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Studies on Growth, Mortality and Stock Assessment of Indian Mackerel *Rastrelliger Kanagurta* (Cuvier, 1817) from the Balochistan Coast of Pakistan, North Arabian Sea

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Abstract

Based on the analyses of 344 specimens of *Rastrelliger kanagurta* collected monthly from three main fish harbors of Balochistan, during the period from January 2017 to December 2018.The fork length of a sum of 344 individuals ranged from 17.1 to 27.0 cm with 84.0-224.0 g in weight. The length weight relationship of the present study shows negative allometric growth (b = 1.719 to 2.376). The von Bertalanffy growth parameters ranged for combined sexes were, K = 0.46 - 1.60 year^{-1}, $L\infty$ =23.63 - 27.83 cm and t_0 = -0.60 - -2.83 year. The total mortality coefficient Z was estimated as ranges from 2.14 to 3.31 year^{1}and the natural mortality coefficient M was from 1.13 to 2.48 year^{-1}. In the present study the calculation indicated an average E_{max} to be 0.367± 0.016 against the present average exploitation rate (E) of 0.366 ± 0.124 thus indicating only limited opportunity exists for production increase from the present grounds along Balochistan coast, Pakistan. In conclusion, for such economically important species further comprehensive studies is suggested. Also the population dynamics and fishery attributes of all important fishes in the Balochistan coast of Pakistan, should be studied for build-up effectual managing strategy.

1. Introduction

The Indian mackerel (*Rastrelliger kanagurta*) is a pelagic species discover out between 20-90 m depth of continental shelf [1, 2]. This species mostly catches out from coastal bays, harbors and deep lagoons, commonly in closely muddy plankton-rich waters [3]. A number of nets have been used to catch for Indian mackerel such as purse seines, encircling gillnets, high-opening bottom trawl, lift nets, and bamboo stake traps [4, 5].

Fishing is avital economic culture along the coast of Pakistan as about 80 % of the coastal population (excluding Karachi) is involved in fisheries associated activities. The marine fisheries resources of Pakistan consist of around 350 different species which are commercially importance [6], out of which about 150 species of fish are commercially landed in Pakistan; among these sardinellas (*Sardinella* spp.), white pomfrets (*Pampus argenteus*), snappers (*Lutjanus* spp.), emperors (Lethrinidae), seabreams (Sparidae), narrow-barred Spanish mackerel (*Scomberoides commerson-nianus*), Indian mackerel (*Rastrelliger kanagurta*), catfishes (*Arius* spp.) and sharks (Carcharhinidae) are dominant [7]. However, by 2010, *Rastrelliger kanagurta* represented 33% of the total catch [8]. The total landing of this species has dropped from 38000 t in 2006 to 24031 t in 2014 [9], due to over fishing, but the world catches for *R. kanagurta* absolutely increased. The total catch documented for this species for 2010 was 273 877 t which increased to 499 474 t in 2016 [10]. The leading catch countries were included India (28.6%) and Malaysia (22.8%) [11]. Environmental parameters are known to influence the fishery of mackerel, often leading to wide seasonal and annual fluctuations in landings [12].

Although the Indian mackerel *R. kanagurta* have commercial importance in the Pakistan's fisheries, but there is only one prior study addressed with the assessment of its growth, mortality and stock assessment [9]. On the other hand, some studies carried out on biochemical composition of the Indian mackerel [13, 14] and length-weight relationship of *R. kanagurta* was evaluated by Ahmed *et al.* [15]. While Moazzam *et al.* [16] explained biology and fishery of that fish. No appropriate work has been done from Balochistan Coast discuss about stock assessment, landing and on growth estimation. The present study was therefore commenced, to assess the fishery, stock status, growth and mortality of Indian mackerel landed along Balochistan coast, Pakistan.

2. Methodology

2.1 Study area

Pakistan's coastline extended around 990 km [17], splitting into two Maritime Provinces or "fishing areas", Sindh Coast (270 km) and Balochistan Coast (720 km). The Balochistan coastal shelf (approximately 14,500 km^2) is rocky and narrower than that of Sindh (approximately 35,700 km^2), and has no major freshwater input or estuaries [8]. The Indian mackerel *Rastrelliger kanagurta* Cuvier (1817) is one of the almost significant marketable fish captured through the gillnetting from Balochistan coast (Figure 1).

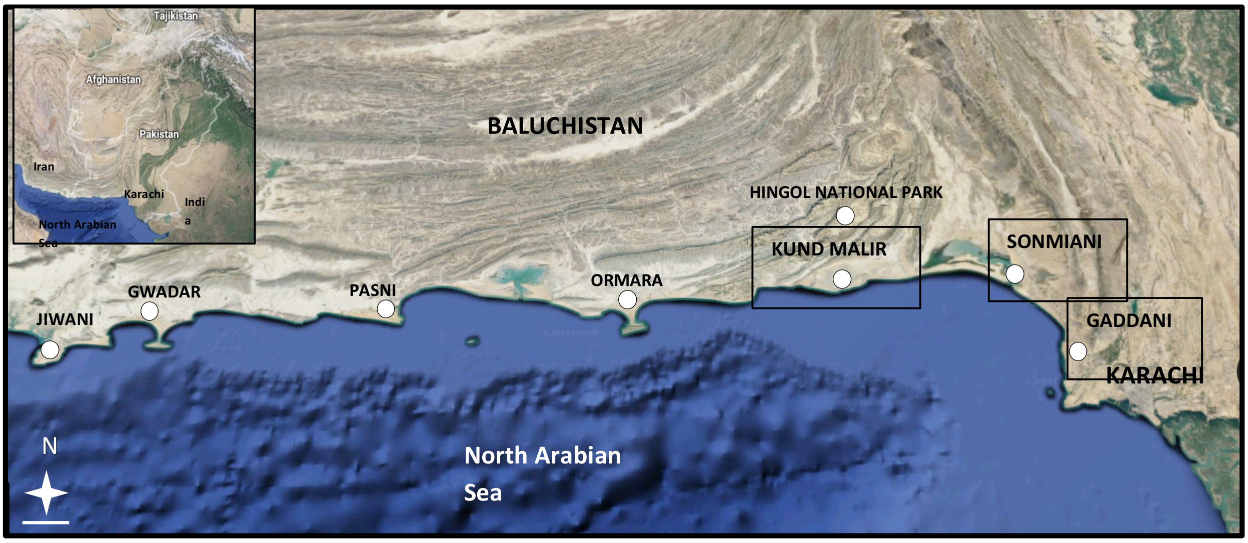

Figure 1: Map showing the collection sites. Scale bar 50 km. Inset shows the coastline of Pakistan

2.2 Sample collection and analysis

Approximately 344 samples (more than 100 from each harbors) of Indian mackerel (*Rastrelliger kanagurta*) were collected on monthly basis from three main fish landing harbors of Balochistan, Sonmiani, Gadani and Kund Malir during period January 2017 to December 2018 except for few months (when fisherman not allowed to access the open seas). Specimens were measured to the nearest cm for fork length (FL) and weighed the nearest g for total weight (TW). Total landings of *R. kanagurta* were also monitored monthly at all harbors.

Length - weight relationship commonly determined by using equation: $W = a L^b$ [18], where W is the total weight (g), L is the fork length (cm) and a & b are constants calculated by Rao [19].

Population dynamics: The FISAT II software [20] was used to calculated population dynamics parameters. The fork length (FL) was grouped into 1 cm class interval, theoretical growth parameter $L\infty$ and K was computed from monthly length-frequency distributions using ELEFAN I by FISAT II software [21]. Growth was calculated by Von Bertalanffy growth function equation [22] which has been used extensively for this purpose [23, 24]. The von Bertalanffy equation is as follows:

$$L_t = L_\infty [1 - e^{-K(t - to)}]$$

Where L_t is the fork length at age t, L_∞ is the asymptotic length or maximum theoretical length of fish, K is the growth coefficient (the rate of growth of fish to its maximum size), and t_0 is the theoretical age at length 0. While the hypothetical age at length zero (t_0) was estimated using the K and L_∞ values by the formula [23, 25]:

$$t_o = 1/K \ln [(L\infty - Lc)/ L\infty]$$

Where K is the growth coefficient, L_∞ is the asymptotic length and L_c is the length at age t = 0 or length of recruits.

The longevity (t_{max}) was obtained by the following equation Pauly [26]: $t_{max} = t_0 + 3/k$ Where t_{max} is the estimated maximum age of the fish of a given study population.

The growth performance index Ø was determined according to Pauly &Munro [24] and Patterson [27] as following:

$$Ø = \log K + 2\log L_\infty.$$

Mortality: The natural mortality rate (M) was calculated by using empirical equation given by Pauly and Munro [24] taking the mean ambient temperature of 28 ^{0}C.

$$Log_{10}M = - 0.0066 – 0.279 \log_{10}L\infty + 0.6543 \log_{10}K + 0.4634 \log_{10} T$$

Where K is the growth coefficient, $L\infty$ is the theoretical length at age infinity, and T = temperature in ^{o}C. The total mortality rate (Z) was determined according to age-based catch curves [22].The instantaneous rate of fishing mortality (F) was estimated as: F = Z-M.

The exploitation rate (E) was computed as equal to the fraction of fishing mortality relative to total mortality, that is, E = F/Z [28].

Biological reference point was computed by relating estimates of the fishing mortality rate with target (F_{opt}) and limit (F_{limit}) biological reference points or reference points for management by formula of Patterson [27]: (F_{opt}) and (F_{limit}): $F_{opt} = 0.5M$ and $F_{limit} = 2/3M$.

Relative yield per recruit Y'/R and relative biomass per recruit B'/R were calculated using the model of Beverton and Holt [29, 30] as modified by Pauly *et al.* [2] using FISAT software as: B'/R = (Y'/R)/F.

3. Results and Discussion

3.1. Fishery

The mackerel fishery along the coast of Balochistan is basically supported by only single species, *Rastrelliger kanagurta.* The fishery of Indian mackerel *R. kanagurta* is typically categorized through yearly and showed variations in the 2 years of collection. Catch of Indian mackerel has varied from 938.0 t in 2017 to 877.70 t in 2018 at Sonmiani, 874.85 t in 2017 to 836.30 t in 2018 at Gadani and 895.12 t in 2017 to 788.15 t in 2018 at Kund Malir (Table1). Average monthly catch of mackerel (combine data of three harbors) varied from 0.4 tons in August 2017 was minimum landing recorded to 391.8 tons in December 2017 was maximum catch observed (Figure 2). It was observed that November to December of both years appears as the most productive period (Figure 2).

Table 1. Total Catch of *Rastrelliger kanagurta* at three fish harbors of Balochistan from January 2017 to December 2018.

YEAR	SONMIANI FISH HARBOR (metric tons)	GADANI FISH HARBOR (metric tons)	KUNDMALIR FISH HARBOR (metric tons)
2017	938.00	874.85	895.12
2018	877.70	836.30	788.15

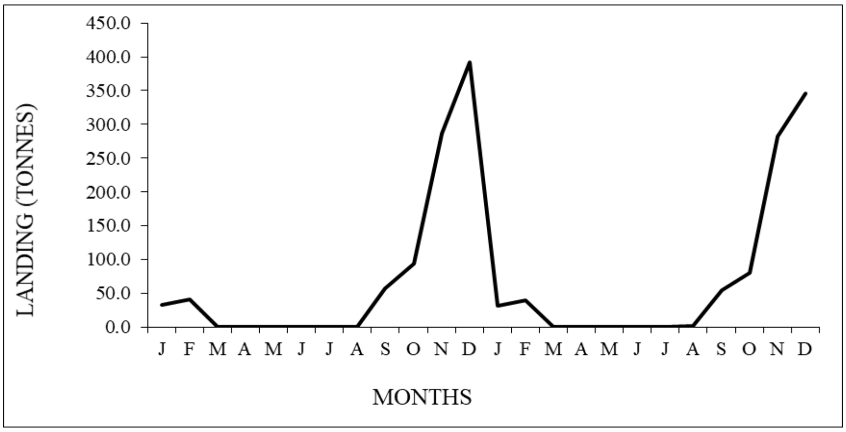

Figure 2: Seasonal landing of *R. kanagurta* landed on Balochistan coast during January 2017 to December 2018

3.2. Growth estimates

Sonmiani

In the present study the fish range in fork length from 18.0 cm to 23.2 cm. The dominant size class in the catch was 21.1 – 22.0 cm (44.14%) (Figure 3). The estimated length-weight relationship in *R. kanagurta* was, $W=0.0985 \times L^{2.376}$ (r^2=0.906) at Sonmiani (Figure 4).

Gadani

Fork lengths vary from 17.2 to 27.0 cm. The leading size class in the catch was 21.1 – 22.0 cm (43.44%) (Figure 3). The calculated length-weight relationship was $W=0.8279 \times L^{1.719}$ (r^2=0.820) at Gadani (Figure 4).

Kund Malir

At Kund Malir fork length found from17.1 to 22.5 cm and the main size class was 20.1 to 21.0 cm (29.73%) (Figure 3). The length-weight relationship was W=0.1687 x $L^{2.307}$ (r^2=0.808) (Figure 4). The length weight relationships of *R. kanagurta* according to three harbor's collection along the Balochistan coast indicated negative allometric growth as b values is significantly different from the theoretical slope of 3.0 (Figure 4).

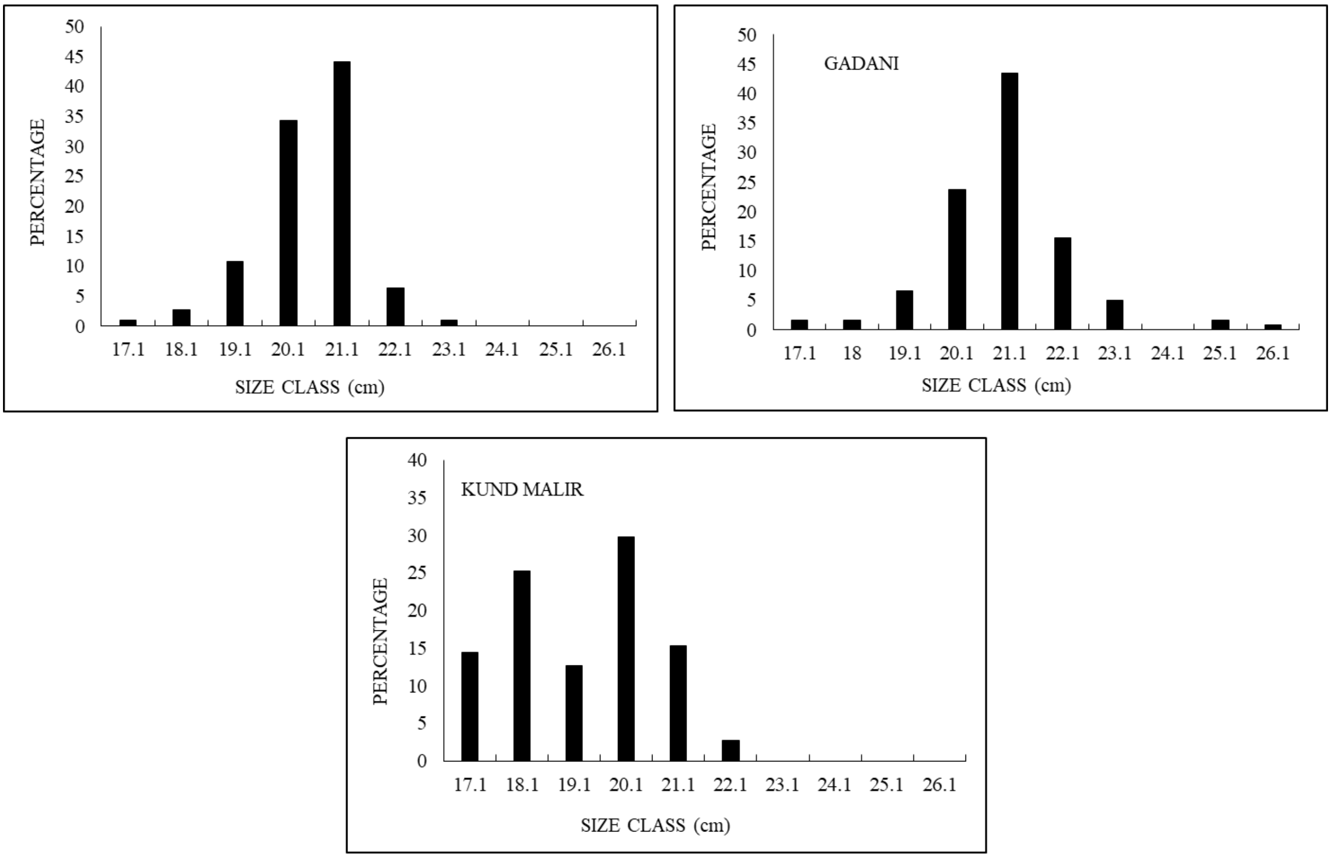

Figure 3: Fork length (FL) frequency distribution of *R. kanagurta,* collected from three fish harbors of Balochistan, Pakistan, Northern Arabian Sea.

3.3. Growth parameters and growth performance index (ф)

Sonmiani

Growth coefficient K = 0.46 $year^{-1}$, asymptomatic length L∞= 24.73 cm, and theoretical age t_o = -2.83 year (Figure 5). The lengths compute according to von Bertalanffy growth function equation were 20.5, 22.0, 23.0, 23.7 cm at the age of 1, 2, 3 and 4 years, respectively (Figure 6). The growth performance index (Φ) was calculated as 2.45for Indian mackerel. Longevity (t_{max}) was estimated as 3.69 years.

Gadani

Growth coefficient K = 1.60 $year^{-1}$, asymptomatic length L∞ = 27.83 cm, and theoretical age at length zero t_o = -0.60 (Figure 5). The lengths calculate according to von Bertalanffy growth function equation were 25.7, 27.4, 27.7,27.8 cm at the age of 1, 2, 3 and 4 years, respectively (Figure 6). The growth performance index (Φ) was 3.09. Longevity was 1.28 years.

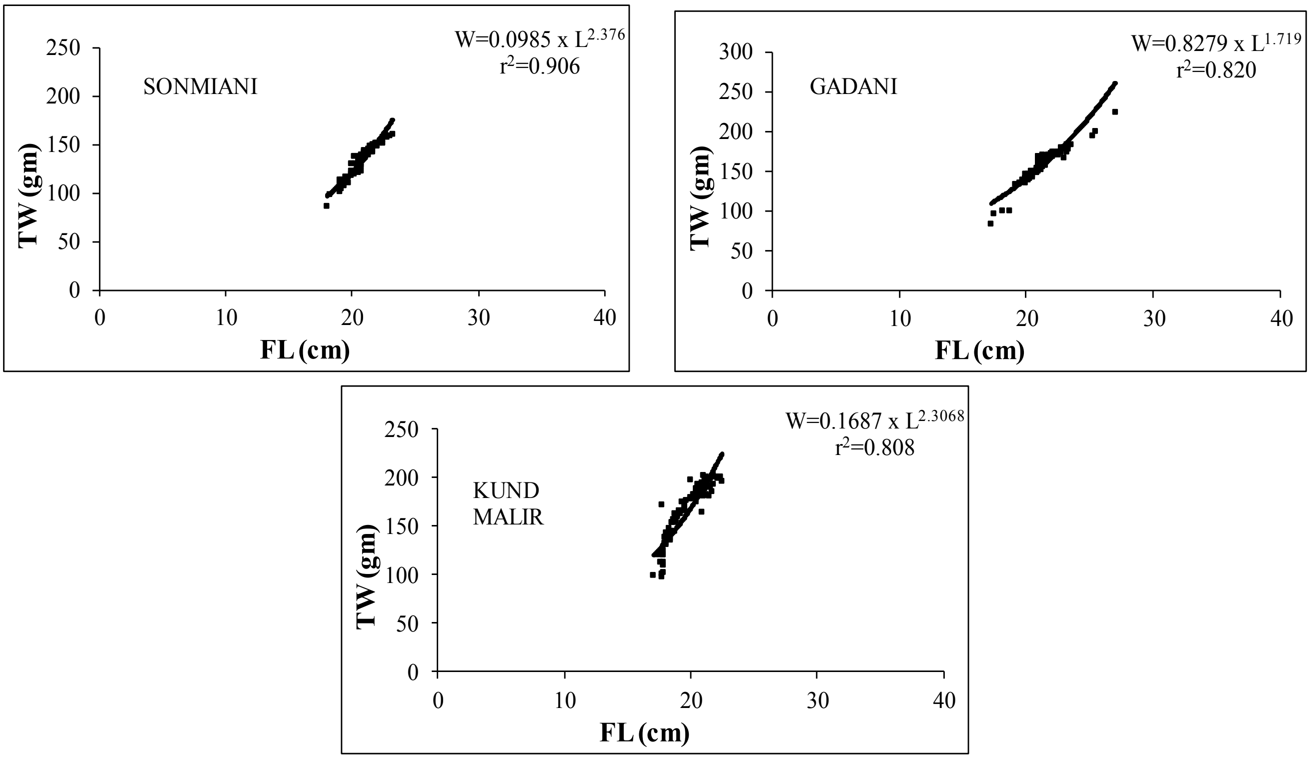

Figure 4: Fork length–weight relationships of *R. kanagurta* collected from three fish harbors of Balochistan, Pakistan, North Arabian Sea.

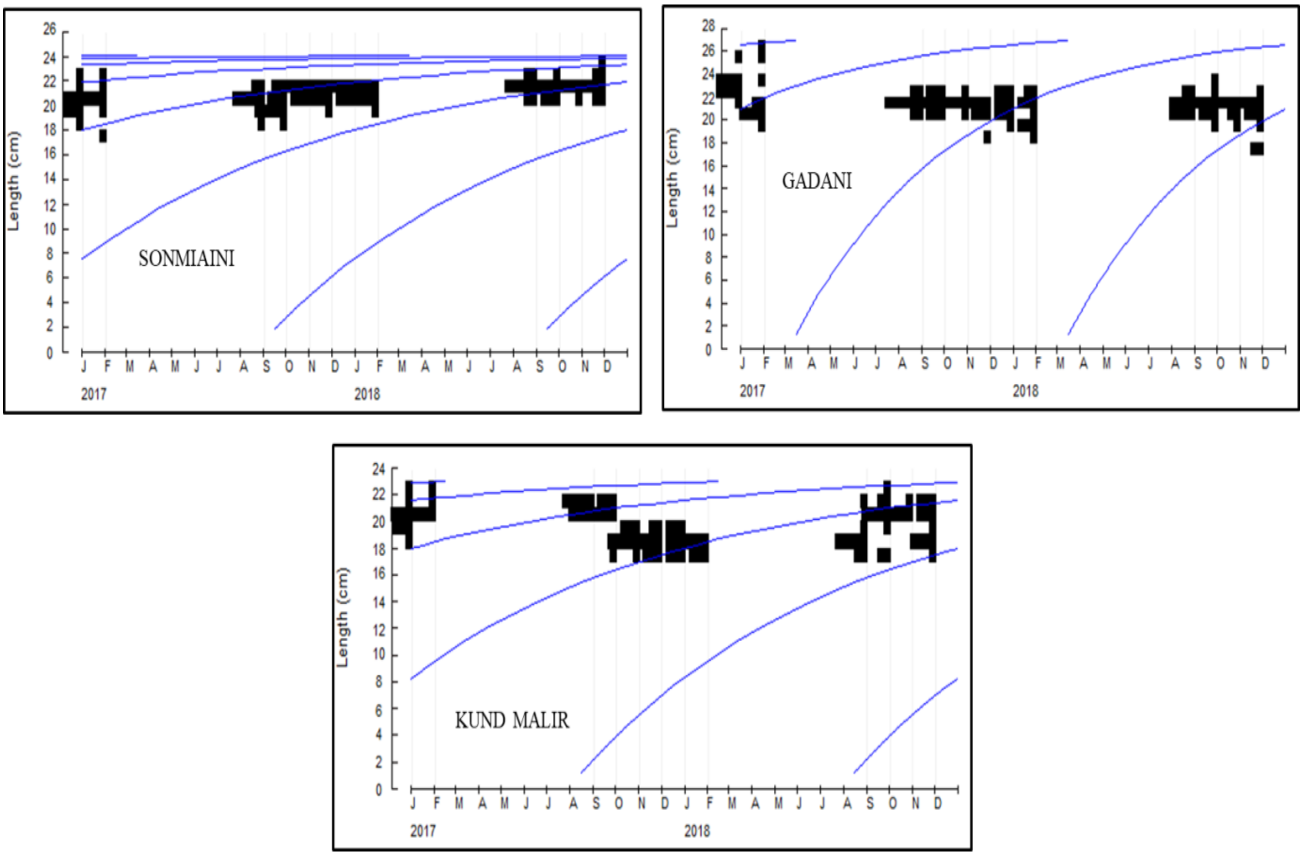

Figure 5: Growth parameter estimates L∞ = 24.73 cm, K = 0. 46 year^{-1} (Sonmiani), L∞ = 27.83 cm, K = 1. 60 year^{-1} (Gadani), and L∞ = 23.63 cm, K = 0. 62 year^{-1} (Kund Malir) for *R. kanagurta* in Balochistan coastal water.

Kund Malir

At Kund Malir K = 0.62 year^{-1}L∞ = 23.63 cm, and t_o = -2.07 (Figure 5). The lengths compute 20.1, 21.7, 22.6, 23.1 cm at the age of 1, 2, 3 and 4 years, respectively (Figure 6). According to this harbor's collection the growth performance index (Φ) was estimated 2.54 for Indian mackerel. Longevity was 2.77 years.

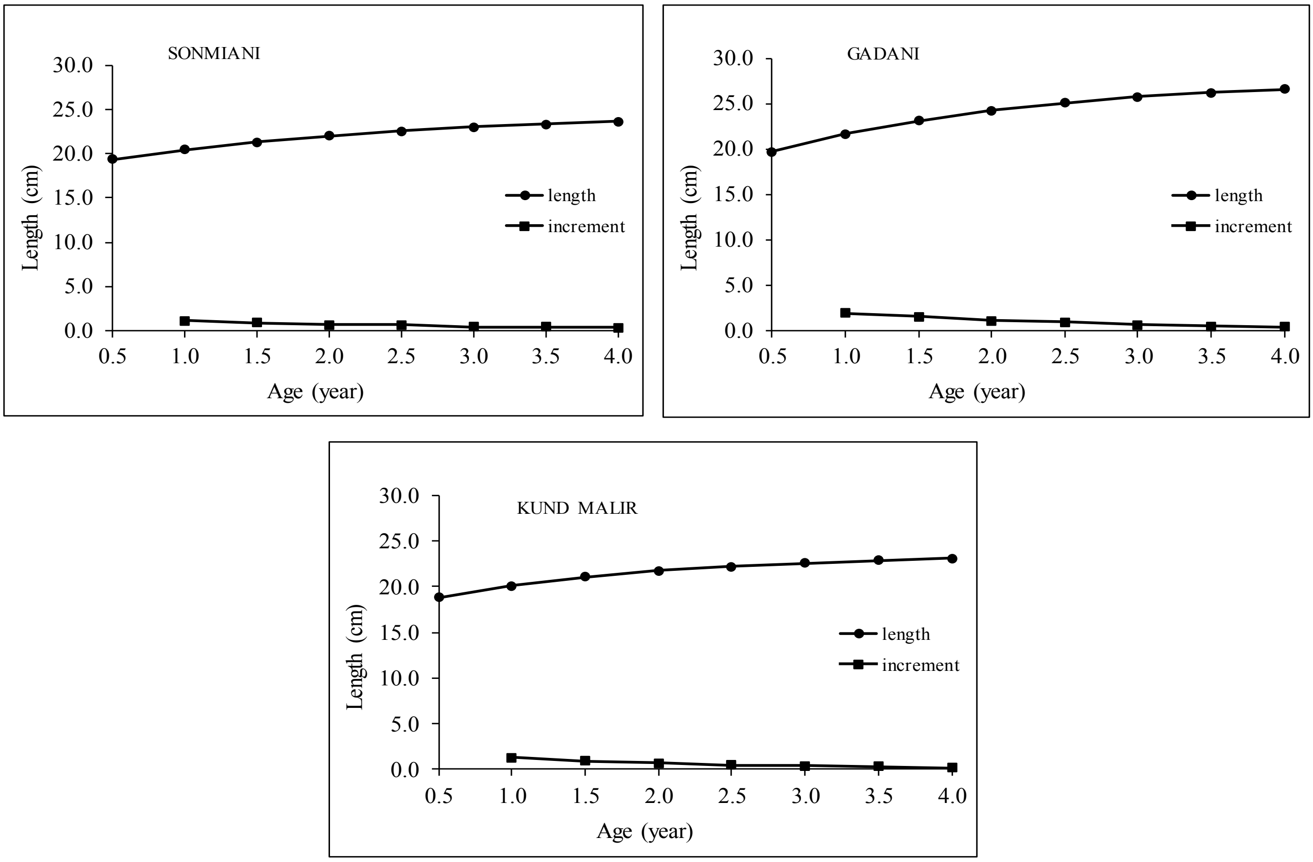

Figure 6: A growth curve showing the fork length of *R. kanagurta* (collected from three fish harbors) at different age calculated by von Bertalanffy growth model.

3.4. Mortality and exploitation rates

Sonmiani

The instantaneous rate of natural mortality (M) was estimated to be 1.13 year^{-1} with an average temperature of 28°C. A length-converted catch curve (Figure 7) was employed for the estimation of the instantaneous total mortality at Z = 2.26 year^{-1}. The fishing mortality (F) was estimated to be 1.128 year^{-1} which was much greater than both the target (F_{opt} = 0.566 year^{-1}) and limit (F_{limit} = 0.755 year^{-1}) biological reference points. The exploitation rate (E) was estimated to be 0.499 year^{-1}. The estimation of relative yield per recruit of *R. kanagurta* is presented graphically in Fig. 8. The present level of exploitation rate (E = 0.499) was higher than the exploitation ratio for maximum yield per recruit (E_{max} = 0.355) (Figure 8).

Gadani

At Gadani the instantaneous rate of natural mortality (M) with an average temperature of 28°C was calculated as 2.48 year^{-1}. The instantaneous total mortality was Z = 3.31 year^{-1}(Figure 7) and fishing mortality (F) was estimated to be 0.833 $year^{-1}$ which was much smaller than the target (F_{opt} = 1.239 $year^{-1}$) and limit (F_{limit} = 1.651 $year^{-1}$) biological reference points. The exploitation rate (E) was calculated to be 0.252 $year^{-1}$. The evaluated relative yield per recruit of *R. kanagurta* is shown graphically in Fig. 8. The value of exploitation rate (E = 0.252) was less than the exploitation ratio for maximum yield per recruit (E_{max} = 0.385) (Figure 8).

Kund Malir

The natural mortality (M) was estimated to be 1.39 $year^{-1}$. A length-converted catch curve (Figure 7) for the calculation of the instantaneous total mortality at Z = 2.14 $year^{-1}$. The fishing mortality (F) was 0.746 $year^{-1}$. Fishing mortality was observed to be almost equal with the target (F_{opt} = 0.697 $year^{-1}$) and lower than the limit (F_{limit} = 0.929 $year^{-1}$) biological reference points. The exploitation rate (E) was estimated to be 0.349 $year^{-1}$. The estimation of relative yield per recruit of *R. kanagurta* explained graphically in Fig. 8. The present level of exploitation rate (E = 0.349) was nearly equal with the exploitation ratio for maximum yield per recruit (E_{max} = 0.361) (Figure 8).

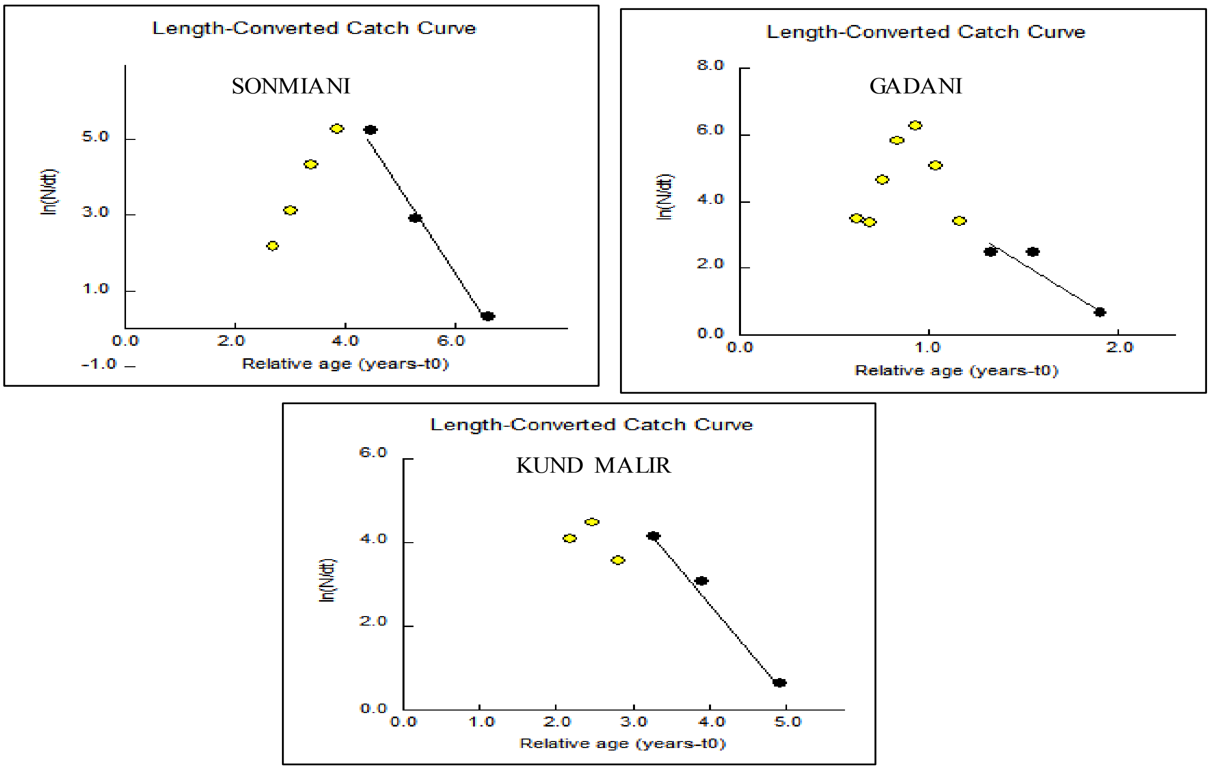

Figure 7: Catch curve analysis of *R. kanagurta,* collected from three harbors of Balochistan, Pakistan

In the present study total landings of mackerel in 2017 were observed 2707.97 which were decreased to 2502.15 metric tons in 2018. Overfishing is causing a rapid decline in the catch of Indian mackerel, which has emerged as a major commercial fish species along the country`s coast in recent years. Nearly 30 plants set up between 2008 and 2010 specifically to process mackerel along Balochistan coast, but had closed down [31]. Overfishing of mackerel was also having a huge impact on its exports as its export quantity had declined by up to 40 per cent [32].

In the present study highest catch of Indian mackerel was recorded in November to December on Balochistan coast, same favorable season was mentioned [33] from Indian Coast. Wind speed, sea surface temperature and precipitation are known to influence the catch rates of mackerel. As coastal water productivity and nutrient levels was impacted by wind speed and sea surface temperature [34].

Higher productivity outcomes in rich contribution of food which ultimately leads to higher possibility of larval survival and recruitment, eventually important to increases in fish abundance and catch [35]. Earlier it was believed that the disappearance of predatory fish such as shark and tuna due to food imbalance in the sea had led to an increase of mackerel but later the theory was rejected. Now, climate change factors are thought to be behind its increase in population in the Arabian Sea, as some responses of the fish to climate change included extension in the distributional boundary, physical changes and extension in the depth of occurrence [31].

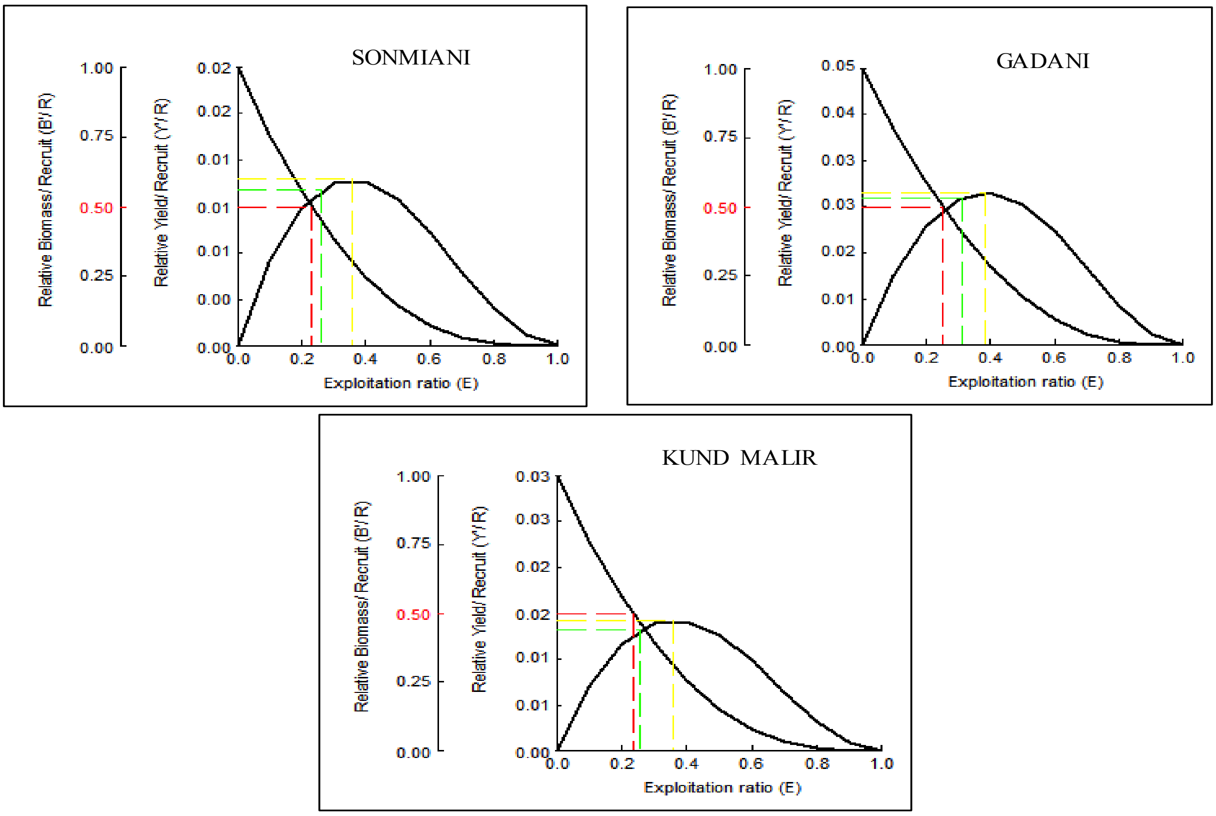

Figure 8: Relative yield per recruit of *R. kanagurta* of three fish harbors of Balochistan, Pakistan

The fork length of a sum of 344 individuals of *R. kanagurta* ranged from 17.1 to 27.0 cm with 84.0 - 224.0 g in weight. The length weight relationship data of the present study shows negative allometric growth (b = 1.719 to 2.376) in Indian mackerel, while, previously Ahmed *et al.*[15] and Rehman *et al.*[9] also reported negative allometric growth in Indian mackerel from coastal water of Pakistan. It is found that the value of the power “b” obtained from the present study is more or less similar to those mentioned for *R. kanagurta* from the previous studies of different parts of the world. Mustafa and Ali [36] calculated ‘b’ value of 2.89from the Bay of Bengal. Rahman and Hafzath [37] from Kuantan coastal water, Malaysia observed negative LWR of *R. kanagurta* in some months. While from some other part of the world isometric growth of this fish was also reported [38, 23] as well as positive allometric growth [39, 35].

In the present study the asymptotic length (L_∞) ranging from 23.63 to 27.83 cm looks to be a realistic figure as fishes having a dominant size class concentrated20.1 to 22.0 cm was available in the regular catches. The asymptotic length of Indian mackerel in the present study was found to be smaller as reported from values of this parameter from different part of the world. Al-Mahdawi and Mehanna [23] estimated L_∞= 32.5 cm from the Yemen coast, Pawase *et al.* [40] calculated L_∞ value of 32 cm from

Maharashtra, India. While according to Amin *et al.* [41] L_∞ = 33.79 cm from Gulf of Suez, Egypt. However earlier reported data from coastal water of Pakistan for *R. kanagurta* was L_∞ = 24.57 cm [9] which lies between our present study of estimated asymptotic length range (23.63 to 27.83 cm). Differences in environmental parameters, food availability, predation, exploitation and type of fishing gears used, manipulate the growth parameters [37, 35].

The lengths were calculated according to von Bertalanffy growth function equation and results are shown in Fig 4. The obtained values from all harbors data show that Indian mackerel attains length of 20.1-25.7 cm, 21.7 – 27.4 cm, 22.6 – 27.7 cm, 23.1 – 27.8 cm at the end of 1st, 2nd, 3rd and 4rth year of life, respectively. It is apparent that Indian mackerel reach their highest growth ratio in length during the first year of life, after which, the yearly increment in length decreases with further increase in age till it achieve its minimum value at the end of the 4rth year of life (Fig. 4). This present finding is same with the result of George and Banerji [42] who described that the young stages of *R. kanagurta* are considered by a higher growth rate than the old ones. Amin *et al.* [41] calculated mean lengths at 17.29, 22.38, 27.20 and 30.50 cm for the 1st, 2nd, 3rd and 4rth year of life, respectively for *R. kanagurta* from Gulf of Suez, Egypt. Al-Mahdawi and Mehanna [23] found that the Indian mackerel reaches a total length of 16.15, 23.29, 27.54 and 29.61 cm by the end of the 1st, 2nd, 3rd and 4th year of life, respectively from the Yemeni coast of Red Sea. However, Rehman *et al.* [9] estimated lengths at the 18.9, 22.1, 23.5, and 24.1 cm for the 1st, 2nd, 3rd and 4rth year of life, respectively from coastal water of Pakistan.

Natural mortality coefficient (M) of a fish is directly correlated to the growth coefficient (K) and inversely linked to the asymptotic length (L∞) and life span [43]. In the present study *R. kanagurta* with higher growth coefficient of 0.46 to 1.60year-1 and shorter lifespan of 1.28 to 3.69 years was found to have relatively higher natural mortality coefficient of 1.13 to 2.47 per year. The range of M/K ratio found between1.55 to 2.46, which was within the normal range of 1 - 2.5, as proposed by Beverton and Holt [43]. Natural mortality coefficient values in the present study were in range when compared to 0.72 - 2.64 described previously by several authors [44, 36, 45, 39, 23, 41, 35, 33, 40]. However, present estimated total mortality (Z) rates as 2.14 - 3.31 year^{-1}and previously calculated total mortality Z = 3.89 year^{-1} by Rehman *et al*. [9] along the North Arabian Sea were smaller than 4.92 - 8.28 year^{-1} suggested by others researchers from other sharing part of Arabian sea [36, 39, 35, 33, 40]. Estimation of total mortality depends on the behavior of the fish. Fish stock seems in the exploited area unpredictably and move away from the functioning range of apparent gears with variations in environment. This can cause inaccuracy in the assessment of abundance of larger size groups and therefore in the mortality rates.

Patterson [28] explained that if Exploitation rates above F_{limit} indicated that the stock is under decline whereas below this limit, it presented tendency towards stock retrieval. While Exploitation below F_{opt} permits stock to grow in size. In the present study the calculation indicated an average $E_{\max}$ to be 0.367± 0.016 against the present average exploitation rate (E) of 0.366 ± 0.124 thus indicating only limited opportunity is existing for production increase from the present grounds along Balochistan coast, Pakistan, however, Rehman *et al.* [9] analysis showed an $E_{\max}$= 0.421 in contrast to the exploitation rate (E) of 0.567, showing species is under fishing pressure along Karachi Coast, Pakistan.

Conclusion

It may possibly be concluded that the *R. kanagurta* stock in the Arabian Sea has to be maintained without further increase fishing efforts otherwise it will be reached to its state of overexploitation and present exploitation rate must be decreased to the level of $E_{0.5}$ for the management purpose. It is prudent to standardize the fishery at a more inferior level than the optimum exploitation level.

Disclosure statement

Conflict of Interest: The authors declare that there are no conflicts of interest.

Compliance with Ethical Standards: This study was performed in accordance with ethics committee measures of animal experiments.

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