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Research Article

Growth and mortality parameters of Platycephalus *indicus*, *Grammoplites scaber*, and *G. suppositus* (Teleosti: Platycephalidae) in the southern coastal waters of Iran

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Abstract

Population parameters of three dominant benthic fish (Bartail flathead, Spotfin flathead, and Rough flathead) were estimated during the period from April 2022 to October 2023; The specimens were caught as by-catch of shrimp bottom trawlers, and also in coastal stake nets. The *b* value of the total length and weight relationship for the Bartail flathead was 3.23 and for Spotfin and Rough flatheads were calculated as 3.33 and 3.29, respectively, which revealed a positive allometric growth pattern in all species. Von Bertalanffy's growth parameters including $TL\infty$, K, and t_0 were estimated at 56 mm, 0.5 (Y^{-1}), and -0.27 for *P. indicus*; 40 mm, 0.6 (Y^{-1}), and -0.25 for *G. suppositus* and 33 mm, 0.9 (Y^{-1}), and -0.17 for *G. scaber*, respectively. The natural mortality (M) for the mentioned species was estimated (at 0.95, 1.17, and 1.61 per year), fishing mortality (F) was (1.16, 1.39, and 2.57 per year) and total mortality was (2.11, 2.56, and 4.18 per year), respectively. The exploitation coefficient (E) was estimated at 0.55 for the Bartail flathead, 0.54 for Spotfin flatheads, and 0.61 for the Rough flathead, which indicates the relatively high fishing pressure on these species in the region. To mitigate this pressure, it is recommended to reduce fishing efforts, install bycatch reduction devices on trawl nets, and increase monitoring of coastal stake nets in the region.

Introduction

The flathead fish, Platycephalidae Swainson, 1839 with 17 genera and 86 valid species shows a worldwide distribution (Fricke *et al*., 2024) with 10 reported species in the southern waters of Iran, including benthic fishes with a relatively significant abundance of the fish fauna of the Persian Gulf and Sea of Oman (Valinassab and Sedghi Marouf, 2013; Eagderi *et al*., 2019). This species was recognized as having a flathead and the location of their eyes on the top of the head according to their benthic lifestyle, as well as the location of their pelvic fins in the vicinity and behind the base of their pectoral fins. Most species are sometimes buried in sand or mud beds from 10 to 300 m in marine areas (some species in brackish waters) (Nelson *et al.*, 2016). They include small and medium-sized fish, and only species of the genus *Platycephalus* are of commercial size, and their length may reach up to one meter. Among the species found in the Iranian coastal waters of the Persian Gulf and the Sea of Oman, *Platycephalus indicus* (Linnaeus, 1758) has only a relatively large size and has always been of interest to fishermen and also as a target species for fishing in the study area (Carpenter *et al*., 1997; Valinassab *et al.*, 2006). Two other dominant species of this family are rough flathead, *Grammoplites scaber* (Linnaeus, 1758), and spot fin flathead, *Grammoplites suppositus* (Troschel, 1840), which are relatively smaller in size (Carpenter *et al.*, 1997). The mentioned species are often seen as bycatch of shrimp bottom trawlers as well as in coastal stake nets and wire traps. The platycephalid species are deep-sea predators, so they are particularly important as predators in controlling populations in benthic marine communities (Abdurahiman *et al*., 2007). Age determination is one of the most important subjects in fish biology studies. Without considering the age of many studies such as growth, comparing the length of fish with each other will be meaningless (Begenal and Tesch, 1978). The length-weight relationship (LWR) is one of the components of fisheries evaluation (Goncalves *et al*., 1996). Also, by measuring length and weight relationship can be obtained information such as stock composition, life span, mortality, and growth (King, 2007). The estimation of biological parameters such as growth and mortality is vital in terms of evaluating and better management of stocks and ensuring the sustainable development of fisheries (Chen and Paloheimo, 1994).

Previous studies have been focused on the aspects of population dynamics, biological characteristics and determining the age and growth of *P. indicus* (Mohammadikia *et al*., 2014; Hashemi *et al*., 2014; Mousavisabet *et al*., 2015) and the growth and mortality parameters and reproductive biology of *G. suppositus* in the region (Izdifar *et al*., 2019, 2020). So far, a comprehensive study that simultaneously examines the population parameters of these three benthic species in the Persian Gulf has not been reported. This study analyzed the growth and mortality parameters of dominant platycephalid species in the coastal waters of the Persian Gulf, along with estimating the length-weight relationships for the three mentioned species. The findings provide crucial information for the protection and optimal

management of benthic fish species in the region.

Materials and methods

Monthly sampling was carried out from shrimp trawlers (as bycatch) and also from coastal stake net, for 18 months from April 2022 to October 2023 in the coastal waters of the Persian Gulf (Hormozgan Province) (Fig. 1). The specimens were transferred to the laboratory immediately after being placed in ice powder. After separating the species by identification keys (Fischer and Bianchi, 1984; Carpenter *et al*., 1997), the biometric data included total length (TL) with an accuracy of one cm, and total weight (W) with an accuracy of 0.1 kg of 512 Bartail flatheads, 447 Spotfin flatheads, and 555 Rough flatheads were measured.

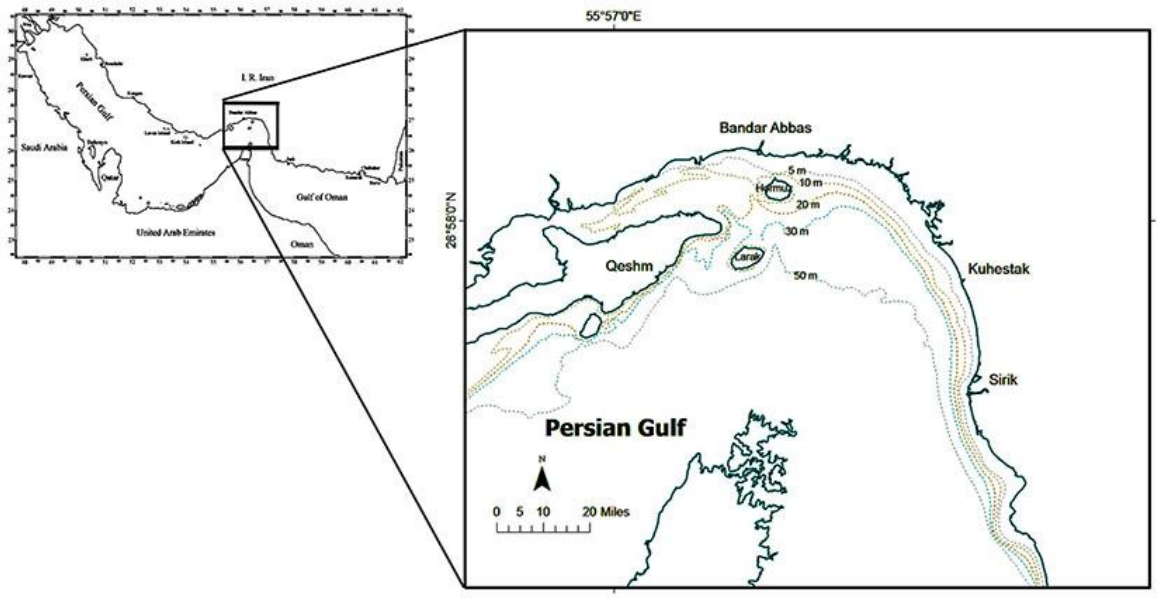

Figure 1: Sampling locality of three benthic fish in the Persian Gulf, Iran.

To establish the length-weight relationship, the commonly used relationship $W=a\ L^b$ was applied by Pauly (1983), Where: *W* is the weight (kg), *L* is the total length (cm), *a* is the intercept (condition factor) and *b* is the slope (growth coefficient). A linear equation (ln W=ln a+b ln TL) was fitted for log-transformed data. The parameters *a* and *b* were estimated using power regression and the coefficient of determination (R^2) to show the total length-weight relationship. The parameter *b* is a shape parameter for the body form of the fish species. In theory, one might expect that the exponent *b* would have a value of roughly *b*=3 because the volume of a 3-dimensional object is roughly proportional to the cube of length for a regularly shaped solid. Computing *b* value estimated with 3 was tested by using the t-test (Pauly, 1983):

$$t = ((s.d(L)/(s.d(W)) \times ((b-3)/(\sqrt{1-r2})) \times (\sqrt{n-2})$$

Where: s.d. (L) is the standard deviation of the ln TL values, and s.d. (W) is the standard deviation of the ln *W* values, n being the number of fish used in the

computation. The value *b* is different from 3 if t is greater than the table value for t in n - 2 df. (Pauly, 1983).

The values of K and TL∞ were estimated for combined sex using the von Bertalanffy growth equation:

$Lt = L\infty\ (1 - \exp{-K\ (t-t_0)})$

Where Lt is the total length at time *t*, L∞ is the asymptotic length (cm), K is the growth coefficient (Yr^{-1}), and t_0 is the hypothetical age when the size of the fish is zero. Using input data from length frequencies which were grouped in total length classes at 2 cm intervals and the ELEFAN1 program in FiSAT II software, asymptotic length (TL∞) and growth coefficients (K) were estimated for combined sex. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to goodness-of-fit tests by assessing the ESP/ASP ratio (Rn).

To have a comparison between the estimated growth parameters of fish from this study with those from other studies, Ø' (an index for the comparison of growth performance in marine animals with the von Bertalanffy type of growth) was used. Details on growth comparison using Ø' as an index are discussed in Pauly and Munro (1984):

$Ø' = \text{Log } K + 2*\text{Log } L\infty.$

The instantaneous rate of natural mortality (M) was obtained using Pauly's empirical formula (Sparre and Venema, 1998):

$$\ln M = -0.0152 - 0.279 \times \ln L\infty + 0.6543 \times \ln K + 0.463 \times \ln T$$

Where L∞ is the asymptotic total length (cm), K is the growth coefficient (Y^{-1}) and T is the annual average of water temperature (°C), in the covering area in which it was 27.5°C.

From estimates of the growth parameters (K, TL∞), the instantaneous rate of total mortality (Z) was estimated using a length-converted catch curve in FiSAT II software (Pauly, 1983). To estimate the theoretical lifespan, the (tmax) of flathead species was obtained using Pauly's formula (1983):

$Tmax=3/k+t_0$

Subtracting the estimates of M and Z, the instantaneous rate of fishing mortality (F) is given by:

$F = Z - M$

The exploitation rate E = F/ Z.

Results

Size structure and total length-weight relationship

The total length (TL) ranged from 10.0 to 43.3 cm for *P. indicus*, 11.2 to 31.3 cm for *G. suppositus*, and 10.0 to 27.9 cm for *G. scaber* (Fig. 2 a-c). The mean (±SE) TL varied between 23.2±031, 20.6±0.22, and 18.5±0.13, respectively (Fig. 2 d-f). Meanwhile, the mode of Tl frequency for *P. indicus*, *G. suppositus*, and *G. scaber* was observed in 15-17cm, 25-27, and 20-22 cm, respectively.

Principal parameters and relations between the total length and weight of all benthic fish are given in Table 1. The b values for *P. indicus*, *G. suppositus*, and *G. scaber* were 3.23, 3.33, and 3.29,

respectively, which revealed a positive allometric growth pattern in all species.

Growth and Mortality Parameters and Performance Index (Ø')

The TL∞ for *P. indicus*, *G. suppositus*, and *G. scaber* was estimated as 56, 40, and 33 cm respectively. The growth coefficient (K) was estimated as 0.5 (Y^{-1}) for *P. indicus*, 0.6 (Y^{-1}) for *G. suppositus*, and 0.9 (Y^{-1}) for *G. scaber*. Also, the t_0 was estimated at -0.27 for Bartail flathead, -0.25 for Spotfin flathead, and -0.17 for Rough flathead per year. The Ø' index was estimated as 3.20, 2.98, and 2.99 for the mentioned species, respectively. The recorded results showed that at least 3 cohorts were observed each month of the year for three benthic species (Figs. 3 and 4) and also the maximum life span of *P. indicus*, *G. suppositus*, and *G. scaber* was estimated as 6.3, 5.2, and 3.5 years, respectively.

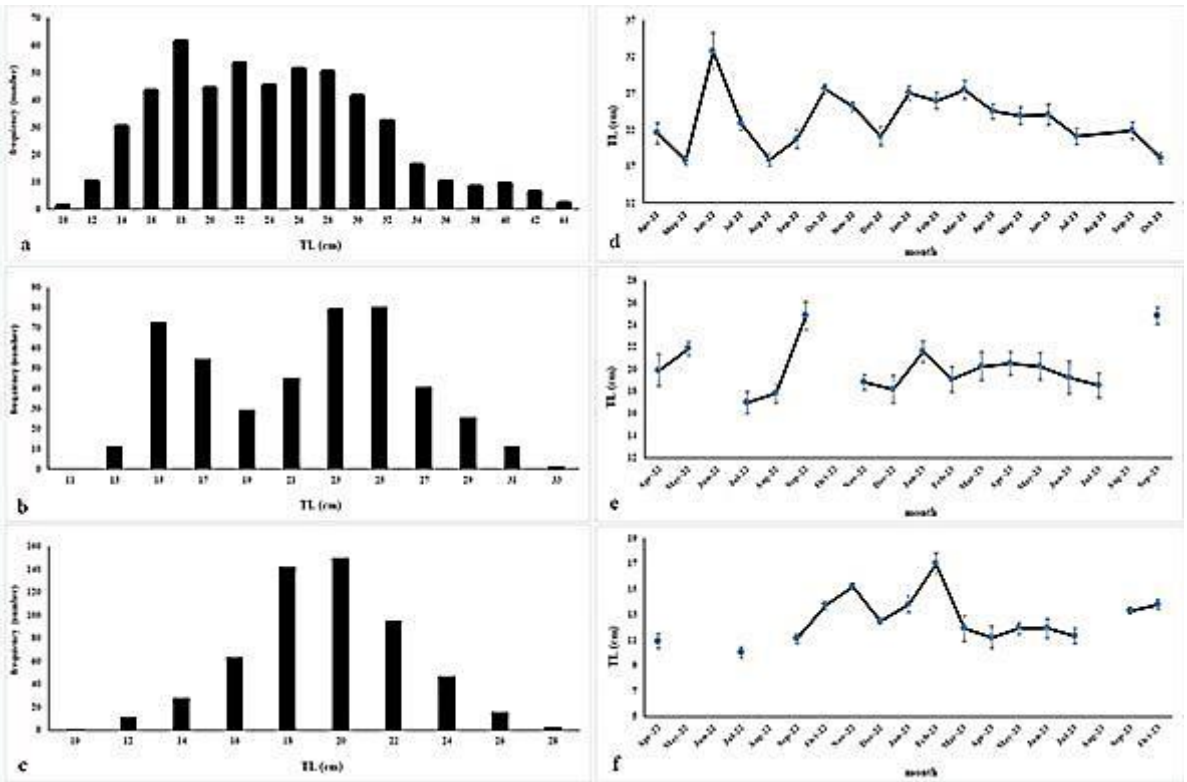

Figure 2: Total length frequency distribution of *P. indicus* (a), *G. suppositus* (b), and *G. scaber* (c) and TL changes (mean ± s.e.) in different months of *P. indicus* (d), *G. suppositus* (e), and *G. scaber* (f) in coastal waters of the Persian Gulf, Iran.

Table1: Length-weight relationship in three species of Platycephalidae and its components in the Persian Gulf, Iran

Species	w=aTL^b	a	b	n	R^2	t
P. indicus	$W=0.000003*(TL)^{3.23}$	0.000003	3.23	512	0.95	7.14
G. suppositus	$W=0.000002*(TL)^{3.33}$	0.000002	3.33	447	0.99	20.81
G. scaber	$W=0.000002*(TL)^{3.29}$	0.000002	3.29	555	0.92	7.15

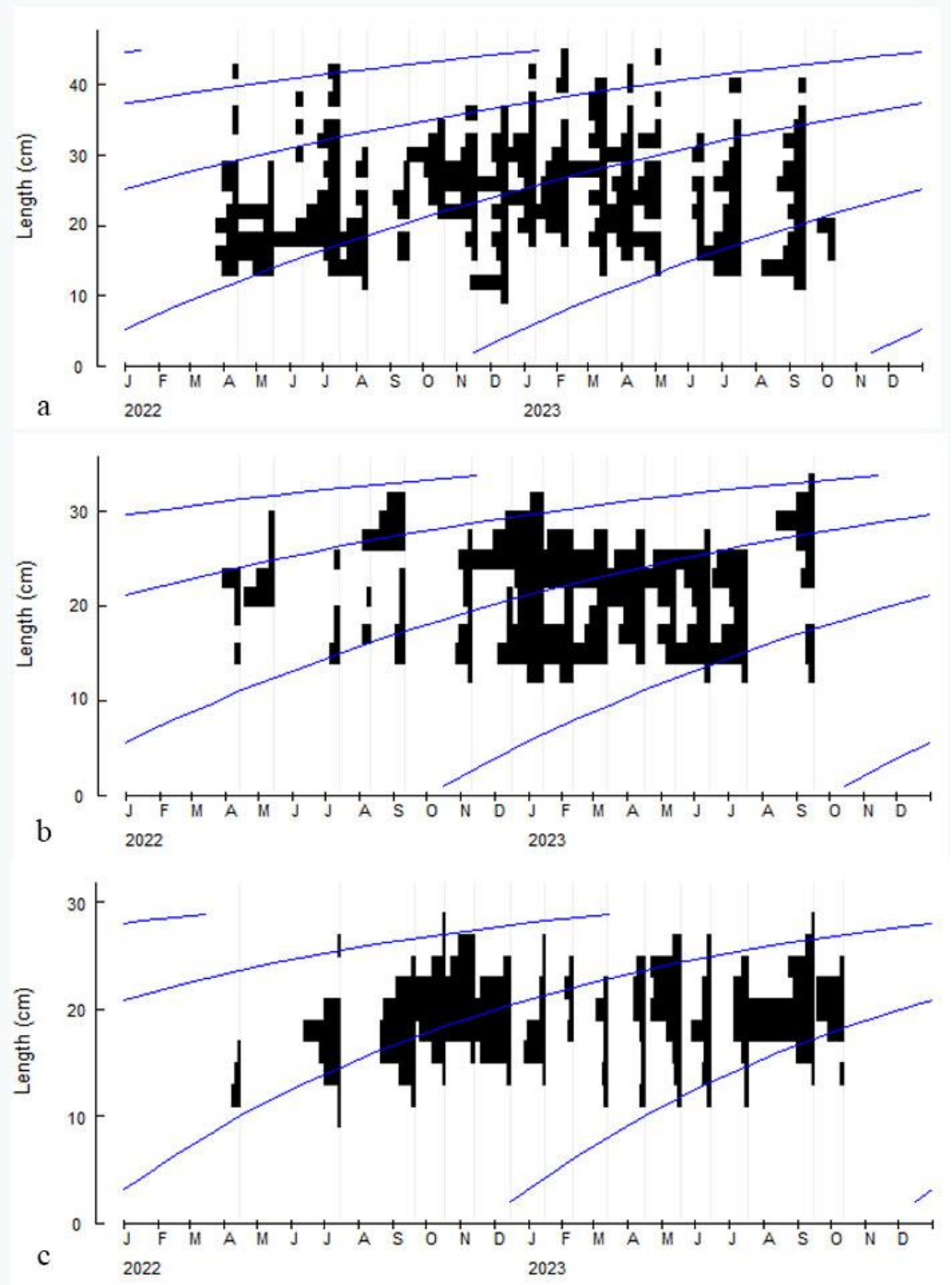

Figure 3: The growth curves of *P. indicus* (a), *G. suppositus* (b), and *G. scaber* (c), in the Persian Gulf, Iran.

The natural mortality (M) for *P. indicus*, *G. suppositus*, and *G. scaber* was estimated (at 0.95, 1.17, and 1.61 per year), and fishing mortality (F) was (1.16, 1.39, and 2.57 per year) and total mortality was (2.11, 2.56, and 4.18 per year), respectively. The exploitation coefficient (E) was estimated for the Bartail flathead at 0.55, for the Spotfin flatheads at 0.54, and for the Rough flathead at 0.61, which indicates the exploitation of these species in the region is not in favourable conditions.

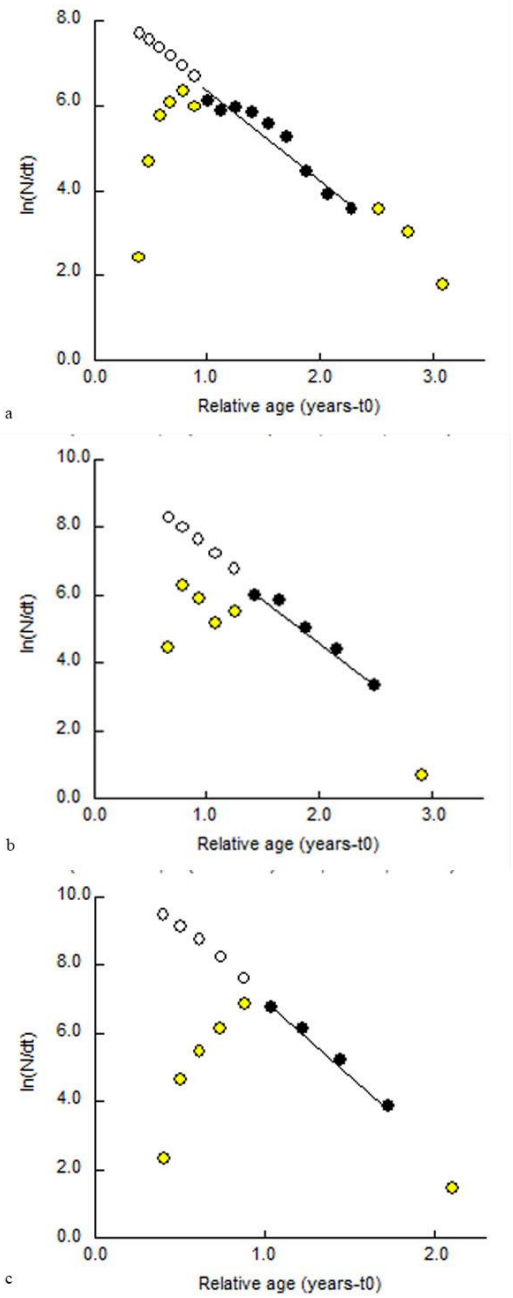

Figure 4: The length-converted catch curve of *P. indicus* (a), *G. suppositus* (b), and *G. scaber* (c), in the Persian Gulf, Iran.

Discussion

In this study, the biometric data of three benthic Platycephalidae including 512 Bartail flatheads, 447 Spotfin flatheads, and 555 Rough flatheads were measured over 18 months. The results showed that the range of total length and weight of *P.indicus* was between 10.0-43.3 cm and 5.4-509.1 g and between 11.2 -31.3 cm and 8.1-210.9 g for *G. suppositus* and also varied between 10.0-27.9 cm and 3.9-120.6 g for *G. scaber*. Mousavi-sabet *et al*. (2015) by examining the population structure and morphometric relationships of *P. indicus* specimens that were caught in six different regions in the Persian Gulf indicated that the total length and weight of this species varied between 17.8 - 55.3 cm and 80-1290 g, respectively. Also, Akita and Tachihara (2019), in their study, reported the total length range of males of this species between 19.6-61.9 cm and for females between 21.7-76.9 cm in Okinawa-jima Island, Japan. The total length of another species of this family, the thorny flathead, *Rogadius asper* (Cuvier, 1829) was reported from 9.2 to 25.9 cm (with a mean of 17.4±2.95 cm) in the Coastal Waters of the Suez Gulf (Sabrah *et al*., 2015). The range of total length of male and female *G. suppositus* in the Persian Gulf was reported as 13.2-27.2 and 13.5 -32.3 cm, respectively, and also the weight of females and males ranged between 12.5-207.6 g and 10.2-122 g, respectively (Izadifar *et al*., 2019), which is consistent with the recorded results in the present study for same species. During the study period, the mode of Tl frequency for *P. indicus*, *G. suppositus*, and *G. scaber* was observed in 15-17cm, 25-27, and 20-22 cm, respectively. Mohammadikia *et al*. (2014) reported that *P. indicus* was the most abundant in the length class of 33-35 cm of total length in the Persian Gulf. Also, the results of the study by Izadifar *et al*. (2019) showed that the highest frequency of total length of male and female *G. suppositus* in the Persian Gulf was observed at 16-18 cm

and 22-24 cm, respectively. It seems that the total length range of *P. indicus* in the Persian Gulf region in the study by Mousavi-sabet *et al*. (2015) compared to the recorded results in this study shows the decreasing trend of the size of this fish in the region, which can be caused by the increase in fishing pressure during recent years on similar species in the region or can be considered affected by used the different fishing gears, the presence of different age groups in the same area and at a certain time (Yesaki, 1989; King, 2007).

The length-weight relationship and the estimated components offer precise information about fish growth patterns, biomass determination, and ecology, and are also utilized in stock assessment models. These relationships provide valuable insights into the fish's habitat, life cycles, and overall species health (Froese *et al*., 2011). In the present study, the value of b in the total length-weight relationship of *P.indicus, G. suppositus,* and *G. scaber* was estimated at 3.23, 3.33, and 3.29, respectively, which indicated positive allometric growth patterns in all species. Hashemi *et al*. (2014) reported the value of b for the *P. indicus* in the coastal waters of the Persian Gulf (Khuzestan province) to be close to 3, which revealed that weight increases with length allometrically. The positive allometric growth pattern was reported for *P. indicus* in Bardawil Lagoon, Egypt (Kassem *et al*., 2021). Also, Izadifar *et al*. (2019) obtained the value of b in the total length-weight relationship for male and female *G. suppositus* as 3.35 and 3.21, respectively, which indicated positive allometry growth in this species. The reason for the difference in the values of a and b can depend on changes in environmental conditions, fish physiology, gender, gonadal development, the amount of food available, time and method of sampling, as well as the study area (Biswas, 1993).

This research estimated the growth parameters TL∞ and K for *P. indicus* as 56 cm and 0.5 per year, respectively. These values were estimated at 40 cm and 0.6 (Y^{-1}) for *G. suppositus* and at 33 cm and 0.9 (Y^{-1}) for *G. scaber*, respectively. Masuda *et al*. (2000) in their study on *P. indicus* the value of k for males and females at 0.67 and 0.48, respectively. Also, a study on the age and growth of *P. indicus* in the coastal waters of the western parts of the Persian Gulf by Mohammadikia *et al*. (2014) reported k-values of 0.46 and 0.50 for males and females, respectively. They also reported the t_0 for males and females at -0.30 and -0.32, respectively. Hashemi *et al*. (2014) investigated aspects of the population dynamics of *P.indicus* and reported a K value of 0.5 per year and a TL∞ value of 62.16 cm. They also found the value of t_0 to be -0.26 (Table 2). Akita and Tachihara (2019) studied the age and growth of *P. indicus* in Japan and found the K value at 0.68 for males and 0.48 for females per year, and the TL∞ value for males, and females 53.6 and 72 cm, respectively, as well as the value of t_0, was reported as- 0.38 for males and - 0.36 for females. Izadifar *et al*. (2019) reported the value of TL∞ as 35 cm for males and 40 cm for females *G. suppositus*, and the growth rate (K) as 0.74 and 0.65 per year for males and females, respectively. They also estimated the t_0 as -0.20 for males and -0.22 for females. Usually, the asymptotic length

varies from point to point, because the estimate of the asymptotic length is strongly influenced by the largest length found in the population under study (Froese and Binohlan, 2000). One of the obvious characteristics of a stock is that in different periods, its growth parameters are proportional to each other in a specific geographical area (Pauly, 1984). The phi prime index is used to compare the growth coefficients of similar fishes (Pauly and Munro, 1984). The difference in the estimation of growth rates, even though the use of different methods causes differences in its calculations, but the difference in growth rates largely depends on the measured length class, although Haddon (2011) believes that environmental differences such as access to food, temperature, etc. have a greater effect in this regard.

Table 2: Population dynamics parameters of Platycephalidae species in different areas.

Species	Sex	TL∞ (cm)	K (Y^{-1})	t_0 (Y^{-1})	M (Y^{-1})	F (Y^{-1})	Z (Y^{-1})	ϕ’	region	Reference
Platycephalus indicus	male	43.03	0.68	-0.09	-	-	-	-	Japan	Masuda *et al* (2000)
	female	55.15	0.48	-0.13	-	-	-	-		
P.indicus	male	43.40	0.46	-0.32	0.736	0.884	1.62	3.28	Persian Gulf/ Iran	Mohammadikia *et al* (2014)
	female	63	0.5	-0.30	0.886	0.544	1.43	3.29		
P.indicus	total	62.16	0.5	-0.26	0.77	1.82	2.59	1.19	Persian Gulf/ Iran	Hashemi *et al* (2014)
Rogadius asper	male	24	0.53	-0.35	0.58	0.93	1.51	2.51	Gulf of Suez	Sabrah *et al*. (2015)
	female	27.2	0.43							
P.indicus	male	53.6	0.68	-0.38	-	-	-	-	Japan	Akita and Tachihara (2019)
	female	72.6	0.48	-0.36	-	-	-	-		
Grammoplites suppositus	male	35	0.74	-0.20	1.38	2.95	4.33	2.96	Persian Gulf/ Iran	Izadifar *et al* (2020)
	female	40	0.65	-0.22	1.22	3.05	4.27	3.02		
P.indicus	total	59.98	0.34	-0.44	0.48	0.67	1.15	3.09	Bardawil Lagoon, Egypt	Kassem *et al.*, 2021
P. indicus	total	56	0.50	-0.28	0.95	1.16	2.11	3.20	Persian Gulf/ Iran	Present study
G. suppositus	total	40	0.60	-0.25	1.17	1.39	2.56	2.98	Persian Gulf/ Iran	Present Study
G. scaber	total	33	0.90	-0.17	1.61	2.57	4.18	2.99	Persian Gulf/ Iran	Present study

The difference in the growth parameters estimation in various studies can be due to the use of different fishing gear in each region as well as different methods for growth estimations.

Total mortality is a fundamental concept in the study of exploited fish stocks. A higher total mortality rate indicates a faster stock decline and a shorter maximum lifespan. Total mortality is influenced by human factors, such as the fishing mortality rate,

and natural factors, such as natural mortality. Both types of factors reduce the survival rate and consequently decrease the overall stock (Cadima, 2003). The natural, fishing, and total mortality for the *P. indicus* was estimated at 0.95, 1.16, and 2.11 per year, respectively. these values were estimated as 1.17, 1.39, and 2.56 per year for *G. suppositus* and as 1.61, 2.57, and 4.18 per year for *G. scaber*, respectively. Also, the exploitation coefficient (E) was estimated for *P. indicus*, *G. suppositus*, and *G. scaber* at 0.55, 0.54, and 0.61, indicating that these species' exploitation in the region is not in favorable conditions. Mohammadikia *et al*. (2014) found that the natural mortality (M) for male and female *P. indicus* in the Persian Gulf was 0.74 and 0.89 per year, respectively, and the fishing mortality (F) was 0.88 for males and 0.54 for females and also the exploitation coefficient for males and females was 0.54 and 0.38, respectively. in addition, Hashemi *et al*. (2014) reported the natural and fishing mortality rates for the same species in the Persian Gulf at 0.77 and 1.82, respectively. They also noted the exploitation coefficient was 0.7. The fishing mortality rate in males and females of *G. suppositus* in the coastal waters of the Persian Gulf was estimated at 2.95 and 3.05, respectively (Izadifar *et al*., 2019). They also reported the exploitation coefficient (E) for this species was 0.68 in males and 0.71 in females.

Based on the recorded results, it was evident that the exploitation rate of the three benthic species exceeded the optimal level of 0.5, suggesting significant exploitation pressure. Despite flathead fish not being the primary target of commercial fisheries, they face substantial exploitation due to their market value, contributing to their high by-catch rates and insufficient income for fishers.

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Confilicts of interest

The authors declare that they have no conflict of interest.

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