Population dynamics of Indian mackerel *Rastrelliger kanagurta* in northwestern coastal waters of Sri Lanka

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Abstract

The population dynamics of *Rastrelliger kanagurta* from the northwestern coastal waters of Sri Lanka were studied based on the length frequency data collected from October 1993 to September 1994. The resource is mainly exploited by gillnets and beach seines. The length frequency distributions of *Rastrelliger kanagurta* for the two gear types were similar with two prominent peaks at 13.5-15.5 cm and 20.5-24.5 cm (total length) length ranges. In addition, smaller individuals with total lengths varying from 7.5-10.5 cm were also observed among the beach seine catches.

Population parameters were estimated using the FiSAT software package. The asymptotic length, growth constant and the growth performance index were estimated to be 28.0 cm (total length), 1.5 year⁻¹ and 3.07 respectively. The estimated value for the natural mortality coefficient using the Pauly's empirical formula was 2.37 year⁻¹. The fishing mortality coefficient for the combined fishery was estimated at 2.62 year⁻¹ while the estimated values for the total mortality coefficient and the exploitation rates were 4.99 year⁻¹ and 0.53 respectively. The recruitment was continuous with two peaks per year.

The length based Thompson and Bell model was used in the bio-economic prediction. Of the possible scenarios, increasing the gillnet effort while maintaining that of the beach seines at the present level appeared to be the most realistic in accordance with the existing social and legal framework. The maximum sustainable yield and maximum sustainable economic yield for the combined fishery were estimated at 207 MT and 200 MT respectively. As the corresponding effort levels were 3 and 1.6 times the present effort, it is reasonable to conclude that the stocks are not over-exploited at present.

Introduction

Indian mackerel *Rastrelliger kanagurta* (Family: Scombridae) is a valuable food fish variety, making a substantial contribution to the small pelagic fishery resource in the shallow sea off Sri Lanka. It is an epipelagic marine fish occurring in the depth range of 20-90 m and in areas where the surface water temperature is at least 17°C. This species is abundant in Indo-West Pacific i.e., in Red sea, South Africa and Seychelles, east of Indonesia, north to Ryuku island and China, south to Australia, Melanesia and Samoa (Collete and Nauen 1983; Anon. 2000) (Fig. 1).

The world production of Indian mackerel has fluctuated from around 96,000 t in 1975 to the peak catch of 351,000 t in 1994 (Anon. 2000). In India, especially in the seas off the west coast, a major fishery targeting Indian mackerel has been established. *R. kanagurta* made a substantial contribution to the small pelagic fishery resource from the western Indian ocean while the production of *Rastrelliger* spp. and *R. kanagurta* from the eastern Indian ocean were estimated at 224,000 and 43,000 t respectively (Collete and Nauen 1983). Purse seines, drifting gillnets, high-opening bottom trawls, lift nets and bottom set gillnets were the major gear used to exploit this resource (Pradhan 1956; Guanco 1991; Dayaratne 1997).

The fishing season for Indian mackerel along the Kanara coast of west India is from October to February/March and the production gradually declines towards April and disappears in May (Pradhan 1956; Sekharan 1958). Its fishing season in the study area, overlaps with that of the western coastal waters of India, indicating the possibility of the existence of a similar fishery in the Sri Lankan waters (Pradhan 1956).

However, a well-established fishery targeting mackerels is not in existence in the seas off Sri Lanka. The present study was therefore, conducted to evaluate the status of the Indian mackerel fishery resource in the coastal waters off Sri Lanka. A multi-fleet stock prediction model was used in the analysis to predict the possible trends in the fish production in relation to the change of fishing efforts by the two types of gear i.e., beach seines and gillnets operated in the study area.

Materials and Methods

Study area and Data collection

Length frequency data of *Rastrelliger kanagurta* were collected from gillnet and beach seine catches from the northwestern coastal waters of Sri Lanka from October 1994 to September 1995 (Fig. 1). Sampling was conducted fortnightly at three landing sites viz. Udappu, Sinnapadu and Mampuri. On each sampling day, more than 30% of the crafts operating gillnets and beach seines were sampled randomly. Catch in kg/haul in terms

Population dynamics of Indian mackerel

of beach seines and kg/boat/day for gillnets were considered as the catch per unit effort. On each sampling day, total lengths of around 100-200 fish were measured to the nearest 0.1 cm using a measuring board.

Figure 1. Map of the study area indicating fishing grounds and sampling sites off Kalpitiya. (A) Inset shows the world distribution of *Rastrelliger kanagurta* in Indo-Pacific region.

Analysis of data

The monthly length frequency distributions of *R. kanagurta* for gillnet and beach seine catches were raised separately to the total *R. kanagurta* production in the study area. One of the common causes of bias of length frequency data is the selection property of the gear used for sampling. This bias can partially be overcome by correcting the length frequency data using the probability of capture values (Gayanilo et al. 1994). Steps-wise procedure presented by Amarasinghe and De Silva (1992), with some modifications, was used in the analysis.

1. Initial values of L_{∞} and Z/K were estimated using the Wetherall method (Pauly, 1986; Wetherall, 1986).

2. Preliminary estimates for growth parameters were obtained using ELEFAN I, via iteration of the initial estimates of population parameters, as implemented in FiSAT software package (Gayanilo et al. 1994).

3. Initial estimate for M was obtained using the Pauly's Empirical formula, (Pauly 1980)

$\text{Log}_{10} M = -0.0066 - 0.279 \text{Log}_{10} L_{\infty} + 0.6534 \text{Log} K + 0.4634 \text{Log}_{10} T$
where L_{∞} = Asymptotic total length in cm, K = Growth constant (year^{-1}), M = Natural mortality and T = Temperature in Celsius.

4. Using the values estimated for L_{∞} , K and M , a VPA was performed to estimate the fishing mortality values by length classes (F- array).

5. The probabilities of capture by length were estimated dividing the corresponding fishing mortality values by the estimated highest value in the F- array (Sparre and Venema 1992).

6. The observed length frequency data were corrected using the estimated probabilities of capture.

7. Improved values of L_{∞} and K were obtained from the corrected length frequency data. Growth performances index (ϕ') was estimated using the following formula described by Pauly and Munro (1984).

$$\phi' = \text{Log}_{10} K + 2 \text{Log}_{10} L_{\infty}$$

8. Using the improved L_{∞} and K values, M and Z were estimated by Pauly's empirical formula (Pauly 1980) and the length converted catch curve method respectively. Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) by the relationship $E = F/Z$ (Gulland 1983). The recruitment pattern was derived using the FiSAT software package.

Population dynamics of Indian mackerel

An approximate value for theoretical age at length zero (t_0) calculated by the following equation (Pauly 1979) was used to estimate recruitment pattern.

$$\text{Log}_{10}(-t_0) = -0.392 - 0.275 \text{Log}_{10} L_{\infty} - 1.038 \text{Log}_{10} K$$

9. A VPA was also performed using the new estimates.

10. Finally the length based Thompson and Bell (1934) model was used to predict long-term yield of *R. kanagurta*.

Results

Size composition of *R. kanagurta*

In the northwestern coastal waters of Sri Lanka, the Indian mackerel resource is mainly exploited by two types of gear, namely gillnets and beach seines. The production trends of *R. kanagurta* by the two types of gear were comparable (Table 1). The estimated total annual length frequency distributions of this species for the two types of gear were similar with two prominent peaks at 13.5-15.5 cm and 20.5-24.5 cm (total length). In addition, beach seines also caught smaller individuals with total length varying from 7.5 cm to 10.5 cm especially during the period February-March (Fig. 2).

Table 1. Estimated production of *R. kanagurta* for different types of gear operating in the northwestern coastal waters of Sri Lanka.

	Gillnets operating at dawn (3.30-6.30 am)	Gillnets operating at night (7.00-11.00 pm)	Beach seine (6.00am-6.00 pm)
Total annual fish production (MT)	619.67	82.89	1288.85
<i>R. kanagurta</i> production (MT)	94.97	3.27	90.89
% composition of <i>R. kanagurta</i>	15.32	3.94	7.05

Figure 2. Length frequency distributions of *R. kanagurta* in gillnets and beach seines.

Probabilities of capture

The overall probabilities of capture values estimated from the VPA method are shown in Fig. 3. It clearly indicates that the animals within the size range 13.5-15.5 cm and 20.5-24.5 cm are the most vulnerable to the fishing gear with probabilities of 0.01-0.2 and 0.5-1.0 in the respective size ranges.

Figure 3. The estimated selection curves of *R. kanagurta*.

Population dynamics of Indian mackerel

Growth parameters

The growth curves superimposed on the length frequency distribution of *R. kanagurta* are given in Fig. 4. The asymptotic length (L_{∞}), growth constant (K) and growth performance index (ϕ') were estimated to be 28.0 cm (total length), 1.5 year⁻¹ and 3.07 respectively.

Figure 4. The estimated growth curves of *R. kanagurta* superimposed on the length frequency distribution. Length frequency distributions of individuals collected during January-July 1994 were inserted in the corresponding period of the previous year to demonstrate the continuation of the growth curve.

Mortality and exploitation rate

Instantaneous rate of natural (M), fishing (F) and total mortality coefficients (Z) were estimated to be 2.37 year⁻¹, 2.62 year⁻¹ and 4.99 year⁻¹ respectively. The variations of the fishing mortality by length classes, and the results obtained from the VPA analysis are given in the Fig. 5, which indicate that there are three prominent peaks, corresponding to the peaks observed in the length frequency distribution. The overall exploitation rate (E) was estimated to be 0.53.

Figure 5. Length structured virtual population analysis of *R. kanagurta*.

Theoretical age at length zero (t_0)

The estimated theoretical age at length zero (t_0) for *R. kanagurta* was -0.106 years.

Recruitment pattern

The estimated recruitment pattern was continuous with two peaks per year from July to December and a small peak from February to March (Fig. 6).

Length based Thompson and Bell yield prediction

Thompson and Bell (Thompson and Bell 1934) long term yield and stock prediction indicated, that of the possible scenarios, increasing the gillnet effort while maintaining the beach seines effort at the present level would be the most realistic in accordance with the existing social and legal frame work (Fig. 7). In this scenario, the maximum sustainable yield (MSY) for the combined fishery was estimated at 207 MT at f-factor value of 3. The contribution of gillnets and beach seines to MSY was estimated to be 155 and 53 MT respectively. However, the maximum sustainable economic yield (MEY) would be attained at much lower fishing effort when the total production is around 200 MT at the f-factor value of 1.6.

Population dynamics of Indian mackerel

Figure 6. The recruitment pattern of *R. kanagurta* in the northwestern coastal waters of Sri Lanka.

Since the small fish were also recorded among the beach seine catches during the present study, the analysis was extended to evaluate the impact of beach seines on the production of *R. kanagurta* resource in the study area. Predicted fish yields at 0.8, 1.0 and 1.2 f-factor value for beach seines and at f-factors of 0.4 to 2.0 for gillnets (Fig. 8) indicated that the change in the beach seine effort has little influence over the estimated MSY in the study area. A 20% change in the fishing effort of beach seine would result only a change of 5 MT over the total fish production in the study area. However, increasing fishing effort of gillnets by 20%, would result in reaching MEY at f-factor value of 1.4 and 20% decrease would result in optional MEY at f-factor value of 1.8. In both situations, the total production of *R. kanagurta* in the study area would remain around 200 MT.

Discussion

The estimated total length frequency distributions of *R. kanagurta* for both gillnets and beach seines were similar with two prominent modes from 13.5 to 15.5 and from 20.5 to 24.5 cm (total length). Small quantities of juveniles with total lengths varying from 7.5 to 10.5 cm were caught among the beach seine catches. These undersized fish together with large fishes of 20.5-27.5 cm in total length appear to be first recruited to the beach seine fishery in January. The small mode then shifts to 9.5-12.5 cm in February and at the total length of 13.5-cm they appear to be caught in

Figure 7. Results of the Thompson and Bell long term yield and stock prediction. Here, the beach seine effort was kept at the present level while the gillnet effort was changed.

Figure 8. Variation of the total yield and value for combine fishery at different gear combinations. Here the f-factor of the beach seine fishery was changed from 0.8 to 1.2 and that of gillnet from 0.4 to 2.

Population dynamics of Indian mackerel

considerable numbers. The catch of *R. kanagurta* in the study area was reported to be low from April to August. This could either be due to low fishing effort during the southwest monsoon period or due to the migration pattern of fish, which is related to their reproductive behaviour. According to Rao (1967), from January to May the mackerel move away from near shore waters as they mature, resulting in a poor mackerel fishery in the West Indian coast from June to September. During this period fishermen extend the area of operation of gillnets to the areas with a depth of 12-30 m. The fishermen in the east coast of India operate dragnets to harvest the mackerel resources from the sea bottom. Guanco (1991) reported that the larger fishes of 20-32 cm in total length ($L_{max} = 38$ cm) were also exploited by trawling in the seas off central Philippines. Therefore, it appears that there is a tendency for *R. kanagurta* to aggregate in deeper areas of the sea, rather than to form schools near the surface. Consequently, it is worthwhile to investigate the possibility of exploiting large *R. kanagurta* (>25cm) in deeper waters during June-September period with bottom set gillnets with stretched mesh sizes of >60 mm.

One of the major constraints that has to be overcome in estimation of the growth parameters is the influence of the selectivity of gillnets. However, during the present study, length frequency data over a wide range (7.0 cm to 29.0 cm) were collected using selective and non-selective gear, strengthening the accuracy of the computation procedure used.

The estimated values for L_{∞} , K and growth performance index (ϕ') for *R. kanagurta* during the present study (28.0 cm, 1.5 year⁻¹ and 3.07 respectively) were in agreement with the mean values of those parameters (28.5 cm, 1.6 year⁻¹ and 3.05) recorded in the literature (Ingles and Pauly, 1981), confirming the reliability of the estimated population parameters during the present analysis.

Fish ranging in size from 12.5 cm to 15.5 cm and from 20.5 cm to 24.5 cm were the most vulnerable size groups with fishing mortalities varying from 0.35 year⁻¹ to 1.33 year⁻¹ and from 1.65 year⁻¹ to 5.52 year⁻¹ respectively. Since the fishing mortality of fish below 12.0 cm in total length was < 0.02 year⁻¹ the fishing mortality of this size group was considered to be insignificant. Since individuals > 26.0 cm in total length were less abundant, the fishing mortality of this age group was also considered to be insignificant.

The *R. kanagurta* production in the study area was estimated to be 190.1 MT. In the most realistic scenario, i.e., when the gillnet effort is increased while maintaining the effort of the beach seines at the present level, the estimated MSY for the overall fishery was 207 MT. The respective effort was 3 times of the present effort. In the economic view point, increasing the fishing effort by 3 folds to obtain additional 17 MT is not only uneconomical but also will create social problems among the fishermen by decreasing their daily catch rates. The analysis also indicated

that the maximum sustainable economic yield could be obtained by 60% increase of the existing fishing effort. Even at this stage the total production would increase only by 10 MT. These results therefore indicate that the *R. kanagurta* resources in the study area are exploited at the optimum level.

As indicated by the present analysis, the decrease of the fishing effort of beach seines by 20% will result in a decrease in the present total production by 5 MT, with the provision to accommodate additional 20% of the gillnet effort to reach the present production (190.1 MT). Although, the total production is slightly influenced by the change of the beach seine effort, from the socio-economic viewpoint it could facilitate the entry of more fishermen to the fishery targeting Indian mackerel in the study area. However, the influence of increasing beach seine effort on other fish stocks in the study area should also be carefully evaluated prior to implementing such a management recommendation.

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Population dynamics of Indian mackerel

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