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Original Article

Age, growth, and population dynamics of the Shovelnose catfish, *Arius subrostratus* (Valenciennes, 1840) in Cochin estuary, India

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Abstract: Population parameters studies of Shovelnose catfish, *Arius subrostratus*, from the Cochin estuary were conducted to determine age, growth, mortality, yield per recruit, and exploitation rate. Length frequency data of 1,205 species were collected from different landing centres of the Cochin estuary for this estimation. The Von Bertalanffy growth model is described as Lt = 364 (1-e $^{-0.53 (t+0.023)}$) from the findings. The values of L∞ and K were calculated to be 364 mm and 0.53, respectively. The estimated lifespan of the catfish, based on the present study, is 5.43 years. The study also revealed total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) as 1.56 y^{-1}, 0.59 y^{-1}, 0.97 y^{-1}, and 0.62, respectively. The recruitment pattern of *A. subrostratus* exhibited a single peak throughout the study period. The present findings revealed overexploitation of the species in the Cochin Estuary and suggested some management measures to ensure its conservation.

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Introduction

Estimating the age and growth of fish is indispensable for understanding their population dynamics. Length-frequency analysis is widely used to estimate population parameters, including longevity, mortality, and yield per recruit of fish species (Paton et al., 1994). Moreover, precise knowledge is crucial for effective resource management and forecasting upcoming fishing stocks. The accurate determination of fish age is critical for elucidating the dynamics and structure of fish populations, thereby informing effective management and conservation strategies. The growth patterns of fish species influence annual fluctuations in fisheries. The sudden emergence or collapse of a fishery, accompanied by notable declines in catch rates, presents significant challenges for fishery biologists in effectively managing the resource. Therefore, data on the age, length, and weight of fish samples can be effectively used to analyze trends in a fishery and to assess key population parameters, such as longevity, age at maturity, spawning dynamics, mortality and survival rates, senescence, and overall population size.

The study of age and growth in fish was first proposed by Petersen (1895), who formulated a technique for determining fish age from length-frequency curves, in which the peaks of the length distribution were assumed to represent different age groups. Hence, the length frequency method was employed in the present study for age determination. Age and growth studies on catfishes were carried out by Andem et al. (2013) on the African catfish, *Chrysichthys nigrodigitatus,* and Taherimirghaed et al. (2013) on the thin-spined sea catfish, *Plicofollis tenuispinis*. They have used length frequency analysis, in which peaks in the length distribution are expected to represent different age groups. Mehanna et al. (2012) conducted a study on the thinspine sea catfish *Tachysurus tenuispinis* along the Arabian Coast. The growth and mortality of *Arius arius*, based on length frequency, were examined by Chirwatkar et al. (2021). Although historical records of the population parameters of *Arius subrostratus* from the Indian subcontinent were scarce, the present study

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establishes the stock parameters of *A. subrostratus*, which are crucial for the sustainable management of the Cochin estuary ecosystem.

Materials and Methods

Sampling: Fish specimens were collected monthly from Cochin estuary (76°9'25"E - 76°24'28"E and 9°47'31"N - 10°12'N) from April 2011 to March 2013. A total of 1,205 specimens of *A. subrostratus* (628 males and 577 females), ranging in size from 12.5 to 34.5 cm in total length (TL) and 16 to 410 g in weight, were studied for length frequency analysis. From these length data, frequencies of length classes were tabulated. Length data were grouped into 5 mm length classes. The total length was measured from the tip of the snout to the tip of the upper caudal lobe to the nearest mm, and the weight to 0.5 g accuracy. The growth parameters were formulated using Von Bertalanffy's (1938) equation, based on length data from a monthly model progression.

Age and growth parameters: The simplest version of VBGF has the form $Lt = L_\infty (1-e^{-k(t-t_0)})$, where, Lt = the length of fish at age t, L_∞ = the average maximum length (asymptotic length or length infinity), K = a measure of the growth rate (the rate at which fish is approached asymptotic length), t_0 = The time (age) at which length is zero, and e (exp) = the base of the natural log. These parameters were obtained from the growth curves and from the maximum goodness-of-fit (R_n value). Growth parameters and age-length key of the fishes were estimated using the ELEFAN programme of the FISAT II software (Gayanilo and Pauly, 1997). Longevity was obtained from the following equation (Pauly, 1983): $Tmax = t_o + 3/K$ where, t_0 is the theoretical age at length zero and which can be obtained from the following empirical relationship (Pauly, 1983) of $Log(-t_0) = -0.3922 - 0.2752 \, Log \, L_\infty - 1.038 \, Log \, K$, where, L_∞ is expressed in mm and K is expressed in yearly basis.

Growth performance index (Ø) was calculated using the following formula (Pauly and Munro, 1984): $Ø = \log K + 2 \log L_\infty$. The selectivity curve depicts the length at first capture, L_{50} or L_c (length and age at which 50% of the fish entering the gear are retained) and values of the length at capture at probabilities (sizes at which the gear retains 25%, 75% and 100% of the catches) of 25 (L_{25}), 75 (L_{75}) and 1 (L_{100}), respectively. Size at first maturity was calculated separately for males and females, grouped into 20 mm increments. The length at which 50% of the fish that attained first maturity was also estimated (White, 2007).

Estimation of mortality rates, exploitation, and yield per recruit: The total mortality rate (Z) was estimated using length-converted catch curve analysis, following the method of Beverton and Holt (1956). Natural mortality (M) was calculated using Pauly's (1980) equation of $Log_{10} M = 0.0066 - 0.279 \, Log_{10} L_\infty + 0.6543 \, Log_{10} K + 0.4634 \, Log_{10} T$, which incorporates water temperature and the VBGF growth parameters L_∞ and K. The annual mean water temperature for the study area was 29°C.

The annual instantaneous fishing mortality (F) was taken as the difference between total and natural mortality: F = Z-M. Estimation of optimum length of exploitation was performed using the equation of $L_{opt} = 3 * L_\infty / 3 + m/k$ (Froese and Binohlan, 2000), where L_{opt} = Optimum length of exploitation, L_∞ =The asymptotic length, M = The natural mortality, and K = Growth coefficient. The exploitation ratio (E) is equal to the fraction of deaths caused by fishing. The exploitation rate (E) was obtained manually using the equation E = F/Z (where Z = F + M) (Gulland, 1971). The yield per recruit (Y/R) and Biomass per recruit (B/R) were estimated using the knife–edge selection method of the Beverton-Holt model. $E_{0.1}$ is the value of the exploitation ratio (E) at which the marginal increase in Y/R is 10% of its value at E = 0, where $E_{0.5}$ is the value of E at 50% of the unexploited relative biomass per recruit.

Results

In the present study, the Von Bertalanffy growth model for *A. subrostratus* in the Cochin estuary was described as $Lt = 364 (1-e^{-0.53(t+0.023)})$ (Fig. 1). Here, the values of L_∞ and K were calculated as 364 mm and 0.53, respectively. In the current study, the R_n

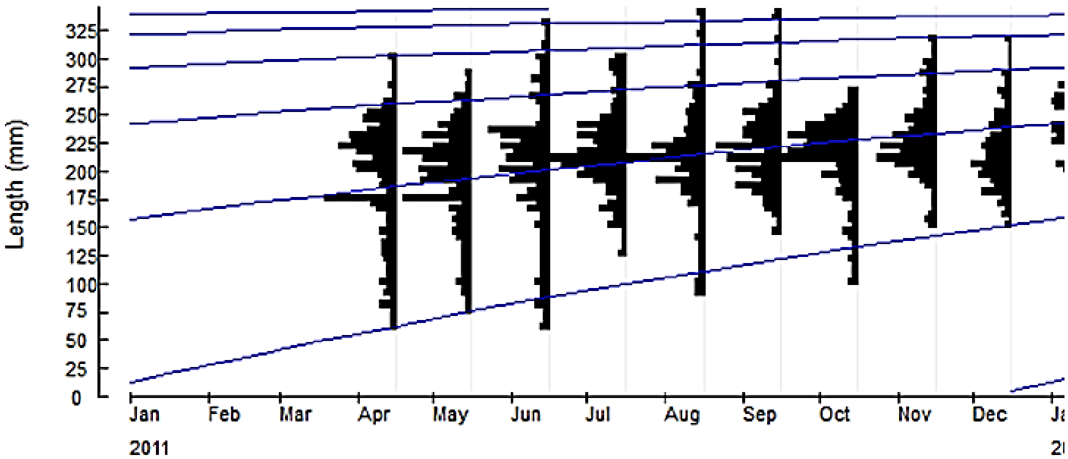

Figure 1. Length frequency and fitted Von Bertalanffy growth curves of *Arius subrostratu* ($L\infty$ = 364, K = 0.53 year $^{-1}$, and t_0 = - 0.23).

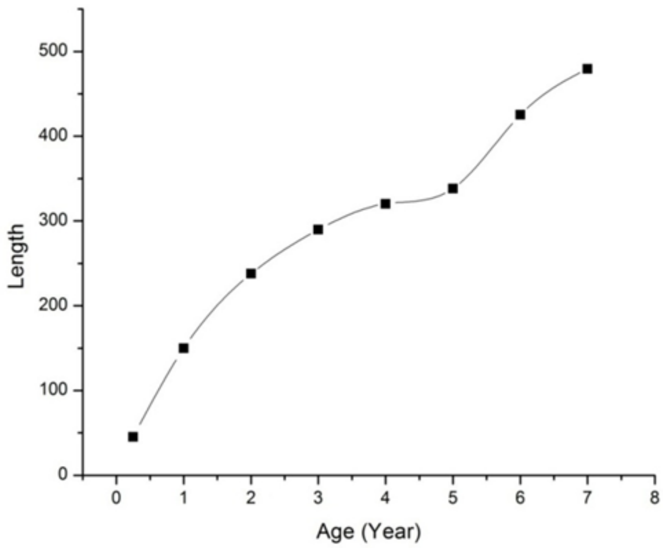

Figure 2. Relative age of *Arius subrostratu* based on years.

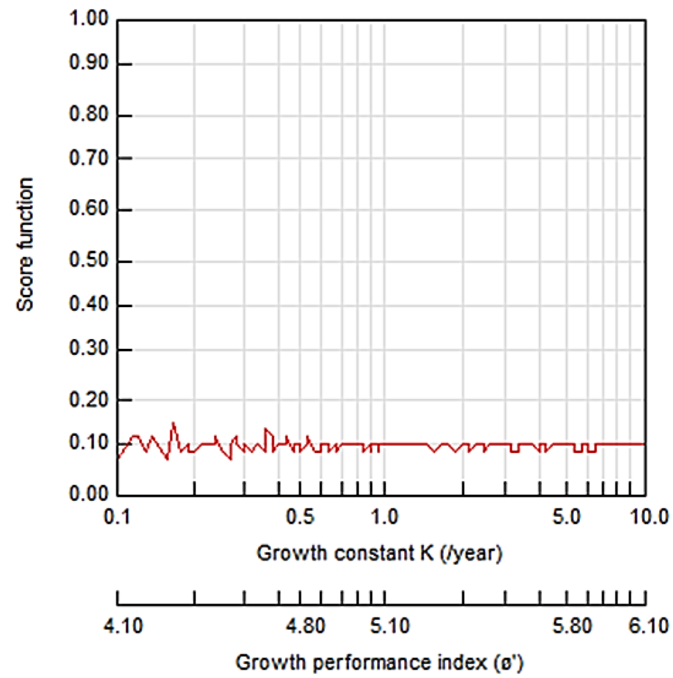

Figure 3. Growth performance index of *Arius subrostratu* from the Cochin estuary.

value (goodness of fit index) was 0.127. The yearly growth curve derived from the Von Bertalanffy growth parameters indicated that fish attained lengths of 150, 238, 290, 320, and 338 mm, respectively, from years one to five (Fig. 2). Based on the results, the lifespan of *A. subrostratus* was estimated to be 5.43 years. The t_0 calculated from Pauly's empirical relationship was -0.023, and the growth performance index (Ø) calculated from the growth parameter was 4.85 (Fig. 3).

The probabilities of capture value were L_{25} = 157.50, L_{50} = 194.39, L_{75} = 207.50, and L_{100} = 257.50 mm, and the value of L_{50} is equal to the value of length at first capture (L_c) (Fig. 5). The mean length at first capture or L_{50} or L_c was at 194.39 mm. Based on the results, the size at first maturity in males was 240-250 mm length group (mean 245), and in females it was 220-230 mm length group (mean 225) (Fig. 6). The value of Lc was 194.39, L_m was 225, and L_{opt} was 266.3 mm.

The total mortality rate (Z) was 1.56 y^{-1}, natural mortality (M) was estimated as M = 0.59 y^{-1}, the annual instantaneous rate of fishing mortality (F) was 0.97 y^{-1}, and the exploitation rate (E) was 0.62 (Fig. 4). Moreover, the relative yield per recruit and biomass per recruit are shown in Figure 7. The relative yield per recruit yielded the following results: M/K ratio, Z/K ratio, and Lc/L_∞ were 1.1, 2.94, and 0.534,

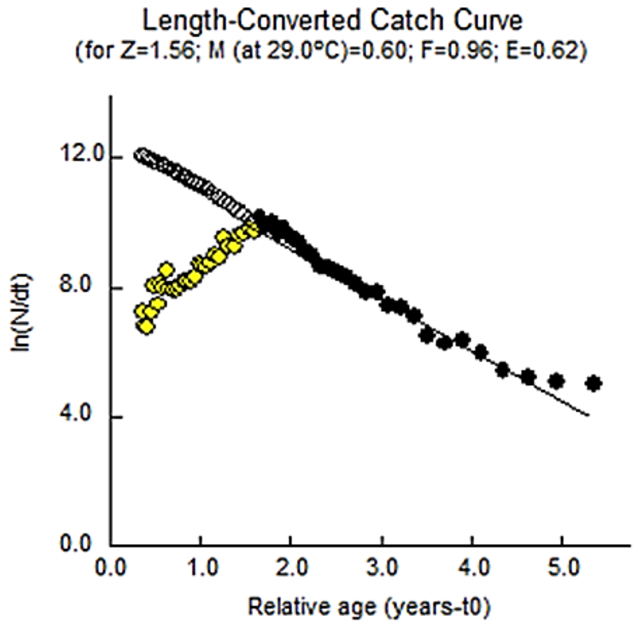

Figure 4. Graphic output of the catch curve analysis showing mortality estimates of *Arius subrostratu* from the Cochin estuary.

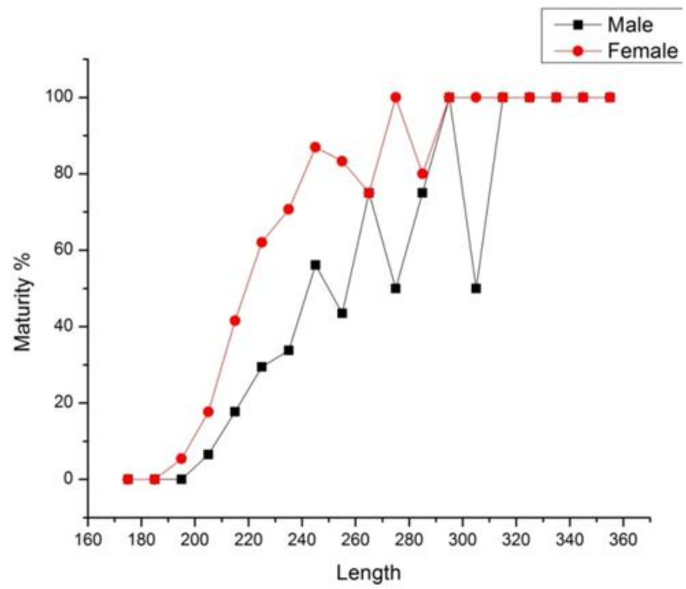

Figure 6. Length at first maturity of *Arius subrostratu* from the Cochin estuary during April 2011 to March 2013.

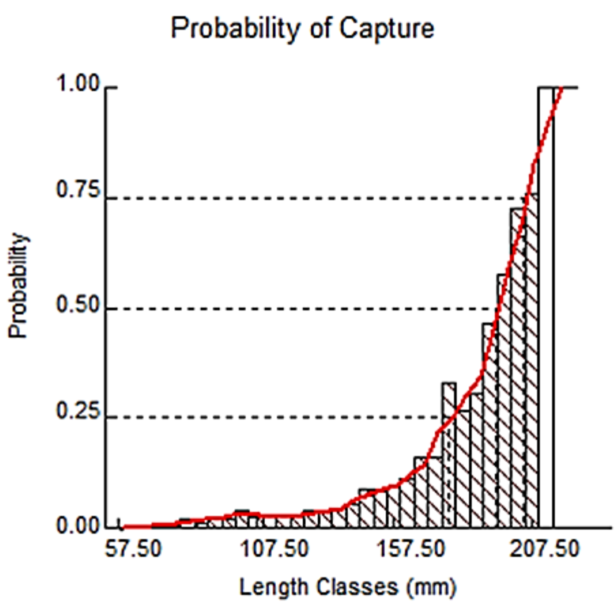

Figure 5. Selectivity catch curve showing probability captures of *Arius subrostratu*.

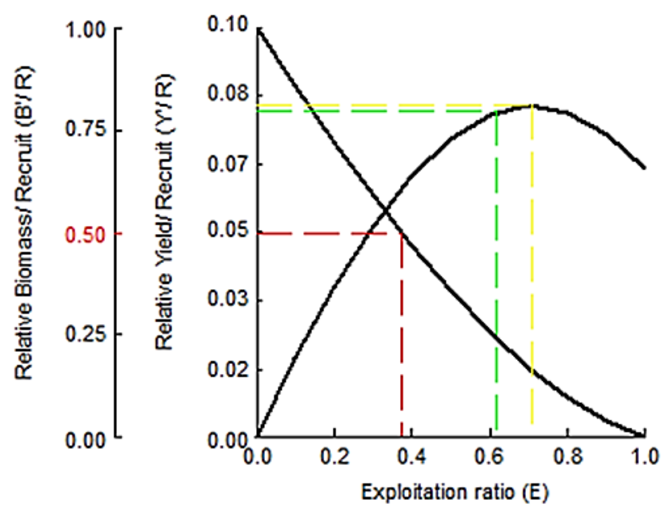

Figure 7. Relative yield per recruit and relative biomass per recruit of the pooled population of *Arius subrostratus* (yellow line (Emax); Green line (E 10); Red line (E 50).

respectively. The maximum sustainable yield (E_{max}) was 0.703. The computed exploitation rate, derived from relative yield-per-recruit analysis (E), was 0.62, whereas the maximum exploitation rate (E_{max}) was estimated to be 0.708. The estimated values of $E_{0.1}$ and $E_{0.5}$ were 0.620 and 0.374, respectively.

The virtual population analysis aids in predicting future catches by examining past mortality rates resulting from both fishing and natural causes. The outcome of the length-based virtual population analysis (VPA) indicated that depletion of the stock due to natural causes was most pronounced in the 175-180 mm size group. An increase in fishing mortality became more pronounced in the size group beyond 210-215 mm. Here, fishing mortality peaked at 4.9 in the 215-220 mm size group. Catches upsurged steadily from the 200-205 mm size group to the 235-240 mm

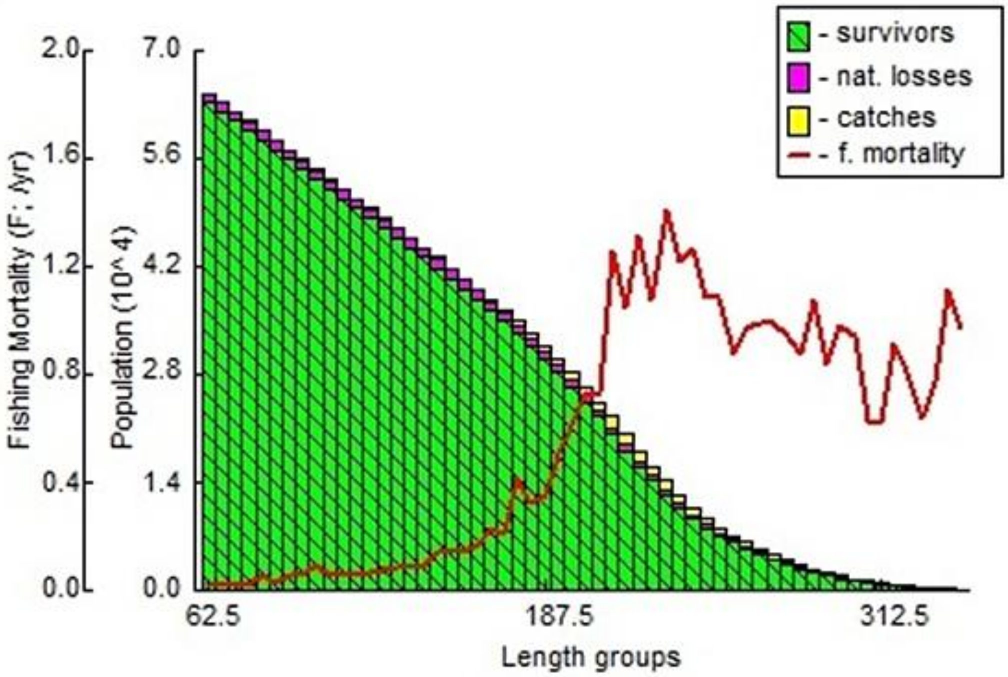

Figure 8. Length-based virtual population analysis (VPA) of *Arius subrostratus* from the Cochin estuary.

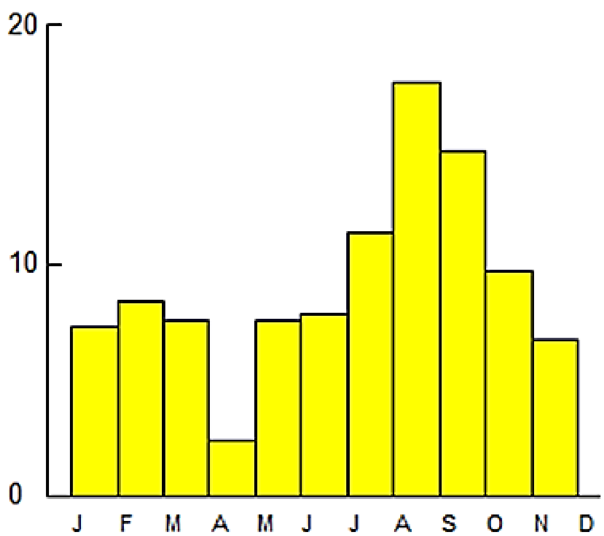

Figure 9. Recruitment pattern of *Arius subrostratus* from the Cochin estuary.

size group, reaching a maximum in the 210-215 mm length group (Fig. 8). The recruitment pattern observed in the present study indicates that *A. subrostratus* was primarily recruited in August, accounting for 17.48% of the total recruitment (Fig. 9).

Discussions

Age and growth analyses yield critical insights on stock composition, age and maturity, life span, mortality rates, growth patterns, and overall production. Annual fluctuations in fishery yield are influenced by the growth pattern and associated life-history traits of fish species. The Von Bertalanffy model is one of the most widely used approaches for studying theoretical growth in fishery biology. The Von Bertalanffy growth parameters estimated an L_∞ value of 364 mm and a growth coefficient (K) of 0.53. According to Von Bertalanffy, a plot was created to estimate the growth coefficient K. The length at infinity (L_∞) is a theoretical length, known as the asymptotic length, beyond which the fish does not grow. Pauly (1984) stated that K might range from 0 to 1 per year for long-lived fish species and exceed 1 for short-lived species. Similar findings were reported in the study on *Lepturacanthus savala*, where the K-value was estimated at 0.55 (Pallavi et al., 2013). Akombo et al. (2015) also reported a similar K-value (0.58) in *Synodontis schall* in the Lower Benue River, at Makurdi, Nigeria. Pauly (1984) again specified that species with shorter lifespans have a high K-value and reach their L_∞ within one or two years. The Ariidae family generally exhibits a high L_∞ value and a low k, and these values are inversely correlated (Velasco and

Oddone, 2004). In this study, *A. subrostratus* exhibited a low K value, indicating a slow growth rate and delayed maturation.

The R_n values indicate how well the estimated growth curve fits the observed length frequency data, particularly in the ELEFAN method. Typically, values range from 0 to 1. An R_n value approaching 1 indicates a strong fit, meaning the growth curve closely aligns with the observed data. The low value observed in the current findings (0.127) suggests that recruitment pulses were present. The growth parameters derived from the Von Bertalanffy growth curves for *A. subrostratus* showed that the species attained lengths of 150, 238, 290, 320, and 338 mm from the first to the fifth year, respectively, indicating a slow growth rate. Additionally, *A. subrostratus* exhibited slow maturation, with an estimated length at first maturity of 225 mm. Fish species exhibit varying life spans, which can be categorized as short, intermediate, or long-lived. Conversely, the shortest lifespan, ranging from 1 to 2 years, was observed in *Secutor insidiator* as reported by Nagarajan (2013). Some fish species have a long lifespan, ranging from 70 to 152 years, such as *Schizothorax oconnori* (Ma et al., 2010) and *Gerres filamentosus* (Megha et al., 2013). Environmental factors, such as temperature, salinity, and predation, as well as biological factors (sex, size, genetic composition, and age at maturity), are thought to influence fish life span (Das, 1994). The low K-value and higher asymptotic length (L_∞) exhibited by *A. subrostratus* indicate its long lifespan.

Pauly (1983) noted that t_0-values are generally negative, and the present study supports this observation with a calculated t_0 value of -0.023. In this study, the growth performance index (Ø) was calculated as 4.85 based on the estimated growth parameters. The range of growth performance index (Ø) usually varies from 2.65 to 5.29 (Kadharsha et al., 2014). Akombo et al. (2015) also stated that these values are consistent with those commonly reported for tropical fish species. The growth performance index is used to determine either L_∞ or K when one of these parameters is unavailable (Enin et al., 1995).

Capture probabilities are estimated using selectivity curves. L_{50} calculated by the probabilities of capture method is equal to the value of length at first capture (L_c). For a sustainable fishery, the value of length at first capture (L_c) exceeds the value of length at first maturity (L_m). A high value of length at first maturation compared to length at first capture (L_c) is observed in some fishes, like *Siganus canaliculatus* from the Arabian Gulf (Al-Qishawe et al., 2014). In *A. subrostratus*, the value of Lc was 194.39 mm, and that of L_m was 225 mm, representing a mortality-dominated fishery. Fish smaller than L50 or L_c should not be captured to better exploit the stock. Here, the majority of individuals are harvested during the pre-spawning phase. To ensure sustainability, the length at first capture should be increased. The fully recruited size of fish to the fishery, or L_{100}, was 257.50 mm. The length class that generates a high yield of a stock is the optimum length (L_{opt}). Here, the value of L_{opt} obtained was greater than the length at first capture of *A. subrostratus* from the present study.

Length-converted catch curves were employed in this study to evaluate total, natural, and fishing mortality rates. Some short-lived fish exhibited high mortality rates. Based on this criterion, *Periophthalmus barbarous* (mudskipper) from southeast Nigeria exhibited a short life span of 3 years with high natural mortality ($M = 2.04\ Y^{-1}$) (Udoh et al., 2013). Gulland (1971) opined that if a fish stock is optimally exploited at a level of fishing mortality that generates an Exploitation ratio (E) of 0.50. Here, the exploitation ratio (E = 0.62) was higher than the optimal level, which denotes overexploitation of the resources.

The yield was calculated from the monthly catch data of *A. subrostratus* from the Cochin estuary during 2011-2013. Pooled annual catch of this period is referred to as yield (Y). The normal range of M/K ratio should be within the range of 1.0-2.5, and the Z/K will be within the range of 1, then it can be considered as growth dominated, and beyond 2, then it is mortality dominated (Beverton and Holt, 1959). According to the present study, the Z/K ratio obtained 2.94 indicates a mortality-dominated fishery of *A. subrostratus.* A study of the population dynamics of *Odaxothrissa mento* (James et al., 2013) revealed a

Z/K ratio of 1.716, indicating slight exploitation of the stock. From the relative Yield per Recruit analysis, the computed exploitation rate (E = 0.62) does not exceed the maximum exploitation rate (E_{max} = 0.708). To manage overexploitation, the current exploitation rate should be reduced to the optimal exploitation rate. Allowing fish to spawn at least once during their lifespans is crucial to ensuring adequate recruitment and maintaining stock sustainability.

Virtual Population Analysis (VPA) is commonly used to assess the status of fish populations and forecast future catch levels. In this study, the fishing mortality rate for the species increased progressively from the 200 mm size group up to the 240 mm group, with the highest fishing mortality recorded in the 210-215 mm size group. Thus, small and large-sized fish exhibited lower fishing mortality rates, while medium-sized fish showed notably higher values. Based on these results, it can be concluded that fishing mortality rates tend to increase within the medium-size group. Therefore, increasing the mesh size of fishing nets would be a prudent measure toward the sustainable management of this fishery resource.

Conclusion

The present findings signify the overexploitation of the fishery resources in the Cochin estuary. Based on the results, *A. subrostratus* may be classified as a vulnerable species. To ensure the sustainability of the fishery, it is imperative to implement effective management strategies for this species. Increasing mesh size and enforcing fishing regulations, at least during the spawning season, would help prevent the overexploitation of resources. Resource conservation can also be boosted by mitigating water pollution in the surrounding areas, chiefly by controlling the discharge of hospital waste and industrial effluents into the backwaters.

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References

Abdulkarim M., Yusuf Z.A., Musa B.L., Ezra A.G. (2009). Population parameters of *Clarias gariepinus* (catfish) in Gubi dam, Bauchi State, Nigeria. Journal of Animal and Plant Sciences, 5(2): 531-538.

Abowei J.F.N., Davies O.A. (2009). Age, growth, mortality, and condition factor study of *Gnathonemus tamandua* (Gunther, 1862) from the freshwater reaches of Lower Nun River, Niger Delta, Nigeria. Current Research Journal of Biological Sciences, 1(1): 28-34.

Akombo P.M., Akange E.T., Atile J.I. (2015). Age and growth of catfish *Synodontis schall* (Bloch and Schneider, 1801) in the Lower Benue River, at Makurdi, Nigeria. International Journal of Fisheries and Aquatic Studies, 2(5): 184-190.

Al-Qishawe M.M.S., Ali T.S., Abahussain A.A. (2014). Stock assessment of white spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Jubailmarine wildlife sanctuary, Saudi Arabia. International Journal of Fisheries and Aquatic Studies, 1(6): 48-54.

Andem A.B., George U.U., Eyo V.O. (2013). Length frequency distribution of (*Chrysichthys nigrodigitatus)* (Lecepede, 1803) (*Chrysichthys*, Bagridae) from Itu Head Brigde, in Akwa Ibom State, Nigeria. International Journal of Science and Research (IJSR), 2(9): 258-260.

Beverton R.J.H., Holt S.J. (1956). On the dynamics of exploited fish populations. Chapman and Hall, London. 533 p.

Beverton R.J.H., Holt S.J. (1959). A review of the life-spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. In: GEW. Wolstenholme, MO. Connor (eds.), CIBA Found. Colloq. on Ageing, 5: 142-80.

Chirwatkar B.B., Das S.K., Bhakta D., Nagesh T.S., Behera S. (2021). Growth, mortality and stock assessment of *Arius arius* (Hamilton, 1822) from Hoogly-Matlah estuary, West Bengal. Indian Journal of Geo-Marine Sciences, 50(04): 302-309.

Chukwu K.O., Deekae S.N. (2010). Growth, mortality and recruitment of *Periopthalmus barbarous* (Linneaus 1766) in New Calabar River, Nigeria. Agriculture and

Biology Journal of North America, 2(7): 1066-1068.

Das M. (1994). Age determination and longevity in fishes. Gerontology, 40(24): 70-96.

Enin U.I., Lowenberg F., Kunzel T. (1995). Population dynamics of the estuarine prawn (*Nematopalaemon hastatus*, Aurivilus 1898) of the Southeast Coast of Nigeria. Fisheries Research, 26: 17-35.

Froese R., Binohlan C. (2000). Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit of fishes, with simple method to evaluate length frequency data. Journal of Fish Biology, 56: 758-773.

Gayanilo J.F.C., Pau1y D. (1997). The FAO-ICLARM Stock Assessment Tools (FiSAT) Reference Manual FAO Computerized information Series (Fisheries). No.8, FAO, Rome. 262 p.

Gulati M.D., Devarajand Palaniswamy R. (1996). Stock assessment of soldier catfish *Osteogeneiosus militaris* along the northwest coast of India. Journal of Indian Fisheries Association, 26: 1-8.

Gulland J.A. (1971). The fish resources of the ocean, West Poly fleet, Survey Fishing News (books) Ltd., FAO Tech. 97: 428.

James P.U., Imaobong E.E., Emah E.E. (2013). Preliminary biodata and growth parameters of *Odaxothrissa mento* in the lower Cross River, Southeast Nigeria. Aquaculture, Aquarium, Conservation and Legislation - International Journal of the Bioflux Society, 6(6): 599-610.

Kadharsha K.P., Mohan Chander P., Lyla P.S., Ajmal Khan S. (2014). Age and growth of brushtooth lizard fish *Saurida undosquamis* (Richardson, 1848) occurring in Parangipettai Southeast Coast of India. Indian Journal of Geo-Marine Sciences, 43(9): 1-5.

Khadim Hussain M., Qun L., Kalhoro A., Saleem Chang M., Nabi Mirjat A. (2015). Estimation of growth, mortality and exploitation of lesser tiger toothed croaker *Otolithes cuvieri* (Trewavas ,1974) in Pakistan. Indian Journal of Geo-Marine Sciences, 44(1).

King R.P. (1997). Growth performance of Nigerian fish Stocks. NAGA, the ICLARM Quarterly, 20(2): 31-35.

Ma B-S., Xie C-X., Huo B., Yang X-F., Huang H-P. (2010). Age and growth of a long-lived fish *Schizothorax oconnori* in the Yarlung Tsangpo River, Tibet. Zoological Studies, 49(6): 749-759.

Megha A., Ambily V., Bijoy Nandan S. (2013). Age and growth of *Gerres filamentosus* (Cuvier, 1829) from Kodungallur, Azhikode Estuary, Kerala. African Journal of Agricultural Research, 8(20): 1-8.

Mehanna S.F., Zaki S., Iman Al-Kharusi I., Al-Habsi S., Al-Kiyumi F. (2012). Stock assessment of the thinspine sea catfish *Tachysurus tenuispinis* (Day, 1877) in the Arabian Sea, Oman. INOC-CNRS, International Conference on "Land-Sea Interactions in the Coastal Zone" Jounieh – Lebanon. pp: 430-439.

Nagarajan D. (2013). A study of age and growth of *Secutor insidiator* (Bloch) from Tuticorin waters of Southeast coast of India. International Journal of Research in Fisheries and Aquaculture, 3(4): 122-129.

Pallavi K.P., Swapnaja A.M., Suresh D.N., Asish S.M. (2013). Length frequency analysis and length-weight relationship of ribbon fish, *Lepturacanthus savala* (Cuvier, 1829) off Ratnagiri coast, Maharashtra. International Journal of Fisheries and Aquatic Studies, 1(2): 25-30.

Paton D., Cardona L., Gisbert E. (1994). Comparative growth in relation with the age assessed by Skeletochronology in two mullet fishes of genus *Liza*. Animal Production, 59: 303-307.

Pauly D., Munro J.I. (1984). Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2: 21-23.

Pauly D. (1980). On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal of the International Council for the Exploration of the Sea, 39(2): 175-192.

Pauly D. (1983). Some simple methods for the assessment of tropical fish stock. Food and Agriculture Organisation of the United Nations. FAO Technical Paper, 234: 2- 41.

Pauly D. (1984). Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Student Review, 8: 325.

Petersen V.G.J. (1895). Eine methods Zur Bestmmung des alters and wochses des fiche. Mitt. Dtsch. Seefischerei – Vereins. 11: 8.

Sahoo D.K., Karna S.K., Panda S. (2012). Length weight relationship (LWR) and growth estimation of *Mugil cephalus* (Linnaeus, 1758) in the Chilika Lagoon, Orissa, India. Asian Journal of Experimental Biological Sciences, 3(4): 700-705.

Sajan S., Anna Mercy T.V., Malika V. (2015). Age, growth and population dynamics of an endangered fish *Sahyadria denisonii* (Day 1865) from the Western Ghats hotspot of India. Asian Fisheries Science, 28: 130-142.

Taherimirghaed A., Hashemi S., Hosseini A. (2013). Population Parameters and length-weight relationship of Thinspine Sea Catfish (*Plicofollis tenuispinis*) in Northwest of Persian Gulf (Khuzestan Coastal Waters, Iran). Advances in Biological Research, 7(4): 124-128.

Udoh J.P., Brownson I., Udo M.T., Ofor C. (2013). Population dynamics of mudskipper, *Periophthalmus barbarous* (Linneaus 1766) (Teleostei: Gobiidae) in the artisanal fishery of Imo river estuary, southeast Nigeria. Journal of Fish and Aquaculture, 4(3): 148-153.

Von Bertalanffy L. (1938). A quantitative theory of organic growth. Human Biology, 10: 181-213.

White W.T. (2007). Catch composition and reproductive biology of whaler sharks (Carcharhiniformes: Carcharhinidae) caught by fisheries in Indonesia. Journal of Fish Biology, 71(5): 1512-1540.