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RESEARCH PAPER

Spatio-Temporal Patterns of Abundance, Biomass and Length of the Silver-Cheeked Toadfish *Lagocephalus sceleratus* in the Gulf of Antalya, Turkey (Eastern Mediterranean Sea)

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Abstract

The variations in abundance, biomass and length frequency of 811 individuals of *Lagocephalus sceleratus* (Gmelin, 1789) according to the seasons, locations, and depth levels in the Gulf of Antalya were reported in this study. *L. sceleratus* was sampled from 61 of 116 hauls of commercial bottom trawl that were realized seasonally between August 2009 and April 2010, at six locations and at six depth levels (25, 50, 75, 100, 150, 200 m). The frequency of occurrence was 56.48% at the depths between 25 and 150 m, but the fish were absent at 200 m. The overall mean abundance was calculated as 136.21 ind./km^2 (11.67 ind./h) and biomass as 15.73 kg/km^2 (1.37 kg/h). The total length (TL) ranged from 11 to 50 cm, and the mean TL was calculated as 19.99 cm. According to the available data, this is the widest depth range of *L. sceleratus* and the deepest record of the species in the Mediterranean Sea.

Keywords: Tetraodontidae, puffer fish, Lessepsian migration, trawl, spatio-temporal distribution.

Introduction

Lagocephalus sceleratus (Gmelin, 1789), also known as silverstripe blaasop or silver-cheeked toadfish, is an extremely poisonous fish in the family Tetraodontidae (puffer fishes or fugu). It is common in the tropical waters of the Indian and Pacific Oceans, and completely absent from cold waters (Froese & Pauly, 2014). Its certain internal organs, such as liver, and sometimes the skin contain tetrodotoxin (TTX) which is a potent neurotoxin. According to the current European Union (Regulation 853/2004/EC; Regulation 854/2004/EC) and Turkish legislative requirements (Anonymous, 2012), poisonous fish of the family Tetraodontidae and products derived from them must not be placed on the markets. However, probably due to its large size that can reach up to 110 cm and weight up to 7 kg (Froese & Pauly, 2014), it is being sold and consumed in some Mediterranean countries like Egypt, Israel, Turkey and Lebanon and there are several cases of poisoning (Aydın, 2011; Nader, Indary, & Boustany, 2012; Beköz, Beköz, Yılmaz, Tüzün, & Beköz, 2013). In addition to its great risk to human health if consumed, *L. sceleratus* has been recorded to destroy fishing nets and lines by its two strong teeth in each jaw, leading to economic losses for fishers (EastMed, 2010).

It is considered as one of the faster expanding exotic species originating from the Indo-Pacific region and entered to the Mediterranean Sea via the Suez Canal. It established abundant populations along the coasts of many countries of the eastern basin such as Turkey (Mediterranean, Aegean and Marmara Sea coasts), Israel, Lebanon, Greece (Aegean and Ionian coasts) and Cyprus and expanded westwards along the coasts of Egypt, Libya, Tunisia, Algeria, Italy, Croatia and Malta (Akyol, Ünal, Ceyhan, & Bilecenoğlu, 2005; Bilecenoğlu, Kaya, & Akalın, 2006; Golani & Levy, 2005; Corsini, Margies, Kondilatos, & Economidis, 2006; Katsanevakis, Tsiamis, Ioannou, Michailidis, & Zenetos, 2009; Halim & Rizkalla, 2011; Milazzo, Azzurro, & Badalamenti, 2012; Jribi & Bradai, 2012; Kalogirou, 2013; Azzurro, Castriota, Falautano, Giardina, & Andaloro, 2014; Sulić Šprem, Dobroslavić, Kožul, Kuzman, & Dulčić, 2014; Irmak & Altınağaç, 2015; Deidun *et al.*, 2015; Kara, Lamine, & Francour, 2015 and references therein).

Due to its rapid expansion and potential threats to humans, *L. sceleratus* was the subject of several recent studies in Turkey with different aspects (Aydın, 2011; Başusta, Başusta, & Özer, 2013; Beköz, Beköz, Yılmaz, Tüzün, & Beköz, 2013; Köşker, Özoğul, Ayas, Durmuş, & Uçar, 2015).

Previously a few studies have also reported the presence and CPUE values of *L. sceleratus* in trawl hauls from Turkey (Gücü, 2012; Yemişken, Dalyan, & Eryılmaz, 2014; Bilecenoğlu, 2016). However, there has been no study on the spatial and temporal distribution of *L. sceleratus* in Turkey. In the present study, the status of the stocks of *L. sceleratus* are set forth depending on seasons, depth levels and locations in the Gulf of Antalya and these are the first data from the region.

Materials and Methods

Study Area

The Gulf of Antalya is located in the Northeastern Levantine Basin and is characterized by high temperature and salinity. The geographical coordinates of the trawling areas at six locations vary between N36° 52' 485 - 36° 23' 000 - E31° 32' 322 - 30° 29' 488 (Figure 1). Samplings were carried out at six depth levels (25, 50, 75, 100, 150, 200 m) at locations (locs.) A and B. Because of the narrow and steep continental shelf, trawling at 150 and 200 m depth levels, however, could not be realized at locs. C, D and E and 200 m at loc. F. The survey was conducted seasonally, both in "closed fishing" season (August, 2009) and "open fishing" seasons (November, 2009; February, 2010 and April, 2010) and both in the no-trawl zones and open areas.

Turkish national regulation on commercial fisheries covers a complex scheme of open/closed zones and seasons for trawl fisheries (Anonymous, 2012). Bottom trawling is prohibited during the whole year within 2 NM off the coast and between 15 April and 15 September in territorial waters where trawling is permitted. Since 2005, all sorts of trawling activities have been prohibited between the territorial waters off Side District, Selimiye Lighthouse (36º45,928' N- 31º 23,092' E) and Alanya, Gazipaşa District, Kesik Cape (36º 09,964' N- 32º23,418' E). Loc. A and the month of the Manavgat River (covers the area marked with long lines in Figure 1) are located in this prohibited area. The main commercial trawl area in the Gulf of Antalya is represented by loc. B where two main streams reach the sea. Locs. C and D are located off the yacht marina and Great Harbor of Antalya, respectively, and both are closed zones for trawling. The depth levels of 25 and 50 m in locs. E and F are located within 2 NM off the coast so closed for trawling, but it is permitted in deeper areas.

Sampling Methods

A total of 116 hauls were made during the daytime; however, 8 hauls at depth of 200 m were not taken into account, since *L. sceleratus* was not encountered in the catches from this depth level. The duration of each haul was limited to one hour. Trawling was carried out by a commercial fishing vessel "Akyarlar" which was 24.80 m long with 450 HP engine. The cod-end mesh size was 22 mm (knot to knot) and the average towing speed was 2.5 knots *L. sceleratus* individuals were counted, and the total catch weight (Wet Weight, WW: ±1.0 g) were recorded on board immediately after capture. Subsequently, all fish were measured (total length (TL)) to the nearest 0.5 cm.

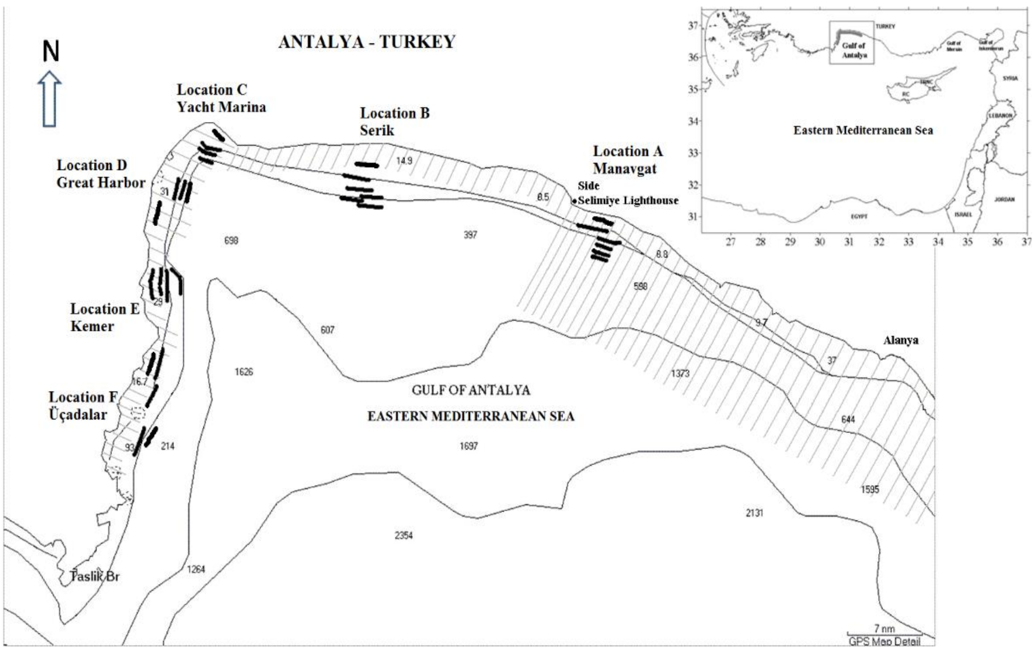

Figure 1. Map of the Gulf of Antalya- Turkey (NE Mediterranean Sea) showing the six sampling locations (named A, B, C, D, E, F from east to west) and depth levels of 29 trawl hauls. The areas marked with grey lines showing "no-trawl zones".

Data Analyses

The total catch from each haul was identified to species, counted, weighed and the stock amount was calculated according to the swept area method; the abundance and catch weight (Cw) divided by the swept area (a) for each species and for each haul (Spare & Veneme, 1992). The coordinates of the trawl operation were recorded by 30 seconds intervals by GPS and the cover of distance was calculated by summing the distances between the recorded coordinates. The swept area (a) for each haul was estimated as: $a = D.h.X$ (h: length of the head-rope, *D:* cover of distance, X: fraction of the headrope length which was equal to the width of the path swept by the trawl (accepted as 0.5). Abundance (number of individuals per km^2) and biomass (kg per km^2) per sampling was calculated, and the mean values were computed according to seasons, locations and depth levels. Euclidean distance dissimilarity matrix, based on the log-transformed abundance and biomass was tested by 3-way orthogonal nonparametric (permutation based) MANOVA (PERMANOVA) for assessing differences at seasons, locations and depth levels under a model in which all of them are fixed factors using PRIMER 6+ PERMANOVA software package (Anderson, Gorley, & Clarke, 2008). Three-way analysis of variance using a general linear model was undertaken on standardized total length data considering season, location and depth as factors, after testing for normality of data (chi-square goodness of fit test) and homogeneity of variances (Levene's test). Fisher's LSD (Least Significant Difference) test was used for pairwise comparison by using STATISTICA software package (Statsoft, 2004). All the statistical analyses were considered at significance level of 5% ($P<0.05$).

Results

L. sceleratus was sampled from 61 of the 116 hauls at the depths between 25 and 150 m, but it was absent at 200 m. The frequency of occurrence (F%) was 56.48% at the depths between 25 and 150 m (Figure 2, 3). The overall mean abundance and biomass were 136.21 ind./km^2 and 15.73 kg/km^2, respectively (Table 1). *L. sceleratus* was encountered in all seasons and locations. The differences of abundance and biomass among seasons were statistically significant (Table 2). The mean abundance, biomass, and F% were the highest in winter and the lowest in summer (Table 1). According to the results of the Fisher's LSD test for pairwise comparison performed after one-way ANOVA, seasonal differences was only significant between winter and the other seasons ($P<0.05$).

Mean abundance was the highest at 25 m, and biomass and F% at 50 m depth (Table 1). There was no difference of abundance and biomass among depth levels (Table 2).

The highest mean abundance and biomass was found in loc. C and the lowest in loc. B (Table 1). The difference in abundance was significant among locations and especially in between the eastern locations (locs. A and B) and loc. C. There was no difference of biomass among locations (Table 2). The variation of total length (cm) according to locations and depth levels is presented in Figure 4 and the length frequency distribution in Figure 5. The total lengths (TL) of 811 specimens ranged from 11 to 50

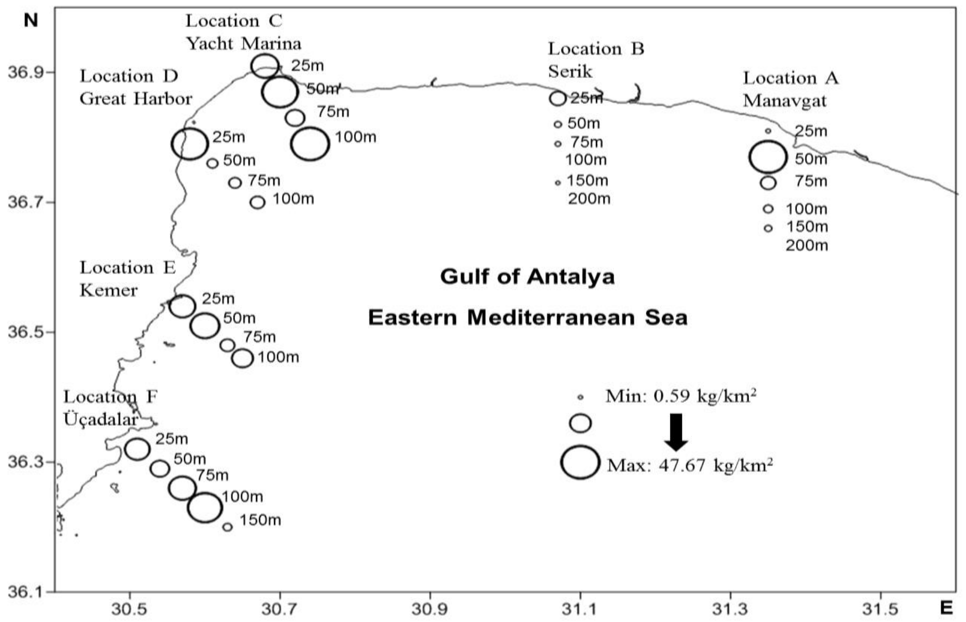

Figure 2. The mean biomass (kg/km^2) of *L. sceleratus* caught in the Gulf of Antalya according to locations and depth levels (average of four seasons).

cm, and the mean TL was calculated as 19.99 cm. The mean TL and the mean biomass per abundance (W/N) were the highest in summer and the lowest in winter (Table 1). While the main effects of season and location as well as the interactions between them were significant sources of variation in TL, there was no difference among depth levels (Table 3). The mean TL was the highest at 150 m and the lowest at 25 m depth (Table 1). According to the results of the Fisher's LSD test for pairwise comparison, the seasonal variation in TL (P<0.05) was only between summer and the other seasons. The mean TL was the highest in loc. A and the lowest in loc. D (Table 1).

Discussion

L. sceleratus has become a dominant species in many parts of the eastern Mediterranean Sea and is

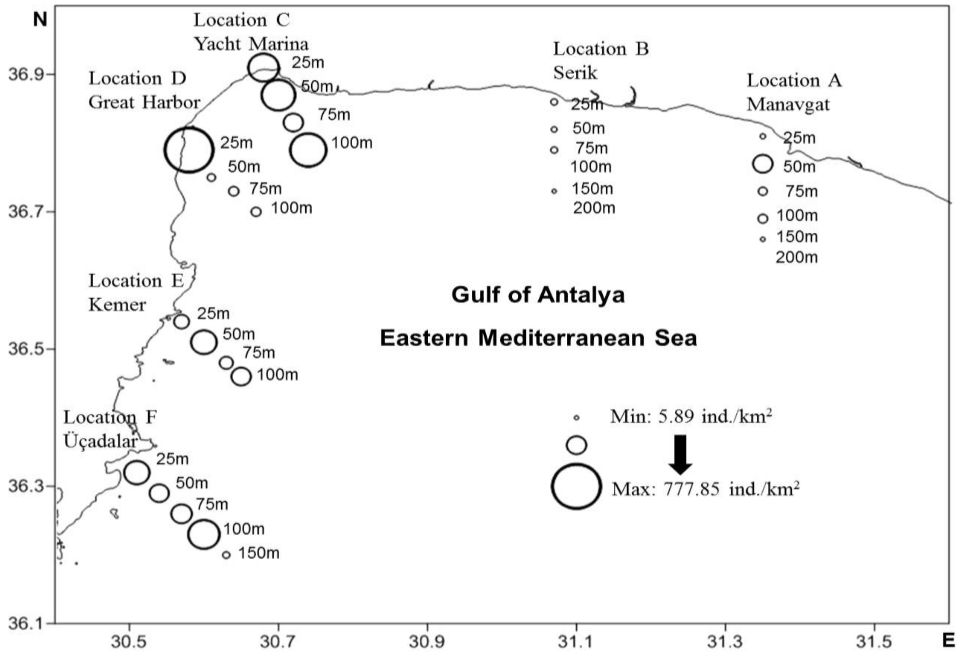

Figure 3. The mean abundance (ind./km^2) of *L. sceleratus* caught in the Gulf of Antalya according to locations and depth levels (average of four seasons).

Table 1. The mean abundance (ind./km^2) and biomass (kg/km^2) of *L. sceleratus* caught in the Gulf of Antalya according to seasons, locations and depth levels (Mean abundance (ind./km^2(±se)), percentage of total sum of individuals (ind.%), mean biomass (kg/km^2(±se)), percentage of total sum of biomass (bio.%), mean biomass/mean abundance in grams (W/N), the number of individuals (N), total length (TL))

Season	No. of hauls	ind./km^2 (±se)	ind.%	kg/km^2 (±se)	bio.%	F%	W/N	N	TL Mean	TL Min	TL Max.
Summer	27	22.69±6.89	4.2	5.80±1.96	9.2	40.74	255.78	32	28.73	11.5	40.0
Autumn	27	43.58±13.49	8.0	6.92±2.36	11.0	59.26	158.72	74	20.70	11.0	50.0
Winter	27	404.07±115.60	74.2	42.76±8.75	67.9	85.19	105.81	567	19.47	13.0	50.0
Spring	27	74.48±40.18	13.7	7.45±3.76	11.8	40.74	100.02	138	19.72	12.0	49.5
Location											
A	20	39.90±19.76	5.4	11.69±6.11	13.8	50	293.07	49	26.79	11.0	50.0
B	20	9.58±3.87	1.3	2.37±1.65	2.8	30	247.24	10	24.30	16.0	50.0
C	16	312.86±129.30	34.0	31.75±11.39	29.9	62.5	101.49	226	20.36	13.5	42.0
D	16	216.31±158.57	23.5	14.53±6.67	13.7	62.5	67.19	178	16.63	12.0	43.0
E	16	121.46±50.38	13.2	17.91±6.64	16.9	68.75	147.44	127	21.26	14.5	49.5
F	20	165.52±59.74	22.5	19.53±7.36	23.0	70	118.00	221	19.88	11.0	47.0
Depth(m)											
25	24	234.50±115.31	38.3	20.00±6.55	28.3	58.33	85.31	279	17.77	11.0	50.0
50	24	147.31±58.41	24.0	22.16±7.32	31.3	70.83	150.44	231	21.37	12.0	49.0
75	24	67.55±26.47	11.0	9.45±4.26	13.3	50.00	139.90	104	21.16	11.0	50.0
100	24	158.68±75.31	25.9	18.38±7.16	26.0	54.17	115.80	190	20.73	14.5	43.0
150	12	9.79±4.86	0.8	1.60±0.79	1.1	41.67	163.59	7	25.07	18.0	29.0
Total	108	136.21±33.92	100.0	15.73±2.89	100.0	56.48	115.50	811	19.99	11.0	50.0

Table 2. Results of PERMANOVA for abundance (individuals per km^2) and biomass (kg per km^2) with seasons, locations and depth levels as fixed factors: bold number shows that P-value is less than 0.05 (df: degrees of freedom, SS: sum of squares, MS: mean square, F: F-value, P (perm): calculated probability value; number of iterations = 1000)

		Abundance				Biomass			
Source	df	SS	MS	F	P (perm)	SS	MS	F	P (perm)
Season	3	93,609	31,203	7,5674	0,001	246,07	82,023	4,2432	0,009
Location	5	65,577	13,115	3,1808	0,016	186,98	37,395	1,9345	0,111
Depth	5	38,131	7,6262	1,8495	0,12	173,69	34,738	1,797	0,128
Seas. x Loc.	15	43,718	2,9145	0,70683	0,752	140,89	9,3927	0,48589	0,93
Seas. x Depth	15	43,653	2,9102	0,70578	0,777	205,22	13,682	0,70776	0,773
Loc. x Depth	18	89,445	4,9692	1,2051	0,294	346,7	19,261	0,9964	0,478
Residual	54	222,66	4,1233			1043,9	19,331		
Total	115	690,3				2629,1			

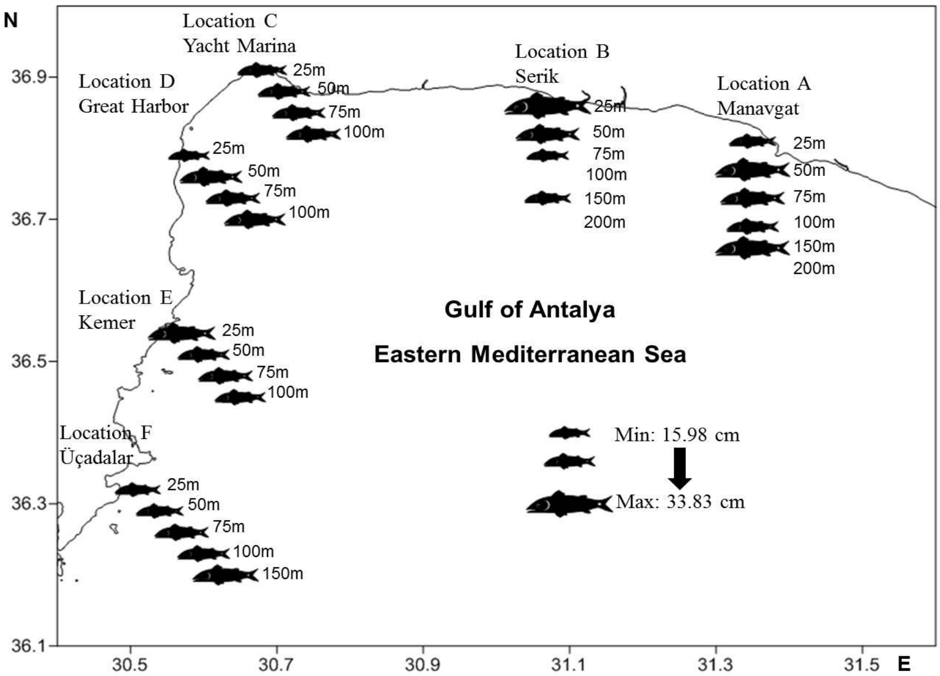

Figure 4. The mean length (cm) of *L. sceleratus* caught in the Gulf of Antalya according to locations and depth levels (average of four seasons).

characterized as an invasive species and included in the list of the 100 "worst invasives" in the Mediterranean (Streftaris & Zenetos, 2006). The reasons for its success was summarized by Michailidis (2010) as fast growth, early reproduction, high adaptation, no fishing pressure, absence of predators or competitors, and opportunistic behaviour. Like in many other coastal areas of the Mediterranean Sea, *L. sceleratus* has a significant negative impact on the artisanal fisheries in the Turkish Mediterranean coasts (Ünal *et al.*, 2015), since it causes serious damages to the fishing gears and loss in the catch, and eventually reducing fishers' income significantly.

The landing statistics of *L. sceleratus* is only available from Cyprus in the Mediterranean Sea. Between the years of 2010 and 2013, the average annual landing of this species was reported as 31.5 tonnes (FAO, 2013). The presence and CPUE values of *L. sceleratus* in trawl hauls were previously reported from Mersin (Gücü, 2012), İskenderun (Başusta, Başusta, & Özer, 2013; Yemişken, Dalyan, & Eryılmaz, 2014), Antalya and Muğla (Bilecenoğlu, 2016) in Turkey. The studies reporting the CPUE/CPUA values of *L. sceleratus* in trawl hauls compared to the present results are given in Table 4. For comparison, the overall average abundance and biomass of *L. sceleratus* were calculated according to the CPUA (ind./km^2; kg/km^2) and CPUE (ind./h; kg/h) for each and overall depth levels.

The abundance, biomass and size structure of *L. sceleratus* varied seasonally and spatially in the Gulf of Antalya. Lower values reported by Bilecenoğlu (2016) from the Gulf of Antalya could be related to the difference in location of the sampling areas. The present study covers both "trawl zones" and "no-trawl zones", however the study area of Bilecenoğlu (2016)

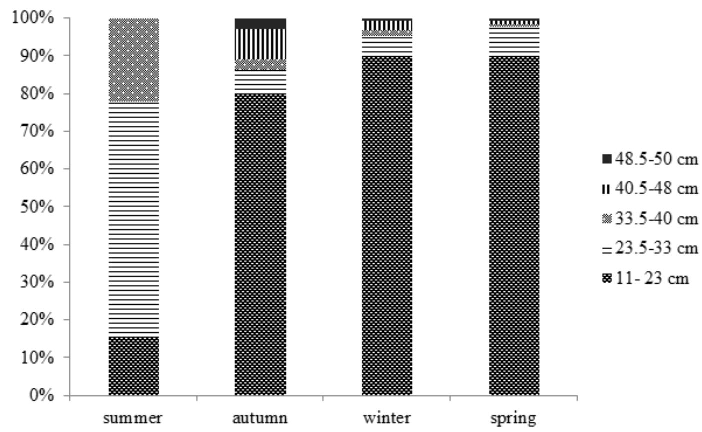

Figure 5. Length-frequency distribution of *L. sceleratus* caught in the Gulf of Antalya in four seasons.

Table 3. Results of 3-way ANOVA testing effect of season, location and depth level on total length of *L. sceleratus* (df: degrees of freedom, SS: type III sum of squares, MS: mean square, F: F-value, bold number shows that P-value is less than 0.05)

Source	df	SS	MS	*F*	*P*
Season	3	10.343	3.448	5.182	0.002
Location	5	13.102	2.620	3.939	0.002
Depth	4	2.915	0.729	1.095	0.358
Season * Location	14	38.007	2.715	4.081	0.000
Season * Depth	10	22.431	2.243	3.372	0.000
Location * Depth	15	43.451	2.897	4.354	0.000
Season * Location * Depth	8	9.518	1.190	1.788	0.076
Error	750	498.966	0.665		

Table 4. Comparison of the mean abundance and biomass of *L. sceleratus* to the previous studies (CPUA= Catch per Unit Trawling Area (ind./km^2, kg/km^2); CPUE= Catch per Unit Trawling Effort (ind./time, kg/time))

Location	Date	Depth (m)	CPUA-CPUE	Source
Average of monthly hauls in Mersin - Turkey	May 2007-March 2010	0-25	0.47 kg/h	Gücü (2012)
Average of monthly hauls in Mersin - Turkey	May 2007-March 2010	25-50	0.091 kg/h	Gücü (2012)
Average of monthly hauls in Mersin - Turkey	May 2007-March 2010	50-100	0.192 kg/h	Gücü (2012)
Single haul in Gulf of Antalya - Turkey	Oct.–Nov. 2011	9-46.3	0.9 kg/h	Bilecenoğlu (2016)
Single haul in Finike, Antalya - Turkey	Oct.–Nov. 2011	9-46.3	0.4 kg/h	Bilecenoğlu (2016)
Single haul in Dalaman, Muğla - Turkey	Oct.–Nov. 2011	9-46.3	2.1 kg/h	Bilecenoğlu (2016)
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	25	234.50 ind/km^2-20.00 kg/km^2 22.85 ind/h-2.06 kg/h	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	50	147.31 ind/km^2-22.16 kg/km^2 14.16 ind/h-2.23 kg/h	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	75	67.55 ind/km^2-9.45 kg/km^2 4.74 ind/h-0.71 kg/h	Present Study
Average of 24 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	100	158.68 ind/km^2-18.38 kg/km^2 10.46 ind/h-1.13 kg/h	Present Study
Average of 12 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	150	9.79 ind/km^2-1.60 kg/km^2 0.64 ind/h-0.10 kg/h	Present Study
Average of 108 hauls in Gulf of Antalya - Turkey	Aug. 2009- April 2010	25-150	136.21 ind/km^2-15.73 kg/km^2 11.67 ind/h-1.37 kg/h	Present Study

covers only the trawl zone in the eastern part of the gulf. The values seem to be similar when compared with the mean CPUE values of the locs. A and B (1.1 kg/h and 0.2 kg/h, respectively). Thus the difference can be interpreted as the fishing pressure on the population of the species in the “trawl zones” of the Gulf of Antalya.

In this study, the spatial distribution of *L. sceleratus* was found to vary among the locations in the Gulf of Antalya. The possible fishing effect can be seen in loc. B with the lowest mean abundance, biomass and frequency of occurrence values. However, larger individuals were found to occur in loc. A and especially in the shallow waters of loc. B. All sorts of trawling have been prohibited in loc. A since 2005. Slightly higher abundance and biomass in loc. A compared to loc. B, which is the main commercial trawl area of the Gulf, may be interpreted as the recovery of the “no-trawl zone”. Similar distribution patterns were also previously reported in the Gulf of Antalya (Özgür Özbek, Kebapçıoğlu, & Çardak, 2013; Özgür Özbek, Çardak, & Kebapçıoğlu, 2015; 2016). Due to the wide and shallow coastal plain along the eastern part of the Gulf of Antalya, the area is very suitable for the trawl fishery. However, outside 2 NM off the coast, there are still many areas shallower than 50 m depth and covered by *Posidonia oceanica* (Linnaeus) Delile, 1813 beds. The highest abundance, represented by small individuals was sampled from 25 m depth and larger individuals were found at 150 m depth; however, the biomass and frequency of occurrence were highest at 50 m depth. Kalogirou (2013) also investigated the habitat use by different life-stages of *L. sceleratus* and reported the importance of the sandy areas for the early life stages and *P. oceanica* habitats for larger, reproductive adults. He interpreted this habitat shift was possibly related to the increased demand in prey availability and requirement for appropriate spawning ground with increased size. In the eastern locations (locs. A and B), the salinity is lower comparing to the west due to three main streams and Manavgat River reaching the sea. Larger individuals in the eastern part could also be related to the sufficient resourcesnear the river mouths. The mean abundance and biomass of *L. sceleratus* were highest inside the Gulf (locs. C and D) where are closed zones for trawl. Although the depth levels of 75, 100 m of loc. E and 75, 100, 150 m of loc. F were located outside 2 NM off the coast due to the limited trawl area, the commercial trawlers generally do not prefer these regions for trawl. However, both locations are mostly preferred for small-scale fisheries.

Kara, Lamine, and Francour (2015) summarized the chronology of documented records (location of capture, date, number and length of the specimens, depth) of *L. sceleratus* in the Mediterranean. The present study reports the highest number of individuals sampled in the Mediterranean Sea; however, the maximum TL in this study is well below the maximum values of the previous studies. Also, it is the widest depth range of *L. sceleratus* from 25 to 150 m and the deepest record of the species in the Mediterranean Sea.

Previous studies reported that spawning of *L. sceleratus* in Eastern Mediterranean takes place mainly in early summer with a peak in June (Michailidis, 2010; Aydın, 2011; Yıldırım, 2011). Regarding this information, the bigger fish found in summer and the increase in the percentage of small fish in autumn could be corresponding to the new recruitment of fish probably that were born in early summer. Kalogirou (2013) also mentioned the larger reproductive individuals in summer and increased fish abundance in autumn. The exponentially higher values of the mean abundance, biomass, and frequency of occurrence in winter comparing to other seasons could be related to the increasing catchability of fish in winter due to the decreasing sea temperature. There are at present a total of 384 Lessepsian migrants in the Mediterranean Sea (Galil, Marchini, & Occhipinti-Ambrogi, 2016), and this proves that changes have occurred in the ecosystem. Long-term approaches are required to monitor the exotics in proportion to local species as well as determine the seasonal and spatial distribution and status of the populations of alien species.

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