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Population dynamics of an emergent invasive fish, striped piggy, *Pomadasys stridens* (Actinopterygii, Perciformes, Haemulidae) in the Gulf of İskenderun, north-eastern Mediterranean

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Abstract

The striped piggy, *Pomadasys stridens* (Forsskål, 1775), is a recent invasive fish species in the eastern Mediterranean. Although its population dynamics was investigated in detail in its natural distribution area, the western Indian Ocean, an important data gap still exists in the Mediterranean. This study was carried out to determine the growth, mortality, and the length–weight and length–length relations of invasive striped piggy right after its establishment in the area. Samples were collected seasonally between April 2014 and December 2015 by using bottom trawl from 10 and 20 m depth contours off the north-western coast of the Gulf of Iskenderun. After the length, weight, and sex of fish were recorded, sagittal otoliths were extracted and examined for age determination. Then length–length, length–weight, and length at age relations, growth performance, and mortality rates were calculated for both sexes and pooled data. In the study, a total of 1131 individuals were investigated, the total length of which ranged between 7.3 and 18.9 cm. The mean length was 12.32 ± 0.11 cm. There was no significant difference between the length–weight relation (LWR) parameters of sexes and pooled data. The overall LWR was found to be TW = 0.0113 * TL^3.096 in all specimens. The von Bertalanffy growth parameters were not significantly different between males and females. The model parameters for both sexes were L_∞ = 22.01 cm, K = 0.22 years^{-1}, t_0 = –1.30 years. The growth performance index ($Ø'$) was calculated as $Ø'$ = 2.03. For combined sexes, the total, natural and fishery mortality rates were Z = 1.14 years^{-1}, M = 0.66 years^{-1}, and F = 0.48 years^{-1}, respectively. The exploitation rate of the stock was found to be E = 0.42. The growth performance of the invasive striped piggy population was determined to be similar to the ones reported from the Gulf of Suez where was the closest natural distribution area of the species. Although striped piggy is proper for human consumption and commercially caught in its native range, its fishery has not yet been established in the Eastern Mediterranean and we found that there was insufficient fishery pressure on the invasive population.

Keywords

Exploitation, growth, Lessepsian fish, Levant Basin, mortality

Introduction

Striped piggy, *Pomadasys stridens* (Forsskål, 1775), naturally distributed in the western Indian Ocean extending from the Pakistani coasts to the east African coasts including the Red Sea (Froese and Pauly 2018), the Gulf of Suez, and the Suez Canal (El-Azim et al. 2017). It was introduced to the Mediterranean via the Suez Canal. According to Bodilis et al. (2013), its first occurrence in the Eastern Mediterranean was reported from Port-Said, Egypt. After a while, its first substantiated record was documented by Ben-Tuvia (1976), from the Israeli and by Mouneimne (1977) from Lebanese coasts. In Turkey, its occurrence was first reported by Bilecenoğlu et al. (2009) from Yumurtalık coast of the Gulf of Iskenderun and it spread westward quickly (Ergüden et al. 2010; Akyol and Çoker 2018). After 2013, striped piggy population significantly increased in a short while invading the coastal soft bottom habitats of the Gulf of Iskenderun and it became one of the most dominant species (Mavruk et al. 2017; Ozyurt et al. 2018).

The Gulf of İskenderun is an important fishery ground (Gücü and Bingel 1994) along with being an invasion hotspot in the eastern Mediterranean. Lessepsian fishes unquestionably dominate the gulf in where their rate frequently exceeds 99% of total fish abundance and 95% of total fish biomass in the shallow soft bottoms (Mavruk et al. 2017). This is because the prevailing environmental condition of the gulf is quite similar to the Gulf of Suez (Avşar 1999). The Gulf of İskenderun is characteristic with high temperature, salinity, and primary production as well as shallow bathymetry and sandy-muddy bottom structure, which are well pre-adapted by Lessepsian fishes (Golani 2010). As a consequence, Lessepsian fishes form an important part of the commercial fishery (Yemisken et al. 2014). Although striped piggy has economic importance in its native range (Osman et al. 2019; El-Azim et al. 2017), it is discarded in the Turkish fishery (unpublished data).

Striped piggy is a small sized demersal fish species inhabiting in shallow waters with sandy and muddy bottom structure feeding on crustaceans and small fishes (Froese and Pauly 2018). Its spawning period is in spring and summer in the Gulf of Iskenderun (Özbek 2017). Although the population dynamics of the striped piggy has been comprehensively studied in the Indo-Pacific region (Safi et al. 2013, 2014a; Osman et al. 2019; El-Azim et al. 2017), there is still insufficient information on its age, growth, mortality, and morphometry in the Eastern Mediterranean. Therefore, the aim of this study was to determine the population dynamical parameters in the Gulf of Iskenderun, five years after the establishment of the population. In this context, the von Bertalanffy growth parameters, mortality, length–weight and length–length relations of striped piggy, were calculated and growth performance of the Gulf of Iskenderun population was compared with those of the native range.

Materials and methods

Sample collection

Samplings were seasonally performed in April, July, October, and December 2014 and 2015 off Yumurtalık, Gulf of Iskenderun (Fig. 1) using commercial bottom trawl nets. Trawling transects were located at 10 and 20 m depth contours. Each tow lasted one hour using Mediterranean type trawl nets with 44 mm mesh size. The details of samplings were given in Mavruk et al. (2017). In the samplings, all striped piggy specimens were collected onboard and carried to the laboratory. When the sampling amount is high, a subsampling procedure proposed by Holden and Raitt (1974) was used.

Sample processing

In total, 1134 specimens were investigated in the context of the study. To determine the morphometric characteristics; total length (TL), fork length, standard length, body width, head width, body depth, head depth, and total weight were measured. Lengths and weights were measured to the nearest millimeter using a digital caliper, and to the nearest 0.01 g using a digital scale, respectively. The sex of specimens was determined by a visual examination when the gonads are ripe or with a stereomicroscope (Olympus SZ 60), otherwise.

The age of fish was determined by otolith investigations following the methods suggested by Holden and Raitt (1974). For this purpose, sagittal otoliths were removed from the fish, cleaned in alcohol to wipe off all tissue remnants, and kept in glycerin until examination. Age determination was performed under a stereomicroscope. The zones which form a complete circle around the otolith were considered as true annual rings whereas the rings which were not continuous around the otolith were excluded from the counting. This was a necessary step to correctly describe the seasonal increments, which is crucial so that a reliable length at age data can be provided and overestimation of growth coefficients can be prevented.

Statistical analyses and modelling

The sex-based changes of length frequency distribution were tested using Kolmogorov–Smirnov test. The season and sex-based variations of the mean TL were analyzed using two ways ANOVA. TL–length and TL–girth relations were fitted using ordinary linear regressions. TL–weight (W) relations were fitted using the allometric equation given by Ricker (1975);

$$W = a \cdot L^b$$

The von Bertalanffy (von Bertalanffy 1938) growth functions (VBGF) were fitted using a non-linear least

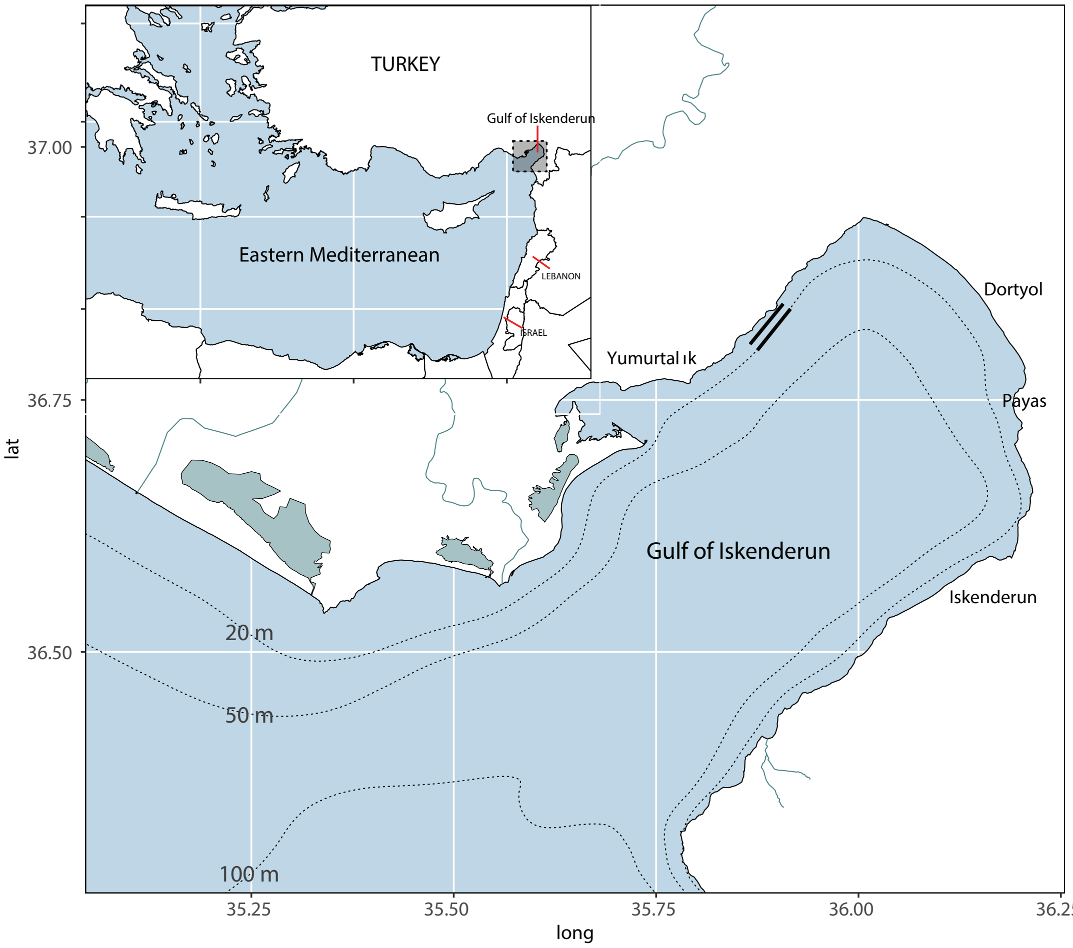

Figure 1. Sampling area and bottom trawl transects (10 m: 35.87°E, 36.82°N to 35.91°E, 36.86°N; 20 m: 35.89°E, 36.80°N to 35.93°E, 36.84°N).

square method with TropFishR package (Mildenberger et al. 2017). Then the lengths at age values were predicted using the parameters of VBGF. The 95% confidence intervals of predictions were calculated using R library propagate (Spiess 2018). VBGF was as follows

$$L_t = L_\infty \left(1 - e^{\left(-K\left(t - t_0\right)\right)}\right)$$

where; L_t, is the total length at age t, L_∞ is asymptotic length, K is growth coefficient and t_0 is theoretical age at zero length. Then the generation time was calculated using LN[3]/K equation given by Froese and Pauly (2018).

In order to determine the growth performance, Pauly and Munro (1984)'s growth performance index (Ø′) was calculated using the following equation

$$Ø' = \text{Ln}\, K + 2 \cdot \text{Ln}\, L_\infty$$

The total mortality rate was calculated from the linearized catch curve method based on Ursin (1967). Natural mortality was calculated from the empirical equation given by Pauly (1980) using TropFishR library

$$\text{Ln}\, M = -0.0152 - 0.279 \cdot \text{Ln}\, L_\infty + 0.6543 \cdot \text{Ln}\, K + 0.463 \cdot \text{Ln}\, T$$

where T [°C] shows the mean annual water temperature of the study area which is assumed as 23°C. After the total and natural mortality were determined, fishing mortality was calculated from equation

$$Z = F + M$$

Then the exploitation level (E) of the stock was calculated using $E = F / Z$ equation given by Sparre and Venema (1992). All calculations were performed using R 4.0 Language and Environment for Statistical Computing (R Core Team 2020).

Results

In the study, a total of 1131 individuals were examined, 445 of which were males and 471 of which were females. In 215 specimens, sex could not be determined. The total length of females ranged between 7.8 and 18.9 cm, and of males between 9.1 and 18.6 cm. The overall mean length and weight values were 12.32 ± 0.11 (95% confidence interval) cm and 29.19 ± 0.85 g, respectively. The overall mean length and weight of females were found to be 12.79

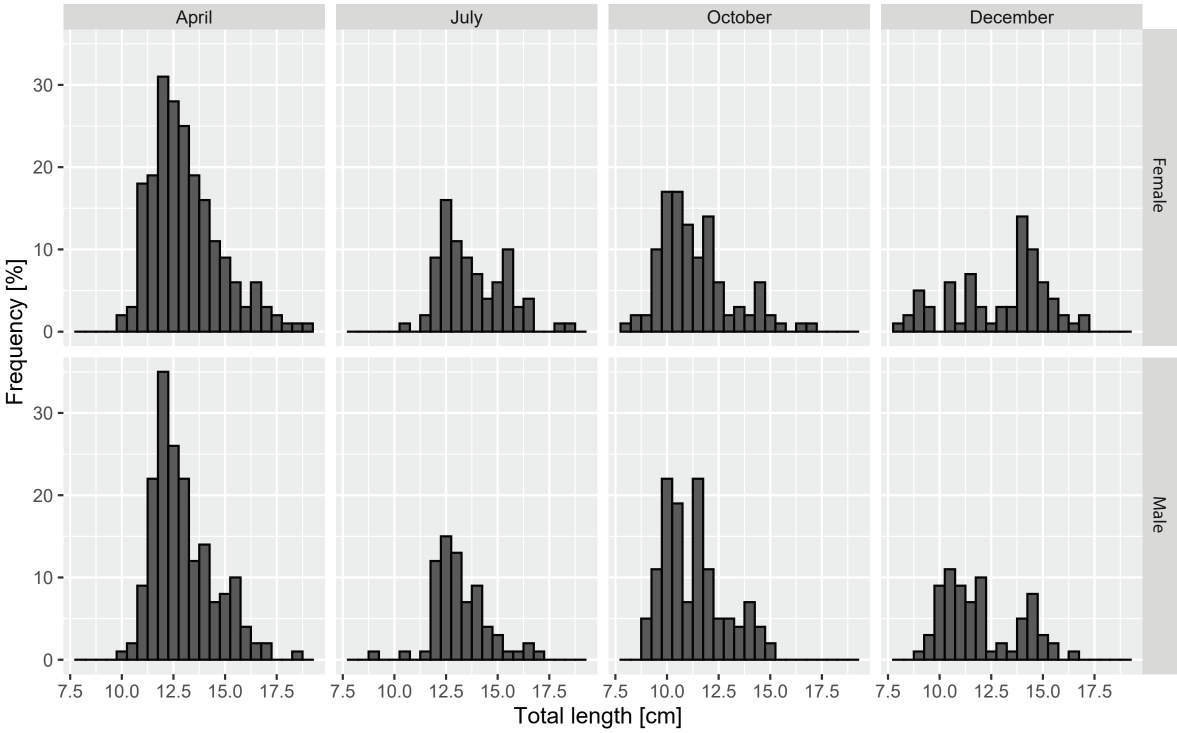

Figure 2. Length-frequency distributions of striped piggy, *Pomadasys stridens*, from the Gulf of Iskenderun, by sexes and seasons.

Table 1. Regression parameters of morphometric relations calculated for striped piggy, *Pomadasys stridens* from the Gulf of Iskenderun, by sexes and pooled data.

		Total length–fork length						**Total length–head width**			
		Par.	**Ste.**	***t***	**sig.**			**Par.**	**Ste.**	***t***	**sig.**
Male	***a***	0.254	0.071	3.581	<0.001***	**Male**	***a***	0.172	0.067	2.551	0.011*
	b	0.921	0.006	162.513	<0.001***		***b***	0.835	0.005	154.901	<0.001***
	r^2	0.984					r^2	0.982			
Female	***a***	0.411	0.092	4.472	<0.001***	**Female**	***a***	–0.040	0.124	–0.320	0.749ns
	b	0.909	0.007	128.037	<0.001***		***b***	0.852	0.010	89.239	<0.001***
	r^2	0.972					r^2	0.944			
Overall	***a***	0.267	0.056	4.801	<0.001***	**Overall**	***a***	0.065	0.060	1.083	0.279ns
	b	0.920	0.004	206.002	<0.001***		***b***	0.844	0.005	174.770	<0.001***
	r^2	0.974					r^2	0.964			
		Total length–standard length						**Total length–girth at opercle**			
		Par.	**Ste.**	***t***	**sig.**			**Par.**	**Ste.**	***t***	**sig.**
Male	***a***	–0.736	0.099	–7.451	<0.001***	**Male**	***a***	–0.397	0.085	–4.677	<0.001***
	b	0.286	0.008	35.365	<0.001***		***b***	0.199	0.007	28.720	<0.001***
	r^2	0.769					r^2	0.672			
Female	***a***	–0.601	0.084	–7.121	<0.001***	**Female**	***a***	–0.152	0.077	–1.972	0.049*
	b	0.275	0.007	40.890	<0.001***		***b***	0.180	0.006	29.257	<0.001***
	r^2	0.825					r^2	0.673			
Overall	***a***	–0.691	0.053	–13.138	<0.001***	**Overall**	***a***	–0.271	0.047	–5.799	<0.001***
	b	0.280	0.004	64.760	<0.001***		***b***	0.188	0.004	48.986	<0.001***
	r^2	0.816					r^2	0.706			
		Total length–body width						**Total length–maximum girth**			
		Par.	**Ste.**	***t***	**sig.**			**Par.**	**Ste.**	***t***	**sig.**
Male	***a***	–1.434	0.169	–8.474	<0.001***	**Male**	***a***	–0.798	0.146	–5.450	<0.001***
	b	0.773	0.014	57.049	<0.001***		***b***	0.612	0.012	52.190	<0.001***
	r^2	0.881					r^2	0.861			
Female	***a***	–1.095	0.152	–7.185	<0.001***	**Female**	***a***	–0.612	0.140	–4.386	<0.001***
	b	0.745	0.012	63.270	<0.001***		***b***	0.600	0.011	55.597	<0.001***
	r^2	0.896					r^2	0.868			
Overall	***a***	–1.265	0.094	–13.508	<0.001***	**Overall**	***a***	–0.691	0.085	–8.150	<0.001***
	b	0.757	0.008	100.746	<0.001***		***b***	0.604	0.007	88.740	<0.001***
	r^2	0.900					r^2	0.875			

Par.: parameter, Ste.: standard error of parameter, ns: not significant.

± 0.18 cm and 32.85 ± 1.46 g, and of males were found to be 12.38 ± 0.16 and 29.18 ± 1.21 g. Length-frequency distributions of males and females were significantly different than each other ($D = 0.12$, $P < 0.01$). Females were slightly larger than males ($P < 0.01$). In addition, seasonal variations of the mean length were found to be significant ($P < 0.001$). Length frequency distributions by seasons and sexes are given in Fig. 2.

Linear relations between the TL and fork length, standard length, head and body width, as well as maximum girth and girth at opercle are given in Table 1. In general, determination coefficients TL–length and TL–width relations were higher than TL–girth regressions.

Table 2. Parameters of length–weight relations calculated for striped piggy, *Pomadasys stridens*, from the Gulf of Iskenderun, by sexes and pooled data.

Sex	N. of samples	*a*	*b*	r^2
Male	445	0.0116 ± 0.09	3.087 ± 0.053	0.967
Female	471	0.0123 ± 0.13	3.064 ± 0.069	0.941
Overall	1131	0.0113 ± 0.18	3.096 ± 0.038	0.958

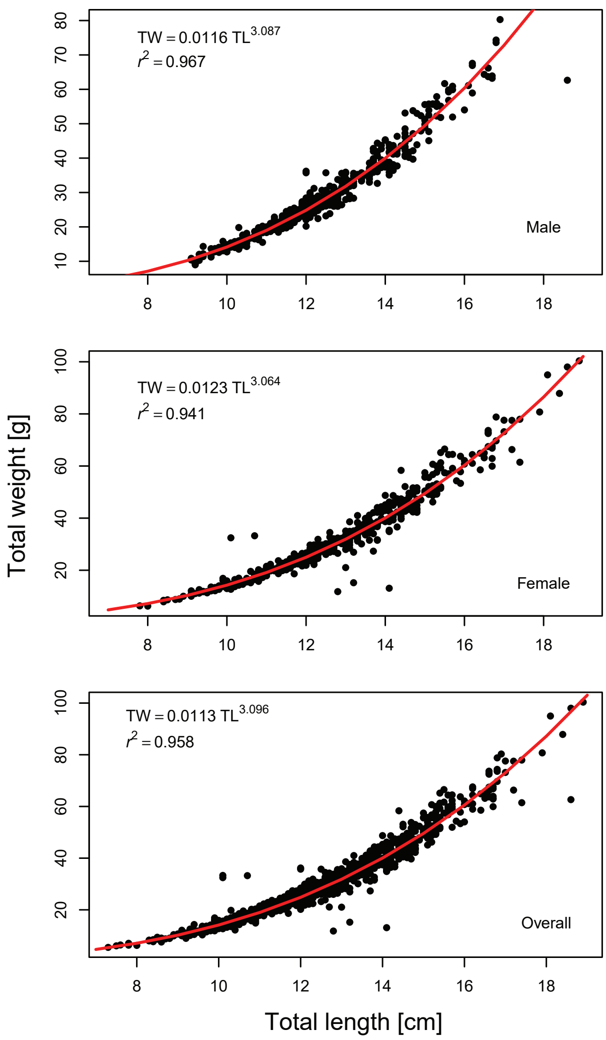

Figure 3. Length–weight relations by sexes and overall data in striped piggy, *Pomadasys stridens*, from the Gulf of Iskenderun.

The parameters of length–weight relations calculated for males, females and pooled data are given in Table 2 and Fig. 3. The *b* values of allometric equations revealed that males and pooled data showed a slightly positive allometric growth ($P < 0.05$); however, females showed isometric growth. There were not statistically significant differences among the intercept and slope parameters of regressions.

The maximum age determined for both sexes was found to be seven years. It was determined that the first age group was dominant for both sexes and pooled data constituting 62.5% of males and 52.7% of females. The von Bertalanffy growth parameters calculated for male, female, and pooled data were given in Table 3 and the length at age plots were given in Fig. 4. Based on 95% confidence intervals, no significant difference was found among L_∞, K, and t_0 values of sexes and pooled data. Using the growth coefficient for combined sexes ($K = 0.22$ year^{-1}) the generation length of striped piggy was calculated as 5 years in the Gulf of Iskenderun. Growth performance index values were calculated as 2.01 for males and 2.03

Table 3. Von Bertalanffy growth parameters with confidence intervals (95%) and growth performance indices calculated for males, females and combined data in this study and previous studies.

Ref.	Location	Sex	L_∞ [cm]	K [year^{-1}]	t_0 [year]	Ø′
ps	Mediterranean	M	20.99 (± 2.56)	0.24 (± 0.07)	–1.31 (± 0.46)	2.03
ps	Mediterranean	F	21.60 (± 2.04)	0.23 (± 0.06)	–1.25 (± 0.37)	2.01
ps	Mediterranean	C	22.01 (± 1.63)	0.22 (± 0.04)	–1.30 (± 0.25)	2.03
1	Mediterranean	M	17.96	0.34	–1.54	2.04
1	Mediterranean	F	32.70	0.10	–1.14	2.01
1	Mediterranean	C	22.52	0.19	–2.05	1.98
2	Suez Canal	C	16.64	0.51	–0.65	2.15
3	Suez Canal	C	23.15	0.51	–0.29	2.44
4	Gulf of Suez	C	20.37	0.28	–1.33	2.07
5	Gulf of Suez	C	20.60	0.19	–2.40	1.91
6	Persian Gulf	C	26.00	0.70	–0.65	2.68
7	Persian Gulf	C	24.54	0.14	–4.41	1.93

ps: presently reported study, 1: Uyan et al. (2018), 2: Al-Ganainy and Sabra (2008), 3: El-Azim et al. (2017), 4: El Sayed (1990) taken from Al-Ganainy and Sabra (2008), 5: Osman et al. (2019), 6: Hashemi and Taghavimotlagh (2012), 7: Karimi et al. (2015), M: male, F: female, C: combined.

Table 4. Mean length values, lower (CIL), and upper (CIU) limits of 95% confidence intervals calculated from von Bertalanffy growth equation.

	Male			Female		
Age	**CIL TL [cm]**	**Mean TL [cm]**	**CIU TL [cm]**	**CIL TL [cm]**	**Mean TL [cm]**	**CIU TL [cm]**
I	8.50	8.75	8.92	8.39	8.82	9.08
II	11.18	11.38	11.48	11.14	11.48	11.64
III	13.26	13.49	13.60	13.21	13.58	13.76
IV	14.92	15.17	15.30	14.86	15.25	15.45
V	16.23	16.53	16.70	16.13	16.57	16.81
VI	17.23	17.61	17.87	17.09	17.62	17.95
VII	17.99	18.48	18.85	17.79	18.45	18.90

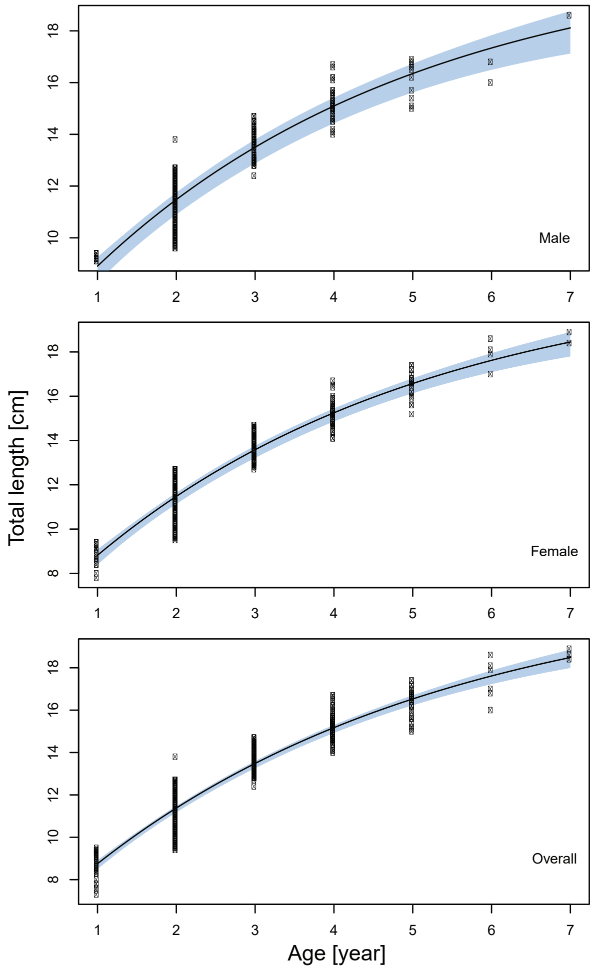

Figure 4. Observed and fitted length at age values and von Bertalanffy growth curves with 95% confidence intervals for both sexes and overall specimens of striped piggy, *Pomadasys stridens*, from the Gulf of Iskenderun.

Table 5. Total mortality (*Z*), natural mortality (*M*), fishing mortality (*F*), and exploitation rate (*E*).

	Z [year^{-1}]	*M* [year^{-1}]	*F* [year^{-1}]	*E*
Male	1.19	0.71	0.48	0.40
Female	1.02	0.68	0.34	0.33
Overall	1.14	0.66	0.48	0.42

for females and all individuals. Ø′ values calculated using the growth parameters reported in the previous studies were between 1.91 (Gulf of Suez) and 2.44 (Suez Canal) (Table 3). There was no difference between the lengths at age values of sexes calculated from VBGF (Table 4).

The total mortality (*Z*), natural mortality (*M*), fishing mortality (*F*), and exploitation rate (*E*) calculated for each sex of the *P. stridens* are given in Table 5. The deaths caused by fisheries on both sex groups were less than those of natural causes. Therefore, the exploitation rates were calculated less than 0.5 showing the population was underexploited in the Gulf of Iskenderun (Table 5).

Discussion

Here, we investigated the population dynamical parameters of an invasive fish species striped piggy (*Pomadasys stridens*) soon after its establishment in the study area. In the context of the study, the mean length of investigated individuals was 12.32 ± 0.11 cm ranging from 7.3 to 18.9 cm. In previous studies, the maximum length was reported as 23.5 cm by Hashemi and Taghavimotlagh (2012), 19.3 cm by Wright (1989) in the Persian Gulf, 21.9 cm in Pakistan coasts (Safi et al. 2013 and 2014a, 2014b). In comparison with the studies performed in the natural distribution area; various parts of the western Indian Ocean, the maximum length values were apparently smaller in our study. In accordance with this, Edelist (2014) reported the maximum length of striped piggy as 14.5 cm from Israeli coasts and Ergüden et al. (2015) as 17.7 cm from the Gulf of Iskenderun in the Mediterranean where is out of the native range. Along with the differences among the ecological properties of different study areas, this is probably because of that the striped piggy do not have a long history in our study area. Although its first record in the Gulf of Iskenderun was given in 2009 (Bilecenoğlu et al. 2009), its population abundance dramatically increased after 2013 (Mavruk et al. 2017). The samples investigated in this study were collected in 2014 and 2015, right after striped piggy has established a dominant population in the area.

Contrary to the above-mentioned hypothesis, the studies performed in the Gulf of Suez and the Suez Canal reported maximum length values close to our study which were 19 cm (Osman et al. 2019) and 15.6 cm (El-Ganainy and Sabra 2008) even though they are in the native range of the species. Based on exploitation rates reported in these studies, striped piggy populations are overfished in the Suez Canal (*E* = 0.64; El-Ganainy and Sabra 2008 and *E* = 0.69; El-Azim et al. 2017) and in the Gulf of Suez (*E* = 0.72; Osman et al. 2019). In comparison, we determined that the population inhabit the Gulf of Iskenderun was clearly under fished with an exploitation rate of 0.42.

Although, the first specimens of the striped piggy were collected in 2009 in our study area (Bilecenoğlu et al. 2009), our oldest specimens were seven years old. Based on this, several individuals may be existing in the area at least one year before the first observation. On the other hand, age determination increasingly harder in older age groups since zone formation gradually tightens (Matta and Kimura 2012). Therefore, this may also be a methodological fault.

Although the observed the mean length of females was found to be larger than males, no statistically significant difference was observed between the von Bertalanffy growth parameters and length at age values of sexes. Therefore, the presence of larger females in the sampling area may indicate differences between the distribution patterns of sexes. This should be investigated in further studies.

In the context of our study, *b* values of length–weight relation were calculated between 3.064 and 3.096. A slightly positive allometric growth profile was observed for males and pooled data; however, isometric growth was detected in females of the striped piggy population in the Gulf of Iskenderun. In general, negative allometry is prevalent for striped piggy in the studies performed in both native and introduced range of the species. From the northern Persian Gulf, Safi et al. (2013) and (2014a) reported b values between 2.73 and 2.86. Within the introduced range, in the Gulf of Iskenderun, Özbek (2017) reported isometric growth for males and pooled data, however, females revealed negative allometric growth. From the same area, Uyan et al. (2018) also reported isometric growth, although their b values were far below 3 ranging between 2.03 and 2.84. In accordance with our study, Edelist (2014) reported positive allometric growth from the Israeli coast of the Mediterranean (b = 3.07). Additionally, Ergüden et al. (2015) also reported a remarkably positive allometric growth (b = 3.406) from the Gulf of Iskenderun. Although the differences between the Indian Ocean and the Mediterranean can be explained with the different ecological properties of study areas, the studies performed in the Mediterranean, even in the same gulf, revealed different growth profiles for the same striped piggy population. In addition, these differences cannot be attributed to the different sampling methodologies since all of the studies performed in the Mediterranean used bottom trawls to collect the striped piggy samples. Possible explanations of this discrepancy may be the different sampling periods or differences in the sample processing procedures of the studies.

Although the asymptotic length (L_∞) is a theoretical size of the infinitely old fish, its value is influenced by the number of large sized fishes in the sample. Therefore, it does not represent a reliable measure of the maximum growth potential of an average fish in a population if the population is not sampled representatively, including all available size classes. Moreover, its value directly influences the growth parameter (K), e.g., an overestimated L_∞ value causes underestimation of K. Accordingly, the asymptotic length (L_∞), growth coefficient (K), and theoretical age at zero length (t_0) of striped piggy varied in a wide range in the both native and introduced distribution area. For example, in the Suez Canal, El-Ganainy and Sabra (2008) reported L_∞ value as 16.64 cm and t_0 value as –0.653 year^{-1}, whereas El-Azim et al (2017) reported L_∞ value as 23.15 cm and t_0 value as –0.29 year^{-1} in the same area. The same discrepancy also exists in the Gulf of Iskenderun. Uyan et al. (2018) reported that the L_∞ was 32.7 cm and K was 0.096 year^{-1} in females of the striped piggy population in the Gulf of Iskenderun. These values look quite unrealistic and significantly different than that calculated in our study, in where L_∞ was 21.6 cm and K was 0.23 year^{-1} in females. Although females' parameters were statistically significantly different from males, the parameters calculated for males and pooled data were closer in this study and Uyan et al. (2018).

In spite of the above-mentioned methodological obstacles in making direct comparisons among the growth parameters, the growth determined in different studies can be compared using the growth performance index ($Ø'$) of Pauly and Munro (1984). However, this index is apparently calculated using different logarithmic bases in the previous studies. In addition, only a few studies reported $Ø'$ values. Therefore, we recalculated $Ø'$ values for different striped piggy populations employing the same base with this study and using L_∞ and K values reported in the previous studies. Growth performance values calculated in this study and Uyan et al. (2018) were in a narrow range between 2.01 and 2.03 in accordance with each other. Since the both studies performed in the same area, the Gulf of Iskenderun, this was an expected outcome. Moreover, the growth performance values calculated from the Gulf of Suez were also close to the values given in our study. From the growth parameters given by El-Sayed (1990), $Ø'$ value was calculated as 2.07 and by Osman et al. (2019), $Ø'$ value was calculated as 1.91. This conformity may be explained with the similar ecological conditions, particularly temperature of the Gulf of Iskenderun and the Gulf of Suez (Ben-Tuvia 1966, Avşar 1999). The Gulf of Iskenderun is believed to be providing an ultimate habitat for Lessepsian fish species because of the mentioned ecological similarity (Mavruk and Avşar 2008). In addition, the Gulf of Suez is the last point before the Suez Canal, the biota of which constitutes the source for founder populations of Lessepsian organisms. Therefore, the populations that inhabit the Gulf of Suez can be expected to be more similar to Lessepsian ones genetically, however, this hypothesis should be investigated with further studies.

The striped piggy populations inhabit the Suez Canal seem to have better growth performance with 2.15 (El-Ganainy and Sabra 2008) and 2.44 (El-Azim et al. 2017) $Ø'$ values than in the Mediterranean and the Gulf of Suez. As mentioned above, the populations are overfished here, and they are smaller in size. Therefore, the higher growth rates can be attributed to the younger population structure along with specific environmental conditions in the canal.

The establishment and dispersal of an invader is a complicated process depending on a lot of intrinsic and extrinsic factors from the biological traits of the species to climate change (Bianchi and Morri 2003; Arndt and Schembri 2015). Koutsidi et al. (2020) showed that the opportunist life history strategy can be associated with high establishment success in Lessepsian fishes. According to our results, striped piggy can be considered an opportunistic species with a short generation time, small body size, and fast growth.

Conclusions

The striped piggy is an invasive species, the first observation of which has been reported in 2009 in the study area (Bilecenoğlu et al. 2009). After its first record, its population remarkably increased spreading throughout the Mediterranean coasts of Turkey within a few years (Mavruk et al. 2017; de Meo et al. 2018). Recently, it constitutes one of the most dominant fish in the shallow coastal waters (Ozyurt et al. 2018) completely invading the soft bottoms. This study assessed the growth patterns of a founder population in the Gulf of Iskenderun, the northeastern Mediterranean. In addition, no other study has been found that investigated the population dynamics of striped piggy in other places of the Mediterranean. Therefore, the results presented here will constitute an important baseline for future studies.

Although striped piggy is suitable for human consumption and has economic importance in its native range (Osman et al. 2019), it is discarded in the Turkish fishery. Consequently, we found that the fishery pressure on striped piggy is insufficient in the study area. Therefore, creating a market for striped piggy can increase economic importance and this may prevent further invasion and spread as well as reduce fishery pressure on the native species, the majority of which are already overfished (Demirel et al. 2020).

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