Biology and stock assessment of the bigeye croaker *Pennahia anea* (Bloch, 1793) landed along Andhra Pradesh, north-east coast of India

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ABSTRACT

Fishery and biology of the bigeye croaker *Pennahia anea* landed by shrimp trawls at Visakhapatnam during June 2007 to December 2011 was studied and stock assessment was carried out for Andhra Pradesh. *Pennahia anea* formed 12.8% of the total sciaenids landed in the state. The mean length was 18.34 cm and length at first maturity was 16.65 cm. The growth parameters L_∞ and K were estimated as 33.0 cm and 0.7 year^{-1}. The length-weight relationship was estimated separately for male and female as Log W = -1.567 + 2.812 Log L ($r^2 = 0.88$) and Log W = -1.9229 + 3.094 Log L ($r^2 = 0.96$) respectively. Female bigeye croaker showed positive allometric growth whereas male showed negative allometric growth. The total mortality (Z) was 4.23, natural mortality (M) 1.35 and fishing mortality (F) was 2.88. The exploitation rate (E) was 0.68. Yield-per-recruit at current fishing was 37.905 g and maximum yield-per-recruit was 38.282 g indicating that the stock of bigeye croaker along Andhra Pradesh coast is being optimally exploited.

Keywords: Andhra Pradesh, Bigeye croaker, Sciaenids, Shrimp trawls

Introduction

Sciaenids form an important constituent of the demersal fish resources exploited along Andhra Pradesh coast, forming 10-15% (Rao, 1976) and 7.5-8.8% (Rajkumar *et al.*, 2005) of trawl landings during 1994 - 2003. The bigeye croaker *Pennahia anea* (Bloch, 1793) is an important species contributing substantially to the commercial sciaenid catch of the state, from as early as 1961. It contributed 29% during 2002 (Mohanraj *et al.*, 2003) and 12.5% during 1994-2003 to sciaenid landings in demersal trawl fishery off Visakhapatnam (Rajkumar *et al.*, 2005). The biology of the species has been studied from Waltair and Kakinada in Andhra Pradesh (Rao, 1964; Rao, 1976, Murty and Ramalingam, 1986). Growth studies are however more recent (Bhuyan *et al.*, 2012). However, holistic information of biology, growth and stock assessment of *P. anea* in recent times is lacking for this area. The present study aims at bridging this gap by providing information on fishery, biology and stock status of *P. anea* exploited along Andhra Pradesh.

Materials and methods

Monthly data on catch and effort of mechanised trawls were collected throughout the year from major and minor fish landing centres in Andhra Pradesh during the period from 2007 to 2011, except during the seasonal ban period (April 15 - May 31). Monthly and annual estimates of landings for the state were estimated following the Stratified Multistage Random Sampling Design (Srinath *et al.*, 2005). Data on species composition of sciaenids landed was collected weekly from Visakhapatnam Fisheries Harbour. Fish samples were collected and were measured for length (cm) and weight (g). A total of 2562 (1365 females and 1197 males) samples with a length range of 10.0 - 26.0 cm were used for estimating the length-weight relationship. Length-weight relationship was estimated as W=aL^b (Le Cren, 1951) separately for each sex. Difference in length-weight relationship between sexes was tested at 5% level of significance by testing difference in slopes by ANACOVA (Snedecor and Cochran, 1967). The slope

value b was tested against the isometric value of 3 using Student's t-test at 5% level of significance (Snedecor and Cochran, 1967). Maturity stages were followed as described by Rao (1964) based on the classification given by the International Council for the Exploration of the Sea. Size at first maturity was estimated by fitting the proportion of mature fish in a given length class of 1 cm each to the logistic curve (King, 1995):

P   = $1 / (1 + \exp[-r(L-Lm)])$

where,

P   =   proportion of mature fish in each length class

R   =   slope of the logistic curve

L   =   total length of fish (cm)

Lm =   Length which corresponds to a proportion
       of 0.5 in reproductive condition

Fish length data was grouped into 1cm class intervals for each month to arrive at monthly length frequency data. The length frequency data pooled over five years was used for estimation of growth parameters. Growth was estimated using von Bertalanffy's growth equation (von Bertalanffy, 1938), $L_t = L_\infty(1-e^{(-k(t-t0))})$ using the ELEFAN I module in FiSAT II software (Gayanilo *et al.*, 2005). The probability of capture and size at first capture (Lc) were estimated as in Pauly (1984) and the age at zero length (t_0) from Pauly's (1979) empirical equation, $Log (-t_0) = -0.392 - 0.275 Log L_\infty - 1.038K$.

Natural mortality (M) was calculated using Pauly's empirical formula (Pauly, 1980), taking the mean sea surface temperature to be 28°C and total mortality (Z) calculated from length converted catch curve (Pauly, 1983b) using FiSAT II software. Fishing mortality (F) was estimated as: F = Z - M. Exploitation rate was estimated from the equation, E = F/Z. The relative yield per recruit (Y/R) and biomass per recruit (B/R) at different levels of F was estimated from Beverton and Holt Yield per Recruit model. Status of stock is evaluated based on Y/R. Longevity was estimated by $t_{max} = 3/K + t_0$ (Pauly, 1983a).

Results and discussion

Fishery of sciaenids and bigeye croaker

The average annual landing of sciaenids by shrimp trawls along Andhra Pradesh during 2007-2011 was 7590.8 t, ranging from 6085 t in 2007 to 8246 t in 2011. Sciaenids formed on an average 6.7% of total marine landings of shrimp trawls. The average annual landing of bigeye croaker during the study period was 877 t ranging from 553 t in 2007 (June to December) to 1146 t in 2010. Bigeye croaker contributed 12.6% of total croaker

landings of the state. The catch rate (catch per hour) of the species ranged from 0.07 kg h⁻¹ in 2008 to 0.1 kg h⁻¹ in 2010 (Table 1). The highest landing of *P. anea* was in the month of January followed by September (Fig. 1).

Table 1. Total landings, catch rate and percentage contribution of *Pennahia anea* along Andhra Pradesh

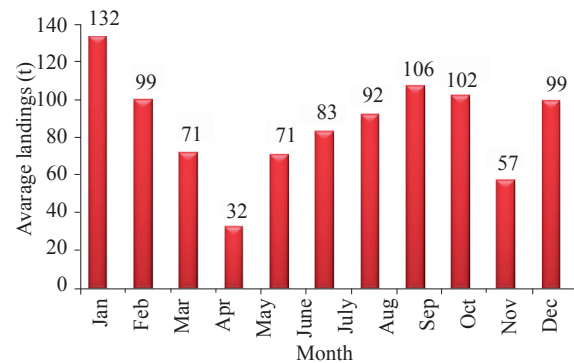| Year	Total landings of *P. anea* (t)	Catch rate of *P. anea* in trawls (kg h⁻¹)	Contribution of *P. anea* to croaker landings in Andhra Pradesh (%)
2007	553	0.09	15.0
2008	736	0.07	9.98
2009	1081	0.09	16.7
2010	1146	0.10	13.6
2011	869	0.08	7.75

Fig. 1. Average monthly landings of *Pennahia anea* along Andhra Pradesh.

Sciaenids are distributed all along the Andhra - Odisha coast (Sekharan *et al.*, 1973; Rao, 1976) with good fishing grounds both north and south of Visakhapatnam. Rao (1976) based on the results of exploratory surveys made during the year 1975-76, stated that catch rates of sciaenids was 0.6 kg h⁻¹ and 0.4 kg h⁻¹ from depths of 20 - 30 m and 40-59 m respectively from Visakhapatnam. This group contributed 10-15% of the catches in trawlers along Visakhapatnam (Rao, 1976). During 1979-88, the resource formed 6% of the state's total landings (Rao *et al.,* 1992). The potential for sciaenids as estimated from the work of Reuben *et al.* (1987) for Andhra Pradesh was 9351 t. During the study period, the average landings of sciaenids was 7590 t which is 81.2% of the potential, indicating optimal exploitation.

Rao (1982) reported that *P. anea* was the most important sciaenid species caught by mechanised trawls in this area and constituted more than 60% of the sciaenids landed by trawlers at Waltair during 1963-1970 (Rao, 1981). During the year 2000, bigeye croaker formed 29% of all sciaenids from Visakhapatnam (Mohanraj *et al.*, 2003). The present study has indicated that the species formed only 12.8% of total sciaenids landed by trawlers.

The consistent reduction in contribution of this species to sciaenid landings indicate either diminished catches of the species or enhanced catches of other sciaenid species. Lack of time series data on landings of sciaenid species for Andhra Pradesh limits any inferences that can be made regarding this issue.

Length-weight relationship

The length-weight relationship of bigeye croaker was estimated for each sex separately as follows:

Female : Log W = -1.9229 + 3.094 Log L (r^2 = 0.96)
Male : Log W = -1.567 + 2.812 Log L (r^2 = 0.88)
    where, W = weight of fish in g and L = total length of fish in cm.

The length-weight relationship of male and female showed significant differences in slope (p < 0.05). Hence a pooled length-weight relationship was not estimated. The slope value for both male and female fish varied significantly from the isometric value of 3 (p <0.05) indicating positive allometric growth in females and negative allometric growth in males.

The length-weight relationship of *P. anea* caught from Andhra-Odisha coast was estimated by Rao (1982) as log W = -1.6317 + 2.8459 log L. The length-weight relationship for the species landed at Kakinada was estimated as log W = -4.63735 + 2.89708 log L with isometric growth (Murty and Ramalingam, 1986). Both the length-weight relationships mentioned above were calculated by pooling data of both sexes as the ANOCOVA tests performed by the authors did not show significant difference at 5% level. Further, they did not report significant difference of b value from 3, implying isometric growth. However, separate length-weight relationship was estimated in the present study as significant difference was observed between sexes at 5% level (p < 0.05). In addition, the 'b' values for male and female fish also were significantly different from 3 at 5% level (p < 0.05). The present results indicated positive allometric (b > 3) growth in female fish and negative allometric (b < 3) growth in male fish in the area. A b value greater than 3 indicates that large specimens have increased in height or width more than in length, either as a result of notable ontogenetic change in body shape with size or most large specimens in the sample were thicker than small specimens (Froese, 2006). A b value less than 3 indicates that large specimens have changed their body shape to become more elongated (Froese, 2006). Thus large sized male and female fish differ in their growth patterns with female fish putting on weight faster than length. This is to be expected as female

fish will exhibit increasing weights of the gonads with respect to maturity and spawning.

Size range of bigeye croaker reported by Rao (1976) ranged from 7.1 to 32.0 cm from the Andhra - Odisha coasts. More recently the L_{max} reported for the species was 28.6 cm from Paradeep, Odisha (Bhuyan *et al*., 2012). The size in the present study ranged from 9.5 cm to 28.3 cm indicating a reduction in maximum size obtained. Fishing tends to remove the large sized specimens from the stock which could result in lower L_{max}.

Size at first maturity

The length at first maturity was estimated at 16.65 cm (Fig. 2). The smallest mature fish in the sample was 13.4 cm. The mean length of female fish was 18.36 cm.
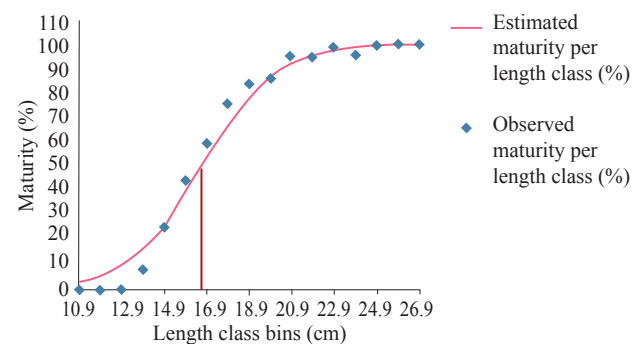

Fig. 2. Length at first maturity for *Pennahia anea* (female)

Size at first maturity was reported as 14.7 cm at Kakinada (Murty and Ramalingam, 1986), 15.0 cm at Waltair (Rao *et al*., 1992) and 13.5 cm at Palk Bay (Rao *et al*., 1992). Male and female fish attained sexual maturity at 13.4 cm and 14.8 cm lengths at Porto Novo (Gandhi, 1982). The size at first maturity for *P. anea* estimated in our study is higher than reported earlier indicating that this species is now maturing at a larger size. This indicates an environment that is conducive for the fish to mature at larger sizes. Fishing effort in the area has shown progressive increase and with increasing fishing, fish tend to mature faster. The contraindication here could be due to the extension of fishing grounds that has happened since 1990 when sona boats were introduced in the trawl fishery of Andhra Pradesh (Rajkumar *et al*., 2005). All previous maturity studies for the species from this area have been prior to 1990. Sona boats undertake long voyage fishing trips and have resulted in enormous increase in fishing effort in the study area as well as new areas are being subjected to fishing. Thus populations of *P. anea* present

in areas not being fished before 1990, would have faced relatively low fishing pressure and consequently would exhibit better (slower growth, late maturation) life history parameters. Hence it is possible that the present landings of bigeye croaker are dominated by fish caught from relatively less fished areas resulting in the late maturation seen in the present study. Environmental and climatic change could also be a contributor especially influencing the availability of food for the species.

Spawning season

A prolonged spawning season with mature and gravid fish in the catch was observed throughout the year. The lowest percentage of mature fish was seen in April (14.8%) and the highest percentage in July (58.8%) (Fig. 3). High percentage of mature fish was also seen in February, September and December.

A short spawning season from December to March has been reported earlier for the species from Visakhapatnam (Rao, 1964) and from September to October at Porto Novo (Gandhi, 1982). However a protracted spawning season from October to June at Kakinada was reported
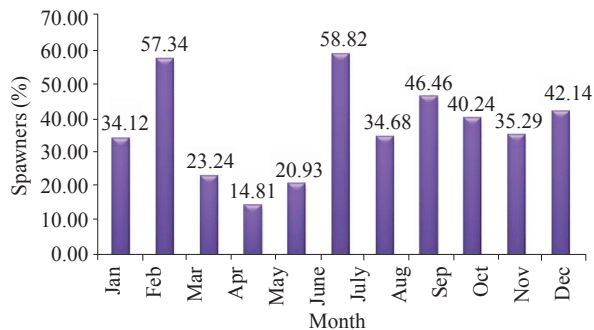

Fig. 3. Monthly occurrence of spawners (%) of *Pennahia anea.*

by Murty and Ramalingam (1986). Thus the spawning season of this species varied with location. Murty and Ramalingam (1986) have also reported that female adult *P. anea* spawns twice a year similar to *Johnius vogleri*. A protracted spawning season as indicated in the present study indicates mixing of sub-populations that spawn at different times based on different fishing areas being covered.

Growth

The asymptotic length or L_∞ for bigeye croaker was estimated as 33.0 cm. The growth parameter K was estimated as 0.70 year^{-1}. Length at age zero (t_0) was estimated at -0.03. Thus the von Bertalanffy growth equation for *P. anea* landed at Visakhapatnam is:

$$L_t = 33(1-e^{(-0.7\,t-(-0.03))})$$

Using the above equation, length of *P. anea* at the end of first and second year was estimated as 16.94 and 24.86 cm respectively. The longevity was estimated as 4.26 years. The length at which 50% of the fish were caught (L_c) was 15.56 cm and their corresponding age was 0.88 years. The smallest length recorded in our study was 9.5 cm corresponding to an age of 0.46 years. The maximum length obtained in the study was 28.3 cm corresponding to an age of 2.76 years. The mean length of the sample was 18.34 cm corresponding to an age of 1.13 years. The length at 50% maturity of 16.65 cm corresponds to an age of 0.97 years. The fishery was dominated by 15.9-21.9 cm classes which correspond to ages of 0.91-1.53 years. Hence most of the fish get caught by the trawlers before completing two years of age.

Estimates of growth parameters L_∞ and K for the species from Paradeep (Bhuyan *et al.*, 2012) are 30.4 cm and 0.86 year^{-1}. Our estimate of L_∞ is higher at 33.0 cm and K lower at 0.7 year^{-1}. The results of Bhuyan *et al.* (2012) are based on samples collected for only one year, during 2011-2012, possibly leading to the difference in estimates. Other studies in India, from Bombay waters (Chakraborty, 1996; Chakraborty *et al.*, 1997) have reported L_∞-K combinations of 26.0 cm - 1.2 year^{-1} and 24.5 cm - 0.64 year^{-1}. The largest sized fish recorded in Bombay was 24.9 cm and 22.9 cm, which are lower when compared to the present L_{max} of 28.3 cm.
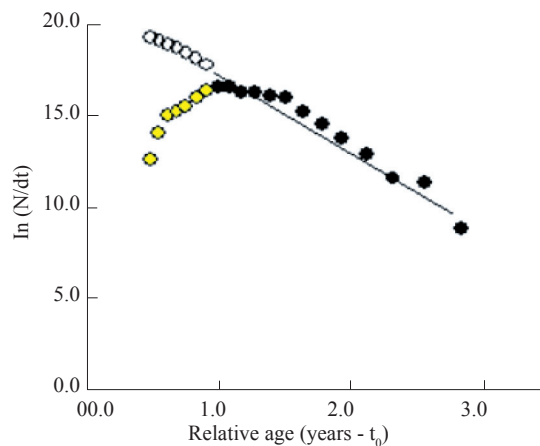
Mortality

The total mortality (Z), natural mortality (M) and fishing mortality (F) were estimated as 4.15, 1.38 and 2.77 respectively (Fig. 4). The exploitation rate (E) was estimated as 0.67.

Yield and yield/recruit

The Beverton and Holt yield per recruit model indicated that at present fishing levels, the yield and yield per recruit was 887.0 t and 37.905 g (Fig 5). The maximum yield and yield per recruit of 895.83 t and 38.282 g can be obtained at fishing levels of 1.4 *i.e.*, at an increase of 40% from present fishing levels.

The fishery is dominated by fish that are one year old and E is above 0.5 indicating exploitation above optimum levels. However the yield per recruit analysis indicates that the stock is being optimally exploited. Only a meager increase in yield per recruit will be affected by increasing fishing effort which in turn could be detrimental to other species being caught in the trawls.

Pennahia anea is caught as bycatch in shrimp trawls along Andhra Pradesh and has been commercially

(for Z = 4.15; M (at 28.0⁰C) = 1.38; F = 2.77; E = 0.67)

Fig. 4. Length-converted catch curve for estimation of mortality rates of *Pennahia anea*
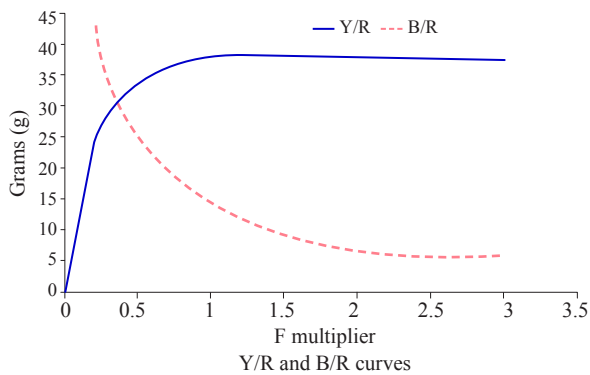

Y/R and B/R curves

Fig. 5. Yield-per-recruit and biomass-per-recruit curves for *Pennahia anea*

important since 1960s. Results of this study indicate that the stock of bigeye croaker is presently being optimally exploited.

Acknowledgements

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