270	10 837	12 501	10 579	15 426	11 843	119 604
Effort (landings)	1 488	1 025	613	1 263	1 700	1 825	1 138	1 925	1 450	1 192	1 969	1 619	17 204
Effort (hauls)	5 950	4 100	2 450	5 050	5 350	5 756	4 263	7 700	6 735	5 370	8 581	6 220	67 524
Av. hours/landing	5.7	7.0	5.1	6.7	6.8	6.7	6.4	5.6	8.6	8.9	7.8	7.3	7.0
Av. crew/craft	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Catch Value (Rs'000)	1 416	792	522	1 386	2 631	1 268	1 821	4 456	1 536	1 243	5 992	3 269	26 334
Av. Price (Rs/kg)	49.9	66.7	74.3	75.6	80.3	63.2	97.2	83.0	91.4	73.2	95.9	95.2	81.9
CPUE (kg/landing)													
P. indicus	0.24	0.20	0.23	0.11	0.17	0.09	0.13	0.27	0.43	0.33	0.11	0.17	0.20
P. semisulcatus	0.01	0.03	--	--	--	--	0.01	0.02	0.00	0.00	0.00	0.00	0.01
P. monodon	0.03	0.04	0.04	0.01	0.03	0.02	0.03	0.05	0.03	0.01	0.01	0.01	0.02
P. merguiensis	0.03	0.04	0.04	0.01	0.08	0.07	0.25	0.17	0.06	0.07	0.05	0.02	0.08
small shrimp spp.	6.96	5.66	5.54	7.51	10.00	4.06	10.06	15.80	6.63	7.57	23.19	13.63	10.56
sub-total	7.27	5.96	5.86	7.64	10.27	4.23	10.47	16.32	7.16	7.97	23.36	13.83	10.87
others (mostly fish)	11.82	5.62	5.63	6.89	9.00	6.76	5.99	11.59	4.44	6.29	8.38	7.38	7.82
total	19.09	11.58	1.48	14.53	19.28	10.99	16.47	27.90	11.59	14.26	31.74	21.22	18.69
CPUE (kg/hr)													
P. indicus	0.042	0.029	0.046	0.017	0.024	0.013	0.020	0.048	0.050	0.037	0.015	0.024	0.029
P. semisulcatus	0.002	0.004	--	--	--	--	0.001	0.003	0.000	0.000	0.000	0.000	0.001
P. monodon	0.005	0.005	0.008	0.001	0.005	0.002	0.005	0.010	0.004	0.001	0.001	0.002	0.004
P. merguiensis	0.004	0.006	0.007	0.002	0.011	0.011	0.039	0.031	0.007	0.008	0.007	0.002	0.011
small shrimp spp.	1.211	0.805	1.089	1.119	1.465	0.606	1.574	2.807	0.769	0.853	2.959	1.863	1.519
sub-total	1.265	0.849	1.151	1.139	1.506	0.633	1.638	2.898	0.830	0.898	2.981	1.891	1.563
others (mostly fish)	2.056	0.800	1.106	1.026	1.319	1.010	0.938	2.059	0.515	0.708	1.070	1.009	1.126
total	3.322	1.649	2.257	2.166	2.825	1.642	2.576	4.957	1.345	1.606	4.051	2.901	2.689

Table 11: Monthly catch weight and fishing effort for mechanised trawls

	Mar'97	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Year
Catch Weights (kg)													
P. indicus	428	150	551	511	1 813	457	107	240	64	127	43	22	4 513
P. semisulcatus	--	--	--	--	9	--	--	--	--	--	--	4	14
P. monodon	45	87	108	43	99	30	12	2	0	7	1	1	433
P. merguiensis	--	27	96	203	497	396	100	55	35	2	4	1	1 415
small shrimp spp.	502	1 995	4 004	7 595	21 671	20 390	9 308	6 122	1 764	1 273	912	1 040	76 577
sub-total	975	2 259	4 758	8 352	24 089	21 273	9 528	6 418	1 863	1 408	960	1 068	82 951
others (mostly fish)	2 550	3 908	6 975	17 396	22 659	13 875	7 236	12 246	6 347	3 783	5 238	2 217	104 429
total	3 525	6 166	11 734	25 748	46 748	35 148	16 764	18 664	8 210	5 191	6 198	3 285	187 380
Effort (hr)	1 474	1 995	3 785	4 384	7 894	8 488	4 607	5 189	3 212	2 681	2 454	2 711	48 875
Effort (landings)	225	338	650	713	1 025	1 175	700	831	538	413	406	444	7 456
Effort (hauls)	831	1 350	2 819	3 047	5 123	5 196	3 215	3 549	2 242	1 730	1 658	1 575	32 333
Av. hours/landing	6.6	5.9	5.8	6.2	7.7	7.2	6.6	6.2	6.0	6.5	6.0	6.1	6.6
Av. crew/craft	3.1	4.0	4.0	4.0	4.1	4.9	4.2	3.6	3.2	3.1	3.1	3.3	3.9
Catch Value (Rs'000)	234	400	815	1 292	3 843	3 206	1 555	1 227	402	286	339	325	13 924
Av. Price (Rs/kg)	66.4	64.8	69.4	50.2	82.2	91.2	92.7	65.8	49.0	55.2	54.6	99.0	74.3
CPUE (kg/landing)													
P. indicus	1.90	0.44	0.85	0.72	1.77	0.39	0.15	0.29	0.12	0.31	0.11	0.05	0.61
P. semisulcatus	--	--	--	--	0.01	--	--	--	--	--	--	0.01	0.00
P. monodon	0.20	0.26	0.16	0.06	0.10	0.03	0.02	0.00	--	0.02	0.00	0.00	0.06
P. merguiensis	--	0.08	0.15	0.28	0.48	0.34	0.14	0.07	0.06	0.00	0.01	0.00	0.19
small shrimp spp.	2.23	5.91	6.16	10.66	21.14	17.35	13.30	7.36	3.28	3.09	2.25	2.34	10.27
sub-total	4.33	6.69	732	11.72	23.50	18.11	13.61	7.72	3.47	3.41	2.36	2.41	11.13
others (mostly fish)	11.33	11.58	10.73	24.42	22.11	11.81	10.34	14.73	11.81	9.17	12.89	5.00	14.01
total	15.67	18.27	18.05	36.14	45.61	29.91	23.95	22.45	15.27	12.58	15.26	7.40	25.13
CPUE (kg/hr)													
P. indicus	0.290	0.075	0.145	0.117	0.230	0.054	0.023	0.046	0.020	0.047	0.018	0.008	0.092
P. semisulcatus	--	--	--	--	0.001	--	--	--	--	--	--	0.001	0.000
P. monodon	0.030	0.044	0.028	0.010	0.012	0.004	0.003	0.000	--	0.003	0.000	0.000	0.009
P. merguiensis	--	0.014	0.025	0.046	0.063	0.047	0.022	0.011	0.011	0.001	0.002	0.000	0.029
small shrimp spp.	0.341	1.000	1.058	1.733	2.745	2.402	2.020	1.180	0.549	0.475	0.372	0.384	1.567
sub-total	0.662	1.132	1.257	1.905	3.052	2.506	2.068	1.237	0.580	0.525	0.391	0.394	1.697
others (mostly fish)	1.730	1.958	1.843	3.968	2.871	1.635	1.571	2.360	1.976	1.411	2.135	0.818	2.137
total	2.391	3.090	3.100	5.874	5.922	4.141	3.639	3.597	2.556	1.936	2.526	1.212	3.834

SPECIES COMPOSITIONS FOR SHRIMP

Introduction

The available data were from the sampling of catches. All or parts of catches were purchased at or adjacent to the landing sites over a period of fourteen months. Generally there were three purchases, each containing about one kilogram (shrimp and others), in each of four or five days per week. The numbers of shrimp of each species found in the samples were raised to the weight of the sampled catches. This was done separately in respect to each gear type. These numbers were summed over all the sampled catches for the month in question, and then raised to the total catch in the month. The latter were as reported in the previous section. The reference used when determining species was the FAO Species Identification Field Guide for Fishery Purposes (De Bruin, Russell and Bogusch, 1994). The Field Guide was also useful in providing brief descriptions of the preferred habitat and local biology for each species. The estimates for the annual catch numbers by species and gear are shown in Table 12.

Species in the Catches

A total of fourteen species were found. Twelve of these were in the catches from within the lagoon. The species caught exclusively outside the lagoon were *Pa. coromandelica* and *Pa. uncta*. *P. indicus* was the main contributor to the trammel net, cast net, and brush pile catches. *M. dobsoni* was the most abundant in both the stake net and trawl catches. It was the only species found to be abundant in the catches from both within and outside the lagoon. *P. semisulcatus* was important in the trammel net and lagoon seine catches. *M. moyebi* was also a major contributor to the catches from lagoon seines, as well as from stake nets.

Table 12: Species compositions.

Species	Annual Catch Number by Gear Type ('000)								
	Lagoon Seine	Brush Pile	Cast Net	Trammel Net	Fyke Net	Stake Net	Non-Mech. Trawl	Mech. Trawl	All Gears
P. indicus	449	966	9 649	36 794	20	4 345	132	162	52 516
P. semisulcatus	6 483	--	577	8 902	--	6 477	5	--	22 443
P. merguiensis	0	--	6	5	--	48	24	66	149
P. monodon	1	2	1	693	--	7	5	2	711
P. latisulcatus	9	--	--	--	--	393	--	--	402
P. canaliculatus	3	--	--	--	--	609	--	--	612
Pa. coromandelica	--	--	--	--	--	--	14 791	13 264	28 055
Pa. uncta	--	--	--	--	--	--	490	104	594
Pa. cornuta	--	--	--	--	--	111	7	1	119
M. dobsoni	1 060	22	--	--	6 354	84 907	63 215	17 798	173 357
M. elegans	107	0	26	810	353	7 299	18	14	8 628
M. moyebi	7 354	0	59	238	--	42 923	54	--	50 629
M. monoceros	112	--	4	47	6	2 664	6	--	2 837
M. affinis	1	0	4	--	--	300	211	169	684
Totals	15 580	991	10 325	47 489	6 733	150 081	78 957	31 579	341 737

Discussion

Six species (*P. indicus, P. semisulcatus, Pa. coromandelica, M. dobsoni, M. elegans, and M. moyebi*) accounted for some 98 % (by number) of the total (all gears) catch. According to the literature *P. indicus*, *P. semisulcatus* and *M. dobsoni* breed in the sea. Their postlarvae migrate inshore (to lagoons and estuaries) for growth and maturation, and then return to the sea in the process of becoming adults. As such, they were expected to occur in the catches from both inside and outside the lagoon. This was found to be so, although *P. indicus* and *P. semisulcatus* were much more prevalent in the catches from the lagoon. It is possible that relatively few of these species survive the exploitation levels currently being applied within the lagoon. The findings given in a later section, suggest this may be the case for *P. indicus*, although unlikely for *P. semisulcatus*. Both *M. elegans and M. moyebi* are described in the literature as being able to complete their life cycles within lagoon habitats. This would account for their very low abundance in the catches from trawling. *Pa. coromandelica* is reported as a strictly marine species, which accords well with the findings from this study.

LENGTH COMPOSITIONS FOR SHRIMP

Introduction

The section concerns the individual lengths of the shrimp in the catches. Again, the data used for this purpose were from the sampling of catches. Measurements were taken of the carapace length (distance from the tip of the rostrum to the mid-dorsal termination of the carapace) for all the shrimp in each sample. The resulting length frequencies (ie. the numbers at each length) were raised to the weights of the sampled catches. Then, separately for each gear type and month, these frequencies were summed, and raised to the weight of the total catches. The resulting plots of the annual length frequencies for each combination of main species, sex and gear type are given in Figures 2 to7. The maximum size ranges for each species by sex are shown in Table 13. Presumed migration paths (for juveniles and adults) are shown for some of the species in Figures 8 to 11.

Sizes in the Catches

The smallest *P. indicus* were caught with brush pile and lagoon seines (drag nets), these being the gears used in near-shore waters within the lagoon. The largest sizes in the lagoon catches were from trammel nets and cast nets. These gears produced generally larger sizes than from stake nets set at the entrance. The catches from the non-mechanised trawlers, contained similar sizes to those from the stake nets, as well as much larger individuals. The sizes in the catches from mechanised trawlers were generally larger than from the non-mechanised trawlers. This linkage between size and gear type was generally the same for *P. semisulcatus*. A major difference was that only intermediate sizes were found in the trawl catches.

Similarly for *M. moyebi*, *M. elegans*, and *M. dobsoni*, the smaller sizes were generally from those gears used around the margins of the lagoon, particularly lagoon seines. These species were all poorly represented in the catches from trammel nets and cast nets. The largest sizes in the lagoon catches were from stake nets and fyke nets. The small numbers of *M. moyebi* and *M. elegans* found in the trawl catches were of much the same lengths as from stake nets. In contrast, the *M. dobsoni* found in trawl catches were much larger, than from any of the gears used in the lagoon. The sizes of *Pa. coromandelica* caught from each of the non-mechanised and mechanised trawlers were generally the same. In respect to all species, the females present in the catches were generally larger than the males. This difference was most pronounced for *M. elegans*.

Table 13: Maximum size ranges in the catches.

	Carapace Length Range (cm)		Gear
	Male	Female	
P. indicus	6.4 – 6.6	7.4 – 7.6	Mechanised trawl
P. semisulcatus	4.6 – 4.8	5.4 – 5.6	Stake net
Pa. coromandelica	4.0 – 4.2	4.8 – 5.0	Non-mechanised trawl
M. dobsoni	3.6 – 3.8	4.6 – 4.8	Non-mechanised trawl
M. elegans	3.4 – 3.6	4.6 – 4.8	Stake net
M. moyebi	3.0 – 3.2	3.8 – 4.0	Stake net

Discussion

There are several reasons why the sizes of shrimp in the catches might differ between gears. One concerns the affect of the gear itself (ie. gear selectivity). Another concerns the migration of shrimp as they grow larger. Typically, juveniles occur in shallow depths, and progressively migrate to deeper and more saline water as they grow. Hence, those gears used in shallow waters can be expected to catch smaller sizes than the gears set at greater depth. Similarly, for those species caught both inside and outside the lagoon, the catches from outside should contain the larger individuals. The sizes that might ultimately be reached will also be affected by mortality rates. Fewer individuals will reach large sizes when mortalities (as from fishing and natural causes) are high.

The observation that *P. indicus* (and *P. semisulcatus*) caught with stake nets are generally smaller than from trammel or cast nets was unexpected. It seems that while many individuals migrate through the entrance at small sizes, another portion remains for a longer period within the lagoon. The time lag is possibly until the next rainy season. This interpretation is supported by the second grouping of lengths (eg. at about 4.5 cm for males and 5.1 cm for females of *P. indicus*) in each of the stake net frequencies. Relatively few shrimp are represented by these groupings, which presumably is indicative of most being caught (as well as dying from natural causes) while inside the lagoon. This would accord with the substantial fishing effort being exerted by the trammel net and cast net fishermen.

In contrast, the migration of *M. dobsoni* appears not to include a portion remaining within the lagoon for a longer period. Only one size group is represented in the stake net frequencies. Also, many more are caught at the entrance or outside the lagoon, than within the lagoon. These observations indicate a stronger impulse to migrate from the lagoon at an early age. In this respect, *P. semisulcatus* appears somewhat intermediate, between *P. indicus* and *M. dobsoni*. The length frequencies for *Pa. coromandelica* contain no information about migration behaviour. The extent to which there might be migration between the two trawling grounds is completely unknown. This is so for all the species. The length frequencies for *M. elegans* and *M. moyebi* are consistent with there being little migration outside (or far from) the lagoon.

The largest sizes of *M. dobsoni, M. elegans* and *M. moyebi* caught within the lagoon, were from both stake nets and fyke nets. These gears are set at opposite ends of the lagoon. It had been expected that the catches with fyke nets would have contained much smaller shrimp. The explanation (untested) might be that the mesh sizes in the fyke nets are larger, and hence allow the small shrimp to escape. Another possible explanation is that in addition to the migration to the entrance at the northern end, there might also be migration through the narrow waterway at the southern end. The latter connects to the Handela Canal, which connects to the Peliyagoda River, which enters the sea some 20 km south of the entrance to the Negombo Lagoon. While this southward migration seems unlikely, due to the smallness of the waterway, it nevertheless remains a possibility.

Figure 2: Annual length frequencies for *P. indicus*.

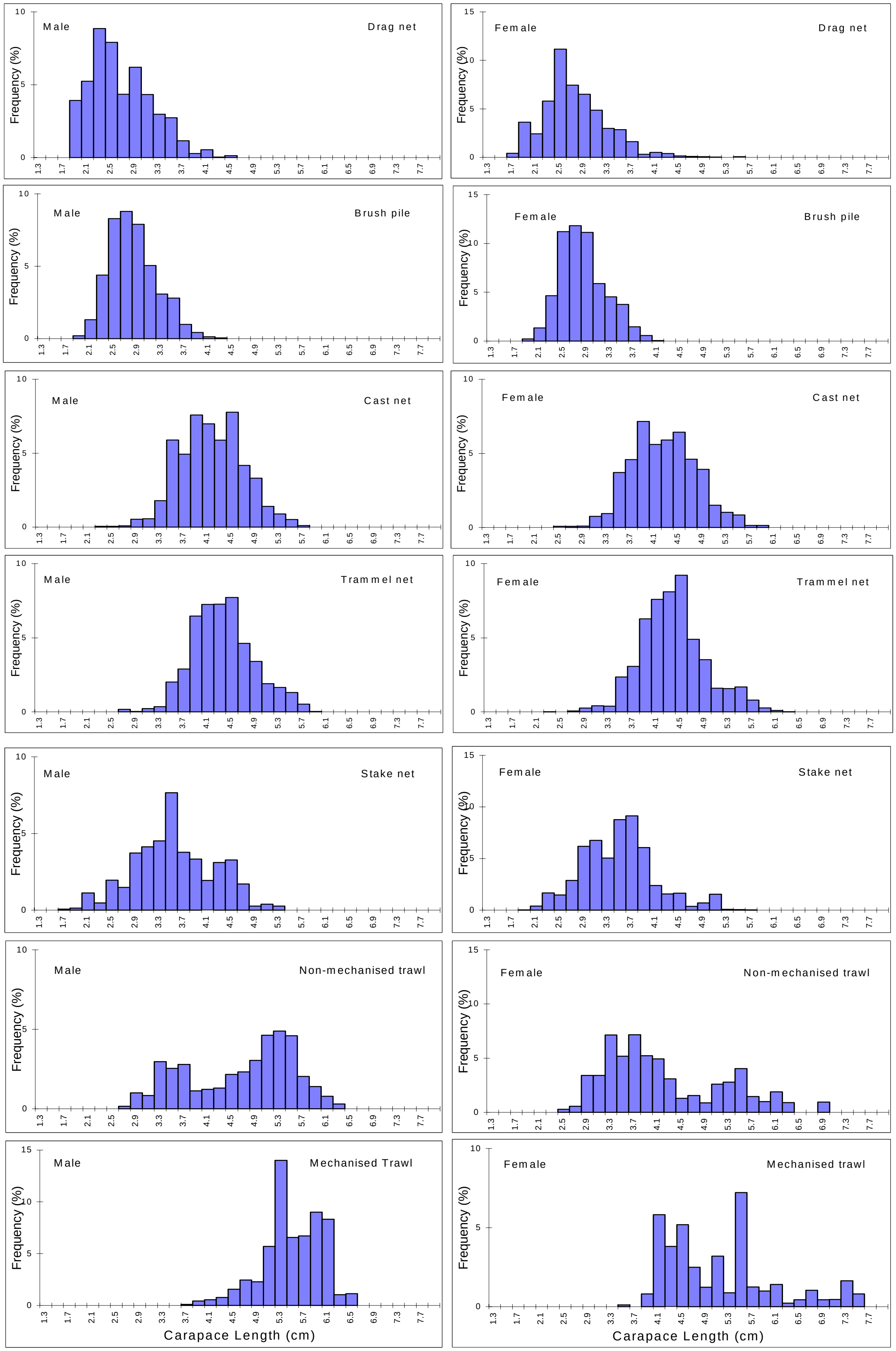


Figure 3: Annual length frequencies for *P. semisulcatus.*

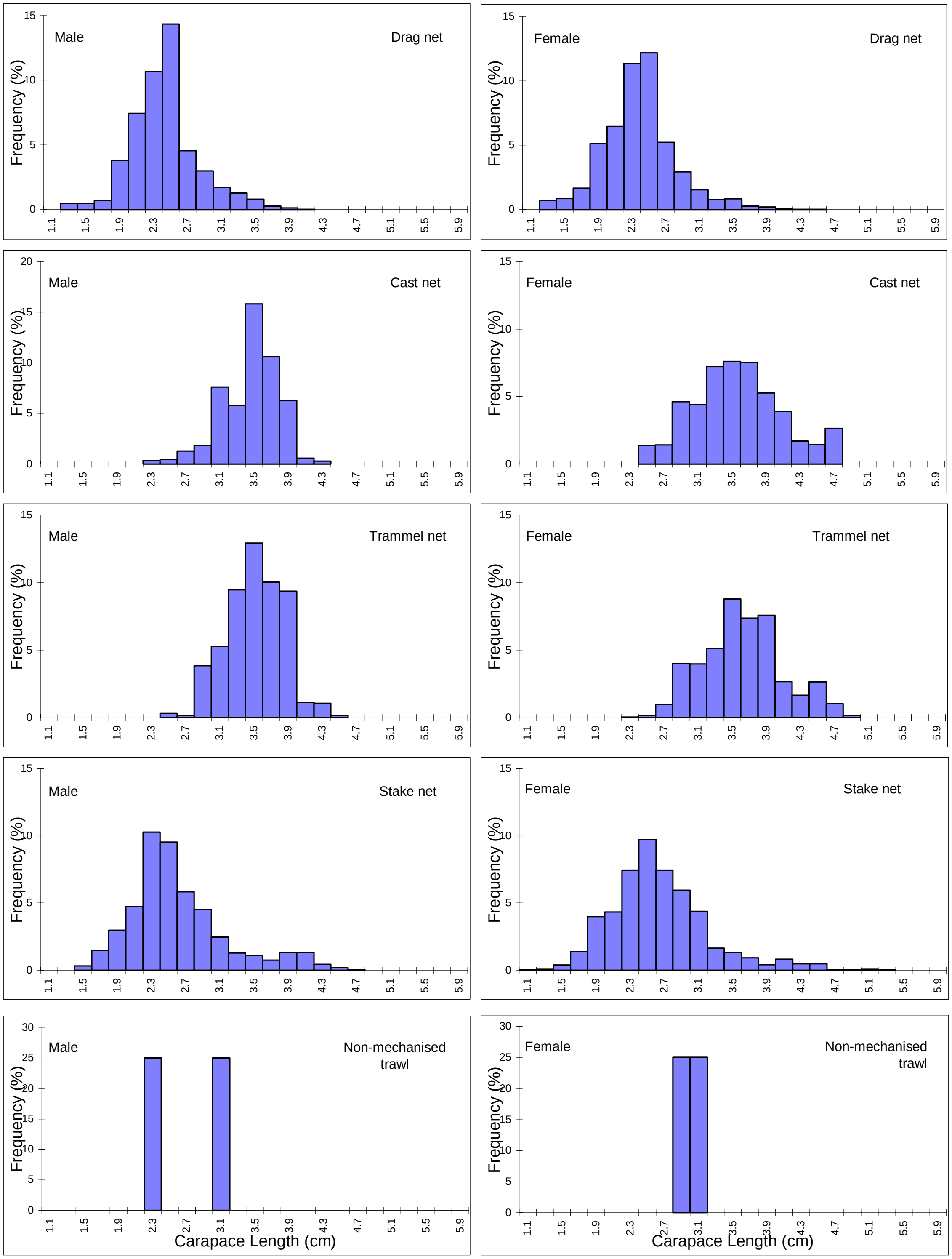


Figure 4: Annual length frequencies for *Pa. coromandelica.*

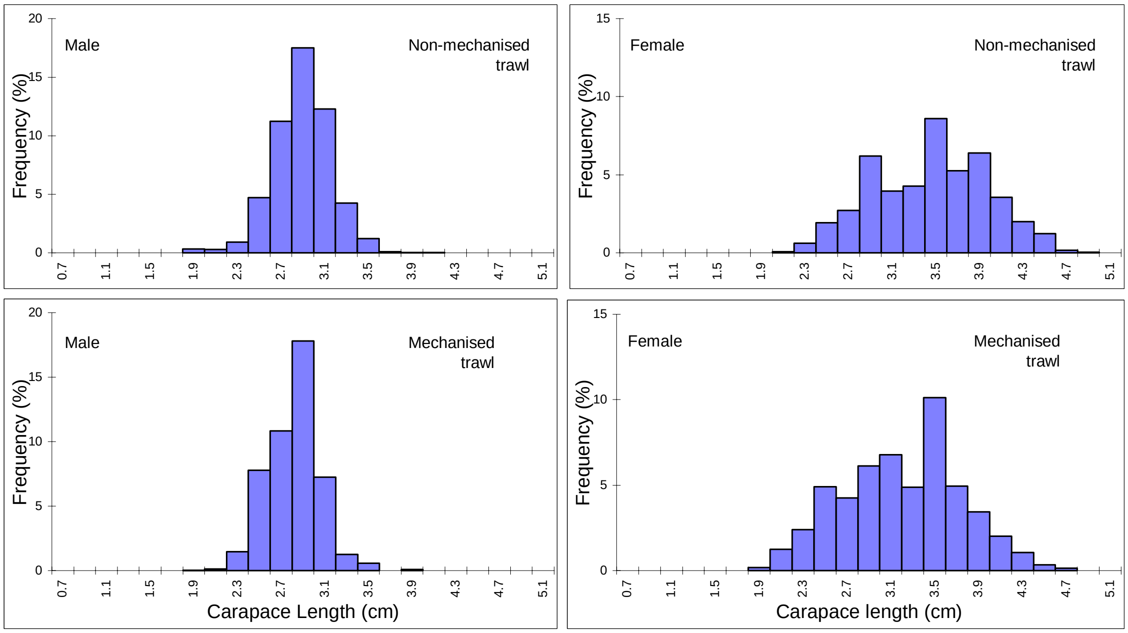


Figure 5: Annual length frequencies for *M. dobsoni*.

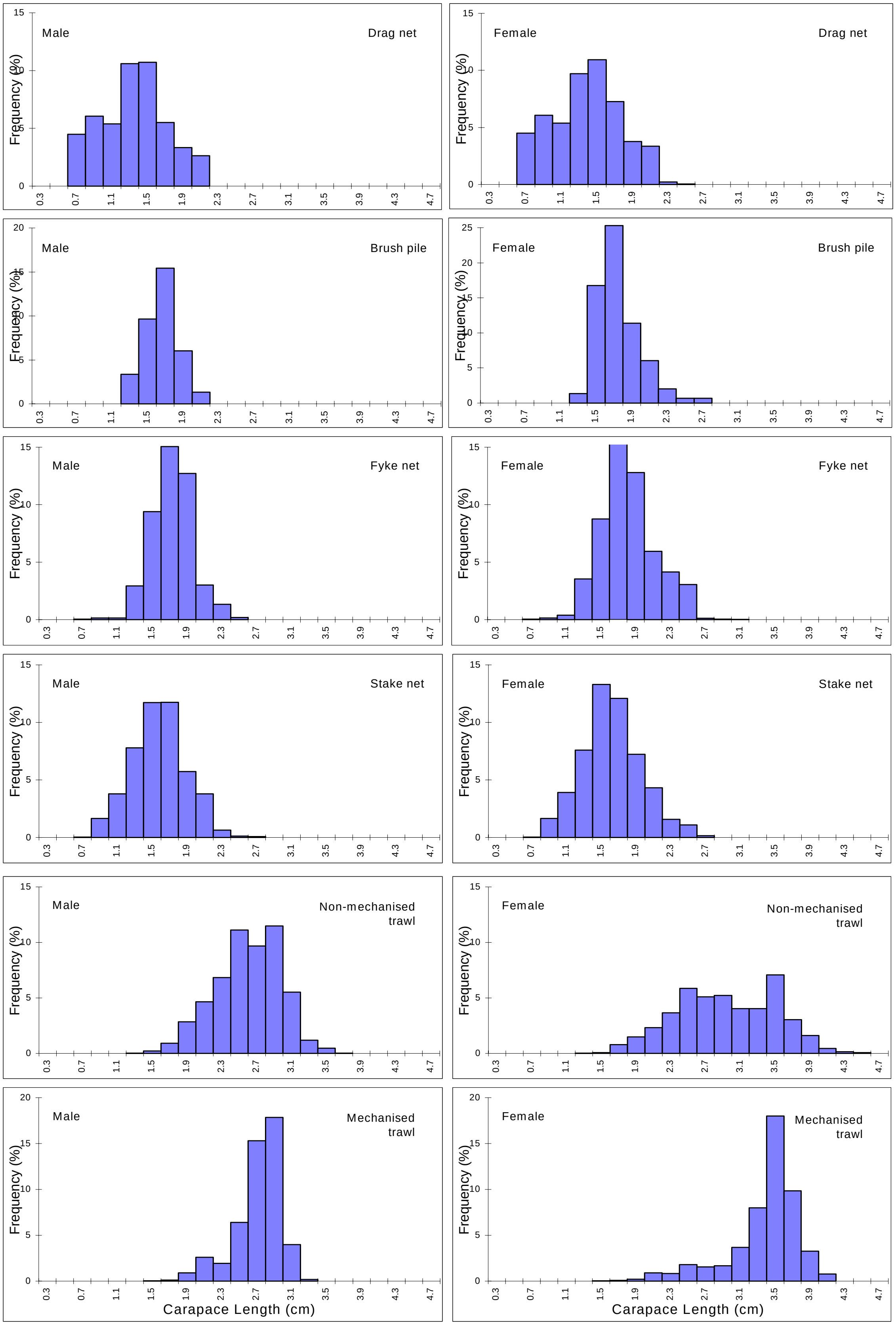


Figure 6: Annual length frequencies for *M. elegans*.

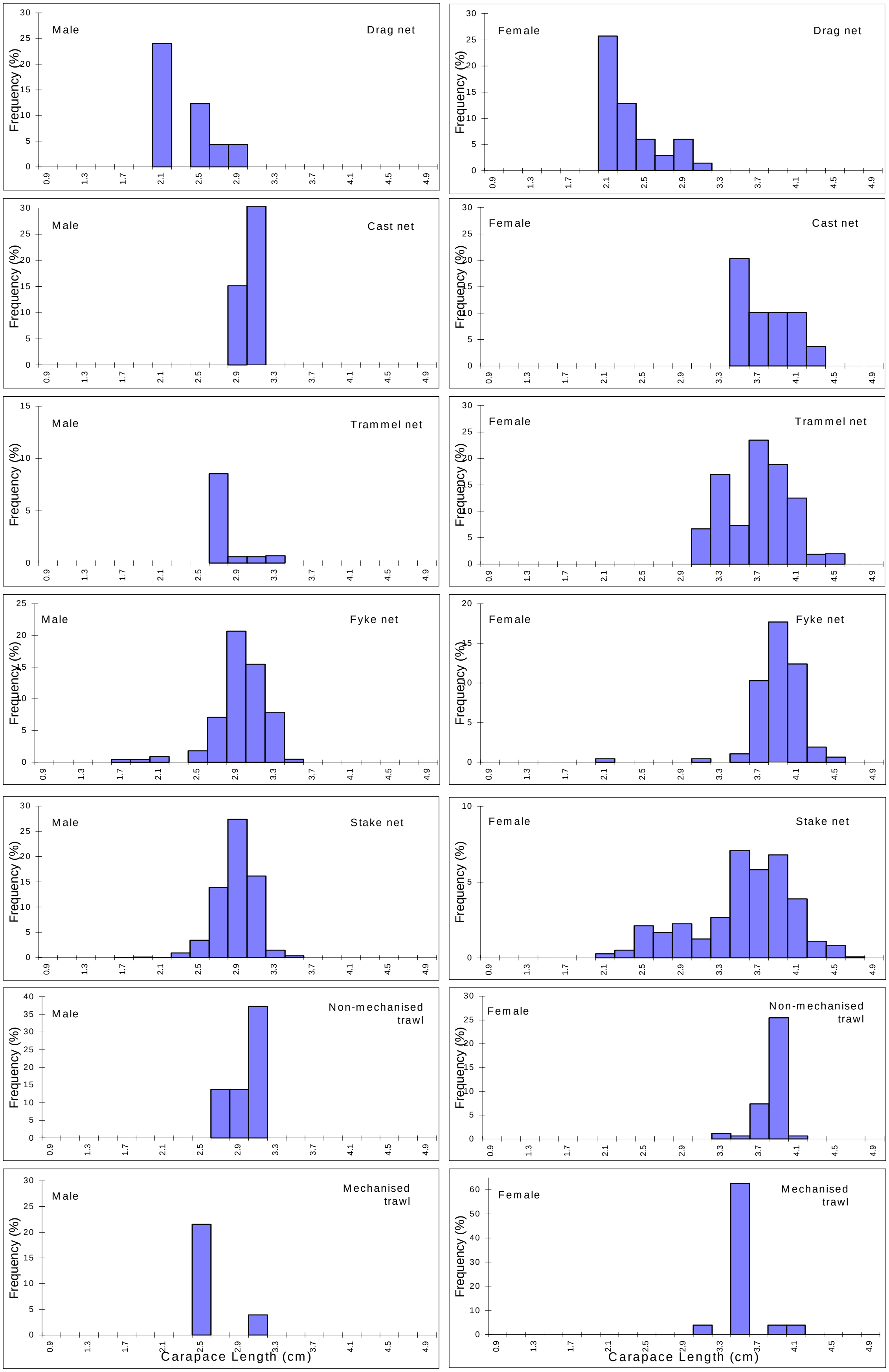


Figure 7: Annual length frequencies for *M. moyebi*.

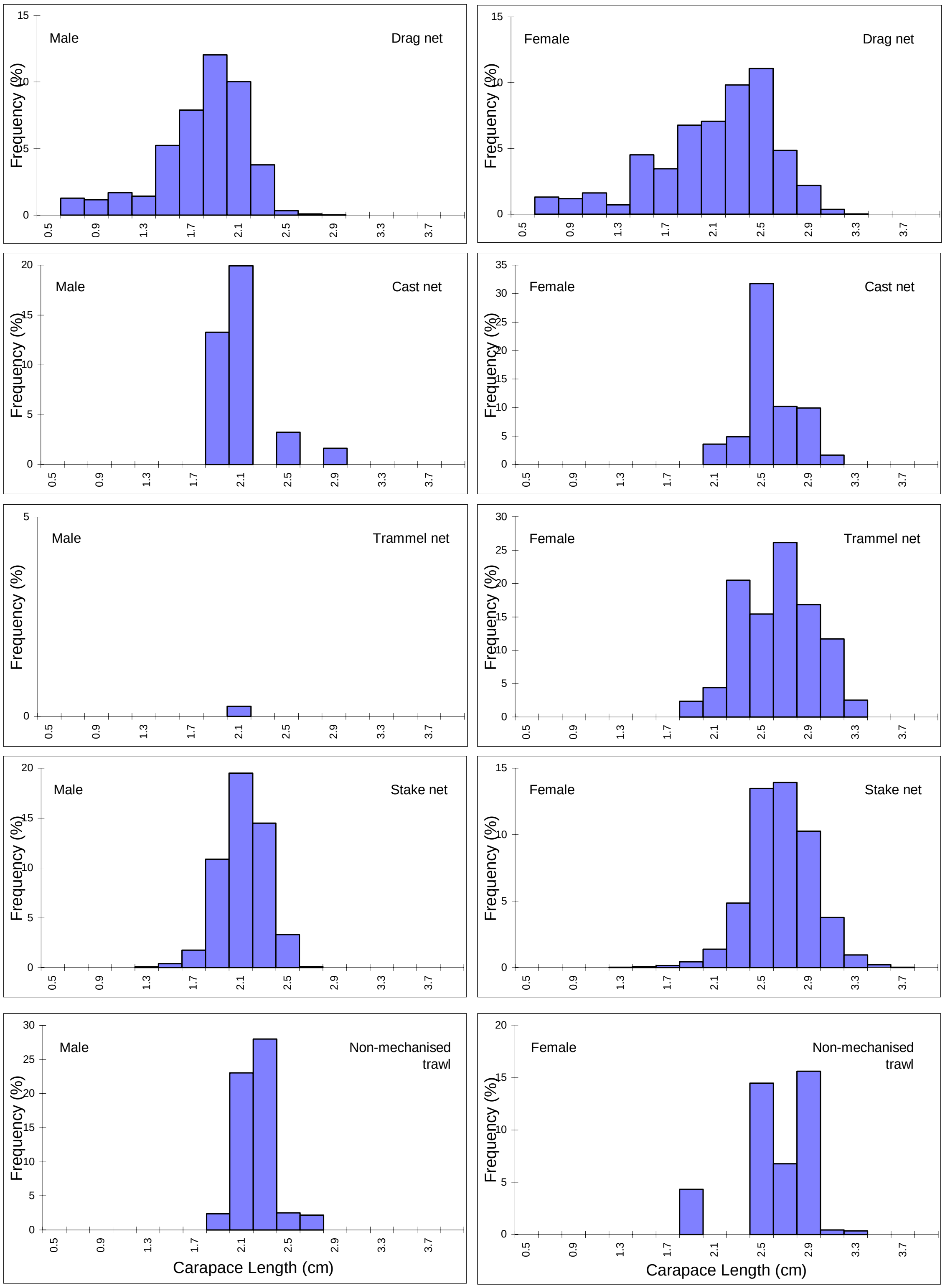


Figure 8: Migration path for *P. indicus*.

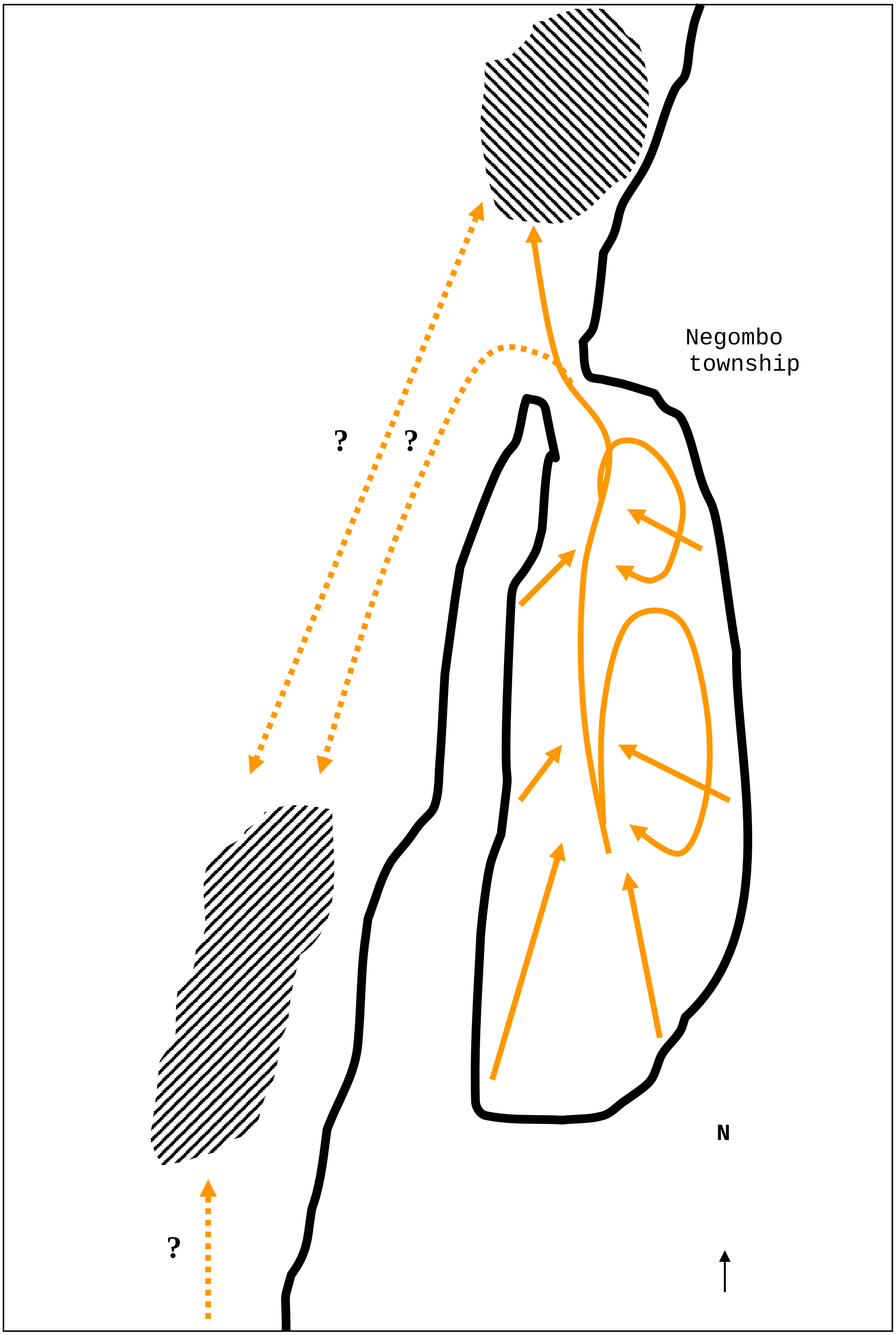


Figure 9: Migration path for *M. dobsoni*.

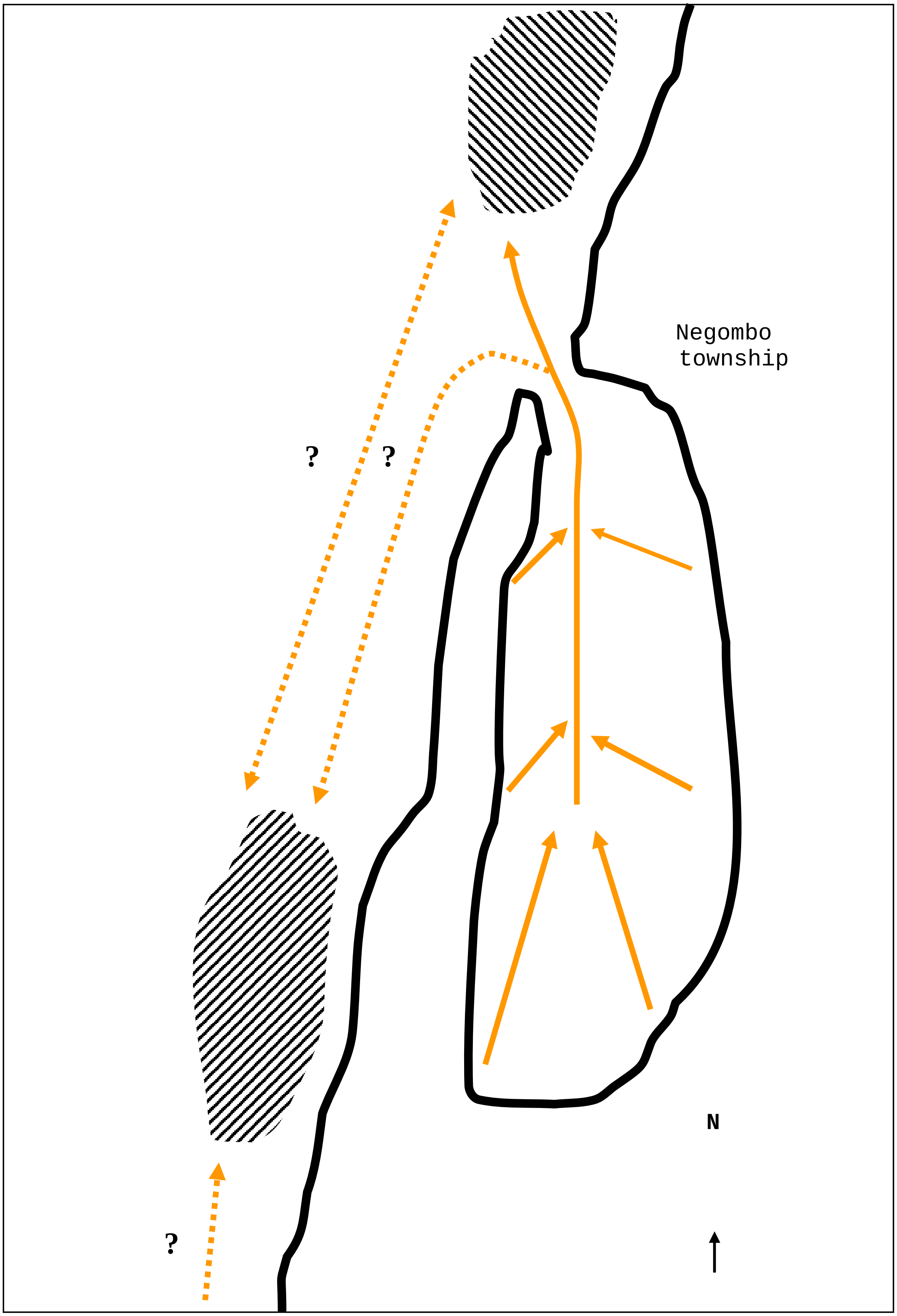


Figure 10: Migration path for *M. moyebi*.

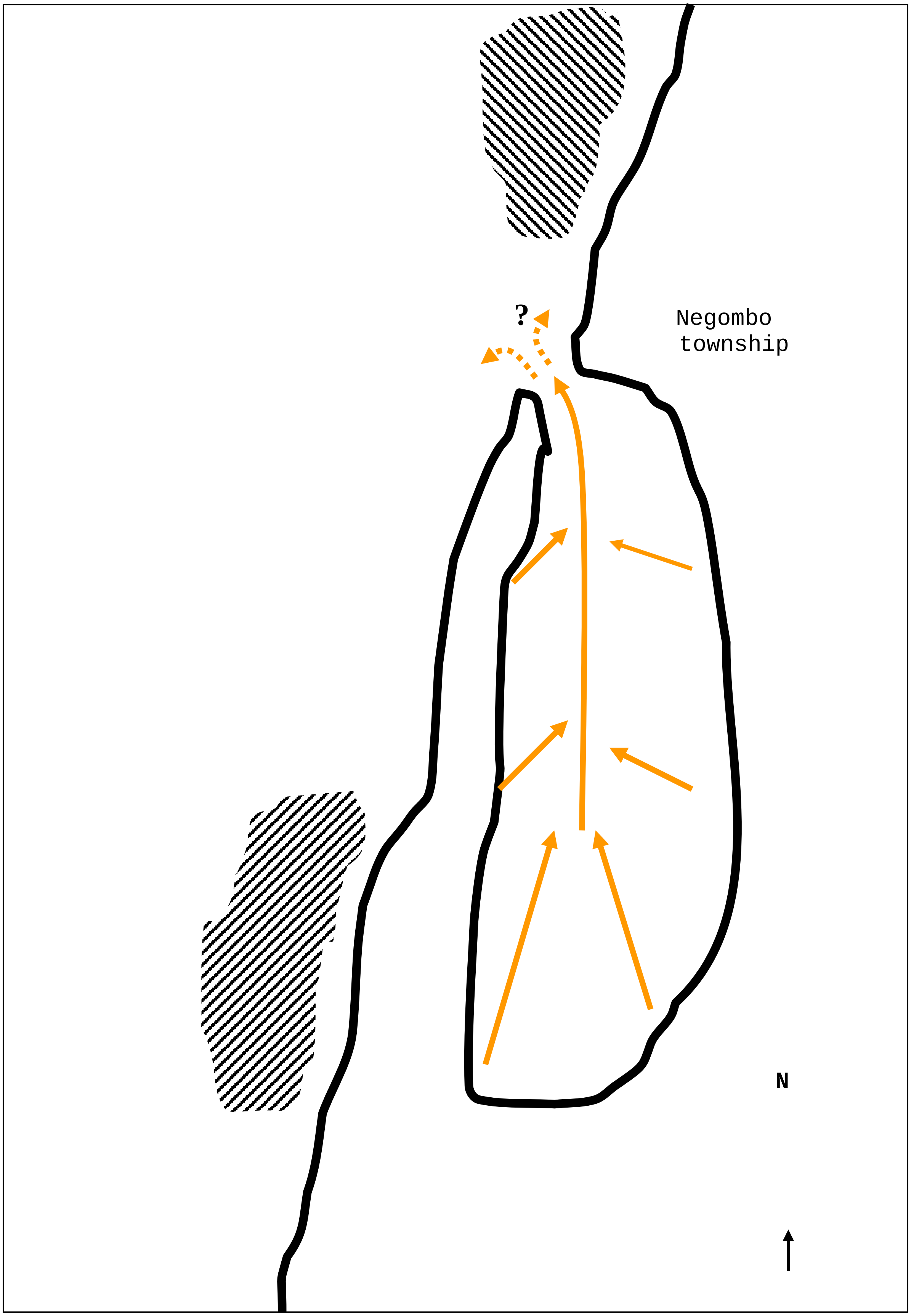
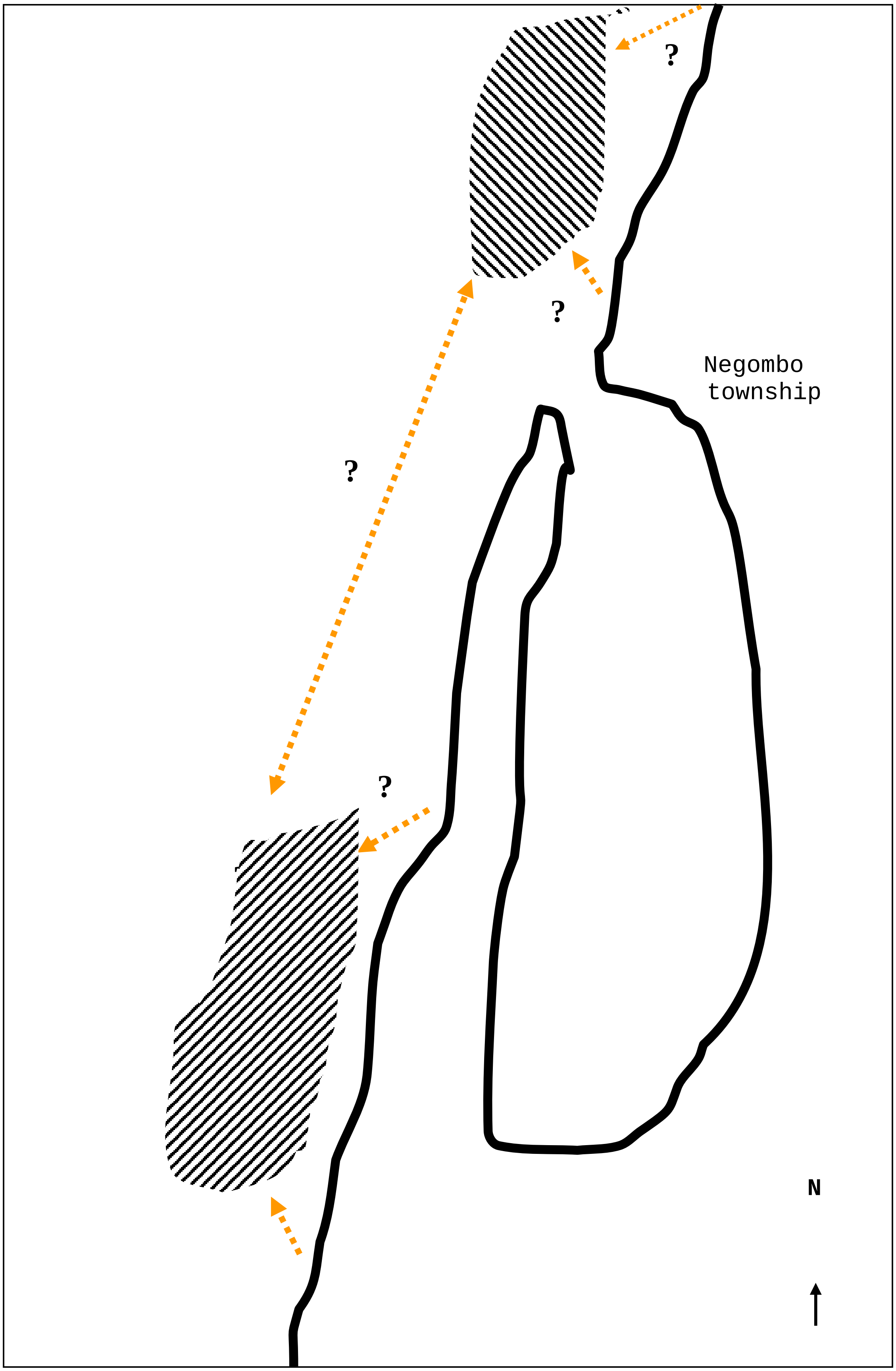


Figure 11: Migration path for *Pa. coromandelica*.



MORPHOMETRIC RELATIONSHIPS FOR SHRIMP

Introduction

During the study, the principal measurement of size for individual shrimp was carapace length. The additional measurements of total length (distance from the tip of the rostrum to the tip of the telson) and total weight were taken for a lesser number of shrimp. These combined data were analysed to determine the conversion constants in the relationships between carapace length and total length, and between total weight and each of carapace length and total length. In respect to the first, the relationships were assumed to be linear, while for the second a power curve relationship was assumed. In all cases, determining the best fit to the data was by 'least-squares' fit, using the curve fitting procedures in EXCEL. The conversion equations and plots of the data are shown for each species and sex combination in Table 14 and Figures 12 to 17.

Length to Weight Conversion

The relationships between weight and length, were found to be well represented by the power curve equation. It had been expected that the slope constants for females would be higher than for males, and that the intercept constants would be lower, as reported elsewhere (Dall *et al*., 1990). In the relationship between total weight and total length, this was found to be so for all species other than *P. semisulcatus*. This is suggestive of the males having a greater total weight for a given total length, at the upper end of the carapace length range; and possibly a lower total weight for a given total length, at the lower end of the range. In general, however, the weights at length for males and females were little different.

Length to Length Conversion

In all the species except *P. semisulcatus*, the linear slope constants for males were higher and the intercept constants were lower, when total length was regressed against carapace length. The opposite occurred when carapace length was regressed against total length. These are suggestive of the males having a greater total length for a given carapace length, at the upper end of the carapace length range; and possibly a lower total length for a given carapace length, at the lower end of the range. In reality, these differences between the sexes appear small for the size ranges represented in the data.

Table 14: Morphometric parameters.

Species	Sex	Total Weight vs. Carapace Length		Total Weight vs. Total Length		Total Length vs. Carapace Length		Carapace Length vs. Total Length	
		a x 10-5	*b*	*a* x 10-5	*b*	*a*	*b*	*a*	*b*
P. indicus	Male	3.52	3.22	0.343	3.11	-2.274	2.484	2.920	0.382
	Female	3.95	3.19	0.250	3.17	0.122	2.426	2.425	0.386
P. semisulcatus	Male	5.74	3.30	0.290	3.22	-1.333	2.772	0.903	0.355
	Female	7.04	3.24	0.291	3.22	-1.029	2.795	0.578	0.355
M. dobsoni	Male	36.3	2.63	0.827	2.91	5.846	2.441	-2.117	0.406
	Female	34.7	2.64	0.288	3.17	11.225	2.196	-4.316	0.445
Pa. coromandelica	Male	7.84	2.99	0.234	3.21	0.018	2.356	4.556	0.357
	Female	2.33	3.28	0.098	3.40	2.112	2.171	0.344	0.442
M. elegans	Male	22.2	2.83	0.370	3.13	6.990	2.425	-0.343	0.376
	Female	4.65	3.30	0.012	3.92	12.471	2.258	-4.887	0.435
M. moyebi	Male	30.1	2.77	1.030	2.88	3.921	2.684	0.161	0.346
	Female	31.4	2.74	0.330	3.17	8.549	2.409	-2.117	0.394

Note: The respective relationships are $TW = a.CL^b$, $TW = a.TL^b$, TL = a + b.CL , and CL = a + b.TL , with the weights measured in grams and the lengths in millimetres.

Discussion

The main utility of the relationships presented here is in enabling the conversion between the different measurements of length, and from lengths to weights. This is necessary, for example, when describing how size as both length and weight increases with age. The estimates of the constants in the relationships between length and age are given in the next section. The conversion from numbers-at-length to weights-at-length is demonstrated in the later section dealing with modelling the performance of the fisheries.

Figure 12: Morphometrics for *P. indicus*.

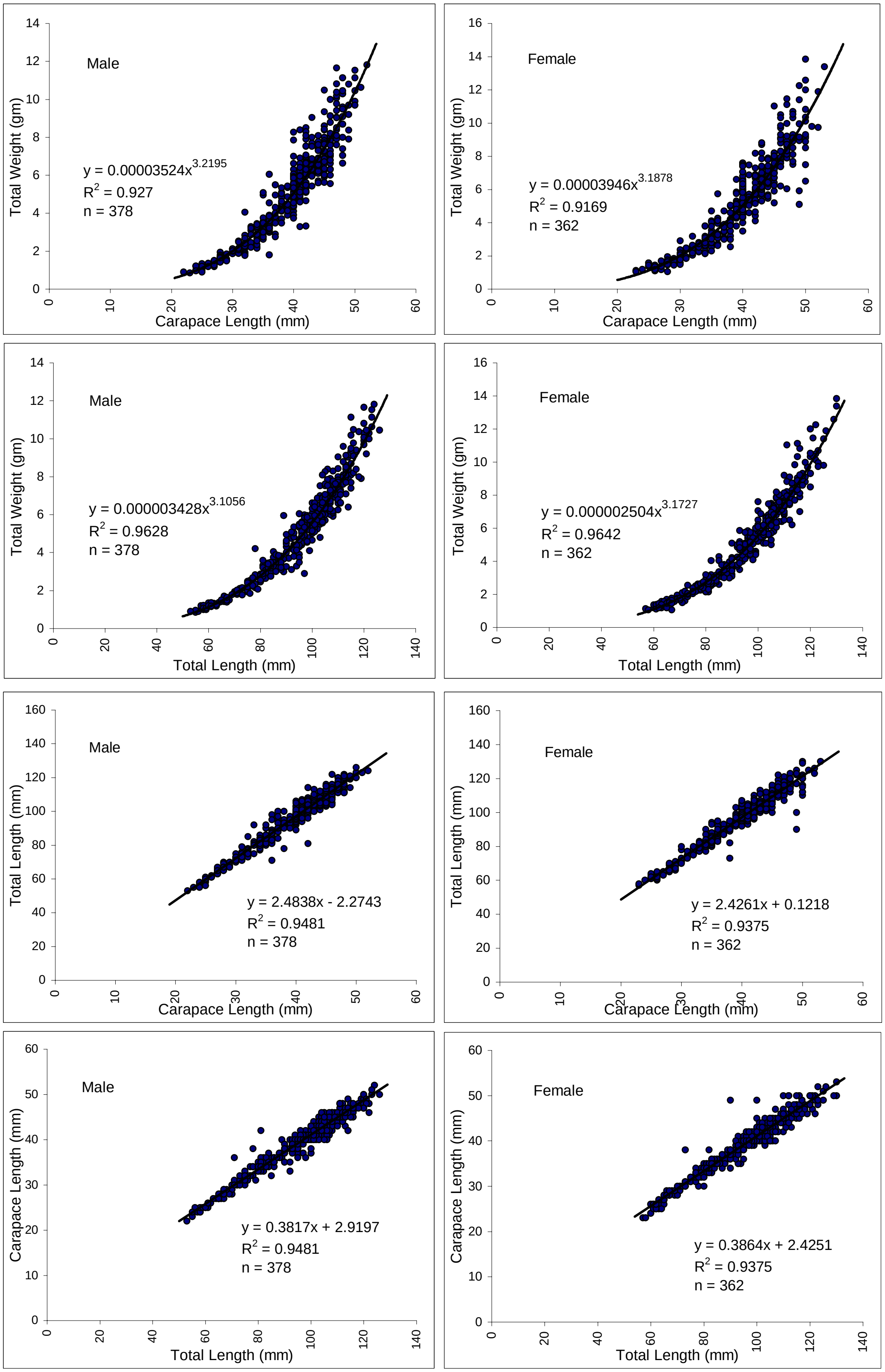


Figure 13: Morphometrics for *P. semisulcatus*.

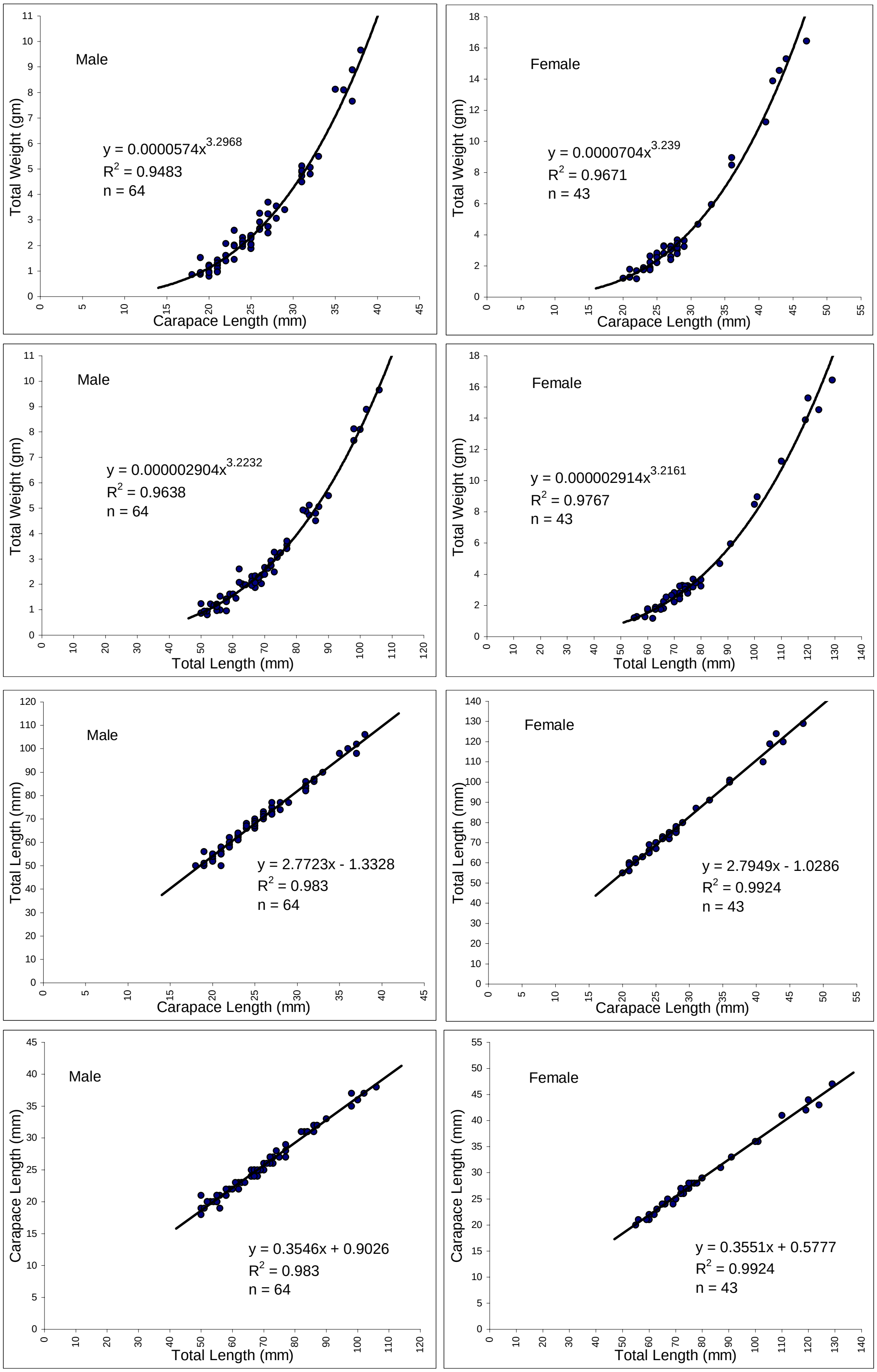


Figure 14: Morphometrics for *M. dobsoni*.

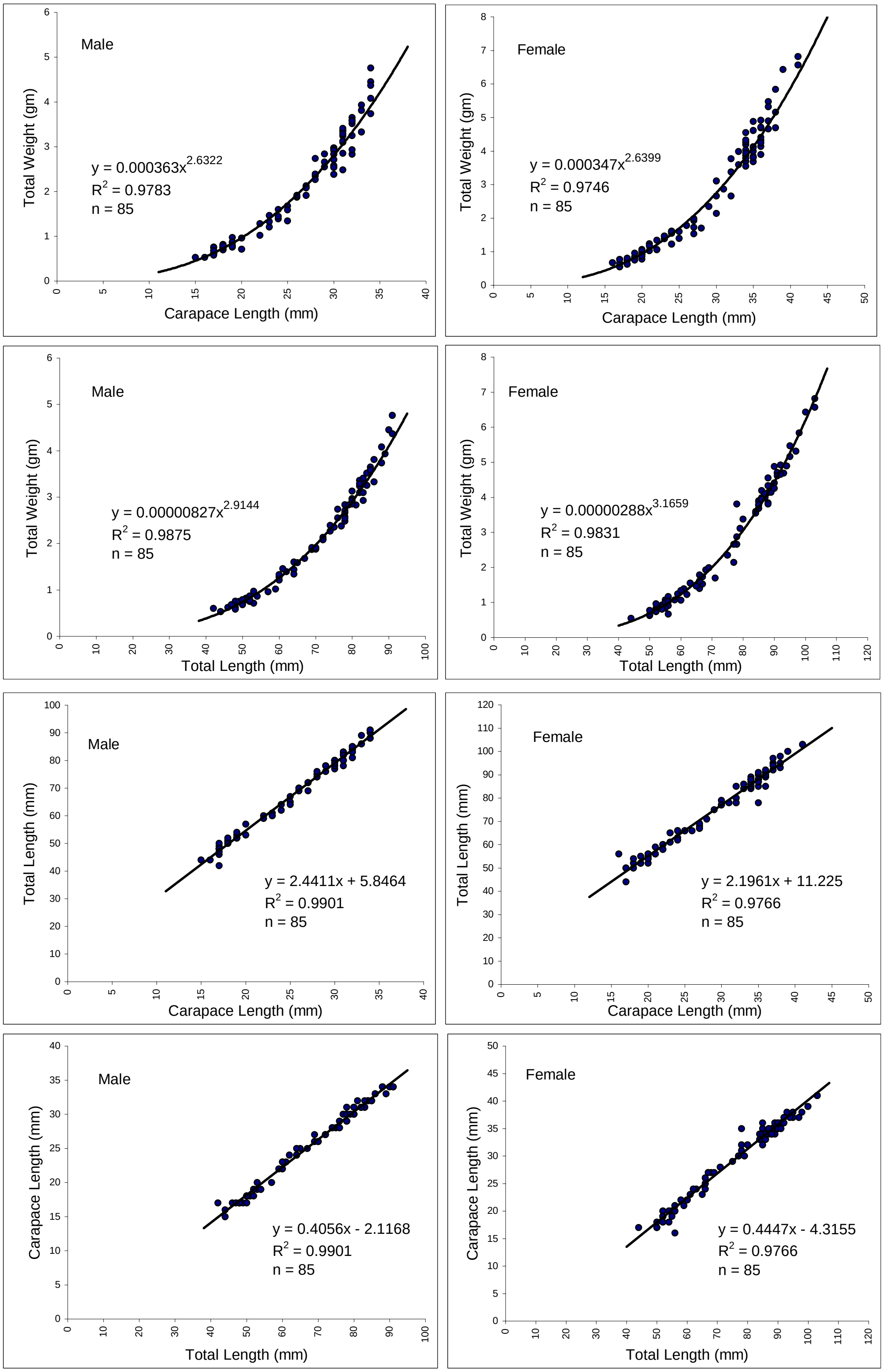


Figure 15: Morphometrics for *Pa. coromandelica.*

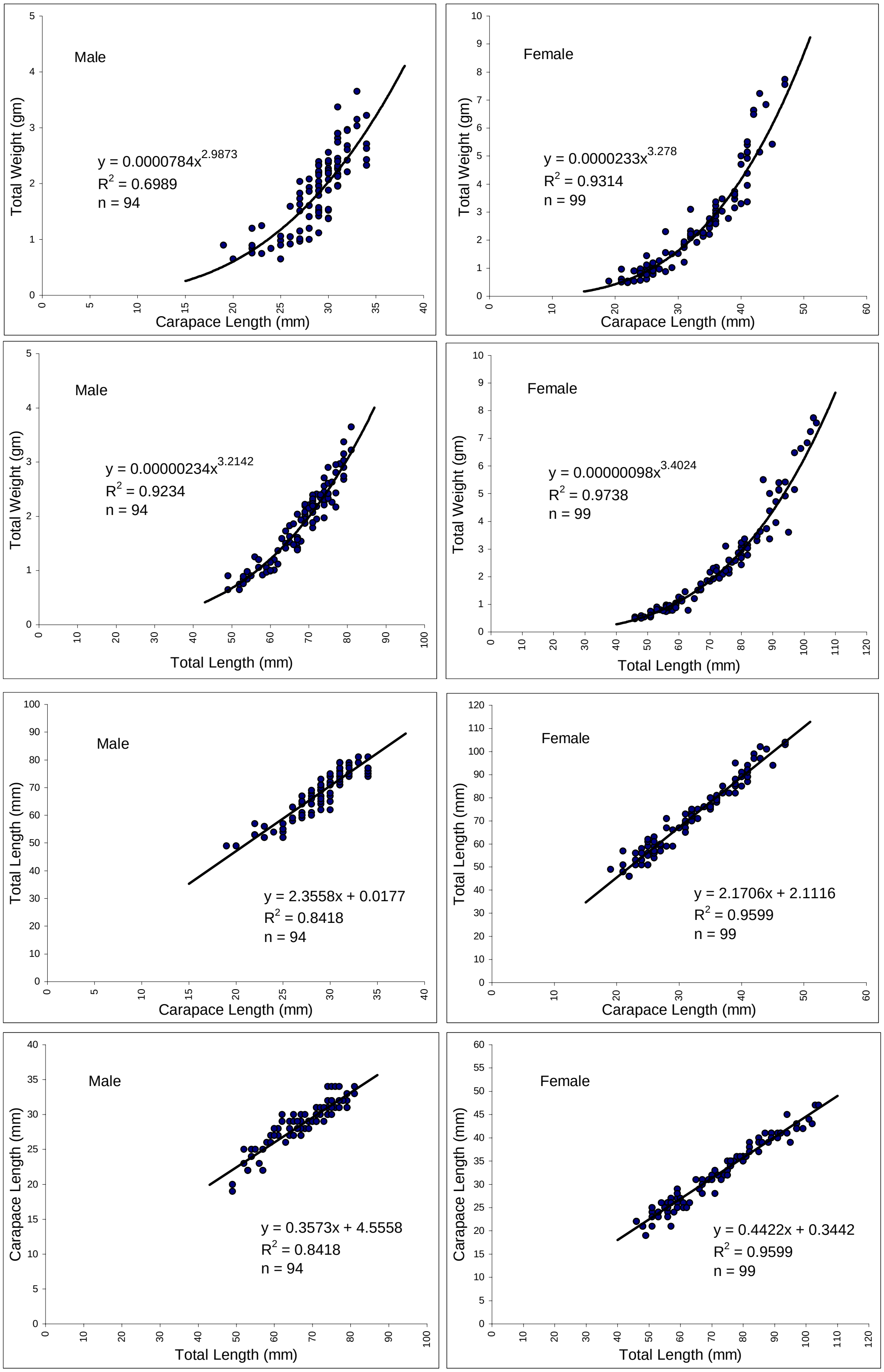


Figure 16: Morphometrics for *M. elegans*.

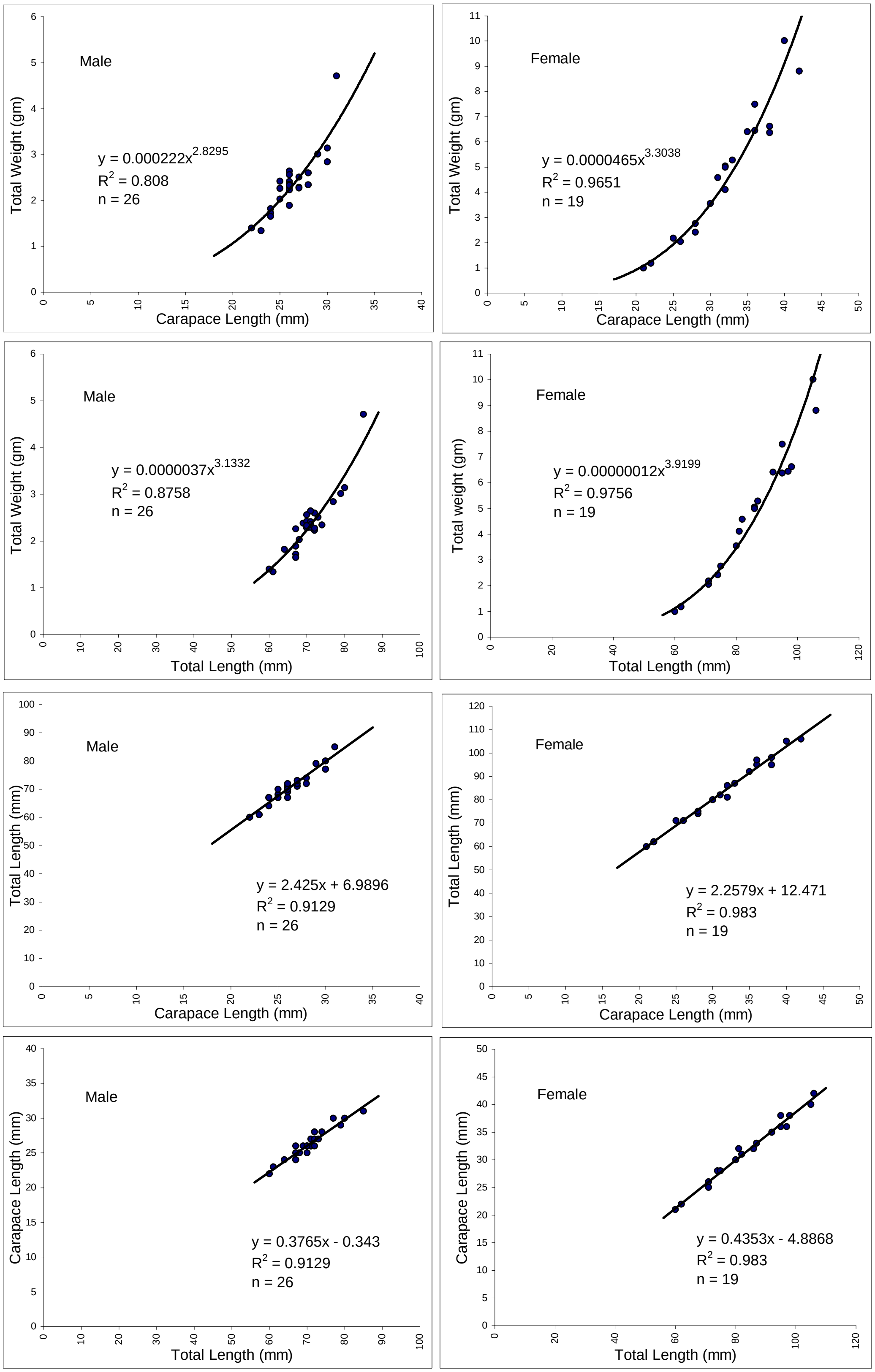
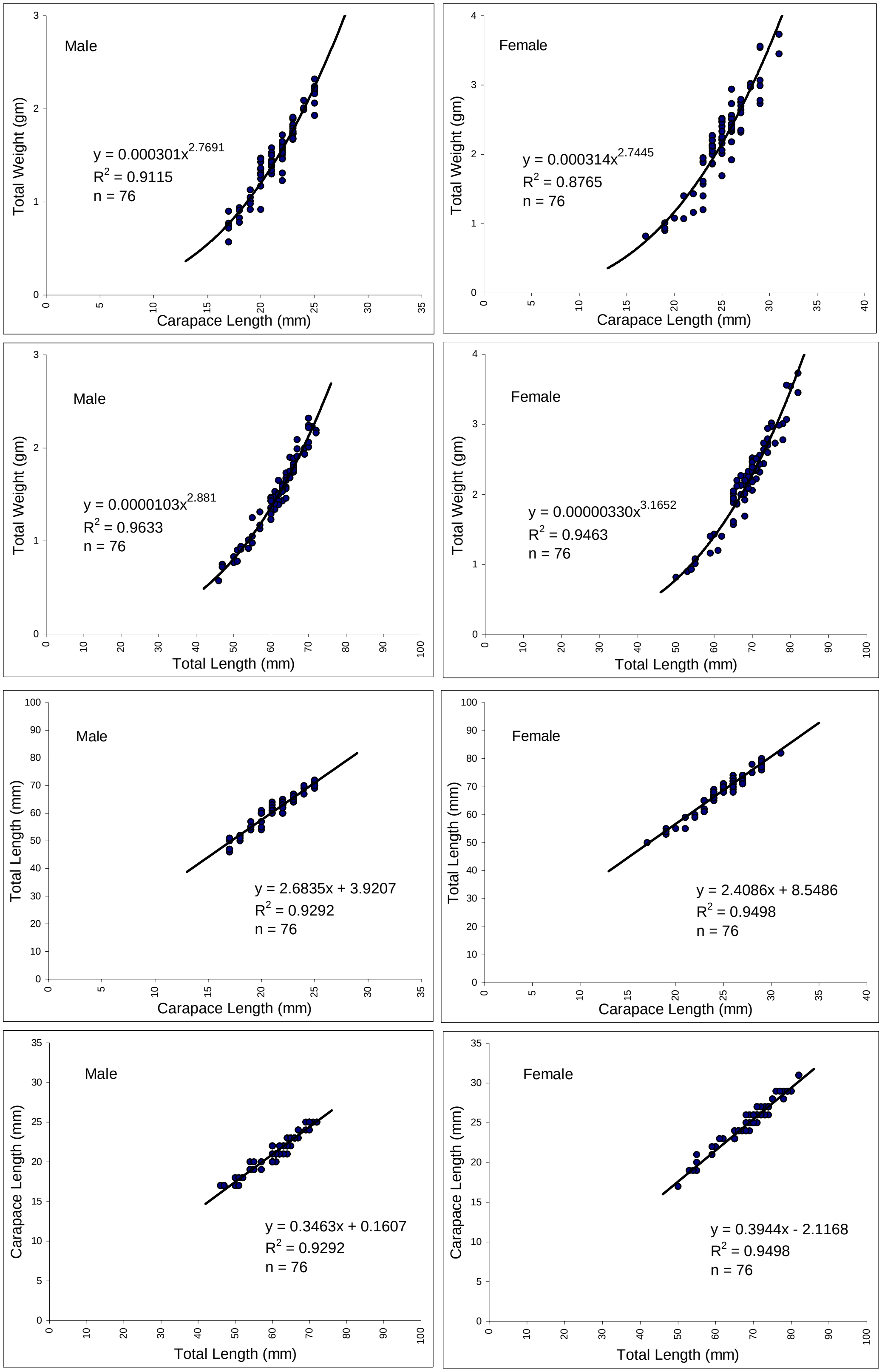


Figure 17: Morphometrics for *M. moyebi*.



LENGTH AT AGE RELATIONSHIPS FOR SHRIMP

Introduction

The data used for determining the length at age relationships were the length frequencies from the sampling of catches. The particular frequencies chosen were from sampling the non-mechanised trawl catches in the case of *P. indicus*, *M. dobsoni* and *Pa. coromandelica*; from sampling the stake net catches in the case of *P. semisulcatus*, *M. elegans* and *M. moyebi* females; and from sampling the lagoon seine catches in the case of *M. moyebi* males. These choices were in reflection of the perceived suitability of the data, including the need to minimise the biasing affect of migration. Growth was assumed to conform to the von Bertalanffy equation. The estimation procedures were those available within the FISAT computer software package (see Gayanilo *et al*, 1994). Plots of the length frequencies are shown in Figures 18 to 24. The estimates for the von Bertalanffy constants (L_∞ and K) and other indicators of growth performance (L_∞.K/2 and ϕ') are shown in Table 15. The relevant equations are given below this table. Approximate birth dates are given in Table 16.

Length at Age Parameters

The estimates for L_∞ and to a lesser extent K were highest for *P. indicus* and *P. semisulcatus*. This reflects their growth to larger sizes and at faster rates. The lowest values are for *M. moyebi*. The growth rate when the shrimp are at their 'mid-length' (ie. half L_∞) is given by L_∞.K/2. The estimates for CL_∞.K/2 are approaching 1 mm/week (carapace length) for *P. indicus* and *P. semisulcatus*, about 0.6 mm/week for *Pa. coromandelica*, *M. dobsoni* and *M. elegans*, and about 0.4 mm/week for *M. moyebi*. The values for females are higher than for males. The same trend in growth performance is indicated by the estimates of ϕ'.

Table 15: Growth performance.

Species	Sex	CL_∞ *(mm)*	TL_∞ *(mm)*	*K* *(yr^{-1})*	*K* *(wk^{-1})*	$CL_\infty.K/2$ *(mm/wk)*	ϕ'
P. indicus	Male	64.6	177.8	1.50	0.0288	0.93	2.08
	Female	66.5	184.8	1.55	0.0297	0.99	2.12
P. semisulcatus	Male	55.0	151.1	1.47	0.0282	0.78	1.93
	Female	60.2	167.2	1.42	0.0272	0.82	1.99
M. dobsoni	Male	37.6	97.6	1.43	0.0274	0.52	1.59
	Female	48.7	118.2	1.52	0.0292	0.71	1.84
Pa. coromandelica	Male	39.0	91.9	1.41	0.0270	0.53	1.61
	Female	49.1	108.7	1.51	0.0290	0.71	1.84
M. elegans	Male	34.6	90.9	1.39	0.0267	0.46	1.50
	Female	47.0	118.6	1.50	0.0288	0.68	1.80
M. moyebi	Male	25.6	72.6	1.43	0.0274	0.35	1.25
	Female	35.0	92.8	1.40	0.0268	0.47	1.52

Note: L_∞ and K are constants in the von Bertalanffy equation: $L_t = L_\infty.(1 - \exp(-K.(t - t_o)))$.
$TL_\infty = a + b.CL_\infty$ where a and b are the total length vs. carapace length constants given earlier.
$\phi' = \log_{10} K + 2.\log_{10} CL_\infty$ is from Pauly and Munro (1984).

Approximate Birth Dates

Visual examination of the length frequencies indicated two cohorts, and hence two spawning periods in each year. This was so for all species, and is presumably synchronised with the rainy seasons. The birth dates were determined, by firstly estimating lengths at age (using the relevant L_∞ and K values), and then backward extrapolation to length zero. As it was necessary to assume that shrimp of all ages grow according to the von Bertalanffy equation (which may not be correct during early life) the birth dates should be considered as approximate. They are generally indicative of spawning occurring around April and October. This could be confirmed by the future collection of data on gonadal maturity stages. The apparent differences between the sexes should be ignored, as in reality males and females will have identical birth dates.

Table 16: Approximate birth dates.

Species	Sex	Approximate Birth Dates	
		Spring Cohort	Autumn Cohort
P. indicus	Male	April 10	October 11
	Female	April 14	October 14
P. semisulcatus	Male	April 10	October 10
	Female	March 15	September 16
M. dobsoni	Male	March 19	September 19
	Female	May 9	November 11
Pa. coromandelica	Male	April 28	October 28
	Female	February 5	August 4
M. elegans	Male	April 6	October 7
	Female	June 14	December 15
M. moyebi	Male	January 9	July 10
	Female	March 8	September 8

Discussion

The estimates for the von Bertalanffy growth constants are indicative of the shrimp attaining close to their maximum sizes at ages of about 2 years. All values appear credible, and are in general agreement with those reported elsewhere (Dall *et al*, 1990). While the L_∞ values for *P. indicus* are somewhat higher, they are compatible with the large sizes found in the trawl catches. The estimates for *P. semisulcatus* might need to be viewed with caution, being based on the length frequencies from stake nets (in which the large-sized individuals were generally absent). This was necessary due to this species being poorly represented in the catches from trawling. The estimated birth dates generally coincide with the normal occurrence of the rainy seasons. This might not necessarily mean that the onset of the rains is the triggering mechanism. The timing of the rainy season has been highly variable in recent years.

Figure 18: Annual length frequencies for *P. indicus* (non-mechanised trawl).

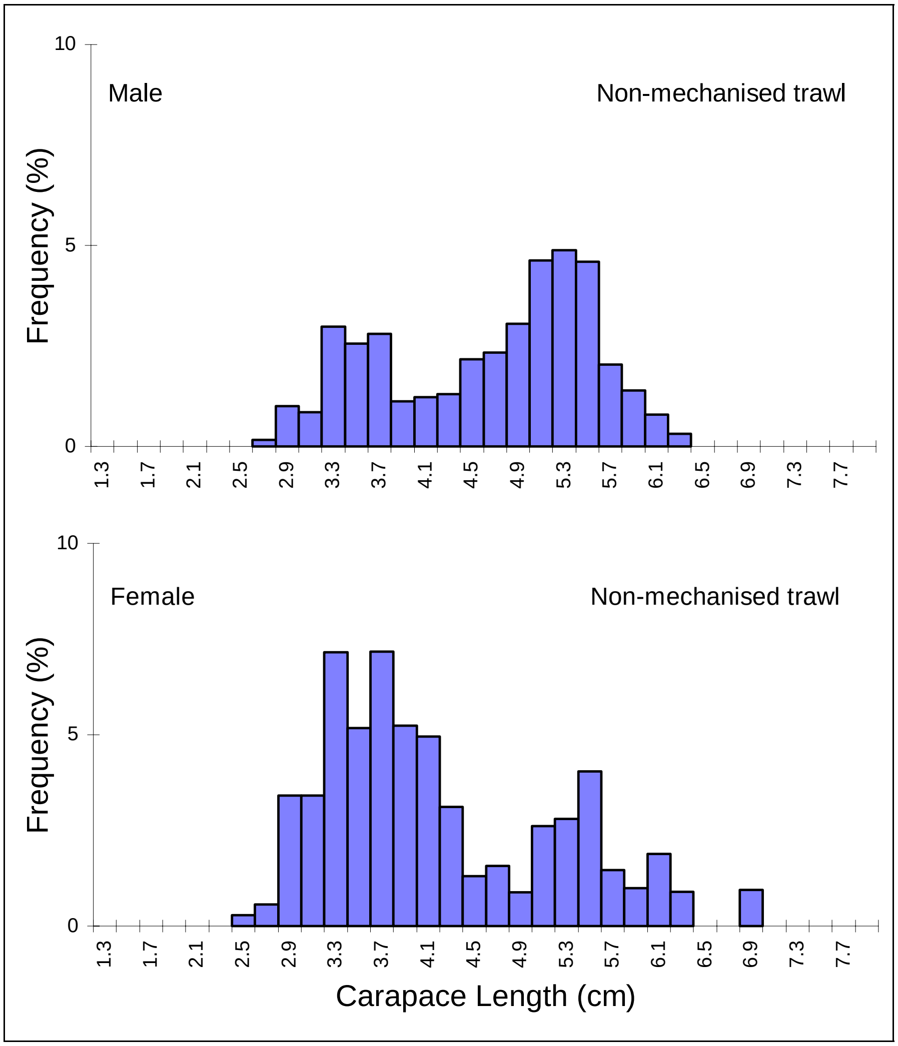


Figure 19: Monthly length frequencies for *P. semisulcatus* (stake net).

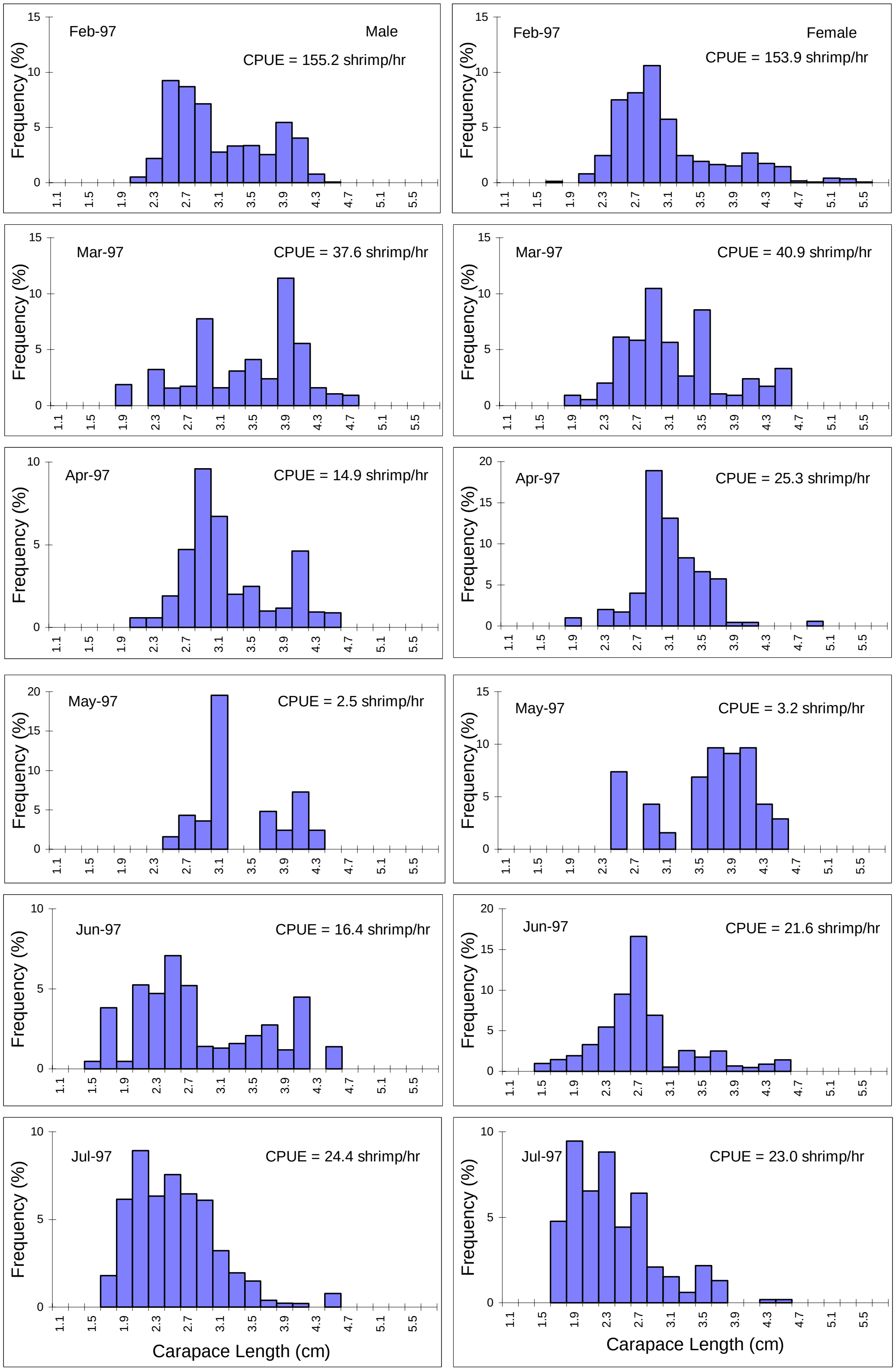


Figure 19: Monthly length frequencies for *P.semisulcatus* (stake net).(continued)

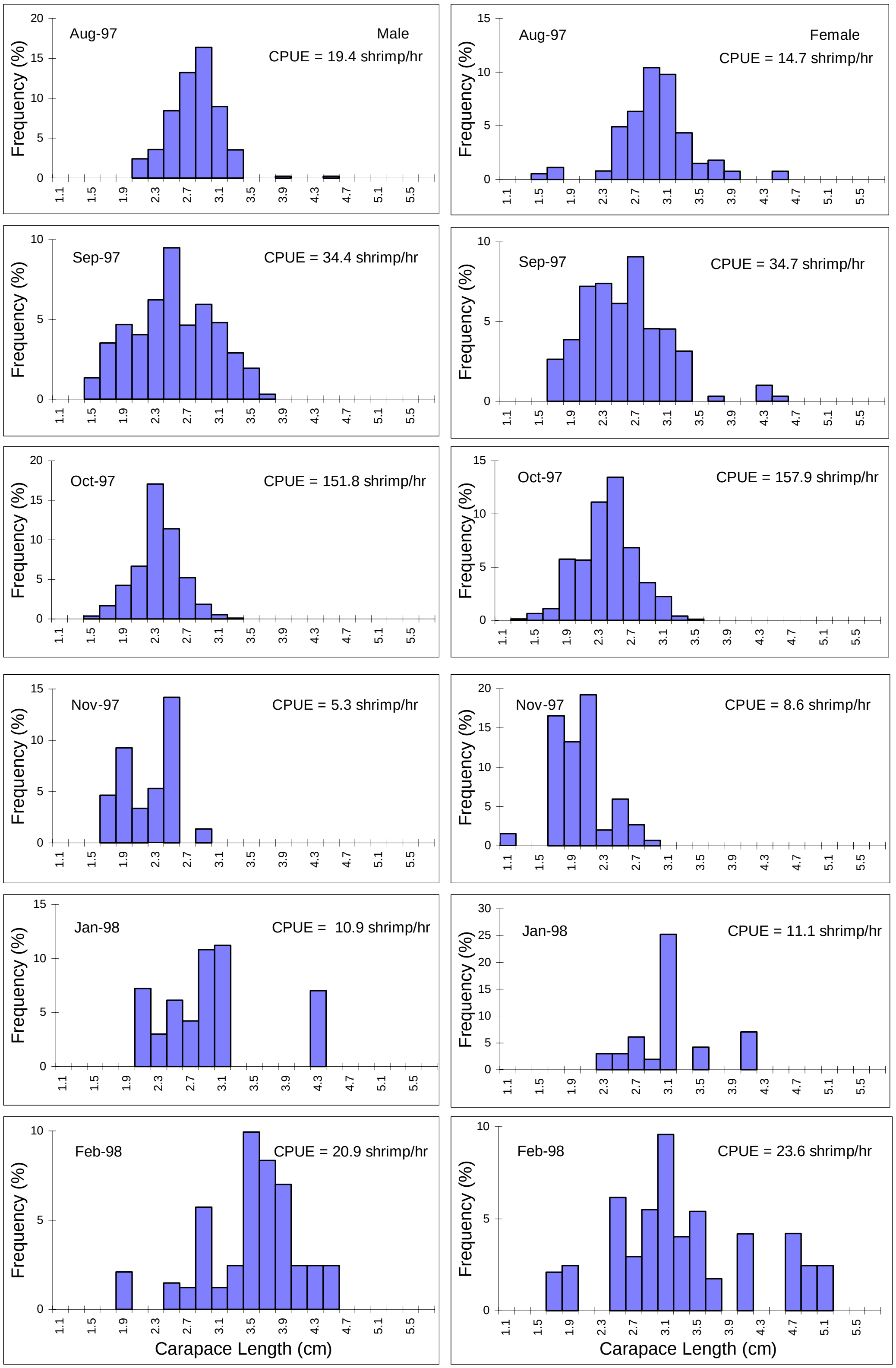


Figure 20: Monthly length frequencies for *M. dobsoni* (non-mechanised trawl).

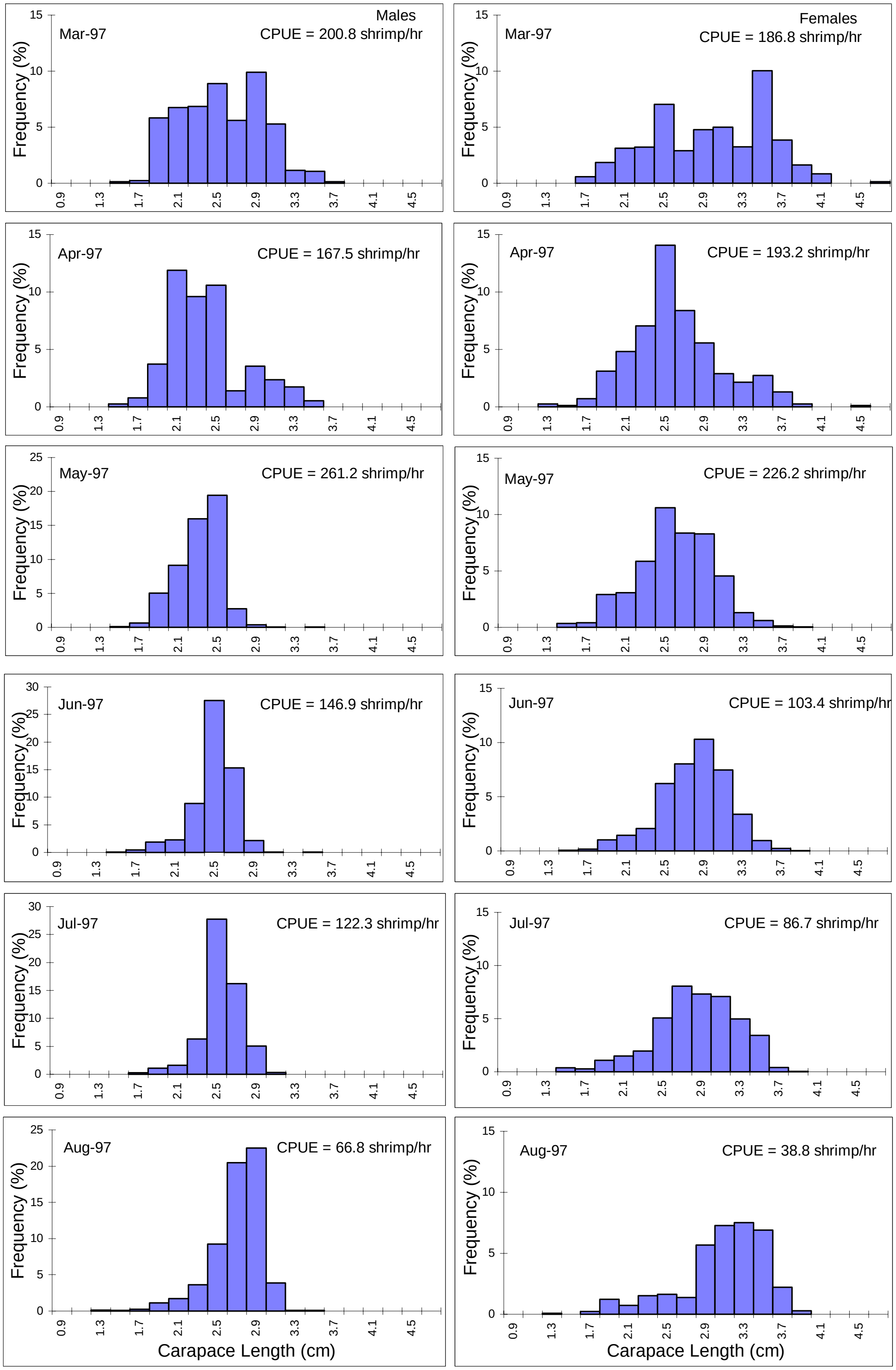


Figure 20: Monthly length frequencies for *M.dobsoni* (non-mechanised trawl).(continued)

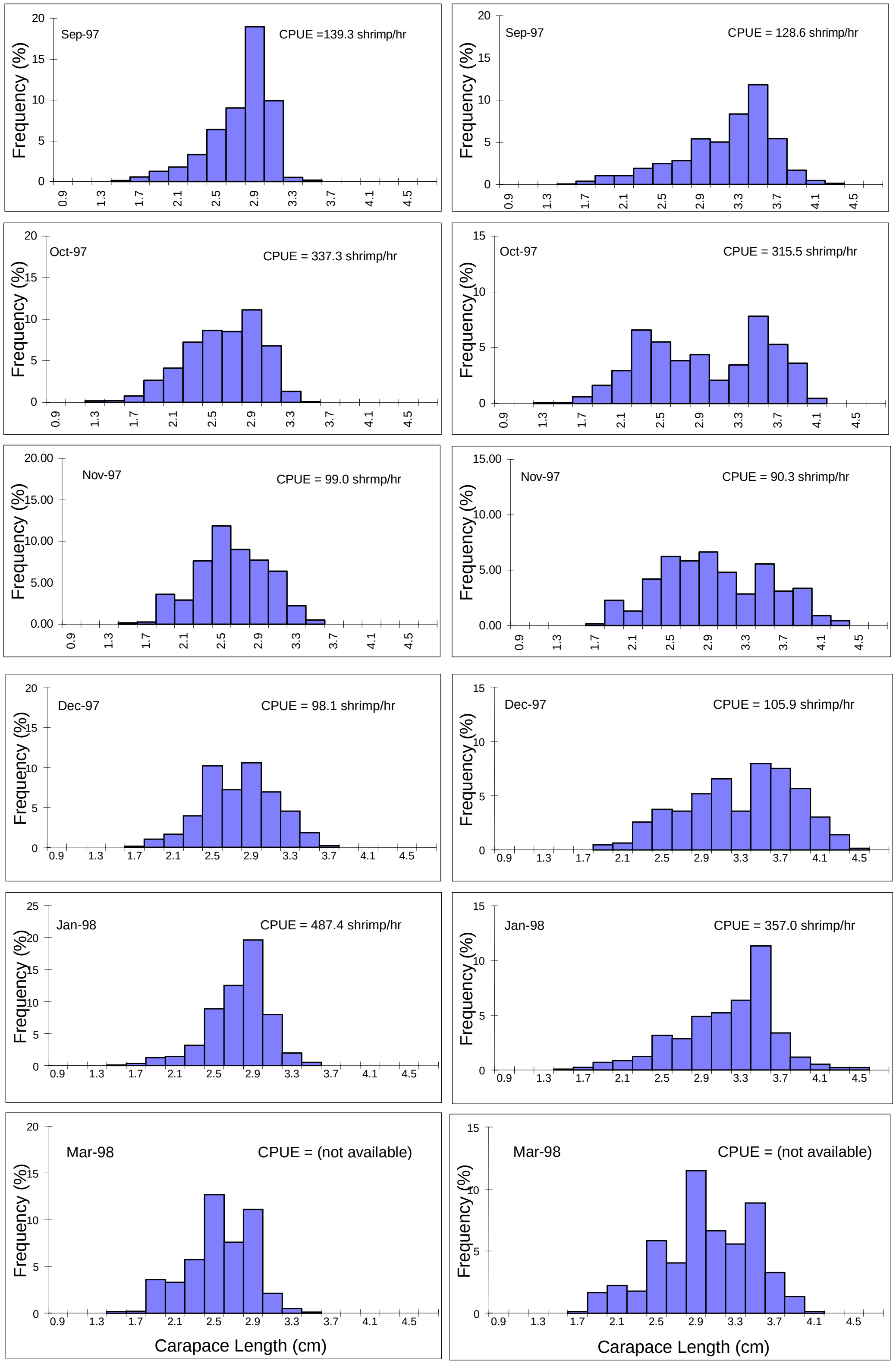


Figure 21: Monthly length frequencies for *Pa. coromandelica* (non-mechanised trawl).

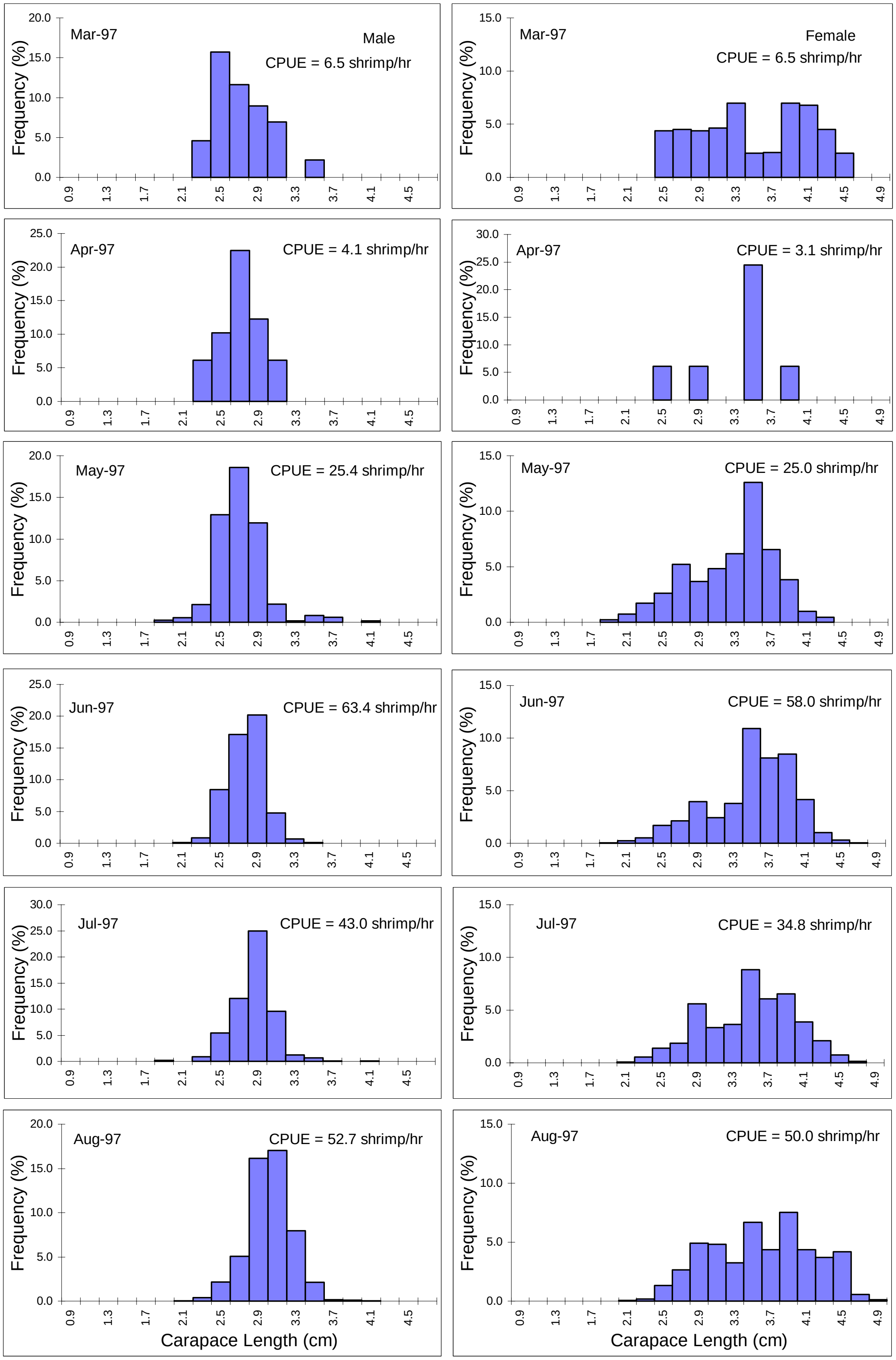


Figure 21: Monthly length frequencies for *Pa.coromandelica* (non-mechanised trawl).(continued)

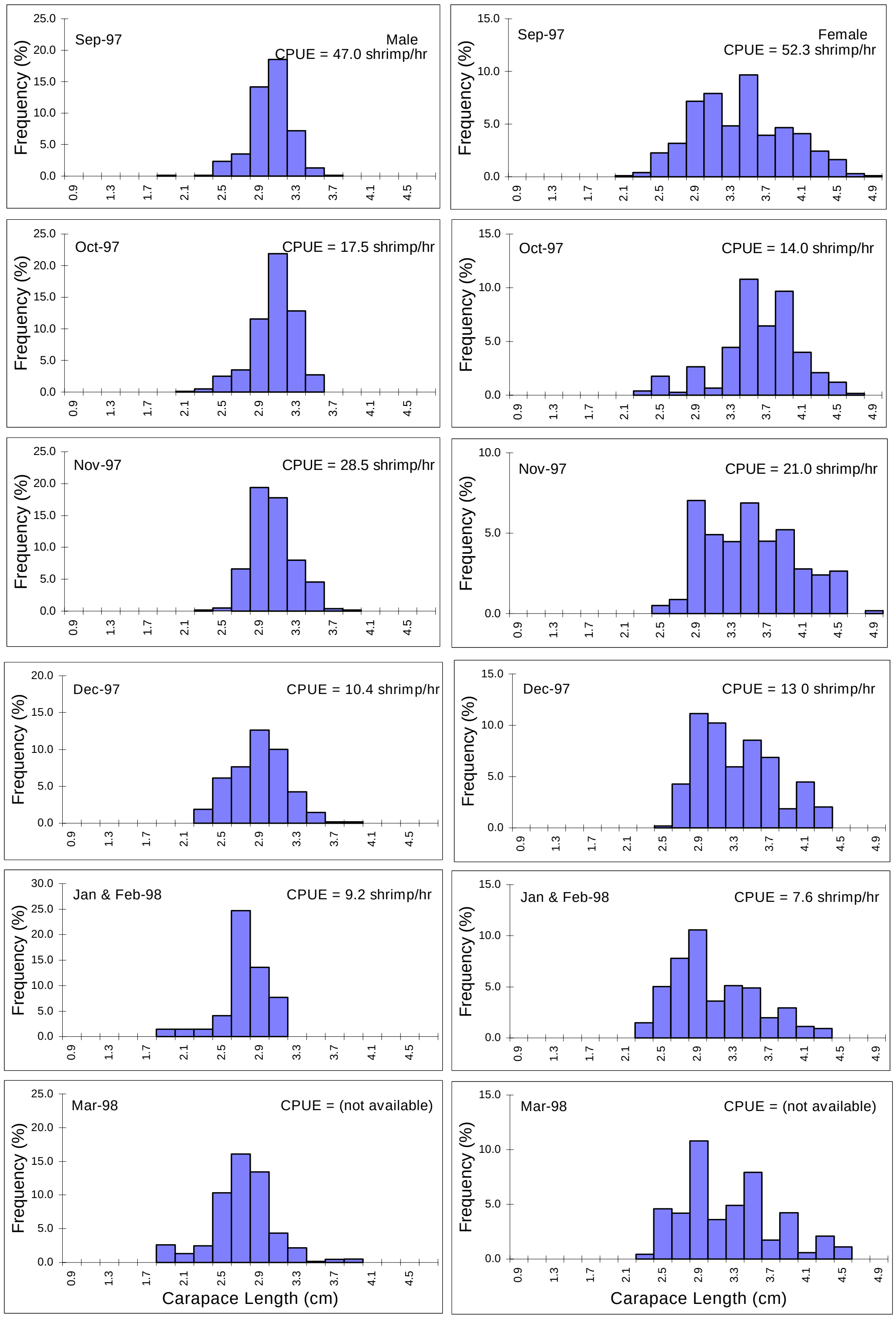


Figure 22: Monthly length frequencies for *M. elegans* (stake net).

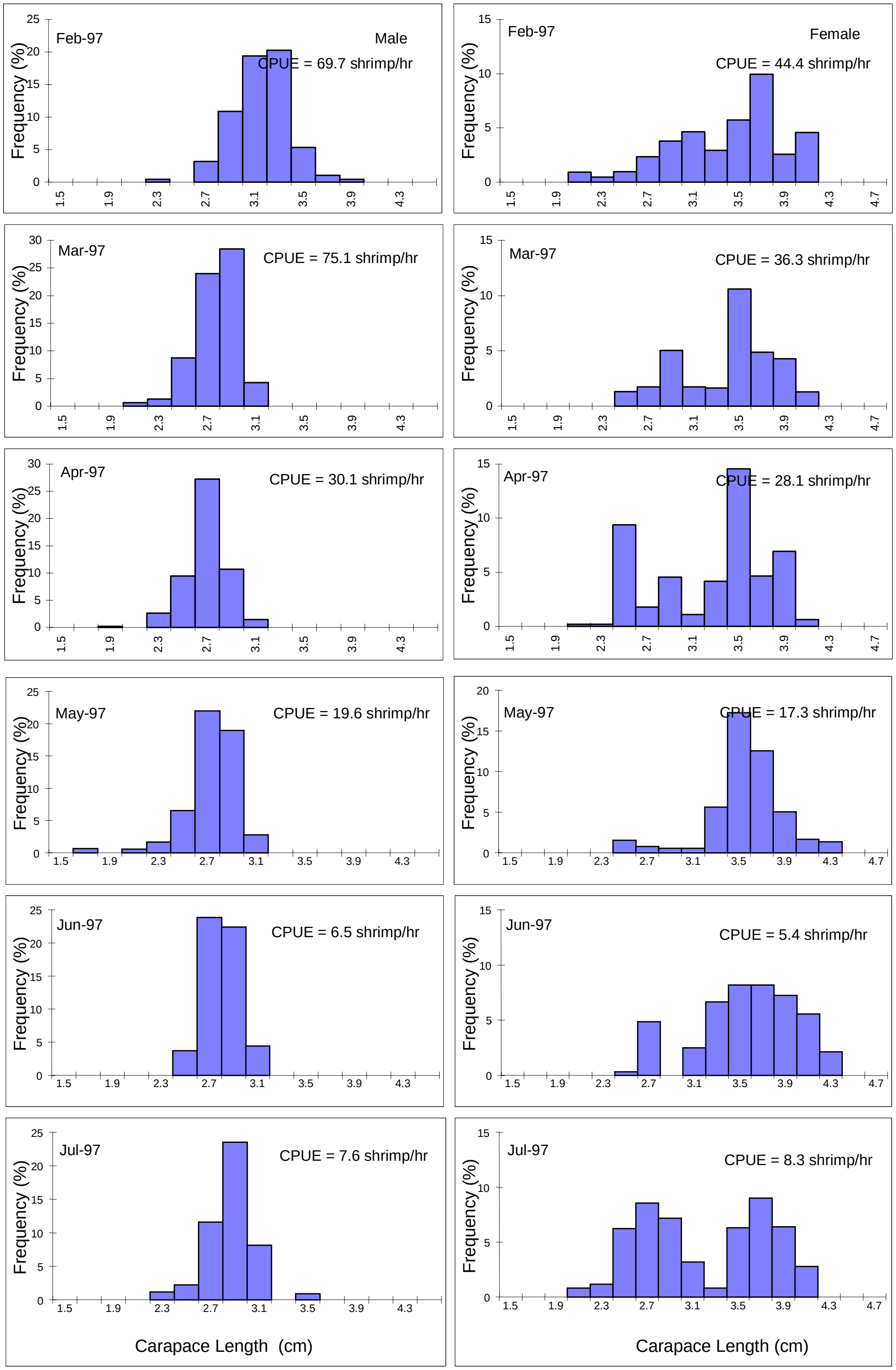


Figure 22: Monthly length frequencies for *M.elegans (*stake net).(continued)

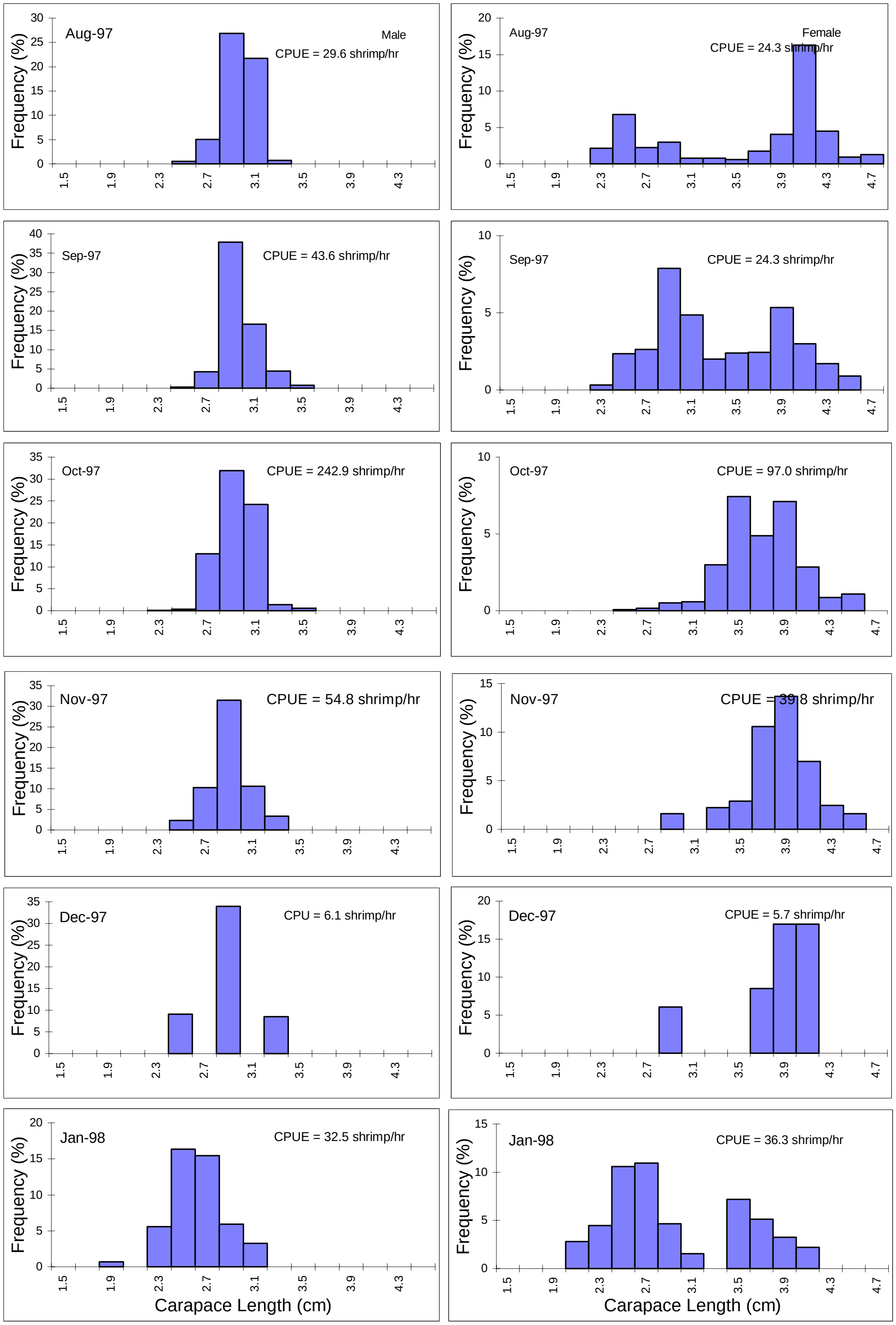


Figure 23: Monthly length frequencies for *M. moyebi* (stake net).

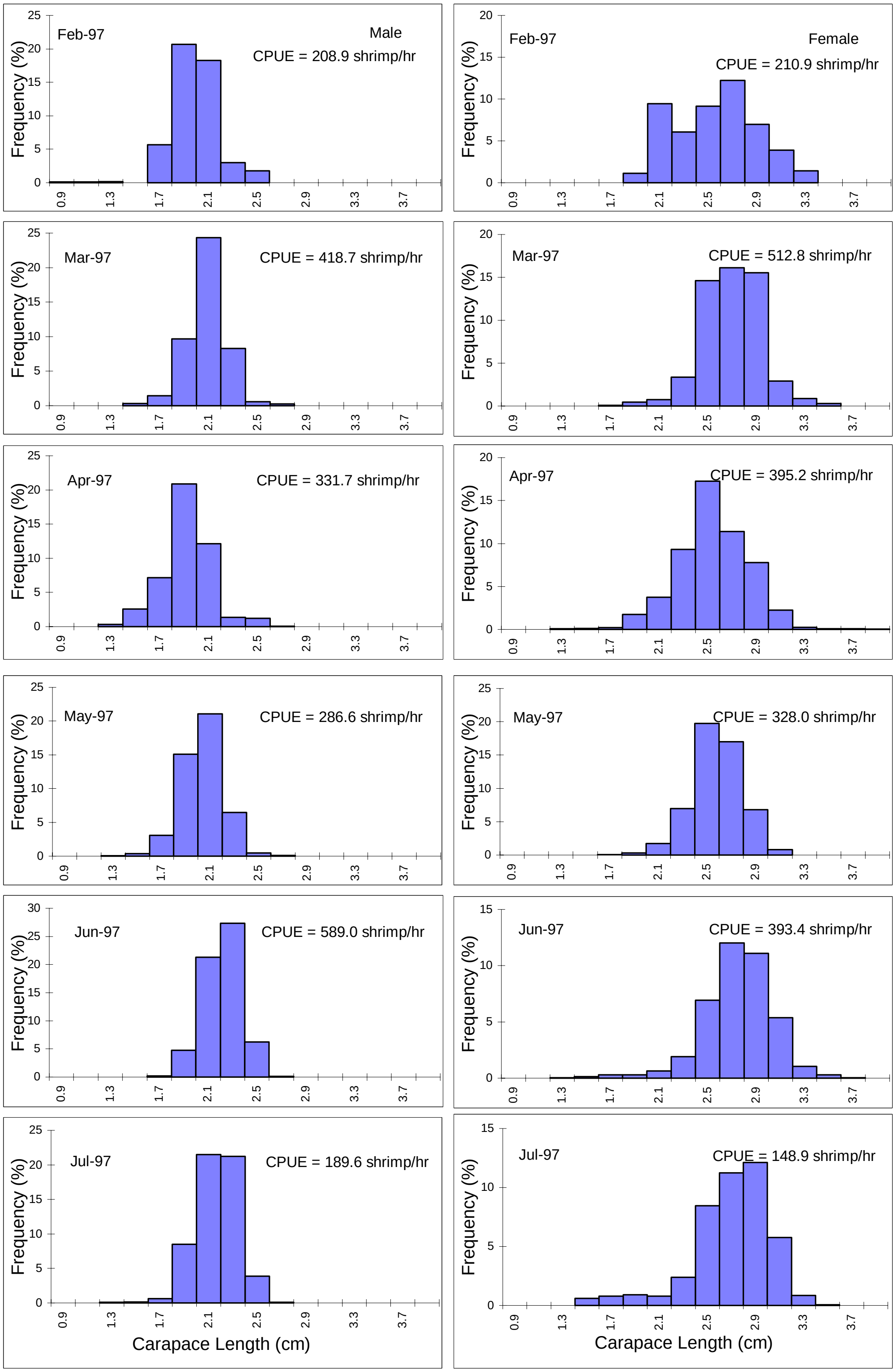


Figure 23: Monthly length frequencies for *M.moyebi* (stake net).(continued)

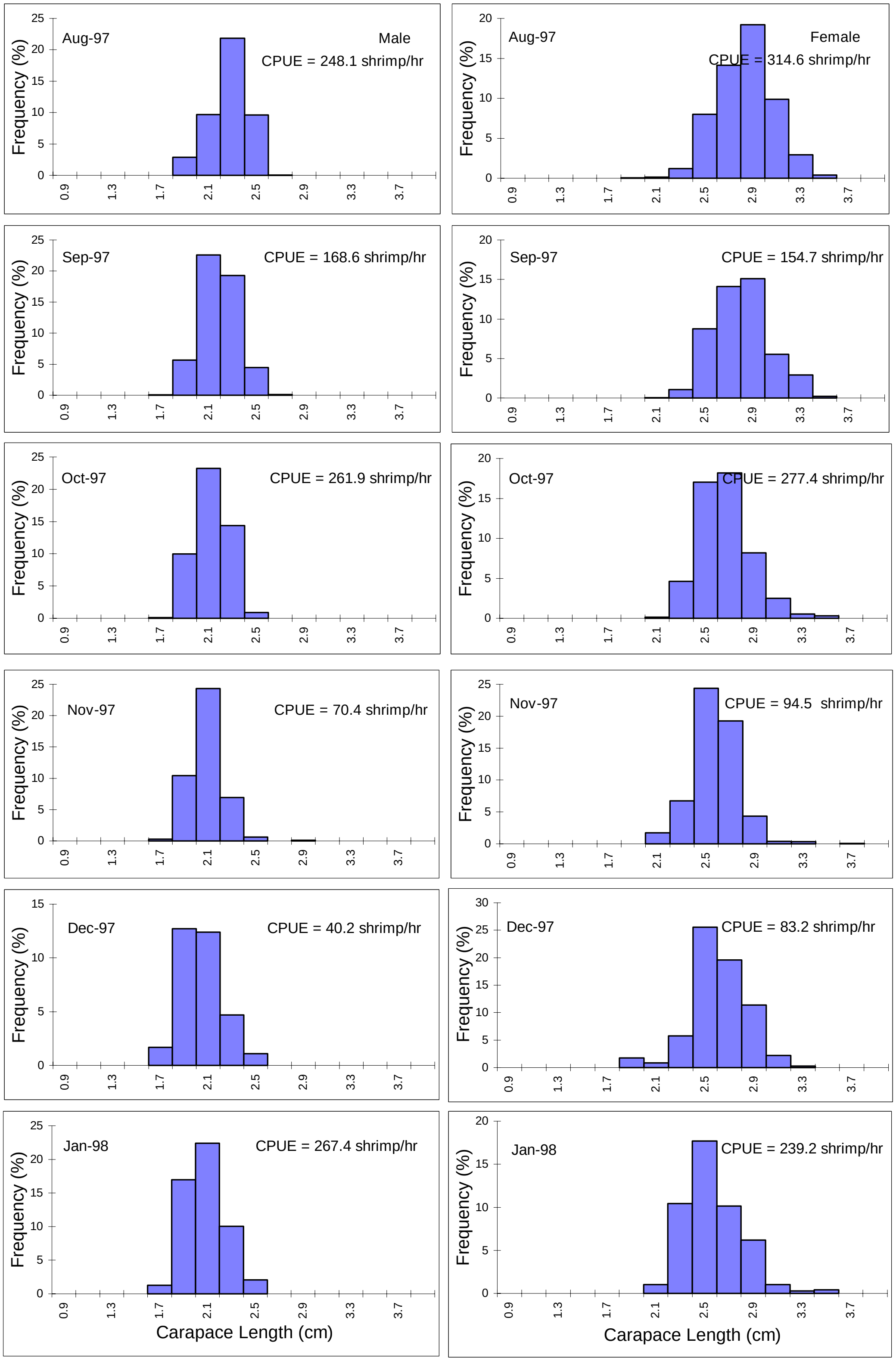


Figure 24: Monthly length frequencies for *M. moyebi* (lagoon seine).

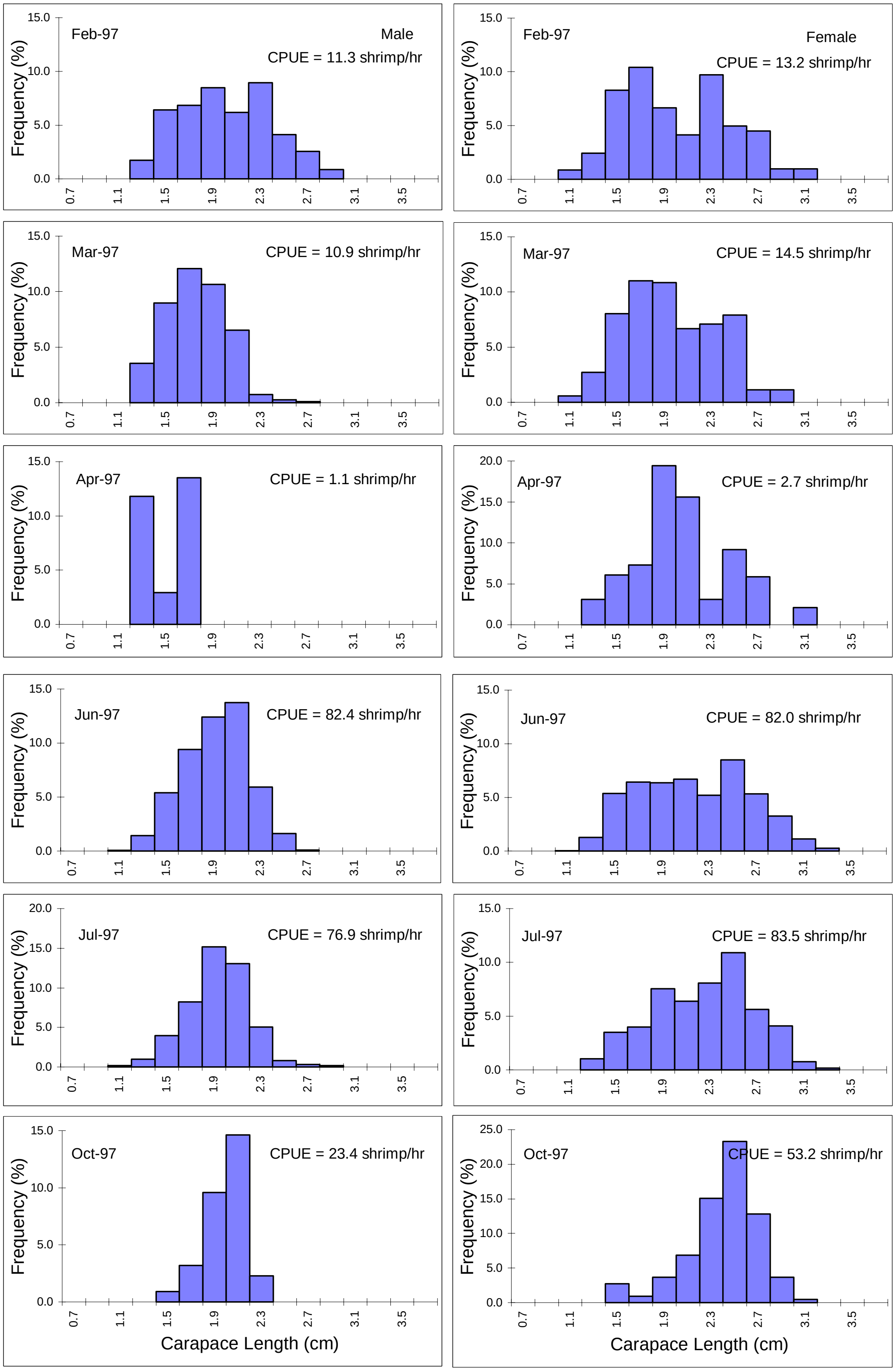
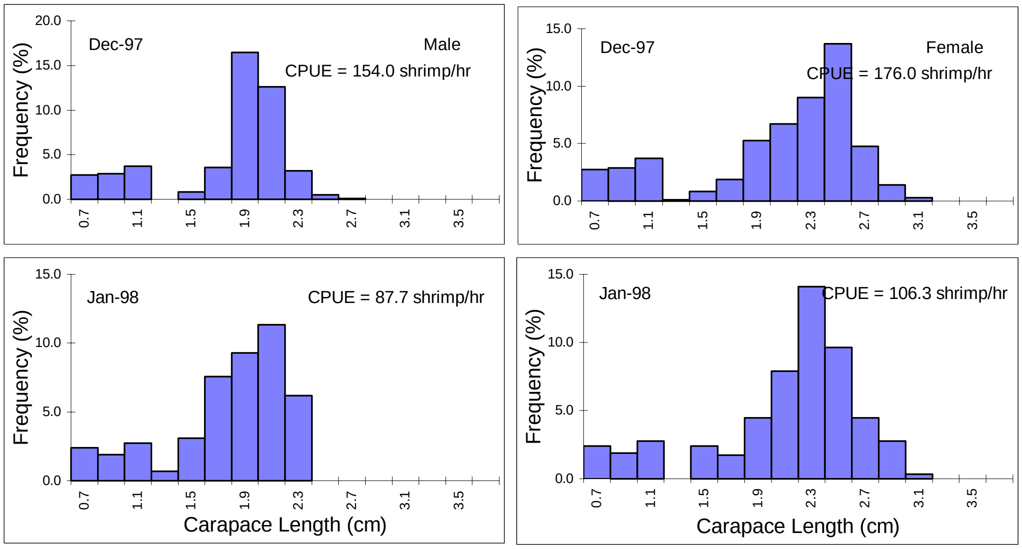


Figure 24: Monthly length frequencies for *M.moyebi* (lagoon seine).(continued)



NATURAL MORTALITY RELATIONSHIPS FOR SHRIMP

Introduction

Natural mortality rates applying to shrimp are known to be high. One of the methods for estimating natural mortalities, utilises the relationship between natural mortality and longevity (ie. duration of life) and hence growth rate. It was applied here to estimate the natural mortality rate for adult shrimp. Another method, which required information about egg production and mean parental age, was used to estimate the constants in the relationship between natural mortality and age. This was done in recognition that natural mortality is highest during early life, when the shrimp are small and fragile. The outputs from both methods are given in Table 17. An example of the estimation process in respect to the second method is shown in Table 18. The associated equations and a very brief description of the methods are given with these Tables.

Natural Mortality Parameters

The magnitude of the natural mortalities for adults is indicated by the M values. They are lowest for *P. indicus* and *P. semisulcatus*. This is consistent with their being less vulnerable to predation due to attaining much larger sizes. The linkages between natural mortality and growth are reflected by the estimates of M/K, which are supposed to be similar for like species. They were found to be lowest for the larger species. The utility of the values for the constants A and B, was in enabling the estimation of natural mortality rates for shrimp of different ages, as required for the modelling exercise described in a later section.

Table 17: Natural mortality parameters.

Species	Sex	*M* (yr^{-1})	*M/K*	*A*	*B*
P. indicus	Male	2.69	1.79		
	Female	2.72	1.75	1.8280	0.9266
P. semisulcatus	Male	2.78	1.89		
	Female	2.64	1.86	1.7448	0.9497
M. dobsoni	Male	3.08	2.15		
	Female	3.02	1.99	2.2689	0.8606
Pa. coromandelica	Male	3.11	2.21		
	Female	3.10	2.05	2.3476	0.8536
M. elegans	Male	3.09	2.22		
	Female	3.01	2.01	2.2586	0.8489
M. moyebi	Male	3.35	2.34		
	Female	3.08	2.20	2.3648	0.8471

Note: Adult M values were determined from L_∞, K, and water temperature T = 28 ^{o}C using the Pauly equation: LN(M) = - 0.0152 – 0.279.LN(L_∞) + 0.6543.LN(K) + 0.463.LN(T) where L_∞ is total length in centimetres. The relationship between natural mortality and age: $M_t = A + B/t$ is from Caddy (1991). A modification of the method of Caddy (1996) was used to estimate A and B. It is based on two progeny surviving to the mean parental age (MPA), from the lifetime egg production of a female (MLF), with the constraint that the adult M is as determined from the Pauly equation. The MPAs were assumed to be 1 year for all of the species. The assumed MLF values were: 550 000 for *P. indicus* and *P. semisulcatus*, 300 000 for *M. dobsoni* and *Pa. coromandelica*, 250 000 for *M. elegans*, 200 000 for *M. moyebi*. These are based on the fecundities reported in Dall *et.al*. 1990.

Table 18: Estimation of the natural mortality at age constants for *P. indicus*.

Carapace Length (cm) L1,L2	Age (yr) t1,t2	Mean Age (yr) t'	Natural Mortality Coef. (/yr) M_t'	Population Number N1,N2
0.0001	0.000	0.003	360.21	550,000.0
0.2	0.020	0.029	34.15	456.9
0.4	0.040	0.050	20.44	228.3
0.6	0.061	0.071	14.82	148.7
0.8	0.083	0.093	11.74	107.8
1.0	0.105	0.116	9.79	82.8
1.2	0.128	0.140	8.44	66.0
1.4	0.153	0.165	7.45	53.8
1.6	0.178	0.190	6.70	44.6
1.8	0.204	0.217	6.10	37.5
2.0	0.231	0.245	5.61	31.8
2.2	0.259	0.274	5.21	27.1
2.4	0.289	0.304	4.87	23.2
2.6	0.320	0.336	4.59	19.9
2.8	0.353	0.370	4.34	17.2
3.0	0.387	0.405	4.12	14.8
3.2	0.423	0.442	3.92	12.7
3.4	0.462	0.482	3.75	10.9
3.6	0.503	0.524	3.59	9.4
3.8	0.547	0.570	3.45	8.0
4.0	0.594	0.619	3.33	6.8
4.2	0.644	0.671	3.21	5.8
4.4	0.699	0.729	3.10	4.8
4.6	0.759	0.792	3.00	4.0
4.8	0.825	0.862	2.90	3.3
5.0	0.899	0.949	2.80	2.7
5.239	1.000	1.039	2.72	2.0
5.4	1.078	1.134	2.65	1.6
5.6	1.191	1.258	2.56	1.2
5.8	1.327	1.412	2.48	0.8
6.0	1.500	1.616	2.40	0.6
6.2	1.737	1.921	2.31	0.3
6.4	2.117	2.601	2.18	0.1

Description

Objective: Estimate A and B in the relationship M_t' = A + B/t' where M_t' is the natural mortality coefficient at mean age t' [=(t2-t1)/LN(t2/t1)] and A and B are constants (see Caddy, 1991).

Method: Input values for the von Bertalanffy growth constants L_∞ and K were used to estimate t1 and t2; and the latter used to estimate t'. Next, estimates of M_t' were obtained based on assumed values for A and B. The latter were improved by 'iteration' with the best choice being when the mean lifetime fecundity (MLF) of an individual female is reduced to two offspring at the mean parental age (MPA), with the adult mortality at this age being as determined from the Pauly equation.

Inputs: L_∞ = 6.65 cm, K = 1.55/yr, MLF = 550,000 eggs, MPA = 1 yr, and adult M = 2.72.

Outputs: A = 1.8280 and B = 0.9266.

Note: MPA is the age attained by an average parent, and MLF is the eggs released during the lifetime of an average parent. The Solver routine in EXCEL was used for the iterations.

Discussion

The estimates of adult M are high for all species. They are in good agreement with values in the literature, and reflect maximum ages of about two years. The values for A and B are for female shrimp. In the absence of a suitable procedure for estimating natural mortality at age constants for males, it was assumed (for the purpose of the later modelling exercise) that they have the same values as the females. This is somewhat in contradiction with the estimates of adult M. These were found to be generally higher for males, and in accord with males being likely to experience higher predation, because of being generally smaller.

FINANCIAL ANALYSIS OF CONTEMPORARY PROFIT

Introduction

This simple analysis of financial performance has sought to determine the extent to which the fisheries are profitable. It is based mainly on data of fishing costs collected during interviews with fishermen-owners of craft. There were about fifteen interviews in respect to each gear type, other than fyke nets for which no fishing costs data were collected. The latter costs are believed to be similar but lower than for stake nets. In analysing the data, it was necessary to define base case fishing units considered typical for each gear type. The results are presented as cash flows over a 10 year period, with the product prices and costs assumed to remain constant. The catch rates are based on those determined during the study, and also assumed to remain constant. The net remuneration to each of the fishermen-owners and crew were the outputs of principal concern. Internal rates of return (IRR) were also estimated. The analyses are presented in Tables 19 to 25.

Fishing Costs

The fishing costs were generally low for all gear types, except for mechanised trawlers. Daily trip costs other than the payments to crew, were negligible, in most cases consisting only of the cost of lantern fuel. Although claimed during interviews, it was decided not to consider the provision of food and water as a cost against fishing. The fixed charges for administration were likewise negligible. Most persons interviewed claimed only the cost of renewing the registration and licences for their craft. No craft were insured. Labour costs were important (for those gears associated with the need for crew). The other main items of cost were those associated with the investment in craft and gear, and for repairs and maintenance. The additional and substantial cost for mechanised trawl units was for engine fuel and oil.

Remunerations to Crew

Crew were invariably paid a share of the catch value less trip operating costs, with the share differing according to the number of crew and other circumstances. The estimates from the analysis are presented as average monthly values. They are remarkably similar across gear types. In the case of stake nets, the remuneration per crew was estimated to be Rs 5 316, based on receiving a 33.3 % share. The estimate for lagoon seines was Rs 4 986, based on a 40 % share. This more even sharing between the lagoon seine fisherman owner and crew, presumably reflects both being directly engaged in the physically demanding task of dragging the net. The estimate for non-mechanised trawlers was Rs 5 950, based on 3 crew members receiving a 60 % share. The estimate for mechanised trawlers was Rs 4 359, based on the 3 crew receiving a 45 % share. The base case for brush piles, trammel nets and cast nets were without crew, and hence no crew remunerations were estimated.

Remunerations to Fishermen-owners

The estimates from the analysis are after subtracting all costs, including depreciation, but before the payment of interest (on borrowed money) and tax. Few of the fishermen-owners claimed to have borrowed. Roughly an equal number claimed receipt of government subsidies when purchasing craft and gear. The estimates for the remunerations are roughly similar across gears, although understandably higher for gears in which the investment costs are highest. The remunerations as average monthly values were Rs 6 345 for cast nets, Rs 5 523 for brush pile, Rs 5 619 for trammel nets, Rs 7 108 for lagoon seines, Rs 10 160 for stake nets, Rs 10 633 for non-mechanised trawlers, and Rs 12 825 for mechanised trawlers. These have been listed in order of increasing investment. The cash-in-hand will be higher than the values given, by amounts equal to the estimates for depreciation.

Internal Rate of Return (IRR)

In the estimation of IRR, it was necessary to separate the labour and investment components in the remunerations to the fishermen-owners. This was done by assuming that the remunerations to labour were 110 % of the estimated remuneration per member of crew. Where the gears were operated without crew, the monthly remuneration to labour was assumed to be Rs 5 000. The resulting estimates of IRR are 71 % for cast nets, 26 % for brush pile, 20 % for trammel nets, 45 % for lagoon seines, 92 % for stake nets, 55 % for non-mechanised trawls, and 32 % for mechanised trawls. These are generally high for all gears, although of little practical relevance. IRR is a measure of financial performance from the viewpoint of potential investors, whereas the opportunities being sought from these fisheries are more to do with subsistence and employment.

Discussion

The remunerations to crew are very similar across gears, with the monthly values ranging between about Rs 5 000 – 6 000. They presumably accord with the opportunity cost of similarly skilled labour within the local communities being about Rs 5 000. The estimates for the monthly remunerations to fishermen-owners range between about Rs 5 000 – 13 000. These include returns to both labour and investment. The true return to labour is unlikely to be much different from the remunerations to crew. In comparing the profitability of non-mechanised and mechanised trawlers, it seems that the former has the better performance. The estimated remuneration to the crew for the mechanised trawlers is low. The remuneration to the fishermen-owners is likewise low, having in mind the substantial investment required to own a 3.5 t craft. These findings accord with many of the mechanised trawlers being operated only during the months around June and July when the shrimp are abundant. Another factor contributing to the modest performance, is the exclusion of these craft during other months from grounds adjacent to Colombo. This has been applied only during recent years, and stems from the enlargement of the security zone around the commercial port.

Table 19: Cash flow analysis for lagoon seines.

			Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	4.52	kg/day		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
other	5.58	kg/day		5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	83	Rs/kg		83	83	83	83	83	83	83	83	83	83
other	40	Rs/kg		40	40	40	40	40	40	40	40	40	40
2. Projected efforts and catches per craft													
fishing days	250	/yr		250	250	250	250	250	250	250	250	250	250
shrimp catch				1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130	1,130
other catch				1,395	1,395	1,395	1,395	1,395	1,395	1,395	1,395	1,395	1,395
total catch				2,525	2,525	2,525	2,525	2,525	2,525	2,525	2,525	2,525	2,525
4. Gross revenue per craft (Rs)													
from shrimp				93,790	93,790	93,790	93,790	93,790	93,790	93,790	93,790	93,790	93,790
from fish				55,800	55,800	55,800	55,800	55,800	55,800	55,800	55,800	55,800	55,800
total **(A)**				149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590
5. Investment per craft (Rs)													
hull	new 18 ft FRP oru		16,000										
gear	2 drag nets @ Rs 14,000/piece		28,000										
total **(B)**			44,000										
6. Trip operating costs per craft (Rs)													
lamp fuel quantity	0	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				0	0	0	0	0	0	0	0	0	0
7. Trip labour costs													
number of crew (not including skipper/owner)	1	persons											
crew share (% gross revenue - trip op. costs)	40.0	%											
labour cost **(D)**				59,836	59,836	59,836	59,836	59,836	59,836	59,836	59,836	59,836	59,836
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		800	800	800	800	800	800	800	800	800	800
gear	10	% of investment		2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800	2,800
total **(E)**				3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		50	50	50	50	50	50	50	50	50	50
total **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull	5	% of investment		800	800	800	800	800	800	800	800	800	800
total **(H)**				800	800	800	800	800	800	800	800	800	800
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				85,302	85,302	85,302	85,302	85,302	85,302	85,302	85,302	85,302	85,302
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		7,108	7,108	7,108	7,108	7,108	7,108	7,108	7,108	7,108	7,108
remuneration to crew		Rs/month/crew		4,986	4,986	4,986	4,986	4,986	4,986	4,986	4,986	4,986	4,986
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590
capital recovery													8,000
total inflow				149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	149,590	157,590
outflow													
investment **(B)**			44,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				0	0	0	0	0	0	0	0	0	0
trip labour **(D)** plus skipper's labour **(= 110% of 12 x I)** costs				125,656	125,656	125,656	125,656	125,656	125,656	125,656	125,656	125,656	125,656
repairs/maintenance/replacement costs **(E)**				3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
registration and fishing licence **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			44,000	129,308	129,308	129,308	129,308	129,308	129,308	129,308	129,308	129,308	129,308
net cash flow			-44,000	20,282	20,282	20,282	20,282	20,282	20,282	20,282	20,282	20,282	28,282
internal rate of return	45%												

Table 20: Cash flow analysis for brush piles.

			Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	0.29	kg/day		0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
other	6.18	kg/day		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	93	Rs/kg		90	90	90	90	90	90	90	90	90	90
other	40	Rs/kg		40	40	40	40	40	40	40	40	40	40
2. Projected efforts and catches per craft													
fishing days	250	/yr		250	250	250	250	250	250	250	250	250	250
shrimp catch				73	73	73	73	73	73	73	73	73	73
other catch				1,545	1,545	1,545	1,545	1,545	1,545	1,545	1,545	1,545	1,545
total catch				1,618	1,618	1,618	1,618	1,618	1,618	1,618	1,618	1,618	1,618
4. Gross revenue per craft (Rs)													
from shrimp				6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525	6,525
from fish				61,800	61,800	61,800	61,800	61,800	61,800	61,800	61,800	61,800	61,800
total **(A)**				68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325
5. Investment per craft (Rs)													
hull — new 15 ft FRP oru			15,000										
gear — 1 brush pile net @ Rs 10,000/piece			10,000										
total **(B)**			25,000										
6. Trip operating costs per craft (Rs)													
lamp fuel — quantity	0	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				0	0	0	0	0	0	0	0	0	0
7. Trip labour costs													
number of crew (not including skipper/owner)	0	persons											
crew share (% gross revenue - trip op. costs)	0.0	%											
labour cost **(D)**				0	0	0	0	0	0	0	0	0	0
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		750	750	750	750	750	750	750	750	750	750
gear	5	% of investment		500	500	500	500	500	500	500	500	500	500
total **(E)**				1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		50	50	50	50	50	50	50	50	50	50
total **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull	5	% of investment		750	750	750	750	750	750	750	750	750	750
total **(H)**				750	750	750	750	750	750	750	750	750	750
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				66,273	66,273	66,273	66,273	66,273	66,273	66,273	66,273	66,273	66,273
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		5,523	5,523	5,523	5,523	5,523	5,523	5,523	5,523	5,523	5,523
remuneration to crew		Rs/month/crew		0	0	0	0	0	0	0	0	0	0
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325
capital recovery													7,500
total inflow				68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	68,325	75,825
outflow													
investment **(B)**			25,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				0	0	0	0	0	0	0	0	0	0
trip labour **(D)** plus skipper's labour **(= 12 x Rs. 5,000)** costs				60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
repairs/maintenance/replacement costs **(E)**				1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
registration and fishing licence **(F)**				53	53	53	53	53	53	53	53	53	53
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			25,000	61,303	61,303	61,303	61,303	61,303	61,303	61,303	61,303	61,303	61,303
net cash flow			-25,000	7,023	7,023	7,023	7,023	7,023	7,023	7,023	7,023	7,023	14,523
internal rate of return	26%												

Table 21: Cash flow analysis for cast nets.

Item	Value	Unit	Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	1.89	kg/day		1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89
other	1.71	kg/day		1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	149	Rs/kg		149	149	149	149	149	149	149	149	149	149
other	25	Rs/kg		25	25	25	25	25	25	25	25	25	25
2. Projected efforts and catches per craft													
fishing days	250	/yr		250	250	250	250	250	250	250	250	250	250
shrimp catch				473	473	473	473	473	473	473	473	473	473
other catch				428	428	428	428	428	428	428	428	428	428
total catch				900	900	900	900	900	900	900	900	900	900
4. Gross revenue per craft (Rs)													
from shrimp				70,403	70,403	70,403	70,403	70,403	70,403	70,403	70,403	70,403	70,403
from fish				10,688	10,688	10,688	10,688	10,688	10,688	10,688	10,688	10,688	10,688
total **(A)**				81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090
5. Investment per craft (Rs)													
hull new 18 ft FRP sail oru			16,000										
outrigger and sail			2,000										
gear 4 cast nets @ Rs 1,500/piece			6,000										
total **(B)**			24,000										
6. Trip operating costs per craft (Rs)													
lamp fuel quantity	0	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				0	0	0	0	0	0	0	0	0	0
7. Trip labour costs													
number of crew (not including skipper/owner)	0	persons											
crew share (% gross revenue - trip op. Costs)	0.0	%											
labour cost **(D)**				0	0	0	0	0	0	0	0	0	0
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		800	800	800	800	800	800	800	800	800	800
outrigger and sail	10	% of investment		200	200	200	200	200	200	200	200	200	200
gear	50	% of investment		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
total **(E)**				4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		50	50	50	50	50	50	50	50	50	50
total **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull,	5	% of investment		800	800	800	800	800	800	800	800	800	800
outrigger and sail	5	% of investment		100	100	100	100	100	100	100	100	100	100
total **(H)**				900	900	900	900	900	900	900	900	900	900
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				76,138	76,138	76,138	76,138	76,138	76,138	76,138	76,138	76,138	76,138
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		6,345	6,345	6,345	6,345	6,345	6,345	6,345	6,345	6,345	6,345
remuneration to crew		Rs/month/crew		0	0	0	0	0	0	0	0	0	0
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090
capital recovery													9,000
total inflow				81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	81,090	90,090
outflow													
investment **(B)**			24,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				0	0	0	0	0	0	0	0	0	0
trip labour **(D)** plus skipper's labour **(= 12 x Rs. 5,000)** costs				60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
repairs/maintenance/replacement costs **(E)**				4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
registration and fishing licence **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			24,000	64,053	64,053	64,053	64,053	64,053	64,053	64,053	64,053	64,053	64,053
net cash flow			-24,000	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038	17,038	26,038
internal rate of return	71%												

Table 22: Cash flow analysis for trammel nets.

Item	Value	Unit	Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	1.238	kg/day		1.238	1.238	1.238	1.238	1.238	1.238	1.238	1.238	1.238	1.238
other	3.304	kg/day		3.304	3.304	3.304	3.304	3.304	3.304	3.304	3.304	3.304	3.304
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	148	Rs/kg		148	148	148	148	148	148	148	148	148	148
other	45	Rs/kg		45	45	45	45	45	45	45	45	45	45
2. Projected efforts and catches per craft													
fishing days	250	/yr		250	250	250	250	250	250	250	250	250	250
shrimp catch				310	310	310	310	310	310	310	310	310	310
other catch				826	826	826	826	826	826	826	826	826	826
total catch				1,136	1,136	1,136	1,136	1,136	1,136	1,136	1,136	1,136	1,136
4. Gross revenue per craft (Rs)													
from shrimp				45,806	45,806	45,806	45,806	45,806	45,806	45,806	45,806	45,806	45,806
from fish				37,170	37,170	37,170	37,170	37,170	37,170	37,170	37,170	37,170	37,170
total **(A)**				82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976
5. Investment per craft (Rs)													
hull — new 15 ft FRP lagoon oru			15,000										
gear — 27 net pieces @ Rs 700/piece			21,000										
total **(B)**			36,000										
6. Trip operating costs per craft (Rs)													
lamp fuel — quantity	1.4	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
7. Trip labour costs													
number of crew (not including skipper/owner)	0	persons											
crew share (% gross revenue - trip op. costs)	0.0	%											
labour cost **(D)**				0	0	0	0	0	0	0	0	0	0
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		750	750	750	750	750	750	750	750	750	750
gear	50	% of investment		10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
total **(E)**				11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		50	50	50	50	50	50	50	50	50	50
total **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull	5	% of investment		750	750	750	750	750	750	750	750	750	750
total **(H)**				750	750	750	750	750	750	750	750	750	750
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				67,424	67,424	67,424	67,424	67,424	67,424	67,424	67,424	67,424	67,424
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		5,619	5,619	5,619	5,619	5,619	5,619	5,619	5,619	5,619	5,619
remuneration to crew		Rs/month/crew		0	0	0	0	0	0	0	0	0	0
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976
capital recovery													7,500
total inflow				82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	82,976	90,476
outflow													
investment **(B)**			36,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
trip labour **(D)** plus skipper's labour **(= 12 x Rs. 5,000)** costs				60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
repairs/maintenance/replacement costs **(E)**				11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250	11,250
registration and fishing licence **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			36,000	74,803	74,803	74,803	74,803	74,803	74,803	74,803	74,803	74,803	74,803
net cash flow			-36,000	8,174	8,174	8,174	8,174	8,174	8,174	8,174	8,174	8,174	15,674
internal rate of return	20%												

Table 23: Cash flow analysis for stake nets.

			Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	17.70	kg/day		17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
other	8.58	kg/day		8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	83	Rs/kg		83	83	83	83	83	83	83	83	83	83
other	35	Rs/kg		35	35	35	35	35	35	35	35	35	35
2. Projected efforts and catches per craft													
fishing days	110	/yr		110	110	110	110	110	110	110	110	110	110
shrimp catch				1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947
other catch				944	944	944	944	944	944	944	944	944	944
total catch				2,891	2,891	2,891	2,891	2,891	2,891	2,891	2,891	2,891	2,891
4. Gross revenue per craft (Rs)													
from shrimp				161,601	161,601	161,601	161,601	161,601	161,601	161,601	161,601	161,601	161,601
from fish				33,033	33,033	33,033	33,033	33,033	33,033	33,033	33,033	33,033	33,033
total **(A)**				194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634
5. Investment per craft (Rs)													
hull — new 28 ft FRP stake net oru			28,000										
gear — 2 stake nets @ Rs 15,000/piece			30,000										
total **(B)**			58,000										
6. Trip operating costs per craft (Rs)													
lamp fuel quantity	2.8	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080
7. Trip labour costs													
number of crew (not including skipper/owner)	1	persons											
crew share (% gross revenue - trip op. costs)	33.3	%											
labour cost **(D)**				63,787	63,787	63,787	63,787	63,787	63,787	63,787	63,787	63,787	63,787
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
gear	50	% of investment		3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
total **(E)**				4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		50	50	50	50	50	50	50	50	50	50
total **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull	5	% of investment		1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
total **(H)**				1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				121,914	121,914	121,914	121,914	121,914	121,914	121,914	121,914	121,914	121,914
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		10,160	10,160	10,160	10,160	10,160	10,160	10,160	10,160	10,160	10,160
remuneration to crew		Rs/month/crew		5,316	5,316	5,316	5,316	5,316	5,316	5,316	5,316	5,316	5,316
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634
capital recovery													14,000
total inflow				194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	194,634	208,634
outflow													
investment **(B)**			58,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080	3,080
trip labour **(D)** plus skipper's labour **(= 110% x12 x I)** costs				133,954	133,954	133,954	133,954	133,954	133,954	133,954	133,954	133,954	133,954
repairs/maintenance/replacement costs **(E)**				4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400
registration and fishing licence **(F)**				52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5	52.5
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			58,000	141,486	141,486	141,486	141,486	141,486	141,486	141,486	141,486	141,486	141,486
net cash flow			-58,000	53,148	53,148	53,148	53,148	53,148	53,148	53,148	53,148	53,148	67,148
internal rate of return	92%												

Table 24: Cash flow analysis for non-mechanised trawl.

			Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	10.0	kg/day		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
other	7.5	kg/day		7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	115	Rs/kg		115	115	115	115	115	115	115	115	115	115
other	45	Rs/kg		45	45	45	45	45	45	45	45	45	45
2. Projected efforts and catches per craft													
fishing days	240	/yr		240	240	240	240	240	240	240	240	240	240
shrimp catch				2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
other catch				1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
total catch				4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200
4. Gross revenue per craft (Rs)													
from shrimp				276,000	276,000	276,000	276,000	276,000	276,000	276,000	276,000	276,000	276,000
from fish				81,000	81,000	81,000	81,000	81,000	81,000	81,000	81,000	81,000	81,000
total **(A)**				357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000
5. Investment per craft (Rs)													
hull — new 28 ft FRP sail trawl oru			90,000										
gear — 4 trawl nets @ Rs 1,500/piece			6,000										
total **(B)**			96,000										
6. Trip operating costs per craft (Rs)													
lamp fuel — quantity	0	Litre/day											
price	10	Rs/litre											
fuel cost **(C)**				0	0	0	0	0	0	0	0	0	0
7. Trip labour costs													
number of crew (not including skipper/owner)	3	persons											
crew share (% gross revenue - trip op. costs)	60.0	%											
labour cost **(D)**				214,200	214,200	214,200	214,200	214,200	214,200	214,200	214,200	214,200	214,200
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull	5	% of investment		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
gear	100	% of investment		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
total **(E)**				10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
9. Registration and fishing licence (Rs)													
craft registration	2.5	/craft		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
fishing operations licence		/craft		200	200	200	200	200	200	200	200	200	200
total **(F)**				202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
10. Insurance costs per vessel (Rs)													
hull	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull	5	% of investment		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
total **(H)**				4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				127,598	127,598	127,598	127,598	127,598	127,598	127,598	127,598	127,598	127,598
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		10,633	10,633	10,633	10,633	10,633	10,633	10,633	10,633	10,633	10,633
remuneration to crew		Rs/month/crew		5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950	5,950
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000
capital recovery													45,000
total inflow				357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	357,000	402,000
outflow													
investment **(B)**			96,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				0	0	0	0	0	0	0	0	0	0
trip labour **(D)** plus skipper's labour **(= 110% x12 x I)** costs				292,740	292,740	292,740	292,740	292,740	292,740	292,740	292,740	292,740	292,740
repairs/maintenance/replacement costs **(E)**				10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
registration and fishing licence **(F)**				202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5	202.5
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			96,000	303,443	303,443	303,443	303,443	303,443	303,443	303,443	303,443	303,443	303,443
net cash flow			-96,000	53,558	53,558	53,558	53,558	53,558	53,558	53,558	53,558	53,558	98,558
internal rate of return	55%												

Table 25: Cash flow analysis for mechanised trawl.

			Year 0	1	2	3	4	5	6	7	8	9	10
1. Definition of fishery change scenarios													
assumed annual decrease in catch rates	0	%											
estimated catch rate index				100	100	100	100	100	100	100	100	100	100
projected catch rates shrimp	8.72	kg/day		8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72	8.72
other	13.00	kg/day		13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
assumed annual change in product price	0	%											
estimated price index				100	100	100	100	100	100	100	100	100	100
shrimp	128	Rs/kg		128	128	128	128	128	128	128	128	128	128
other	45	Rs/kg		45	45	45	45	45	45	45	45	45	45
2. Projected efforts and catches per craft													
fishing days	240	/yr		240	240	240	240	240	240	240	240	240	240
shrimp catch				2,093	2,093	2,093	2,093	2,093	2,093	2,093	2,093	2,093	2,093
other catch				3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120	3,120
total catch				5,213	5,213	5,213	5,213	5,213	5,213	5,213	5,213	5,213	5,213
4. Gross revenue per craft (Rs)													
from shrimp				267,878	267,878	267,878	267,878	267,878	267,878	267,878	267,878	267,878	267,878
from fish				140,400	140,400	140,400	140,400	140,400	140,400	140,400	140,400	140,400	140,400
total **(A)**				408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278
5. Investment per craft (Rs)													
hull — used 28 ft FRP 3.5 tonner incl. engine			300,000										
gear — 3 trawl nets @ Rs 7,000/piece			21,000										
total **(B)**			321,000										
6. Trip operating costs per craft (Rs)													
Engine fuel — quantity	4	gallonday											
price	62	Rs/gallon											
fuel cost **(C)**				59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520
7. Trip labour costs													
number of crew (not including skipper/owner)	3	persons											
crew share (% gross revenue - trip op. costs)	45.0	%											
labour cost **(D)**				156,941	156,941	156,941	156,941	156,941	156,941	156,941	156,941	156,941	156,941
8. Repairs/maintenance/replacement costs per craft (Rs)													
hull and engine	5	% of investment		15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
gear	50	% of investment		10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
total **(E)**				25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500
9. Registration and fishing licence (Rs)													
craft registration	15.0	/craft		15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
fishing operations licence		/craft		400	400	400	400	400	400	400	400	400	400
total **(F)**				415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0
10. Insurance costs per vessel (Rs)													
hull and engine	0	% of investment		0	0	0	0	0	0	0	0	0	0
gear	0	% of investment		0	0	0	0	0	0	0	0	0	0
total **(G)**				0	0	0	0	0	0	0	0	0	0
11. Depreciation costs (Rs)													
hull and engine	4	% of investment		12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
total **(H)**				12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
12. Profit per craft (Rs) before interest and tax **(A-(C+D+E+F+G+H))**				153,902	153,902	153,902	153,902	153,902	153,902	153,902	153,902	153,902	153,902
13. Cash remuneration (Rs)													
remuneration to skipper/owner (after depreciation)		Rs/month		12,825	12,825	12,825	12,825	12,825	12,825	12,825	12,825	12,825	12,825
remuneration to crew		Rs/month/crew		4,359	4,359	4,359	4,359	4,359	4,359	4,359	4,359	4,359	4,359
14. Discounted cash flow analysis (Rs)													
inflow													
gross revenue **(A)**				408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278
capital recovery													120,000
total inflow				408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	408,278	528,278
Outflow													
investment **(B)**			321,000	0	0	0	0	0	0	0	0	0	0
trip operating costs **(C)**				59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520	59,520
trip labour **(D)** plus skipper's labour **(= 110% x12 x I)** costs				214,486	214,486	214,486	214,486	214,486	214,486	214,486	214,486	214,486	214,486
repairs/maintenance/replacement costs **(E)**				25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500	25,500
registration and fishing licence **(F)**				415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0	415.0
insurance costs **(G)**				0	0	0	0	0	0	0	0	0	0
total outflow			321,000	299,921	299,921	299,921	299,921	299,921	299,921	299,921	299,921	299,921	299,921
net cash flow			-321,000	108,357	108,357	108,357	108,357	108,357	108,357	108,357	108,357	108,357	228,357
Internal rate of return	32%												

BIOLOGICAL MODEL OF THE FISHERIES

Introduction

This section concerns the formulation of a mathematical model of the fisheries. The model is of the length-based 'Thompson and Bell' type. The biological inputs included those concerning growth in length (L_∞ and K), the conversion of length to individual weight (a and b), and the natural mortality at age constants (A and B). The values used were as presented in the earlier sections. Most of the remaining inputs were determined internally within the model. These include the annual numbers of zero-aged shrimp (R), the catchability coefficients (q), and the selection/recruitment ogive constants (Ls and s, or S1 and S2). The latter were relevant to the estimation of size distributions for the shrimp in the catches. The remaining input was the annual fishing effort (X), as numbers of landings, for each gear type. The contemporary values were those estimated for 1997 (see Table 1).

The outputs from the model were estimated catch numbers, catch weights, and catch values, the associated CPUEs, and the shrimp length frequencies. They were in respect to each of the six main shrimp species, and eight gear types. In order to obtain output for the other shrimp, it was assumed their proportion (by number) would remain as presently observed, and their average individual weights would be the same as for the main species. In estimating the catch weights for the non-shrimp species (mainly fish), it was assumed their proportions (by weight) would also remain as presently observed for each gear type. A flowchart representation of the model is given in Figure 25. More detailed structure and example calculations are shown in Table 26. The underlying equations are described in Table 27.

Internal Estimation of Inputs

The internal estimation of model inputs involved iteration (ie. trial and error). After inputting the observed annual fishing efforts for each gear, the 'best choice' values for the number of zero-aged recruits, catchability coefficients and selection/recruitment ogive constants, were those for which the estimated and observed catch length frequencies (by species and sex) were in closest agreement. The latter was determined as when the sums of the squared differences between the estimated and observed length frequencies were minimised. The iterations were undertaken using the Solver routine in EXCEL. The resulting estimates for the inputs, including those determined outside the model, are shown in Tables 28 to 33. The estimated and observed length frequencies are shown in Tables 34 to 45.

Catch Numbers, Weights and Values from the Model

The estimated catch numbers, weights and values, from inputting the contemporary fishing efforts, are shown in Table 46 for each species and gear. As would be expected the estimates from the model are in good agreement with the observations given in earlier sections The estimated and observed catch weights for shrimp, for example, are respectively 862 t and 878 t. They are 1 183 t and 1 194 t for the non-shrimp species. These values do not include catches from gill nets or hand lines. These gears were not represented in the model, due to their not being used to target shrimp

Discussion

The main objective of the analyses was to produce estimates for those inputs to the model, for which external estimation was not possible. While the estimates appear sensible, there is no objective way in which this can be confirmed at present. Their correctness or otherwise will be revealed over time from additional research and observation. A shortcoming which is likely to have caused some biasing, is the absence of ‘spatial separation’ within the model, as required to fully reflect the presumed migration patterns. It was not included because of the need for a more complete understanding of the migration behaviour for each species.

As structured, the model assumes that the exploitation of shrimp with different gears takes place simultaneously. This assumption is not valid for some of the gear interactions. The simultaneous exploitation of the shrimp occurring on the trawl grounds, for example, would require that they migrate rapidly backwards and forwards between the two grounds. As the grounds are some 10 km apart, this is unlikely. In the extreme there may be no migration between the grounds. The assumption of simultaneous exploitation for the larger *P. indicus* (and *P. semisulcatus*) occurring both inside and outside the lagoon, is obviously not realistic. The shrimp which have left the lagoon will not be accessible to trammel and cast nets, nor will those remaining (for a longer period) within the lagoon be accessible to trawlers.

Figure 25: Model flowchart.

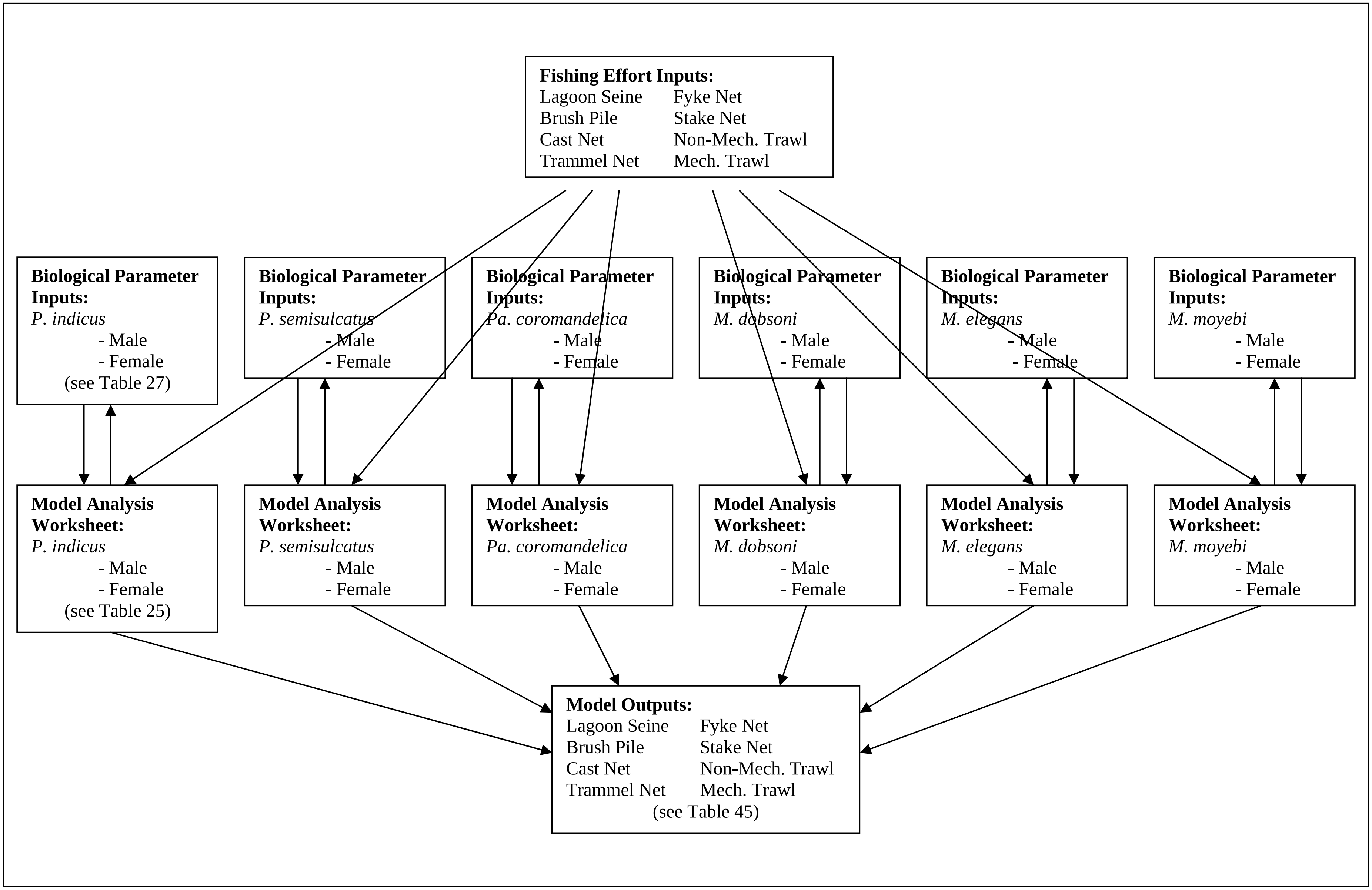


Table 26: Worksheet example for *P. indicus* females.

Carapace Length Interval (cm)	Start Age (yr)	Mean Age (yr)	Probability of Capture Ogive								Fishing Mortality Coefficient							
			Lagoon Seine	Brush Pile	Cast Net	Trammel Net	Fyke Net	Stake Net	Non-Mech. Trawl	Mech. Trawl	Lagoon Seine	Brush Pile	Cast Net	Trammel Net	Fyke Net	Stake Net	Non-Mech. Trawl	Mech. Trawl
L1, L2	t1, t2	t'	Od'	Ob'	Oc'	Ot'	Of'	Os'	On'	Om'	Fd'	Fb'	Fc'	Ft'	Ff'	Fs'	Fn'	Fm'
0.0 0.2	0.000	0.003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.2 0.4	0.020	0.029	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.4 0.6	0.040	0.050	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.6 0.8	0.061	0.071	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.8 1.0	0.083	0.093	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0 1.2	0.105	0.116	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.2 1.4	0.128	0.140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.4 1.6	0.153	0.165	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.6 1.8	0.178	0.190	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.8 2.0	0.204	0.217	0.11	0.03	0.00	0.00	0.01	0.01	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0 2.2	0.231	0.245	0.25	0.10	0.00	0.00	0.02	0.02	0.00	0.00	0.0001	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
2.2 2.4	0.259	0.274	0.49	0.28	0.00	0.00	0.02	0.05	0.00	0.00	0.0002	0.0003	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000
2.4 2.6	0.289	0.304	0.76	0.58	0.00	0.00	0.04	0.11	0.04	0.00	0.0003	0.0007	0.0001	0.0000	0.0000	0.0006	0.0000	0.0000
2.6 2.8	0.320	0.336	0.96	0.89	0.01	0.00	0.06	0.22	0.14	0.00	0.0004	0.0011	0.0002	0.0000	0.0000	0.0013	0.0000	0.0000
2.8 3.0	0.353	0.370	0.99	1.00	0.02	0.00	0.09	0.38	0.37	0.00	0.0004	0.0012	0.0005	0.0002	0.0000	0.0023	0.0000	0.0000
3.0 3.2	0.387	0.405	0.83	0.82	0.04	0.01	0.13	0.59	0.68	0.00	0.0004	0.0011	0.0013	0.0012	0.0000	0.0037	0.0001	0.0000
3.2 3.4	0.423	0.442	0.56	0.49	0.09	0.02	0.18	0.80	0.88	0.00	0.0003	0.0007	0.0032	0.0045	0.0000	0.0054	0.0001	0.0000
3.4 3.6	0.462	0.482	0.31	0.21	0.18	0.07	0.25	0.95	0.97	0.00	0.0002	0.0003	0.0067	0.0146	0.0000	0.0068	0.0001	0.0000
3.6 3.8	0.503	0.524	0.14	0.07	0.32	0.18	0.32	1.00	0.99	0.02	0.0001	0.0001	0.0126	0.0390	0.0000	0.0077	0.0001	0.0000
3.8 4.0	0.547	0.570	0.05	0.02	0.51	0.37	0.41	0.93	1.00	0.13	0.0000	0.0000	0.0213	0.0859	0.0000	0.0076	0.0001	0.0001
4.0 4.2	0.594	0.619	0.02	0.00	0.71	0.62	0.51	0.76	1.00	0.56	0.0000	0.0000	0.0323	0.1567	0.0000	0.0067	0.0002	0.0003
4.2 4.4	0.644	0.671	0.00	0.00	0.89	0.87	0.62	0.54	1.00	0.92	0.0000	0.0000	0.0437	0.2366	0.0000	0.0052	0.0002	0.0006
4.4 4.6	0.699	0.729	0.00	0.00	0.99	1.00	0.72	0.35	1.00	0.99	0.0000	0.0000	0.0531	0.2963	0.0001	0.0036	0.0002	0.0007
4.6 4.8	0.759	0.792	0.00	0.00	0.98	0.94	0.82	0.19	1.00	1.00	0.0000	0.0000	0.0579	0.3081	0.0001	0.0022	0.0002	0.0008
4.8 5.0	0.825	0.862	0.00	0.00	0.86	0.73	0.90	0.10	1.00	1.00	0.0000	0.0000	0.0567	0.2666	0.0001	0.0012	0.0002	0.0009
5.0 5.2	0.899	0.940	0.00	0.00	0.67	0.47	0.96	0.04	1.00	1.00	0.0000	0.0000	0.0501	0.1924	0.0001	0.0006	0.0003	0.0010
5.2 5.4	0.983	1.030	0.00	0.00	0.47	0.25	0.99	0.02	1.00	1.00	0.0000	0.0000	0.0401	0.1163	0.0001	0.0003	0.0003	0.0011
5.4 5.6	1.078	1.134	0.00	0.00	0.29	0.11	1.00	0.01	1.00	1.00	0.0000	0.0000	0.0292	0.0591	0.0001	0.0001	0.0004	0.0013
5.6 5.8	1.191	1.258	0.00	0.00	0.16	0.04	0.97	0.00	1.00	1.00	0.0000	0.0000	0.0195	0.0256	0.0002	0.0000	0.0004	0.0016
5.8 6.0	1.327	1.523	0.00	0.00	0.08	0.01	0.92	0.00	1.00	1.00	0.0000	0.0000	0.0121	0.0095	0.0002	0.0000	0.0005	0.0020
6.0 6.2	1.500	1.791	0.00	0.00	0.03	0.00	0.84	0.00	1.00	1.00	0.0000	0.0000	0.0073	0.0032	0.0002	0.0000	0.0008	0.0028
6.2 6.4	1.737	1.921	0.00	0.00	0.01	0.00	0.75	0.00	1.00	1.00	0.0000	0.0000	0.0045	0.0010	0.0003	0.0000	0.0012	0.0044
6.4 6.6	2.117	2.601	0.00	0.00	0.00	0.00	0.64	0.00	1.00	1.00	0.0000	0.0000	0.0043	0.0004	0.0008	0.0000	0.0033	0.0121
6.6 6.64	3.155	5.934	0.00	0.00	0.00	0.00	0.58	0.00	1.00	1.00	0.0000	0.0000	0.0137	0.0009	0.0047	0.0000	0.0217	0.0795

Carapace Length Interval (cm) L1, L2	Natural Mortality Coef. M'	Population Number Start (mill.) N1, N2	Population Number Mean (mill.) N'	Catch Number ('000) Lagoon Seine Cd'	Brush Pile Cb'	Cast Net Cc'	Trammel Net Ct'	Fyke Net Cf'	Stake Net Cs'	Non-Mech. Trawl Cn'	Mech. Trawl Cm'	Indiv. Whole Weight (gm) w'	Catch Weight (kg) Lagoon Seine Yd'	Brush Pile Yb'	Cast Net Yc'	Trammel Net Yt'	Fyke Net Yf'	Stake Net Ys'	Non-Mech. Trawl Yn'	Mech. Trawl Ym'
0.0 0.2	7.0931	2 985 016	420 484	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
0.2 0.4	0.6939	2 480	1 788	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0	0	0	0
0.4 0.6	0.4289	1 239	1 008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	001	0	0	0	0	0	0	0	0
0.6 0.8	0.3215	807	690	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0	0	0	0	0	0	0	0
0.8 1.0	0.2635	585	514	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.04	0	0	0	0	0	0	0	0
1.0 1.2	0.2276	450	402	0.05	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.08	0	0	0	0	0	0	0	0
1.2 1.4	0.2036	358	324	0.23	0.02	0.00	0.00	0.01	0.18	0.00	0.00	0.14	0	0	0	0	0	0	0	0
1.4 1.6	0.1868	292	266	0.86	0.16	0.01	0.00	0.02	0.64	0.00	0.00	0.22	0	0	0	0	0	0	0	0
1.6 1.8	0.1746	242	222	2.65	1.00	0.03	0.00	0.04	2.08	0.00	0.00	0.33	1	0	0	0	0	1	0	0
1.8 2.0	0.1657	203	187	6.72	4.67	0.13	0.00	0.05	6.00	0.00	0.00	0.47	3	2	0	0	0	3	0	0
2.0 2.2	0.1592	172	159	14.01	16.13	0.51	0.01	0.08	15.37	0.00	0.00	0.65	9	10	0	0	0	10	0	0
2.2 2.4	0.1547	147	136	23.94	41.07	1.83	0.10	0.12	34.99	0.00	0.00	0.87	21	36	2	0	0	30	0	0
2.4 2.6	0.1516	126	117	33.45	76.97	5.87	0.73	0.17	70.56	0.49	0.00	1.13	38	87	7	1	0	80	1	0
2.6 2.8	0.1498	108	100	38.17	105.98	16.81	4.32	0.23	125.85	1.44	0.00	1.44	55	153	24	6	0	182	2	0
2.8 3.0	0.1492	93	86	35.51	107.04	42.94	21.18	0.31	198.27	3.46	0.00	1.81	64	194	78	38	1	360	6	0
3.0 3.2	0.1497	79	73	26.90	79.18	97.62	85.63	0.41	275.43	5.76	0.00	2.24	60	178	219	192	1	618	13	0
3.2 3.4	0.1511	68	63	16.53	42.77	197.03	284.28	0.52	336.40	6.77	0.00	2.74	45	117	539	778	1	921	19	0
3.4 3.6	0.1537	58	53	8.20	16.76	350.75	770.14	0.63	358.92	6.60	0.05	3.30	27	55	1 158	2 543	2	1 185	22	0
3.6 3.8	0.1573	48	43	3.24	4.71	543.79	1 681.05	0.73	330.33	5.92	0.36	3.94	13	19	2 143	6 626	3	1 302	23	1
3.8 4.0	0.1621	39	34	1.00	0.93	719.20	2 895.88	0.78	256.86	5.01	2.34	4.66	5	4	3 352	13 498	4	1 197	23	11
4.0 4.2	0.1684	29	24	0.23	0.12	791.19	3 838.84	0.76	164.55	3.93	8.11	5.47	1	1	4 325	20 984	4	899	21	44
4.2 4.4	0.1763	20	16	0.04	0.01	711.07	3 846.14	0.66	85.29	2.83	9.53	6.36	0	0	4 524	24 470	4	543	18	61
4.4 4.6	0.1861	13	10	0.01	0.00	524.60	2 926.51	0.51	35.94	1.88	6.82	7.35	0	0	3 858	21 521	4	264	14	50
4.6 4.8	0.1986	7	6	0.00	0.00	328.96	1 751.01	0.37	12.75	1.19	4.37	8.45	0	0	2 779	14 791	3	108	10	37
4.8 5.0	0.2143	4	3	0.00	0.00	185.06	869.50	0.26	4.02	0.76	2.80	9.65	0	0	1 785	8 388	2	39	7	27
5.0 5.2	0.2345	2	2	0.00	0.00	98.00	376.04	0.19	1.18	0.52	1.89	10.96	0	0	1 074	4 121	2	13	6	21
5.2 5.4	0.2612	2	1	0.00	0.00	49.91	144.68	0.14	0.33	0.38	1.38	12.39	0	0	618	1 792	2	4	5	17
5.4 5.6	0.2976	1	0.8	0.00	0.00	24.24	49.11	0.11	0.09	0.30	1.09	13.94	0	0	338	685	2	1	4	15
5.6 5.8	0.3496	1	0.6	0.00	0.00	10.94	14.34	0.09	0.02	0.24	0.89	15.62	0	0	171	224	1	0	4	14
5.8 6.0	0.4217	0.5	0.4	0.00	0.00	4.48	3.51	0.07	0.00	0.20	0.74	17.44	0	0	78	61	1	0	4	13
6.0 6.2	0.5564	0.3	0.2	0.00	0.00	1.62	0.70	0.05	0.00	0.17	0.61	19.39	0	0	31	14	1	0	3	12
6.2 6.4	0.8761	0.2	0.1	0.00	0.00	0.49	0.11	0.04	0.00	0.13	0.48	21.49	0	0	11	2	1	0	3	10
6.4 6.6	2.2679	0.1	0.0	0.00	0.00	0.11	0.01	0.02	0.00	0.09	0.32	23.74	0	0	3	0	1	0	2	8
6.6 6.64	13.5814	0.0	0.0	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.04	25.21	0	0	0	0	0	0	0	1
totals				211	497	4 707	19 563	8	2 316	48	42		343	857	27 117	120 734	40	7 760	210	342

Table 27: Equations used in the model.

t1 = -(1/K).LN(1–L1/L_{∞})
t’ = (t2–t1)/LN(t2/t1)
O’ = EXP(-((((L1+L2)/2)–Ls)^2)/(2.s^2))   or
O’ = 1/(1+EXP(S1–S2.(L1+L2)/2))
F’ = (t2–t1).O’.q.X where X is fishing effort
M’ = (t2-t1).(A+(B/(t2-t1)).LN(t2/t1))
N2 = N1.EXP(-(F’+M’)) where F’ is summed for all gears
N’ = (N1-N2)/(F’+M’) where F’ is summed for all gears
C’ = F’.N’
w’ = (1/(L2-L1)).(a/(b+1)).(L2^(b+1)-L1(b+1))
Y’ = C’.w’
C = SUM(C’)
Y = SUM(Y’)

Table 28: Biological inputs to the model for *P. indicus*.

	Male				Female			
No. of zero length recruits	R =	2 932 679	000 000		R =	2 985 016	000 000	
Asymptotic carapace length	$L\infty$ =	6.46	cm		$L\infty$ =	6.65	cm	
Curvature coefficient	K =	1.50	/yr		K =	1.55	/yr	
Total weight/carapace length constants	a =	0.0000352			a =	0.0000395		
(when w in gm and l in mm.)	b =	3.2195			b =	3.1878		
Natural mortality at age constants	A =	1.8280			A =	1.8280		
(when age in yr)	B =	0.9266		F (/yr) =	B =	0.9266		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00000176		0.0096	q =	0.00000224		0.0122
Catchability coefficient (brush pile)	q =	0.00000399		0.0270	q =	0.00000538		0.0363
Catchability coefficient (cast net)	q =	0.00005966		0.9362	q =	0.00005688		0.8927
Catchability coefficient (trammel net)	q =	0.00001956		4.4752	q =	0.00002165		4.9526
Catchability coefficient (fyke net)	q =	0.00000019		0.0007	q =	0.00000032		0.0012
Catchability coefficient (stake net)	q =	0.00001145		0.1274	q =	0.00001576		0.1753
Catchability coefficient (non-mech.trawl)	q =	0.00000787		0.1355	q =	0.00000018		0.0032
Catchability coefficient (mech. trawl)	q =	0.00003537		0.2637	q =	0.00000156		0.0116
Optimum selection length (lagoon seine)	Ls =	2.7284	cm		Ls =	2.8283	cm	
Std. dev. of selection length (lagoon seine)	s =	0.5492	cm		s =	0.4403	cm	
Optimum selection length (brush pile)	Ls =	2.8617	cm		Ls =	2.8714	cm	
Std. dev. of selection length (brush pile)	s =	0.4149	cm		s =	0.3580	cm	
Optimum selection length (cast net)	Ls =	4.4795	cm		Ls =	4.5799	cm	
Std. dev. of selection length (cast net)	s =	0.5629	cm		s =	0.5853	cm	
Optimum selection length (trammel net)	Ls =	4.5307	cm		Ls =	4.5397	cm	
Std. dev. of selection length (trammel net)	s =	0.4651	cm		s =	0.4534	cm	
Optimum selection length (fyke net)	Ls =	4.7737	cm		Ls =	5.4240	cm	
Std. dev. of selection length (fyke net)	s =	0.9098	cm		s =	1.1485	cm	
Optimum selection length (stake net)	Ls =	4.1447	cm		Ls =	3.6799	cm	
Std. dev. of selection length (stake net)	s =	0.8643	cm		s =	0.5626	cm	
Selection constants (non-mech. trawl)	S1 =	19.2330			S1 =	19.1994		
(when l in cm)	S2 =	3.5617			S2 =	6.4352		
Selection constants (mech. trawl)	S1 =	46.5660			S1 =	44.3493		
(when l in cm)	S2 =	8.9927			S2 =	10.8788		

Table 29: Biological inputs to the model for *P. semisulcatus*.

		Male				Female		
No. of zero length recruits	R =	2 179 741	000 000		R =	1 905 088	000 000	
Asymptotic carapace length	L∞ =	5.50	cm		L∞ =	6.02	cm	
Curvature coefficient	K =	1.47	/yr		K =	1.42	/yr	
Total weight/carapace length constants	a =	0.0000574			a =	0.0000704		
(when w in gm and l in mm.)	b =	3.2968			b =	3.239		
Natural mortality at age constants	A =	1.7448			A =	1.7448		
(when age in yr)	B =	0.9497		F (/yr) =	B =	0.9497		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00006127		0.3332	q =	0.00006611		0.3595
Catchability coefficient (brush pile)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (cast net)	q =	0.00000462		0.0725	q =	0.00000307		0.0482
Catchability coefficient (trammel net)	q =	0.00000469		1.0725	q =	0.00000356		0.8152
Catchability coefficient (fyke net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (stake net)	q =	0.00002329		0.2590	q =	0.00002796		0.3110
Catchability coefficient (non-mech.trawl)	q =	0.00000001		0.0001	q =	0.00000008		0.0014
Catchability coefficient (mech. trawl)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Optimum selection length (lagoon seine)	Ls =	2.4481	cm		Ls =	2.4400	cm	
Std. dev. of selection length (lagoon seine)	s =	0.3064	cm		s =	0.3318	cm	
Optimum selection length (brush pile)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (brush pile)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (cast net)	Ls =	3.6028	cm		Ls =	3.7220	cm	
Std. dev. of selection length (cast net)	s =	0.3025	cm		s =	0.5265	cm	
Optimum selection length (trammel net)	Ls =	3.6445	cm		Ls =	3.7572	cm	
Std. dev. of selection length (trammel net)	s =	0.3572	cm		s =	0.4723	cm	
Optimum selection length (fyke net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (fyke net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (stake net)	Ls =	2.5253	cm		Ls =	2.6753	cm	
Std. dev. of selection length (stake net)	s =	0.3914	cm		s =	0.4664	cm	
Selection constants (non-mech. trawl)	S1 =	124.1333			S1 =	9.9000		
(when l in cm)	S2 =	57.4923			S2 =	2.0000		
Selection constants (mech. trawl)	S1 =	0.0000			S1 =	0.0000		
(when l in cm)	S2 =	0.0000			S2 =	0.0000		

Table 30: Biological inputs to the model for *Pa. coromandelica*.

		Male				Female		
No. of zero length recruits	R =	1 720 767	000 000		R =	1 577 345	000 000	
Asymptotic carapace length	L∞ =	3.90	cm		L∞ =	4.91	cm	
Curvature coefficient	K =	1.41	/yr		K =	1.51	/yr	
Total weight/carapace length constants	a =	0.0000784			a =	0.0000233		
(when w in gm and l in mm.)	b =	2.9873			b =	3.2780		
Natural mortality at age constants	A =	2.3476			A =	2.3476		
(when age in yr)	B =	0.8536		F (/yr) =	B =	0.8536		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (brush pile)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (cast net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (trammel net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (fyke net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (stake net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (non-mech.trawl)	q =	0.00018939		3.2583	q =	0.00014614		2.5143
Catchability coefficient (mech. trawl)	q =	0.00024540		1.8297	q =	0.00013805		1.0293
Optimum selection length (lagoon seine)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (lagoon seine)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (brush pile)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (brush pile)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (cast net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (cast net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (trammel net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (trammel net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (fyke net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (fyke net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (stake net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (stake net)	s =	0.0000	cm		s =	0.0000	cm	
Selection constants (non-mech. trawl)	S1 =	20.5767			S1 =	10.1167		
(when l in cm)	S2 =	7.0913			S2 =	2.6484		
Selection constants (mech. trawl)	S1 =	20.2114			S1 =	8.8611		
(when l in cm)	S2 =	7.2666			S2 =	2.7336		

Table 31: Biological inputs to the model for *M. dobsoni*.

		Male				**Female**		
No. of zero length recruits	R =	4 406 614	000 000		R =	2 796 931	000 000	
Asymptotic carapace length	L∞ =	3.76	cm		L∞ =	4.87	cm	
Curvature coefficient	K =	1.43	/yr		K =	1.52	/yr	
Total weight/carapace length constants	a =	0.000363			a =	0.000347		
(when w in gm and l in mm.)	b =	2.6322			b =	2.6399		
Natural mortality at age constants	A =	2.2689			A =	2.2689		
(when age in yr)	B =	0.8606		F (/yr) =	B =	0.8606		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00000090		0.0049	q =	0.00000155		0.0084
Catchability coefficient (brush pile)	q =	0.00000002		0.0002	q =	0.00000004		0.0003
Catchability coefficient (cast net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (trammel net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (fyke net)	q =	0.00001515		0.0559	q =	0.00002809		0.1036
Catchability coefficient (stake net)	q =	0.00004417		0.4913	q =	0.00008804		0.9793
Catchability coefficient (non-mech.trawl)	q =	0.00022013		3.7871	q =	0.00013222		2.2747
Catchability coefficient (mech. trawl)	q =	0.00022474		1.6757	q =	0.00043084		3.2123
Optimum selection length (lagoon seine)	Ls =	1.5600	cm		Ls =	1.5769	cm	
Std. dev. of selection length (lagoon seine)	s =	0.3351	cm		s =	0.3984	cm	
Optimum selection length (brush pile)	Ls =	1.7000	cm		Ls =	1.7309	cm	
Std. dev. of selection length (brush pile)	s =	0.2045	cm		s =	0.2585	cm	
Optimum selection length (cast net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (cast net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (trammel net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (trammel net)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (fyke net)	Ls =	1.7925	cm		Ls =	1.8412	cm	
Std. dev. of selection length (fyke net)	s =	0.2266	cm		s =	0.2708	cm	
Optimum selection length (stake net)	Ls =	1.6900	cm		Ls =	1.6993	cm	
Std. dev. of selection length (stake net)	s =	0.3107	cm		s =	0.3161	cm	
Selection constants (non-mech. trawl)	S1 =	12.7979			S1 =	9.0778		
(when l in cm)	S2 =	4.7574			S2 =	3.1624		
Selection constants (mech. trawl)	S1 =	24.6762			S1 =	37.9149		
(when l in cm)	S2 =	9.0010			S2 =	11.1721		

Table 32: Biological inputs to the model for *M. elegans*.

		Male				**Female**		
No. of zero length recruits	R =	1 155 598	000 000		R =	913 336	000 000	
Asymptotic carapace length	L∞ =	3.46	cm		L∞ =	4.70	cm	
Curvature coefficient	K =	1.39	/yr		K =	1.50	/yr	
Total weight/carapace length constants	a =	0.000222			a =	0.0000465		
(when w in gm and l in mm.)	b =	2.8295			b =	3.3038		
Natural mortality at age constants	A =	2.2586			A =	2.2586		
(when age in yr)	B =	0.8489		F (/yr) =	B =	0.8489		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00000071		0.0039	q =	0.00000188		0.0102
Catchability coefficient (brush pile)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (cast net)	q =	0.00000334		0.0524	q =	0.00000035		0.0055
Catchability coefficient (trammel net)	q =	0.00000010		0.0229	q =	0.00000145		0.3314
Catchability coefficient (fyke net)	q =	0.00004904		0.1809	q =	0.00004171		0.1538
Catchability coefficient (stake net)	q =	0.00016910		1.8809	q =	0.00014989		1.6672
Catchability coefficient (non-mech.trawl)	q =	0.00000005		0.0009	q =	0.00000002		0.0003
Catchability coefficient (mech. trawl)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Optimum selection length (lagoon seine)	Ls =	2.2319	cm		Ls =	2.1694	cm	
Std. dev. of selection length (lagoon seine)	s =	0.2433	cm		s =	0.1110	cm	
Optimum selection length (brush pile)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (brush pile)	s =	0.0000	cm		s =	0.0000	cm	
Optimum selection length (cast net)	Ls =	3.2946	cm		Ls =	3.8158	cm	
Std. dev. of selection length (cast net)	s =	0.1677	cm		s =	0.3054	cm	
Optimum selection length (trammel net)	Ls =	2.7700	cm		Ls =	4.1217	cm	
Std. dev. of selection length (trammel net)	s =	0.2000	cm		s =	0.4586	cm	
Optimum selection length (fyke net)	Ls =	3.1252	cm		Ls =	4.0294	cm	
Std. dev. of selection length (fyke net)	s =	0.1984	cm		s =	0.2114	cm	
Selection constants (stake net)	S1 =	41.0000	cm		S1 =	13.7201	cm	
(when l in cm)	S2 =	15.4000	cm		S2 =	3.5906	cm	
Selection constants (non-mech. trawl)	S1 =	10.0000			S1 =	12.8075		
(when l in cm)	S2 =	4.0000			S2 =	7.0000		
Selection constants (mech. trawl)	S1 =	0.0000			S1 =	0.0000		
(when l in cm)	S2 =	0.0000			S2 =	0.0000		

Table 33: Biological inputs to the model for *M. moyebi*.

	Male				Female			
No. of zero length recruits	R =	5 002 779	000 000		R =	4 550 555	000 000	
Asymptotic carapace length	L∞ =	2.56	cm		L∞ =	3.50	cm	
Curvature coefficient	K =	1.43	/yr		K =	1.40	/yr	
Total weight/carapace length constants	a =	0.000301			a =	0.000314		
(when w in gm and l in mm.)	b =	2.7691			b =	2.7445		
Natural mortality at age constants	A =	2.3648			A =	2.3648		
(when age in yr)	B =	0.8471		F (/yr) =	B =	0.8471		F (/yr) =
Catchability coefficient (lagoon seine)	q =	0.00001600		0.0870	q =	0.00001835		0.0998
Catchability coefficient (brush pile)	q =	0.00000054		0.0037	q =	0.00000050		0.0034
Catchability coefficient (cast net)	q =	0.00000012		0.0019	q =	0.00000013		0.0020
Catchability coefficient (trammel net)	q =	0.00000001		0.0023	q =	0.00000060		0.1375
Catchability coefficient (fyke net)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Catchability coefficient (stake net)	q =	0.00016039		1.7840	q =	0.00013939		1.5504
Catchability coefficient (non-mech.trawl)	q =	0.00000039		0.0067	q =	0.00000029		0.0051
Catchability coefficient (mech. trawl)	q =	0.00000000		0.0000	q =	0.00000000		0.0000
Optimum selection length (lagoon seine)	Ls =	2.1965	cm		Ls =	2.9120	cm	
Std. dev. of selection length (lagoon seine)	s =	0.3382	cm		s =	0.5956	cm	
Optimum selection length (brush pile)	Ls =	2.0148	cm		Ls =	2.0142	cm	
Std. dev. of selection length (brush pile)	s =	0.0266	cm		s =	0.0266	cm	
Optimum selection length (cast net)	Ls =	2.0345	cm		Ls =	2.5000	cm	
Std. dev. of selection length (cast net)	s =	0.0869	cm		s =	0.1100	cm	
Optimum selection length (trammel net)	Ls =	4.3988	cm		Ls =	4.6068	cm	
Std. dev. of selection length (trammel net)	s =	0.7518	cm		s =	0.8124	cm	
Optimum selection length (fyke net)	Ls =	0.0000	cm		Ls =	0.0000	cm	
Std. dev. of selection length (fyke net)	s =	0.0000	cm		s =	0.0000	cm	
Selection constants (stake net)	S1 =	21.7312	cm		S1 =	20.7040	cm	
(when l in cm)	S2 =	10.5733	cm		S2 =	8.1649	cm	
Selection constants (non-mech. trawl)	S1 =	43.6193			S1 =	13.5196		
(when l in cm)	S2 =	20.1313			S2 =	4.4577		
Selection constants (mech. trawl)	S1 =	0.0000			S1 =	0.0000		
(when l in cm)	S2 =	0.0000			S2 =	0.0000		

Table 34: Estimated and observed catch numbers for male *P. indicus*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
0.1																
0.3																
0.5																
0.7												1				
0.9												1				
1.1		1										2				
1.3		3										5				
1.5		5		1								8				
1.7		10		3							3	14				
1.9	20	16	3	10							6	23				
2.1	32	23	13	23		1					49	36				
2.3	33	29	42	44	3	2					20	53				
2.5	30	32	74	68	3	7		1	0.6	0.1	85	76				
2.7	22	32	88	83	8	21	69	6		0.2	65	104				
2.9	33	27	80	80	52	54	35	28		0.3	162	134	0.6	0.1		
3.1	22	20	46	61	74	125	93	106		0.3	179	164		0.1		
3.3	12	13	34	37	176	251	106	325	1.7	0.4	196	190	3.3	0.2		
3.5	11	8	37	18	661	441	921	822		0.6	333	206		0.3		
3.7	5	4	10	7	600	665	1 415	1 683	1.5	0.6	164	207	8.4	0.6	0.2	
3.9	1	2	8	2	854	844	3 187	2 733		0.7	144	187	1.7	1.0	0.7	
4.1	2	1	1		776	877	3 385	3 426		0.6	85	150	1.0	1.5	0.9	
4.3			1		719	734	2 916	3 263		0.5	135	103	1.8	2.2	1.2	0.1
4.5					675	498	2 739	2 375		0.4	142	62	2.1	2.8	2.6	0.3
4.7					259	284	1 392	1 370	1.5	0.2	74	34	1.3	3.4	3.9	1.2
4.9					117	143	627	660	1.5	0.1	11	18	5.2	3.9	3.6	4.0
5.1					25	67	232	277	1.5	0.1	17	9	2.7	4.5	9.2	11.5
5.3					22	29	69	103		0.1	12	5	4.1	5.1	22.5	18.0
5.5					1	12	40	34				2	11.4	5.0	10.6	16.6
5.7						4	13	9				1	3.8	4.2	10.9	12.9
5.9						1	1	2				1	2.4	3.1	14.6	9.6
6.1													1.9	1.7	13.6	6.5
6.3													1.2	0.2	1.7	3.5
6.5															1.8	0.3
Totals	224	227	439	436	5 027	5 060	17 240	17 225	8.3	5.4	1 881	1 818	52.9	45.2	97.9	84.4

Table 35: Estimated and observed catch numbers for female *P. indicus*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1																
1.3																
1.5												1				
1.7	1	3		1								2				
1.9	17	7	2	5						0.1	1	6				
2.1	9	14	12	16		1				0.1	17	15				
2.3	21	24	33	41		2				0.1	73	35				
2.5	44	33	89	77	5	6		1	1.5	0.2	64	71	0.3	0.5		
2.7	34	38	107	106	7	17	10	4		0.2	125	126	0.6	1.4		
2.9	37	36	114	107	18	43	152	21	1.5	0.3	269	198	1.2	3.5		
3.1	26	27	58	79	66	98	172	86		0.4	293	275	1.2	5.8		
3.3	12	17	48	43	140	197	119	284		0.5	219	336	11.6	6.8		
3.5	12	8	38	17	431	351	1 000	770	2.4	0.6	381	359	1.2	6.6	0.2	
3.7	7	3	16	5	588	544	1 485	1 681		0.7	397	330	16.4	5.9		
3.9	1	1	9	1	856	719	3 329	2 896		0.8	263	257	3.5	5.0	1.3	2.3
4.1	2		1		617	791	3 710	3 839	0.6	0.8	103	165	9.3	3.9	9.6	8.1
4.3	1				630	711	3 475	3 846		0.7	68	85	8.6	2.8	6.2	9.5
4.5	1				624	525	3 177	2 927	1.7	0.5	71	36	2.3	1.9	8.5	6.8
4.7					361	329	1 525	1 751	0.6	0.4	16	13	1.8	1.2	4.1	4.4
4.9					182	185	877	869		0.3	31	4	1.2	0.8	1.8	2.8
5.1					53	98	267	376	1.5	0.2	66	1	3.4	0.5	5.0	1.9
5.3					37	50	132	145	1.5	0.1	3		3.7	0.4	1.4	1.4
5.5					7	24	79	49		0.1	2		5.3	0.3	11.7	1.1
5.7					1	11	35	14		0.1	1		1.9	0.2	2.0	0.9
5.9						4	6	4		0.1			1.3	0.2	2.9	0.7
6.1						2	2	1		0.1			2.5	0.2	2.2	0.6
6.3													1.2	0.1	2.3	0.5
6.5														0.1	2.7	0.3
6.7													1.2		1.7	
Totals	226	211	527	498	4 622	4 707	19 554	19 564	11.4	7.4	2 463	2 316	79.7	48.1	63.6	41.8

Table 36: Estimated and observed catch numbers for male *P. semisulcatus*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine		Brush Pile		Cast Net		Trammel Net		Fyke Net		Stake Net		Non-Mechanised Trawl		Mechanised Trawl	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1												2				
1.3	31	2										11				
1.5	30	13									20	40				
1.7	46	69									96	114				
1.9	246	238									193	256				
2.1	482	537									307	441				
2.3	692	792			2			2			666	586	1.2	0.2		
2.5	930	760			3		28	15			617	598		0.2		
2.7	295	477			7	2	15	65			378	471		0.2		
2.9	194	197			11	9	344	214			293	287		0.2		
3.1	111	53			44	28	468	514			159	135	1.2	0.1		
3.3	83	9			33	58	843	889			83	48		0.1		
3.5	53	1			91	76	1 151	1 099			71	13		0.1		
3.7	18				61	63	895	972			49	3		0.1		
3.9	8				36	34	834	626			87	1		0.1		
4.1	2				3	12	101	298			86			0.1		
4.3					2	3	95	106			28					
4.5							15	28			13					
4.7								5			2					
4.9								1								
5.1																
5.3																
Totals	3 220	3 147			293	284	4 788	4 834			3 147	3 005	2.3	1.5		

Table 37: Estimated and observed catch numbers for female *P. semisulcatus*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
0.1																
0.3																
0.5																
0.7																
0.9												2				
1.1		1									2	6				
1.3	45	5									4	19				
1.5	55	26									25	52				
1.7	109	102									89	119				
1.9	333	282						1			259	231				
2.1	420	547				1		4			281	374				
2.3	737	737				2	5	16			483	504				
2.5	788	689			8	6	15	46			631	565				
2.7	339	448			8	12	85	113			483	526				
2.9	190	204			27	21	357	233			386	410	1.2			
3.1	100	64			25	31	353	401			283	266	1.2			
3.3	52	14			42	40	457	576			106	143		0.1		
3.5	53	2			44	43	781	687			85	64		0.1		
3.7	18				43	40	656	677			59	23		0.1		
3.9	13				30	32	675	555			27	7		0.1		
4.1	7				23	23	237	380			53	2		0.1		
4.3	2				10	14	147	219			32			0.1		
4.5	2				8	7	237	106			31			0.2		
4.7					15	3	93	43			2			0.2		
4.9						1	15	15			2			0.2		
5.1								4			4			0.2		
5.3								1			4			0.2		
5.5											1			0.2		
5.7														0.2		
5.9														0.1		
Totals	3 263	3 121			284	280	4 113	4 076			3 331	3 313	2.3	2.3		

Table 38: Estimated and observed catch numbers for male *Pa. coromandelica*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine		Brush Pile		Cast Net		Trammel Net		Fyke Net		Stake Net		Non-Mechanised Trawl		Mechanised Trawl	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1																
1.3																
1.5																
1.7																
1.9													48	18	3	21
2.1													43	62	18	72
2.3													134	207	193	246
2.5													699	650	1 033	763
2.7													1 663	1 675	1 437	1 735
2.9													2 590	2 589	2 363	2 057
3.1													1 819	1 824	959	1 161
3.3													630	625	165	363
3.5													180	111	77	63
3.7													15	7		4
3.9													9		14	
4.1																
totals													7 829	7 768	6 262	6 485

Table 39: Estimated and observed catch numbers for female *Pa.coromandelica*.

Carapace Mid-Length	Catch Numbers (‘000)															
	Lagoon Seine		Brush Pile		Cast Net		Trammel Net		Fyke Net		Stake Net		Non-Mechanised Trawl		Mechanised Trawl	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1																
1.3																
1.5																
1.7																
1.9													1	92	24	152
2.1													13	133	166	221
2.3													92	193	317	318
2.5													285	277	650	448
2.7													402	392	563	608
2.9													917	542	812	778
3.1													586	716	899	917
3.3													632	887	648	973
3.5													1 272	996	1 344	912
3.7													780	988	656	747
3.9													946	828	454	526
4.1													525	563	267	310
4.3													296	293	140	146
4.5													183	103	44	48
4.7													25	17	19	8
4.9													6	1		
totals													6 962	7 021	7 002	7 110

Table 40: Estimated and observed catch numbers for male *M. dobsoni*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
0.1																
0.3		1										4				
0.5		3										31				
0.7	48	12							4		28	203				
0.9	64	35							9	1	1 408	962				
1.1	57	74		0.1					9	20	3 224	3 130				
1.3	113	111	0.7	0.7					186	161	6 620	6 853	17	156		
1.5	114	118	2.1	2.4					597	593	9 956	9 951	139	320	5	1
1.7	58	87	3.4	3.0					956	995	9 974	9 505	586	654	24	3
1.9	35	45	1.3	1.5					808	764	4 865	5 983	1 792	1 320	160	13
2.1	28	16	0.3	0.3					191	269	3 209	2 489	2 937	2 609	465	63
2.3		4							85	43	535	674	4 314	4 831	348	292
2.5		1							13	3	105	114	7 033	7 564	1 142	1 186
2.7											62	11	6 113	8 477	2 723	2 988
2.9												1	7 265	5 806	3 175	2 835
3.1													3 493	2 299	707	1 118
3.3													756	506	31	235
3.5													297	46		21
3.7													11			
Totals	517	517	8.0	8.0					2 858	2 851	39 987	39 936	34 753	34 588	8 780	8 753

Table 41: Estimated and observed catch numbers for female *M. dobsoni*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
0.1																
0.3		4										4				
0.5		10										34				
0.7	48	24							4		28	215				
0.9	64	50							9	4	1 395	999				
1.1	57	82							25	49	3 315	3 232				
1.3	103	107		1					225	228	6 454	7 148	16	255		
1.5	116	110	4	3					557	621	11 286	10 638	43	390	8	
1.7	77	87	6	3					1 013	978	10 254	10 587	499	592	15	
1.9	40	54	3	2					813	896	6 142	7 086	937	894	36	
2.1	36	26	1	1					378	482	3 660	3 219	1 478	1 343	158	
2.3	2	10							264	152	1 330	993	2 314	1 983	150	
2.5		3							195	28	918	206	3 703	2 794	322	1
2.7		1							8	3	128	28	3 226	3 619	277	6
2.9									4		8	3	3 302	4 167	299	45
3.1									2				2 557	4 182	656	317
3.3													2 546	3 572	1 422	1 648
3.5													4 477	2 447	3 201	3 010
3.7													1 922	1 320	1 752	1 936
3.9													1 014	586	582	856
4.1													286	212	138	305
4.3													94	57		81
4.5													45	9		13
4.7													5			1
4.9																
Totals	543	568	14	11					3 496	3 442	44 920	44 391	28 462	28 422	9 018	8 219

Table 42: Estimated and observed catch numbers for male *M.elegans*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Est.	Brush Pile Obs.	Est.	Cast Net Obs.	Est.	Trammel Net Obs.	Est.	Fyke Net Obs.	Est.	Stake Net Obs.	Est.	Non-Mechanised Trawl Obs.	Est.	Mechanised Trawl Obs.	Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1																
1.3																
1.5																
1.7		2							2		2					
1.9		8							2		6					
2.1	26	13							3		3	1		1		
2.3		12						5			67	22		1		
2.5	13	5						22	6	3	251	346		1		
2.7	5	1					69	35	25	29	1 013	1 951	3	1		
2.9	5				4	3	5	15	73	77	2 000	1 488	3	1		
3.1					8	7	5	2	55	50	1 178	520	7			
3.3						2	6		28	6	107	84				
3.5									2		25	1				
3.7																
Totals	48	42			12	13	85	79	195	165	4 653	4 414	12	5		

Table 43: Estimated and observed catch numbers for female *M.elegans*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine		Brush Pile		Cast Net		Trammel Net		Fyke Net		Stake Net		Non-Mechanised Trawl		Mechanised Trawl	
	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.	Obs.	Est.
0.1																
0.3																
0.5																
0.7																
0.9																
1.1																
1.3														0.1		
1.5														0.2		
1.7														0.4		
1.9		2												0.8		
2.1	28	27							2		20	11		1.0		
2.3	14	14									37	20		0.9		
2.5	6							2			155	35		0.8		
2.7	3							6			123	61		0.7		
2.9	6							17			164	105		0.6		
3.1	2					1	54	42	2		91	175		0.5		
3.3						2	137	83			194	278		0.4		
3.5					5	3	59	132	4	7	517	400		0.3		
3.7					3	4	190	163	36	34	424	491	1	0.3		
3.9					3	3	152	148	62	64	496	479	5	0.2		
4.1					3	1	101	95	44	42	284	349		0.1		
4.3					1		15	39	7	9	80	179				
4.5							16	8	2		58	52				
4.7											5	2				
Totals	59	44			14	13	725	734	159	156	2 646	2 636	6	7		

Table 44: Estimated and observed catch numbers for male *M.moyebi*.

Carapace Mid-Length	Catch Numbers ('000) Lagoon Seine Obs.	Est.	Brush Pile Obs.	Est.	Cast Net Obs.	Est.	Trammel Net Obs.	Est.	Fyke Net Obs.	Est.	Stake Net Obs.	Est.	Non-Mechanised Trawl Obs.	Est.	Mechanised Trawl Obs.	Est.
0.1																
0.3																
0.5																
0.7	95	1														
0.9	86	4									1	1				
1.1	125	26									1	4				
1.3	105	111									25	26				
1.5	385	331									168	159				
1.7	581	679						0.1			753	937				
1.9	885	914			8	9		0.1			4 664	4 479	1	1		
2.1	738	689	0.2	0.2	12	12	1	0.2			8 374	9 081	12	12		
2.3	278	214			1			0.1			6 226	4 287	15	15		
2.5	33	13			2						1 452	377	2	1		
2.7																
Totals	3 313	2 983	0.2	0.2	22	21	1	0.6			21 664	19 351	31	30		

Table 45: Estimated and observed catch numbers for female *M.moyebi*.

Carapace Mid-Length	Lagoon Seine Obs.	Lagoon Seine Est.	Brush Pile Obs.	Brush Pile Est.	Cast Net Obs.	Cast Net Est.	Trammel Net Obs.	Trammel Net Est.	Fyke Net Obs.	Fyke Net Est.	Stake Net Obs.	Stake Net Est.	Non-Mechanised Trawl Obs.	Non-Mechanised Trawl Est.	Mechanised Trawl Obs.	Mechanised Trawl Est.
	Catch Numbers ('000)															
0.1		1														
0.3		1														
0.5		3														
0.7	95	8														
0.9	86	20														
1.1	119	45						1				1				
1.3	52	94						1			6	2				
1.5	332	176						3			29	10				
1.7	254	296	0.1					5			60	40				
1.9	498	444					6	10			192	162	2	1		
2.1	520	590	0.1	0.3	2		10	18			592	643		1		
2.3	723	682			3	4	49	28			2 086	2 286		2		
2.5	815	658			19	17	37	40			5 782	5 550	8	4		
2.7	357	497			6	2	62	46			5 984	6 517	4	5		
2.9	161	278			6		40	42			4 405	4 109	8	5		
3.1	28	107			1		28	28			1 615	1 723		3		
3.3	2	21					6	10			402	404		1		
3.5		1									105	14				
3.7																
Totals	4 041	3 923	0.3	0.3	36	24	237	233			21 259	21 460	23	23		

Table 46: Estimates of contemporary catch numbers, weights and values from the model.

	Annual Catch Number ('000)	Annual Catch Weight (kg)	Annual Catch Value (Rs)	Annual Catch Number ('000)	Annual Catch Weight (kg)	Annual Catch Value (Rs)	Annual Catch Number ('000)	Annual Catch Weight (kg)	Annual Catch Value (Rs)
		Lagoon Seine			**Brush Pile**			**Cast Net**	
P. indicus	439	659	58 931	934	1 587	142 668	9 767	54 636	8 336 052
P. semisulcatus	6 268	13 296	1 164 807	--	--	--	564	4 277	462 312
Pa. coromandelica	--	--	--	--	--	--	--	--	--
M. dobsoni	1 186	477	22 762	17	11	493	--	--	--
M. elegans	85	109	9 336	0	0	0	26	138	13 512
M. moyebi	6 945	10 008	774 494	0	1	58	46	77	6 456
other shrimp	122	200	16 531	2	4	360	15	86	12 795
sub-total	15 045	24 749	2 046 860	954	1 602	143 579	10 417	59 213	8 831 128
others (mainly fish)		37 929	1 517 164		37 033	1 481 304		30 012	750 311
total		62 678	3 564 024		38 635	1 624 883		89 226	9 581 439
		Trammel Net			**Fyke Net**			**Stake Net**	
P. indicus	36 788	224 500	36 179 962	13	66	7 640	4 135	14 219	1 684 321
P. semisulcatus	8 911	69 848	7 725 972	--	--	--	6 318	16 041	1 412 425
Pa. coromandelica	--	--	--	--	--	--	--	--	--
M. dobsoni	--	--	--	6 294	4 435	178 709	84 364	47 619	2 361 363
M. elegans	813	5 504	630 529	321	1 864	166 779	7 049	31 159	3 368 167
M. moyebi	234	591	52 355	--	--	--	40 810	82 827	7 168 621
other shrimp	743	4 774	708 516	6	6	308	4 038	9 988	944 041
sub-total	47 489	305 217	45 297 334	6 634	6 371	353 436	146 714	201 853	16 938 937
others (mainly fish)		744 498	33 502 399		5 166	129 158		92 629	3 242 015
total		1 049 715	78 799 733		11 537	482 594		294 482	20 180 952
		Non-mechanised Trawl			**Mechanised Trawl**			**All Gears**	
P. indicus	93	774	177 086	126	1 561	545 868	52 295	298 001	47 132 528
P. semisulcatus	4	55	12 621	--	--	--	22 065	103 516	10 778 138
Pa. coromandelica	14 789	33 239	4 330 656	13 595	27 132	3 583 242	28 384	60 371	7 913 899
M. dobsoni	63 011	141 505	15 604 054	16 972	56 510	6 840 121	171 844	250 557	25 007 502
M. elegans	13	30	3 376	0	0	0	8 307	38 805	4 191 699
M. moyebi	53	110	11 981	--	--	--	48 088	93 614	8 013 965
other shrimp	741	1 695	224 704	336	702	101 045	6 002	17 454	2 008 300
sub-total	78 703	177 408	20 364 479	31 029	85 904	11 070 276	336 986	862 317	105 046 030
others (mainly fish)		127 758	5 749 105		108 147	4 866 602		1 183 172	51 238 057

total	305 166	26 113 584	194 051	15 936 878	2 045 489	156 284 086

PROJECTIONS OF PERFORMANCE FROM USING THE MODEL

Introduction

Despite its shortcomings (ie. the non-inclusion of 'spatial separation'), the model was used to investigate the possible consequences to annual catch weights, catch values, and CPUEs from applying more or less fishing effort. The values for all the inputs to the model, other than the fishing efforts, were kept constant as previously determined. Three hypothetical scenarios were examined. In the first scenario the fishing effort with stake nets was varied (from zero to twice the contemporary effort). In the second scenario the fishing effort with trammel nets was varied. In the third scenario the fishing effort in the trawl fisheries was varied. In respect to all scenarios, the efforts exerted with the other gears were kept constant. Plots of the results concerning Scenario 1 are given in Figure 26, those for Scenario 2 in Figure 27, and for Scenario 3 in Figure 28. In all of these the 'effort multiplier' applies to the gear(s) for which the fishing effort was varied. The contemporary fishing effort is indicated by an 'effort multiplier' of unity.

Changing the Stake Net Effort (Scenario 1)

The results show that increasing the effort with stake nets causes a near proportional increase in the catch from stake nets. The estimated catch increases from 294 to 486 t in the extreme case of doubling the present effort. Over the same range of efforts the reductions in the estimated trawl catches are minor, from 305 to 272 t in the case of non-mechanised trawlers, and from 194 to 176 t for mechanised trawlers. The CPUEs are reduced for each of the gears, although only to a modest extent, even from a large increase in the effort. In reality, however, there is very little scope for increased effort from stake nets. This is because the suitable sites at the entrance of the lagoon are already fully utilised. Reducing the stake net effort gives only a minor increase in the catches from trawlers, compared to the substantial loss of catch from stake nets. The associated increase in the CPUEs of the trawlers is minor. The findings as such provide no justification for a reduction in the stake net effort.

Changing the Trammel Net Effort (Scenario 2)

The results suggest that the catch from trammel nets could be increased, for example, from 1 050 to 1 448 t in the extreme case of doubling the trammel net effort. The associated decline in the estimated CPUEs is substantial, however, from the already low value of 4.6 kg/landing to 3.2 kg/landing. The estimated decrease in the catches for the other gears are from 294 to 288 t for stake nets, from 89 to 61 t from cast nets, and almost no change in the catches from trawl nets. The lack of 'spatial separation' has a serious biasing affect on the estimated outcomes from reduced trammel net effort. The increase in the catches from stake net effort would be more than projected, although probably not to the extent of compensating for the lower trammel net catches. Overall, the findings provide no compelling evidence to support a deliberate change in the trammel net effort.

Changing the Trawl Effort (Scenario 3)

In this scenario both the non-mechanised and mechanised trawler efforts were changed simultaneously (ie. the 'effort multiplier' was applied to both). This was necessary to minimise the biasing from not including 'spatial separation'. The results indicate that the potential to increase the catches from the mechanised trawl fishery is negligible. In the extreme case of doubling the contemporary effort (in both fisheries), for example, the estimated increase in catch is from 194 to 204 t. The associated decline in CPUEs is from

26.0 to 13.7 kg/landing. The scope to increase the catch from the non-mechanised trawl fishery appears greater. In this case the estimated increase in catch from doubling the contemporary effort is from 305 to 400 t. The associated decline in the CPUEs, however, is from 17.7 to 11.6 kg/landing. As the CPUEs being experienced are already quite low, any deliberate move to increase the effort in either the non-mechanised or mechanised trawl fisheries would lack justification.

Discussion

The implication from these findings is that the fisheries (collectively) are performing satisfactorily at present. This is in the sense that there appears to be very little opportunity to increase either catches or employment. The opportunities that do exist would be associated with reduced CPUEs, and hence remuneration levels (unless compensated by increased product prices). The reductions in CPUEs may in reality be greater than estimated. The model does not include a stock-recruitment relationship, and hence makes no allowance for the possibility of reduced annual recruitments of shrimp when parent stocks are depleted (as from very high fishing efforts). While reduced numbers of fishing units would result in improved CPUEs for those remaining in the fishery, there would be a serious negative impact, both from lowered catches and the loss of employment for those displaced. The latter would be particularly serious, with the present severe shortage of alternative employment opportunities.

Figure 26: Model outputs from change in stake net effort (scenario1).

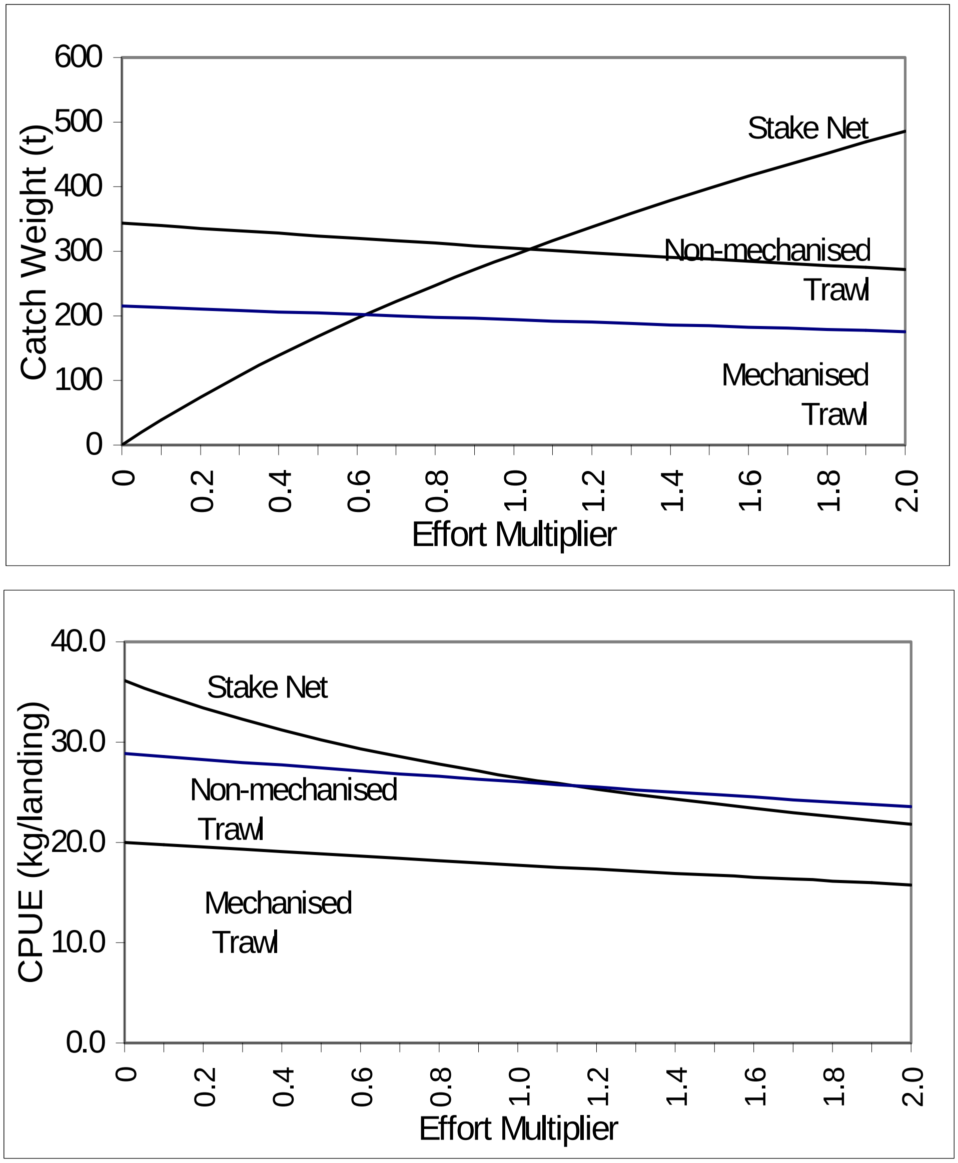
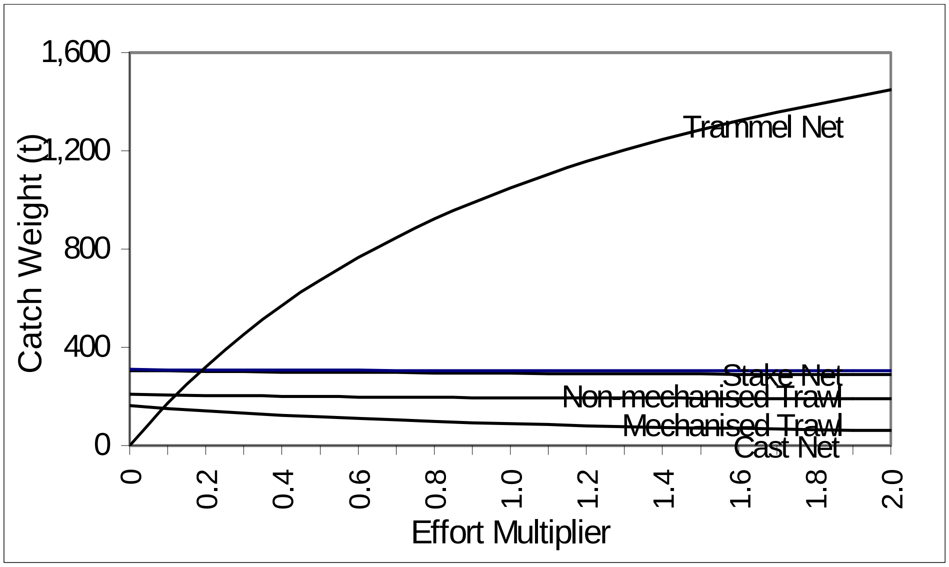


Figure 27: Model outputs from change in trammel net effort (scenario2).



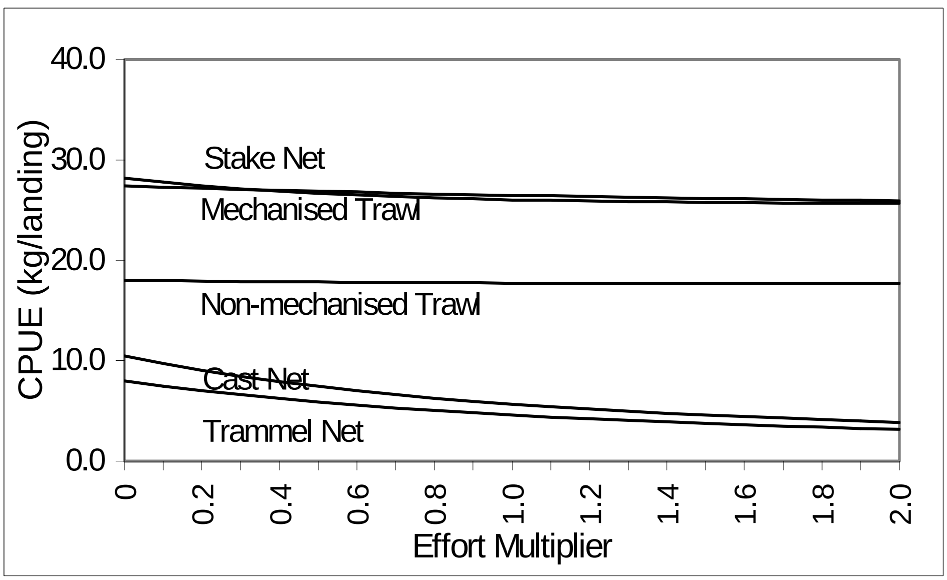
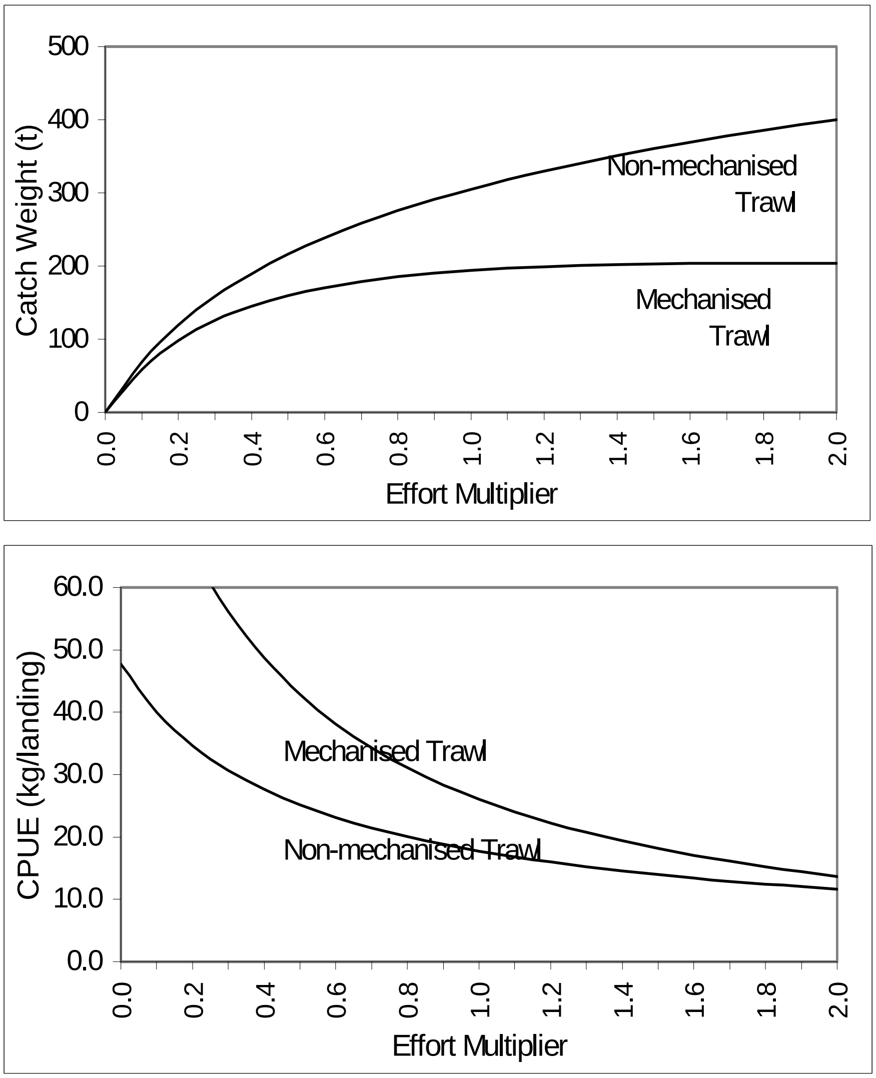


Figure 28: Model outputs from change in trawl effort (scenario3).



CONCLUDING COMMENTS

The study has clarified many important features of the lagoon fisheries. They are characterised, for example, by low costs of fishing. This is highly important in preserving acceptable remuneration levels. Attempts to introduce new technologies that might ultimately lead to increased costs and hence reduced remunerations must be avoided. Another feature is the remarkable integration of the fisheries. This is in the sense of there being a multitude of gears targeted at different species and sizes of shrimp. It seems that all the available niches for exploiting shrimp stocks have been identified, and are being successfully utilised. A further feature is the ability of fishermen to shift operations, from one fishery to another (other than the stake net fishery). This is reflected by remuneration levels being generally the same across fisheries, and confers additional stability to the performance of the fisheries (collectively).

The estimated remuneration levels are generally low to modest. They would be reduced in the event of an increase in the number of fishing units. The latter could occur, for example, from a downturn in the non-fisheries component of the local economy, with displaced persons then seeking to engage in fishing. While such an influx is not believed to be imminent, there is nevertheless good justification for establishing a management regime that allows for the number of fishing units to be controlled. A useful initial step would be to confine participation in the fisheries to the number of units presently engaged. Whether this number were reduced or increased in the future, could then be judged on prevailing circumstances. This is in large part the view adopted by the Committee established in early 1996 by the Director of Fisheries to advise on management of the lagoon fisheries.

In its draft management plan (which is now in the early stages of implementation) the Committee proposed that the fishing units able to be operated within the lagoon should initially be restricted to the number presently engaged. It also proposed that the fishing communities establish a network of management committees, as provided for under the Fisheries and Aquatic Resources Act No. 2 of 1996. The purpose of these management committees includes providing advice to the Minister, formulating management plans, and directly assisting with management measures. The latter are expected to include the monitoring of fishing activity, the resolution of disputes, the administration of loans, and social welfare activities. The highly successful 'community-based management' applying to the stake net fishery has been cited as an example upon which the management of the other lagoon fisheries could be based.

There are about 500 fishermen belonging to the five stake net societies. The number is strictly controlled, with the allocation of fishing sites amongst member fishermen involving both an annual ballot and auction procedure (WCP, 1994). As there are more fishermen than sites, three fishermen are given entitlement to each site. These fishermen utilise the sites on alternative days, and hence exercise their entitlement during 10 days per month. The societies also control the size and design of the stake nets used, settle disputes between and on behalf of members, and administer loans and scholarships. They are closely linked to the local community structures (particularly the Catholic Church), and engage in a range of welfare functions on behalf of members and their families. The entitlement to become a member of a society is hereditary. It may only be passed on to a male member of the immediate family. No more than one member of a family may have the entitlement. New entitlements are sometimes issued, although only to married male descendants of stake net fishermen, who can demonstrate they have the necessary equipment and knowledge in fishing.

Although not investigated during this study, the future performance of the fisheries is highly vulnerable to changes in the environment within the lagoon. The lagoon is a shallow, largely enclosed water body, surrounded by urban development, and industrial encroachment. There are already many instances of degradation, including siltation, loss of sea grass beds, removal of mangroves, water pollution, and land reclamation. In 1991 the Cabinet of Ministers approved implementation of the Master Plan for Muthurajawela Marsh and Negombo Lagoon, based on the findings of an ecological survey. Subsequently, a Conservation Management Plan was prepared (WCP, 1994). The implementation of both plans is continuing. Notwithstanding, the future health of the lagoon remains under substantial threat, and must continue to be safeguarded.

Concerning future research, there is a need for additional studies both to confirm and improve on the present findings. A further sampling of catches and examination of the reproductive stages, for the main shrimp species, would be useful in confirming the seasonality of spawning. More importantly, there needs to be better understanding of the migration patterns. Future studies should seek to determine, for example, the extent of migration between the two trawling grounds, the proportions of the shrimp leaving the lagoon which migrate to each ground, and the proportions which delay leaving the lagoon (eg. until the next rainy season). The most direct way to achieve this knowledge is to undertake a substantial shrimp tagging (marking) exercise. Large numbers of small shrimp would need to be tagged and released inside the lagoon, and also on the trawl grounds. This in turn would need to be associated with substantial publicity and rewards, to encourage the return of information (from the fishermen) in the event of recapturing tagged shrimp.

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