Fishery, biology and stock assessment of spotted seer, *Scomberomorus guttatus* (Bloch & Schneider) off Andhra Pradesh

V. U. Mahesh, S. Ghosh*, K. Sreeramulu[1], M. V. Hanumantha Rao and M. Satish Kumar
Visakhapatnam Regional Centre of ICAR-CMFRI, Pandurangapuram, Visakhapatnam-530 003, Andhra Pradesh, India
[1]Department of Zoology, Andhra University, Visakhapatnam-530 003, Andhra Pradesh, India

* Correspondence e-mail: subhadeep_1977@yahoo.com

Original Article

Abstract

The fishery, biology and stock of the spotted seerfish, *Scomberomorus guttatus* (Bloch & Schneider) along Andhra Pradesh was studied during 2012-2014. The annual average landing of spotted seer during the period along Andhra coast was 2,614 t. Major contributors were trawlnets-1,104 t (42.2%) and gillnets-950 t (36.3%). Catches were higher during August-December. Length-weight relationship varied significantly between males, females and indeterminates. Growth was isometric in males and allometric in females and indeterminates. Overall sex ratio was 1:1.87. Length at first maturity was 38.9 cm. Peak spawning was observed during November-April. Higher Gonado-somatic index coincided with periods of peak spawning. Mature ovaries contained both maturing (0.41 mm-0.70 mm) and matured (0.71 mm-0.90 mm) ova. von Bertalanffy growth equation was $L_t = 71.98 [1-e^{-0.23(t + 0.0722)}]$. Natural mortality, fishing mortality and total mortality were 0.54, 0.49 and 1.03. Exploitation ratio was 0.48. Annual total stocks, biomass and Maximum Sustainable Yield were 8,546 t, 5,335 t and 2,747 t. A minor increase in yield and yield/recruit is possible by increasing the present level of fishing by 20%.

Keywords: Fishery, biology, stock structure, *Scomberomorus guttatus*, Andhra Pradesh

Introduction

Andhra Pradesh is one of the leading seerfish producing states in India, with the catch made up by spotted seer, *Scomberomorus guttatus* (Bloch & Schneider) and the king seer *S. commerson* (Lacepede). Seerfishes formed on an average 3.5% of the national marine landings during 2000-2014. Recent landings in India fluctuated from 56,170 t in 2012 to 49,209 t in 2014, with an all-time peak of 62,171 t in 2007. Landings in Andhra Pradesh have increased from 5,437 t in 2000 to 7,729 t in 2014, with highest catch of 11,466 t recorded in 2007. The contribution of *S. guttatus* to the total seerfish catch in recent years has increased at the expense of *S. commerson*. It now contributes on average 37.8% of the total seerfish caught (Maheswarudu *et al.*, 2013).

S. guttatus is an epipelagic, neritic species known to undertake longshore migrations (Randall, 1995). It is exploited by a variety of gears *viz.*, drift gill nets, hook and lines, trolling, trawl nets and seines (Ghosh *et al.*, 2009). *S. guttatus* is heavily concentrated and highly localized with bulk of the fishery from within a narrow belt of 45 km at depth range of 20-70 m. Hence, it could well be possible that the resource is currently overexploited. It islocally known as 'Vanjaram' owing to its high unit value

and economic returns, and hence is one of the commercially important marine pelagic finfish resources of the state and the country. The catches are mostly consumed fresh or frozen.

Historical information is available on the fishery and stock dynamics of spotted seer from waters all along the Indian coast (Devaraj, 1977, 1981, 1987; Kasim *et al.*, 2002; Muthiah *et al.*, 2002; Kasim and Abdussamad, 2003; Muthiah *et al.*, 2005; Ghosh *et al.*, 2009). However specific studies from Andhra Pradesh are lacking. No information is available on the fishery, biology and stock status of the spotted seer from the east coast for the last decade or more. Hence, the present study focuses on elucidating the fishery, reproductive biology and stock assessment of *S. guttatus* from the waters off Andhra Pradesh.

Material and methods

Catch data of *S. guttatus* and effort expended were collected weekly from all gears at Palasa, Mukkam, Visakhapatnam, Pudimadaka, Kakinada, Machilipatnam and Odarevu, Andhra Pradesh, for three years from January 2012 to December 2014. Monthly and annual estimates of catches were made following the procedure adopted by the Fishery Resource Assessment Division of Central Marine Fisheries Research Institute, India (Srinath *et al.*, 2005).

A total of 4,668 specimens of *S. guttatus* ranging in size from 20.0 to 69.0 cm were collected randomly and measured for fork length (cm) and body weight (g to 0.01 g precision). Length-weight relationship was calculated as $W = aL^b$ (Le Cren, 1951), separately for both sexes and indeterminates. Significant differences between males, females and indeterminates in the slopes of the regression lines were ascertained by ANACOVA (Snedecor and Cochran, 1967). Sex ratio for each month during the period was estimated from 4,388 specimens, with chi-square test done for testing the distribution of homogeneity of male and female. Size at first maturity (L_{50}) was estimated from 2,827 female specimens using the nonlinear least square regression method, logistically by fitting the fraction of mature fish (stage III and above) against length interval (King, 1995). Spawning season was ascertained by estimating the proportion of gravid and ripe females (V and VI) over months. Gonadosomatic index (GSI) for females was calculated as GSI = (weight of gonad x 100) / weight of fish. The number of ova in all subsamples, obtained from the anterior, middle and the posterior regions of mature and ripe ovary (V and VI), was raised to the total ovary weight for determining fecundity. Ova diameter distribution in each ovary subsample was studied using calibrated ocular micrometer under a microscope.

As stock assessment procedures works with age composition, in tropical waters, von Bertalanffy growth model is used, which converts length frequency data into age composition (Sparre and Venema, 1998). Month-wise length composition data of three years were pooled and grouped with 1 cm class interval and analyzed for estimation of von Bertalanffy growth parameters, $L\infty$ and K, using the ELEFAN I module of FiSAT software version 1.2.0 (Gayanilo *et al.*, 1996). Growth performance index (ϕ) was computed employing Pauly and Munro (1984). Size at first capture (L_c) was determined as by Pauly (1984). From the empirical equation, Log $(-t_0) = -0.392 - 0.275$ Log $L\infty - 1.038K$ (Pauly, 1979), age at zero length (t_0) was calculated. von Bertalanffy growth equation, $L_t = L\infty (1 - exp^{-k(t-t0)})$, was used for determining age and growth. Length at recruitment (Lr) was taken as the midpoint of the smallest length group in the catch. Longevity or t_{max} was determined as $3/K + t_0$ (Pauly, 1983a). Natural mortality (M) was estimated using the formulae of Pauly (1980) taking mean sea surface temperature as 28°C (International Comprehensive Ocean Atmospheric Data Sets; http://www.esrl.noaa.gov/psd). Length converted catch curve, using FiSAT software, was used to calculate total mortality (Z) (Pauly, 1983b). Fishing mortality (F) was calculated by substracting M from Z. Fishing mortalities per length class were obtained from length structured virtual population analysis (VPA) of FiSAT. Exploitation ratio (E) was F/Z. The ratios Y/U and Y/F were used to estimate total stock (P) and biomass (B); where Y is the annual average yield in tonnes and U is the exploitation rate. Maximum Sustainable Yield (MSY) was calculated by the equation of Gulland (1979). Beverton and Holt Yield per Recruit model was used to estimate the relative yield per recruit (Y/R) and biomass per recruit (B/R) at varying levels of fishing intensity using Excel worksheet.

Results

Fishery

During 2012-2014, an annual average of 2,614 t of spotted seer was landed along Andhra Pradesh coast. Catches has increased over the years from 2,356 t in 2012 to 4,142 t in 2014 (Fig. 1). Major contributors were trawlnets and gill nets, contributing on an average annually 1,104 t (42.2%) and 950 t (36.3%). Contributions were low from hooks and lines (345.5 t and 13.2%) and seine nets (214.6 t and 8.2%). Average catch rates in trawl nets, gill nets, hooks and lines and seinenets were 0.25 kg / h, 1.30 kg / unit, 0.44 kg / unit and 1.77 kg / unit. It formed 1.20%, 1.18%, 0.52% and 0.21% of the total catches in trawlnets, gill nets, hooks and lines and seinenets. In trawl nets (2,310 t) and seine nets (575 t), catches have increased drastically in 2014. On the contrary, in gill nets (1,112 t) and hooks and lines (543 t), landings were highest in 2012. Monthwise, August-December recorded higher catches (Fig. 2) for trawl nets, gill nets and hooks and lines.
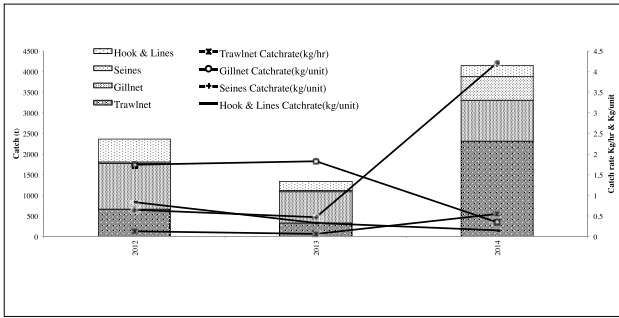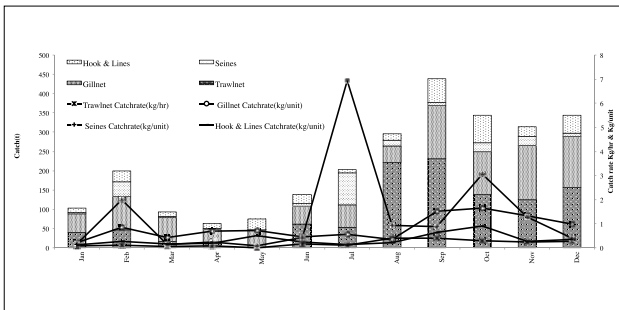
Fig. 1. Annual catch and catch rates of *S. guttatus*

Fig. 2. Monthly catch and catch rates of *S. guttatus*

Length composition

Unimodal length frequency was observed with a single peak representing size ranges from 40.5 cm to 49.5 cm, which are thought to dominate the fishery. More juveniles were encountered in 2012 and 2013, when compared to 2014, especially during June-September. Mean length was more or less similar, varying marginally from 44.29 ± 2.31 cm (2012) to 45.05 ± 2.32 cm (2013). Seasonally, it fluctuated from 42.6 ± 0.73 cm in August to 46.39 ± 1.47 cm in December (Fig. 3).
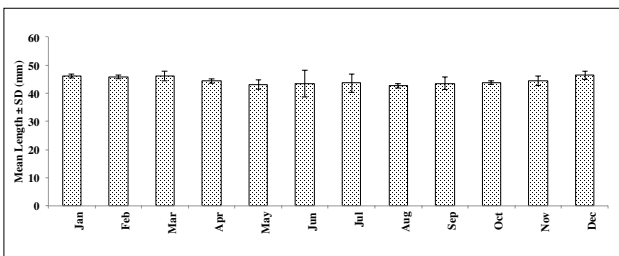

Fig. 3. Mean length of *S. guttatus* in different months

The length-weight relationships estimated separately for sexes and indeterminates were:

Male : $\log W = -2.1716 + 2.9950 \log L$ ($r^2 = 0.91$)
Female : $\log W = -1.5031 + 2.5936 \log L$ ($r^2 = 0.90$)
Indeterminate : $\log W = 0.2128 + 1.5258 \log L$ ($r^2 = 0.89$)

The length-weight relationship for males, females and indeterminates were found to be significantly different at 5 % level. Slopes of the regression relation for females ($t_{cal} = 25.21$; $t_{crit\ 0.05} = 1.96$) and indeterminates ($t_{cal} = 49.30$; $t_{crit\ 0.05} = 1.97$) were significantly different from the isometric value of 3 indicating negatively allometric growth; whereas in males, the slope ($t_{cal} = 0.21$; $t_{crit\ 0.05} = 1.96$) did not deviate from 3 indicating isometric growth.

Sex Ratio and Size at first maturity

Significant dominance ($p < 0.05$) was observed by females during August-March. Overall sex ratio was 1:1.87. Males outnumbered females marginally ($p > 0.05$) during May-July. Annual sex ratio varied from 1.80 (2012) to 2.03 (2013). Sexual maturity is reached at a size of 38.9 cm (Fig. 4). However, gonadal development and sexual maturity commenced from 31.5 cm onwards.
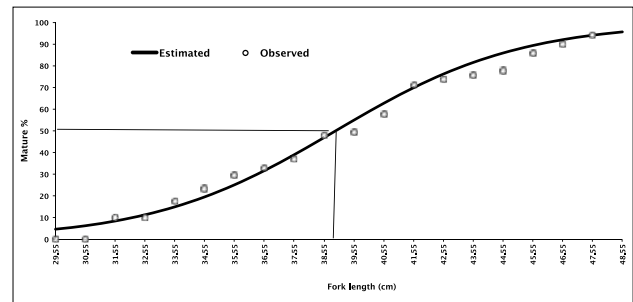

Fig. 4. Length at first maturity for females of *S. guttatus*

Spawning season and Gonado somatic index (GSI)

For spotted seer, high proportion of mature females was observed in most months of the year, with mature females available throughout the year. Peak spawning (46.4 %-51.3 % of mature females) were observed between November and April. GSI, similarly, was higher between November-March (1.16-1.27). GSI results are in full conformity to the presence of mature females (Fig. 5). Peak GSI values ranging from 1.26-1.27 was observed during November-December.
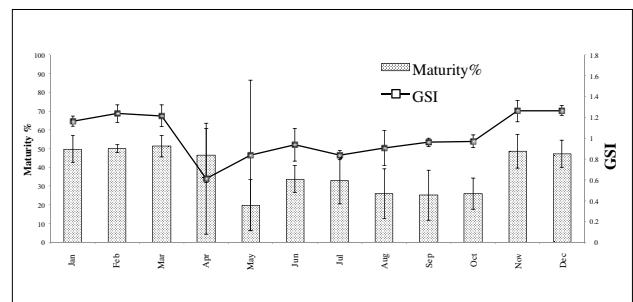

Fig. 5. Maturity and gonadosomatic index (GSI) of females in different months

Fecundity and ova distribution

Fecundity increased with the length and weight of the fish. Relation between fecundity and length was Log F = 2.83 + 1.46 Log L (r^2 = 0.79) and between fecundity and weight was Log F = 4.27 + 0.35 Log W (r^2 = 0.71). Absolute fecundity ranged from 1,25,440 eggs to 2,46,601 eggs, with a mean of 1,95,388 eggs. Relative fecundity per g body weight varied from 131.52 eggs to 310.17 eggs with an average of 253.51 eggs. Mature ovaries contained both maturing and mature ova. Mature ova ranged from 0.71 to 0.90 mm in diameter whereas the maturing ova ranged from 0.41 to 0.70 mm (Fig. 6). Yolked ova of different sizes in mature ovaries observed for most months of the year.
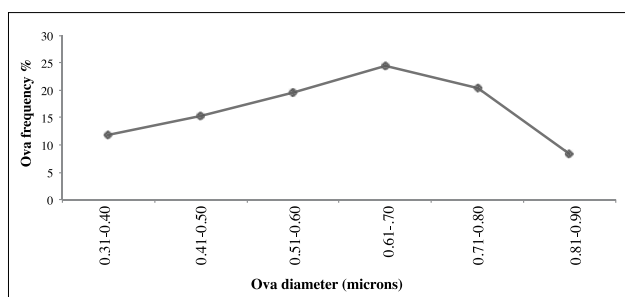

Fig. 6. Ova diameter distribution in females

Growth

Growth parameters, L_∞ and K (annual) estimated using the ELEFAN I programme were 71.98 cm and 0.23/year. Growth performance index (ϕ) was 3.08 and t_0 was -0.0722 years. von Bertalanffy growth equation was: $L_t = 71.98 [1\text{-exp}^{-0.23 (t + 0.0722)}]$.

The fish attained size of 15.73 cm, 27.29 cm, 36.47 cm, 43.77 cm and 49.56 cm respectively by the end of 1, 2, 3, 4 and 5 years. Longevity was close to 13 years. Fishery was dominated by fishes of 4 and 5 year old classes. Length at first capture (L_c) was 20.28 cm, which corresponds to an age (t_c) of 1.37 year.

Recruitment

The recruitment pattern observed was bimodal with recruitment occurring in all months for *S. guttatus*. One peak in recruitment was during March-April and the other between June-August. Recruitment pulse during March-April produced 26.92% of the recruits and that during June-August produced 38.92% of the recruits. Average annual recruit into the fishery was 3,03,02,544 numbers. Smallest length of recruitment was 19.55 cm.

Mortality, exploitation and Virtual Population Analysis

Mortality rates M, F and Z were 0.54, 0.49 and 1.03 respectively. The exploitation ratio (E) was 0.48. The main loss in the stock up to 38.5 cm size was due to natural causes, as indicated by VPA. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased. Fishing mortality was equal to natural mortality at lengths of 55.5 cm and outnumbered natural mortality at 60.5 cm. Fishing mortality was maximum, 0.548 at size of 60.5 cm.

Stock and Maximum Sustainable Yield (MSY)

The annual total stock, biomass and MSY were 8,546 t, 5,335 t and 2,747 t, respectively.

Yield / Recruit

Yield and biomass curves revealed yield and yield/recruit to marginally increase by increasing the present fishing level by 20% (Fig. 7). Maximum yield and yield per recruit obtained by increasing the present fishing intensity by 20% is 2,635.5 t and 86.97 g, whereas at the present level of fishing, it is 2,614.0 t and 86.26 g. At the increased effort, the increase in relative yield is only a marginal 0.82%, which may not be remunerative (Fig. 8).
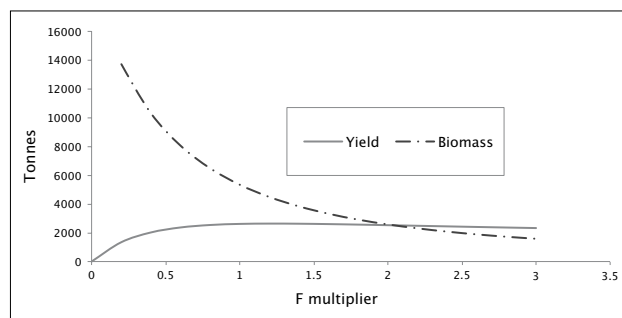

Fig. 7. Yield and biomass of *S. guttatus* for different multiples of fishing intensity

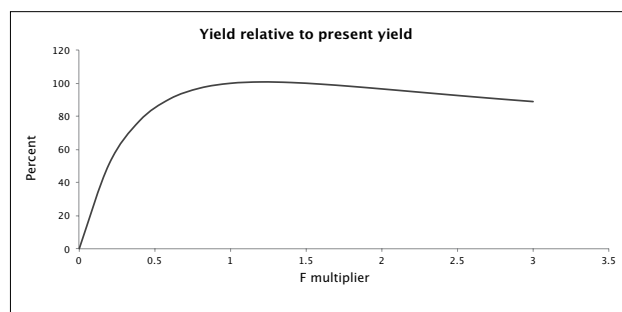Fig. 8. Relative yield of *S. guttatus* for different scenarios of fishing intensity

Discussion

Spotted seer catch has increased over the years. Earlier, highest landing of 4,139 t was reported by Maheswarudu *et al.* (2013). In the present study, 4,142 t were landed in 2004, which is the highest recorded landing of *S. guttatus* from the waters of Andhra Pradesh till date. A multitude of gears (trawlnets, gill

nets, hooks and lines and seinenets) exploit the resource in the state. Peak landings in individual gears are commensurate with the increased effort of the gear. Trawlnets with cod end mesh ranging from 20 to 30 mm exploit *S. guttatus*, as do gill nets (multifilaments and monofilaments) having mesh size ranging from 30 to 150 mm. Smaller meshed gill nets land juveniles, whereas large meshed gill nets land adults. The differences in the fishing grounds and the depth of operation coupled with changes in the distribution of the species account for the variations in catch and catch rates observed among various gears and various months.

Length and weight ranges recorded were similar to that reported earlier from Indian waters (Naik *et al.*, 1998). Mean length was more or less similar, with minimal fluctuations. Silk (small meshed gill) nets are operated between July-September, which land good catches of juveniles of *S. guttatus* (Maheswarudu *et al.*, 2013). Length-weight relationship varied significantly between males, females and indeterminates. Growth was isometric in males and negatively allometric in females and indeterminates. Similar exponent values varying from 2.82 to 2.89 were reported earlier by Devaraj (1981), Naik *et al.* (1998) and Ghosh *et al.* (2009). Length weight relationship is influenced by changes in ecosystem and in biological phenomena like maturity stages, feeding behavior and competition for food.

As reported earlier by Bal and Rao (1990) and Naik *et al.* (1998), there was a dominance of females in the catch. Differential fishing caused by changes in the pattern of migration of sexes to and from the fishing grounds could have attributed to this dominance. Fish attained sexual maturity and spawned at the end of third year. Length at first maturity is similar to that reported earlier (Bal and Rao, 1990).

Devaraj (1987) reported on an extended spawning period from January-August, with a peak in April-May. The same author reported on the occurrence of three batches of ova in mature ovary of different stages of maturity. Kasim and Hamsa (1989) reported peak spawning during July. Contrarily, along Andhra Pradesh, peak spawning occurred between November and April. Also ripe ovaries contained two batches of ova, one maturing and the other mature. Higher values of gonadosomatic index coincided with peak periods of spawning. The size progression of yolked ova during different months is in concurrence to the spawning season. Fecundity estimates are lower than 3,85,000 eggs to 11,00,000 eggs reported by Bal and Rao (1990).

The asymptotic length observed in the study was 71.98 cm which is closer to 72.4 cm reported by Muthiah *et al.* (2002) and 75.0 cm reported by Kasim *et al.* (2002) from the east coast of India. From the west coast, lower values (61.3 cm, 64.3

cm and 65 cm) were reported (Ghosh *et al.*, 2009; Muthiah *et al.*, 2002; Kasim *et al.*, 2002), possibly because of lower length range encountered due to higher fishing pressure and differences in the gears used for exploitation (Pillai *et al.*, 1993). Using pooled data from both the coasts, Somvanshi *et al.* (2003) recorded asymptotic length as 69.0 cm from the Indian waters. Higher values of growth co-efficient (1.0-1.6), has been observed by most authors (Kasim *et al.*, 2002; Somvanshi *et al.* 2003; Ghosh *et al.*, 2009), except Devaraj (1981). Length attained each year for five years were lower to those estimated by Rao (1978), Devaraj (1981), Naik *et al.* (1998) and Ghosh *et al.* (2009). Differences in environmental parameters and food availability, predation and exploitation, the type of fishing gears used and the methodology used in the estimation are the reasons attributed for variation in growth parameters. Longevity from the east coast in the present study is much higher than that reported from the west coast (Kasim *et al.*, 2002; Ghosh *et al.*, 2009). Length at first capture (20.28 cm) is similar to that reported (21.05 cm) from Veraval (Ghosh *et al.*, 2009). It is much lower than length at first maturity indicating that majority of them were caught before they could mature and spawn at least once in their life. This indicated stress on spawning stock with consequential impacts on recruitment and could be addressed by increasing their size and age at exploitation.

Natural mortality and exploitation ratio in the present study is much lower when compared to 1.41 and 0.77 reported by Devaraj (1981) and 1.79 and 0.62 reported by Ghosh *et al.* (2009). Natural mortality coefficient of a fish is directly related to the growth coefficient (K) and inversely related to the asymptotic length (L_∞) and life span (Beverton and Holt, 1956). *S. guttatus* with lower growth coefficient of 0.23 per year and higher asymptotic length of 71.98 cm and lifespan of 13 years was found to have relatively lower natural mortality coefficient of 0.54 per year. M/K ratio of 2.35 was within the normal range of 1-2.5, as suggested by Beverton and Holt (1959). Z/K ratio of 1.0 is considered as growth dominated and if it is more than 2, then it is mortality dominated. In the present study, it was higher than 4, indicating that fishery of *S. guttatus* is highly mortality dominated (Pauly and Soriano, 1986).

With E (0.48) very close to E_{max} (0.53) and annual average yield (2,614 t), again very close to MSY (2,747 t), further increase in yield is only marginally possible by increasing the present fishing intensity. By increasing the fishing effort by 20%, a trivial 0.82% increase in yield is possible. Therefore, a more realistic management measure would be to pursue the present fishing effort without further increase. Moreover in a multispecies multi-gear fishery, as exists presently, changes in effort will have to take into consideration other target species as well. Seerfishes

being highly migratory; multiple fisheries occur at different locii on the overall migratory routes and stock abundance depends on the condition prevailing elsewhere also. Thus, information gained from stock assessment will have its own limitations but will provide valid evidence necessary for management guidelines and can be taken as an indicator of the present status of the fishery off Andhra Pradesh. A seasonal ban on usage of small meshed gill nets is an option to reduce overfishing. Harvesting by highly selective gear *viz.*, large meshed drift gill nets and hooks and lines will conserve the juveniles of seerfish.

Acknowledgements

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