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Stock Analysis of Shrimp Scad (*Alepes djedaba*) Fishery from Northern Arabian Sea, Balochistan Coast, Pakistan

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AM executed the experimental work. MAK supervised the study. ZL and CL helped in data analysis and paper writing and editing. FS helped in writing and review process.

Key words
***Alepes djedaba*, Electronic lenght-fequency analysis, Exploitation rate, Isometric growth, Length-weight relationship, Pakistan, Van Bertalanffy growth equation**

ABSTRACT

Alepes djedaba (Forssakal, 1775), is commonly known as yellowtail fish/shrimp scad, belonging to Carangidae family widely spread in tropical waters. *A. djedaba* is commercially important fish species from northern Arabian Sea, Pakistani waters. Present study was conducted on stock status of shrimp scad *A. djedaba* fishery from Balochistan coast, Pakistan. The data was collected from March 2019 to February 2020, and a total of 1,027 pairs of length-weight and length-frequency data distribution were measured. Computer software FiSAT package was used to analyze the growth and mortality rate parameters. The length-weight relationship values for male was W= $0.016xb^{2.906}$ (R^2 = 0.950) and female was W= $0.029xb^{2.724}$ (R^2 = 0.941). The combined data of both sexes were W= $0.021xb^{2.830}$ (R^2 = 0.945). The electronic length-frequency analysis (ELEFAN) method was used to estimate the VBGF parameters, which were $L\infty$ = 39.9 cm (FL), K = 1.6 yr^{-1}. However, total mortality (Z) was estimated using a length-converted catch curve analysis and found at Z = 5.31 yr^{-1} with a 95% confidential interval (CI = 4.77-5.84). Natural mortality was estimated at M = 2.16 yr^{-1} using an average temperature of sea 26°C in Pakistani waters, though, the fishing rate was obtained by F = Z-M = 3.15 yr^{-1}. Exploitation rate (E) was at E = F / Z = 0.593 yr^{-1}. The length-weight relation values show the isometric growth in nature and similar to previous studies. The mortality and exploitation rate was found higher than previous studies which indicate the high commercial demand of this species from Pakistani waters. The exploitation rate from Pakistani waters is higher than limit point (> 0.5) which indicates that stock of this fishery is in overexploitation state. It may also be recommended that some management measures should be taken to maintain the stock of this fishery at sustainable level for future generation.

INTRODUCTION

Pakistani waters situated at northern Arabian Sea and consist about 1100 km coastline with exclusive economic zone (EEZ) consisting 350 nautical miles (NM) with 240,000 km², with additional continental shelf area of about 50,000 km². Pakistan coastline is divided in to two provinces (Sindh and Balochistan), however, geographically, the coast of Pakistan can be divided into five parts, from the Indian border in the east to Sir Creek in the west to Gwater Bay (Fig. 1). Sindh coast line is about 348 km, due to the influx of freshwater from the Indus River creates rich mangrove ecosystem in result creates most productive area and nursery ground along coast of Sindh, Pakistan. There are many large fishing grounds along Sindh coast such as Hajamro, Ibrahim Hydri, Kati Bandar, Pattani, Gharo, Khobar, Korangi and Khadi.

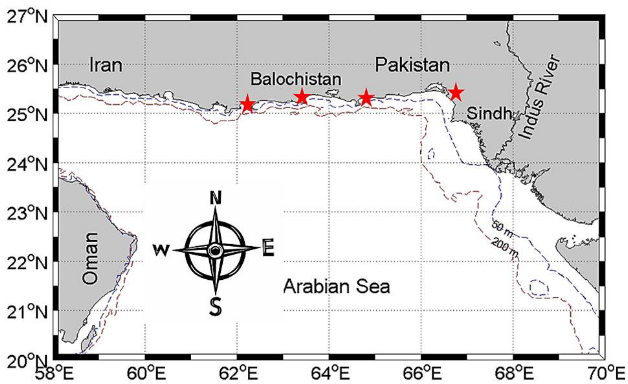

Fig. 1. Pakistan coastline, divided in to Sindh and Balochistan, stars indicating the fish landing sites along Balochistan coast.

Balochistan coastline is about 772 km, it also have mangrove ecosystem at few places of coast but Sonmiani bay generates finest nursery grounds for finfish and shellfish fisheries. This coast also has some important

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fishing grounds such as Gwatar Bay, Sonmiani Bay, Pasni and Ormara (Baloch, 1987; FAO, 2009). Pakistan commercial fishery resources consist about 15 medium pelagic fish species, 20 large pelagic, 50 small pelagic and demersal 250 species of fish (FAO, 2009). In the offshore waters species are caught Tuna, marlins and other large pelagic species from 24 to 250 nautical miles along coastline. In the coast up to almost 50 meter depth the demersal fish species were captured such as crabs, shrimp, catfish, croakers, lobster, snapper (MFF Pakistan, 2016). The fisheries sector produced employment about 1% of national labor force with four lacs directly and six lacs indirectly. Along coastline and inland areas of Pakistan the fisheries sector instead favoring particular sub-branches of livelihood to relevant folks. In 2016-17 obtained gross domestic products (GDP) about 5.3% compared to the previous year 2015-16 (4.5) with difference of 0.8% (Ebrahim, 2014; Sherani, 2017).

The *Alepes djedaba* (Forssakal, 1775), shrimp scad, is also known as slender yellowtail kingfish and belongs to Jack family, Carangidae a large tropical marine fish (Medhat *et al*., 2014). Species of this family are found marine and estuaries water in subtropical, temperate and tropical areas (Shuaib and Ayub, 2011). Fishes of this family are highly valuable for aquaculture, recreational and commercial purpose (Katsuragawa *et al*., 1992). *A. djedaba* occurs throughout the western Indian Ocean, but limited found in western Pacific Ocean where it is identified only from Thailand, Taiwan, Sumatra and Philippines, and also identified from eastern region of Mediterranean Sea (coasts of Egypt, Israel and Lebanon) latest refugee from Red Sea via the Suez Canal (Fischer and Bianchi, 1984; FAO, 2009). This species feed on two types of animals, juvenile fishes and crustacean larvae depending on the availability of these food items (Sivakami, 1990). Several studies has been conducted on stock appraisal of different fish species using different data like length frequency and yearly fish catch and effort data to estimate the sustainable level from Pakistani waters (Kalhoro *et al*., 2013, 2014a, b, 2015a, b, 2017a, b, 2018; Memon *et al*., 2015, 2016; Afzaal *et al*., 2016, 2018; Nadeem *et al*., 2017; Razzaq *et al*., 2019; Baloch *et al*., 2020).

Number of studies has been conducted on different aspects of shrimp scad from different parts of the world like on feeding habits of *Alepes djedaba is* from Indian (Sivakami, 1990). Length weight relationship and other biological parameters from India (Sajana and Bijoy., 2017; Sivakami, 1990; Raje, 1993), Indonesia (Siwat *et al*., 2016; Vonklauss *et al*., 2016; Jaliadi *et al*., 2017), Taiwan (Chu *et al*., 2011), Turkey (Taskavak and Bilecenoglu, 2001), France (Kulbicki *et al*., 1993), Egypt (Attia, 2018), Philippine (Schoeder, 1982), Pakistan (Shuaib and Ayub, 2011) and Iran (Parsa and Khoshdarehgi, 2017).

Few studies have been conducted on growth and mortality parameters in Egypt (El-Sayed, 2005; Attia, 2018), Indonesia (Vonklauss *et al*., 2016), Saudi Arabia (Medhat *et al*., 2014), Philippine (Corpuz *et al*., 1985; Cinco and Silvestre, 1992), India (Reuben *et al*., 1992; Bandkar *et al*., 2016), and from Southeast Asia (Hannesson *et al*., 2006). However, limited work has been done on the stock analysis *A. djedaba* fishery from northern Arabian Sea, Pakistani waters. Current study is focus on length-weight relationship, growth, mortality and exploitation rate and stock analysis of *A. djedaba* from northern Arabian Sea Pakistan. Findings of the present study will contribute the knowledge about biological parameters and the current status of this fishery from Pakistani waters which helps fishery managers to set the fishing goals for future generation.

MATERIALS AND METHODS

The samples were collected on a monthly basis in collaboration with research survey data through research project from different fish landing sites along Balochistan coast, Pakistan during March 2019 to February 2020. Pair of length-weight for both sexes (male and female) and length frequency distribution data was collected during present study. Fork length was measured in centimeters (cm) using a wooden measuring board. However, weight was measured using a digital weight balance into grams (g). Total of 1,027 pair data of length-weight and length frequency distribution data were investigated to analyze growth, mortality (total, natural and fishing), growth performance index and exploitation rate from Pakistani waters.

Length-weight relationship

A total of 1,027 *A. djedaba* samples were collected to assess the length-to-weight relationship by: W = aL^b, whereas, W indicates the weight of species in grams (g), L indicates fork length (cm), *a* is condition factor and *b* is the slope.

Growth rate parameters

Growth rate values were calculated by inserting length frequency data into the Van Bertalanffy growth equation (VBGF) $L_t = L_\infty (1 - exp(-k(t - t_0)))$; Where, L_t is the predicted length (cm) in age t. L_∞ is the asymptomatic length, *K* is the growth capacity and t_0 is hypothetical age at which the length of the fish is equal to zero (mostly negative, Haddon, 2011).

Growth performance index (Ø')

Performance index of growth (Ø') of *A. djedaba* were estimated with equation by Pauly and Munro (1984): Ø' = $\log_{10} K + 2 \log_{10} CW_{\infty}$; that is present in computer Package with VBGF parameters growth.

Mortality parameters

Total mortality (Z) was estimated using the length-converted catch curve analysis method (Pauly, 1983). Natural fish death (M) was estimated from Pauly empirical formula. $\log_{10}(M) = -0.006 - 0.279 \log_{10} L_{\infty} + 0.654 \log_{10}(K) + 0.634 \log_{10}(T)$; L_{∞} and K indicates the VBGF parameters and T indicates the annual average sea surface temperature (26°C). The exploitation rate (E) is calculated from the equation: E = F / Z where F is the rate of fishing which is calculated by F = Z - M.

Virtual population analysis

Virtual population analysis of *A. djedaba* were estimated by using growth, Length, weight, and natural and fishing mortality rates are estimated in the FiSAT.

RESULTS

Length frequency distribution

Total of 1027 length frequency data were collected during March 2019 to February, 2020 from Balochistan coast, Pakistan. Length frequency was assembling in 3 cm length classes interval ranges from 14 to 38.5 cm. The highest number of frequencies was observed from 14-26 cm length class (Fig. 2).

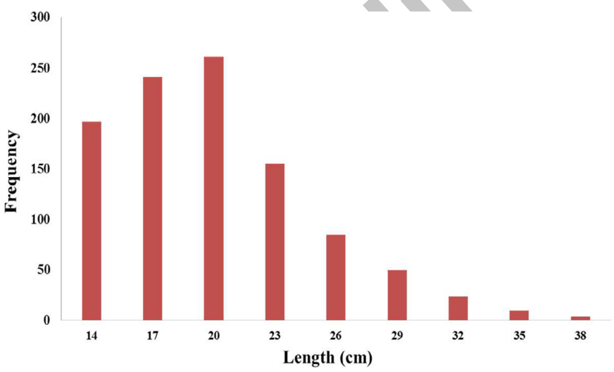

Fig. 2. Length-frequency distribution data (n=1027) of *A. djedaba* from northern Arabian Sea, Balochistan coast, Pakistan.

Length-weight relationship

Total of 1027 relationship of length-weight of *A. djedaba* were gathered to estimate the length and weigh ratio of the fish. The length size and weight range were between 14 to 38.5 cm (male: 21.50±4.93; female, 21.56±4.96) and 45 to 603 g (100.73±SD), respectively. The relationship between length-weight of male, female and combine sexes was estimated. Total of 603 pairs for male was collected and length-weight slop *b* for male was estimated at *b*=2.906 (R^2 = 0.950) (Fig. 3A), and total pair of 424 for female was collected and slope *b* was estimated at 2.724 (R^2=0.941) (Fig. 3B), while, both sexes combine length-weight relationship were calculated at *b*=2.830 (R^2=0.945) (Fig. 3C).

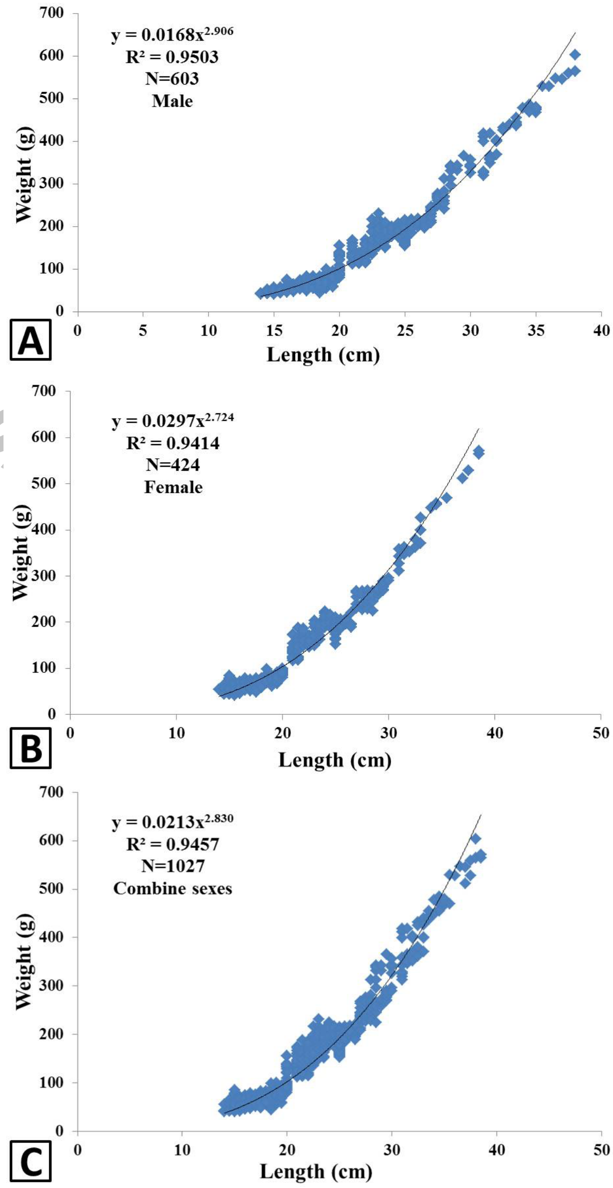

Fig. 3. Length-weight relationship of male (A), female (B) and combined sexes (C) of *A. djedaba* (Male) from Balochistan coast, Pakistan.

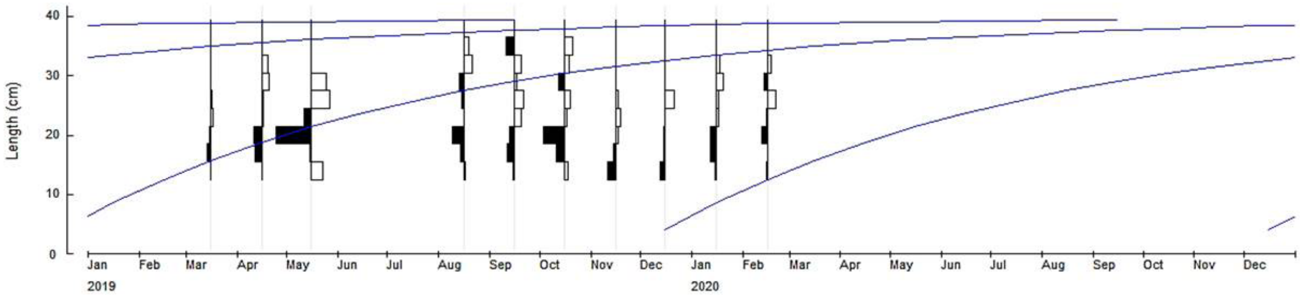

Fig. 4. Length frequency distribution data fitted with growth curve to estimate the growth rate (at L∞ = 39.9 cm and K = 1.6 yr^{-1}) of *A. djedaba* fishery from northern Arabian Sea, Balochistan, coast, Pakistan.

Growth rate

Total length frequency number of 1027 value was calculated to find growth parameters. The electronic length frequency analysis (ELEFAN) method was used to estimate the VBGF growth parameter of *A. djedaba* with von Bertalanffy equation from Balochistan coast, the estimated values were obtained at L_∞ = 39.9 cm and K = 1.6 yr^{-1} (Fig. 4).

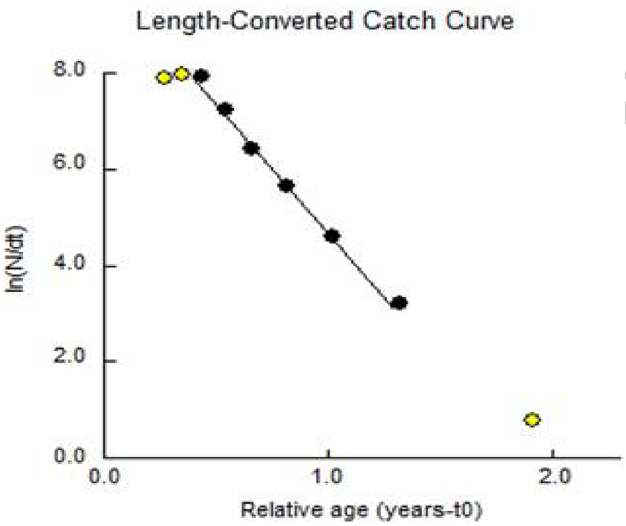

Fig. 5. Total mortality (Z=5.31) calculated by length converted catch curve where 95% confidential interval (CI =4.77-5.84), black dots showing data selected for mortality estimation while yellow dots were excluded from estimation for *A. djedaba* fishery from Balochistan coast, Pakistan.

Growth performance index (Ø')

Growth performance was projected from the input values of growth rate (L_∞= 39.9 cm and *K*= 1.6 yr^{-1}) to find the performance growth value. The calculated value of for *A. djedaba* was at Ø' =3.406 from northern Arabian Sea Balochistan coast, Pakistan.

Mortality rate parameters

Mortality rate parameters were assessed using data (n= 1027) of length frequency distribution, the length converted catch curve method was used to calculate total mortality (Z), total mortality with 95% confidential interval were Z = 5.31 yr^{-1} (CI = 4.77-5.84) (Fig. 5). Whereas, (M) natural mortality is estimated from the empirical equation with an average sea surface temperature of 26°C in Pakistani waters and calculated at M= 2.16 yr^{-1}, whereas, F value (fishing mortality) at Z-M= 3.15 yr^{-1}. The value of exploitation rate (E) were estimated at F/Z = 0.593 yr^{-1} (Fig. 6).

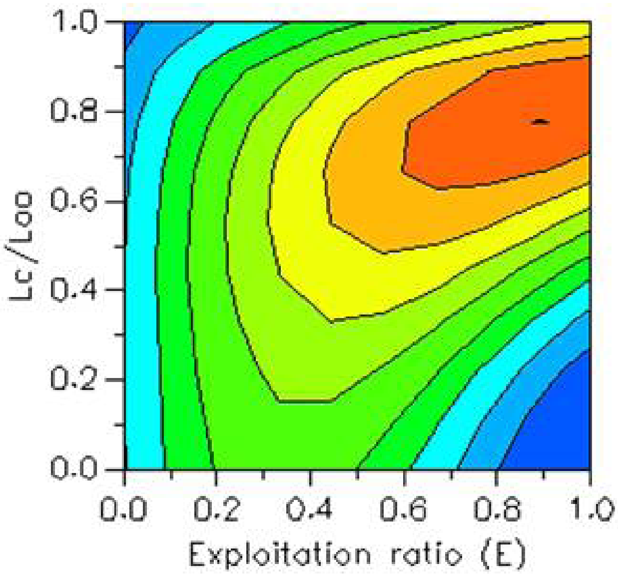

Fig. 6. The exploitation rate was estimated using mortality parameter which showing the exploitation rate is E=0.593 from Balochistan coast, Pakistan.

Virtual population analysis

Virtual population analysis was calculated using growth parameter and length-weight values. It was observed that the loss of fish is about the size of a small fish while the pressure of fishing is on the larger size of the fishes *i.e.* 14 to 38.5 cm species (Fig. 7).

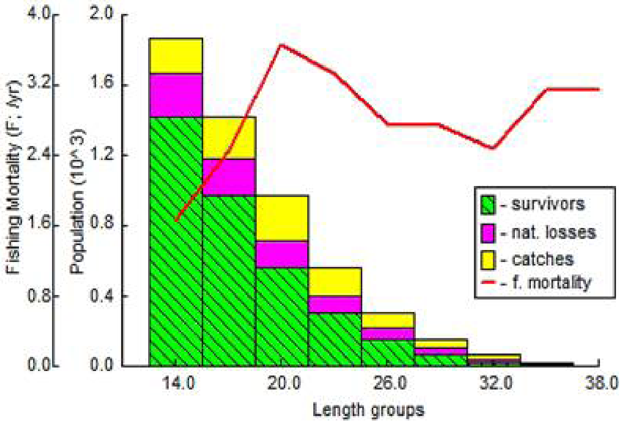

Fig. 7. Virtual population analysis indicates fishing pressure in which fish species range in length from 14 to 38 cm.

DISCUSSION

Length-weight relationship

Length-weight relationship is an important tool to know the different components of fish population dynamics and basic components for the stock assessment (Attia, 2018). During current study total of 1027 length-weight relationship data was analyzed. The slope *b* value for male was estimated at *b*=2.906 (R^2 = 0.950) while, for female at *b*= 2.724 (R^2=0.941), however, the relationship for both sexes was estimated at *b*=2.830 (R^2=0.945), this value is close to 3, which indicates that the fish has isometric growth from Balochistan coast, Pakistan. The usually coefficient of determination describe the goodness of fit test (R^2) value range between 0-1 (1-100%), while, the current study values close to 1 (R^2 = 0.945) that shows percentage data good fitted in model. It is commonly known that the slop *b* value ranges from 2.5-3.5 shows that fish have isometric growth in nature (Le-Cren, 1951; Froese, 2006).

During present study the overall estimated slop *b* values are close to 3, which indicate that the *A. djedaba* fishery has isometric in growth. Present findings of length-weight values also compared to previous studies from various regions (Table I). The values from Taiwan (Chu *et al*., 2011), Turkey (Taskavak and Bilecenoglu, 2001), France (Kulbicki *et al*., 1993), Indonesia (Jaliadi *et al*., 2017), India (Raje, 1993), Philippine (Schoeder, 1982), Iran (Parsa and Khoshdarehgi, 2017) are lower or close to current results. While, values from India (Sivakami, 1990; Sajana and Bijoy, 2017), Indonesia (Vonklauss *et al*., 2016), Pakistan (Shuaib and Ayub, 2011), and Egypt (Attia, 2018) are slight higher than present study. However, majority of the *b* slope values are near or similar to current study. This small difference in values expected to various aspects which influencing the growth rate (length and weight) of fish. Accessibility of food, maturity of fish, various environment and climate change are important factors which influencing the fish growth (Froese, 2006; Biswas, 1993; Baloch *et al*., 2020).

Table I.- Different parameters of the length-weight relationship compared to previous results.

Area	*a*	*b*	R^2	References
Kerala , India	0.01	2.976/M	0.995	Sajana and Bijoy, 2017
		2.949/F	0.997	
Indonesia	0.05	2.939	0.961	Vonklauss *et al*., 2016
Taiwan	0.05	2.580	0.970	Chu *et al*., 2011
Karachi, Pakistan	0.05	2.830/M	0.821	Shuaib and Ayub, 2011
	0.05	3.084/F	0.891	
Turkey	0.00075	2.816	0.860	Taskavak and Bilecenoglu, 2001
From Cochin, India	0.005	3.147	0.960	Sivakami,1990
France	1.69E-02	2.761	0.918	Kulbicki *et al*., 1993
India	-4.804/M	2.922	-	Raje, 1993
	-4.380/F	2.740	-	
Indonesia	0.017	2.8971	0.993	Jaliadi *et al*., 2017
Coast of Sinai , Egypt	0.0064	3.134	0.856	Attia, 2018
Philippine	-	2.670	-	Schoeder, 1982
Persian Gulf, Iran	0.034	2.685	0.964	Parsa *et al*., 2017
Pakistan	0.016	2.906/M	0.945	Present Study
	0.029	2.724/F	0.941	

Table II.- Growth rate parameter from present study is compared to previous studies from different areas of the world.

Area	Length ($L\infty$)	Growth (K)	$-t_o$	(Ø')	References
Abu Qir Bay, Egypt	33.29	0.247	-0.51	-	El-Sayed, 2005
Indonesia	23.0	2.422/M	-	-	Vonklauss *et al*., 2016
	-	2.432/F	-	-	
Saudi Arabia	41.71	0.360	-0.76	-	Medhat *et al*., 2014
Philippine waters	40.0	1.20		2.54	Corpuz *et al*., 1985
Egypt	26.94	0.295	-1.041	2.33	Attia, 2018
Indian Sea	32.60	0.610		2.81	Reuben *et al*., 1992
Philippines	14.40	0.850	2.246	-	Cinco and Silvestre, 1992
Southeast Asia	21.33	0.890		2.53	Hannesson *et al*., 2006
India	28.90	1.0	-0.004	-	Bandkar *et al*., 2016
Pakistan	39.90	1.60	-	3.41	Present study

Table III.- Mortality rate and exploitation factors compare to previous findings from various regions of the world.

Area	M	F	Z	E	Reference
Abu Qir Bay	0.62	1.23	1.85	0.56	El-Sayed, 2005
Arabian Gulf	0.80	1.27	2.07	-	Medhat *et al*., 2014
Philippines	2.0	6.54	8.54	0.77	Cinco and Silvestre, 1992
SW coast , India	0.99	4.16	5.15	0.81	Pillai, 1999
Coast of Sinai, Egypt	0.44	0.48	0.92	0.53	Attia, 2018
South and Southeast Asia	5.43	7.20	1.77	0.78	Hannesson *et al*., 2006
Coast Maharashtra, India	1.80	1.43	3.23	0.45	Bandkar *et al*., 2016
Pakistan	2.16	3.15	5.31	0.593	Present study

Growth rate parameters

Different methods were used to estimate the age and growth parameters using age-structure from otolith and hard parts of the fish body. Estimation of growth rate using different methods could be used to analyze the growth performance of fish from any water body which could be used for the stock assessment (Sparre *et al*., 1992; El-Sayed, 2005). In the current study, VBGF techniques using length frequency data were used to calculate growth parameters. Present finding values of growth rate (L_∞= 39.9 cm and K= 1.6 yr^{-1}) were also compared to previous findings from various regions (Table II). The growth rate values from Saudi Arabia (Medhat *et al*., 2014) and Philippine (Corpuz *et al*., 1985) are higher than current findings. But, values from Egypt (El-Sayed, 2005; Attia, 2018), Indonesia (Vonklauss *et al*., 2016), India (Reuben *et al*., 1992; Bandkar *et al*., 2016), Philippines (Cinco and Silvestre, 1992), and Southeast Asia (Hannesson *et al*., 2006) are lower or close to current study. The growth parameters of present study are little different then previous studies which indicate that various biotic and abiotic factors effecting on the growth rate of fish (Devaraj, 1981; Adam, 1980; Ciloglu, 2005; Sparre *et al*., 1992; Baloch *et al*., 2020).

Mortality rate

The total mortality coefficient (Z) is defined as the total loss by death (natural and fishing) of individuals from a population during a certain time interval. The total mortality coefficient is composed of two components namely fishing mortality (F) by fishing activities and natural mortality (M) by all other reasons than fishing (predation, ecological conditions and diseases *etc*.) The natural mortality is clearly associated with life-past issues such as growth rate and maximum age (Papaconstantinou and Kapiris, 2003). The present study assessed parameters of natural (M), fishing (F) and total mortality (Z) rate at M=2.16, F=3.15, Z=5.31, respectively and exploitation rate was estimated at E= 0.593. The present mortality values were compared to earlier reports from various areas of world (Table III).

Present findings was compared to the previous studies from different regions of the world like Z, M and F parameters from Qir Bay, Egypt was 1.85, 0.62 and 1.23 yr^{-1}, respectively (El-Syed, 2005). While, the values from Arabian Gulf was Z= 2.07, M= 0.8 and F= 1.27 (Medhat *et al*., 2014). Philippine Z=8.54, M=2.0, F=6.54 (Cinco and Silvestre, 1992) and Z=5.15, M=0.99 and F=4.16 (Pillai, 1999). However, the values from Egypt was Z=0.919, M=0.43 and F=0.48 (Attia, 2018), Z=1.77, M=5.43, and F=7.2 (Hannesson *et al*., 2006), whereas, the mortality rate values from India was Z=3.23, M=1.802 and F=1.428 (Bandkar *et al*., 2016).

Overall mortality values are close to the current results from diverse parts of the world, little difference in values is may be because of commercial importance of this fishery increases the catch rate of this fish. During present study the exploitation rate was estimated at E= 0.593. According to Gulland (1971) the exploitation rate must be less than 0.5, if this value higher than limited point than the stock may be measured at overexploitation state. While, Patterson (1992) suggested that the exploitation rate must be maintained at 0.4 level for the conservation of the species for long term and sustainable use. Agreeing to Christensen and Pauly (1997) for juveniles, predation mortality is occasionally much greater than fishing mortality. The difference indicate that mortality calculation different from author to author and vary from one area to another, environment temperature and von Bertalanffy limitations of equation are major sources of different values of natural mortality (Pauly, 1985). Based on the present mortality and exploitation rate (E=0.593) findings shows that the exploitation rate is higher than the catch limit and considered to be at over-exploitation state.

CONCLUSION

Present study on stock status of *A. djedaba* was conducted from northern Arabian Sea, Balochistan coast, Pakistan. The length-weight relationships findings indicate the isometric growth from Pakistani waters. The outcomes were matched to earlier studies which observed similar or close to the previous studies. However, growth and mortality parameter values are close or similar to previous studies from different regions. Variation in the growth rate values may be because of some environmental, genetically and availability of food causing on the impact on growth. It was also observed that fish catching method and data collection methods may also effect on the results. However, the exploitation rate of *A. djedaba* fishery is higher than limit level which indicates that the stock of this fishery is an over-exploitation state. Government fisheries assets management must take some deliberate steps to maintain stock of this fishery from Balochistan coast Pakistan. Present study also recommends that use the appropriate gear varieties, proper mesh size as well the fishing techniques and ban on illegal and unreported fishing gears. The fishing activities must be restricted during fishing ban season. It may also be recommended that further research based on research survey and life history parameters should be conducted for better management particularly for this fishery. The fishery administration divisions and fishery research organization and universities should work collectively to get solution for better fishery management.

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Statement of conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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