Shrimp fishery in the Negombo lagoon on the west coast of Sri Lanka

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ABSTRACT
The results of the study of traditional shrimp fishery in the Negombo lagoon are presented. Fishing was mainly conducted by traditional dug out canoes and log rafts. Trammel nets, brush piles, cast nets, drag nets and stake-seine nets were the major fishing gears employed. The estimated mean catch rates for trammel nets, brush piles, cast nets, drag nets and stake-seine nets were 4.15, 5.92, 0.65, 13.33 and 23.21 kg/operation respectively in 1998 and 5.18, 7.09, 0.7, 15.68 and 26.19 kg/operation respectively in 1999. The annual total catch was estimated at 827 MT in 1998 and 1024 MT in 1999. Stake nets, drag nets, trammel nets and cast nets caught more shrimps and brush piles favoured fish catches. The highest income/fishing operation was estimated for stake-seine nets (Rs. 2 050.00), while the lowest was for cast nets with Rs. 115.00/operation. In the stake-seine net fishery, the fishing community itself has formulated a mechanism for equity sharing.

Introduction
Sri Lanka has 120,000 ha of brackish water bodies consisting of extensive lagoons, tidal flats, estuaries, swamps etc. (Anon, 1985). The relatively deep lagoons and estuaries cover 80,000 ha and are the sites of important fisheries, while the shallow lagoons, mangrove swamps and salt marshes represent potential area for aquaculture.

The Negombo lagoon is (Fig. 1), 3,164 ha in extent, situated north of Colombo and is a part of the Muthurajawela Marsh-Negombo lagoon coastal wetland (6,232 ha). The lagoon is connected to the north by a single narrow opening with the open sea at Negombo. Except at the entrance, water within the lagoon is less than 2 m in depth (Sanders et al. 2000). The Dandugam Oya drains a catchment of 727 km² and discharges fresh water at the south junction of the lagoon and into the marsh (Anon, 1994), particularly during the rainy seasons of April/May and October/November.

There is an expanding year-round fishery for shrimps in the lagoon and the associated coastal eco-system. There are
four major fishing gears, trammel net, drag net, brush piles, cast nets used within the lagoon and one gear at the mouth (stake-seine net) targeting shrimps. Adults are exploited in the offshore areas by trawling.

During the present investigation total production of the shrimp fishery, fishing effort and its variation, variation in the catch rates, species composition of the catches and the economy of fishing activities in the Negombo lagoon were studied. Also included is a description of the types of fishing craft and gear deployed and the operation of a community-based management system of the stake-seine net fishery.

**Material and methods**

A pilot survey was first conducted to gather basic information on the fishing activities in the study area using the methodology of Bazigos (1974) and Caddy and Bazigos (1985) from which the following rigorous sampling scheme was formulated. Catch and effort data were collected from 8 sampling sites selected from 17 fish landing sites scattered around the Negombo lagoon (Fig. 1) during January 1998 to December 1999. Catch and effort data of different fishing methods employed to exploit shrimps in the lagoon (mainly trammel nets, drag nets and brush piles) were collected separately from haphazardly selected crafts and that of cast nets at 3 shrimp collection centres situated around the lagoon. In addition catch and effort data from the stake-seine nets operating at the sea mouth of the lagoon were collected at the auction site in Negombo where the stake net catch were sold. On each sampling day more than 30% of the total number of fishing gear operated at each fish landing site was sampled randomly.

![Fig. 1 Map of the study area](image)

The monthly total production (MTP) with respect to each fishing method was estimated as the product of mean catch in kg per operation (CPUE), mean number of fishing crafts operated per day (NFC) and mean number of fishing days for that particular month (MFD)

\[
MTP = CPUE \times NFC \times MFD
\]

A forward stepping linear regression technique (SPSS, 1999) was employed to evaluate the relative efficiencies of different fishing methods practised in the system. The multiple regression equation was forced to go through origin (Zar, 1984) and it was in the following form.

\[
Y = \sum a_i f_i + \sum b_j f_j^2 + \sum \sum c_{ij} f_i f_j
\]

Where \( Y \) = yield per ha per month, \( f_i \) =fishing effort per ha (fishing intensity) per month for gear i and \( f_j \) =fishing effort per ha (fishing intensity) per month for gear j.
TABLE 1. Specifications of the crafts and gear used and the information of the fishing activities in the Negombo lagoon

<table>
<thead>
<tr>
<th>Craft type</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Length of the outrigger (m)</th>
<th>Type of the gear used</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log raft</td>
<td>4.2</td>
<td>0.9</td>
<td>3.65</td>
<td>TN</td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td>3.65</td>
<td>0.84</td>
<td></td>
<td>TN</td>
<td>Wooden</td>
</tr>
<tr>
<td>Dug out canoe</td>
<td>8.05-8.4</td>
<td>0.21-0.23</td>
<td>3.5-5.1</td>
<td>TN</td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DN</td>
<td>Wooden</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ECGN-BP</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CN</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SN</td>
<td></td>
</tr>
<tr>
<td>FRP boats</td>
<td>5.5-8.9</td>
<td>0.21-0.27</td>
<td>3.5-3.63</td>
<td>TN</td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td>5.6</td>
<td>1.95</td>
<td></td>
<td>TN</td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td>4.1</td>
<td>1.65</td>
<td></td>
<td>TN</td>
<td>Fiber</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Craft/gear combination</th>
<th>No. of net pieces used</th>
<th>Mesh size (mm)</th>
<th>Mean true fishing time (hours)</th>
<th>No. of fishermen involved in a single operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR/TN</td>
<td>25</td>
<td>4.02</td>
<td>28-56</td>
<td>4.73</td>
</tr>
<tr>
<td>DC/TN</td>
<td>23</td>
<td>3.07</td>
<td>28-56</td>
<td>4.96</td>
</tr>
<tr>
<td>FRP/TN</td>
<td>27</td>
<td>3.45</td>
<td>28-56</td>
<td>4.12</td>
</tr>
<tr>
<td>DC/DN</td>
<td>1-2</td>
<td>10-14</td>
<td>8.76</td>
<td>2-4</td>
</tr>
<tr>
<td>DC/ECGN-BP</td>
<td>1</td>
<td>6</td>
<td>4.66</td>
<td>2</td>
</tr>
<tr>
<td>DC/CN</td>
<td>1</td>
<td>11</td>
<td>4.62</td>
<td>1</td>
</tr>
<tr>
<td>DC/SN</td>
<td>1</td>
<td>10</td>
<td>5.35</td>
<td>2</td>
</tr>
</tbody>
</table>

TN - Trammel net
DN - Drag net
ECGN-BP - Encircling gillnet for brush piles
CN - Cast net
SN - Stake-seine net
LR/TN - Log raft / Trammel net
DC/TN - Dug out canoe / Trammel net
FRP/TN - Fibre reinforced on plastic / Trammel net
DC/DN - Dug out canoe / Drag net
DC/ECGN-BP - Dug out canoe / ECGN-BP - Encircling gillnet for brush piles
DC/CN - Dug out canoe / Cast net
DC/SN - Dug out canoe / Stake-seine net

Results

Fishing crafts and gear used in the estuarine system

In the Negombo lagoon fishing is mainly conducted by log rafts and dug out canoes. There were around 1160 dug out canoes and 317 log rafts. In addition to the above there were around 85 FRP (fiberglass reinforced plastic) boats. The information of the fishing crafts and gear used in the shrimp fishery in the estuarine system is given in the Table 1. Trammel nets, brush piles (surrounding net used in association with the brush pile is a form of Fish Aggregating Device - FAD), cast nets and drag nets were the major fishing gears. In the Negombo lagoon, several islands are present close to the sea mouth so that the northern part of the lagoon is segmented into number of channels. In this channel


Table 2: Catch and effort statistics of different fishing methods

<table>
<thead>
<tr>
<th>Fishing gear</th>
<th>Fishing effort (total number of operations)</th>
<th>CPUE in kg/operation</th>
<th>Total</th>
<th>Total production (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag net</td>
<td>6,367</td>
<td>7,803</td>
<td>3.57</td>
<td>4.11</td>
</tr>
<tr>
<td>Brush pile</td>
<td>25,128</td>
<td>29,407</td>
<td>0.11</td>
<td>0.39</td>
</tr>
<tr>
<td>Cast net</td>
<td>7,493</td>
<td>18,107</td>
<td>0.65</td>
<td>0.7</td>
</tr>
<tr>
<td>Trammel net</td>
<td>80,205</td>
<td>89,934</td>
<td>0.29</td>
<td>1.25</td>
</tr>
<tr>
<td>Total</td>
<td>119,193</td>
<td>145,251</td>
<td>53.89</td>
<td>188.38</td>
</tr>
<tr>
<td>Stake net</td>
<td>8,857</td>
<td>7,559</td>
<td>19.1</td>
<td>21.36</td>
</tr>
<tr>
<td>Total</td>
<td>128,050</td>
<td>152,810</td>
<td>252.37</td>
<td>362.33</td>
</tr>
</tbody>
</table>

With the exception of stake-seine nets, the total fishing effort of all the other gears showed an increase (Table 2). The proportional distribution of the annual fishing effort in the Negombo lagoon does not show any substantial change during the two years studied (Table 2). However, the estimated total annual fishing effort for stake-seine net fishery decreased from 8,857 to 7,559 fishing operations which is around 15%. No clear seasonal pattern was observed in terms of utilization of different gear types in the Negombo lagoon. In general, April, August and November in 1998 and January to July and September of the year 1999, could be considered as the peak periods in terms of the total effort of the fishing activities. On the other hand for stake-seine nets, the fishing effort was comparatively high in April, June and July of 1998 and during the period January to May of 1999.

**Catch rates**

The total catch rate of almost all the gear types is mostly dependent upon the catch rate of fish. On the other hand the stake-seine nets operated at the sea mouth of the lagoon catch more shrimps than fish. The highest mean catch rates of 23.21 and 26.19 kg/operation and shrimp catches of 19.1 and 21.36 kg/operation for the years 1998 and 1999 respectively were in the stake-seine nets, while the lowest for the cast nets operated were in the central region of the lagoon (Table 2). On the other hand highest mean fish catches were recorded for the drag nets (9.76 and 11.57 kg/operation for 1998 and 1999 respectively) (Table 2). The catch per unit effort increased for all the fishing methods between the two years studied. No clear seasonal pattern was observed in the mean catch rates of different fishing methods operating in this estuarine system with substantial fluctuations throughout the period of investigation.
The annual total catch was estimated at 827 MT in 1998 and 1024 MT in 1999 (Table 2), which was a 24% increase. For shrimps, the single most productive gear was stake-seine nets, which caught 198 and 174 MT (79 and 48% respectively) of shrimps in 1998 and 1999 respectively. The trammel nets were the most productive in the overall scenario, catching around 41% of the catch in 1998 and 46% in 1999. The increase in the total catch from the fishing methods between the two years studied can be explained by the increase in the mean CPUE and the fishing effort between the two years.

The monthly variation pattern of the total catch is greatly influenced by the variation of the trammel net catch (Fig. 2). The peak values for total production occurred in April-1998 and during the period January to June and in September-1999. The total catch from May to December of 1998 was low during May to December of 1998.

For stake-seine nets the periods from February to April/May and August to September/October were peak in terms of total catch. Generally November to January-February was the lean period.

Negombo lagoon is a highly productive tropical ecosystem with a high species diversity. Seventy species of finfish and crustaceans belonging to 32 different families of commercial value have been identified. Almost all the fish and crustacean species caught are of marine origin. Although a large number of species are caught only a few dominated. The important finfish groups, which dominate catches, include the catfishes, carangids, milkfishes, cichlids, mullets, spinefoots, silverbiddies, halfbeaks, sea pearchs, perchlets, snappers, anchovies and leiognathids. Of the crustacean species Penaeus indicus, P. semisulcatus, P. monodon, Metapenaeus dobsoni, M. moyebi, M. elegans, Portunus pelagicus, P. sanguinolentus and Scylla serrata are the commercially important species.

The catch compositions of different fishing gears were different with drag nets, trammel nets and cast nets catching more shrimps and brush piles favouring fish catches. The contribution of shrimps to the total catch of brush piles, trammel nets and drag nets were around 5, 15 and 33% respectively. Of the fourteen shrimp species identified, P. indicus was the main. In addition to P. indicus, M. dobsoni and M. moyebi also made substantial contributions to the total catch of drag nets. P. semisulcatus was also an important component of the trammel and cast net catch. Of the different finfish species caught, mullets, cichlids and sea pearchs made significant contributions to the total catch of brush piles, while in drag nets apart from shrimps, sea pearchs and halfbeaks were the major contributors. In addition to shrimps, crabs, catfishes, cichlids and mullets were the major contributors to the trammel net catches. The primary...
target of the stake-seine net fishery is shrimp making a contribution of around 82% to the stake net catch. *P. indicus* and *M. dobsoni* were the major contributors to the above making 14 and 22% of the stake net catch respectively. The other shrimps comprising *P. semisulcatus* and *M. moyabi* were a substantial component since they form almost 46% of the catch. Of the vital finfish species caught anchovies and ponyfishes were the most important.

**Size composition of shrimps**

Drag nets, which are used in the shallow near-shore waters catch juvenile shrimps. The size frequency distribution for *P. indicus* (Fig. 3) was from 3.4 to 12.6 cm with a modal size of 7 cm. Comparatively larger individuals of *P. indicus* were found in the catches from gear operating in the deeper central region: trammel nets (range 6.2 to 13.4 cm, modal value 10.6 cm) and cast nets (range 4.6 to 13.4 cm, modal value 9.4 cm). Trammel nets were more selective, exploiting a narrower length range, catching fewer small shrimps. Stake-seine nets operating at the sea mouth caught both smaller and larger individuals of *P. indicus*, exploiting the widest range (3.8 to 13.4 cm). The length distribution in stake-seine nets was bimodal (modal values were 8.2 and 10.2 cm respectively).

For *M. dobsoni* (Fig. 4), smaller sizes were found in the catches from drag nets (1.7 to 5.9 cm, modal value 4.5 cm). The largest sizes in the lagoon catches were from stake-seine nets (range 2.9 to 7.9 cm, modal value 4.3 cm). However, *M. dobsoni* did not make substantial contribution to the shrimp catches from trammel nets, cast nets and brush piles operated in the central region. It was also noted that the females present in the catches were generally larger than males.

**Economics**

Drag nets seem to be the most profitable gear with an average daily income varying from Rs. 300 to 1,688 (Mean = 1,076). There are around 24 fishing days per month and four fishermen are involved in fishing hence one-fifth of the income is paid to the crew member with the owner receiving two fifths. Therefore, average net monthly income per drag net owner and crew member are estimated to be about Rs. 10,326 (range Rs. 2,880 to 16,205) and 5,165 (range Rs. 1,440 to 8,102) respectively. Based on the assumption that the fishing operations with trammel nets, brush piles and cast nets involved single fisherman, average monthly incomes per fisher were estimated at Rs. 8,784 (range Rs. 4,440 to 17,520), 3,888 (range Rs. 1,504 to 6,256) and 2,760 (range Rs. 1,344 to 6,216) respectively.

The mean monthly income per stake net operation varied from Rs. 750 to 4980, with an annual mean of Rs. 2,050. There were around 10 fishing days per month for each fisherman and one-third of the income was paid to the helper. Therefore, average net monthly income per fisher is estimated to be about Rs. 13,667 (range Rs. 5,000 to 33,200).

**Community based fisheries management mechanism**

The rights for resource use in the stake-seine net fishery are vested only to members of the four Kattudel Fisheries Societies (KFS). Only descendants of the stake-seine fishing families have the right to become KFS members. Since there were disputes among resource users in 1940s the Roman Catholic Church worked as a mediator to settle the disputes (Atapattu, 1987).
Fig. 3 The length frequency distributions of P. indicus in the total annual catch of different types of gear.
Subsequently the four KFS have been given legal status by the "Negombo (Kattudel) fishing regulations" which were gazetted in 1958.

At the 22 stake-seine sites, which produce different shrimp yields, 57-63 stake-seine nets can be fixed. Therefore, fishermen in the four KFS have formulated a procedure for sharing these stake-seine sites. The members of these Kattudel Fisheries Societies meet on three consecutive days in March every year. At these meetings they are assigned numbers using a lottery system.

In accordance with the number assigned, priority will be given to the fishermen to select suitable site to fix their net on a particular fishing day. Different days are allocated to the members of different KFS on rotational basis so that the members of particular KFS receive the bidding rights once in four days.

**Relative efficiencies of the different fishing methods**

The results of the simple linear regression analysis performed between the relative yield and fishing effort of
The results of the stepwise linear regression technique using forward stepping employed to evaluate the relative efficiencies of the different methods practised in the Negombo lagoon are given in the Table 4. The following is the most significant model estimated between the relative yield and the relative effort of different gears:

\[ \text{Yield} = 3.47 \times 10^{-2} \text{BP} + 2.56 \times 10^{-2} \text{DN} \times \text{TN} + 1.34 \times 10^{-2} \text{CN} \times \text{BP} + 1.79 \times 10^{-3} \text{TN}^2 \quad (r^2 = 0.99, P < 0.05) \]

Where: DN = Drag net; CN = Cast net; TN = Trammel net; BP = Brush pile

The computed model reflects the
relative efficiencies of the different fishing methods. There were no linear terms for drag nets, cast nets, trammel nets and stake-seine nets, as the coefficients of these terms were not significantly different from zero. This would indicate that either these fishing methods do not make substantial contributions to the total yield from the system or they would deplete the shrimp/fish resources in the system. The latter would probably be the reason as the present study indicated that the contribution of these fishing methods to the total yield from the system was substantial. It was noted that the contribution of brush piles to the total yield from the lagoon was also significant. The positive coefficients of the cross product terms (drag net/trammel net and cast net/brush pile combinations) indicated that these combinations of fishing methods could successfully coexist at optimal level.

**Discussion**

The present study shows that the five different fishing methods of trammel drag, cast nets, brush piles and stake nets catch an average rate of 4.66, 14.5, 0.68, 6.5 and 24.7 kg/operation respectively. For the trammel net operations by canoes in the Puttalam lagoon and the Mundel Lake on the north-west coast of Sri Lanka, Dayaratne et al. (1995) reported average catch rates of 9.6 kg/operation and 15.75 kg/operation respectively. For the trammel net by canoes in the Puttalam lagoon and the Mundel Lake on the north-west coast of Sri Lanka, Dayaratne et al. (1995) reported average catch rates of 9.6 kg/operation and 15.75 kg/operation respectively. Although there has been a little increase in the catch rates over the two years studied, moderate or considerably low catch rates observed for almost all the fishing methods in Negombo lagoon could be partially explained by the high existing fishing effort in the system.

The present study indicated that February to April/May and August to September/October could be considered as the most productive periods for stake-seine net fishery. These coincide with the south-western and the north-eastern rainy seasons of the island. Jayasinghe (1987) and Amarasinghe et al. (1997) have also made similar observations. According to Samarakoon (1983) and De Silva and De Silva (1984) salinity levels in the lagoon decline during the inter-monsoonal rainy seasons and this might be the alarming factor for emigration of shrimps to the sea. Although these factors are yet be investigated properly, measures to maintain the present patterns of the salinity changes in the lagoon are necessary, as there are proposals to develop fisheries harbours in the area (Anon, 1994) which might alter hydrological patterns in the lagoon and result in salinity changes. These developments could lead to a collapse of the stake-seine net fishery. Collapse of the organisation and operation of the stake-seine net fishery in Negombo lagoon must be avoided at any cost to prevent severe sociological problems.

The estimated fish productivity of the Negombo lagoon was 262 kg/ha in 1998 and 324 kg/ha in 1999. However, these figures appear to be much higher than the estimated average fish productivity of Sri Lankan brackish water lagoons (28 kg/ha) (Pillai, 1965). Productivity estimates made for the Malala, Rekawa and Mawella lagoons on the south coast of the island were 120, 40 and 30 kg/ha respectively (Jayakody, 1994). Even with such high productivity figures, the existing low or moderate catch rates for almost all the fishing methods in the lagoon could presumably be due to the high fishing effort. The increased effort and number of fishing craft and the continuous use of the drag nets are serious matters that need to be addressed in the management of the
fisheries in this system. Drag nets catch more undersized shrimps and fish leaving poor economic returns to the fishermen. A decline in fishery resources in other lagoons, such as Puttalam, has been reported as a result of unregulated fisheries and other human activities (Dayaratne et al., 1995).

Bio-economic assessment of the fisheries has clearly indicated that the fisheries have reached the maximum sustainable levels with respect to P. indicus and M. dobsoni and these levels have now been exceeded (Jayawardane, 2001). In order to arrive at the maximum sustainable economic yield, fishing effort should be reduced substantially. An alternative management option is to limit the number of trammel nets be used in a fishing unit and the introduction of an appropriate mesh regulation for the shrimp fishery in view of increasing mean size of shrimps exploited. In addition, in the context of minimising damage to the lagoon environment and the resource from fishing activities it will be emphasised that consideration should be given to prohibit the use of drag nets (Jayawardane, 2001).

The total yield from the fishery in an estuarine system would be the best indicator of the productivity of that system. It is not possible to derive a single optimal management strategy for a multiple gear/species fishery such as the shrimp fishery in the Negombo lagoon. The present study has mainly focused on the aspects related to shrimp fishery in the Negombo lagoon. The shrimp fishermen in the study area also catch substantial quantity of by-catch, which mainly consists of finfish. It was noted that the juveniles of finfish utilising Negombo lagoon as the nursery ground form considerable portion of the by-catch. Although finfish seemed to supplement the economy of the shrimp fishermen in the study area especially during the lean season of the fishery, so far considerable attention has not been paid in view of management of this component. The present study indicated that the destructive fishing methods used in the lagoon destroy critical habitats and result in the extensive removal of juvenile shrimps, fish etc. from this nursery environment. Therefore, it is advisable to initiate a proper investigation to evaluate the impact of different fishing methods (including destructive fishing methods such as drag nets) targeting shrimps and juvenile populations of finfish, prior to making conclusions oriented towards management of the shrimp fishery. The findings of the present investigation could be used as the background information for such a comprehensive study programme.

Acknowledgements

The authors wish to express their thanks to the Swedish Agency for Research Co-operation (SAREC) and the National Aquatic Resources Research and Development Agency (NARA) for providing financial assistance and facilities. Thanks are also due to H. A. R. E. Perera, R. A. M. Jayathilaka, M. G. K. Gunawardane, T. H. S. Shantha and K. M. Mudithasena for their assistance in the field work. We are also grateful to National Hydrographic Office (NHO) of NARA for preparing necessary maps.

References


Anon 1985. Coastal Environmental


