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Estimation of CPUE and CPUA of pufferfish (Tetraodontidae) caught by the Bottom Trawl Fishery in the eastern Mediterranean Coasts

Cemal Turan*

Molecular Ecology and Fisheries Laboratory, Faculty of Marine Sciences and Technology, Iskenderun Technical University, 31220 Iskenderun, Hatay, Turkey

Abstract

Two indicators of pufferfish communities, catch per unit effort (CPUE) and catch per unit area (CPUA), were used with surveys of bottom trawl fishery to elucidate the level of the catch of each pufferfish species in the Mediterranean coasts of Turkey, comprising the Iskenderun Bay, Mersin Bay, and Antalya Bay. The surveys were conducted seasonally in 2019. The average rate of CPUE for *Lagocephalus sceleratus*, *L. suezensis*, *L. spadiceus*, and *Torquigener flavimaculosus* were 2.2, 0.8, 0.5, and 0.2 kg km^{-2}, respectively that the highest CPUE values were in winter (8.0 kg km^{-2}) for *L. sceleratus* and also lowest was in winter (0.08 kg km^{-2}) for *L. spadiceus.* The highest and lowest CPUE values were at the depth of 20-50 m (2.7 kg km^{-2}) for *L. sceleratus* and 50-80 m (0.08 kg km^{-2}) for *T. flavimaculosus*, respectively. The highest CPUE values (3.5 kg km^{-2}) were found at the sandy bottom for *L. sceleratus*, and the lowest one (0.01 kg km^{-2}) was at the hardy-ground for *T. flavimaculosus.* The average annual CPUA of pufferfish species at the Iskenderun, Mersin, and Antalya bays was estimated as 15.6, 28.4, and 6.81 kg, respectively, with a mean value of 17.3 kg/day/boat. In multiple correspondence analysis, *L. sceleratus* showed a great contribution to CPUE and CPUA data. However, *T. flavimaculosus* revealed contribution, especially in catch numbers which were positively affected by precipitation. *L. spadiceus*, *L. suezensis*, and *T. flavimaculosus* were positively affected by depth, temperature, month, season, and bottom structure.

Keywords:
Pufferfish, CPUE, CPUA, Mediterranean coast of Turkey

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Introduction

Pufferfishes classified as Tetraodontidae family comprise 28 genera and approximately 184 species commonly distributed in marine waters (Froese & Pauly, 2022). In Turkish marine waters, there is an increasing trend in the number of pufferfish and lessepsian species due to the opening of the

**Corresponding Author: Cemal TURAN, E-mail: cemal.turan@iste.edu.tr*

Suez Canal (Siokou et al., 2013; Yağlıoğlu et al., 2014; Doğdu et al., 2016; Turan et al., 2016; Stamouli et al., 2017; Dragičević et al., 2019; Turan and Doğdu, 2022), while eight species of Tetraodontids have been reported and two of which are native while the others are the Suez Canal invaders (Turan et al., 2018; Turan, 2020).

There are significant concerns about the direct consumption of Tetraodontids since they contain a strong neurotoxin, namely tetrodotoxin in their various tissues (Köşker et al., 2019). Therefore, the landing of pufferfishes is prohibited by Turkish and European fishery management authorities which reduces fishery pressure on pufferfishes and provides an advantage over native species, especially in the eastern Mediterranean ecosystem. Moreover, these species create some negative effects on the fisheries activities in the area coupled with social impact due to its poisoning effect (Ünal et al., 2015).

In fishery management, it is important to elucidate the size of pufferfish stocks for combating and incentive activities. A number of approaches to estimating the status of data-limited stocks have been developed, and data-limited assessment methods are increasingly being used for management purposes (Petrere et al., 2010; Turan, 2021; Ovando et al., 2021; Turan, 2022). The types of data and information utilized in a stock assessment can be diveded in two categories: Fishery-dependent data and fishery-independent data. The most common source of fishery-dependent data from commercial fisheries is catch-and-effort information, expressed as catch per unit effort (CPUE). Given the lack of detailed information about the true nature of the variables, CPUE is an assumed proxy for an index of fish stock abundance (Sparre & Venema, 1998; Maunder, 2001). Variations in catchability among different fishing vessels, gear, methods, and factors other than fish abundance are known to affect CPUE (Maunder et al., 2006; Petrere et al., 2010). The generalized linear models (GLMs) are commonly used to estimate coefficients of factors that influence CPUE (Hilborn & Walters 1992; Ye et al., 2001).

There has been no study on the spatial and temporal distribution of pufferfish species along the Mediterranean coast of Turkey, comprising the Iskenderun Bay, Mersin Bay, and Antalya Bay together. Thus, this study aimed to investigate the distribution and population dynamics of pufferfish species along the Turkish coast of the Mediterranean Sea by analyzing data on species composition, density, size, habitat and depth preference, and interactions in the Iskenderun, Mersin, and Antalya Bays.

Materials and Method

The data used for these analyses were collected during bottom trawl surveys from the Mediterranean coasts of Turkey, comprising the Iskenderun Bay, Mersin Bay, and Antalya Bay. The surveys were conducted seasonally between 2018 and 2019. Trawl hauls were conducted at a speed of 5.2 km/h (2.8 knots) for 70 minutes. Bottom contact and net dimensions were recorded throughout each trawl haul with net mensuration equipment. Trawl survey data were used only if trawl performance was satisfactory and if the distance fished, geographic position, average depth, and water temperature were recorded. Trawl hauls were deemed satisfactory if the net opening was within a predetermined normal range. Data from a total of 29 bottom trawl hauls from two depth stratum 20-50 and 51-100 m were used.

After each haul, all fish captured during a survey tow were sorted into species, counted, and measured for total length and weight. For assessing the status of pufferfish species, catch per unit of effort (CPUE) and catch per unit of area (CPUA) for all fish species were calculated by using the area swept computed from the net width at the wingtips for each tow multiplied by the distance towed recorded with global positioning systems. The abundance as CPUE_n (ind/km^2) and biomass as CPUE_kg and CPUA (kg/km^2) were estimated from the number (n) and weight (kg) of individuals using the swept area per haul method. The CPUE (kg/km^2) for each haul was calculated as follows:

CPUE = Cw/a

where *Cw* is the catch weight (kg), and a is the swept area (km^2). The swept area (a) or the 'effective path swept' for each hauling was estimated as follows:

a = D.h.x

where *h* is the length of the head-rope, and *D* is the cover of distance. *x* is the fraction of the headrope length which is equal to the width of the path swept by the trawl. The value of *x* varies from 0.4 to 0.66 (Spare & Veneme, 1992). A catchability coefficient, given by x = 0.4 (Bingel, 2002), was used. The Gulland equation was used to evaluate the CPUE index for each hauling operation (Gulland, 1983):

CPUE = Cw / t

Where *t* is net hauling time.

Analysis of variance test (ANOVA) was performed for statistical differences, and Spearman's correlation analysis was used to measure the degree of association between factors.

Multiple correspondence analyses (MCA) were applied to plot a matrix set of parameters of pufferfish species with a corresponding matrix of environmental parameters to cluster in geometric space to understand the relationships between species and ecological parameters.

Results

Distribution of CPUE and CPEA

In the present study, CPUE and CPUA values were evaluated both in terms of weight and number of caught species. CPUE values were calculated by collecting data from the catch operations in the sampling seasons. The average rate of CPUE for *Lagocephalus sceleratus*, *L. suezensis*, *L.*

spadiceus, and *Torquigener flavimaculosus* were 2.2, 0.8, 0.5, and 0.2 kg km^{-2}, respectively that the highest CPUE values were in winter (8.0 kg km^{-2}) for *L. sceleratus* and also lowest was in winter (0.08 kg km^{-2}) for *L. spadiceus* (Figure 1).

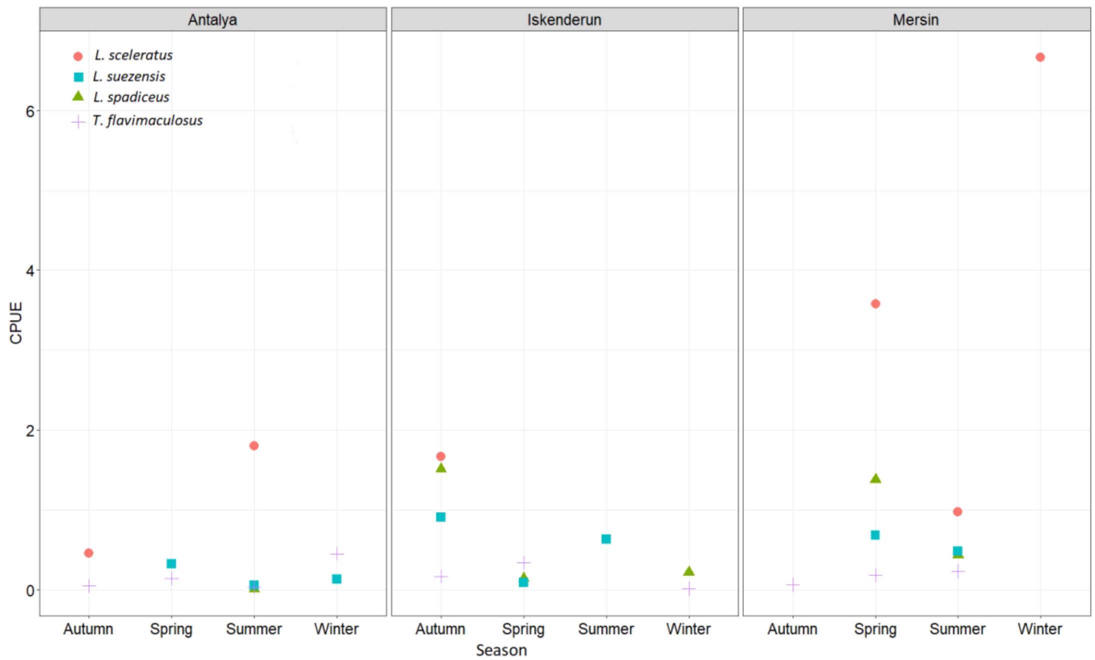

Figure 1. Seasonal distribution of CPUE values for pufferfish species

The highest and lowest CPUE values were at the depth of 20-50 m (2.7 kg km^{-2}) for *L. sceleratus* and 50-80 m (0.08 kg km^{-2}) for *T. flavimaculosus*, respectively (Figure 2).

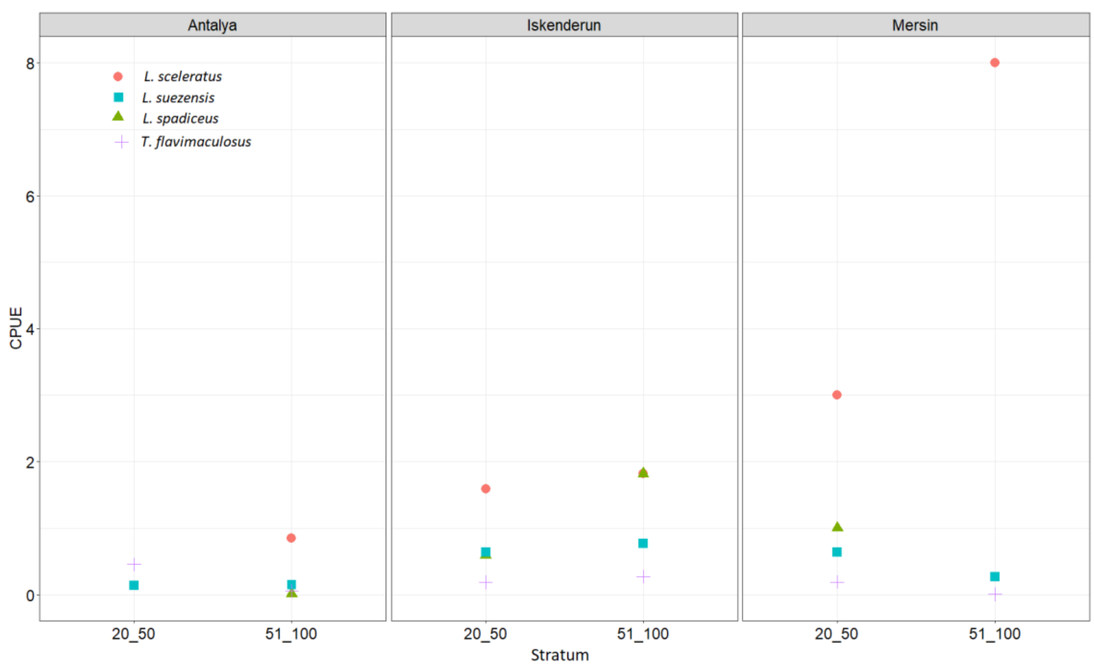

Figure 2. Distribution of CPUE values according to depth stratum for pufferfish species

Concerning trawled ground structure, the highest CPUE values (3.5 kg km^{-2}) were found at the sandy bottom for *L. sceleratus*, and the lowest one (0.01 kg km^{-2}) was at the hardy-ground for *T. flavimaculosus* (Figure 3).

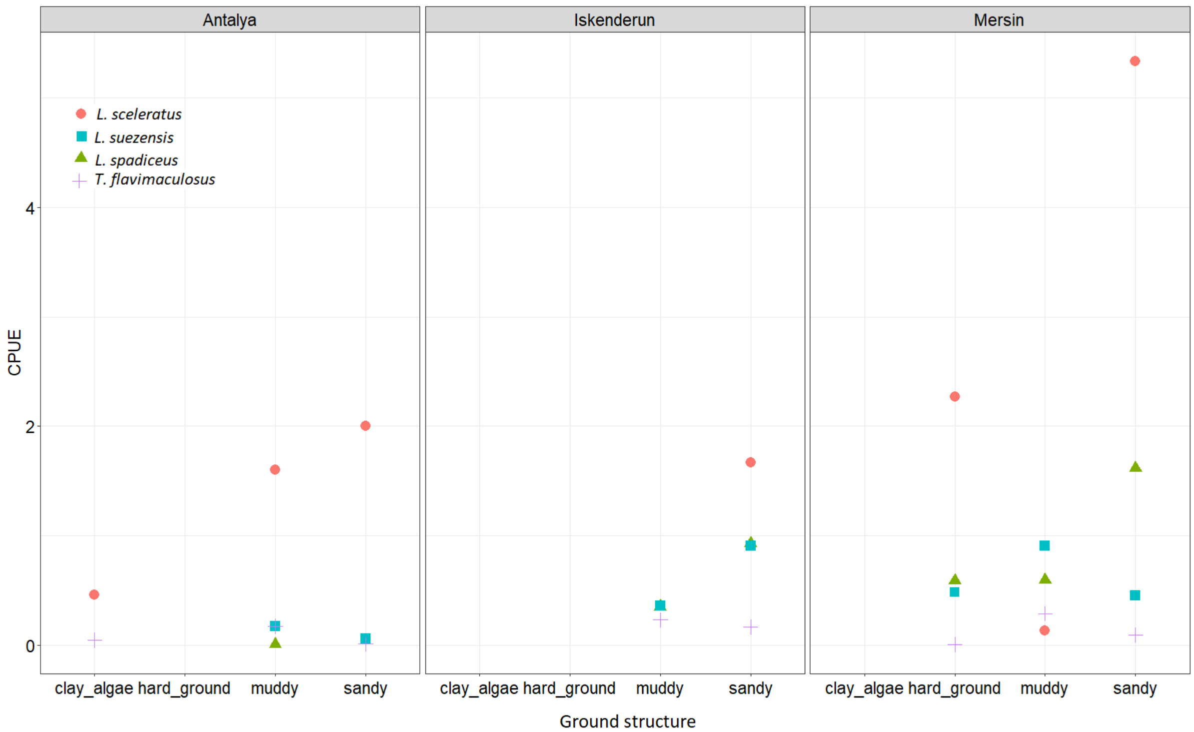

Figure 3. Distribution of CPUE values according to the ground structure for pufferfish species

Species Composition

The present pufferfishes were identified into four species, *Lagocephalus sceleratus*, *L. suezensis*, *L. spadiceus, and Torquigener flavimaculosus*; their catch composition about the region was estimated by number and weight according to the trawled samples. The dominant species were *L. sceleratus* by weight (69.8%) and *T. flavimaculosus* by number (54.8%), while the least abundant species were *T. flavimaculosus* (4.85% by weight) and *L. suezensis* (13.6% by number).

Mapping the CPUA of Pufferfish

The average annual CPUA of pufferfish species at the Iskenderun, Mersin, and Antalya bays was estimated as 15.6, 28.4, and 6.81 kg, respectively, with a mean value of 17.3 kg/day/boat. The distribution and abundance of four pufferfish species (*L. sceleratus*, *L. suezensis*, *L. spadiceus*, and *T. flavimaculosus*) are illustrated in Figure 4. The pufferfish species are more abundant in the Iskenderun Bay than in the other bays in the eastern Mediterranean.

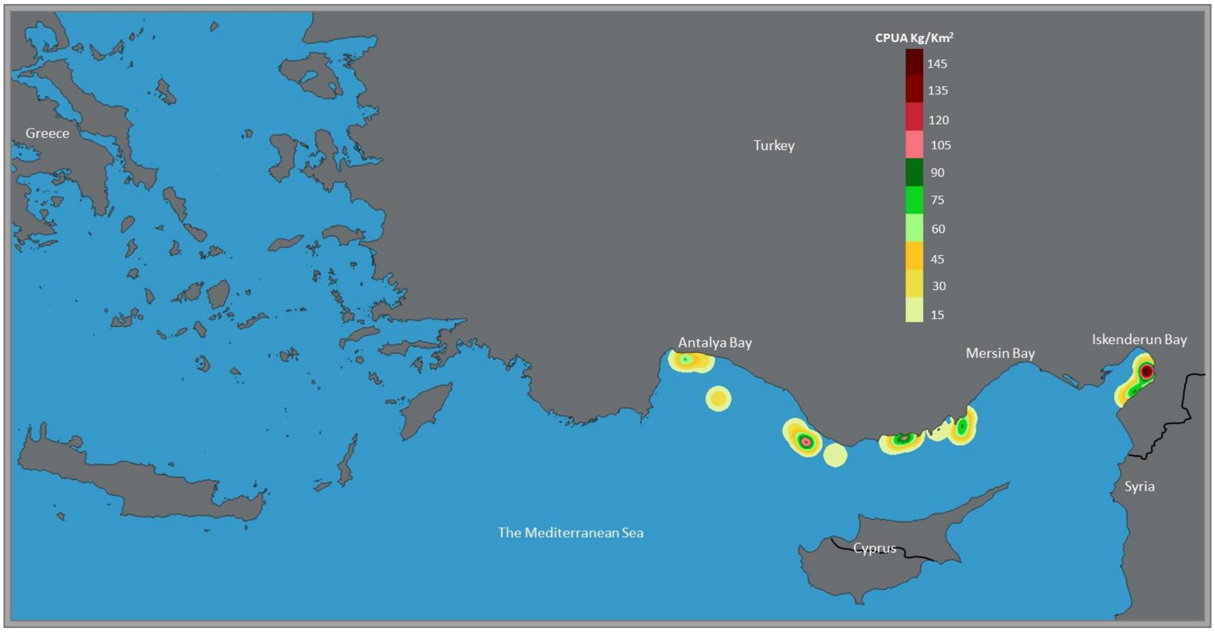

Figure 4. Distribution of CPUA of *L. sceleratus, L. spadiceus, L. suezensis, T. flavimaculosus* along the Mediterranean coast of Turkey comprising 29 trawling stations

During the fishing survey along the coast comprising 29 trawling stations, *L. sceleratus* was a more abundant species in the Antalya Bay along the eastern Mediterranean coast of Turkey. *L. spadiceus* and *L. suezensis* were especially more abundant in the Iskenderun Bay. *T. flavimaculosus* was abundant along the Mediterranean coast of Turkey (Figure 5).

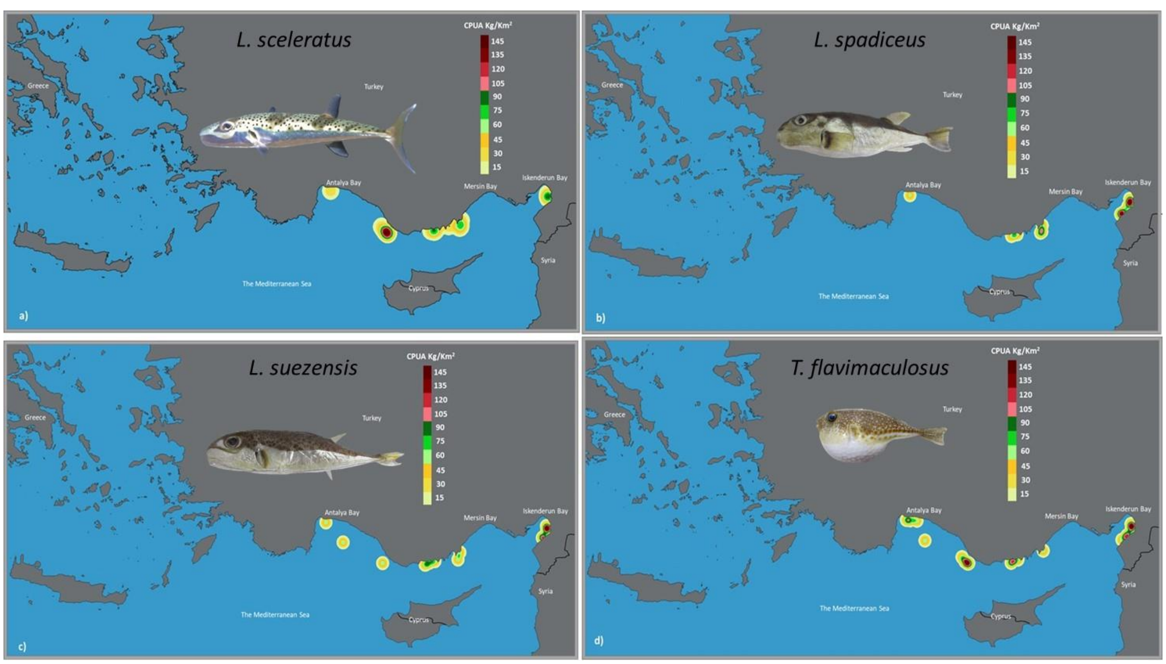

Figure 5. Distribution of CPUA of *L. sceleratus* (a), *L. spadiceus* (b), *L. suezensis* (c), *T. flavimaculosus* (d) along the Mediterranean coast of Turkey

Correlation of Occurrence

The relationship of CPUA values of four pufferfish species was tested with Spearman correlations to understand whether the abundance of each pufferfish species can be related to the occurrence of other pufferfish species. There was a highly significant positive correlation between the abundance of *L. spadiceus* and *L. suezensis* ($P < 0.001$) (Figure 6).

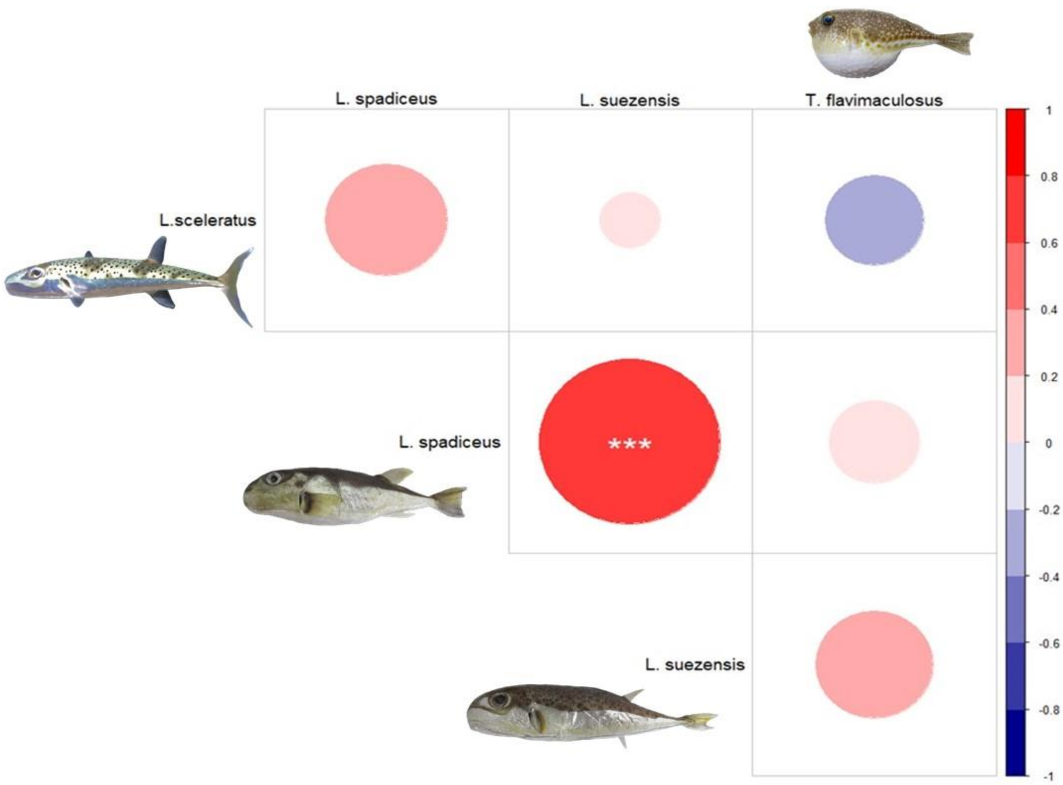

Figure 6. Correlations of CPUA of four pufferfish species. *** indicates significance levels at P < 0.001

Multiple Correspondence Analysis

In multiple correspondence analysis, plotting the first two dimensions revealed 54.21% of the total variation and indicated the relationships between species and ecological parameters. *L. sceleratus* showed a great contribution to CPUE and CPUA data. However, *T. flavimaculosus* revealed contribution, especially in catch numbers which were positively affected by precipitation (Figure 7). *L. spadiceus, L. suezensis*, and *T. flavimaculosus* were positively affected by depth, temperature, month, season, and bottom structure.

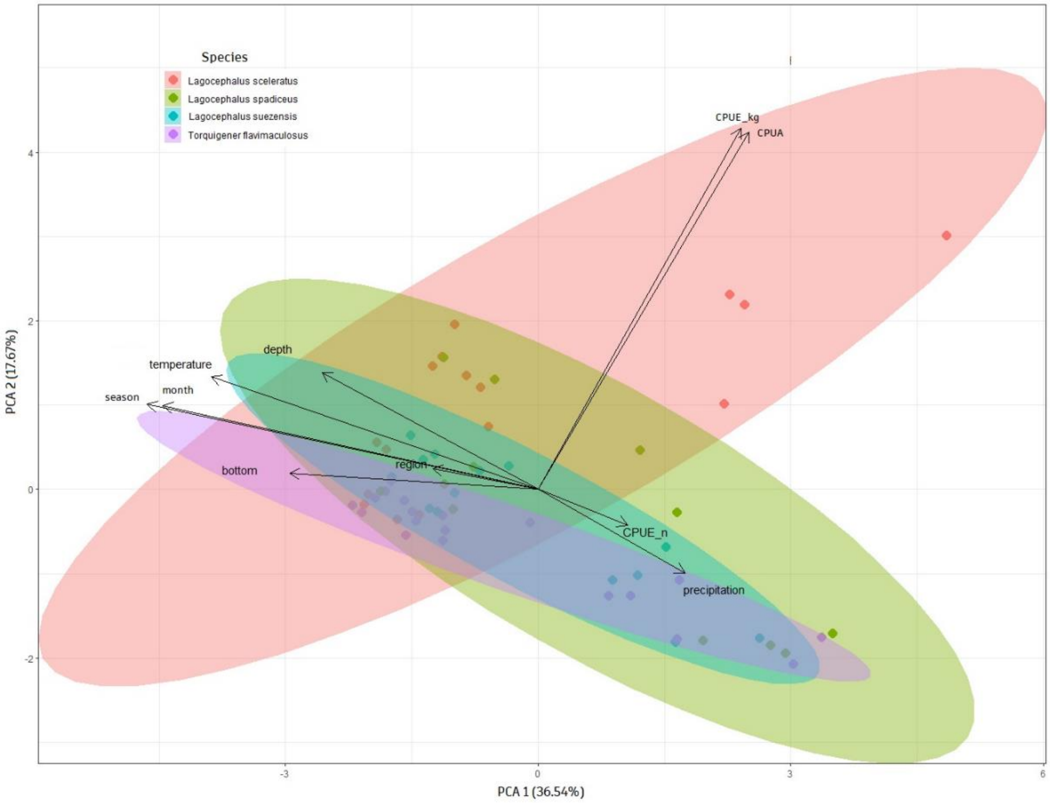

Figure 7. Plotting the first two dimensions of multiple correspondence analysis, showing the relationships between species and ecological parameters

Discussion

Catch per unit of effort (CPUE) and catch per unit area (CPUA) are the basic quantity to compute stock density in assessments, and these estimations are utilized to acquire other evaluations such as biomass approximations and abundance indices for essential commercial fish stocks (Haggarty & King 2006; Zeinali et al., 2017). Biomass and CPUA estimates are stock indices for the management of demersal resources (Sparre & Venema, 1998). During the fishing survey along the Mediterranean coast of Turkey, *L. sceleratus* was the most abundant species caught from different habitat types (sandy, hard-ground, muddy and clay-algae grounds at depths up to 20-100 m, but they were more abundant in sandy grounds in high depths (50-100 m). *L. spadiceus* and *L. suezensis* was caught from hard-ground, muddy and sandy grounds at depth up to 20-100 m, but they were more abundant in muddy and sandy grounds at high depths (50-100 m). *T. flavimaculosus* was caught from all grounds, depths, and seasons.

The dominant species in Turkish marine waters was *L. sceleratus* by CPUE and CPUA. Considering the distribution of CPUA along the Turkish coast, *L. sceleratus* was relatively more abundant in Antalya Bay (Gazipaşa-Side region), and *L. spadiceus*, *L. suezensis* were more abundant in Iskenderun Bay. *T. flavimaculosus* was distributed commonly along the Mediterranean coast of Turkey.

The relationship of CPUA was tested to understand whether the abundance of each pufferfish species can be related to the occurrence of other pufferfish species that a highly significant positive correlation between the abundance of *L. spadiceus* and *L. suezensis* ($P < 0.001$) was detected indicating that these two species may share the same habitat since they were caught together at a similar abundance (CPUA).

In multiple correspondence analysis, *L. sceleratus* showed a great contribution to CPUA and CPUA data, having no ecological effect. However, *T. flavimaculosus* revealed a high contribution in catch numbers which was negatively affected by precipitation. The depth, temperature, month, season, and bottom structure seem to be important for the abundance and distribution of *L. spadiceus*, *L. suezensis*, and *T. flavimaculosus*. Munro & Somerton (2002) stated that catch patterns for a trawl survey are dependent on the density of available fish, sampled volume by trawl, and trawl efficiency for a particular species. Catch rates, or catch per unit effort, for survey trawls have been shown to correlate with environmental variables such as salinity, temperature, near bottom light, and wave height and winds (Wieland et al., 2011).

In conclusion, catch per unit of effort and catch per unit area were calculated for pufferfish species along the Mediterranean coast of Turkey to compute stock density in assessments as biomass approximations and abundance indices for combating and incentive activities in fishery management. *L. sceleratus* was the dominant species by CPUE and CPUA, and *L. sceleratus* was relatively more abundant in the Antalya Bay (Gazipaşa-Side region), and *L. spadiceus*, *L. suezensis* were more abundant in the Iskenderun Bay. *T. flavimaculosus* was distributed commonly along the Mediterranean coast of Turkey.

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Author Contributions

The article applications, design and writing were done by CT.

Conflict of Interest

The author declares that no conflict of interest.

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