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Growth, Reproduction and Diet of Pufferfish (*Lagocephalus sceleratus* Gmelin, 1789) from Turkey's Mediterranean Sea Coast

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Abstract

Basic biological information of the puffer fish *Lagocephalus sceleratus* is presented based on a 2 year study. A sample of 656 fish with total lengths ranging from 12.5 to 65 cm was collected from commercial catches and fishing line at the Antalya Bay between December 2008 and January 2010. Males made up 51.3% whereas females 48.7% of the population. The length - weight relationship was given by TW = 0.012 $TL^{2.979}$. The Bhattacharya method was used to separate cohorts from a length frequency distribution obtained pooling monthly samplings. The von Bertalanffy growth model was used to fit growth curve to the length frequency data. The von Bertalanffy growth equation were $L_t=126.11(1–e^{-0.099(t+1.4349)})$. The spawning takes place during early summer. Relative fecundity was 781±172 eggs g^{-1} the total body weight and average egg size was 640 µm in diameter in June. Analysis of the diet composition showed that the fish is carnivorous and crustaceans are the major food items for *L. sceleratus*.

Keywords: Growth parameters, reproductive, diet, puffer fish, *Lagocephalus sceleratus*.

Türkiye'nin Akdeniz Sahillerindeki Balon Balıklarının (*Lagocephalus sceleratus* Gmelin, 1789) Büyüme, Üreme ve Beslenme Özellikleri

Özet

Balon balıklarının (*Lagocephalus sceleratus*) bazı biyolojik verileri iki yıl süren çalışma ile elde edilmiştir. Total boy aralıkları 12,5 ile 65,0 cm arasında değişen 656 adet balon balığı Antalya Körfezi'ndeki ticari balıkçılıktan ve olta avcılığıyla, Aralık 2008 ile Ocak 2010 tarihleri arasında elde edilmiştir. Populasyonun %51,3 erkek, %48,7'si dişi bireylerden oluşmaktadır. Boy ağırlık ilişkisi TW = 0,012 $TL^{2,979}$ şeklindedir. Aylık örneklemelerden elde edilen boy frekans dağılımlarından yararlanılarak Bhattacharya metodu kullanılarak cohortlar belirlenmiştir. Von Bertalanffy büyüme modeli kullanılarak boy dağılımları verilerinden büyüme eğrisi çizilmiştir. Von Bertalanffy büyüme denklemi $Lt = 126,11\ (1–e^{-0,099\ (t+1,4349)})$ şeklindedir. Bu türde üremenin yaz başlarında gerçekleştiği, relatif fekondite 781±172 yumurta g^{-1} total vücut ağırlığı olarak ve ortalama yumurta çapı Haziran ayında 640 µm olarak tespit edilmiştir. Beslenme alışkanlıkları incelendiğinde balon balıklarının karnivor bir tür oldukları ve daha çok crustacea türleri ile beslendikleri belirlenmiştir.

Anahtar Kelimeler: Büyüme parametreleri, üreme, beslenme, balon balıkları, *Lagocephalus sceleratus*.

Introduction

The puffer fishes are commonly known of all type of fish poisoning and has been recognized from ancient times. It is probably the most common fish poisoning along the coasts of Asia. There are as many as 120 species of puffer fish that live mostly in tropical seas. All belong to the order Tetraodontiformes. They also called blowfish, toadfish, swellfish, globefish and balloon fish (Torda *et al*., 1973). They are named after their habit of inflating themselves with water or air when threatened, making it difficult for a predator to swallow them.

This fish is known to carry tetrodotoxin (TTX) (Bilecenoglu *et al*., 2006; Kasapidis *et al*., 2007; Sabrah *et al*., 2006) which is known a non-protein organic compound (aminoperhy-droquinazoline) and one of the strongest marine paralytic toxins today. TTX named after the order of fish from which it is most commonly associated, the Tetraodontiformes (*tetras*-four and *odontos*-tooth) or the tetraodon puffer fish (Halstead, 1978). TTX can be found in the liver, gonads, intestines, and skin of these fish and can cause death in approximately 60% of persons who ingest it (Ellenhorn and Barceloux, 1988). The toxin

has only occasionally been detected in the muscles of these fishes. If cleaned and dressed properly, the puffer flesh or musculature is edible and considered a delicacy by some Japanese (Torda *et al.*, 1973). It is considered as the most delicious sea food in Suez City, Egypt and illegally sold in spite of several fatal poisonings reported in this city (Zaki, 2004). In Turkey, although landing of these fishes is forbidden as a commercial species they are illegally landed and can be consumed in the Mediterranean coast.

The puffer fish, *Lagocephalus sceleratus* (Gmelin,1789), belongs to the Tetraodontidae. Distributed in the Indo- West Pacific Ocean (Smith and Heemstra, 1986), primarily at depths ranging from 18 to 100 m, it is also a reef inhabitant (Randall, 1995). *Lagocephalus sceleratus* was first recorded in the Mediterranean region in the Gökova Bay (Turkey) in 2003 by Akyol *et al*. (2005). More reports followed from the Jaffa and Haifa Bays, Israel (Eisenman *et al*., 2008) and (Golani and Levy, 2005), Ladiko, Greece (Corsini *et al*., 2006), Kemer, Turkey (Bilecenoglu *et al*., 2006) and the Heraklion Bay, Greece **(**Kasapidis *et al*., 2007).

The biology and toxicity of *Lagocephalus sceleratus* have investigated in the Mediterranean by many authors (Sherif *et al.*, 1994; Ali *et al*., 1995; Kotb, 1998; Youssef, 1999; Mohamed, 2003; Zaki, 2004; Sabrah *et al*., 2006).

So far, there has been no study on the biology and toxicity of the puffer fishes particularly on silver stripe blaasop *Lagocephalus sceleratus* in the Turkey. Therefore, the present study to attempts to investigate the biology of the puffer fish *Lagocephalus sceleratus* along the Mediterranean coasts of Turkey with regard to growth, reproduction and feeding habits.

Materials and Methods

Specimens of the puffer fish *Lagocephalus sceleratus* were collected monthly from the commercial catches and fishing line at the Antalya Bay between December 2008 and January 2010 (Figure 1). The fish were transported to the Fisheries Laboratory of Mediterranean Fisheries Research Production and Training Institute, in Antalya.

In this study, a total of 656 *L. sceleratus* was examined. The total lengths (TL) of all fish were measured to the nearest mm, whereas the weights were recorded with an electronic balance at the nearest 0.01 g. Sex and maturity were determined macroscopically and the gonad weights (GW) were recorded to the nearest 0.01 g. The spawning season was determined following the monthly changes of the gonadosomatic index (GSI), and calculated after (Anderson and Gutreuter, 1983); GSI = 100 x (GW/TW) where GW is the gonad weight and TW is the total fish weight.

Fecundity and egg size were evaluated from 20 females. The gonads of fish were removed and placed in 5% formalin solution to facilitate the counting. The weight of the ovaries were also taken. Excess of water was removed from the surface of the ovaries with blotting paper before their weights were taken. To estimate the fecundity, gravimetric method was used. Relative fecundity was calculated as Fr= F/W (g). Fecundity (F)–total length (TL), fecundity–weight (W) relationships were determined from the equation $F= a*x^b$ where F= fecundity, x= length or weight, a= a constant and b= an exponent (Bagenal, 1978).

Egg size was determined by using a sensitive micrometer (at 0.01 mm sensitivity). Long and short axes of eggs were measured. Mean egg diameter were calculated as follows: Mean Egg Diameter (mm)= (length of long axis + length of short axes) / 2 (Murua *et al*., 2003; Jakobsen *et al*., 2009).

The relationship between weight and total length was established by the exponential regression equation, $TW = a\ TL^b$, where TW is the total weight in g, TL the total length in cm, a and b the parameters to be established (Ricker, 1975).

The Bhattacharya method was used to separate cohorts from a length frequency distribution obtained pooling monthly samplings (Bhattacharya, 1967). The von Bertalanffy growth model was used to fit growth curve to the length frequency data. The length for any age was calculated by employing the von Bertalanffy

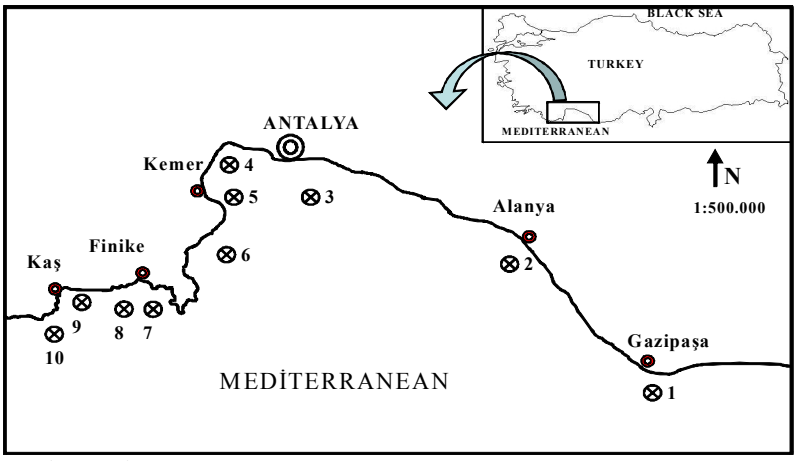

Figure 1. Sampling area, the Antalya Bay.

equation $L_t = L_\infty (1–e^{-K (t - to)})$, where t is age, L_t is length at time t. The asymptotic length (L_∞) and the growth coefficient (K) and theoretical age (t_0) were obtained using Ford-Walford method (Pauly, 1984; Wetherall, 1986; Gulland, 1988 and Avşar, 1997).

The growth performance index ($\Phi = \log10\ K + 2\ \log10\ L_\infty$) of Pauly and Munro (1984) was calculated to allow comparison of growth parameters. Fulton's coefficient of condition factor was calculated by $C = (W/TL^3) \times 100$ (Sparre and Venema, 1992).

A total of 656 *L. sceleratus* specimens stomach was examined during the study for stomach content analysis. The stomach was separated from the body and its contents carefully removed and weighed for each month. Intact food organisms in the alimentary canal were classified into families using various textbooks (Fischer *et al*., 1987; Jereb and Roper, 2005). The percent composition of the each content was determined based on weight of each prey to evaluate their contributions to the diet. Food selection by the fish was expressed as the percent distribution of the monthly consumed food types.

Student's t-test was employed for statistical comparisons (Sokal and Rohlf, 1969; Duzguneş *et al*., 1983).

Results

The puffer fish individuals used in this study consisted of 656 total fish, 336 of which were (51.3%) male and 320 (48.7%) female. Length frequency distribution of *L. sceleratus* collected from the Antalya Bay is presented in Figure 2.

The total length of males ranged from 12.5 to 65 cm with a mean TL of 27.3±12.02 cm. The corresponding weight ranged from 22.8 to 3463 g with a mean weight of 380.3±490.84 g. The lengths of females ranged between 13.5 and 63 cm with a mean length of 28.8±13.35 cm and weight between 29 and 3465 g with a mean weight of 465.9±623.7 g. The total length-weight relationships were calculated for male, female and combined sexes of puffer fish *L. sceleratus* and are presented in Figure 3.

The mean lengths and weights of males and females were not significantly different (Student's t-test) ($P = 0.966$ and 0. 948 respectively).

Length-weight regression constants for males, females and sexes combined are given in Table1. The analysis of length frequency distribution indicated the occurrence of 6 distinct cohorts or age groups (Figure 4).

The first mode at mean length of 17.08 cm could be considered as age group (1). The rate of growth is rapid during the first 4 years of life then it slows down (Table 2).

Estimates of L_∞, K and t_0 obtained from Ford-Walford were 126.11 cm, 0.099 and -1.4349 respectively. The growth performance index Φ estimated in this study was 3.197. The relationships between age-length were determined using the Bhattacharya method and are given in Figure 5 and Table 3.

The overall sex ratio of males to females was 1: 1.05 and χ^2 analysis showed that which is not significantly different from 1:1 ($P>0.05$).

Monthly variations in GSI are shown in Figure 6. The data indicated increase from march till june. The maximum values were recorded during late spring-early summer indicates that the puffer fish *L. sceleratus* has an extensive spawning period in early summer with a peak in June.

Therefore the number of eggs was determined during the spawning months. The minimum, maximum and mean egg number in 1g ovary values was ranged 9,062, 22,307 and 12,962±889 in June, respectively. The relative fecundity was estimated as 780.8±171.8 eggs g^{-1} (minimum value was 566.4 and maximum 1061.1 eggs g^{-1}) the total body weight. The relationships between fecundity - length and fecundity - weight were given Figure 7 and 8. The diameter of the eggs ranged from 385 µm to 717 µm with a mean of 640±41 µm in June.

The mean physical parameters of the June of Antalya Bay were 24°C Water temperature, 6.5 mg/L Dissolved oxygen, 0.33% Salinity, 88% Oxygen saturation and 7.81 pH.

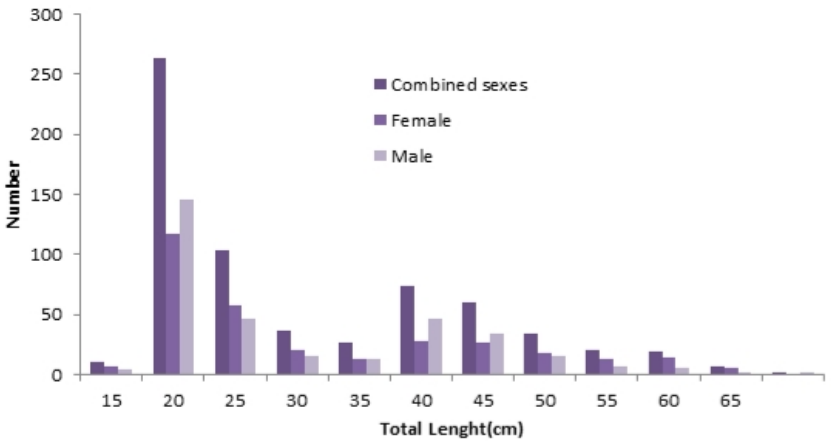

Figure 2. Length frequency distribution of *L. sceleratus* collected from the Antalya Bay.

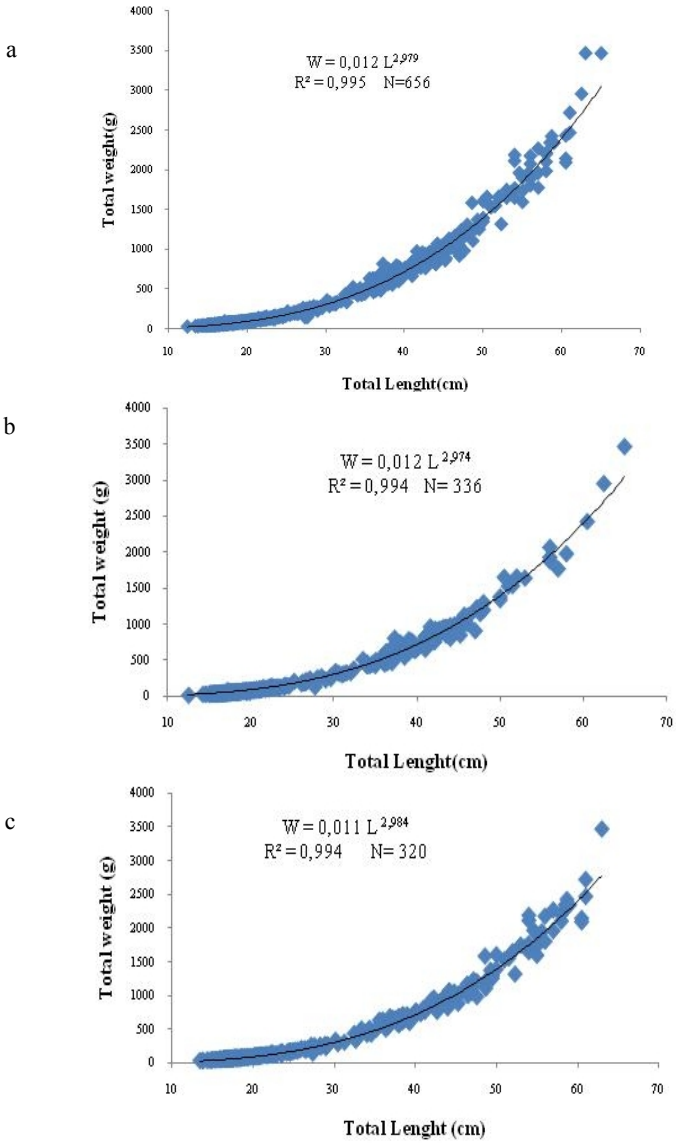

Figure 3. The total length–weight relationships of the a) sex combined, b) males, c) females of puffer fish *L. sceleratus* in the Antalya Bay.

Table 1. Parameters of the length weight relationship for the puffer fish *L. sceleratus*collected from the Antalya Bay

	n	a	b	R^2
Female	320	0.011	2.984	0.994
Male	336	0.012	2.974	0.994
Combined sexes	656	0.012	2.979	0.995

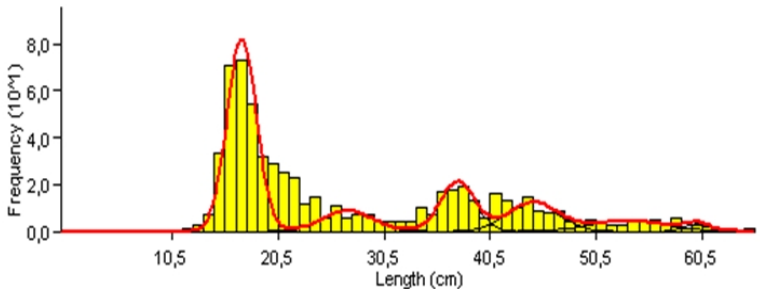

Figure 4. Length frequency distribution and decomposed age groups of *L. sceleratus*.

Table 2. Mean length, standard deviation, population number and separation index (S.I.) for each age group for *L. sceleratus* as estimated from Bhattacharya method and mean length from VBGE

Group	Mean Length (Bhattacharya)	S.D.	Population number	S.I.	Mean Length (VBGE)
1	17.08	1.380	283	n.a	16.8
2	27.03	2.410	53	5,250	27.2
3	37.42	1.630	36	5,140	36.6
4	44.50	2.350	72	3,560	45.1
5	53.53	3.630	10	3,020	52.8
6	59.97	1.150	9	2,690	59.8

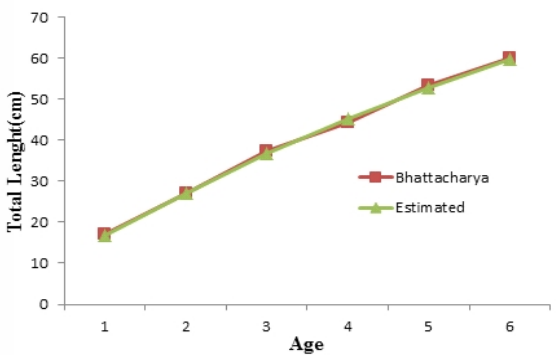

Figure 5. Age-length relationships in *L. sceleratus.*

Table 3. Growth parameters

Parameter	Bhattacharya	Estimated (VBGE)
L_∞	126.1	126.6
K	0.0999	0.0994
t_o	-0.4349	-0.4336

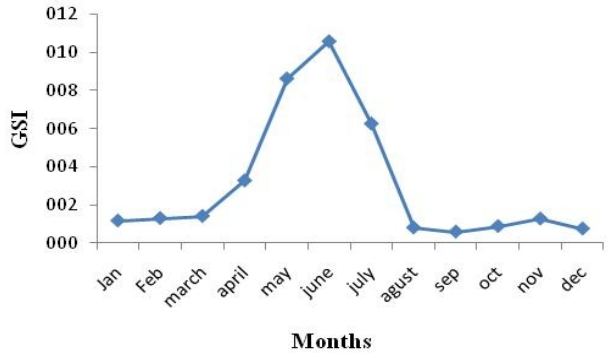

Figure 6. Monthly gonad somatic index (GSI) for *L. sceleratus* from the Antalya Bay.

The analysis of diet composition of the puffer fish *L. sceleratus* showed that the fish is carnivorous and the diet was composed of 54% shrimps (Penaeidae), 17% crabs (Portunidae), 14% fishes 4% squids and cuttlefish (Cephalopods) and 11% others (Figure 9).

Fulton's coefficient of condition factor (C) was established with 656 specimens. The mean condition factors for female, male and both were 1.13±0.10, 1.14±0.10 and 1.14±0.10 respectively.

Discussion

The maximum observed length (65 cm) is well below the maximum values of 110 cm reported in Japan by Masuda *et al.* (1984), 78.5 cm in the Suez Canal by Sabrah *et al.* (2006) and 71.5 cm in New Caledonia by Letourneur *et al.* (1998). Moreover the maximum weight of fish observed in the present study (3465g) is also lower than that of 7000 g reported by Smith and Heemstra (1986).

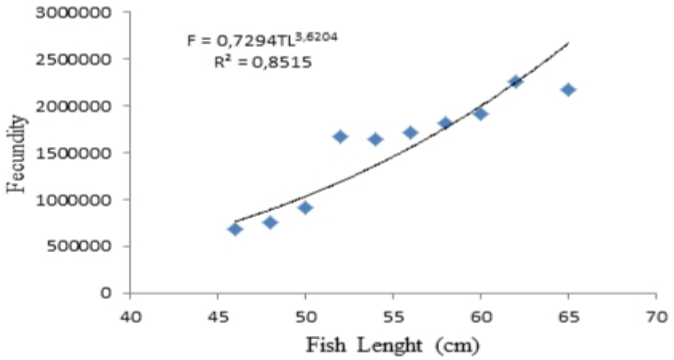

Figure 7. Relation between fecundity and total length for *L. sceleratus.*

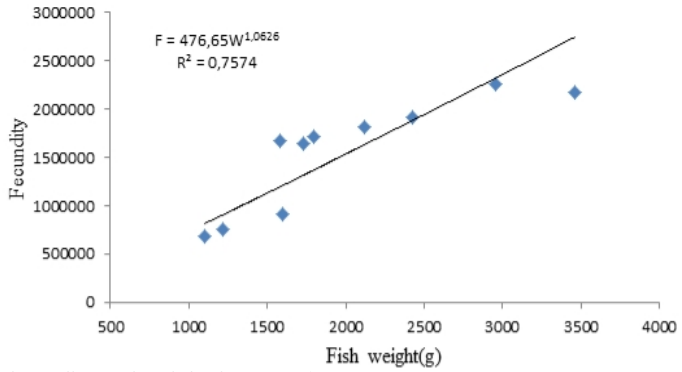

Figure 8. Relation between fecundity and weight for *L. sceleratus.*

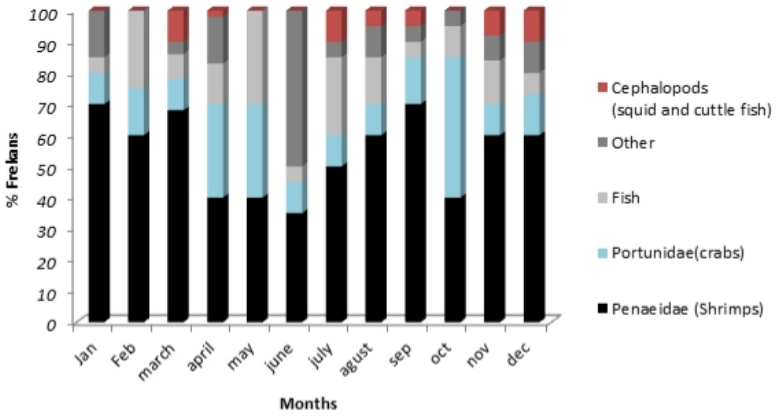

Figure 9. The monthly percent distribution of diet of *L. sceleratus* in the Antalya Bay.

Length and weight are regarded as important growth criteria in the ecology of fish. The correlation coefficient of length and weight was found to be 0.99. The value of b depends on ecological conditions (Ricker, 1975; King, 1995; Avşar, 1997). In this study, b was found to be 2.979 which is a value higher than the range of previously reported values (2.86-2.92) in two studies (Sabrah *et al*., 2006; Kulbicki *et al*., 2005).

In this study the theoretical maximum length value (L_∞) and growth coefficient value (K) were 126.1 cm and 0.099, respectively. This findings are much higher compared with those by Chan and Liew (1986) who estimated L_∞=18.0 cm and K=1.5 in Malaysia. On the other hand Sabrah *et al*. (2006) reported L_∞ and K as 82.3 cm and 0.191 respectively. Their L_∞ estimation close to our to certain degree despite some differences in ecological conditions.

Total lengths of the samples collected from the Antalya Bay ranged from 12.5 to 65 cm. Bhattacharya modal estimated 6 distinct modes or length/age groups in this study. Sabrah *et al*. (2006) collected

176 fish with minimum and maximum lengths 18.5 and.78.5 cm respectively from the Gulf of Suez and they reported 11 distinct modes. The difference between their and our study may stem from differences in the number of samplings and length range or selectivity of gears.

The monthly variations in GSI suggest that the spawning takes place during April, May and June for both sexes of *L. sceleratus*. This finding fully complies with those by Kotb (1998) and Sabrah *et al*. (2006).

The relative fecundity was estimated as 780.8±171.8 eggs g^{-1} the total body weight. The diameter of the eggs ranged from 385 µm to 717 µm with a mean of 640±41 µm in June. The number of eggs and eggs diameter was not reached with the relevant information to the literature.

The population of *L. sceleratus* was seen to feed on shrimps, fishes, crabs, squids and cuttlefish that densely inhibits in the habitat. The analysis of the diet composition of the puffer fish showed that the diet was composed mainly of 54% shrimps, 17% crabs, 14% fishes % 4 squids and cuttlefish and 11% others. Shrimps and crabs are the major food items for *L. sceleratus* from Antalya Bay. Our results are consistent with those of Sabrah *et al*. (2006) who reported that *L. sceleratus* is carnivorous where the diet was composed mainly of 70% cephalopods (squids and cuttlefishes), 25% crustaceans (particularly crabs) and 5% fishes. However we should point out that despite similar stomach contents reported by these authors to ours the percentage values of each diet item are different because of presumably some differences in the habitat. Stomach content analysis of *L. sceleratus* show that this species will share with other demersal carnivores species food in the Mediterranean.

Man made disruption of the ecological balance has resulted in the spread of tetrodotoxin-containing fish from the Indo-Pacific region to the Mediterranean Sea (Lessepsian migration). *L. sceleratus* began to appear intensely in the Antalya Bay during the last 10 years. Although landing of the puffer fish is prohibited in Turkey, it is illegally landed and consumed the Mediterranean coasts. There is no catch statistics for this species. The fish is consumed by local fishermen and their family for years because it is very delicious and low cost. The liver, gonads, intestines, and skin of puffer fishes contain tetrodotoxin (Ellenhorn and Barceloux, 1988). The rest of fish (liver, gonads, intestines, and skin) is not consumed in Turkey so there are no cases of poisoning.

In the end, puffer fishes have rapidly spread and reproduced in the Mediterranean Sea in recent years and competes with other commercial carnivore species. The results of this research showed, the growth, reproduction and feeding habits of this lessepsian species (*L. sceleratus*). But, there is a need to investigate the effects of spreading puffer fish in the Mediterranean ecosystem and the influence of toxicity. It is a hope that this investigation will be the first step for the further studies in the Mediterranean.

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