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RESEARCH PAPER

Recreational Fishing and Biodiversity in Mostaganem: Species Richness, Trophic Level, and Ecological Status of the Population Caught

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Abstract

The objective of this study is to evaluate the impact of recreational fishing on the marine ecosystem in the Mostaganem region, through the assessment of targeted and captured biodiversity, based on annual monitoring, using different statistical tools. The results show a wide range of species caught by boaters, with a total of 79 species belonging to 38 families and 24 orders, dominated by bony fish (86%).
Biodiversity varies seasonally, due to the opportunistic behavior of boaters in targeting species according to their availability in the fishing grounds by using different gears and techniques at different seasons of the year.
These boaters mainly target predators at high trophic level and high economic value, in order to maximize their income, which has negative effects on the top of the food chain, thereby creating a cascading effect on species at a lower trophic level. Thus, 12% of these species are classified as endangered or vulnerable, indicating considerable risks to fisheries resources and the marine ecosystem and its sustainability, suggesting effective management measures to ensure the sustainability of this recreational activity by minimizing environmental impacts.

Introduction

Recreational fishing has been a steadily increasing activity in recent decades, attracting more and more water sports enthusiasts. However, this activity can have a considerable impact on the marine ecosystem, causing a significant decline in biodiversity and fish abundance in fishing grounds, with potentially serious consequences for the marine environment (Côté *et al*., 2001; Cooke & Cowx, 2004, 2006; Lewin *et al*., 2006), by altering species community structure, geographic distribution, disrupting habitats, and altering the size and age of fish populations by increasing juvenile mortality, which can lead to highly variable annual recruitment of stocks (Hsieh *et al*., 2006).

This activity can thus affect non-target species, such as turtles, birds and marine mammals, through the use of non-selective fishing techniques, such as drift nets, which can cause significant damage to marine ecosystems by capturing non-target species as well as protected species (Michallet, 2007; Lewison *et al.,* 2014; Scales *et al.,* 2018). Nevertheless, this fishing activity is poorly studied and poorly regulated and controlled (Edgar, 2011) and often neglected in fisheries management, even though it accounted for more than 10% of total fishing catches in the Mediterranean (Morales-Nin *et al.,* 2005; Font *et al*., 2012). In Algeria, where fishing is an important activity, the so-called recreational fishing has not been studied a lot until now, especially its impact on marine biodiversity and coastal ecosystems.

The studies by Daoudi *et al*. (2023) and Babali *et al*. (2018) assess the contribution of recreational fishing to the local economy in the Algerian basin and report that this fishing activity is important for employment and income generation. It is noteworthy that here, under the designation of 'recreational' we are actually considering both fishing activities carried out with other than professional gear (e.g, boat-based angling, spearfishing) and which are not conducted for commercial or subsistence purposes (FAO, 2012) along with illegal, unreported and unregulated (IUU) fishing, which also includes the use of different types of artisanal fishing gear and boats, and which is carried out in many countries driven by economic imperatives of the population involved (Lamine *et al*., 2018).

Biodiversity is like an image that reflects the behavior of the ecosystem in the context of environmental fluctuations (Naeem & Li, 1997) and human pressure, presenting an indicator that measures the health of the ecosystem (Stamouli *et al*., 2018). This biodiversity is estimated using different indices such as the specific richness which is the number of species recorded, having the advantage of being simple to calculate.

In this context, we conducted this study which focuses on recreational fishing in the Mostaganem region, assessing the species caught and their seasonal variations, as well as their trophic level, and ecological status in order to assess the impact of recreational fishing on biodiversity and the marine ecosystem.

The study is part of a sustainable management of marine resources to ensure the conservation of marine biodiversity and the sustainability of the marine ecosystem.

Materials and Methods

Study Area

The coastline of Mostaganem extends over a distance of 124.5 km (Figure 1), from the mouth of the Macta in the west to Cape Negrawa in the east, with 9 stranding sites for boaters, including 3 ports: Sidi Lakhdar, Mostaganem and Salamandre.

The observations were conducted at four distinct sites, including a harbor (Salamandre), a fishing shelter (Stidia), and two landing beaches, one of which was developed (Sidi Medjedoube) and the other remaining in its natural state (Ben Abdelmalek Ramdane). These observations were mainly carried out at the Salamandre port, as it provided the opportunity to monitor various parameters related to recreational fishing activities. Indeed, fishermen gather on the quay to unload their catch, allowing for the surveillance of the fishing gear used, the species caught, and the quantities landed.

Data Collection

The data were collected from field trips during the years 2021 and 2022 at a rate of four to eight trips per month, of which we monitor the landings of boaters, and note all the species caught by identifying them on site or photographing or buying them for later identification. The type of fishing gear used is noted accordingly. A total of 73 field trips were conducted, of which we tracked 580 recreational landings, broken down by season as shown in Table 1.

We supplemented these data by determining the taxonomic classification of each species according to WoRMS (WoRMS Editorial Board, 2022), habitat (pelagic, benthic, demersal, bentho-pelagic and reef) and trophic level (trophic index) using the Fishbase platform (Froese & Pauly, 2022), as well as the classification and ecological status of these species according to the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2022).

From these data, we calculated the species composition and taxonomic diversity of the recreational catch by season, and classified these species according to their presence by season, their habitat and vertical distribution, their trophic level and ecological status using the hierarchical ascending classification (HAC), in order to better understand and visualize boating activity and its seasonal variations, by determining the species targeted and caught during the different seasons and to estimate its impact on the marine ecosystem and the food chain.

From the trophic index, we classified the species into the top predator (TP), medium predator (MP), low predator (LP), omnivore (OM) and herbivore (HE) according to Santini *et al*. 2014:

Trophic index ≥ 4.2: TP; trophic index [3.8 – 4.2]: MP; trophic index [2.8 – 3.8]: LP; trophic index [2.2 – 2.8]: OM; Trophic index < 2.2: HE.

Taxonomic Diversity

We analyzed the composition and taxonomic relationships between species caught by recreational fisheries using a taxonomic index called the Average taxonomic distinctness index Δ+.

This index is calculated from a taxonomic tree constructed on the basis of the phylogenetic classification of each species (Clarke & Warwick, 1998), considering seven taxonomic levels: species, genus, family, order, class, phylum and kingdom.

From this tree, a taxonomic distance ω_{ij} is quantified between each species pair and is equal to 100 for two species related at the highest taxonomic level (Clarke & Warwick, 1999).

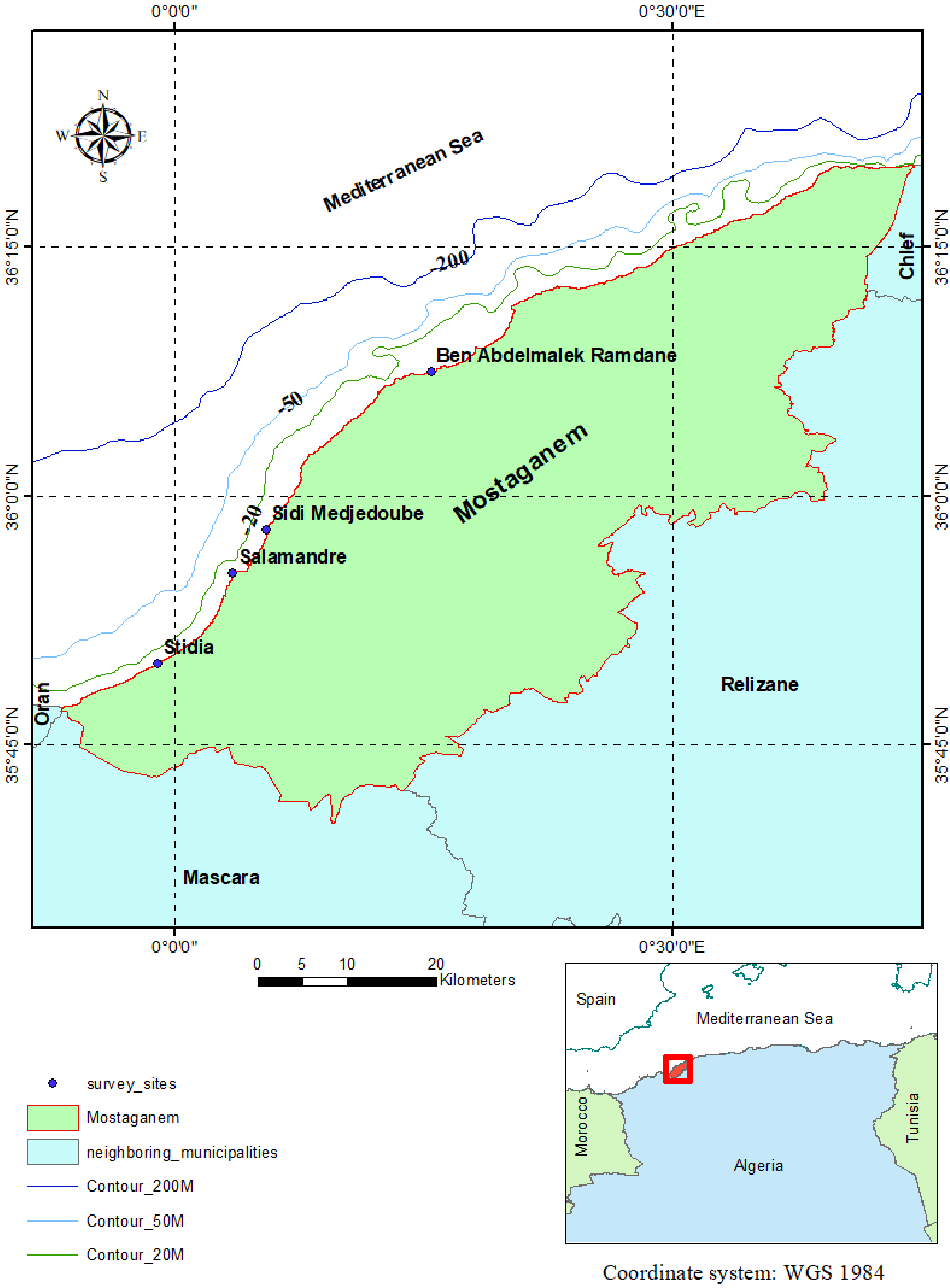

Figure 1. Map of the Mostaganem region

Table 1. Distribution of trips by season

Season	Winter	Spring	Summer	Autumn	Total
Days out	20	18	15	20	73
Recreational landings	124	127	100	229	580

The average taxonomic distinctness Δ+ is calculated by the formula (Clarke & Warwick, 1998):

$$\Delta^{+} = 2\frac{\sum\sum_{i<j}\omega ij}{S(S-1)}$$

Funnel test

In order to detect assemblages whose taxonomic diversity would be influenced by perturbations disturbances, Warwick & Clarke (1998) proposed the "funnel" test.

This test consists in comparing the taxonomic variety of a site to the area to which it belongs, from 1000 random draws of size m species made on the global list of S species listed in the area considered. In our case, we compare the taxonomic composition of each season to the overall annual composition.

Hierarchical Ascending Classification HAC

Hierarchical classification has been described by several authors including Daget (1976); Legendre & Legendre (1984, 1998); Dagnelie (1986); Herrera & Le Gac (2002) and Bouroche & Saporta (2005).

This multivariate analysis consists of partitioning the objects (or descriptors) of the study into groups and subgroups, through the condensation of the information provided, through the data matrix into a similarity or distance matrix. The latter is obtained by calculating a similarity/dissimilarity index or by measuring the distance between objects, depending on the type of initial data. Based on this distance matrix D, different classification algorithms can be used: Ward, single linkage, complete linkage, average linkage (UPGMA), providing different classification dendrograms, with different corresponding ultrametric matrices U. To select the classification algorithm that most accurately represents the similarity matrix D, Merigot *et al.* (2010) propose a measure based on a matrix norm, the 2-norm, which measures the goodness of fit between matrix D and U on the basis of the greatest singular value of the D - U matrix. The dendrogram selected is the one that provides the lowest value of the 2-norm.

We use the HAC to group all species caught by recreational fishing into subsets according to different criteria considered such as taxonomic classification and number of occurrences per season.

All these analysis were performed under the R software version 4.2.2 (R Core Team, 2022), using packages: cluster (Maechler *et al.,* 2022), factoextra (Kassambara & Mundt, 2020), FactoMineR (Lê *et al*., 2008), ggplot2 (Wickham, 2016) and vegan (Oksanen *et al*., 2022).

Results

Fishing Gears

Overall, six types of fishing gear have been identified in recreational fishing activities (*sensu lato*, see above) in the Mostaganem region. These include the drift gillnet (FMD), trammel net, bottom-set gillnet, longline, handline, and octopus traps. Among these gear types, the drift gillnets (FMD) are dominant, used by 68% of recreational fishermen, while trammel nets are used by 15% of them, and bottom-set gillnets by 12% (Figure 2).

The use of fishing gear varies significantly depending on the seasons (Figure 3), with an increase in the use of drift gillnet starting from summer and peaking in autumn, where 95% of recreational fishermen choose

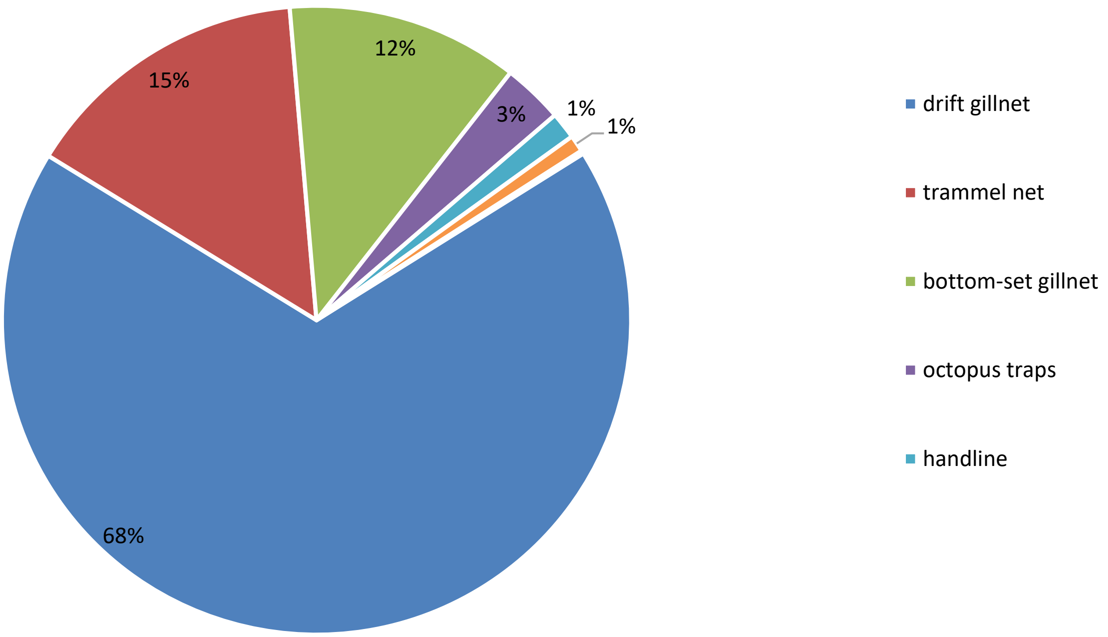

Figure 2. Fishing gear used by Mostaganem recreational boaters

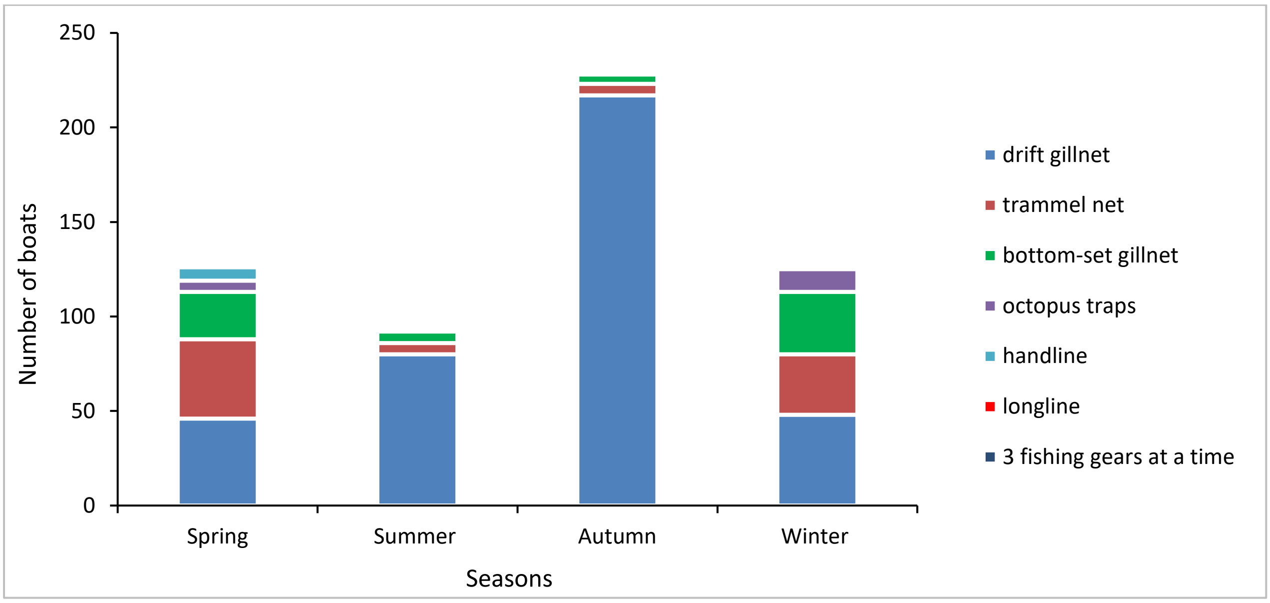

Figure 3. Distribution of fishing gear by season

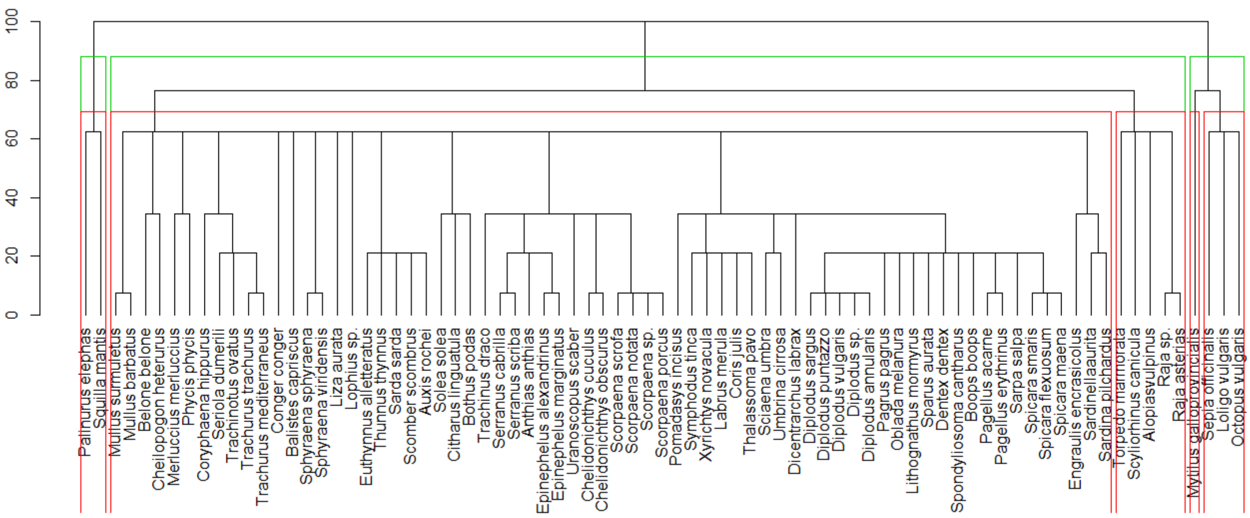

Figure 4. Hierarchical classification of species caught by recreational fisheries according to their phylogenetic classification

this gear to target pelagic species. During the winter and spring, recreational fishermen shift their focus towards demersal and benthic fishing using trammel nets and bottom-set gillnets, with 50% of them opting for one of these two gears during this period.

Species Richness

A total of 79 species have been identified in the landings of recreational fisheries in the Mostaganem region. These species belong to 3 phyla: chordates represented by bony and cartilaginous fish, arthropods by (crustaceans) and mollusks by (cephalopods and bivalves) (Figure 4). These species are grouped in 24 orders. The stand is divided according to inertia jumps, which show 5 fairly clear jumps at 3, 5, 24, 38 and 62, corresponding to the division of the population by phylum, class, order, family and genus respectively.

Bony fishes dominate the catches of boaters with 86% of the total number of species recorded, grouped into 14 orders and 28 families, of which sparids dominate with 25% of all Osteichthyes, represented by 10 genera and 18 species.

Chondrichthyans are represented by 5 species, namely (*Alopias vulpinus* (Bonnaterre, 1788), *Scyliorhinus canicula* (Linnaeus, 1758)*, Torpedo marmorata* Risso, 1810*, Raja asterias* Delaroche, 1809*, Raja sp.*), while 4 species of mollusks by 4 species were recorded (*Octopus vulgaris* Cuvier, 1797, *Loligo vulgaris* Lamarck, 1798, *Sepia officinalis* Linnaeus, 1758, *Mytilus galloprovincialis* Lamarck, 1819) and crustaceans by 2 species (*Palinurus elephas* (Fabricius, 1787) and *Squilla mantis* (Linnaeus, 1758)).

The species richness varies according to the seasons, of which we record a peak in spring with 70 species caught, against a minimum of species in autumn which is about 37 species recorded (Figure 5), of which bony fish dominate during the different seasons. From the number of species appearances per season, the HAC shows 14 species groups (Figure 6).

37 species appear in the recreational landings during 1 or 2 seasons in the year (groups 2 to 9), being species not targeted by recreational fishing and that have been fished accidentally, such as *S. mantis*, *A. vulpinus*, *T. marmorata*, *Balistes capriscus* Gmelin, 1788 or seasonal species that are present in fishing grounds periodically such as *Sardina pilchardus* (Walbaum, 1792), *Engraulis encrasicolus* (Linnaeus, 1758), *Sphyraena viridensis* Cuvier, 1829, *Coryphaena hippurus* Linnaeus, 1758, *Euthynnus alletteratus* (Rafinesque, 1810) and *Sarda sarda* (Bloch, 1793) or rare species in fishing areas, whose stocks are depleted such as *Epinephelus marginatus* (Lowe, 1833), *Sciaena umbra* Linnaeus, 1758, which are strongly attractive and vulnerable, and are considered as fish at risk in terms of numbers (Faure *et al*., 1999; Harmelin, 2013; Culioli, 2018), and *P. elephas*. Indeed, Marengo *et al*. (2020) state that common spiny lobster landings have been in decline since the 1960s, recording a 60% drop in commercial fisheries landings.

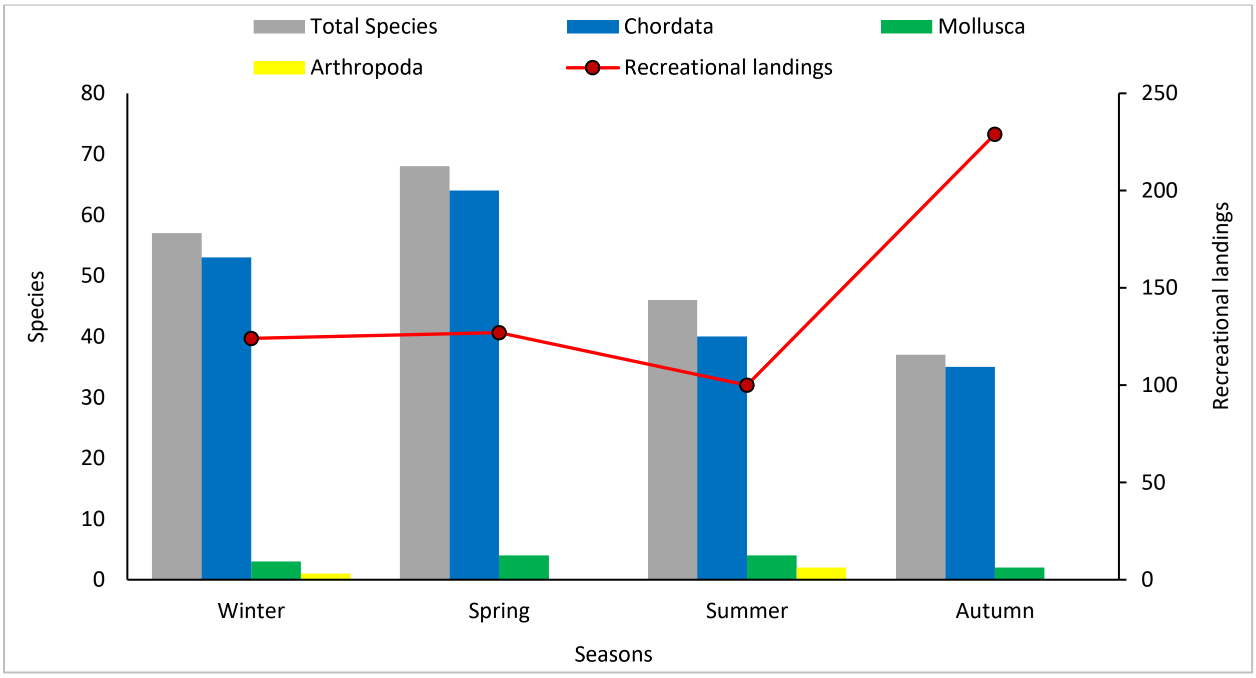

Figure 5. Number of species caught by phylum and season

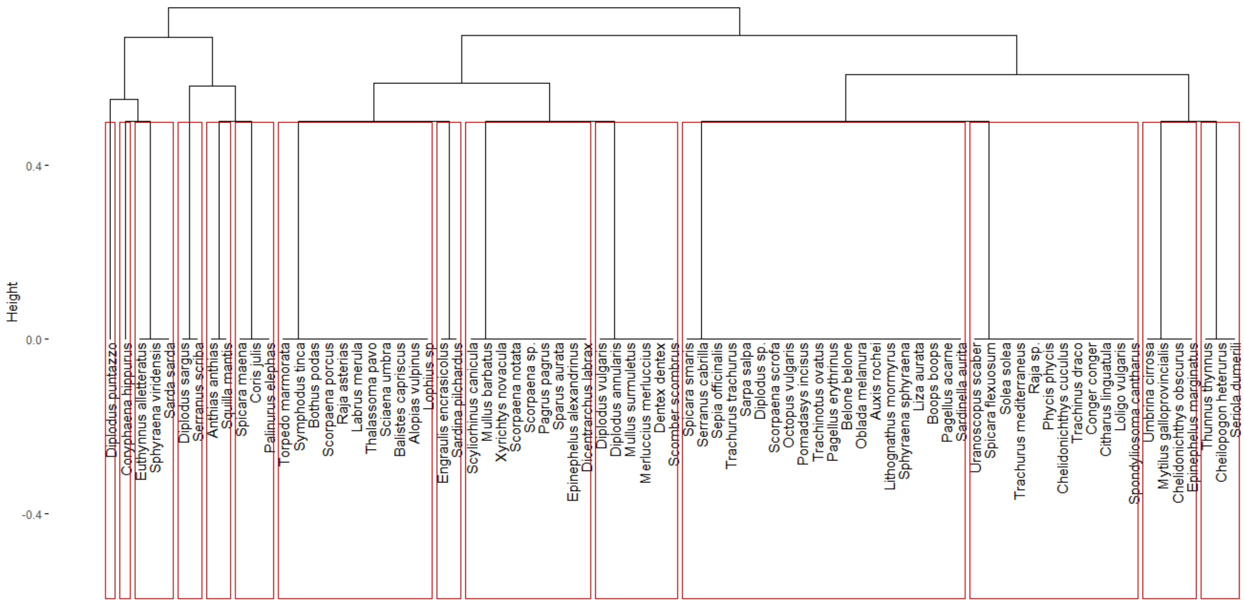

Figure 6. Classification of species by number of appearances per season

42 species are present for 3 out of to 4 seasons among the catches of recreational fishermen (groups 1 and 10 to 14), almost all of which are bony fish in addition to cephalopod mollusks (*O. vulgaris*, *L. vulgaris* and *S. officinalis*). These are Thus, the species most targeted by recreational fishing were (*Auxis rochei* (Risso, 1810), *Sardinella aurita* Valenciennes, 1847, *Thunnus thynnus* (Linnaeus, 1758), *Pagellus acarne* (Risso, 1827), *Pagellus erythrinus* (Linnaeus, 1758), *Dentex dentex* (Linnaeus, 1758), *Mullus barbatus* Linnaeus, 1758, *Diplodus vulgaris* (E. Geoffroy St.-Hilaire, 1817), *Lithognathus mormyrus* (Linnaeus, 1758), *Boops boops* (Linnaeus, 1758), *Conger conger* (Linnaeus, 1758), *O. vulgaris* and *S. officinalis*...), with species associated in their living environments and which are fished together such as: *Trachinus draco* Linnaeus, 1758, *Uranoscopus scaber* Linnaeus, 1758, *Serranus sp., Scorpaena sp.* etc.

In terms of biomass, the catches are largely dominated by two pelagic fish species, accounting for 87% of recreational fisheries production (Figure 7). These are *A. rochei* and *S. aurita*, with *A. rochei* contributing to 71% of recreational landings, totaling an estimated annual production of 22 tons, in addition to 5 tons for *S. aurita*. This highlights a significant fisheries production generated by this fishing activity, despite its recreational status.

The seasonal variation in recreational catches underscores the dominance of the aforementioned two species throughout all four seasons (Figure 8), categorizing them as highly targeted by this fishing activity. *A. rochei* starts to be caught towards the end of the spring season and continues to dominate recreational catches during the summer and autumn (Figure 8A, B). Starting from the winter, recreational fishermen shift their focus to demersal fishing, in addition to *S. aurita*. During this time, we observe the capture of more deep-sea species such as sparids (*B. boops, P. erythrinus, P. acarne, L. mormyrus*), *S. officinalis, O. vulgaris, M. barbatus*, and *Trachurus trachurus* (Linnaeus, 1758) (Figure 8C, D).

Therefore, we emphasize that the entirety of these recreational catches is intended for commercial purposes, which runs counter to the regulations and the fundamental nature of this fishing activity, defined as non-profit recreational fishing (Pitcher & Hollingworth, 2002).

Vertical Distribution

Recreational boaters in the Mostaganem area target species from different bathymetric levels, capturing pelagic, benthic, bentho-pelagic, demersal and reef species (Figure 9) with the use of different fishing gear such as trammel net, driftnet and longline.

Demersal and pelagic species dominated the recreational catches, followed by bentho-pelagic fish, of which we see that recreational fishermen target bottom species between winter and spring through the use of trammel nets and bottom-set gillnet, whose pelagic species will be less available in fishing areas such as tuna species, which are targeted from May (late spring) to December by the use of drift gillnets, which according to regulation is prohibited.

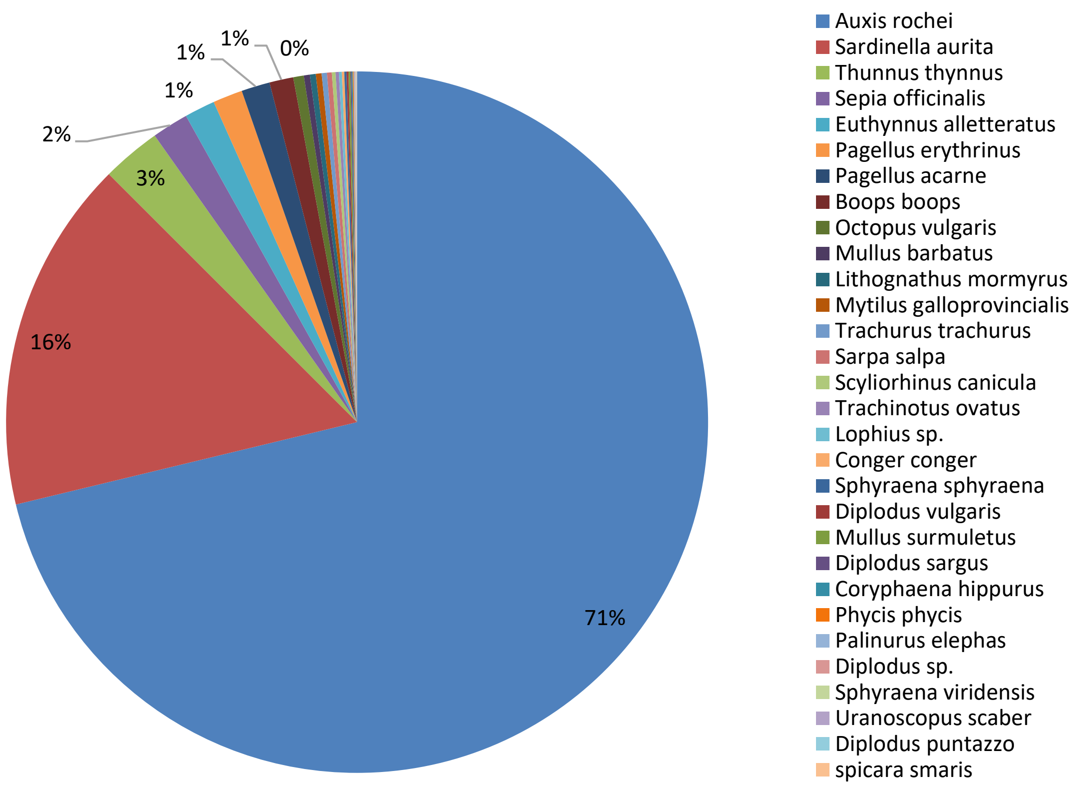

Figure 7. Recreational fish production by weight of main species

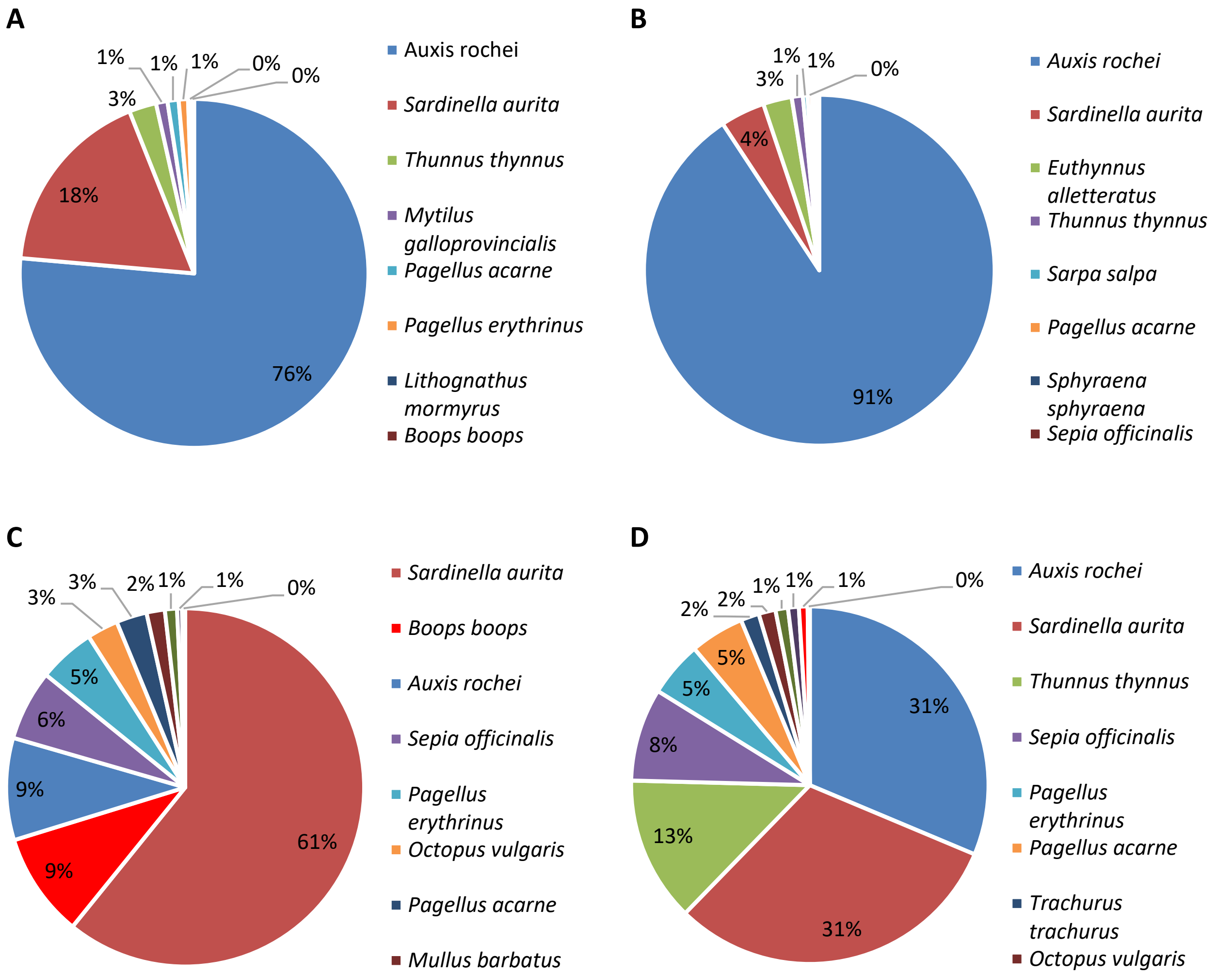

Figure 8. Recreational fishing production by weight of the main species (A: summer, B: Autumn, C: Winter, D: spring)

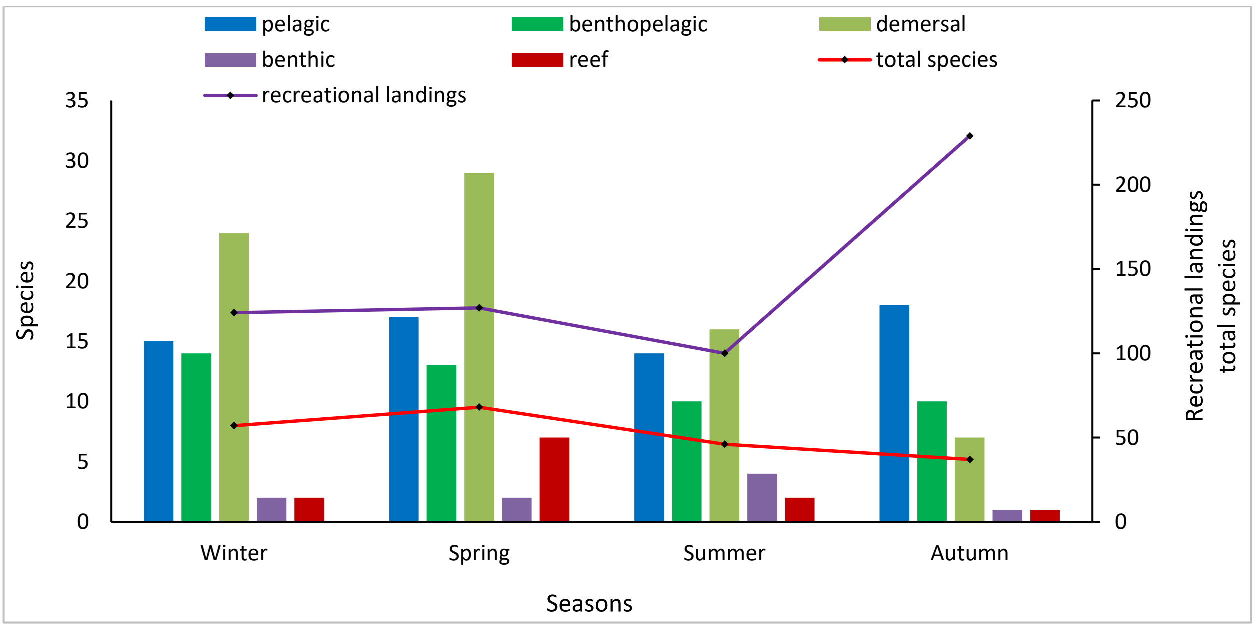

Figure 9. Bathymetric distribution of species caught by season

Trophic Level

In recreational landings, we identified mainly predatory species, with third-degree predators dominating catches, followed by first- and second-degree predators. We thus report the presence of an herbivorous (*S. salpa*) and an omnivore species (*M. galloprovincialis*) (Figure 10).

Assessment of IUCN Status

Of the 79 species fished by recreational boaters, 12% are listed as endangered or vulnerable.

We note a group of 13 species whose stocks are decreasing with 3 endangered species: *A. vulpinus*, *E. marginatus*, *T. thynnus*, and 6 vulnerable species: *B. capriscus*, *S. umbra*, *D. dentex*, *P. elephas*, *Merluccius merluccius* (Linnaeus, 1758), *Umbrina cirrosa* (Linnaeus, 1758).

Taxonomic Diversity

Based on the taxonomic tree, we calculated the taxonomic index (Δ+) on the basis of based on the presence-absence data of the species caught by boaters, the results of which are recorded in Table 2.

The values of the average taxonomic distinctness (Δ+) vary varied between a minimum of 3.62 and a maximum of 4.02 for the different seasons, showing a close and similar taxonomic composition between the four seasons. Δ+ Average is around 3.80 along the year, this which means that the average taxonomic distance between each pair of randomly selected individuals is around 3.8 in the boater landings. In other words, the average number of hierarchical levels in the taxonomic classification that separates two randomly selected species in recreational landings is in the order of 3.8. Thus, on average, the species that make up the stand caught by recreational fishing belong to different orders. Indeed, 86% of these species are of the class Actinopteri (bony fishes), divided into different orders.

The Δ+ values were used in the "funnel" test to compare the taxonomic composition of the stand during each season, with the overall list established throughout the year and to see if there are seasons with fewer or more species compared to the overall list, presenting or not seasonal disturbances.

The mean value of the average taxonomic distinctness Δm+ calculated from 1000 prints of size m made from the overall faunal list is on the order of 3.86. The funnel test (Figure 11) encompasses all four seasons within the 95% confidence interval of Δm+, implying that the value of Δ+ estimated for each season is consistent with the average value Δm+ expected on the annual global list. All seasons therefore show similar complex taxonomic structures.

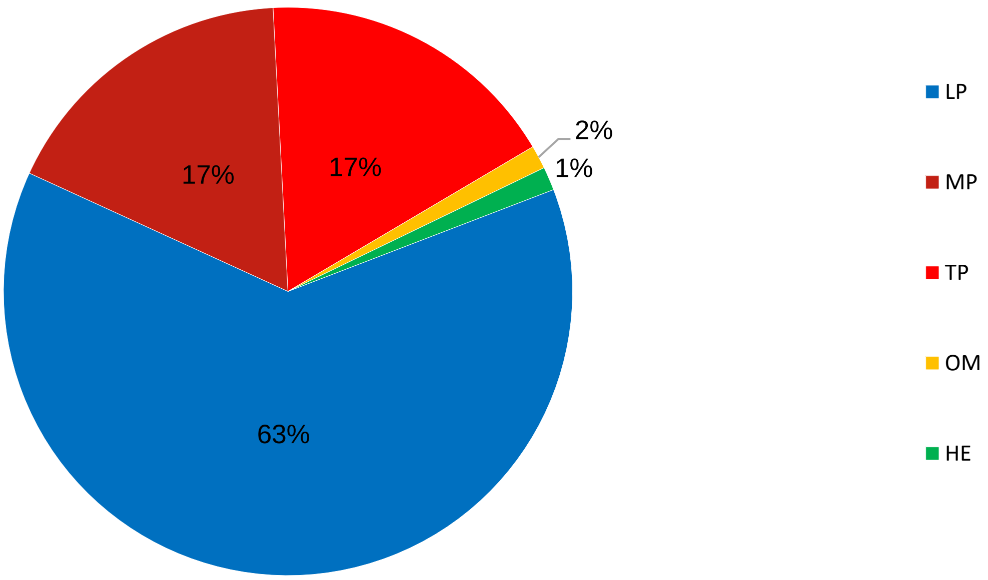

Figure 10. Distribution of species by trophic level

Table 2. Average taxonomic distinctness (Δ+) by season

Season	Species	Δ+
Winter	58	3.72
Spring	70	3.82
Summer	48	4.02
Autumn	37	3.62
Δm+		3.86

Discussion

This study provides a vision on the recreational (*sensu lato*) activity in the Mostaganem region and its impact on the marine ecosystem, identifying a large population targeted and caught by this activity with 79 species fished, with twice as many species recorded in the eastern Mediterranean (Frid *et al*., 2023), and a difference of 11 species compared to the central Mediterranean which has 90 species (Darmanin & Vella, 2019) and 32 species compared to the north of the western Mediterranean, which has 111 species recorded between Spain, France and Italy (Lloret *et al*., 2019). In general, , whose sparids dominate in the various studies conducted in the Mediterranean (Tunca *et al*., 2016; Babali *et al*., 2018; Darmanin & Vella, 2019; Frid *et al.,* 2023).

This seems to show a decreasing gradient of species richness in the Mediterranean basin from west to east (Coll *et al*., 2010), with the dominance of catches by some non-native species in the eastern Mediterranean (Darmanin & Vella, 2019; Frid *et al*., 2023) following the Lessepsian migrations (Bédry, 2021).

The variation in the species richness per season is mainly due to the fishing gear used during the different seasons following the availability of the target species in the fishing areas (Mesnil & Shepherd, 1990; Biseau, 1998). This reflects a deep knowledge of the biology of the species targeted by recreational fishermen, such as the reproduction period, seasonal and daily migrations, and more (Cataudella *et al*., 2015). It is observed that the majority of most recreational fishermen focus on pelagic fishing from the end of the spring season until the end of the autumn, using mostly drift gillnets, to target mainly tuna species that are migratory species (Nakamura, 1969; Baker, 1978) spawning in the Mediterranean (Sabatés & Recasens, 2001). These tuna species approach the coast for spawning between May and December.

Indeed, the primary target species for recreational fishermen during this period is the bullet tuna, *Auxis rochei*, which spawns from March to September (Uchida, 1981; Piccinetti *et al*., 1996; Bök & Oray, 2001).

The same applies to the bluefin tuna (*Thunnus thynnus*), which migrates into the Mediterranean basin for reproduction from mid-June to almost July in the Western and Central Mediterranean (Susca *et al*., 2001; Corriero *et al*., 2003), and around mid-May in the Eastern Mediterranean (Karakulak *et al*., 2004; Oray & Karakulak, 2005). This pattern also holds true for other species of tunas, such as *Euthynnus alletteratus* and *Sarda sarda*, which reproduce from May to July (Sanzo, 1932; Rodriguez-Roda, 1966, 1979; Chur, 1973).

This explains the reduced number of species recorded during the summer and autumn seasons despite the high number of sea trips (229 in autumn), since the species richness is strongly dependent on the sampling effort (Peet, 1974; Magurran, 2004), whose recreational catches during these two seasons are dominated by the minor tuna *A. rochei, E. alletteratus* and *S. sarda* themselves dominated by the first species which is the most abundant in the Mediterranean basin (Sabatés & Recasens, 2001). Among these catches, we report the presence of very young individuals of bluefin tuna in autumn, much smaller than the size at first sexual maturity, which is about 103.5 cm (Froese & Pauly, 2022), which can have negative consequences on the population of this iconic species.

Moreover, from December onwards, recreational fishermen are converting to deep-sea fishing, targeting benthic and demersal species using mainly trammel nets and bottom-set gillnets, which leads to an increase in the number of species caught to reach the maximum of the species richness per season (70 species) in spring.

Thus, recreational fishing in the Mostaganem region mainly targets predatory species with high trophic levels, showing an impact on the top of the trophic chain, which we suggest that the population of recreational fishermen, through their practices, seeks to

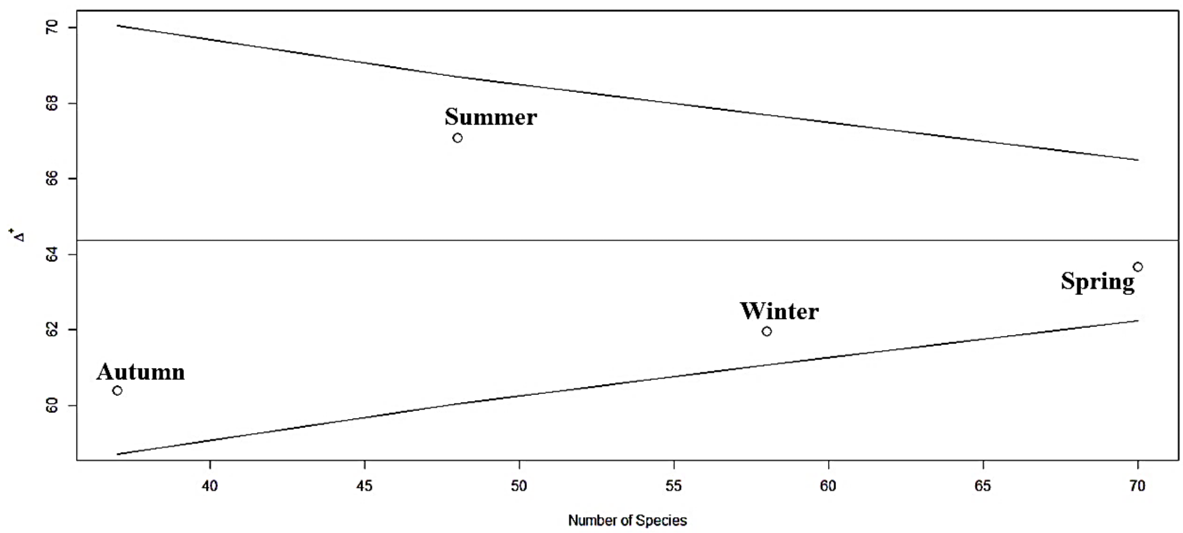

Figure 11. Funnel test

maximize their income by targeting species of high economic value throughout the year, given that all of these recreational fishermen engage in selling their catches.

This can lead to harmful and significant effects on the marine ecosystem and on the balance of the food chain by reducing the number of predators, which can have cascading effects (Prato *et al*., 2016) on lower species by leading to an increase in prey populations, and therefore a reduction in the food available to other species in the ecosystem. In addition, by the fishing pressure exerted on some predator species it can make them more vulnerable to overfishing or even extinction, which is the example of bluefin tuna, dusky grouper and thresher shark which are classified as endangered in the Mediterranean basin by the IUCN, as well as *B. capriscus, S. umbra, D. dentex, P. elephas, M. merluccius, U. cirrosa* which are classified as vulnerable.

Furthermore, recreational fishermen in the Mostaganem region are found to be in violation of the current regulations through various infractions (Daoudi *et al*., 2023):

- Use of prohibited fishing gear for this fishing activity, such as trammel nets, drifting gillnets, and octopus traps (Executive Decree No. 96-121, 1996).
- Sale of recreational fishing products, which is prohibited (Executive Decree No. 96-121, 1996; Executive Decree No. 03-481, 2003).
- Failure to adhere to the minimum size requirements for catches (Executive Decree No. 04-86, 2004).

Recreational fishing represents a noteworthy activity in the Mostaganem region, involving the capture of a diverse array of marine species from various zoological groups, often with substantial biomass. These catches should not be overlooked when assessing and managing fisheries. Nevertheless, this activity can exert significant impacts on the marine ecosystem and disrupt the food chain balance. This becomes particularly concerning when recreational fishing involves the capture of endangered and vulnerable species and targets species at high trophic levels through the use of prohibited and non-selective fishing gear.

It is therefore important to put in place effective management measures to regulate this fishing activity and protect the marine environment, by raising the awareness of the recreational fishermen on the good practices of sustainable and responsible fishing, as well as on the regulations in force and their rigorous application by developing a strict monitoring and control program for this fishing activity.

Ethical Statement

This study does not require any formal authorization, as the sampling was carried out based on monitoring and recording recreational fishing landings.

The authors declare that the present study was conducted in an ethical, professional and responsible manner.

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Author Contribution

All authors contributed to the study conception and design;

Methodology and data collection: Mohamed Daoudi, Ibrahim Elkhalil Behmene;

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Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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