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PROOF
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Population Dynamics of Suez Pufferfish (*Lagocephalus suezensis*) in Iskenderun Bay

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Abstract

Suez pufferfish (*Lagocephalus suezensis*) is a Lessepsian species introduced to the Mediterranean via the Suez Canal. This study was carried out for the identification of some population dynamics parameters of Suez pufferfish (*Lagocephalus suezensis*) distributed along the western coast of Iskenderun Bay. Samples were seasonally collected from two transects at 10 and 20 m depth contours from 2006 to 2017 using a commercial bottom trawl net with 44 mm mesh size. A total of 1279 individuals were investigated. Among them 427 were males, 586 were females, 266 were juveniles. Total length ranged from 5.2 to 24.0 cm and mean length was 13.44 ± 2.02 (± standard error) cm; total weight ranged from 1.77 to 232.97 g and mean weight was 32.05 ± 14.28 g for all individuals. Length-weight relationships were $W=0.02*TL^{2.83}$ for males, $W= 0.02*TL^{2.82}$ for females, and $W=0.02*TL^{2.89}$ for aggregated data. The von Bertalanffy growth parameters were as follows; L_∞ = 24.97 cm, K = 0.60 year^{-1}, t_0= -0.28, R_n = 0.145 for all specimens. Growth performance index was calculated as 5.92. Rates of total (Z) and natural (M) mortality was found to be 1.07 and 0.981 year^{-1}.

Introduction

The family, Tetraodontidae (pufferfishes) comprises 29 genera and 200 species generally distributed in marine waters (Froese & Pauly, 2019). So far, seven species of tetraodontids have been reported in the Eastern Mediterranean two of which are native while the others are the Suez Canal intruders, referred to as Lessepsian species (Bilecenoglu *et al.*, 2014).

The Suez pufferfish *Lagocephalus suezensis* Clark and Gohar (1953) is a lessepsian tetraodontid fish which was first recorded by Moumneimne (1977) on the Lebanese coast of the Mediterranean. Then its occurrence was reported from the Israeli coasts (Golani, 1996) and Turkish coasts (Bilecenoglu et.al., 2002) respectively. Studies on *L. suezensis* are mainly concerned with determination of its geographical distribution and bio-ecological characteristics (Golani, *et al.*, 2006; Turan, 2007), length-weight relationship parameters (Ergüden *et al.*, 2009; Ok, 2012; Başusta *et al.*, 2013; Aydın *et al.*, 2017; Bilge *et al.*, 2017; Mutlu *et al.*, 2017). The population parameters of *L. suezensis* were only investigated by Ok (2012) from Mersin Bay; however, there is no study in İskenderun Bay.

There are significant concerns in direct consumption of tetraodontids because they may contain a strong neurotoxin, namely tetrodotoxin in their various tissues (Kosker *et al.*, 2016; Kosker *et al.*, 2018; Kosker *et al.*, 2019). For this reason, landing of pufferfishes is prohibited by Turkish and European fishery management authorities. This regulation is likely to reduce fishery pressure on pufferfishes and provide an advantage over native rivals in the eastern Mediterranean ecosystem.

Iskenderun Bay is one of the most important fishing areas in the Northeastern Mediterranean (Gucu & Bingel, 1994). The commercial fishing in Iskenderun Bay is primarily based on bottom trawling which is a multispecies fishery. Lessepsian fishes constitute an important part of this fishery as target, by-catch or discard species (Yemisken *et al.*, 2014; Ozyurt *et al.*, 2018).

The purpose of this study is to gather basic biological information on population status of Suez pufferfish, *L. suezensis* distributed in Iskenderun Bay, a semi enclosed shallow water body in the north-eastern tip of Mediterranean. In this context length-weight relationship and growth parameters, and total and natural mortality rates were calculated.

Materials and Methods

Samples were seasonally collected throughout 11 years, between 2006 and 2017 at two transects at 10 and 20 m depth contours between Yumurtalık and Botaş in the west coast of Iskenderun Bay, Northeastern Mediterranean (Figure 1). A commercial bottom trawler using a traditional Mediterranean type bottom trawl net with a 44 mm cod end mesh-size was employed for operations. Each tow lasted one hour. *L. suezensis* samples were sorted from the catch and carried to the laboratory at the Çukurova University Fisheries Faculty of in cold storage. In the laboratory, the length of specimens was measured to the nearest 0.1 cm and the weight was registered to the nearest 0.01 g. Then the sex of specimens was determined and recorded.

The medians and their 95% confidence intervals were calculated for catch per unit effort (CPUE) values in weight and number (Mcgill *et al.*, 1978). The significance of depth related and seasonal changes of CPUE values were tested using Wilcoxon rank sum tests and Kruskal-Wallis tests, respectively (Sokal & Rohlf, 2012). Then significant variations were investigated by applying Chi square-based Nemenyi post-hoc tests (Pohlert, 2014). Interannual changes of CPUE values were tested using Mann-Kendal time series correlation (Hipel & McLeod, 1994; McLeod, 2011). All statistical analyses were performed using R language and environment for statistical computation (R Core Team, 2019).

Electronic length frequency analysis (ELEFAN) (Pauly et. al., 1984) was used to calculate von-Bertalanffy growth functions (VBGF). The parameters of VBGF were estimated using ELEFAN function (Taylor & Mildenberger, 2017) in TropFishR library (Mildenberger *et al.*, 2017) of R. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to the goodness-of-fit tests by assessing the ratio Rn= ($10^{ESP/ASP}$)/10. The VBGF was as follows;

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

L_t, is the total length at age t, L_∞ is asymptotic length, K is growth coefficient and t_0 was calculated using the empirical equation of Pauly (1980):

$$\log_{10}(-t_0) = -0.3922 - 0.2752\ 1og_{10} L_\infty - 1.038 \log_{10} K$$

Pauly and Munro (1984)'s Ø' index was also calculated to compare the growth performance with previous studies;

$$\emptyset' = lnK + 2lnL_\infty$$

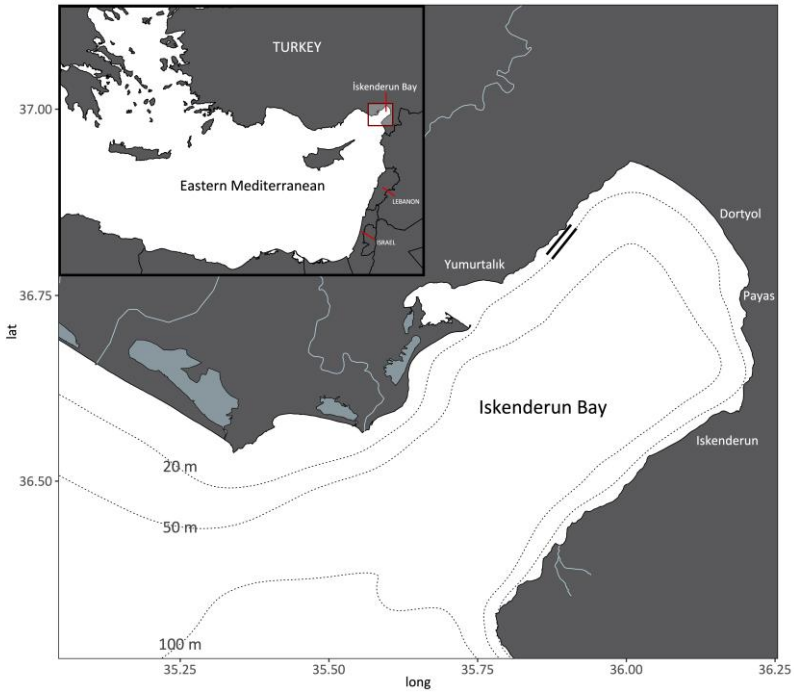

Figure 1. Sampling area and trawling transects at 10 and 20 m.

The length-weight relationships were determined according to the allometric equation given by Ricker (1975). The regressions were fitted using ordinary least square approximation after the length and weight were transformed to their natural logarithms. The allometric equation was as follows:

$$W = aL^b$$

Where; W is the total weight, a and b are regression coefficients, and L is the total length. The confidence intervals (95%) of the regression coefficients were calculated in order to compare sexes.

The difference of overall sex ratio from 1:1 was tested by using χ^2 test. The interannual changes of sex ratio were investigated using Mann-Kendal time series correlation (Hipel & McLeod, 1994; McLeod, 2011).

The rate of total mortality (Z) was calculated using estimates of the growth parameters (K, L_∞), using the average length equation according to Beverton and Holt (1956):

$$Z = Kx\frac{L_\infty - \overline{L}}{\overline{L} - L'}$$

$\overline{L}$: The average total length (13.44 cm) of fish used in the calculation of the growth coefficients and

L': The lower limit of the smallest fully represented the total length class (7 cm) in the samples

The rate of natural mortality (M) was calculated with the empirical formula given by (Then et.al., 2015) using the function M empirical in TropFishR library (Mildenberger *et al.*, 2017).

$$M = 0.418K^{\,0.73}\,L_\infty^{-0.33}$$

Results

During the study period *L. suezensis* was observed in 55 tows out of 92 bottom trawl operations (%60). The median catch per unit effort (CPUE) was 183.98 g/hour (5.49 – 362.47; 95% confidence intervals) in weight, and 7 individual/hour (1 - 13; 95% ci) in number. The depth related changes of CPUE was not significant neither in weight (W = 1189, p = 0.29) nor in number (W = 1219, p-value = 0.19); whereas, significant seasonal changes were detected both in weight (χ^2=32.33, df = 3, P<0.001) and in number (χ^2=28.98, df = 3, P<0.001). Based on Nemenyi post hoc test, the median of the weight and number values were lower in summer in contrast with other seasons (P<0.05). The inter-annual changes of CPUE were not found to be significant both in weight (Mann-Kendal τ = -0.02, p =0.86) and in number (Mann-Kendal τ = -0.04, p =0.70).

For population dynamics, a total of 1279 specimens were investigated. Among them 33.4% were male (427), 45.81% were female (586) and 20.79% were juveniles (266). The overall sex-ratio was calculated as 0.58 (1:0.73) and females were slightly dominant in the population (χ^2= 24.34, P< = 0.001). Interannual changes in the sex ratio were not found to be significant (Mann-Kendal τ = -0.21, p =0.54). The specimens smaller than 9 cm total length could not be sexed. Total length and weight of the examined fish ranged from 5.2-24.2 cm (Figure 2) to 77-232.97 g, respectively. Mean length and weight values and standard deviations were calculated as 13.44 ± 2.02 cm and 32.05 ± 14.28 g, respectively. The seasonal length-frequency distributions and von-Bertalanffy growth curves were shown in Figure 2.

The best fit to the length frequency distributions was obtained by the growth parameters as L_∞ = 24.97 cm, K = 0.60 year^{-1}, Rn = 0.145 for total individuals. Afterwards, t_0 was calculated as -0.28 year. The growth performance index of the population was calculated as $\emptyset'$= 5.92. The total (Z) and natural mortality (M) were calculated as 1.07 year^{-1}, 0.98 year^{-1}, respectively.

Length-weight relationship parameters of *L. suezensis* were given in Table 1. In males, females and overall data, exponential coefficients (b) were significantly smaller than three, which indicates growth is negative allometric in *L. suezensis* population in Iskenderun Bay.

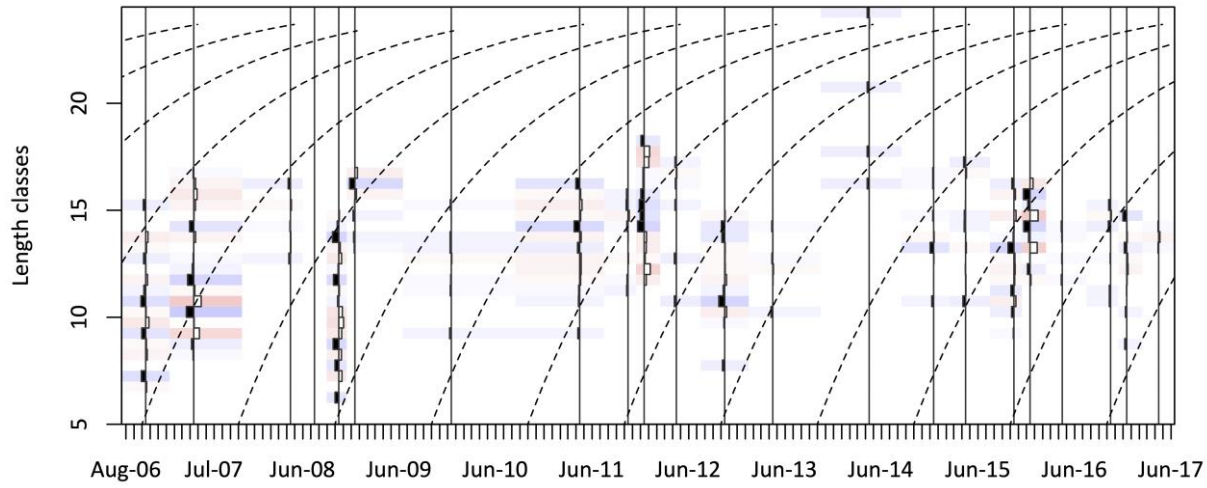

Figure 2. Length-Frequency distributions and von Bertalanffy growth curves.

Table 1. Length-weight relationship parameters for males, females, juveniles and all specimens combined (the ranges in parentheses show 95% confidence intervals)

Sex	Individuals Numbers	Length-Weight Relationship Parameters a	b	R^2
Male	427	0.019 (0.015 - 0.024)	2.83 (2.74 - 2.92)	0.91
Female	586	0.02 (0.017 - 0.024)	2.82 (2.76 - 2.88)	0.93
Juvenile	266	0.016 (0.007 - 0.039)	2.88 (2.53 - 3.24)	0.89
All Specimens	1279	0.017 (0.015 - 0.018)	2.89 (2.85 - 2.93)	0.95

Discussion

In general, length and weight ranges of *L. suezensis* individuals investigated in this study were in accordance with the previous studies performed in the Northeastern Mediterranean (Table 2). On the other hand, here we report a higher maximum length (24 cm) than those from the previous studies (Erguden *et al.*, 2009; Ok, 2012; Basusta *et al.*, 2013; Aydın *et al.*, 2017; Bilge *et al.*, 2017; Mutlu *et al.*, 2017). Our samples were collected in an area where bottom trawl fishery is permanently restricted. Therefore, reduced fishery pressure may be a reason why larger fishes are present in the study area (Bingel, 1987; Cicek *et al.*, 2014). Additionally, temporal coverage of our sampling is wider than previous studies and this should be considered while comparing the results.

In this study, the value of "b" was calculated as 2.83 for males, 2.82 for females and 2.89 for all combined specimens including juveniles; there was no statistically significant difference between the two sexes (Table 1). Additionally, *L. suezensis* population inhabiting Iskenderun Bay showed negative allometry in growth characteristics. These results are in accordance with the previous studies performed in Iskenderun Bay (Erguden *et al.*, 2009; Basusta *et al.*, 2013). On the other hand, both isometry (Aydın *et al.*, 2017) and positive allometry (Ok, 2012) were also reported for this species from Antalya and Mersin Bays, respectively. These controversies can be due to the differences among the spatiotemporal extent of the studies.

The von-Bertalanffy growth parameters of *L. suezensis* calculated in Iskenderun Bay (this study) and Mersin Bay (Ok, 2012) were compared in Table 3. The

Table 2. *L. suezensis* population parameters reported by different researchers in the Mediterranean

Authors	Erguden *et al.*, 2009	Basusta *et al.*, 2013	Ok, 2012	Bilge *et al.* 2017	Aydın *et al.* 2017	Mutlu *et al.* 2017	This study
Area	Iskenderun	Iskenderun	Erdemli- Tırtar	South Aegean Sea	Antalya Bay	Antalya Bay	Iskenderun
N	86	979	1430	84	150	747	1279
Sex Ratio (%)	-	50.46 ♀ 49.54 ♂	32.39 ♀ 23.55 ♂				33.4 ♂ 45.81 ♀
L (cm)							
Min-Mak Mean±Sh	10.2-16.7	6.5-17.1 13.944± 1.296	6-23	8.6-15.9 10.627	11.5- 26.8 16.1±2.9	4-18.5	5.2- 24.0 13.44±2.02
W (g)							
Min-Mak Mean±Sh	12.5-54.88	6.0 -60.0 31.63± 8.903		7.94 43.56 15.47	18.7– 87 58.3±44.7	1.1– 92.4	1.77- 232.97 32.05±14.28
a	0.0236 ♀+♂	0.0198 ♀+♂ 0.027 ♂ 0.0145 ♀	0.0120 ♀+♂ 0.0138 ♂ 0.0115 ♀	0.0213 ♀+♂	0.0142 ♀+♂	0.0195 ♀+♂	0.016 ♀+♂ 0.019 ♂ 0.02 ♀+♂
b	2.749 ♀+♂	2.795 ♀+♂ 2.6764 ♂ 2.9144 ♀	2.9981 ♀+♂ 2.9506 ♂ 3.0252 ♀	2.7586 ♀+♂	2.9557 ♀+♂	2.836 ♀+♂	2.89 ♀+♂ 2.832 ♂ 2.819 ♀
95% CI of b S.E. (b)	± 0.063	± 0.0014 ♀+♂ ± 0.0025 ♂ ± 0.0019 ♀		±0.0157 ±0.0234	+0.048		±0.04 ♀+♂ ±0.09 ♂ ±0.06 ♀
r^2	0.957	0.858	0.9957	0.871	0.9608		0.95

Table 3 Growth parameters of *Lagocephalus suezensis*

	von Bertalanffy Growth Parameters							
Sex	L_∞ (cm)	K (year^{-1})	C	WP	t_0 (year)	Ø′	Region	Authors
Total	24	0.90	0.90	0.10	-	6.25	NW Levant	Ok, 2012
Total	24.97	0.60	-	-	-0.28	5.92	Iskenderun Bay	This study

results were found to be close to each other (Table 3). The asymptotic length was higher and growth coefficient was lower in Iskenderun Bay, as well as the overall growth performance was found to be slightly lower in Iskenderun Bay, according to results of Ø′ index.

Conclusion

Pufferfishes have no commercial importance due to the poison in their edible tissues. According to the recent studies, the amount of tetrodotoxin in the muscle tissue of *L. suezensis* is varying with season and constituting a potential health threat to consumers (Kosker *et al.*, 2019). For this reason, landing of caught pufferfishes has been completely banned by the Turkish national fishery management authority (Anonymous, 2017). Pufferfishes are highly invasive species in the Mediterranean (Mavruk *et al.*, 2017) and the absence of fishery pressure may contribute to their success in colonization and expansion in new habitats. Therefore, even though their direct consumption cannot be suggested, alternative usages of Suez pufferfishes should be explored in order to enhance its economic value and increase exploitation level so that the ecological advantage of low fishery pressure can be suppressed.

Conflicts of Interest

The authors declare that they have no competing interests.

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