

RESEARCH ARTICLE

ARAŞTIRMA MAKALESİ

By-catch and monetary loss of pufferfish in Turkey, the Eastern Mediterranean

Doğu Akdeniz, Türkiye’de balon balıklarının hedef dışı avı ve parasal zararları

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Abstract: Non-native pufferfish have been a part of the Mediterranean marine ecosystem since the 1930s. However, there is a lack of knowledge regarding the by-catch of these species. This study aimed to compare the by-catch of pufferfish species between different types of fishing gear and to determine the monetary losses due to pufferfish on the Aegean (west) and Mediterranean (south) coasts of Turkey. A total of 467 commercial and recreational fishers (n= 244 and n=223 respectively), based in the 7 coastal cities were interviewed in the period of June - December 2017. A semi-structured questionnaire provided detailed information on by-catch amount of pufferfish in fishing gears, and economic loss caused by pufferfish. The most commonly caught pufferfish species was *Lagocephalus sceleratus*. The by-catch amount of pufferfish is higher on the Mediterranean coast in comparison with the Aegean coast. The highest pufferfish by-catch was recorded in purse seines and trawls on the south coasts, but in set nets on the west coasts. When seasonal changes were considered, the highest by-catch was occurred in the summer months for both commercial and recreational fisheries. Regarding the damages caused by pufferfish species in the small-scale fisheries, 92% and 90% of fishers, who fished on the south coasts, claimed that pufferfish species damage their fishing gears and fish entangled to these fishing gears, respectively. In conclusion, pufferfish species (e.g. *L. sceleratus*) are part of the ecosystem with their unknown quantified impacts. In fact, such information is required for fisheries management to mitigate the impacts of these species. The present study contributes to filling the gaps in this area.

Keywords: Pufferfish, *Lagocephalus sceleratus*, by-catch, local ecological knowledge, monetary loss, Mediterranean Sea

Öz: Yerli olmayan balon balıkları 1930’lu yıllardan beri Akdeniz ekosisteminin bir parçası olmasına rağmen bu türlerin hedef dışı avı konusu ile ilgili bilgi eksikliği söz konusudur. Bu çalışma, Türkiye’nin Ege ve Akdeniz kıyılarında balon balıklarının farklı av araçlarındaki hedef dışı avını kıyaslamayı ve balon balıklarından kaynaklanan parasal zararları tespit etmeyi amaçlamıştır. Çalışma kapsamında, Haziran-Aralık 2017 periyodunda 7 kıyı ilinde, toplam 467 ticari ve amatör balıkçı (n= 244 ve n= 223 sırasıyla) ile görüşülmüştür. Yarı yapılandırılmış anket, balon balıklarının av araçlarındaki hedef dışı av miktarı ve balıkçılıkta sebep oldukları parasal zararlar hakkında detaylı bilgi sağlamıştır. Av araçlarında yakalanan en yaygın balon balığı türü *Lagocephalus sceleratus* olarak tespit edilmiştir. Akdeniz kıyısındaki hedef dışı av miktarı Ege kıyısına nazaran daha yüksek bulunmuştur. En yüksek hedef dışı av miktarı, güney kıyılarında gırgır ve trollerden kaydedilirken, batı kıyılarında uzatma ağlarında tespit edilmiştir. Mevsimsel değişimler dikkate alındığında, hem ticari hem de amatör balıkçılıkta en yüksek hedef dışı av yaz aylarında gözlemlenmiştir. Güney kıyılarında avlanan küçük ölçekli balıkçıların % 92’si balon balıklarının av araçlarında hasara sebep olduğunu belirtmiş ve ayrıca balıkçıların %90’ı, bu türlerin yakaladıkları hedef ava da zarar verdiklerini rapor etmişlerdir. Sonuç olarak, balon balığı türleri (örn. *L. sceleratus*), bilinmeyen etkileri ile ekosistemin bir parçasıdır. Bu türlerin etkilerini azaltmak için balıkçılık yönetiminde bazı bilgilere ihtiyaç duyulmaktadır. Mevcut çalışma, bu alandaki boşlukları doldurmaya katkı koymaktadır.

Anahtar kelimeler: Balon balıkları, *Lagocephalus sceleratus*, hedef dışı av, lokal ekolojik bilgi, parasal zarar, Akdeniz

INTRODUCTION

Since the opening of the Suez Canal in 1869, the ecosystem of Mediterranean Sea has been exposed to non-indigenous species (NIS) which are called "Lessepsian" and the rates of immigrations of fish species have increased over several decades (Por, 1964; Kalogirou, 2013). Lessepsian species exhibit both ecological and socio-economic impacts (Kosker et al., 2016). More specifically, some species cause problems for both commercial and recreational fishers; damage through to fishing gears and the target catch (Katikou et al., 2009; Nader et al., 2012; Ünal et al., 2015). Moreover, these species reduce the local stocks of commercial species through the predation (Kalogirou, 2013). Some Lessepsians, such as pufferfish are also dangerous for human and animal consumption (Chamandi et al., 2009; Beköz et al., 2013).

Tetrodontidae family members are commonly known as pufferfish, balloon fish, toad fish or globe fish

and the aforementioned family includes 190 species worldwide (Hastings et al., 2014). To date, although Bilecenoğlu et al. (2014) reported a total of 7 pufferfish species in Turkish waters, according to Turan et al. (2017) 8 pufferfish species have been recorded. This difference is related to the identification of *L. spadiceus* and *L. guentheri*. Vella et al. (2017) suggested that *L. spadiceus* and *L. guentheri* may be the same species and more research needed for the correct taxonomic identification. Table 1 shows the list of pufferfish species have been recorded in Turkish waters, along with details of initial confirmed record data and location where available. The pufferfish, *Lagocephalus sceleratus* was first recorded in Turkish waters in February 2003 in Gökova Bay (Akyol et al., 2005) and was listed within the 100 Invasive Alien Species (IAS) in the Mediterranean Sea because of the presence of tetrodotoxin, a source of food poisoning (Streftaris and Zenetos, 2006; Kalogirou, 2013).

Table 1. Pufferfish species that were first reported in Turkish waters

Species name	Initial Record		
	Year	Location	References
✓ <i>Lagocephalus guentheri</i> (Miranda Ribeiro, 1915)	1949	İskenderun	Kosswig, 1950
✓ <i>Lagocephalus lagocephalus</i> (Linnaeus, 1758)	NA	NA	Aksiray, 1987
✓ <i>Lagocephalus suezensis</i> (Clark and Gohar, 1953)	1998	Mersin	Avşar and Çiçek, 1999
✓ <i>Sphoeroides pachygaster</i> (Müller and Troschel, 1848)	1999	Saros	Eryılmaz et al., 2003
✓ <i>Torquigener flavimaculosus</i> (Hardy and Randall, 1983)	2002	Fethiye	Bilecenoğlu, 2005
✓ <i>Lagocephalus sceleratus</i> (Gmelin, 1789)	2003	Gökova	Akyol et al., 2005
✓ <i>Tylerius spinosissimus</i> (Regan, 1908)	2010	İskenderun	Turan and Yağlıoğlu, 2011

By-catch can be defined as the incidental capture of non-target individuals in fishing gear and it consists of under sized individuals of the target species and all size classes of non-target species that have no commercial value (Kelleher, 2005; Soykan et al., 2008; Kaiser et al., 2011; Öndes et al., 2017a). By-catch can decrease the overall catch of target species and cause damage to fishing gear and the target catch (Kalogirou, 2013; Briceno et al., 2015). Little is documented about the by-catch of Lessepsian species, such as pufferfish (Yemişken et al., 2014; Çiçek and Avşar, 2015; Bilecenoğlu, 2016). The importance of monitoring by-catch species has increased based on the implementation of the Common Fishery Policy (CFP) of the European Commission (EP, 2015). To date, assessment of by-catch has been based on several data sources; fishery dependent data (FDD) (government statistics and logbooks etc.), fishery independent data (FID) (observer data), local ecological knowledge (LEK) and traditional ecological knowledge (TEK).

The LEK is a useful data source to understand the

population ecology of species and to estimate the impact of human activities on ecosystems (Posey and Balick, 2006; Macdonald et al., 2014). In addition the catch characteristics of fish and invertebrates, by-catch issues are evaluated based on the LEK (Leite and Gasalla, 2013; Dawe and Schneider, 2014; Öndes et al., 2017a, b). The aforementioned data source has some advantages in comparison with the FID and FDD. For instance, fishery independent surveys are expensive sampling methods, while LEK is an inexpensive data source and it provides reliable data for the large localities via short terms surveys. It should be noted that LEK is also an important source of information on the distribution and abundance of Lessepsian species overtime (Azzurro et al., 2011; Deidun et al., 2015). Additionally, the data related to the economic losses to fisheries as a result of Lessepsian species is generally estimated using the questionnaire studies (Ünal et al., 2015; Ünal and Göncüoğlu-Bodur, 2017).

Previous studies on pufferfish in Turkish waters were related to the original confirmed records,

distribution (Akyol and Ünal, 2017), toxicity (Acar et al., 2017) reproductive biology (Aydın, 2011; Çek-Yalınz et al., 2017) and feeding ecology (Aydın, 2011; Irmak, 2012). However, the economic impacts of pufferfish on the fisheries have been little studied to date (Ünal et al., 2015; Ünal and Göncüoğlu-Bodur, 2017). There has been no comprehensive study on by-catch issues of this group in Turkey. Consequently, the first objective of the present study was to compare the estimated by-catch amounts of pufferfish in different fishing gears. We also aimed to evaluate ecological knowledge on body size, seasonal and spatial by-catch estimations of pufferfish species as the second objective of the study. The last but not the least objective was to see the trend of the monetary losses caused by pufferfish for fishers compare to the previous values in the same area.

MATERIALS AND METHODS

A total of 244 commercial and 223 recreational fishers, in the seven coastal cities along the Aegean and Mediterranean coastlines of Turkey (Figure 1), were interviewed in the period of June to December 2017.

We had the interviews with the recreational anglers and commercial fishers included longliners, set netters, purse seiners and trawlers. Small scale fisheries were generally performed in shallow waters with boats smaller than 12 m in length with the main target species generally are the sparids, red mullets and octopus, which are also diets of pufferfish (Irmak, 2012; Kalogirou, 2013). Large scale fisheries included purse seiners and trawlers that generally target sardine and anchovy or shrimps and red mullets respectively.

A semi-structured questionnaire provided information on the bio-ecological characteristics,

by-catch amounts and socio-economic impacts of pufferfish species in recreational, small scale and large-scale fisheries in different locations. The survey was conducted in four parts.

The first part gathered the data related to the general characteristics of fishing (the annual days at sea, number of hooks for each operation of longlines, used daily net length for set nets, the averaged operation time for trawls and purse seines).

The second part was related to the local ecological knowledge. In this part, we asked questions to fishers for the identification of pufferfish species (questionnaires included the photos of pufferfish species which distributed Turkish waters and aforementioned photos were shown to fishers for identification). It was aimed to assess information on the comparison of fishing gears (fishing rod, set net, longline, purse seine, and trawl) in terms of estimated by-catch amounts of pufferfish species. In order to understand estimated by-catch amounts in different fishing gears, we asked this question; how many pufferfish did you catch in 2016? Moreover, the seasonal and spatial trends on pufferfish by-catch amounts were investigated. In order to understand the seasonal differences related to pufferfish by-catch, we asked followed question to small scale fishers (longliners and set netter) and recreational fishers, who fish all months during the year, which season have you encountered with the highest pufferfish by-catch? Regarding the spatial differences in the pufferfish by-catch, we compared two sub-area (Mediterranean Sea (south coast) including Hatay, Adana, Mersin and Antalya, and Aegean Sea (west coast) including İzmir, Aydın and Muğla. Other questions were aimed to assess information on;

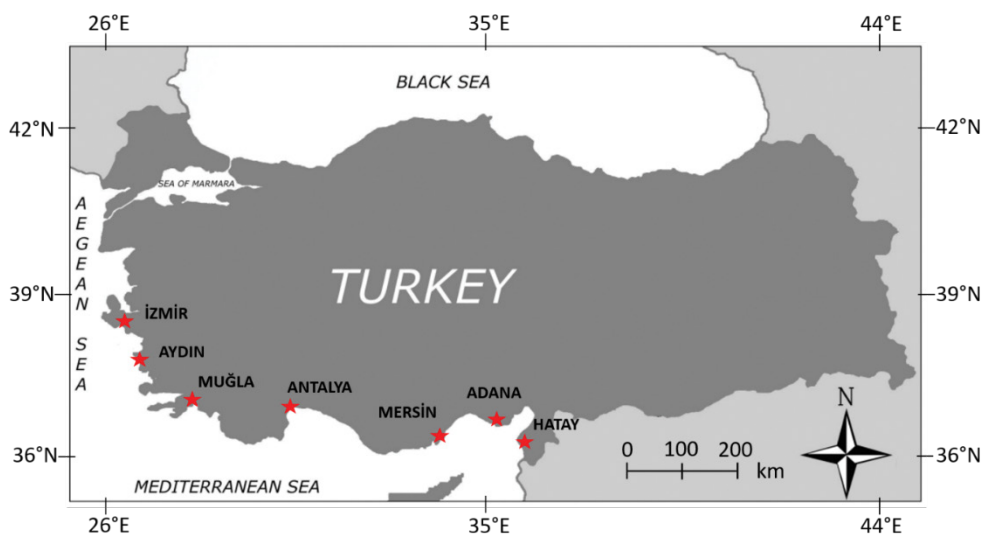


Figure 1. Map of the sampling areas (İzmir, Aydın, Muğla, Antalya, Mersin, Adana, and Hatay)

- a) the mean body length (\pm SD) of caught pufferfish in different fishing gears,
 b) their habitats in terms of depth and substrates.

Third part of the questionnaire dealt with the awareness of the fishers regarding the poisonous status of pufferfish. We aimed to understand whether fishers consume them or not. Other question was aimed to understand what fishers do in case of the caught of pufferfish.

The last part of the survey was evaluating the economic loss related to damaging fishing gears and target catch were estimated based on respondents' declarations to the relevant questions. Similarly, spatial differences related to the economic loss were investigated. It was also aimed to understand whether fishers fish the pufferfish as a target species in the future. We asked the following questions; Can you catch pufferfish, if you would have been paid 5 TL (1TL = 3.3€ in 2016) for each pufferfish specimen? If yes, how many individual can you fish a year? In addition, to estimate the total mean value of the damage related to pufferfish in Turkey, the small scale fishers' numbers of sampling areas (Figure 1) were obtained from TUIK data (TUIK, 2018).

In this study a total of 5 pufferfish species were reported by fishers. For all statistical analyses, graphs and tables, we combined all species because some fishers had a difficulty to identify species. However, it is noted here that 66% of the pufferfish mentioned by fishers (both commercial and recreational) is *L. sceleratus*.

Statistical analyses were performed with the SPSS software (Version 20). The data were tested for normality and homogeneity of variance using a Kolmogorov-Smirnov test and Levene's test, respectively. Dependent on the results of aforementioned tests, parametric or non-parametric tests were performed subsequently. To compare the pufferfish by-catch in different types of fishing gear, Kruskal Wallis test was performed. Similarly, Kruskal Wallis test was performed to understand whether the mean body size was different dependent on fishing gear types (1-fishing rod, 2- set net and onglime, 3- trawl and

purse seine). Mann-Whitney U-test was used to compare spatial patterns in pufferfish by-catch between south and west coasts.

RESULTS

The mean number of hooks used per day on longlines was calculated as 725 ± 400 and the mean net length per each operation of set nets was $2,893 \pm 1,661$ m. The mean daily operation time per trawl and purse seine was estimated as 15 ± 2 and 13 ± 3 hrs respectively. 93% of the commercial fishers interviewed spent 100 to 300 working days at sea a year and the mean value of annual working day was calculated as 161 ± 57 . Estimated annual days at sea of interviewed recreational fishers varied between 5 and 300 days, with 32% fishing for 100 to 300 days a year and the mean was 80 ± 69 days a year.

Respondents identified a total of 5 pufferfish species. These species were *Lagocephalus sceleratus*, *Lagocephalus suezensis*, *Lagocephalus guentheri*, *Sphoeroides pachygaster* and *Torquigener flavimaculosus*. Just 2 pufferfish species were identified on the west coast; *L. sceleratus* and *L. guentheri*. However, all 5 were reported from the south coast. Interviews suggested that the most commonly caught pufferfish species was *L. sceleratus* on both west coast (98%) and south coast (46%).

There was no statistically significant difference in the estimated by-catch amounts (year 2016) between types of fishing gears ($P = 0.165$, Chi-square = 6.49, $df = 4$). The highest pufferfish by-catch was recorded in purse seines and trawls around the south coasts (Table 2). However, there are significant differences in Mediterranean (south) and Aegean (west) coasts in all different fishing gears within the commercial fisheries (Table 2). Similarly, there was a significant spatial difference in by-catch amounts of recreational fisheries between coasts (Table 2). For both commercial and recreational fisheries, the estimated pufferfish by-catch was higher on the south coast than the west coast. When seasonal differences in the by-catch were considered, both recreational and small scale commercial fishers indicated that the highest pufferfish by-catch occurred in summer (Figure 2).

Table 2. Mean catch amount (boat/year) \pm SD (all species; *Lagocephalus sceleratus*, *Lagocephalus suezensis*, *Lagocephalus guentheri*, *Sphoeroides pachygaster* and *Torquigener flavimaculosus*) in different fishing gears

Fishing Gear	Sample Size (n)		Mean Catch Amount (boat/year)		Mann Whitney U-test	
	West C. (n)	South C. (n)	South C.	West C.	U Value	P
Purse seine	10	11	946 ± 1128	6 ± 5	66.000	<0.001
Trawl	36	25	619 ± 1356	4 ± 5	32.000	<0.001
Set net	34	47	360 ± 462	30 ± 111	86.500	<0.001
Longline	28	45	276 ± 261	4 ± 9	11.500	<0.001
Fishing rod	138	85	252 ± 518	3 ± 7	484.000	<0.001

*Purse seine, trawl, set net, and longline are the commercial fishing gears, whilst fishing rod represents the recreational fisheries in this study. South coast includes the cities of Antalya, Mersin, Adana and Hatay while west coast includes the cities of İzmir, Aydın, and Muğla.

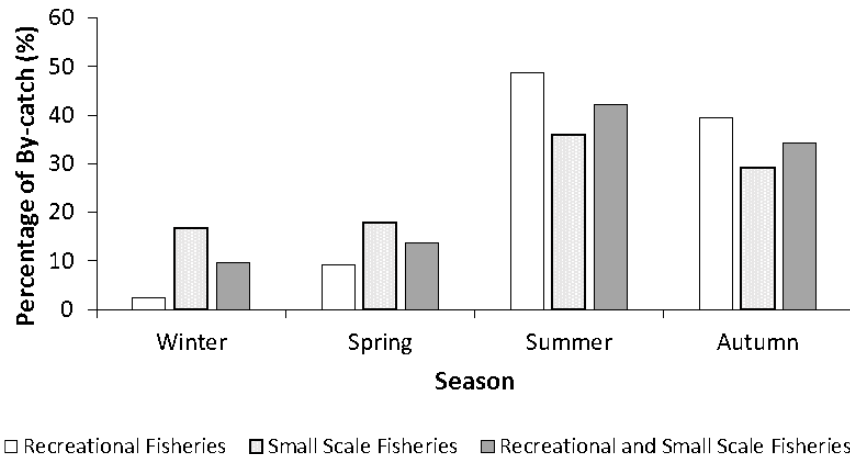


Figure 2. The highest pufferfish by-catch in different seasons for recreational and commercial fisheries

Reported pufferfish body size in by-catch varied between 5 to 85 cm and the common size class was determined as 11-20 cm. The mean body length of pufferfish was calculated as 26 ± 13 cm based on the fishers' declaration. The results show that anglers,

longliners and set netters caught smaller pufferfish in comparison with trawlers and purse seiners (Figure 3). There was a statistically significant difference in body size of pufferfish caught in different fishing gears ($P < 0.001$, Chi-square = 21.76, df = 2).

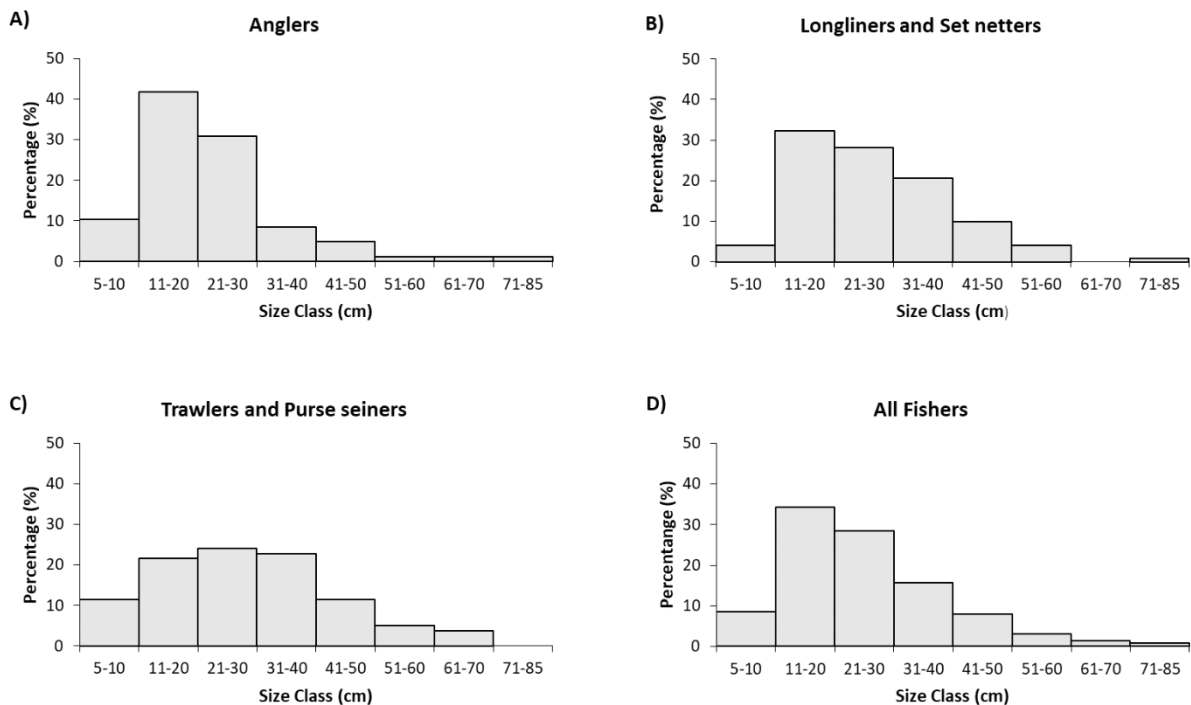


Figure 3. Percentage (%) of body size estimations of pufferfish species caught by A) anglers, B) longliners and set netters, C) trawlers and purse seiners, D) all fishers

Pufferfish species were reported from depths of 2m to 115m. Fishers reported that pufferfish species inhabit various habitats including sand, mud, rock, mixed stone, gravel and seagrass meadows. However, they were not able to identify the most preferred habitat of pufferfish.

On the south coast, 57 % of commercial fishers declared that pufferfish were very negatively affecting their fishing activity, whereas on the west coast only 9 %

of commercial fishers were very negatively influenced. In particular, longliners and set netters were the most impacted fishers by pufferfish (Table 3). Additionally, all longliners and 70% of set netters on the south coast stated that pufferfish in their fishing gears impacted the catch productivity, whilst 48% of longliners and 22% of set netters on the west coast declared that their catch productivity was impacted by pufferfish (Figure 4a, 4b). Similar ratios related to the catch composition were found in south and west coasts (Figure 5a, 5b).

Table 3. Fishers' declaration on pufferfish impacts

Area	Fishers	Sample Size (n)	Very Negative (%)	Negative (%)	Not (%)	Positive (%)	Very Positive (%)
South Coast	Recreational Fishers (Anglers)	136	65	21	14	0	0
	Longliners	31	97	3	0	0	0
	Set netters	36	75	19	6	0	0
	Trawlers	35	17	34	49	0	0
	Purse seiners	10	10	0	90	0	0
	All commercial fishers	112	57	18	25	0	0
West Coast	Recreational Fishers (Anglers)	85	13	39	48	0	0
	Longliners	30	13	23	63	0	0
	Set netters	37	11	16	73	0	0
	Trawlers	21	0	0	100	0	0
	Purse seiners	11	0	0	100	0	0
	All commercial fishers	100	9	13	72	0	0

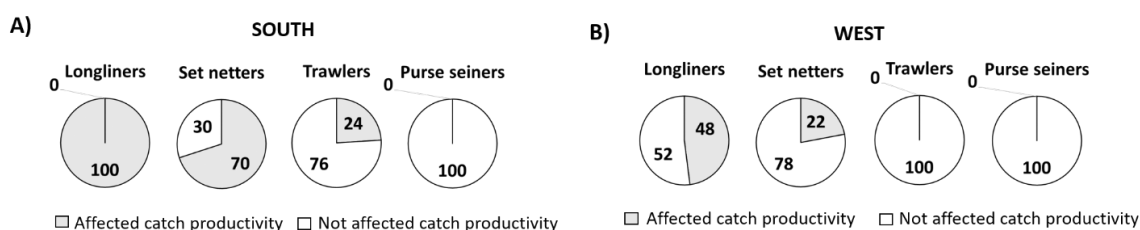


Figure 4. Affected and unaffected catch productivity (%) for different fishers: A) South Coast, B) West Coast

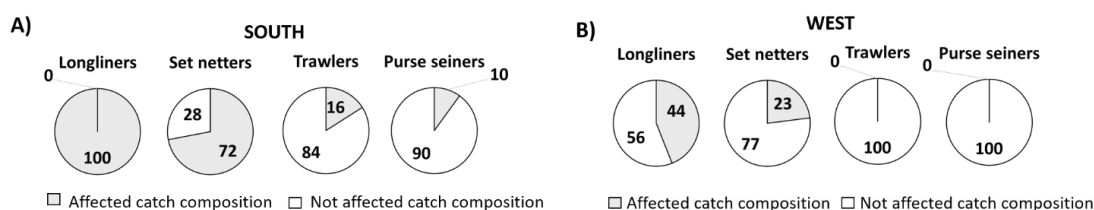


Figure 5. Affected and unaffected catch composition (%) for different fishers: A) South Coast, B) West Coast

On the south coast, 94% and 90% of small scale commercial fishers (longliners and set netters) claimed that pufferfish species damage their fishing gears and fish entangled to these fishing gears, respectively. On the other hand, on the west coast, 30% and 26% of commercial fishers claimed that pufferfish species damage their fishing gears and fish entangled to these fishing gears, respectively. For the small scale fisheries, the average loss originated by pufferfish in 2016 for

longliners was 2,929.00 TL/vessel (approx. 888 Euro) and for set netters was 3,352.90 TL/vessel (approx. 1,016 Euro). The average loss originated by pufferfish in 2016 in both set net and longline (alternately) was 3,070.60 TL/vessel (approx. 931 Euro). Estimates provided in this study were 113% and 20% higher than the reported losses in 2011-2012 and 2013-2014 respectively (Table 4).

Table 4. Annual monetary loss (TL) in fishing gear

Gear Type	Annual monetary loss (TL)		
	Mean \pm SD		
	Ünal et al, 2015 2011-2012 Value	Ünal and Göncüoğlu- Bodur, 2017 2013-2014 Value	Present Study 2016 Value
Longline	942,4 \pm 1,007.7	2,336.1 \pm 2,087.9	2,929.4 \pm 2,026.0
Set net	1,346.9 \pm 1,415.0	2,820.6 \pm 3,393.4	3,352.9 \pm 4,311.8
Longline and set net (alternately)	1,440.6 \pm 900,7	2,559.6 \pm 2,781	3,070.6 \pm 2,949.4

Table 5 shows the annual monetary loss related to the damaged target fish. The small scale fishers interviewed of 59% reported that monetary losses due to pufferfish by-catch and the study area includes 7 cities and 5,373 fishing boats which include set nets

and longlines. It was estimated that a total of 3,170 fishers in the sampling areas might have monetary loss. Thus, the total mean value of the damage related to pufferfish was calculated at 14,825,225 TL (\approx 4,507,644 EUR) per year.

Table 5. Annual monetary loss (TL) in damaged target catch

Gear Type	Annual monetary loss (TL)		
	Mean \pm SD		
	Ünal et al, 2015 2011-2012 Value	Ünal and Göncüoğlu- Bodur, 2017 2013-2014 Value	Present Study 2016 Value
Longline	NA	NA	2,460.0 \pm 1,742.3
Set net	NA	NA	3,410.0 \pm 4,431.1
Longline and set net (alternately)	NA	NA	2,776.7 \pm 2,907.5

76% of the small scale fishers who fish on the south coast and 22% of the small scale fishers fish on the west coast indicated that they would be able to catch pufferfish if 5 TL was paid for each pufferfish specimen. These fishers predicted that if such an application started, they would be able to catch between 300 and 3,000 pufferfish/year.

When pufferfish toxicity awareness was considered commercial fishers had more information than the recreational fishers. According to the survey's results, 10% of recreational fishers and 7% of commercial fishers did not know that pufferfish are poisonous and are dangerous for human health. 14% of recreational

fishers and 21% of commercial fishers declared that they had consumed pufferfish at least one time. Only one commercial fisher stated that he had been poisoned as a result of pufferfish consumption.

In the case of pufferfish by-catch, 31% of commercial fishers returned pufferfish to the sea alive, whereas 67% of fishers killed them first and then returned them to the sea. Regarding the recreational fishery, 14% of fishers returned pufferfish to the sea alive, whereas 79% of fishers killed and returned them to the sea. Moreover, 3 fishers stated that they consumed them, whilst 8 fishers gave pufferfish to other people.

DISCUSSION

In the present study 2 pufferfish species (*L. sceleratus*, *L. guentheri*) were reported by fishers on the Aegean (west) coast, whilst 5 species were found on the Mediterranean (south) coast. Similarly, Irmak (2012) reported that the abundance of *L. sceleratus*, *L. guentheri* and *L. suezensis* decreased from south to north along the Turkish Coasts of Mediterranean Sea and Aegean Sea. Irmak (2012) also noticed that *T. flavimaculosus* and *T. spinosissimus* were rarely reported in the Mediterranean Sea. This may be related to the temperature tolerance of pufferfish, which generally distribute warm waters (Irmak, 2012). The mean annual water temperature of the Mediterranean Sea is warmer than the Aegean Sea (TUIK, 2013). In the current study the most commonly reported pufferfish species was *Lagocephalus sceleratus* in all fishing gears. Coro et al. (2018) evaluated the geographical distribution of *L. scelaratus* in the Mediterranean Basin and reported that the highest abundance of *L. scelaratus* was found in the Eastern Mediterranean. It was estimated that *L. scelaratus* currently represents 4% of the weight of the total artisanal catches (Nader et al., 2012; Coro et al., 2018). On the other hand, in Cyprus, as of 2012, the contribution of this species increased to about 50 % of total catches by weight (Ulman et al., 2015).

Little is known regarding the by-catch amounts of pufferfish. Previous studies have estimated the catch per unit effort (CPUE) of *L. sceleratus* in trawl hauls from Mediterranean coasts (Gücü, 2012; Başusta et al., 2013; Yemişken et al., 2014; Bilecenoğlu, 2016; Özbek et al., 2017), the Aegean coasts (Bilecenoğlu, 2016). The present study indicates that the pufferfish by-catch was highest in purse seine on the south coast, with the highest by-catch on the west coast reported in the set net. Interestingly, Ünal et al. (2015) reported that fishers believe the most suitable fishing gear to extirpate pufferfish is purse seine. By-catch amounts of pufferfish significantly different between fishing areas. For small scale, industrial and recreational fisheries the higher by-catch amounts were recorded on the south coast than the west coast. This is related to abundance of pufferfish in these two different regions. Coro et al. (2018) compared the geographical areas in the Mediterranean basin in terms of the geographical reachability for *L. sceleratus*. According to Coro et al. (2018), the geographical reachability distribution predicts medium-to-high probability of occurrence (0.4–0.6) in the Aegean Sea, whilst it predicts the highest probability (> 0.8) on the South coast of Turkey.

Moreover, the present study demonstrates the highest by-catch occurred in recreational and small scale fisheries (longlines and set nets) in summer months. This may be related to the metabolism of pufferfish, which are less active and exhibit limited

feeding activity when water temperatures decrease (Kalogirou, 2013).

The present study highlights that LEK is a valuable resource from which to estimate size distribution. The mean length of pufferfish was 26 ± 13 cm in the present study. From calliper measurements, Aydın (2011) determined the mean length as 27.3 ± 12.02 cm for males and 28.8 ± 13.35 cm for females of *L. sceleratus* collected around the Antalya Bay. Trawlers and purse seiners in the present study caught larger fish in comparison with the small scale and recreational fishers. The latter two groups generally fish in shallow waters, while purse seiners and trawlers fish in deeper areas. Hence, the body size distribution of pufferfish may be influenced by depth. Alternatively, older individuals may notice passive fishing gears and actively avoid them, whereas they may not escape from mobile fishing gears such as purse seine and trawls.

Previous reports suggest that *L. sceleratus* is commonly found in shallow and intermediate waters (0 to 50 m). They live in various habitats including sandy, rocky substrates and seagrass meadows (Rousou et al., 2014). Özbek et al. (2017) performed trawl operations at six depth levels (25, 50, 75, 100, 150, 200 m) around the Antalya Bay, and reported the highest abundance of *L. sceleratus* at 25m, with non-reported at 200m. From LEK it is suggested that pufferfish inhabit numerous substrates including sand, mud, rock, mixed stone, gravel and seagrass meadows and they were present at the depths between 2m to 115m.

The present study suggests that commercial fishers of the south coasts of Turkey are more affected in comparison to the fishers of the west coasts. In particular, set netters and longliners have economical loss due to both damaged fishing gears and smashed target catch due to pufferfish. Our study emphasizes that the estimated total annual monetary loss has increased markedly compare to Ünal et al. (2015) and reached almost the same value estimated for 2013–2014 by Ünal and Göncüoğlu-Bodur (2017). For the small scale fisheries, our study estimates the average loss originated by pufferfish in 2016 in longline was 2,929.0 TL/vessel (approx. 888 Euro) and in set net was 3,352.9 TL/vessel (approx. 1,016 Euro). However, results signified these species have not economically influenced the small scale fishery around the western coasts yet.

The pufferfish species are carnivorous and generally feed on crustaceans (shrimp, crab), mollusc (squids, octopus) and fish (Rousou et al., 2014). Pufferfish should also be considered a problem due to their damage to target species of the commercial fisheries. Our results show that for the small scale fisheries, the average loss originating from pufferfish to the target

specimens on longlines was 2,460.0 TL/vessel (approx. 746 Euro) in 2016 and on set net was 3,410.0TL/vessel (approx. 1,033 Euro).

Many fishers declared that the populations of pufferfish and other Lessepsians in the Mediterranean Sea have increased markedly for last several years (Tuset et al., 2012; Mavruk et al., 2017). This might be related to decreases in the stocks of native species (particularly predators), because many native species are influenced by overfishing and illegal fisheries (Irmak and Engin, 2015; Engin et al., 2016). When native species are overexploited, invasive species may fill their vacant niche. Pufferfish exhibit fast growth, early reproduction, and high adaptability. There is no fishing pressure, and an absence of natural predators or competitors (Michailidis, 2010; Özbek et al., 2017). Consequently, pufferfish populations are increasing in the Eastern Mediterranean.

These species are consumed by humans in some countries such as Japan (Cohen et al., 2009). However, *L. sceleratus* from the wild (marine capture) is not permitted for human consumption even in Japan (Arakawa et al., 2010; Nader et al., 2012). Therefore, in Japan, *L. sceleratus* is produced by aquaculture sector (Venmathi Maran et al., 2011). The present study suggests that 76% of small scale fishers from the Mediterranean region and 22% of small scale fishers from the Aegean region would target fish pufferfish, if the government regulations allowed it and there was a market value. This may be an effective method to overcome the pufferfish problem in Turkish small scale fishery. The landing statistics of *L. sceleratus* was only available from Cyprus in the Mediterranean Sea where the average annual landing of this species was reported as 31.5 tonnes for the period of 2010-2013 (Özbek et al., 2017).

Consumption of these species can result in human fatalities (Beköz et al., 2013), and this study highlights that Turkish fishers do not have enough information about the poisonous status of pufferfish. The consumption rate is higher in commercial fishers than

recreational fishers. Some fishers also give pufferfish to others for consumption. Fisheries legislation should contain more information about these poisonous species and their impacts on human health. Workshops for fishers may be beneficial.

CONCLUSION

The Common Fishery Policy (CFP) of the European Commission aims to increase the data collection of discard, by-catch and target catch (Öndes et al., 2017a), which is important for ecosystem based fisheries management. However, neither commercial nor the recreational fishers record target catch or by-catch data properly in Turkey. The present study contributes some way to filling the gap in knowledge of the by-catch of pufferfish by providing novel findings related to seasonal by-catch estimations in the small scale and recreational fishery. Another notable contribution of the study is to emphasize the increasing monetary loss caused by pufferfish by years. The annual monetary loss estimated in this study is about 4,507,644 Euro for 2016. This is higher than the losses reported for 2011-2012 (Ünal et al., 2015). The dramatic increase in monetary losses caused by pufferfish should influence future policy decisions.

In conclusion, considering the overall findings of the present study, it is suggested that fisheries management authorities initiate a detailed data collection system for not only target species but also by-catch species particularly those that create considerable socio-economic problems for fishers, marine ecosystem and public health. The magnitude of the problem must be quantified before practical management measures can be formulated and instigated mitigate the economic impacts or solve the problem.

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