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Fishery, biology and stock structure of the King seer, *Scomberomorus commerson* off Andhra Pradesh

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Original Article

Abstract

The fishery, reproductive biology and stock structure of the king seerfish, *Scomberomorus commerson* (Lacepède, 1800) along Andhra Pradesh was studied during 2012 – 2014. An annual average catch of 3991 t was landed during 2012 – 2014. Gillnets were the chief contributor, contributing half of the landings, followed by hooks and lines (21.5 %), trawl nets (16.3 %) and seines (12.0 %). Growth was allometric with significant difference in growth rates between males, females and indeterminates. Overall sex ratio was 1:1.33. Length at sexual maturity was at a size of 62.5 cm. Mature females were observed round the year with a peak between September and March. Higher values of gonadosomatic index coincided with peak periods of spawning. Mature ovaries contained both maturing (0.7 mm to 0.9 mm in diameter) and mature (0.9 mm to 1.4 mm in diameter) ova. Sardine was the most preferred food item, followed by *Stolephorus*. Feeding intensity was very less, with high proportion of fishes exhibiting empty or trace amounts of food in stomach. Von Bertalanffy growth equation was $L_t = 173.2\ [1-e^{-0.24\ (t\ +\ 0.056)}]$. Bimodal recruitment pattern with recruitment occurring in all months was observed. Natural mortality, fishing mortality and total mortality were 0.43, 0.21 and 0.64 respectively. Exploitation rate was 0.33 and exploitation ratio was 0.16. Annual total Stock, Biomass and Maximum Sustainable Yield were 25731 t, 19005 t and 6082 t respectively. Marginal increase in yield and yield/recruit is possible by increasing the present level of fishing by 40%.

Keywords: *Fishery, biology, stock structure, Scomberomorus commerson, Andhra Pradesh.*

Introduction

India is one of the leading seerfish producing nations of the world, chiefly contributed by the king seer, *Scomberomorus commerson* (Lacepède, 1800) (Siddeek, 1996). It is one of the most sought after fish in the country, with excellent meat quality and fetching a very high market price. It is an epipelagic, neritic species undertaking long migrations (Randall, 1995). However, localised stocks exist in the coastal waters off the east coast of India (Chacko *et al.,* 1962). Seerfish is exploited by a variety of gears *viz.,* gillnets, hook and lines, troll lines, trawl nets and other seines. Seerfishes formed on an average 3.50% of the national marine landings during 2000 –2014. Recent landings fluctuate from 56170 t in 2012 to 49209 t in 2014, with an all time peak of 62171 t in 2007. Landings in Andhra Pradesh have increased from 5437 t in 2000 to 7729 t in 2014, with highest catch of 11466 t recorded in 2007. In recent years, the contribution of *S. commerson* to the total seerfish catch has marginally decreased at the expense of *Scomberomorus guttatus*, mostly because of targeted drift gillnet fishery for the later. It now contributes on an average 62.2% of the total seerfish caught (Maheswarudu *et al.*, 2013). It could well be possible that the resource is currently overexploited, as observed earlier by Muthiah *et al.* (2005). In addition to fishing pressure, environmental parameters are also known to influence the fishery of seerfish, often leading to wide seasonal and annual fluctuations in landings (Krishnakumar *et al.,* 2008).

Several studies on fishery (Devaraj, 1977; Muthiah *et al.*, 1999), reproductive biology (Rao, 1962, 1964; Devaraj, 1983) and stock structure (Devaraj, 1981; Thiagrajan, 1987; Yohannan *et al.*, 1992; Pillai *et al.*, 1993, 1994; Kasim *et al.*, 2002; Muthiah *et al.*, 2002; Kasim and Abdussamad, 2003) are available dating back to few decades. However, no study has been conducted on *S. commerson* from the Indian waters in the last decade. In fact, this manuscript makes a maiden attempt to study the fishery biology and stock status of *S. commerson* from the waters off Andhra Pradesh. Assessing stock assumes paramount importance for optimizing production through rational exploitation at both the national and the state level.

Material and methods

Catch data of *S. commerson* and effort expended were collected weekly from all gears at Palasa, Mukkam, Visakhapatnam, Pudimadaka, Kakinada and Machilipatnam, Andhra Pradesh, India 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 4422 specimens of *S. commerson* ranging in size from 20.0 to 165.0 cm were collected randomly and measured for fork length (cm) and body weight (0.01g 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 3210 specimens, with chi-square test done for testing the homogeneity of male and female distribution. Size at first maturity (L_{50}) was estimated from 1621 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. Feeding intensity was determined from 3210 specimens. It was classified as gorged, full, ¾ full, ½ full, ¼ full, trace and empty based on the distension of the stomach and the volume of food contained in it. Index of relative importance (IRI) (Pinkas *et al.*, 1971) was used to assess the relative importance of various food items in the stomach. IRI was calculated as (%N + %V) x %F; where N = number, V = volume and F = frequency of occurrence.

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 2 cm class interval and analyzed for estimation of Von Bertalanffy growth parameters, L_∞ and K, using the ELEFAN I module of FiSAT software version 1.2.0 (Gayanilo *et al.*, 1996). From the estimates of L_∞ and K, growth performance index (φ) was computed (Pauly and Munro, 1984). Probability and size at first capture (L_c), age at zero length (t_0) and longevity or t_{max} was calculated (Pauly, 1979; 1983a; 1984). Von Bertalanffy growth equation, $L_t = L_\infty\ (1 - \exp^{-k\ (t-\ t_0)})$, was used for determining age and growth. Length at recruitment (L_r) was taken as the midpoint of the smallest length group in the catch. Natural mortality (M) was estimated taking the mean sea surface temperature as 28 ^{0}C and total mortality (Z) was calculated from the length converted catch curve (Pauly, 1980; 1983b). Fishing mortality (F) was Z–M. Fishing mortalities per length class were obtained from length structured virtual population analysis (VPA) of FiSAT. Exploitation rate (E) was F/Z and exploitation ratio (U) was F/Z $(1\text{-}\exp^{-z})$. 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. Maximum Sustainable Yield (MSY) was calculated by the equation of Gulland (1979). Beverton and Holt relative yield per recruit (Y/R) and biomass per recruit (B/R) at varying F levels was assessed using Excel worksheet (Sparre, 1987).

Results

Fishery

An annual average catch of 3991 t of *S. commerson* was landed during 2012 – 2014. Highest catch of 4781 t was recorded in

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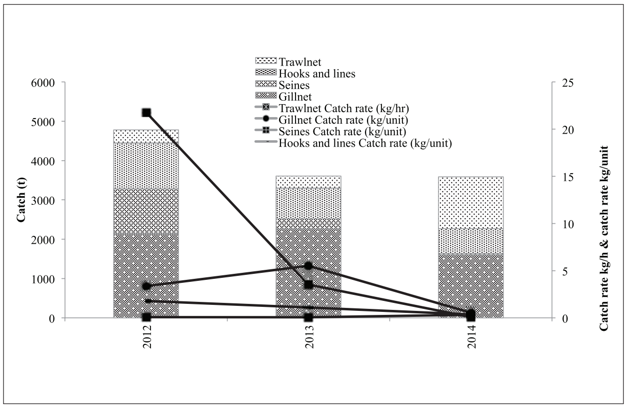

Fig. 1. Annual catch and catch rates of *S. commerson*

2012, after which landings have decreased gradually to 3604 t in 2013 and 3586 t in 2014 (Fig. 1). Gillnets were the chief contributor, contributing half of the landings, followed by hooks and lines (21.5%), trawl nets (16.3%) and seines (12.0%). Majority of the catch was from gillnets, an annual average of 2000 t. Average catch rate in gill net was 3.13 kg/ unit, forming roughly 3% of the gill net catches. Trawlers contributed significantly in 2014 with a landing of 1318 t. Average catch rate in trawls for the period was 0.15 kg/h and it contributed less than 1% of the trawl catch. Catches in hooks and lines (1164 t) and seines (1144 t) were the highest in 2012, after which it decreased sharply, especially in seines. Catch rate in hooks and lines and seines for the period was 1.08 kg/unit and 8.45 kg/unit. It formed on an average 1.31% and 1.46% of the landings from hooks and lines and seines. Seasonal abundance revealed the landings to be the highest during the winter months of November–February (Fig. 2). Gillnets contributed significantly during the first half of the year. Landing in trawls was comparatively higher during August–December, whereas most of the landings from seines were in November. Catch in hooks and lines were more or less steady throughout the year.

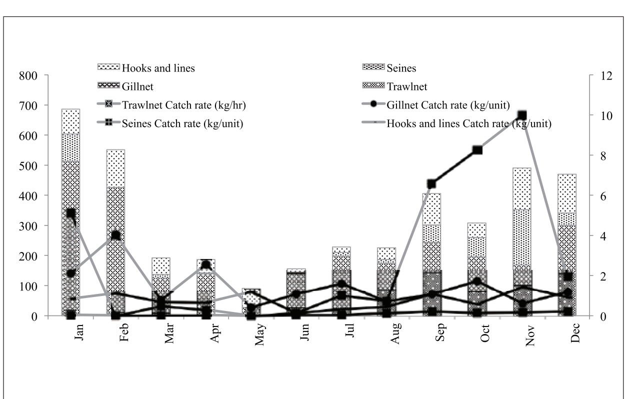

Fig. 2. Monthly catch and catch rates of *S. commerson*

Length composition

The length frequency distribution of *S. commerson* for the three year period indicated exploitation of juveniles during March to July. Among the years, more juveniles were exploited in 2012 and 2014, than in 2013. A single peak in the length frequency was observed, indicating that sizes from 41 cm to 85 cm dominate the fishery. Mean length of 669.8±105.1 mm observed in 2012 increased to 793.5±98.7 mm in 2013, after which it decreased to 737.7±87.7 mm in 2014. Highest mean length of 808.5±26.8 mm was recorded during December and the lowest mean length of 571.3±112.9 mm was recorded in July (Fig. 3).

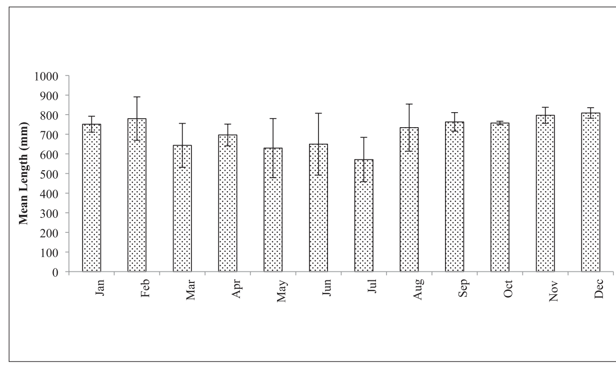

Fig. 3. Mean length of *S. commerson* in different months

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

Male: log W = -1.8002 + 2.8274 log L (r = 0.99) (95 % C. I.)

Female: log W = -2.0609 + 2.9712 log L (r = 0.99) (95 % C. I.)

Indeterminate: log W = -0.4310 + 1.9333 log L (r = 0.98) (95 % C. I.)

Significant differences were observed in the slopes of length-weight relationship for males, females and indeterminates at 5% level. Also, the slopes of the regression relation for males (t_{cal} = 18.34; $t_{crit\ 0.05}$ = 1.96), females (t_{cal} = 3.20; $t_{crit\ 0.05}$ = 1.96) and indeterminates (t_{cal} = 54.07; $t_{crit\ 0.05}$ = 1.97) were significantly different from the isometric value of 3 indicating allometric growth in all.

Sex Ratio and Size at first maturity

Females dominated the commercial catches in most months for all the years with annual sex ratio varying from 1:1.31 to 1:1.38. Overall sex ratio was 1:1.33. Chi-square values indicated significant ($p<0.05$) dominance by females from

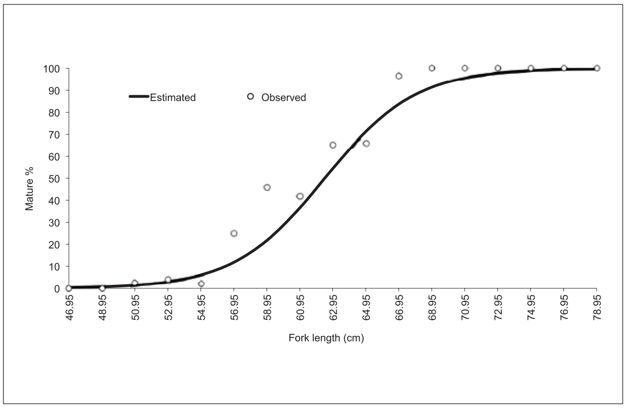

Fig. 4. Length at first maturity for females of *S. commerson*

October to February. *S. commerson* attained sexual maturity at a size of 62.5 cm (Fig. 4). However, gonadal development and sexual maturity in the species was observed to commence from 51 cm onwards.

Spawning season and Gonadosomatic index (GSI)

King seer was found to spawn round the year, as evident in the occurrence of mature females in subsequent numbers throughout the year (Fig. 5). High proportion of mature females, ranging from 31.5 % to 49.1 %, was observed between September and March, confirming it to be the peak spawning season. Annually, maturity of females ranged between 32.8 % and 38.4

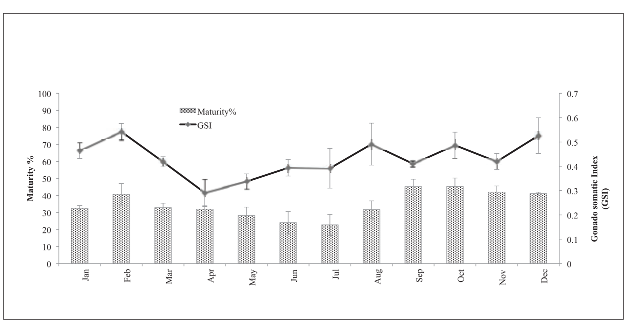

Fig. 5. Maturity and gonadosomatic index (GSI) of females in different months

% and GSI from 0.42 to 0.46. Results obtained from GSI are in full conformity to the presence of matured females. Peak GSI values ranging from 0.53 – 0.54 was observed in December and February (Fig. 5). In general, GSI was higher during August to February.

Fecundity and ova distribution

Fecundity, in general, increased with the length and weight of the fish. Absolute fecundity ranged from 95000 eggs to 372857 eggs, with a mean of 256187 eggs. Relative fecundity per g body weight varied from 18.18 eggs to 87.02 eggs with an average of 45.79 eggs. The mature ovaries contained both maturing and mature ova. The mature ova measured from 0.9 to

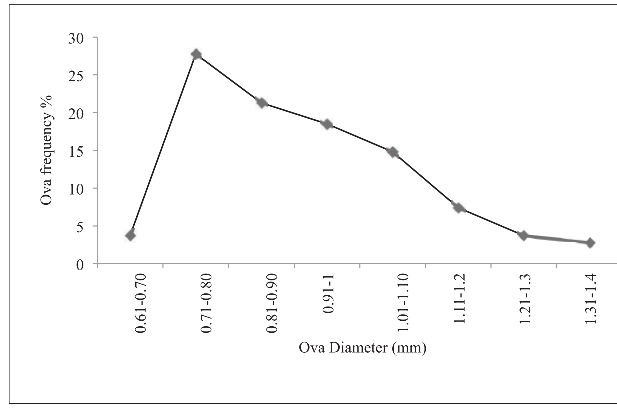

Fig. 6. Ova diameter distribution in females

1.4 mm in diameter whereas the maturing ova measured from 0.7 to 0.9 mm (Fig. 6). The presence of yolked ova of different sizes in mature ovary for most months of the year indicated prolonged spawning. However the largest sizes of yolked ova were encountered mostly from December to February.

Feeding intensity and food composition

Sardine (IRI % 62.4), both oil sardine and lesser sardines and *Stolephorus* (IRI % 20.4) were the principal food constituents of king seer. It was also found to prey on *Acetes* (IRI % 3.4), rainbow sardine (IRI % 2.6), mackerel (IRI % 1.6), *Decapterus* (IRI % 1.4), *Selar* (IRI % 1.3) and *Photololigo* (IRI % 1.9), along with a host of other finfishes and shellfishes. Adults fed mostly on finfishes, while juveniles fed on *Acetes* and juvenile squids. Both, Sardine and *Stolephorus* were abundant in the gut throughout the year. Fishes with empty or trace amounts of food in stomach were high in all the three years (76.8% to 77.8%). Fishes with quarter filled and half filled stomachs varied from

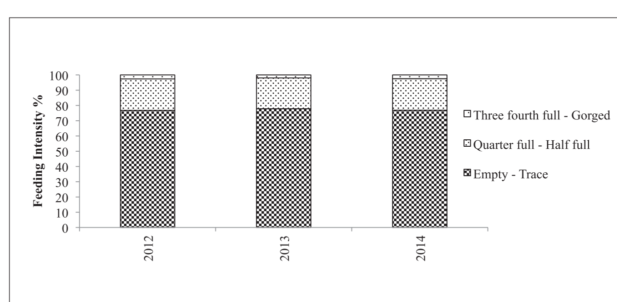

Fig. 7. Annual feeding intensity of *S. commerson*

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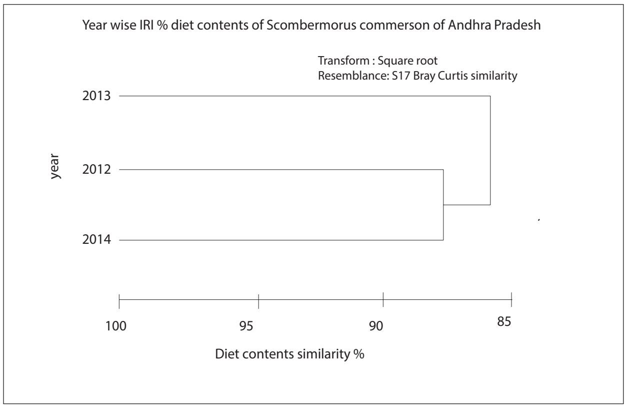

Fig. 8. Annual similarity in the diet contents of *S. commerson*

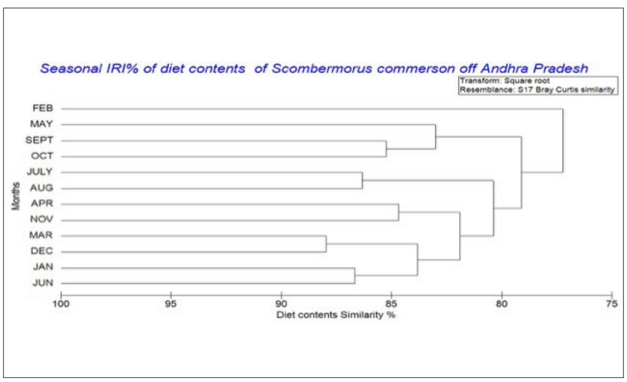

Fig. 9. Monthly similarity in the diet contents of *S. commerson*

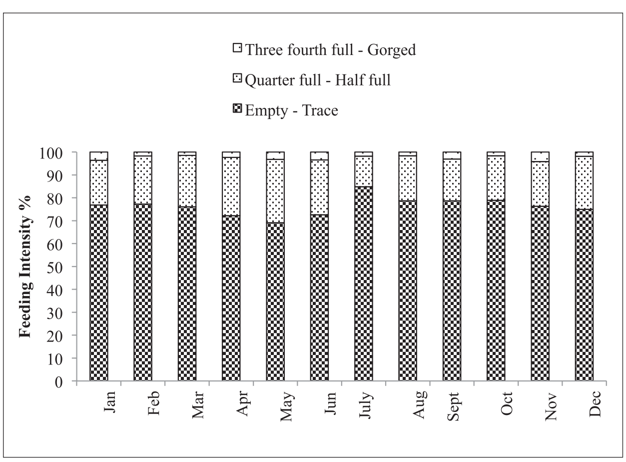

Fig. 10.Monthly feeding intensity of *S. commerson*

20.2% to 20.7% (Fig. 7) There was no significant difference ($p>0.05$) in the food and feeding habits between years (Fig. 8). Feeding intensity was more or less the same throughout the year (Fig. 9), with marginal increase during April to June. Fishes possessing empty stomachs were encountered frequently (69.1 %–84.8 %) in all the months (Fig. 10).

Growth

The growth parameters, L_∞ and K (annual) estimated using the ELEFAN I programme are 173.2 cm and 0.24/year. Growth performance index, φ was found to be 3.86 and t_0 was calculated at -0.056 years. The von Bertalanffy growth equation can be written as:

$$L_t = 173.2\ [1 - \exp^{-0.24\ (t\ +\ 0.056)}]$$

Accordingly, the fish attained a size of 38.76 cm, 67.45 cm, 90.01 cm, 107.76 cm and 121.72 cm respectively by the end of 1, 2, 3, 4 and 5 years. The fish grows faster in the early part of its life. Longevity was >12 years. Fishery was dominated by fishes of 1 year, 2 year, 3 year and 4 year old classes. The length at first capture (L_c) was 19.37 cm which corresponds to an age (t_c) of 0.44 year.

Recruitment

Bimodal recruitment pattern with recruitment occurring in all months was observed for *S. commerson*. One peak in recruitment was during March–June and the other in October–November. Recruitment pulse during March–June produced 42.34% of the recruits and 27.26% of the recruits were in October –November. Average annual recruit into the fishery was 4219721 numbers. The smallest length of recruitment was 19.0 cm.

Mortality, exploitation and Virtual Population Analysis

The mortality rates M, F and Z computed were 0.43, 0.21 and 0.64 respectively. The length converted catch curve utilized in the estimation of Z is represented in Fig.11. The

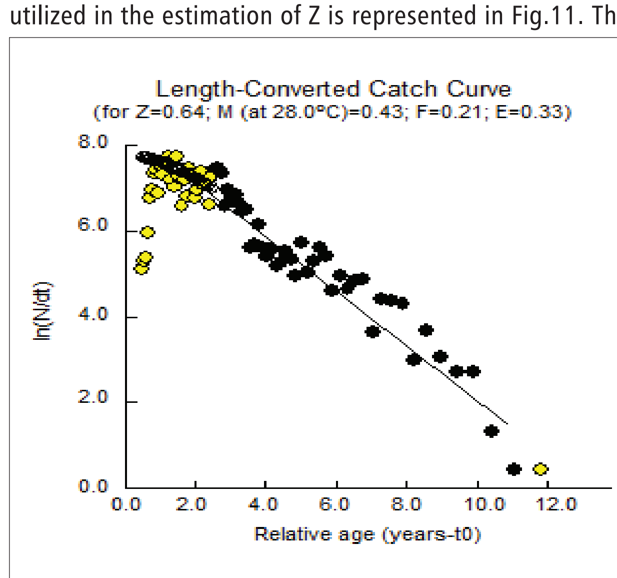

Fig. 11. Length converted catch curve of *S. commerson*

exploitation rate (E) was 0.33 and exploitation ratio (U) was 0.16. The VPA indicated that main loss in the stock up to 77.0 cm size was due to natural causes. Fishes became more vulnerable to the gear after this size and mortality due to fishing increased and eventually outnumbered the natural losses at139.0 cm. Maximum fishing mortality of 1.82 was recorded at size of 159.0 cm.

Stock and Maximum Sustainable Yield (MSY)

The annual total stock, biomass and MSY were estimated at 25731 t, 19005 t and 6082 t respectively.

Yield / Recruit

Yield and biomass curves showed that yield and yield/recruit could marginally be increased by increasing the present level of fishing by 40% (Fig. 12). Maximum yield and yield per recruit obtained by increasing the present fishing effort by 40% is 4115.4 t and 975.3 g, whereas at the present level of fishing, it is 3991.0 t and 945.8 g. Increase in relative yield at the increased effort is a trivial 3.12% (Fig. 13).

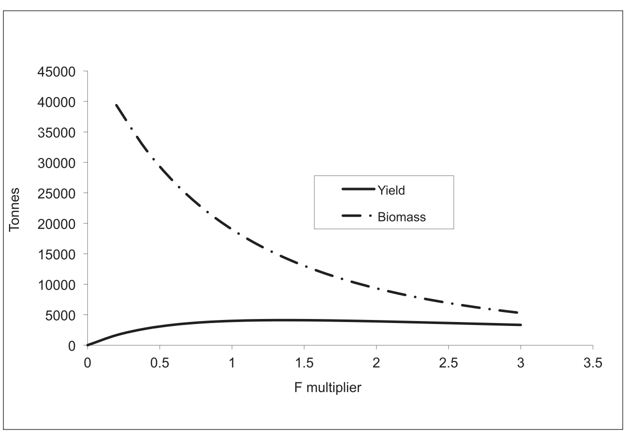

Fig. 12. Yield and biomass of *S. commerson* for different multiples of F

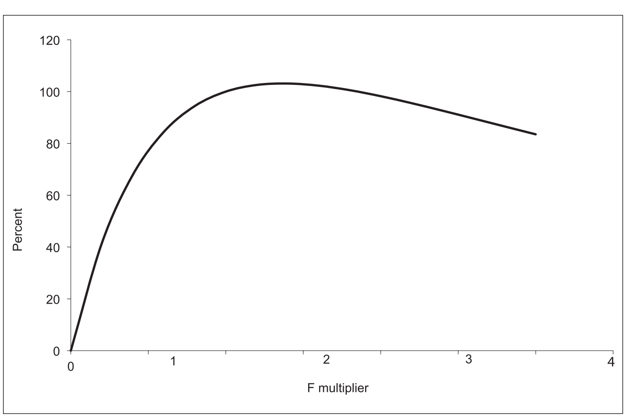

Fig. 13. Yield relative to present yield of *S. commerson* for different multiples of F

Discussion

Catches of *S. commerson* have decreased over the years as is the catch rates. Maheswarudu *et al.* (2013) reported highest landing to the tune of 7326 t in 2007. In the present period, annual average landing is only 3991 t. It is exploited along Andhra Pradesh coasts by a multitude of gears, but mostly by gillnets. Peak landings in individual gears are commensurate with the increased effort of the gear in that period. Large number of gillnets operate here almost throughout the year with increasing the effort year after year and hence contribution by gillnets to the seerfish fishery of this region has become significant. Both monofilament (naravavala) and multifilament (nylon vala) gillnets are actively employed in catching *S. commerson.* Mesh size varies from 120 mm to 200 mm with net length of 8 m to 12 m. Trawlnets with cod end mesh ranging from 20 mm to 30 mm also exploit *S. commerson*, as do ring nets having mesh size of 30 mm to 50 mm. King seer is also caught in good amounts in hooks and lines. Gillnets, ring seines and hooks and lines are operated both from mechanized and motorized crafts (outboard and inboard). The mechanized crafts have an overall length (OAL) ranging from 14 – 16 m and are powered by 100 – 180 hp engines, whereas the motorized crafts have an OAL varying from 7 – 12 m and uses engines of 8 – 20 hp. Trawlers have an OAL from 11 – 15 m and are driven by engines having 90 – 250 hp. Good catches were observed during October – February along the waters off Andhra Pradesh. Variations observed in catch and catch rates among gears and months are due to the differences in the fishing grounds and the depth of operation coupled with changes in the distribution.

Length and weight observed is less than that reported earlier from Palk bay (Devaraj, 1981). Mean length exhibited fluctuating trend. Similar mean lengths, close to 70 cm, was reported from the landings of large meshed gillnets along Karnataka coast (Dineshbabu *et al.*, 2012). Silk (small meshed gill) nets operating in June and July land good catches of juveniles of *S. commerson* (Maheswarudu *et al.*, 2013). Therefore lowest mean length was recorded in July. Highest mean length recorded in December is because of extensive operations of large meshed drift gillnets (mesh size of 170 mm to 190 mm). Growth was allometric with significant difference in growth rates between males, females and indeterminates. Similar exponent values varying from 2.80 to 2.97 were reported earlier by various authors from varied locations (Devaraj, 1981; Kasim and Hamsa, 1989; Thiagrajan, 1987; Pillai *et al.*, 1993; Naik *et al.*, 1998; Muthiah *et al.*, 2002).

In contrary to the findings of Devaraj (1981), dominance of females was reported in all years in most months. This is

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because of differential fishing caused by changes in the pattern of migration of sexes to and from the fishing grounds. Fish attained sexual maturity and spawned at the end of second year. Length at first maturity is lower than 75 cm (FL) reported from Palk bay (Devaraj, 1981) and 70 cm (FL) from the Karnataka waters (Dineshbabu *et al.*, 2012). Differences observed in maturity sizes are because of the differences in exploitation patterns and rates and on the influence of environment on the biology and food availability of the fish.

Mature females were observed round the year with a spurt between September and March. Higher values of gonadosomatic index coincided with peak periods of spawning. Observations on the spawning season are supported by the size progression of yolked ova during different months. In the present study, ripe ovaries contained two batches of ova, one maturing and the other mature. However, from gonad index and ova diameter analysis, Devaraj (1983) reported an extended spawning period from January to September, with a peak in April-May in Palk Bay, Gulf of Mannar and the south-east Arabian Sea. The same author showed the existence of two distinct groups of mature ova released in three batches, spawning successively at an interval of a month or even less, which is in conformity to the present study. Increase in fecundity in relation to the weight of fish was much lower than that of the length of fish.

S. commerson is carnivorous and a top predator. In the present study, it showed preference for Sardine and *Stolephorus* as prey. It is essentially a surface feeder, feeding on a limited diet, of which the sardine is the most important followed by the whitebaits (*Stolephorus*). Abundance of sardines and whitebaits in the waters of Andhra Pradesh has been increasing over the past decade (Maheswarudu *et. al.*, 2013). Similar views were expressed by Rao (1964) and Devaraj (1998). Juveniles fed on *Acetes* and juvenile squids, whereas adults preferred finfishes. Ontogenetic switches in feeding habits result from increase in body and mouth sizes that permit fish to capture a broader range of prey sizes and types (Labropoulou *et al.*, 1997). It showed minimal annual and monthly variations in diet composition and feeding intensity. Feeding intensity was very less, with high proportion of fishes exhibiting empty or trace amounts of food in stomach.

Asymptotic length of 173.2 cm estimated in the present study is more or less similar to 177.72 cm (FL) reported by Thiagrajan (1987). However, much lower estimates ranging from 137.6 cm to 162.0 cm (FL) were reported earlier by various authors (Yohannan *et al.*, 1992; Pillai *et al.*, 1993; Kasim *et al.*, 2002; Muthiah *et al.*, 2002; Dineshbabu *et al.*, 2012). Conversely, Devaraj *et al.* (1981) recorded a very high L_∞ of 208.1 cm. Higher values of growth co-efficient (0.38 – 1.36), from the present study has been observed by all the above authors, except Devaraj *et al.* (1981). A comparison of growth performance index obtained in the present study and those reported by earlier authors is presented in Table1. Length attained each year for five years were similar to those estimated by Devaraj *et al.* (1981), Naik *et al.* (1998) and Kasim *et al.* (2002). Higher initial lengths after 1 year were reported by Thiagrajan, 1987 (623 cm FL), Pillai *et al.*, 1993 (800 cm FL) and Muthiah *et al.*, 2002 (930 cm FL). This wide variation in growth parameters estimated is attributed to differences in environmental parameters and food availability, predation and exploitation and more on the type of fishing gears used and the methodology used in the estimation. Similar conclusions were drawn by Pillai *et al.* (1993), wherein, according to them, variations in growth parameters of king seer was because of different gears (drift gillnets, hooks and lines, troll and trawls) used for their exploitation and the different sizes of fishes caught by these gears. Length attained each year for five years were similar to those estimated by Devaraj *et al.* (1981), Naik *et al.* (1998) and Kasim *et al.* (2002). High value of growth performance index indicated rapid growth for the species.

Table 1. Comparison of growth performance index obtained in the present study and those reported by earlier authors

Value	Reference
3.86	Present Study
3.81	Devaraj, 1983
4.08	Thiagrajan, 1987
3.61	Grandcourt *et. al.*, 2005
4.1	Darvishi *et. al.*, 2011
3.81	Fakhri *et. al.*, 2015

Fishery was dominated by fishes of 1 to 4 year old classes, as reported earlier from the east coast by Thiagrajan (1987) and Kasim *et al.* (2002). Growth in king seer is rapid during the first few years of life, after which it declines (Dudley *et al.*, 1992; McIlwain *et al.*, 2005). Longevity is reported to vary between 7–22 years (Devaraj, 1981; Mackie *et al.*, 2005). Age at recruitment obtained by converting length into age, in the present study was less than half a year, which is similar to 0.25 year reported from Oman and Saudi Arabian waters (Bertignac and Yesaki, 1993). The same authors reported peak recruitment during October–November, which coincided with our study. Length at first capture (19.37 cm) 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. Similar length at first capture varying from 17.5 cm to 22.0 cm was reported by Kasim *et al.* (2002) and Dineshbabu *et al.* (2012). Natural mortality and exploitation ratio in the present study is much lower when compared to 0.73–1.61 and 0.70 – 0.81 reported by several authors (Yohannan *et al*., 1992; Pillai *et al*., 1993; Kasim *et al*., 2002; Muthiah *et al*., 2002; Dineshbabu *et al*., 2012). 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. commerson* with lower growth coefficient of 0.24 per year and higher asymptotic length of 173.2 cm and lifespan of 12 years was found to have relatively lower natural mortality coefficient of 0.43 per year. M/K ratio of 1.79 was within the normal range of 1–2.5, as suggested by Beverton and Holt (1959).

With E less than E_{max} (0.4) and annual average yield less than MSY, increase in yield is possible by increasing the fishing effort. However, maximum increase in yield, to the tune of 3.12%, is only possible by increasing the present fishing effort by 40%. Hence, a more realistic management measure would be to pursue the present fishing effort without further increase. Moreover in a multispecies multigear fishery, as existing 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. So 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. Seasonal ban on usage of small meshed gill nets during the months from March to July is an option to reduce overfishing. Moreover, major recruitment also happens in these months. Harvesting by highly selective gear *viz*., large meshed drift gillnets and hooks and lines will conserve the juveniles of seerfish. Again, efficient management of the fishery during the peak landing months from November to February is of paramount importance as large female spawners are observed in the nearshore waters and are caught during these months. This period is incidentally the peak spawning period for the species and coupled with decrease in length at first maturity, as observed, indiscrimate capture of brood fishes could lead to recruitment overfishing in the near future.

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References

Fakhri, A., H. Fekrandish, A. Pazira and A. Rastgoo. 2015. Length-Weight Relationship and Growth Parameters of Kingfish (*Scomberomorus commerson*) in the North of the Persian Gulf. *J. Fish. Aquat. Sci*., 10: 592-596.

Bertignac, M. and M. Yesaki. 1993. Preliminary assessment of the narrow barred Spanish mackerel stock off Oman using length-frequency distributions by the Bhattacharya method. IPTP Volumes No. 8. Part 2: Review of Status of Stocks and Tuna Biology, p. 88–95.

Beverton, R. J. H. and S. J. Holt. 1956. A review of method for estimating mortality rates in exploited fish population, with special reference to source of bias in catch sampling. *Rapp. P. V. Reun. CIEM*, 140: 67-83.

Beverton, R. J. H. and S. J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. In: Wolsenholmy, G. E. W. and M. O'Connor (Eds.), *Ciba Foundation Colloquia on ageing*, 5: 142-180.

Chacko, P. I., S. D. Thomas and C. Malupillai. 1962. Scombroid fisheries of Madras State, India. *Proc. Symp. Scombroid Fishes.* MBAI, Part 3, p. 1006-1008.

Darvishi, M., F. Kaymaram, A. Salarpouri, S. Behzadi and B. Daghooghi. 2011. Population dynamic and biological aspects of *Scombermorus commerson* in the Persian Gulf and Oman Sea (Iranian coastal). IOTC-2011-WPNT01-23.

Devaraj, M. 1977. The biology and fishery for seerfishes of India. Ph.D. thesis, Madurai Kamaraj University, 337pp.

Devaraj, M. 1981. Age and growth of three species of seerfishes *Scomberomorus commerson*, *S. guttatus* and *S. lineolatus. Indian J. Fish*., 28: 104-127.

Devaraj, M. 1983. Maturity, spawning and fecundity of the king seer, *Scomberomorus commerson* (Lacepede), in the seas around the Indian peninsula. *Indian J. Fish*., 30 (2): 203-230.

Devaraj, M. 1998. Food and feeding habits of the streaked seer, *Scomberomorus lineolatus* (Cuvier and Valenciennes), in the Gulf of Mannar and Palk Bay. *J. Mar. Biol. Ass. India*, 40 (1 & 2): 91-104.

Dineshbabu, A. P., C. Muthiah, G. Sasikumar, P. Rohit and U. S. Bhat. 2012. Impact of non-selective gears on king seer, *Scomberomorus commerson* fishery in Karnataka. *Indian J. Geomarine Sci*., 41 (3): 26 5- 271.

Dudley, R. G., A. P. Aghanashinikar and B. B. Edward. 1992. Management of the Indo-Pacific Spanish mackerel (*Scomberomorus commerson)* in Oman. *Fish. Res*., 15: 17-43.

Gayanilo, F. C. Jr., P. Sparre and D. Pauly. 1996. The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. FAO computerized information series (Fisheries). No. 8. Rome, FAO, 126 pp.

Grandcourt, E. M., T. Z. Al Abdessalaam, F. Francis and A. T. Al Shamsi, 2005. Preliminary assessment of the biology and fishery for the narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacepede, 1800), in the Southern Arabian Gulf. *Fish. Res*., 76: 277-290.

Gulland, J. A. 1979. Report of the FAO/UNDP workshop on the fishery resources of the Western Indian Ocean –South Equator. FAO, Rome, 10FC/DEV/79/ 45: 1-37.

Kasim, H. M. and K. M. S. A. Hamsa. 1989. On the fishery and population dynamics of seerfish *Scomberomorus commerson* (Lacepede) off Tuticorin (Gulf of Mannar). *CMFRI Bull*., 44 (1): 46-53.

Kasim, H. M., C. Muthiah, N. G. K. Pillai, T. M. Yohannan, B. Manojkumar, K. P. Said Koya, T. S. Balasubramaniam, U. S. Bhatt, M. N. K. Elayathu, C. Manimaran and H. K. Dhokia. 2002. Stock assessment of seerfishes in the Indian seas. In: Pillai, N. G. K., N. G. Menon, P. P. Pillai and U. Ganga (Eds.), *Management of Scombroid Fisheries*, Central Marine Fisheries Research Institute, Cochin, p. 108-124.

Kasim, H. M. and E. M. Abdussamad. 2003. Stock assessment of Seerfishes along the east coast of India. In: Somvanshi, V. S., S. Varghese and A. K. Bhargava (Eds.), *Proc. Tuna Meet*, p. 86-96.

King, M. 1995. Fisheries biology, assessment and management, Oxford University Press, Oxford, UK, 342 pp.

Krishnakumar, P. K., K. S. Mohamed, P. K. Asokan, T. V. Sathianandan, P. U. Zacharia, K. P. Abdurahiman, S. Veena and R. N. Durgekar. 2008. How environmental parameters influenced fluctuations in oil sardine and mackerel fishery during 1926-2005 along the south-west coast of India? Mar. *Fish. Inf. Serv. T&E Ser.,* 198:1-5.

Labropoulou, M., A. Machias, N. Tsimenides and A. Eleftheriou. 1997. Feeding habits and ontogenetic diet shift of the striped red mullet, *Mullus surmuletus* Linnaeus, 1758, *Fish. Res*., 31: 257–267.

Le Cren, E. D. 1951. The length weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol*., 20: 201-219.

Mackie, M. C., P. D. Lewis, D. Gaughan and S. J. Newman. 2005. Variability in spawning frequency and reproductive development of the narrow-barred Spanish mackerel (*Scomberomorus commerson*) along the west coast of Australia. *Fish. Bull. National Oceanic and Atmospheric Administration*, 103(2): 344-354.

Maheswarudu, G., G. S. Rao, P. Rohit, P. Laxmilatha, S. Ghosh and M. Muktha. 2013. *Marine fisheries of Andhra Pradesh: a decadal analysis. Indian J. Fish*., 60 (3): 27-33.

McIlwain, J. L., M. R. Claereboudt, H. S. Al-Oufi, S. Zaki and J. S. Goddard. 2005. Spatial variation of the kingfish (*Scomberomorus commerson*) in the coastal waters of the Sultanate of Oman. *Fish. Res*., 73(3): 283–298.

Muthiah, C., H. M. Kasim and U. S. Bhat. 1999. Exploited Seerfish fishery resources of India–A review. In: Pillai, V. N. and N. G. Menon (eds.), Marine Fisheries Research and Management, p. 426-467.

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Muthiah, C., H. M. Kasim, N. G. K. Pillai, T. M. Yohannan, B. Manojkumar, K. P. Said Koya, U. S. Bhatt, T. S. Balasubramaniam, M. N. K. Elayathu, C. Manimaran, H. K. Dhokia and M. V. Somaraju. 2002. Status of exploitation of seerfishes in the Indian seas. In: Pillai, N. G. K., N. G. Menon, P. P. Pillai and U. Ganga. (Eds.), *Management of Scombroid Fisheries*, Central Marine Fisheries Research Institute, Cochin, p. 33-48.

Muthiah, C., N. G. K. Pillai, U. Ganga and M. Srinath. 2005. Stock assessment of Seerfishes along the west coast of India 2003–A review. In: Somvanshi, V. S., S. Varghese and A. K. Bhargava (Eds.), *Proc. Tuna Meet,* p. 97-111.

Naik, S. K., A. Tiburtius and S. R. Bhalkar. 1998. Biology of the seerfish landed by exploratory trawlers. *Indian J. Fish*., 45(1): 35-41.

Pauly, D. 1979. Theory and management of tropical multi-species stocks. A review with emphasis on the South-east Asian demersal fisheries. *ICLARM Studies and Reviews* 1, 35 pp.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. Ciem.*, 39 (2): 175-192.

Pauly, D. 1983a. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper, No. 243, 52 pp.

Pauly, D. 1983b. Length converted catch curves. A powerful tool for fisheries research in tropics (Part-1). *ICLARM Fishbyte*, 1 (2): 9-13.

Pauly, D. 1984. Length converted catch curves. A powerful tool for fisheries research in tropics (Part-II). *ICLARM Fishbyte*, 2 (1): 13-14.

Pauly, D. and J. L. Munro. 1984. Once more, on the composition of growth in fish and invertebrates. *Fishbyte*, 2 (1): 21.

Pillai, P. P., N. G. K. Pillai, T. V. Sathianandan and M. N. K. Elayathu. 1993. Fishery biology and stock assessment of *Scomberomorus commerson* (Lacepede) from the south west coast of India. Expert consultation on Indian Ocean tunas. 5th Session, Mahe, Seychelles, 4-8 October 1993. TVVS/93/2/2, 21 pp.

Pillai, P. P., N. G. K. Pillai, T. V. Sathianandan and M. N. K. Elayathu. 1994. Fishery biology and stock assessment of *Scomberomorus commerson* (Lacepede) from South-west coast of India. *IPTP Coll. Vol. Working Doc*, 8, TWSm/2.2: 55-61.

Pinkas, L., M. S. Oliphant and I. L. K. Iverson. 1971. Food habits of albacore, bluefin tuna and bonito in California waters. *California Fish Game,* 152: 1-105.

Randall, J. E. 1995. Coastal Fishes of Oman. University of Hawaii Press, Honolulu, Hawaii, 439 pp.

Rao, K. S. 1962. Observation on the food and feeding habits of *Scomberomorus guttatus* (Bloch & Schneider) and juveniles of S *lineolatus* (Cuvier & Valenciennes) and *S. commerson* (Lacepede) from the Waltair coast. *Proc. Symp. Scombroid Fishes.* MBAI, 2: 591-598.

Rao, K. S. 1964. Observations on the food and feeding habits of *Scomberomorus guttatus* (Bloch & Schneider) and juveniles of *S. lineolatus* (Cuvier & Valenciennes) and *S. commerson* (Lacepede) from the Waltair coast. In: Proceedings of the Symposium on Scombroid Fishes, Part 2, MBAI, 12-15 January 1962, Mandapam.

Siddeek, M. S. M. 1996. Review of fisheries biology of *Scomberomorus* and *Acanthocybium* species in western Indian Ocean (FAO AREA 51). Department of Fisheries Science and Technology college of Agriculture. Sultan Qaboos University.

Snedecor, G. W. and W. C. Cochran. 1967. Statistical Methods, Oxford and IBH Publishing Co., Calcutta, India, 593 pp.

Sparre, P. 1987. Computer programming for fish stock assessment. Length based fish stock assessment (LFSA) for Apple computers. FAO Fisheries Technical Paper, 101 (Suppl 2), 217 pp.

Sparre, P. and S. C. Venema. 1998. Introduction to tropical fish stock assessment, Part 1-manual. FAO Fisheries technical paper 306-1, Rev. 2.

Srinath, M., S. Kuriakose and K. G. Mini. 2005. Methodology for estimation of marine fish landings in India. CMFRI Special publication 86, 57 pp.

Thiagrajan, R. 1987. Growth of the king Seerfish (*Scomberomorus commerson*) from the South East Coast of India. In: Venema, S.and N. V. Zalinge (Eds.), FAO/ DANIDA/ICAR National Follow-up Training Course on Fish Stock Assessment. FAO GCP/INT/392/DEN/1, p. 142–157.

Yohannan, T. M., A. A. Jayaprakash, M. Srinath, R. Thiagrajan, P. Livingston, H. M. Kasim and G. Luther. 1992. Stock assessment of *Scomberomorus commerson* along the Indian coast. *Indian J. Fish*., 39(3): 111-118.