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Original Article

Population dynamics of bearded croaker *Johnius dussumieri* (Cuvier, 1830) from Pakistani waters

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Abstract

In this study the length frequency data of 2510 bearded croaker *Johnius dussumieri* (Cuvier, 1830), collected from the coast of Pakistan during 2015, were analysed. Total length of the specimens (male and female combined) varied from 4 to 25 cm with dominant individuals ranged between 12 and 15 cm whereas the body weight varied between 3 and 155 g. The length frequency data were analysed for the estimation of population dynamics and the power coefficient *b* of length weight relationship was estimated as 2.83. Other measurements were as follows: asymptotic length, L_∞ = 26.25 cm; growth coefficient, K = 1.00 year^{-1}; total mortality, Z = 2.43 year^{-1}; and natural mortality, M = 1.82 year^{-1}. The fishing mortality (F) and exploitation ratio (E) were 0.61 year^{-1} and 0.251 respectively. The Biological Reference Points (BRPs) with Gulland method for this fishery (F_{opt}) was estimated 1.82 year^{-1} which is higher than current fish mortality. Therefore the present study shows that the *J. dussumieri* fishery is safe in Pakistan.

Keywords: Population dynamics; bearded croaker; *Johnius dussumieri*; fishing mortality; natural mortality

1 | INTRODUCTION

The growth in the world population has resulted in increased consumption of animal protein and the fishery products are important to overcome this demand for human populations (Mathiesen 2012). Pakistan is endowed with marine fisheries resources which not only supply the valuable animal protein, but also contribute to the national economy of the country, take part in the human development and employment (FAO 2009; Baset *et al.* 2017). Pakistan exports fish and fisheries products in the form of chilled, frozen, cured and canned to 47 countries of the world (Mohsin *et al.* 2018). The total amount of exported fish and fishery products was 155,671 metric tons worth 367.472 million USD during 2013-14 (Nazir *et al.* 2014).

Sciaenids, commonly known as Jew fishes, croakers or drummers are moderate to large size, usually carnivorous, a group of relatively warm water fishes, most of

them are distributed in temperate and tropical regions (Sarkar *et al.* 2018). The family Sciaenidae includes approximately 66 genera and 283 species (Lin *et al.* 2020) of demersal fishes found mainly over muddy or sandy bottoms of the continental shelf of the Atlantic, Indian, and Pacific oceans, some inhabit river mouths or enter tidal estuaries, only a few live in freshwater (Najmudeen and Zacharia 2017; Liao *et al.* 2017). Genus *Johnius* consist of 34 species but only four species have been reported from Pakistani waters (Moore 2012).

Johnius dussumieri (Cuvier, 1830) locally known as Musuka, is one of the important commercial species of Pakistan. Its maximum size is 25 cm (Bianchi 1985) in Pakistani waters while the common length is about 15 cm, found in coastal inshore waters at a depth range of 40 m (Bianchi 1985). This species feed on small fishes and invertebrates (Liao *et al.* 2016). Its distribution in the Indian Ocean covers Pakistan to the Andaman Islands (Bianchi 1985). Records of the species outside this area are probably misidentifications (Liao *et al.* 2017). This species is fished commercially and is taken by bottom trawl and boat seines (Madhu *et al.* 2013).

Study of different population parameters including the asymptotic length and growth coefficient, mortalities (natural and fishing) rate and exploitation level are essential for planning and management of marine resources. Lack of knowledge of population structure and exploitation of marine resources demand a detailed study to facilitate better management of the resources (Karim *et al.* 2017).

There are many tools for assessing exploitation level and status of the stock. Of these, FiSAT-II (FAO-ICLARM Stock Assessment Tools) has been commonly used for estimating population parameters of fishes (Jayaprakash 2002; Papaconstantinou and Kapiris 2001) because primarily it requires only length-frequency data but also enables related analysis, of size-at-age, catch-at-age, selection and other analysis.

The croaker fishery is very important in Pakistan. The smaller Sciaenids are taken in bottom trawls while the larger ones are caught with trawls, gillnets or with encircling nets. The 'Handbook of fisheries statistics of Pakistan' reports combined catches of Sciaenids ranging from 11310 t in 1999 to 10695 t in 2002, with an average of 7147 t (Memon *et al.* 2015); however, the contribution of *J. dussumieri* is same as other croakers.

Several studies have been done on different aspects of *J. dussumieri* from different locations of the world (*e.g.* gonadal infection in marine waters of Iraq, Moravec and Ali 2013; preparation and characterization of gelatins from the skin, Cheow 2007; growth, mortality and yield per recruit from Indian waters, Chakraborty 1997; bacterial profile of fresh and spoiled fish mince, Abraham *et al.* 1992; functional and nutritional properties, Souissi *et al.* 2007. Nonetheless, there was no work from Pakistani waters and therefore, the present work was conducted on the population dynamics of *J. dussumieri* from Pakistani waters. It is believed that this study would be helpful for the sustainable management of *J. dussumieri* in Pakistani waters.

2 | METHODOLOGY

A total of 2510 specimens of *J. dussumieri* (Figure 1) were collected from different spots along the coast of Pakistan (Figure 2) in 2015 with the help of the local fishermen using bottom trawls, gillnets and with encircling nets. The total length (TL) of each specimen was measured to the nearest 1.0 cm using standard device. The weight (W) of each specimen was recorded to the nearest 1.0 g. The pooled (both male and female combined) samples were considered in this study. The length frequency data were analysed using FiSAT-II (Gayanilo *et al.* 2003). In this study, the core population parameters including length-weight relationship (LWR), mortality rate, growth, growth performance index, virtual population analysis (VPA) and biological reference point (BRP) were studied.

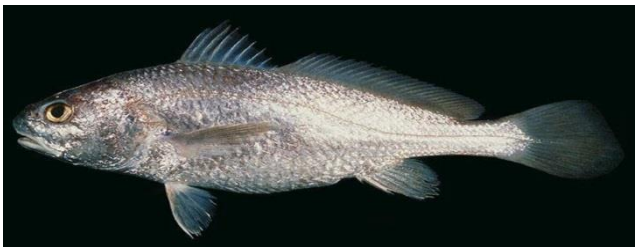

FIGURE 1 The image of bearded croaker *Johnius dussumieri* (Cuvier, 1830) from Pakistani waters.

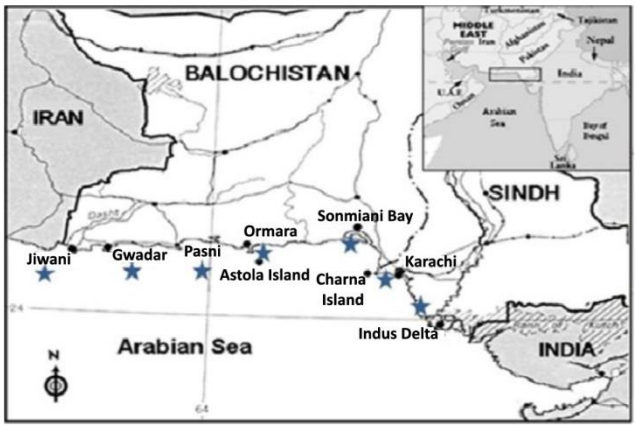

FIGURE 2 Map shows major landing sites (*i.e.* sampling spots) along the Pakistan coast.

The weight (*W*, in g) relationship to the total length (*TL*, in cm) of *J. dussumieri* was established by using a power equation (Pauly 1983), $W = aL^b$, where *W* is the weight of fish, *a* is the constant condition factor intercept, *L* is the total length and *b* is the allometric growth parameter exponent or slope.

The growth of *J. dussumieri* were calculated by using the von Bertalanffy equation for growth (Haddon 2011), as follows,

$Lt = L_\infty (1–exp (–K (t– t_0)))$

where Lt is the length at the predicted time t, L_∞ is the asymptotic length, K is the growth coefficient and t_0 is the hypothetical age or time where length was equal to zero.

Additional estimated value of t_0 was obtained by the following empirical equation (Pauly 1983),

$log_{10} (–t_0) = – 0.3922 – 0.275 log_{10} L_\infty – 1.038 log_{10} K$

The length converted catch curve method (Pauly 1983; Froese 2006) was used to estimate the instantaneous total mortality (Z).

Z: $Ln (N_t) = Ln (N_0) – Z_t$; where N_t is the population size at age t, N_0 is the population size at age 0. Z_t is the total mortality at t.

The total annual mortality (Z) was estimated by the Beverton and Holt's method (Beverton and Holt 1956):

$$Z = K \frac{L_\infty - \bar{L}_{L'}}{\bar{L}_{L'} - L'}$$

where $\bar{L}_{L'}$ is the mean length of fish of length L' and larger; L' is a length such that all fish of that length and larger are fully selected by the fishery. The equation by Pauly (1980) was used for natural mortality (M), $log_{10} M = 0.0066 – 0.279 log_{10} L_\infty + 0.654 log_{10} K + 0.4634 log_{10} T$. Where T = 27 °C, the average annual sea surface temperature of Pakistani waters. The fishing mortality (F) was estimated by using the following equations $F = Z – M$. The exploitation ratio (E) was obtained as per Gulland (1971): $E = F / Z = F / (F + M)$.

The optimal fishing mortality rate $F_{opt} = M$ was determined as the limit biological reference points (following Gulland and Rosenberg 1992; Carvalho and Hauser 1995)

$$\frac{F_W}{R} = FW_\infty e^{-M(t_c-t_r)} \sum_{n=0}^{3} \frac{Q_n e^{-nK(t_c-t_0)}}{F+M+nK} (1 - e^{-(F+M+nK)(t_\lambda-t_c)})$$

The model used by Beverton and Holt incorporated into the FAO FiSAT-II programme (Gayanilo *et al.* 2003) with the formula relative yield per recruitment (Y/R) values as a function of exploitation ratio (E) of *J. dussumieri* during 2015 from Pakistani waters were estimated. Here Y_w/R is the yield per recruit, t_c is the average age of first capture, t_r is the age of recruitment, t_λ is the asymptotically ages and constant and equal to 1, –3, 3 and –1 when n is 0, 1, 2 and 3 respectively, e is the base of natural logarithms (Sasaki 1989).

The estimated growth parameters values of L_∞ (asymptotic length) and K (growth constant) were used to compute the growth performance index (Phi prime, Φ'). Following equations by Pauly and Munro (1984) $\Phi' = log_{10} K + 2 log_{10} L_\infty$ and $\Phi = log_{10} K + 2/3 log_{10} W_\infty$ were used. The length structured virtual population analysis (VPA) was conducted after Sparre and Venema (1992).

3 | RESULTS

Of 2510 specimens of *J. dussumieri* the shortest length was recorded 4 cm whereas the longest was 25 cm, and the majority of the individuals were from 12 to 15 cm in total length (TL) (Figure 3). Body weight of these individuals varied from 3 to 155 g. The length-weight relationship (LWR) was found as $W = 0.0211 \times 2.8392$ ($R_2 = 0.988$; Figure 4).

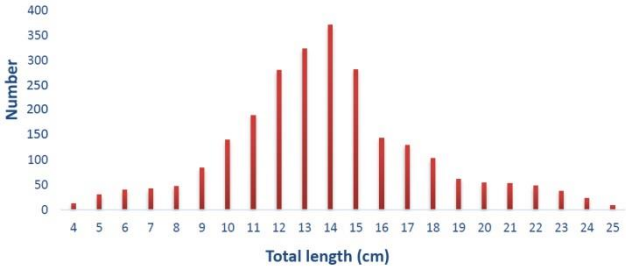

FIGURE 3 Length frequency distribution of *Johnius dussumieri* from the coast of Pakistan during 2015.

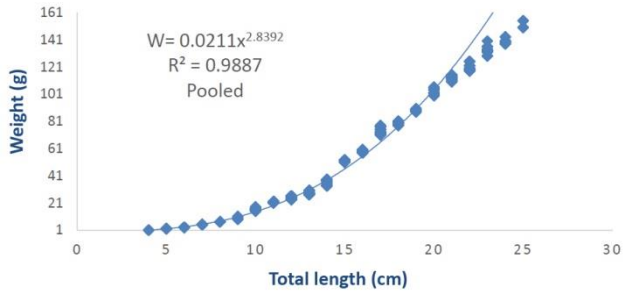

FIGURE 4 Length-weight relationship of *Johnius dussumieri* (N = 2510); length and weight ranging from 4 – 25 cm, 3 – 155 g respectively.

The von Bertalanffy growth parameters for *J. dussumieri* were L_∞ = 26.25 (TL, in cm) and K = 1.00 year^{-1} (Figure 5) with the goodness of fit model at R_n= 0.163. Perhaps, the t_0 value was calculated as –0.16491 years.

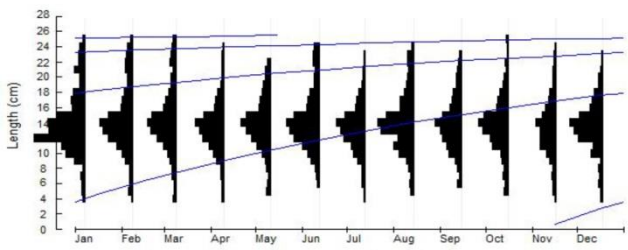

FIGURE 5 Length-frequency distribution data and the growth curves estimated through ELEFAN for *Johnius dussumieri* from Pakistani waters in 2015.

Applying VBGF growth parameters (L_∞, K) and using the

length converted catch curve analysis (LCCCA) Z were found 2.43 years^{-1} (Figure 6). Natural mortality M was calculated as 1.820 year^{-1} (with L_∞ = 26.25, K = 1.00 year^{-1}; average annual sea surface temperature was 27 °C) following Pauly (1980). The fishing mortality was calculated 0.61 year^{-1}. While E was found 0.251 year^{-1}. This is because $\bar{L}_{L'}$ was = 16.614 and L' = 14, the total annual mortality Z, estimated by the Beverton and Holt's method, was 3.686 year^{-1} and optimum fishing mortality rate of 1.88 year^{-1} for the sampling year.

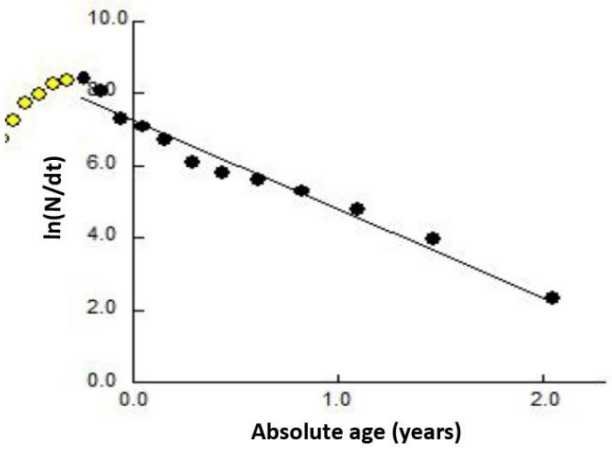

FIGURE 6 Length-converted catch curve for *Johnius dussumieri* in Pakistani waters (L_∞ = 26.25 cm; K = 1.00 year^{-1}).

The yield-per-recruit analysis is shown in Figure 7. The age at first capture was determined 1 year and $F_{current}$ was calculated 0.61 years^{-1}. It is recommended that the present condition of *J. dussumieri* stock in Pakistan is safe.

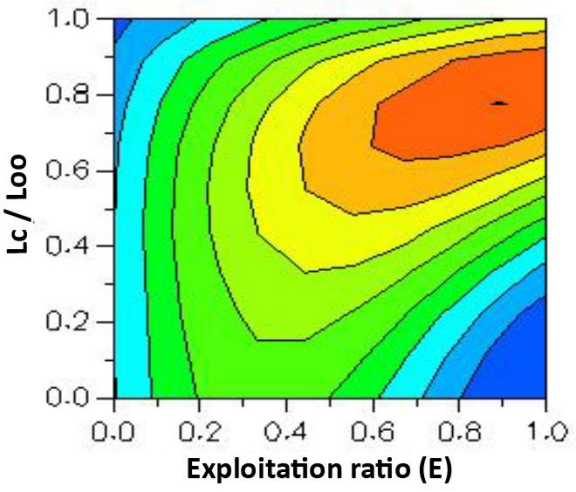

FIGURE 7 Yield per recruit contour map of *Johnius dussumieri* from Pakistani waters in 2015.

The growth performance index (ϕ') for *J. dussumieri* was estimated 2.839 based on length frequency data. The length structured virtual population analysis, as presented in Figure 8, was based on growth parameters (L_∞ and K), mortality parameters (M and F) and LWR parameters (a and b). The length of the high fishing mortality was at 13, 14, 24 and 25 cm length (Figure 8).

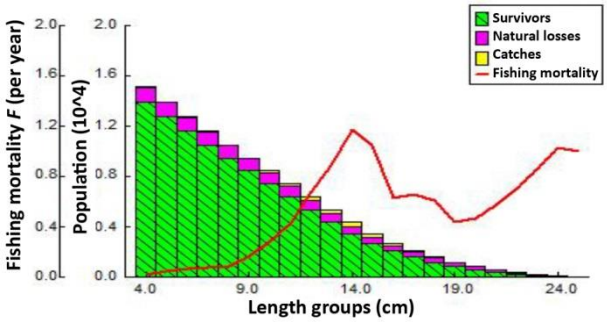

FIGURE 8 Length-structured virtual population analysis (VPA) of *Johnius dussumieri* from Pakistani waters in 2015.

4 | DISCUSSION

4.1 Length-weight relationship

The LWR is a significant factor in the biological study of fishes and their stock assessments which are particularly important in parameterizing yield equations and in the estimation of stock size detection of gonadal maturity, estimations of metamorphosis and rate of feeding (Baset *et al.* 2020). In this study, the value of slope "*b*" of *J. dussumieri* was estimated 2.83 which indicates a negative allometric growth (as $b < 3$; Dumont and D'Incao 2010). The value of slope b can be compared with other studies from different areas of the world (Table 1).

TABLE 1 Comparison of slope *b* of *Johnius dussumieri* with other studies from different parts of the world.

Location	*a*-value	*b*-value	Reference
Karnataka, India	0.052	2.42	Abdurahiman *et al.* (2004)
India	4.6724♀ 5.0608♂	2.88♀ 3.06♂	Chakraborty (2001)
Pakistan	0.0211	2.83	This study

TABLE 2 Comparison of growth parameters of *Johnius dussumieri*. L_∞, asymptotic length; K, growth rate year^{-1}; $Ø$, growth performance index; t_0, hypothetical age at which length of the fish is equal to zero.

Location	L_∞ (cm)	K	t_0	$Ø$	Reference
Mumbai, India	26.5	0.9633	–0.013		Chakraborty *et al.* (1997)
Mumbai, India	27.1	0.92		6.51	Chakraborty (2001)
Pakistan	26.25	1	–0.164	2.839	This study

4.2 Growth

In general, it may be assumed that fish may grow faster when the population density is low or the habitat is im-

proved. VBGF parameters, *i.e.* asymptotic length L_∞, growth rate K and the hypothetical age t_0 were estimated from the length frequency data and compared with other studies (Table 2). L_∞ was 26.25 cm and K was 1.00 in this study which is similar to the findings of Chakraborty *et al.* (1997) in which L_∞ was recorded 26.9 – 27.1 cm. The growth rate K was reported 0.963 (Chakraborty *et al.* 1997) and 0.92 (Chakraborty 2001) in the years 1997 and 2001 respectively which are also closer to the present work. The t_0 was recorded –0.013 from the Mumbai waters, India by Chakraborty *et al.* (1997) which is greater than the value recorded in this study (Table 2). The differences may be due to different sampling strategies, data sets, estimation methods, life patterns and ecological characteristics (Hernandez *et al.* 2010).

4.3 Mortality

The mortality value and exploitation ratios in this study were compared against other studies (Table 3) and total mortality Z and fishing mortality F values were greater in the present study whereas natural mortality M was lower than other study. Predation is a major reason of natural mortality in fishes (Parida *et al.* 2014; Chakraborty 2001). However, in the present study, the fishing mortality (0.61) was lower than natural mortality (1.82) which indicates that the stock of *J. dussumieri* is in sustainable condition in Pakistan. The total annual mortality estimated by the Beverton and Holt's method was 3.686 per year, which is greater than the results of length-converted catch curve analysis. Because the length converted catch curve analysis is more commonly used, so we chose 2.43 as our final result.

4.4 Biological Reference Points (BRPs) and growth performance index

$F_{current}$ was calculated 0.61 in this study which indicates that the current fishing mortality is low for the species concerned. Because the current fishing mortality rate is lower than the target BRPs (F_{opt}, 1.82) it may be said that *J. dussumieri* fishery is in sustainable condition in Pakistani waters. The growth performance index recorded in this study (2.727) is lower than the values (6.51) reported for *J. dussumieri* from Mumbai waters, India (Parida *et al.* 2014).

TABLE 3 Comparisons of mortality rates of *Johnius dussumieri* from Pakistani waters with other study. *Z*, total mortality; *M*, natural mortality; *F*, fishing mortality; *E*, exploitation ratio.

Location	*Z*	*M*	*F*	*E*	Reference
Mumbai, India	2.38	2.02	0.36	0.15	Chakraborty *et al.* (1997)
Pakistan	2.43	1.82	0.61	0.25	This study

5 | CONCLUSIONS

Various mortality and growth parameters of *J. dussumieri* recorded in this study showed that the current fishing mortality of the species is not high in Pakistani waters. The growth rate and the growth performance index were also found to be in good conditions. Therefore the present study concludes that the *J. dussumieri* fishery is safe in Pakistani waters.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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