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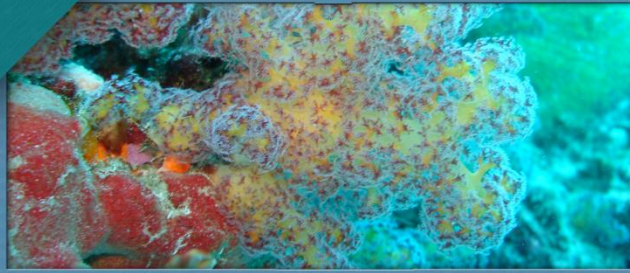
Bay of Bengal Large Marine Ecosystem Project

Fishery biology of Indian mackerel in Sri Lankan coastal waters

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# Study on some biological aspects, fishery, distribution and the abundance of Indian mackerel (*Rastrelliger kanagurta*) in the coastal waters around Sri Lanka

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# Executive summary

Indian mackerel, *Rastrelliger kanagurta,* is one of the most valuable food fish in Sri Lanka. It is the 4th dominant species in the small pelagic fishery and is mostly landed as a by-catch with other small pelagic fish. Small pelagic fish landings are monitored by the National Aquatic Resources Research and Development Agency (NARA) of Sri Lanka, but the sampling coverage under the NARA monitoring programme is inadequate. Also, since little scientific information is available on the fishery, biology and other aspects of Indian mackerel, the present study was conducted by NARA during the period January 2013-January 2014 in view of strengthening the small pelagic fishery data collection and to study Indian mackerel fisheries and biology. The small pelagic fishery sampling included collecting information on fishing operations (e.g. fishing time, fishing depth, gear used), recording the quantity of the landings by species and by different fishing vessel-gear combinations, measuring the lengths of key species including Indian mackerel. A total of 388 individuals of *Rastrelliger kanagurta* obtained from western and southern waters of Sri Lanka were also analysed for their reproductive biology. Gonado-Somatic Index (GSI), Length at first maturity ($L_m$), spawning season with respect to GSI and fecundity, morphological characteristics such as length-length and length-weight relationships were obtained. Stomach contents of the mackerel samples were also analysed to study the variations in food intake. The fishing season of Indian mackerel varies from area to area and is mostly confined to a few months. No significant difference was observed in the average true fishing time of the boats targeting Indian mackerel. The estimated length-weight relationship of *Rastrelliger kanagurta;* $W=0.006L^{3.2}$ for male and $W=0.007L^{3.2}$ for female shows the positive allometric growth of the two sexes of species. All the relationships between length-length parameters were significant. The estimated male to female sex ratio of Indian mackerel was significantly different from 1:1 at 0.01 level of significance. The spawning season of Indian mackerel in the western and southern waters of Sri Lanka was found to be in the months of May and June. Size at first maturity ($L_{50}$) ranged between 255 mm and 265 mm (TL) for females whereas the respective value for males was in the range of 245 mm and 255 mm. Total fecundity estimated in the study varied from 75420 to 101609 eggs and the relative fecundity was at 323±93 eggs per gram body weight of a female mackerel. Studies on food and feeding of mackerel concluded the planktonic diet dominated by zooplankton varieties with higher abundance of copepods and their nauplii stages.

## Acknowledgement

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## Acronyms used

| | |
|---|---|
| BOBLME | Bay of Bengal Large Marine Ecosystem |
| CPUE | Catch per Unit Effort |
| DFAR | Department of Fisheries and Aquatic Resources |
| FAO | Food and Agriculture Organization |
| FL | Fork Length |
| GSI | Gonado-Somatic Index |
| $L_m$ | Length at first maturity |
| LWR | Length-Weight Relationship |
| MBRD | Marine Biological Resources Division |
| MFARD | Ministry of Fisheries and Aquatic Resources Development |
| MTRB | Out-board engine motorised traditional boats |
| NARA | National Aquatic Resources Research and Development Agency, Sri Lanka |
| NTRB | Non-motorised traditional boats |
| OFRP | Out-board engine fibre reinforced plastic boats |
| SL | Standard Length |
| TF | Total Fecundity |
| TFT | Total Fishing Time |
| TL | Total Length |

# 1. Background - Indian mackerel fisheries in Sri Lanka

Indian mackerel *Rastrelliger kanagurta* (Family: Scombridae) is a valuable food fish, making a substantial contribution to the small pelagic fishery in Sri Lanka (Fernando, 2004). Although the Indian mackerel is a popular fish in Sri Lanka, it is mostly landed as by-catch with other small pelagic species, primarily herrings (*Amblygaster sirm*). There are about 100 species of small pelagics around Sri Lanka, of which not more than 25 contribute significantly to the commercial production (Haputhantri, 2008). Among the mackerels, Indian mackerel (*Rastrelliger kanagurta*) dominates the catch (Samaranayake, 2003). Annual catches for the species in 2008 and 2009 have been estimated at 1796 Mt and 862 Mt, respectively (BOBLME, 2011).

While gillnet is the main fishing gear used for catching Indian mackerel, it is also caught as a by-catch for seasonally used beach seines. The length frequency distribution for the two gear types are similar (Fernando, 2004). Gillnet fishery is coastal in nature operating mainly over the narrower shallow continental shelf of the country, operating sometimes out to 25 km offshore in motorised boats and within about 10 km in non-motorised vessels. Different mesh sizes might be used by the same vessel, with a switch to relatively larger mesh nets for a few months of the year, when Indian mackerel is targeted. It has been shown that Indian mackerel represents only around 2-3% of the total catch made by these vessels. The main fisheries districts for small pelagics in the West, Southern and East coasts are Chilaw, Negombo, Beruwala, Galle, Matara, Tangalle, Kalmunai and Trincomalee (Figure 1). National Aquatic Resources Research and Development Agency (NARA) of Sri Lanka carries out a small pelagic fish landing monitoring programme in the above areas, but the sampling coverage under that monitoring programme is inadequate. Also, little scientific information is available in Sri Lanka on the fishery, biology and other aspects of Indian mackerel. Therefore, the present study was conducted in view of strengthening the small pelagic fishery data collection and to study Indian mackerel fisheries and biology.

**Figure 1 Marine fisheries districts in Sri Lanka**

## 2.  Objectives of the study

This study is one component of the Indian mackerel stock structure assessment programme in the Bay of Bengal Large Marine Ecosystem (BOBLME) region, and funded by the BOBLME Project of the Food and Agriculture Organization (FAO). The work was intended to strengthen the NARA data collection programme of small pelagic fish including Indian mackerel both temporally and spatially; it also included studying the reproductive biology/feeding ecology of Indian mackerel along the Sri Lankan coast. The main objectives of this work are as follows:

- Strengthening data collection for Indian mackerel and small pelagics off the coast of Sri Lanka
- Providing information on the morphological characteristics, reproductive biology and feeding ecology of Indian mackerel

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# 3. Methodology

The small pelagic fish landing monitoring programme of NARA focuses only on the day-time sampling at fish landing sites in Beruwela, Negombo and Chilaw fisheries districts on the west coast, Tricomalee and Kalmunai fisheries districts on the east coast, Galle, Matara and Tangalle fisheries districts on the south coast. In addition, sampling coverage at the above landing sites was found to be insufficient. Therefore, additional days were allocated for small pelagic fishery sampling. In addition, night-time sampling was carried out in Kandakuliya and Thalawila fish landing sites in Puttalam fisheries district and the fish landing sites around the Chilaw fish market in Chilaw fisheries district since these sites were found to be important sites for night sampling. However, night fishing activities at these sites was found to be conducted seasonally and was confined only to a few months of the year.

The NARA sampling programme was extended towards new landing sites in Puttalam, Mannar, Jaffna and Mullativu fisheries districts in the north and northwest coasts which have been identified as important districts for small pelagic fishery sampling. This was accomplished by recruiting three new samplers on contract basis for the small pelagic data collection in the districts of Jaffna, Mullativu and Mannar. However, their data collection was confined to nine months from May 2013 to January 2014 due to some delays in recruiting of new samplers by NARA. Data collection in Puttalam district was conducted by the Marine Biological Resources Division (MBRD) research staff. The overall data collection programme was carried out from January 2013-January 2014.

Prior to the beginning of data collection in Jaffna, Mullativu and Mannar, new samplers were well trained on identification of small pelagic species, sampling techniques and filling data sheets. A two day training programme was conducted for new samplers at the NARA head office where they were trained by the scientists of MBRD, NARA on filling of data sheets, sampling techniques on gathering basic fishery data and species identification. A species identification guide showing special features of small pelagic fish was also distributed among the enumerators. They were further trained at the fish landing sites in Negombo fisheries district on how to carry out small pelagic sampling and biological data collection. Training was conducted by experienced scientific staff of MBRD for five days. Guidance and supervision of the MBRD scientists were further given for the entire data collection throughout the study period. The small pelagic fishery sampling included collecting information on fishing operations (e.g. fishing time, fishing depth and gear used), recording the quantity of the landings by species and by different fishing vessel-gear combinations, measuring the lengths of key species including Indian mackerel.

A total of 388 individuals of *Rastrelliger kanagurta* obtained from western and southern waters of Sri Lanka were further analysed for their reproductive biology. Freshly caught mackerel samples were transported to the MBRD laboratory in ice and individual fish were examined for the following: total length (cm), fork length (cm), standard length (cm), total weight (g), gonad and gut weight (g), fecundity and maturity stage. Maturity stages were recorded based on the macroscopic observations of the gonads (**Appendix I**). Indeterminate stages were recorded separately. Fecundity was estimated using the gravimetric method where formalin preserved selected ripe ovaries were washed in tap water, preserved in Gilson's fluid overnight and three sub samples of approximately 0.05 g were taken from middle of the ovary lobe. All the eggs from each sub sample were teased out using fine needles, spread on a glass slide and counted. Gonado-Somatic Index (GSI), Length at first maturity ($L_m$), spawning season with respect to GSI and fecundity, morphological characteristics such as length-length and length-weight relationships were obtained. Moreover, stomach contents of the mackerel samples were analysed to study the variations in food intake. Following equations were incorporated for studying those aspects:

- **Gonado-Somatic Index (GSI)** was calculated for each maturity stage of both sexes using gonads in fresh condition, by the following equation.
  GSI=weight of gonads (g)/body weight (g)*100

- **Length at first maturity (Lₘ)** was estimated corresponding to size at which 50% of the population attains maturity.

- **Fecundity**
  The total fecundity (TF) was estimated using the following equation:
  PF=w/W* OW
  Where, w=the number of eggs in the sub sample; W=total weight of sub sample and OW=total weight of the preserved ovaries of the particular specimen. Relative fecundity was calculated as per the number of eggs per gram body weight.

- **Feeding ecology**
  A total of 58 stomachs were examined for the analysis of gut content. The frequency of occurrence of food items was calculated according to the equation of $F_i=100*N_i/N$ where $F_i$ is the frequency of occurrence of the $i^{th}$ food item in the sample; $N_i$=number of stomach in which the $i^{th}$ item was found and N=total number of stomachs with food examined.

## 4. Fishing crafts and gears, fishing operations, seasonality, target species and Catch per Unit Effort

### 4.1. Fishing crafts and gears

Three types of fishing crafts, which are operated in coastal waters, may target small pelagic fish: out-board engine fibre reinforced plastic boats (OFRP), out-board engine motorised traditional boats (MTRB) and non-motorised traditional boats (NTRB). There are few types of traditional boats: motorised/non-motorised traditional "oru", motorised/non-motorised "wallam" and non-motorised "theppam" etc. (Figure 2).



**Figure 2 Different fishing crafts operate in the small pelagic fishery (from left to right and top to bottom): OFRP, oru, wallam and theppam**

A summary of the vessel types with respective number of vessels which may catch small pelagic fish is shown in Table 1. It should be noted that all vessels described in Table 1 are not operated with the

fishing gear which target small pelagic fish. But, a high proportion of these fishing vessels mostly target small pelagics at least during the fishing season of small pelagic fish. A clear increase in the total number of vessels could be observed. The increased trend is remarkable for OFRP and MTRB boat categories. This implies that small pelagic fish are currently subjected to strongly increasing fishing pressure.

**Table 1 A summary of fishing vessels operated in the coastal fishery in Sri Lanka potentially targeting small pelagic fish: 2001-2013**

(OFRP - out-board engine fibre reinforced plastic boats, MTRB - out-board engine motorised traditional boats, NTRB - non-motorised traditional boats)

| Year | OFRP | MTRB | NTRB | Total |
|------|------|------|------|-------|
| 2001 | 8744 | 640 | 15200 | 24584 |
| 2002 | 9033 | 776 | 15600 | 25409 |
| 2003 | 11020 | 618 | 15040 | 26678 |
| 2004 | 11559 | 674 | 15260 | 27493 |
| 2005 | 11010 | 1660 | 14739 | 27409 |
| 2006 | 13860 | 1842 | 16347 | 32049 |
| 2007 | 15200 | 1680 | 16640 | 33520 |
| 2008 | 14747 | 3179 | 17042 | 34968 |
| 2009 | 17193 | 2126 | 18243 | 37562 |
| 2010 | 18770 | 2680 | 20165 | 41615 |
| 2011 | 22890 | 2960 | 22630 | 48480 |
| 2012 | 23160 | 2340 | 22800 | 48300 |
| 2013 | 23210 | 2480 | 22900 | 48590 |

**Source:** MFARD, 2014

Gillnet is the most popular and widely used fishing gear for catching small pelagic fish. The gillnet fishery has been carried out in Sri Lanka for a few decades. A supplementary fishing gear like hand line is sometimes operated with gillnets and use of such gear combinations was found to be more common on the west coast than other areas.

A wide variety of mesh sizes are used in the commercial gillnet fishery and small meshed gillnets ranging from 1" (25.4 mm) to 3" (76.2 mm) are widely operated for targeting small pelagic fish. But, less than 1" and more than 3" mesh sizes are also used. Gillnets of the mesh sizes ranging from 9/10" (22.86 mm) to 1½" (38.1 mm) are frequently used for catching of clupeids such as *Amblygaster sirm, Sardinella longiceps* and *Sardinella albella*. Mesh sizes below 9/10" (22.86 mm) are used for catching *Stolephorus spp.* and occasionally the juveniles of above mentioned clupeids. The nets with larger mesh sizes ranging from 1½" (38.1 mm) to 2" (50.8 mm) are normally used for catching relatively larger fish such as *Rastrelliger kanagurta, Decapterus spp., Scomberomorus spp.* and *Chirocentrus spp.*

## 4.2.    Fishing operations

All boats described above are engaged in one-day fishing activities. Traditional crafts are usually operated in the shallow coastal waters where the depth is ranging from 5 to 25 meters whereas OFRP boats are frequently operated within 15 to 60 meters depth range. However, operated depth range of the boats varied from 2 to 180 m. The engine sizes of OFRP boats vary between 10 and 35 hp, but the most frequently used engine size range is 15hp-25 hp.

A clear difference in the average Total Fishing Time (TFT - total time taken to the whole fishing operation) was observed among the three types of boat categories. Average TFT of a fishing operation for OFRP boats was the highest (5.84 h) whereas the average TFT for MTRB and NTRB were 4.52 h and 3.35 h, respectively. The variation among the boat categories is mostly due to the

limitations of their capacities. When Indian mackerel is the key target species, the average value of the TFT for OFRP, MTRB and NTRB boats were 5.79 h, 4.47 h and 3.47 h, respectively. A significant difference was not observed in the average TFT between the boats targeting Indian mackerel.

## 4.3. Target species and catch composition

Over 100 species were landed by the fishing vessels which were operated in the coastal fishery in Sri Lanka during the study period and potentially targeting small pelagic fish, but only about 17 species or groups of species contributed more than 1% of the total catch (Table 2). *Amblygaster sirm* is the dominant species followed by *Sardinella gibbosa* and *Sardinella albella.* The relative contributions of the above three species are 21.96%, 11.65% and 9.76%, respectively. The 4th dominant species is Indian mackerel and the contribution of this species is 7.86%. According to the small pelagic database of NARA, the percentage of *Rastrelliger kanagurta* in the small pelagic total production from 2009 to 2011 was 2.6%, 2.3% and 8.2%, respectively. Since some vessels mostly operate with a supplementary fishing gear like handline, it may result in catching of considerable amounts of non-small pelagic fish species like demersal species.

**Table 2 Species/groups of species landed by fishing vessels operated in the coastal waters of Sri Lanka during the study period potentially targeting small pelagic**

| Species/groups | % of the total landing |
|---|---|
| *Amblygaster sirm* | 21.96 |
| *Sardinella gibbosa* | 11.65 |
| *Sardinella albella* | 9.70 |
| *Rastrelliger kanagurta* | 7.86 |
| *Hilsa kelee* | 6.38 |
| Other small pelagics | 5.55 |
| Carangidae | 4.82 |
| Other rockfish | 3.90 |
| *Selar crumenophthalmus* | 3.00 |
| Ariidae | 2.59 |
| *Stolephorus heterolobus* | 1.89 |
| Cuttlefish | 1.87 |
| Other squids | 1.66 |
| *Sardinella longiceps* | 1.59 |
| *Auxis thazard* | 1.43 |
| *Euthynnus affinis* | 1.26 |
| *Coryphaena spp.* | 1.07 |
| Other species | 11.8 |

The catch composition of the vessel and gear combinations which are targeting small pelagic fish may considerably differ from the above figures. The traditional beach seines operated by OFRP boats (without engine) have mostly targeted the species group of *Sardinella spp.* This group of species mainly comprises of three *sardinella* species: *Sardinella gibbosa, Sardinella albella* and *Sardinella longiceps.* The relative contribution of *Sardinella spp.* in the total beach seine catch during the study period was about 60% (Figure 3). On the other hand, the relative contribution of *A. sirm* in the beach seine catch was 3% whereas the relative contribution of *R. kanagurta* was insignificant (less than 1%).

The OFRP vessels with gillnet as the main fishing gear and handline as the supplementary fishing gear, reported a considerably higher percentage of Indian mackerel (20%) (Figure 3). The relative percentage contribution catches of *A. sirm* and *Sardinella spp.* for this gear-vessel combination were 17% and 2%, respectively.
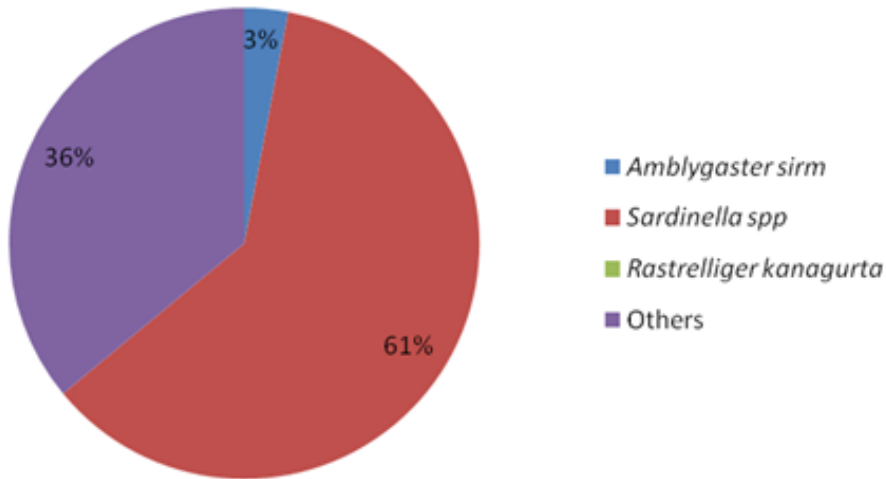
**Figure 3 Catch composition of the traditional beach seine fishery during the study period**
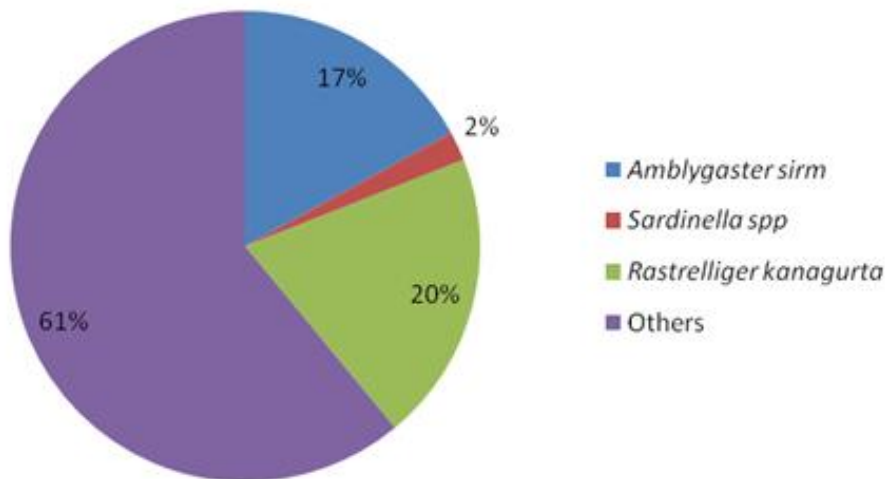


**Figure 4 Catch composition of the OFRP boats operated with gillnets as the main fishing gear and handline as the supplementary fishing gear during the study period**

The catch composition of the OFRP, MTRB and NTRB boats fishing with gillnets during the study period are shown in Figures 5-7. *Sardinella spp.* was the key target species for OFRP and NTRB boats and the relative contribution of this species in the total catch of OFRP and NTRB was 24% and 31% respectively (Figure 5 and Figure 7). *A. sirm* was the key target species for MTRB boats and the relative contribution of this species in the total catch of MTRB boats was 26% (Figure 6). The relative contribution of Indian mackerel in the total catch of OFRP, MTRB and NTRB boats were 5%, 14% and 1%, respectively. Reporting of poor catches of Indian mackerel for NTRB boats as well as for beach seines may probably be due to the factor of confining such fishing operations mostly to the shallow coastal waters where the Indian mackerel is less abundant.
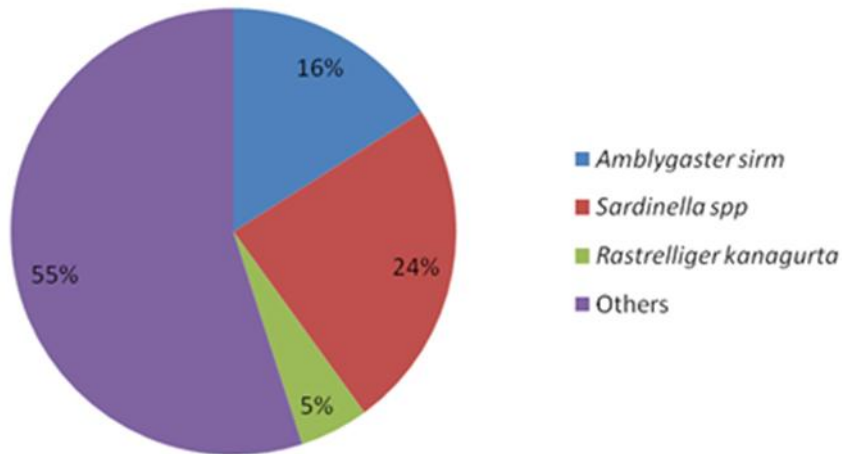
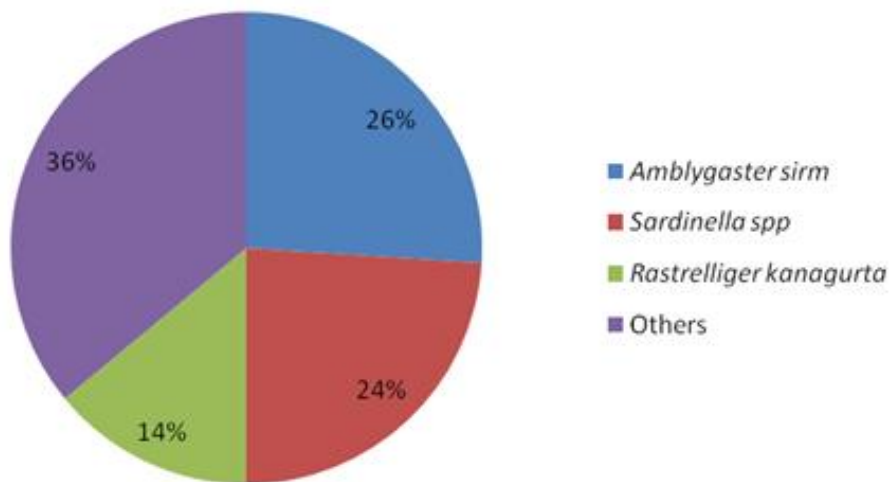**Figure 5 Catch composition of the OFRP boats operated with gillnets during the study period**



**Figure 6 Catch composition of the MTRB boats operated with gillnets during the study period**
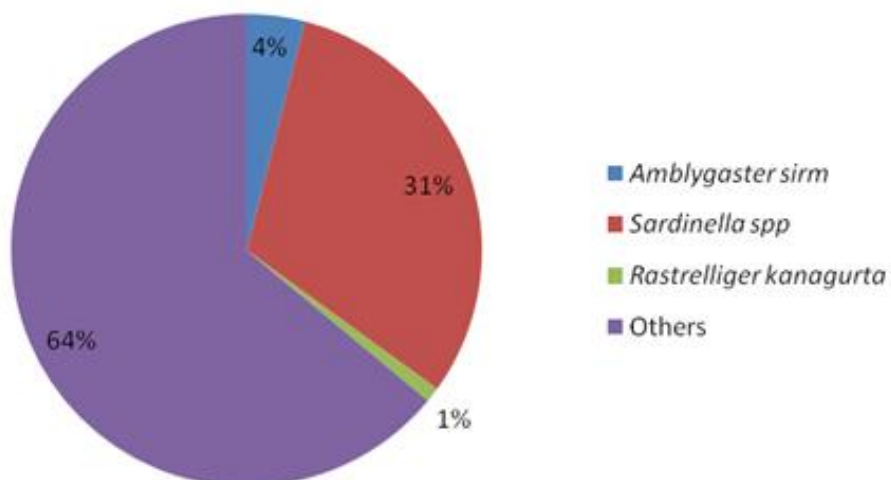


**Figure 7 Catch composition of the NTRB boats operated with gillnets during the study period**

For the purpose of analysing the catch composition of the gillnet fishery with respect to different geographical regions, the coastal belt of Sri Lanka was divided into four regions: north coast which comprises of Mannar, Killinochchi, Jaffna and Mullativu fisheries districts, east coast which comprises of Trincomalee, Batticaloa and Kalmunai fisheries districts, south coast which comprises of Galle, Matara and Tangalle and west coast which comprises of Kalutara, Colombo, Negombo, Chilaw and Puttalam (Figure 1).

*A. sirm* was the dominant species found in the gillnet fishery in the west, south and east coasts whereas the *Sardinella spp.* was the dominant group in the north coast (Figures 8-11). The relative contribution of Indian mackerel in the gillnet catch of north, east, south and west coasts were 1%, 11%, 5% and 13%, respectively.
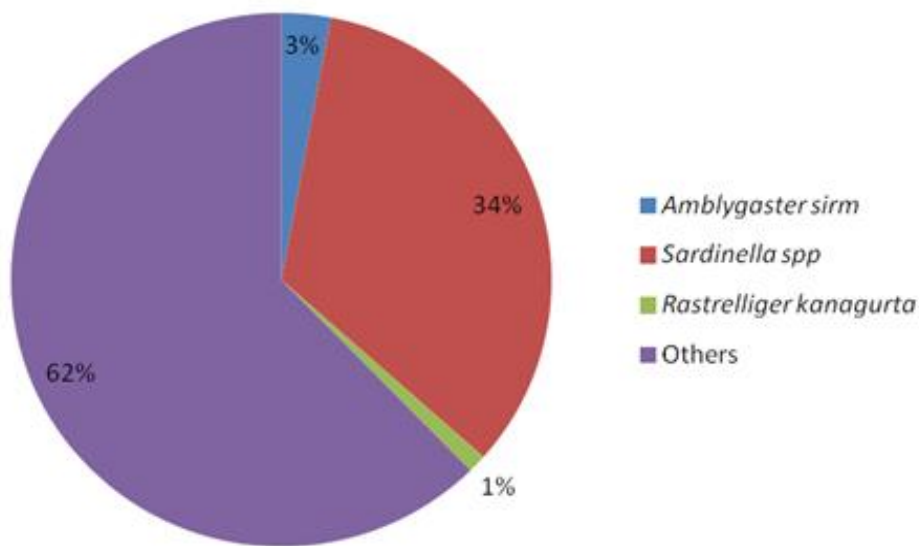


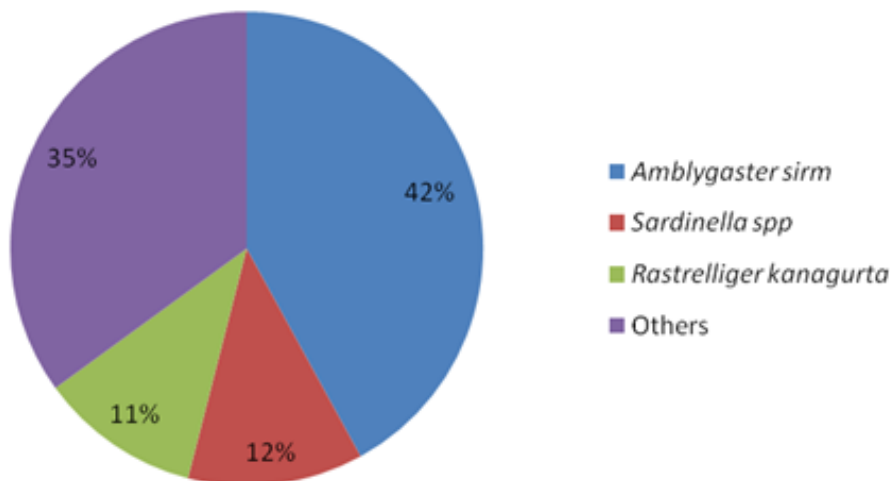**Figure 8 Catch composition of the gillnet fishery in northern coastal waters in Sri Lanka**



**Figure 9 Catch composition of the gillnet fishery in eastern coastal waters in Sri Lanka**
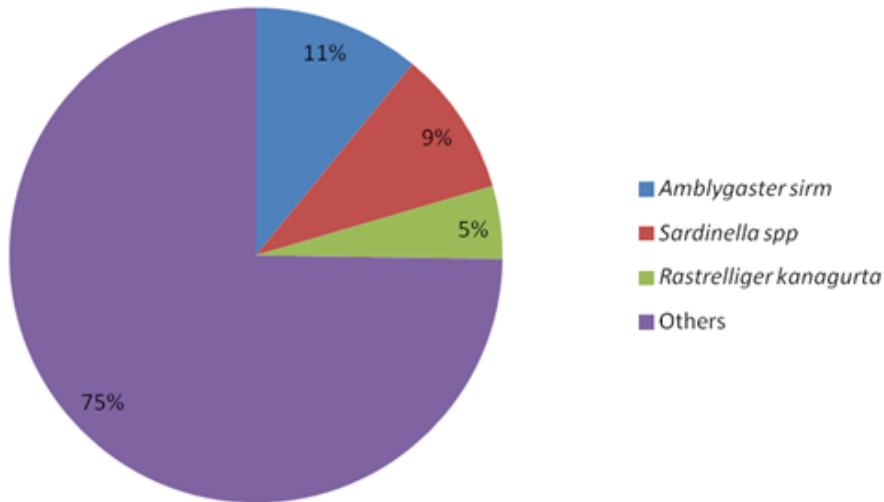
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**Figure 10 Catch composition of the gillnet fishery in southern coastal waters in Sri Lanka**
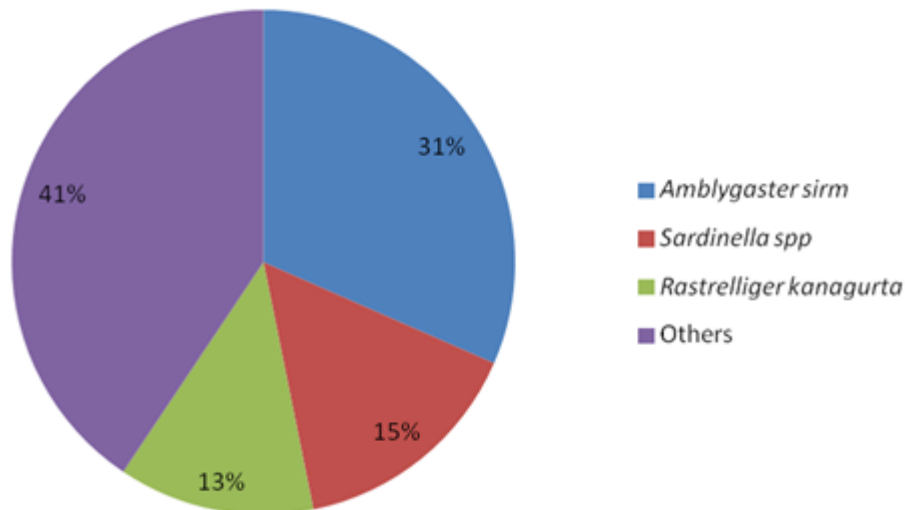


**Figure 11 Catch composition of the gillnet fishery in western coastal waters in Sri Lanka**

Only about 29% of the total boats in the study area during the study period landed Indian mackerel, out of which, about 8% of the boats landed only Indian mackerel. Moreover, 32% of the boats landing Indian mackerel caught Indian mackerel as the target species (i.e., Indian mackerel is more than 50% of the total catch). This as a percentage of the total boats is about 9%. Therefore, it can be concluded that about 9% of the total boats catch Indian mackerel as the key target species. The boats, which did not catch any fish, were excluded for this analysis since actual target species of these boats was not clear. However, the boats that reported zero catches of fish was about 3% of the total operated boats.

About 31% of the total fishing vessels, which fished with gillnet as the main fishing gear landed Indian mackerel. Of these, more than 35% targeted Indian mackerel as the key species. However, traditional beach seiners have always caught Indian mackerel as a supplementary species and the percentage of Indian mackerel being caught by a beach seiner was found to be about 30%. But none of the beach seiners have recorded Indian mackerel even at least as 5% of the total catch. Since beach seiners are operated in less than 10 m depth inshore areas, where the Indian mackerels are

less abundant, no significant catch of Indian mackerel could be expected from the beach seine fishing operations.

About 30% of the total OFRP boats landed Indian mackerel whereas the relevant percentages for MTRB and NTRB were 48% and 9%, respectively. Moreover, about 11% of the operated OFRP has caught Indian mackerel as the target species whereas the relevant percentages for MTRB and NTRB were 12% and 0.5%, respectively. Accordingly, it can be concluded that more MTRB and OFRP boats target Indian mackerel than NTRB boats. Since NTRB are always operated in shallow waters, Indian mackerel is normally a non-target species for such vessels.

### 4.4.     Fishing season of Indian mackerel and Catch per Unit Effort

Although Indian mackerel was found to be seasonal in Sri Lanka, Indian mackerels are fished in many areas in the coastal waters. In addition, the fishing season of Indian mackerel varies from area to area and is mostly confined to only a few months of the year. During the best fishing season, few coastal fishing crafts may target Indian mackerel around the coastal waters.

The monthly average Catch per Unit Effort (CPUE) estimates of Indian mackerel in terms of catch in kg per boat per trip for 2013 was obtained from the boats which reported catches of Indian mackerel. The CPUE estimates show considerable fluctuations over time for three types of boats: OFRP, MTRB and NTRB (Figure 12).
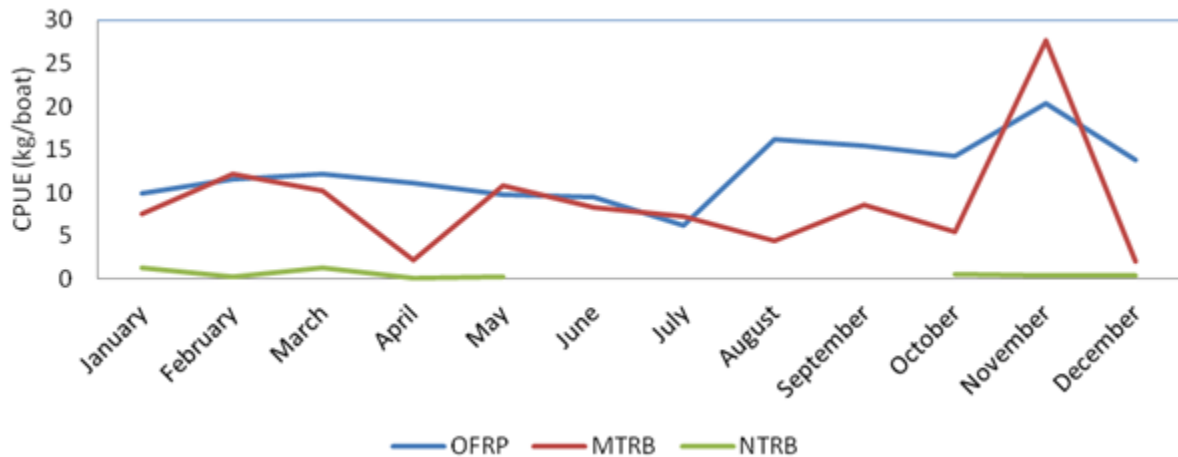


**Figure 12 Variation in the monthly estimates of non-zero CPUE of Indian mackerel for OFRP, MTRB and NTRB boats in 2013**

CPUE of NTRB was found to be low compared to other boat types and CPUE was reported by NTRB vessels only from January to May and October to December. The average monthly CPUE estimates of OFRP boats were higher than the same of MTRB but for several months only. The average monthly CPUE of Indian mackerel for OFRP varies between 6.3 kg and 20.3 kg. The lowest catch rate was reported for OFRP boats in July whereas the highest catch rate was reported in November. The average monthly CPUE of Indian mackerel for MTRB varies between 2 kg and 27.7 kg. The lowest catch rate was reported for MTRB boats in December whereas the highest catch rate was reported in November. In view of above results, it can be concluded that a year round fishery exists for Indian mackerel in Sri Lanka although there are seasonal fluctuations.

A considerable seasonal variation in the CPUE of Indian mackerel was noted as per regions (Figure 13). In general, catch rates are likely to be higher for the second half of the year than the first half of the year, but catch rates could substantially vary in different regions.
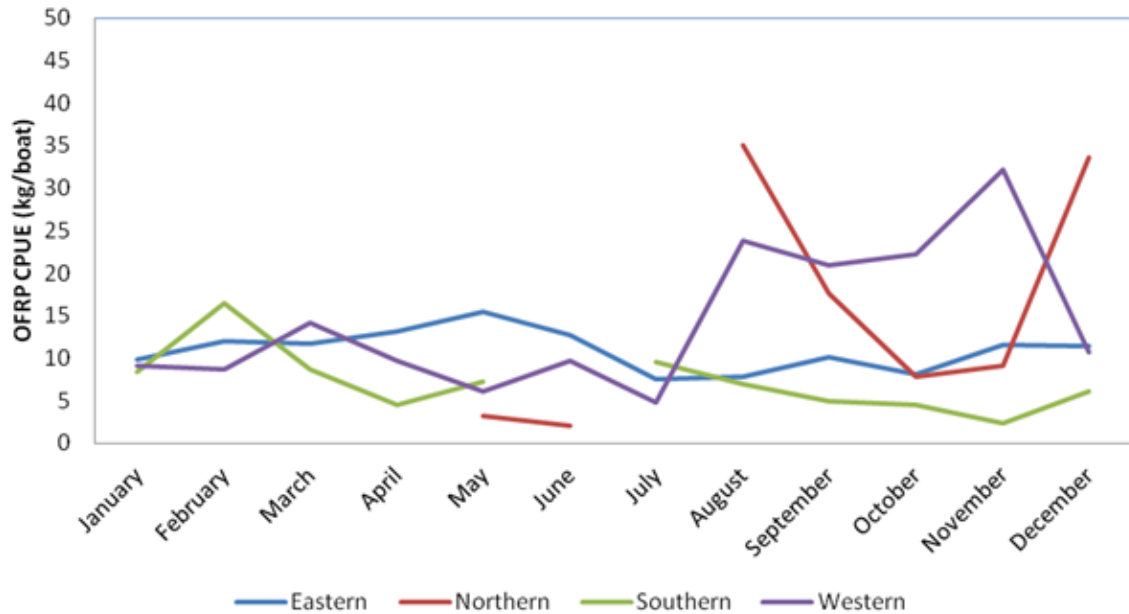
**Figure 13 Variation in the monthly estimates of non-zero CPUE of Indian mackerel for OFRP boats in 2013 for different regions: west, south, east and north**

## 5. Morphological characteristics, reproductive biology and feeding ecology of Indian mackerel

### 5.1. Length-weight relationship

Length-weight relationship (LWR) is a useful tool for evaluating the life history of fish and morphological comparisons between different fish species in different habitats, different time periods or regions. There is a growing need to develop weight-on-length (WL) predictors not only for the target fish species but also for species caught as by-catch or incidental catch.

The following relationships for log transformed total length and log transformed weight were obtained for males and females respectively (Figure 14 and Figure 15).
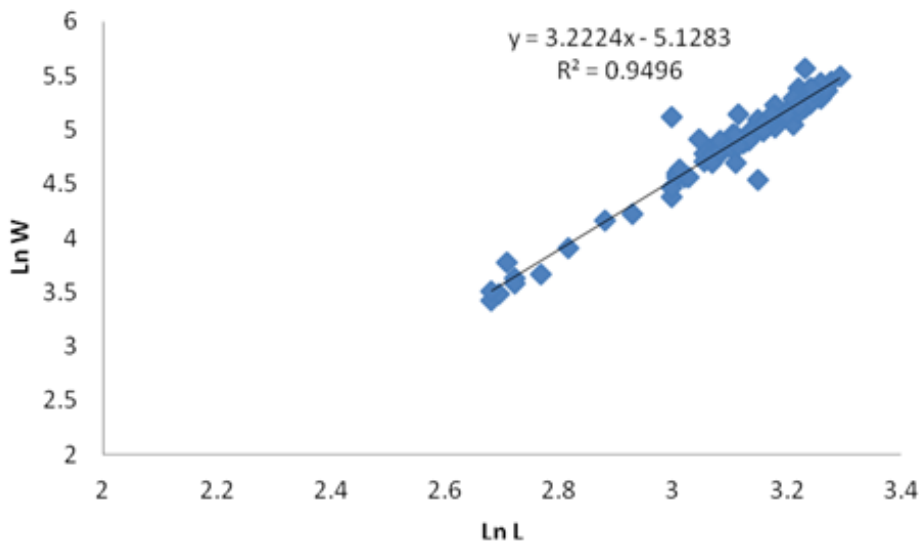


$y = 3.2224x - 5.1283$
$R^2 = 0.9496$

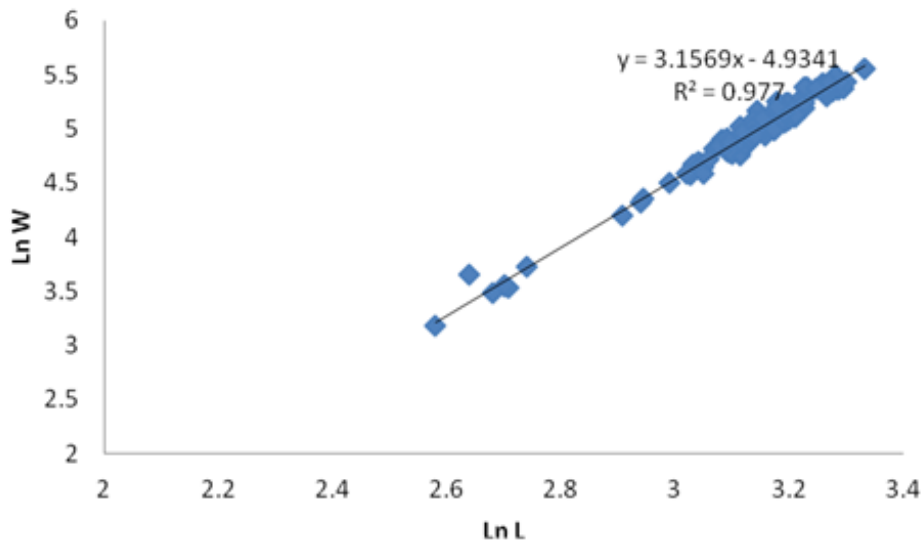**Figure 14 Length-weight relationship of male *Rastrelliger kanagurta***

**Figure 15 Length-weight relationship of female *Rastrelliger kanagurta***

The estimated length–weight relationship for male and female *Rastrelliger kanagurta* were, $W=0.006L^{3.22}$ and $W=0.007L^{3.16}$ respectively. Accordingly, a positive allometric growth of both sexes could be observed. The growth can be affected by a series of factors such as season, habitat, gonad maturity, diet, stomach fullness, health and annual differences in environmental conditions (Bagenal and Tesch, 1978; Froese, 2006).

## 5.2. Length-length relationships of *Rastrelliger kanagurta*

Length-length relationships of *Rastrelliger kanagurta* was obtained for Total Length (TL), Fork Length (FL) and Standard Length (SL) and all relationships were found to be significant at 0.001 (Figure 16). The estimated relationships between FL & TL, SL & TL and SL & FL were FL=0.89TL, SL=0.81TL and SL=0.91FL, respectively.
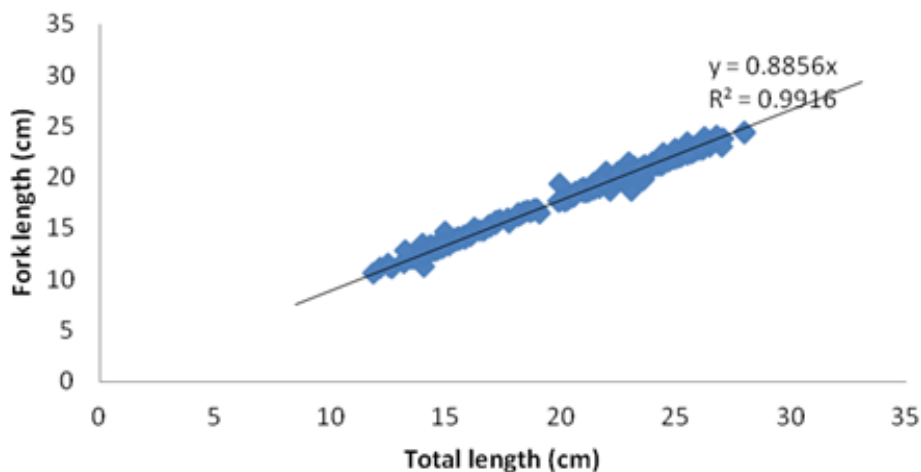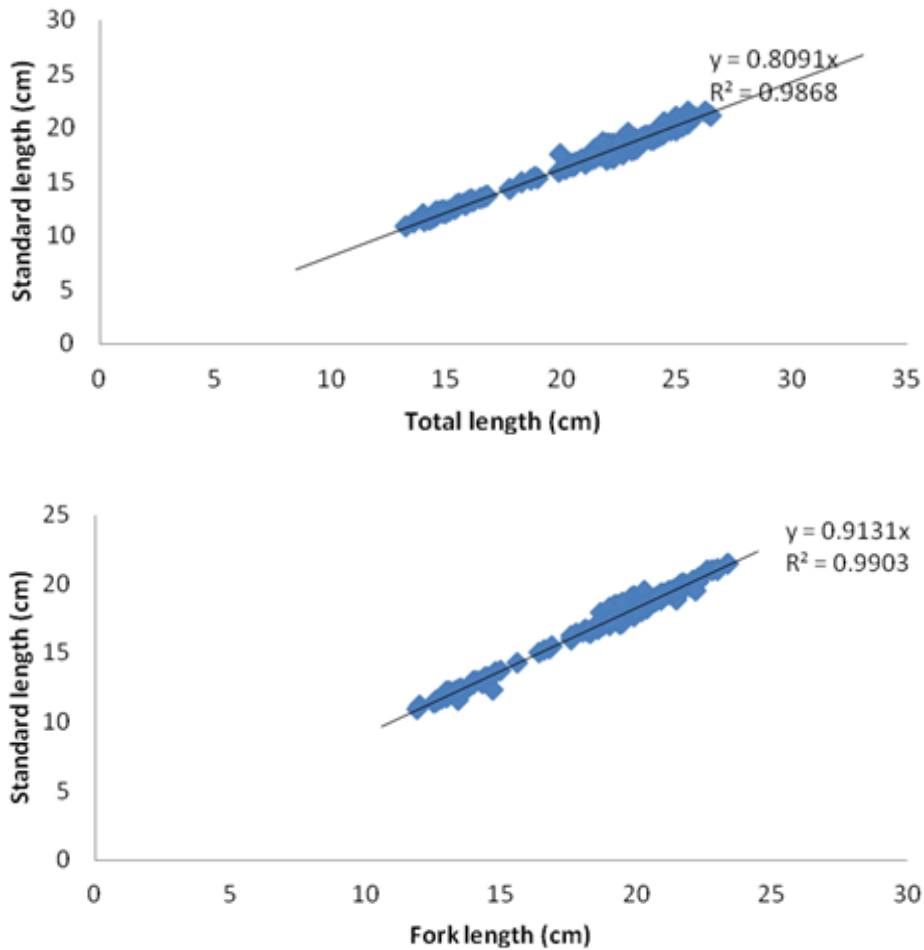
**Figure 16 Length-length relationships of *Rastrelliger kanagurta*: FL & TL, SL & TL and SL & FL**

## 5.3. Maturity stage vs. average Gonado-Somatic Index

The maturity stages for male and female Indian mackerel and their respective Gonado Somatic Index (GSI) values are listed in Table 3. With the onset of maturation; it was clearly visible that the GSI of mackerel increased more prominently in females than males (Figure 17).

**Table 3 Estimated average GSI values for different maturity stages**

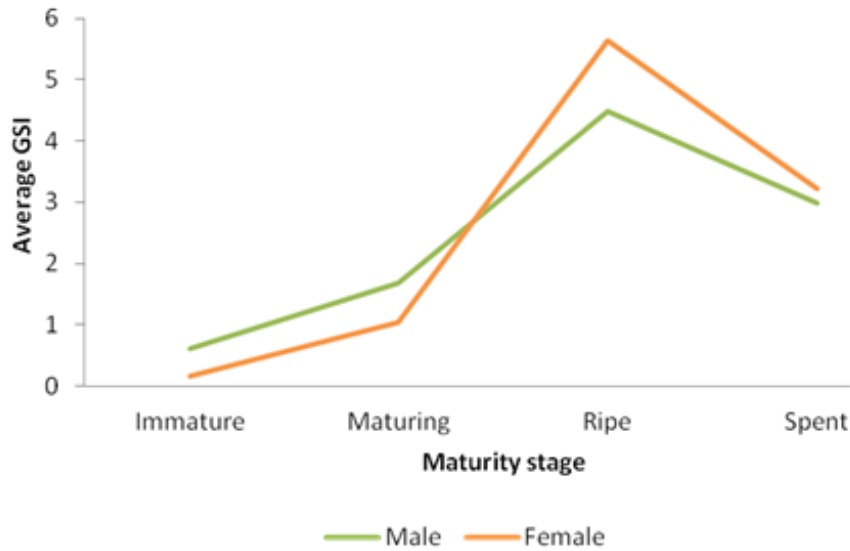| Maturity stage | Average GSI values |
|---|---|
| **Females** | |
| Immature (F1) | 0.15±0.12 |
| Maturing (F2) | 1.03±1.23 |
| Ripe (F3) | 5.65±2.07 |
| Spent (F4) | 3.22±1.34 |
| **Males** | |
| Immature (M1) | 0.62±1.48 |
| Maturing (M2) | 1.68±1.56 |
| Ripe (M3) | 4.49±1.74 |
| Spent (M4) | 2.99±2.53 |

**Figure 17 Maturity stage vs. average GSI for male and female Indian mackerel**

## 5.4. Maturation and spawning

The GSI can be used in identifying days and seasons of spawning, as the ovaries of gravid females swiftly increase in size just prior to spawning. Seasons are determined by plotting monthly mean GSI values. Spawning times are shown when GSI values increase and peak. Based on the present results, peak spawning season of Indian mackerel in the western and southern waters of Sri Lanka was found to be in the months of May and June (Figure 18).
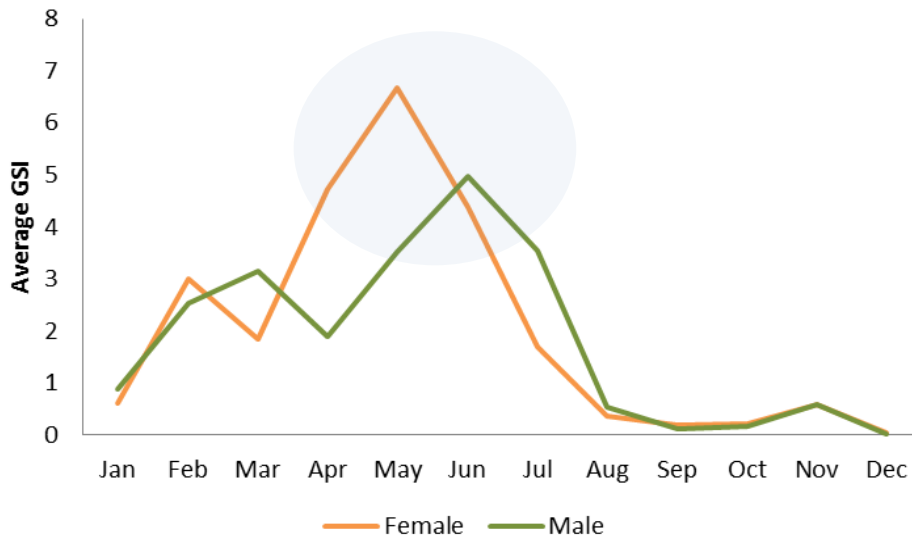


**Figure 18 Seasonal fluctuations of average GSI values of Indian mackerel in western and southern waters, Sri Lanka**

## 5.5. Sex ratio

Sex ratio states the proportion of male to female fish in a population and indicates the dominance of sex in a given population. It also implies basic information necessary for the assessment of the potential of fish reproduction and stock size estimation in fish population (Vicentini and Araujo, 2003). The estimated male to female sex ratio of Indian mackerel was 0.8 which was found to be significantly different from 1:1 at the 0.05 level of significance.

## 5.6.      Length at first maturity

The total length of female Indian mackerel ranged between 132 mm and 280 mm whereas the total length of males varied between 146 mm and 269 mm. The length at the first sexual maturation of males was in the range of 245 mm and 255 mm and that of females was 255 mm and 265 mm (Figure 19). The males of Indian mackerel attained first gonadal maturity earlier than females and this may probably be due to need of lesser quantity of energy reserves for gonad maturation of males than females.
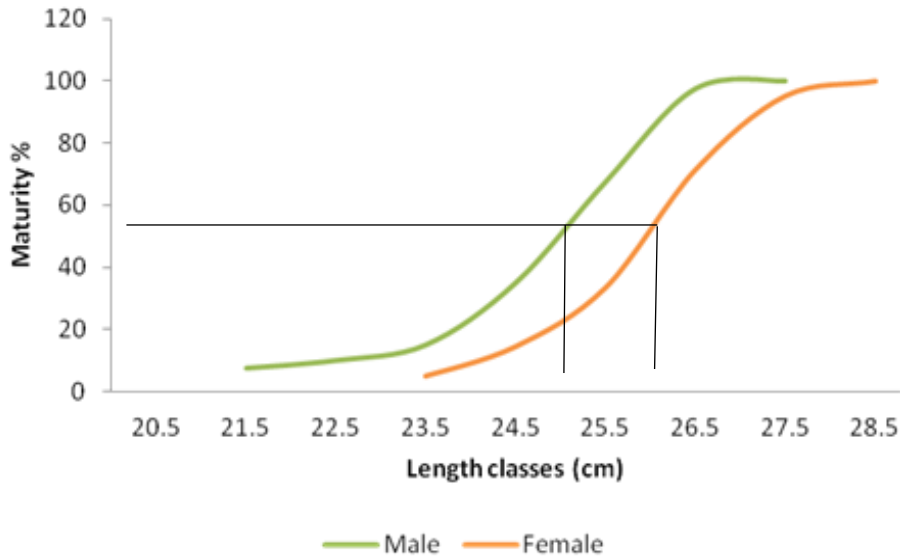


**Figure 19 Length at first maturity for male and female Indian mackerel**

## 5.7.      Fecundity

Knowledge of the fecundity is an important factor in fish stock management since it implies the reproductive potential of a stock. Reproductive potential could be considered as one of the key factors determining the stock size. Total fecundity estimated in the study varied from 75420 to 101609 eggs and the relative fecundity was estimated at 323±93 eggs per gram body weight of a female mackerel.

## 5.8.      Feeding ecology

Studies on food and feeding of mackerel concluded the planktonic diet dominated by zooplankton varieties with higher abundance of copepods and their nauplii stages (Figure 20). The most abundant groups of copepods were represented by four major orders; Calanoida, Cyclopoida, Poecilostomatoida and Harpacticoida (Figure 21). Other food types consisted of cladocerans, amphipods, other crustacean larvae, molluscan larval stages, rotifers and fish eggs. Diatoms and dinoflagellates were identified among the phytoplankton food items.
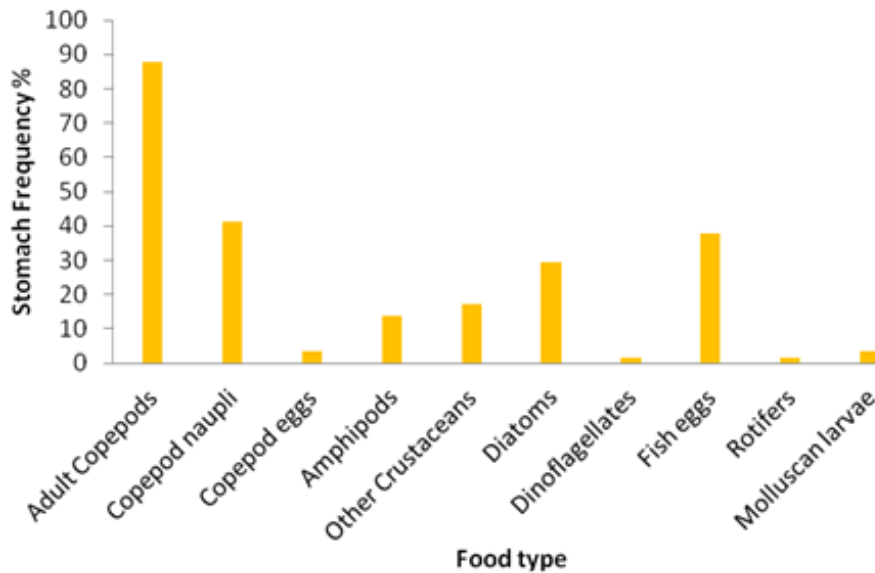
**Figure 20 Frequency of the food items found in the stomach of Indian mackerel**



Calanoid copepod



Poecilostomatoid copepod
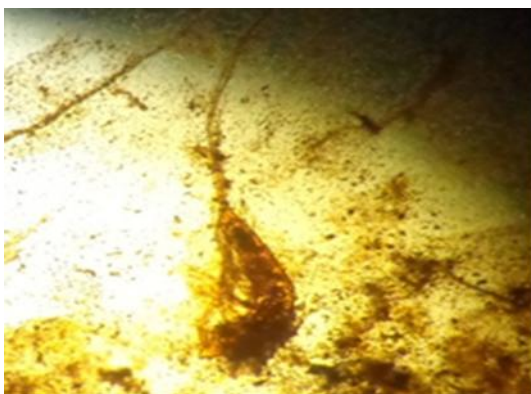


Harpacticoid copepod
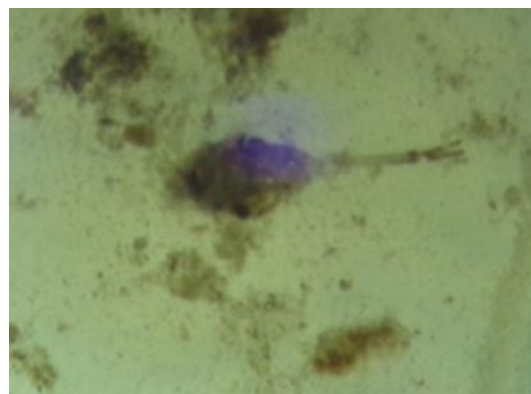


Cyclopoid copepod

**Figure 21 Copepods of different orders found in the stomach content of Indian mackerel**

## 6. Conclusion

Indian mackerel, *Rastrelliger kanagurta* is the fourth dominant small pelagic fish species in Sri Lanka and is mainly targeted by OFRP and MTRB boats which operate with gillnets. The estimated length-weight relationships of *Rastrelliger kanagurta* concluded a positive allometric growth for both sexes. Studies on food and feeding of mackerel concluded the planktonic diet dominated by

zooplankton varieties with higher abundance of copepods and their nauplii. The period of May to June was identified as the main spawning season of Indian mackerel in the western and southern waters of Sri Lanka. Since Indian mackerel is a migratory species, more collaborative research with the participation of the countries where Indian mackerel is harvested is recommended.

## 7.  Recommendations

1.  Carrying out a stock assessment in the coastal waters of Sri Lanka to obtain a clear picture on the present status of coastal resources including small pelagic fish.
2.  Carrying out a regional stock assessment on Indian mackerel with participation of the countries which harvest Indian mackerel.
3.  Implementation of a monitoring programme around entire coast of Sri Lanka which is similar to the one implemented under the study is recommended in order to strengthen the port sampling of small pelagic fish.
4.  Recruiting the three samplers who were trained by NARA for port sampling and to get them involved in small pelagic data collection in the northern waters.
5.  The study needs to be continued further, at least for another year, in order to determine the seasonal variations in the fishery and to confirm the results and thereby to provide management advice to the Department of Fisheries and Aquatic Resources (DFAR) to ensure the sustainable exploitation of the resource.
6.  MFARD and DFAR should find the possibility of regulating the fishing effort in the coastal fishery of Sri Lanka under the technical support of NARA.

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## Appendix I    Maturity stages of female & male Indian mackerel

| Maturity stages of female | Description |
| --- | --- |
| Indeterminate | Gonads tiny and underdeveloped and impossible to differentiate among sex |
| Immature (F 1) | Gonads small, tubular and pink, oocytes not visible |
| Maturing (F 2) | Gonads tubular, light yellow–orange colouration filling about half of the abdominal cavity. Blood vessels visible on the ovary |
| Ripe (F 3) | Gonads dark orange, turgid and filling the body cavity, transparent ova visible |
| Spent (F 4) | Gonads flabby with reddish brown gonads |
| **Maturity stages of male** | **Description** |
| Immature (M1) | Gonads small, whitish and flattened |
| Maturing (M2) | Gonads pinkish-white filling about half of the abdominal cavity |
| Ripe (M 3) | Gonads white, turgid and filling the body cavity, milt is released on applying pressure |
| Spent (M 4) | Gonads flabby with haemorrhagic brownish-white gonads |

**Source:** Ganga, 2010

Bangladesh, India, Indonesia, Malaysia, Maldives, Myanmar, Sri Lanka and Thailand are working together through the Bay of Bengal Large Marine Ecosystem (BOBLME) Project to lay the foundations for a coordinated programme of action designed to better the lives of the coastal populations through improved regional management of the Bay of Bengal environment and its fisheries.

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