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ARTICLE

A multimethod approach to assess marine recreational fishing activity in a Mediterranean area: A case study of the Balagne region (Corsica, France)

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Abstract

Objective: Recreational fishing is a growing concern in the management of fishery resources given its economic impact, the number of people involved, and the magnitude of catches. Despite its significant impact on marine resources and ecosystems, recreational fishing has received less attention in research than commercial fishing.

Methods: This study focuses on marine recreational fishing in Balagne (Corsica, France, northwestern Mediterranean). It presents, for the first time in this region, valuable data on the population size of recreational fishers; their sociological profiles; fishing habits; and, specifically, catch data related to boat fishing.

Result: Through an extensive telephone survey involving 387 households, we estimated that recreational fishers constitutes 10.2% of the population, with the majority being men (84.84%). The average age varies significantly based on the type of fishing practiced: 38.4 years for spearfishing, 50.2 years for shore fishing, and 56.4 years for boat fishing. Additionally, the study found that shore fishers declare practicing no-kill fishing more frequently than do boat fishers (90.00% and 56.67%, respectively). Photographic protocol, fishing logbooks, and boarding provided data on catch composition and fishing characteristics. In the case of boat fishers, catches per unit of effort, estimated from boarding data, were found to be 1.03 $\pm$1.51 individuals/h/fisher and 222.32 $\pm$318.94 g/h/fisher. Despite the great diversity among the species caught (49 species), Comber *Serranus cabrilla*, Blackspot Seabream *Pagellus bogaraveo*, Black Seabream *Spondyliosoma cantharus*, and Painted Comber *Serranus scriba* are overly represented in number among the species of marine fish caught by boat fishers and Common Dentex *Dentex dentex*, Greater Amberjack *Seriola dumerili*, Dolphinfish *Coryphaena hippurus*, and Bluefin Tuna *Thunnus thynnus* are overly represented in weight. Among all individuals caught and measured, about one out of two individuals (48.97% of catches) does not reach the legal size.

Conclusion: This study reveals the need to establish monitoring, surveillance, and control programs to ensure the sustainability of fish stocks and fisheries, including recreational fisheries.

KEYWORDS

boat fisher, CPUE, Mediterranean Sea, recreational fishing, sociological profiles

INTRODUCTION

Exploitation of fishery resources has become a major issue relating to conservation at the global scale. Although commercial fishing is considered one of the main causes of fish stock decline (Botsford et al. 1997; Smith 2002; Christensen et al. 2003; Hilborn et al. 2003; Pauly et al. 2003), recreational fishing is recognized as one of the most widely practiced leisure activities (Arlinghaus et al. 2002, 2015; Ihde et al. 2011; Venturini et al. 2017). Recreational fishing is defined as the harvest of aquatic animals (principally fish), for sport or recreation, that are not the primary food resource and are not sold (Pitcher and Hollingworth 2002; Food and Agriculture Organization of the United Nations 2012). Several studies have demonstrated the importance of its impact on fish stocks (McPhee et al. 2002; Post et al. 2002; Coleman et al. 2004; Cooke and Cowx 2004, 2006; Lewin et al. 2006; Veiga et al. 2010; Ihde et al. 2011; van der Hammen et al. 2016) and its socioeconomic impact (Borch et al. 2011; Armstrong et al. 2013; Herfaut et al. 2013; Hyder et al. 2018).

Commercial fisheries catches by country are documented since 1950 by the Food and Agriculture Organization of the United Nations, which is not the case for catches from recreational fisheries (Freire et al. 2020). Recent estimates suggest that global recreational catches amount to 900,000 metric tons per year, with significant regional variability (Freire et al. 2020). Yet, in Europe, recreational fishing has been excluded from fish stock assessment for many years due to the lack of reliable catch estimates (Pawson et al. 2008; Hyder et al. 2017). Depending on the regulations of each country, this activity is not always subject to declaration, and practitioners are difficult to count and monitor. Unlike commercial fishing, the absence of a monitoring program for recreational fisheries has led to a lack of data, making it difficult to estimate time series on the evolution of catches of recreational fisheries (Lewin et al. 2006; Unal et al. 2010). Moreover, the sparse dimension of the activity, the multitude of techniques used, and the heterogeneity of practitioners involve important human and temporal costs for monitoring purposes.

Nevertheless, several studies argue that recreational fishing may have similar or greater effects on fish populations than commercial fishing (McPhee et al. 2002; Coleman et al. 2004; Lewin et al. 2006; Rangel and Erzini 2007; Font and Lloret 2014). Indeed, in recent years, recreational fishing has become widely democratized, especially with the technological progress of pleasure boats, associated equipment, and fishing gear. In addition to the improvement of boat engines that now enable navigating for longer distances and in a faster and safer way, technologies also enable users to locate fish more easily, in particular with the help of GPS and depth-finder technologies but also with the ability to fish in deeper areas with the help of electric reels or a hoist (Cooke and Cowx 2006; Thurstan et al. 2018; Cooke et al. 2021). Synthetic fibers used for fishing lines, replacing monofilament, have also increased the strength of lines allowing a higher rate of fish capture. Realism of lures has also been greatly improved, integrating lights or even smells or noises (Thurstan et al. 2018; Cooke et al. 2021). All of these equipment developments provide recreational fishers with more tools to fish in more distant or deeper areas and to land more and larger fish (Cooke and Cowx 2006).

In the Mediterranean Sea, recreational fishing is particularly important as it represents more than 10% of the total production of all fisheries (European Union 2004) and commercial fishing is mainly artisanal, at a small scale, and limited to coastal areas (Morales-Nin et al. 2005). Yet, in many regions, recreational fishing

Impact statement

Recreational fishing is a growing concern in the management of fishery resources given its economic impact, the number of people involved, and the magnitude of catches. This study on recreational fishing in Balagne (Corsica, France, northwestern Mediterranean) collected, for the first time in this region, data on the number of recreational fishers, their sociological profiles, and their fishing habits and specific catch data concerning boat fishers. This study shows that it is key to consider the socioeconomic and biological implications of marine recreational fishing in fish stock assessment and overall management strategies of Mediterranean coastal areas.

is a bias in stock assessment and an obstacle to fishery management (Lloret et al. 2008; Pauly and Zeller 2016), first because the exact total biomass taken by the recreational fishery is unknown and second because the activity represents a major component of illegal, unreported, and little or unregulated catches (Moutopoulos et al. 2013; Ben Lamine et al. 2018). Socioeconomic surveys of recreational fishers also make it possible to identify factors that determine the type of fishing practiced, the species targeted, or the fishing locations and are therefore valuable tools for recreational fishery management (Martin et al. 2016; Young et al. 2016; Jiménez-Alvarado et al. 2019).

In France, marine recreational fishing is not subject to any declaration (except in some Marine Protected Areas) or fishing permit; therefore, data on this activity is particularly sparse. Recreational fishing is subject to regulations of the Rural and Maritime Fishing Code (Articles R921-83 to R921-93), and several species are regulated either by a prohibition of fishing or certain fishing techniques or by minimum catch sizes.

Due to the fluctuating nature of recreational fishing characteristics from region to region (e.g., species, regulations, gear, cultural context), specific local studies are needed to take this activity into account in the overall management of fish stocks. This study on recreational fishing in Balagne (Corsica, France, northwestern Mediterranean) collected, for the first time in this region, data on the number of recreational fishers, their sociological profiles, and their fishing habits and specific catch data concerning boat fishers. Surveys on recreational fishing are essential to provide data on the status of fish populations and the actual exploitation of fishery resources in order to improve coastal zone management.

METHODS

Study site

The study was conducted in Balagne, a region located on the northwestern coast of Corsica (France) (Figure 1). This region connects Pietralba to Galeria and includes 36 communes, gathered in two communities of communes: Calvi – Balagne (12,572 inhabitants in 2019) and L'Ile-Rousse – Balagne (10,653 inhabitants in 2019), with a total of 23,225 inhabitants (National Institute of Statistics and Economic Studies [INSEE] 2023). The Balagne coastline is about 90 km long and is mostly composed of granite cliffs interspersed with large beaches spread along the coast. The continental shelf is very narrow in this region (unlike the east of the island) and does not exceed 2 to 3 km of width on average (Pelaprat 2000).

Two fishing reserves are present on the study site: the fishing reserve of Calvi and the fishing reserve of L'Ile-Rousse, where scuba diving and recreational and professional fishing are prohibited. A terrestrial and marine Natura 2000 area (protected area belonging to a European network) was created in 2016 and partially includes three communes of Balagne (Calenzana, Calvi, and Galéria) (Figure 1).

Field counts

In order to take into account the spatial distribution of recreational fishing activity across the Balagne region, counts of fishers along the entire Balagne coastline were carried out from the land using binoculars. In June and July 2020, counts were carried out twice a week: once during the work week (Monday to Friday) and once during the weekend, in a randomly selected area of the Balagne region. In total, 17 survey days were conducted with at least four separate counts per area (Figure A.1 in the Appendix). The start counting time was randomly chosen between 0800 hours and 2000 hours.

In addition, special attention was paid to the bay of Calvi thanks to opportunistic counts conducted during boat trips by the STARESO oceanographic research station during various scientific activities. This monitoring took place from February 2019 to July 2020, with a total of 90 counts at various times of the day. Fixed-time counts were also carried out from the Revellata lighthouse (viewpoint located high in the Bay of Calvi) to estimate, more precisely, the spatial distribution of the activity in the Bay of Calvi. Counts were carried out three times per day (at 0800, 1200, and 1700 hours). In total, 185 counts were carried out between January 2020 and July 2020.

Each fisher observation was recorded with associated geographic coordinates and mapped using Quantum (GIS) 2.18.25 software. All maps in this study were composed, edited, and exported using this software. The reference system used for these elaborations is WGS84.

Telephone surveys

In order to have an initial estimate of the number of local recreational fishers, we conducted a large telephone survey throughout the Balagne region. To ensure that the population sample was representative of the Balagne population, a minimum sample size was calculated using the formula established by Ardilly and Tillé (2006):

$$\text{Sample size required} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left[\frac{z^2 \times p(1-p)}{e^2 N}\right]},$$

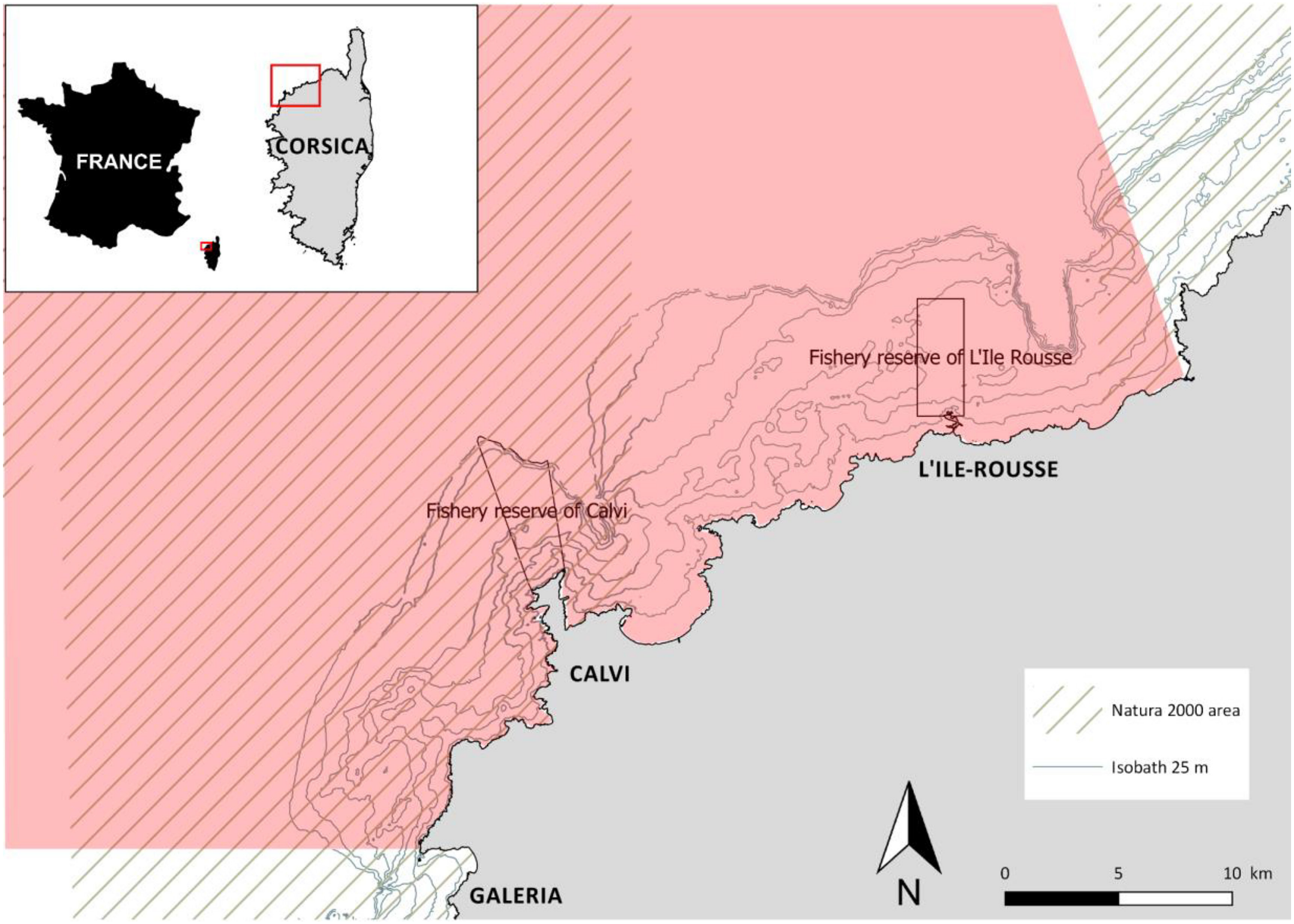

FIGURE 1 Map of Balagne study area (Corsica, France). The area where recreational fishers were sampled is highlighted in red; the stripes represent Natura 2000 areas.

where z = the z-score (number of standard deviations of a given proportion from the mean), set at 1.96 when the desired confidence level is 95% (normal distribution); e = the margin of sampling error, here set at 5% (0.05); p = the estimated prevalence, when the prevalence is unknown as is the case here, the prevalence is set at 0.5; and N = the size of the Balagne population over 15 years old, estimated to be 20,028 inhabitants according to INSEE (2023). As underwater fishing is only permitted in France from the age of 16, only individuals aged over 15 were included in this study.

Thus, estimated sample size, with a 95% confidence level and a 5% margin of error, was set at 377 respondents minimum. Sampling was then carried out by random selection from the 2017 Corsica telephone directory, taking into account the number of households per commune to ensure that the number of households selected was proportional to the commune's size.

A total of 385 survey respondents were reached. To obtain this number, 2576 calls were made between March 23 and April 6, 2020. When a recreational fisher is identified in a household, a questionnaire is conducted by phone to describe his or her fishing habits. A person is considered a recreational fisher if they are older than 16 and have fished at least once in the past 12 months.

To ensure that our sample is representative of the Balagne population, we applied weighting factors to the data collected from the telephone survey. These factors were calculated by adjusting the sample based on known variables, such as gender and age, which were also available for the entire population of Balagne according to INSEE (2023). We employed the ranking ratio method, also known as "iterative proportional fitting" (Sautory 2018), as the considered variables were category-based and the counts of individuals within each category modality were known for the entire Balagne population. Each interviewee was assigned a weighting factor, allowing us to extrapolate the telephone sample data to the entire Balagne population. The range of final weights applied to individual observations varied between 0.33 and 4.96. Our sampling frame appears to be reliably representative as evidenced by the comparison of population characteristics in our telephone sample (postadjustment) with those of the Balagne population as a whole (see Table A.1 in the Appendix). Weighting was carried out using the raking survey data tool available in Excel with XLSTAT 2023.

In situ surveys

In addition to telephone surveys, in situ surveys were also carried out with local fisher associations or during the counts carried out in the field. These surveys enabled us to complete the sociological data of fishers collected over the phone. The minimum age was set at 16, as spearfishing is not permitted under this age in France.

Monitoring of boat fishers

By fishing logbooks

Fishing logbooks were distributed to volunteer recreational fishers between January 2019 and March 2020. Logbooks consisted of two parts. The first part was about the fishing trip profile (date, start time, end time, duration of fishing, type of fishing, number of gears, number of fishers, fishing area, depth of fishing, and bait type). The second part was a record of daily catches (species, size, and possible discard). Logbook data were used to estimate the daily catch but not the fishing frequency, as many fishers forget to fill it out on each trip. A total of 196 fishing trips by 13 different fishers were recorded in the logbooks.

By photographs

A photographic protocol was also proposed to recreational fishers on a voluntary basis, allowing them to send us photographs of their catches of the day. When fishers sent photographs, we took the opportunity to ask them about their fishing trip characteristics (date, time of departure, time of arrival, duration of fishing, type of fishing, number of gears, number of fishers on board, fishing area, depth of fishing, and type of bait). Then, for each image, we identified the species, number of individuals caught, and total length of each fish. To estimate the fish size, we created and distributed measuring sticks, with a reference size of 20 cm (Figure 2). Using this object as a measuring reference, positioned next to the fish, enabled us to estimate the fish size using the free image analysis software IMAGEJ (Abràmoff et al. 2004). A total of 102 photographs were used.

FIGURE 2 Photograph sent by a boat fisher showing his catch of the day, a Common Dentex *Dentex dentex* with a measuring stick positioned next to it, allowing estimation of the fish size (in this case, 64 cm).

By boarding

In addition, scientific boardings were conducted with volunteer recreational boat fishers to observe the fishing trip characteristics, record all the catches made, and measure and weigh all the individuals caught. Between July 2018 and March 2020, 191 h of boarding were conducted.

The same logbooks and photographic protocols were also offered to spear fishers and shore fishers. However, the quantity of data collected was not sufficient for this data to be taken into consideration for this study.

The number of fishers monitored according to each protocol is summarized in Table A.2.

Statistical analysis

Data was integrated into an Excel database. Data treatment, plots, and statistical analyses were done using R version 3.5.3. Plots were created with the ggplot2 package. For all tests, a p-value <0.05 was considered a statistically significant difference.

As the data set was not large enough to conduct robust multivariate analyses, we chose to conduct univariate analyses. Differences in quantitative variables, such as fishers' age (in years), fishing experience (in years), annual budget allocated to fishing (in euros), average number of fishing trips carried out per week, and average duration of fishing trips, between different types of fishing (boat fishing, shore fishing, and underwater fishing) were tested with a Kruskal–Wallis test using the kruskal_test function, with Bonferroni correction, on raw data since it followed a nonnormal distribution (Shapiro–Wilk, $p > 0.05$) even after transformations. The Kruskal–Wallis test, if significant (p-value < 0.05) was followed by a post hoc Dunn's test to verify differences across the fishing types.

Differences, among fishing types, of qualitative declarative variables were tested with a Fisher–Freeman–Halton test (Freeman and Halton 1951): no-kill practice (two-factor modalities: Yes or No), preferred time of year for fishing (nine-factor modalities: Annual, Spring, Summer, Fall, Winter, Spring–Summer, Except Winter, Except Summer, Except Summer and Winter), preferred time of week (three-factor modalities: Weekday, Weekend, or Indifferent), preferred time of day (six-factor modalities: Morning, Afternoon, Evening, Morning–Evening, Day, Indifferent), relationship with other users (three-factor modalities: Good, Indifferent, Conflicting), and knowledge of regulations (three-factor modalities: Good, Medium, Poor). When the result was significant, pairwise post hoc tests were conducted.

Species' richness of catches was estimated as the total number of species caught per hour per fisher. Species' richness was estimated for each fishing trip based on logbook, photographic, and trip data.

The total catch weight was calculated using size–weight relationships of species from the literature and FishBase (http://www.fishbase.org/). The mean CPUE, expressed in weight (g) of fish per hour per fisher, was calculated from the estimated CPUEs for each fishing trip. These CPUEs were calculated from the total catches, total number of hours fished by each vessel, and number of fishers on board. Boat fishers that were monitored during this study were all private fishers with their own boats. Changes in CPUE and specific richness of catches throughout the seasons were compared with a Kruskal–Wallis test using the kruskal_test function, with Bonferroni correction. The Kruskal–Wallis test, if significant (p-value < 0.05) was followed by post hoc Dunn's test to verify differences across transect.

RESULTS

Spatial distribution of marine recreational fishing activity in the Balagne region

The spatial distribution of fishing activity shows a spread-out distribution along the whole coastal line, with higher frequentation rates around the ports of Calvi and L'Ile-Rousse. The most frequented places are accessible by car or via small footpaths in the vicinity without any drop or cliffs (Figure 3). On the other hand, some hot spots of frequentation correspond to the surroundings of fishing reserves or known reefs.

Spatial distribution of recreational fishers in the Bay of Calvi is particularly correlated with the bathymetry and presence of artificial structures at sea. Indeed, the hot spots of frequentation are located near the port of Calvi, near shoals or reefs (Danger d'Algajola, Sec du clocher), on the border of the fishing reserve of Calvi, and in the vicinity of aquaculture or wave recorders (named "houlograph" on the map; Figure 4). It is interesting to note that on several occasions, recreational fishing activities have been observed within the fishery reserve of Calvi, where both professional and recreational fishing are prohibited (Figure 4).

Estimated number of local recreational fishers

Out of the 387 households surveyed over the telephone, 22 people reported practicing marine recreational fishing, representing 5.68% of the sample. After adjusting the data to ensure the representativeness of the interviewed sample within the Balagne population, it was found that recreational fishers constitute approximately 10.22% of the population. With a population of 20,028 in Balagne in 2020 (INSEE 2023), this suggests an estimated number of local recreational fishers at 2046. Among these, males represent 86.84% compared to 13.16% females.

Regarding fishing practices among the weighted fishers interviewed during the telephone survey, boat fishing is the most common at 29.91%, followed by shore fishing at 28.29% and spearfishing at 25.71%. Additionally, 16.09% of respondents reported using a combination of fishing methods.

Social characteristics based on all surveys combined

Among all the surveys conducted ($n = 67$), boat fishers were found to be significantly older than spear fishers (post hoc Dunn test: p-value $= 0.00794$), with an average age of 54.6 ± 17.4 years (mean $\pm$ SD) and 38.4 ± 11.5 years, respectively. The mean age of shore fishers (50.2 ± 16.3 years) is not significantly different from the age of boat or spear fishers (Figure 5).

A majority of boat fishers are retired (50%) or business owners (27%). The population of shore fishers is more diversified, with 30% being retired and 35% being employed. The category of spear fishers is mainly composed of a working population (41% employees and 29% self-employed) (Figure 6).

The annual budget (expressed in euros) allocated for fishing is significantly higher for boat fishers than for shore fishers, with an average budget of 958.78 ± 1438.73 € and 163.21 ± 1424.46 €, respectively. The budget of spear fishers (510.83 ± 804.39 €) does not differ significantly from that of shore fishers (Figure 7).

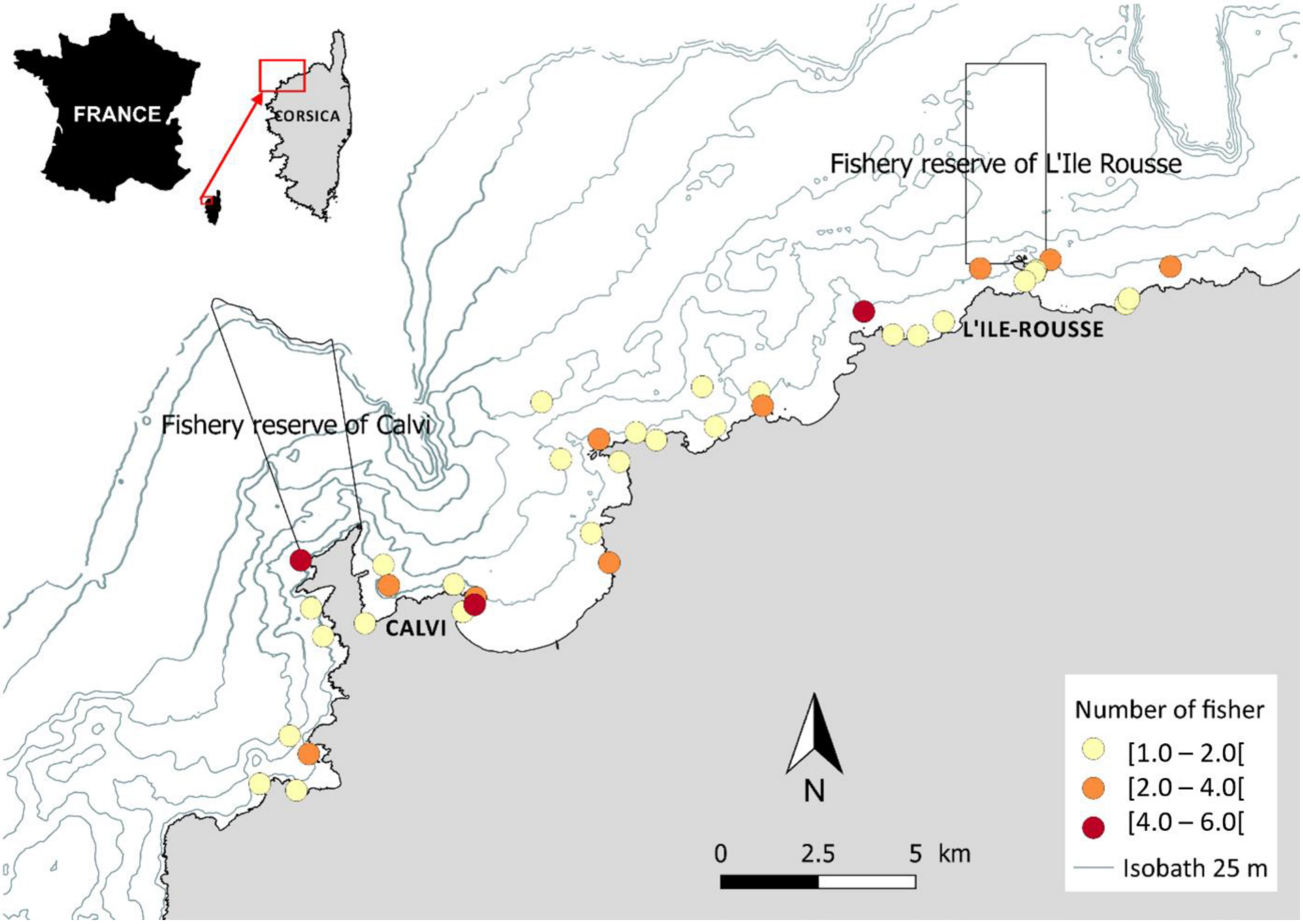

FIGURE 3 Spatial distribution of marine recreational fishers (total number) on the Balagne coastline, counted from the surveys across the whole Balagne region.

Fishing characteristics

The variables "number of trips per week," "duration of trips," and "experience of fisher" do not show significant differences between the three types of fishing (Table 1).

A significantly higher proportion of shore fishers reported practicing no-kill fishing compared with boat fishers (Fisher test: p-value = 0.019), with 90.00% of shore fishers and 56.67% of boat fishers reporting this practice (Table 1).

There is no apparent trend for the preferred time of the year across the types of fishing considered. Most fishers, regardless of the type of fishing, declare that they fish all year round and do not have a preferred day of the week. Boat fishers shows a clear preference for fishing in the morning (53.33%) and have a significantly different behavior than shore fishers (Fisher's test: p-value = 0.01049), who prefer fishing in the morning and evening (30.00% for each) (Table 1). The time preference of spear fishers does not differ significantly from those of boat or shore fishers, although the majority (52.94%) declared fishing in the morning (Table 1). Their relationship with other users of the sea (e.g. professional fishers, divers) does not differ according to the type of fishing and seems to be predominantly good for all fishers (64% to 85% of spear fishers and boat fishers, respectively, declare having good relations) (Table 1). Fishers reported a good level of knowledge about regulations (from 60% to 70.60% reported a good knowledge of regulations governing recreational fishing). Finally, significantly more shore and boat fishers reported losing material (e.g., lead, line, hook) at sea compared with spear fishers (Fisher test: p-value = 0.0330 and p-value = 0.0119, respectively) (Table 1).

Fishing characteristics of boat fisher

Fishing effort

A total of 326 fishing trips by boat, documented through logbook or photograph, were recorded (55 in winter, 90 in spring, 108 in summer, and 73 in autumn) among 13 boat fishers. Some individuals utilized both logbooks and photographs to report their catch, and they were also sampled by fisheries observers during boarding. The mean ±

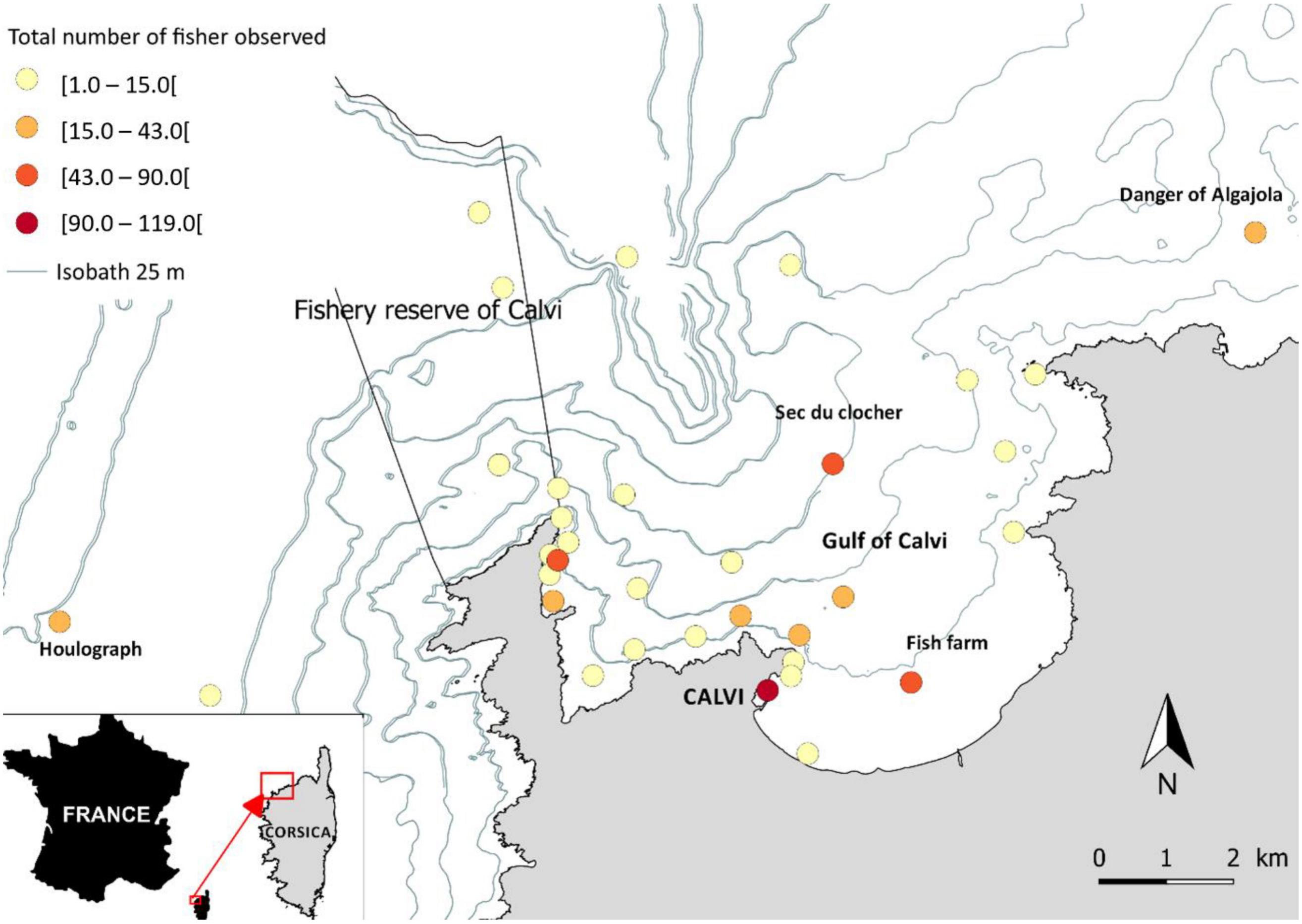

FIGURE 4 Spatial distribution of marine recreational fishers (total number) near and in the bay of Calvi (Corsica), obtained from opportunistic surveys in the bay of Calvi combined with fixed-time counts carried out from the Revellata lighthouse.

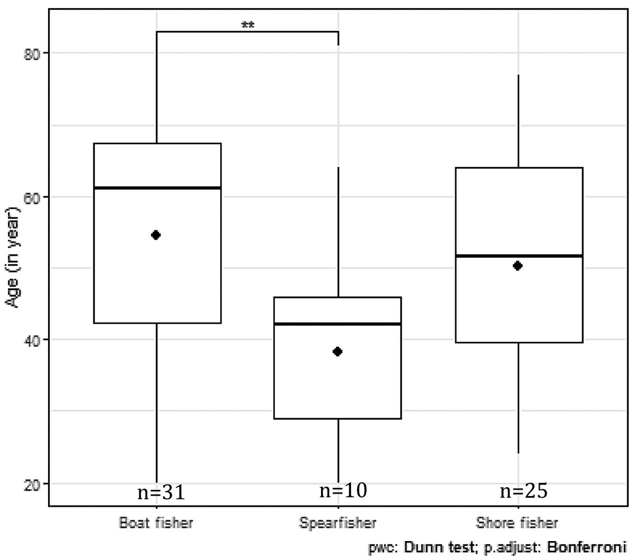

FIGURE 5 Age of fishers ($n = 67$) according to their type of fishing, with mean (diamond symbol), median (horizontal line in the box), first and third quartiles (bottom line and upper line of the boxes), the 5th and 95th percentiles (black whiskers), and outliers (black dots). The asterisk symbols represents significant fishing modality differences (one asterisk: $p < 0.05$, two asterisks: $p < 0.01$, three asterisks: $p < 0.001$, and four asterisks: $p < 0.0001$).

SD duration of fishing trips by boat was 4.90 ± 1.70 h. In addition, 6.75% of fishing trips were conducted in offshore areas, more than 6 nautical miles from the coast. The furthest fishing trip recorded during our study was up to 50 nautical miles offshore.

Catch per unit effort

On average, CPUE (all species and all protocols combined) of boat fishers, expressed in grams of fish caught per hour per fisher, is 740.14 ± 1471.18 g/h/fisher (mean ± SD). The CPUE is significantly higher in autumn than in spring and summer (Dunn test: p-value = 0.00416 and p-value = 0.0284, respectively) (Figure 8).

The CPUE calculated from logbooks only is 773.11 ± 1637.88 g/h/fisher, based on 196 trips recorded by four different fishers. Similarly, the CPUE from photographs only is 789.58 ± 1058.70 g/h/fisher, derived from 95 trips recorded by four different fishers. Conversely, the CPUE from boarding only is 222.32 ± 318.97 g/h/fisher, observed from 35 fishing trips monitored by five different fishers.

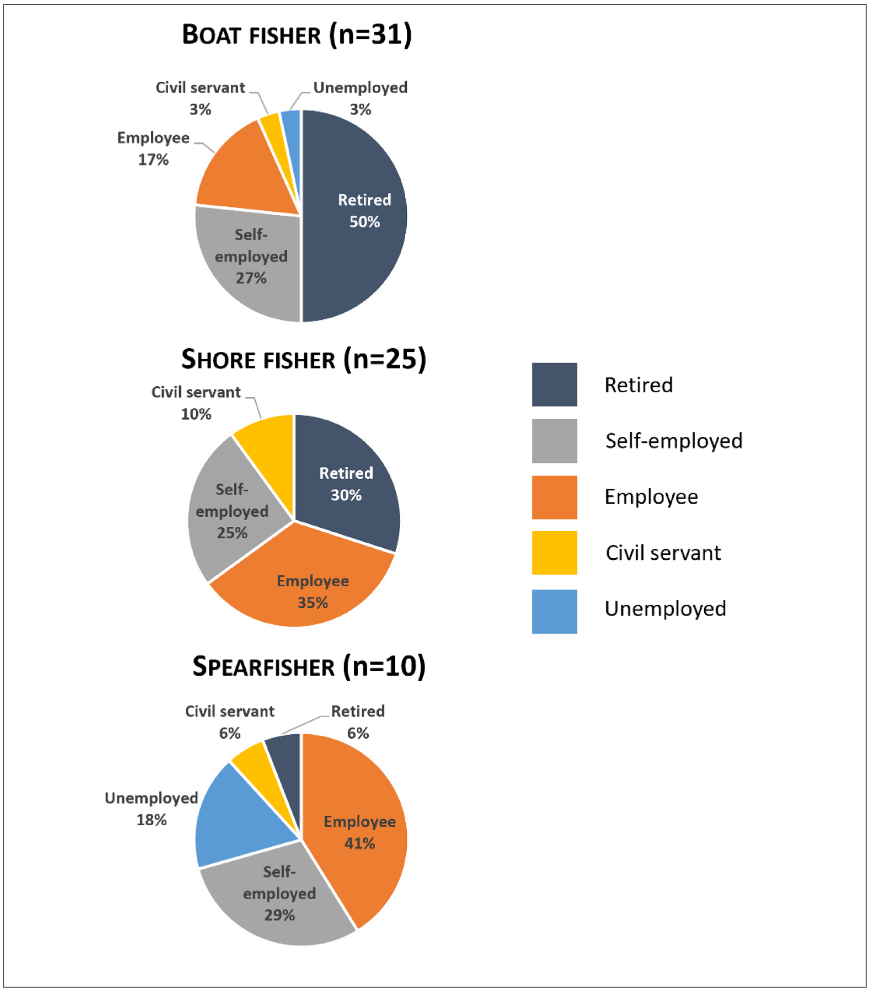

FIGURE 6 Employment status for each fishing modality.

On average, the CPUE (all species and all protocols combined) of boat fishers, expressed in number of fish caught per hour per fisher, is 1.49 ± 3.11 fish/h/fisher. The CPUE is significantly higher in spring than in summer (Dunn test: p value = 0.0483) (Figure 9).

The CPUE calculated from logbooks only is 1.80 ± 3.78 fish/h/fisher (196 trips recorded), 0.99 ± 1.36 fish/h/fisher from photographs only (95 trips recorded), and 1.03 ± 1.51 fish/h/fisher from embarkations only (35 fishing trips monitored).

Catch composition and abundance

Based on the records of catches (all protocols combined), 49 species belonging to 26 families were identified, which reflects the exploitation of a very diverse fauna. The mean ± SD species richness of catches per fishing trip is 1.81 ± 1.44 species caught. Families Sparidae, Labridae, and Scombridae are the most represented in catches, accounting for 22 species caught alone. Despite the diversity of species encountered, eight species alone represented 80% of the total biomass caught: Common Dentex (21.60%), Greater Amberjack *Seriola dumerili* (15.30%), Dolphinfish *Coryphaena hippurus* (13.58%), Bluefin Tuna *Thunnus thynnus* (9.85%), Blackspot Seabream *Pagellus bogaraveo* (7.01%), Black Seabream *Spondyliosoma cantharus* (6.15%), and Bullet Tuna *Auxis rochei* (5.76%) (Figure 10).

In terms of abundance, eight species represented 80% of the total number of individuals caught: Comber *Serranus cabrilla* (35.12%, 886 individuals), Blackspot Seabream (12.13%, 306 individuals), Black Seabream (10.58%, 267 individuals), Painted Comber *Serranus scriba* (8.52%, 215 individuals), Dolphinfish (4.30%, 111 individuals), Bullet Tuna (3.92%, 99 individuals), Mediterranean Horse Mackerel *Trachurus mediterraneus* (3.49%, 88 individuals), and Common Dentex (2.81%, 71 individuals) (Figure 11).

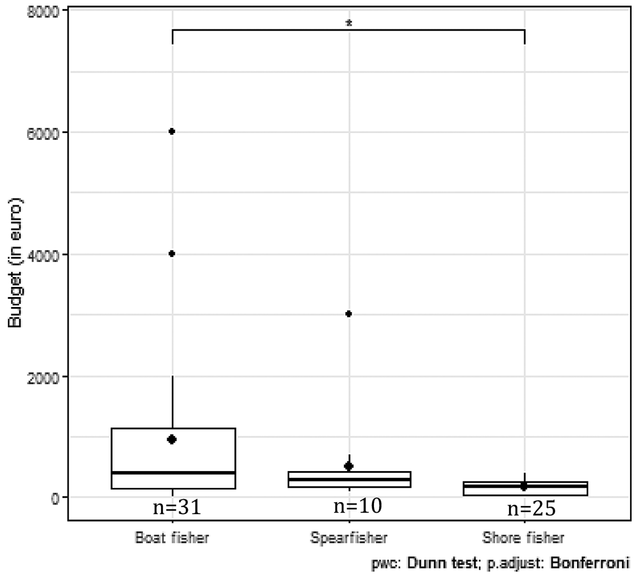

FIGURE 7 Annual budget of fishers ($n=67$) according to their type of fishing, with mean (diamond symbol), median (horizontal line in the box), first and third quartiles (bottom line and upper line of the boxes), the 5th and 95th percentiles (black whiskers), and outliers (black dots). The asterisk symbols represents significant fishing modality differences (one asterisk: $p<0.05$, two asterisks: $p<0.01$, three asterisks: $p<0.001$, and four asterisks: $p<0.0001$).

Compliance with regulatory legal sizes of Mediterranean species

Among all individuals caught and measured, approximately half (48.97% of fish landed) were smaller than the length at which they can be legally retained (defined at the national level by the Decree of 26th October 2012).

The legal size per species, set for recreational fishers, is only respected in the case of four species: Forkbeard *Phycis phycis* ($n=4$), Surmullet *Mullus surmuletus* ($n=4$), Mediterranean Horse Mackerel ($n=17$), and Common Two-banded Seabream *Diplodus vulgaris* ($n=22$). For the species Common Pandora *Pagellus erythrinus* ($n=14$), Red Porgy *Pagrus pagrus* ($n=30$), and Gilt-head Sea Bream *Sparus auratus* ($n=6$), only one or two individuals per species measured below the legal size (Figure 12).

Bluefin Tuna ($n=12$), Blackspot Seabream ($n=186$), Black Seabream ($n=129$), and Red Scorpionfish *Scorpaena scrofa* ($n=15$) are the species the most impacted by non-compliance with the regulations in place, with respectively 91.67, 86.02, 27.13, and 33.33% of the individuals caught and measured not corresponding to the minimum size authorized (Figure 12).

DISCUSSION

Overview of social characteristics and fishing practices of recreational fishers in the Balagne region

The estimated proportion of recreational fishers globally ranges from 3% (Kelleher et al. 2012) to 11.5% (Cooke and Cowx 2004). However, this rate varies across the regions (Cooke and Cowx 2006; Hyder et al. 2018). This study constitutes a preliminary phase aiming at acquiring knowledge about recreational fishing activity in Balagne, the northwestern region of Corsica (France). Telephone surveys estimated that the population of resident recreational fishers in Balagne accounted for 10.23% of the total population for the reference year 2020. This estimate aligns with the proportion of recreational fishers assessed in French Mediterranean regions, which ranges from 5% to 10% (Herfaut et al. 2008, 2013). Other studies conducted in Corsica have reported similar findings, such as 7.49% of the population in Cap Corse (northeastern region) in 2012 (Girard 2012) and 12% in the Bouches de Bonifacio Nature Reserve (Tomasi 2011), which is consistent with our results.

The data collected allowed us to first quantify the recreational population and then to describe their profiles and practices. Some characteristics of recreational sea fishing are specific to Mediterranean countries as demonstrated in different studies (Morales-Nin et al. 2005; Lloret et al. 2008; Unal et al. 2010; Font and Lloret 2011; Herfaut et al. 2013; Gordoa et al. 2019) and consistent with the results presented here. Indeed, the characterization of recreational fishers showed that they were most often middle-aged men (between 40 and 50 years old). Nevertheless, the average age of the individuals varies based on their fishing practice. Spear fishers are on average younger, which can be explained by the fact that this activity requires a good physical condition (e.g., resistance to cold, swimming, apnea). Boat fishers are on average older and mostly retired. These social profiles have been referenced in numerous studies (Morales-Nin et al. 2005; Lloret et al. 2008; Herfaut et al. 2013; Gordoa et al. 2019).

Fishing characteristics

According to our results, fishing from a boat is the most practiced type of fishing (29.90%), closely followed by shore fishing (28.29%). Similar observations have been made in other Mediterranean areas, where boat fishing is the most common practice, followed by shore fishing and spearfishing (Morales-Nin et al. 2005; Unal

TABLE 1 Declarative fishing characteristics for each type of fishing.

Variables	Modalities	Shore fishers ($n = 25$)	Boat fishers ($n = 31$)	Spear fishers ($n = 10$)
Mean ± SD number of trips per week		1.16 ± 1.02	1.20 ± 2.11	1.11 ± 1.07
Mean duration of fishing trip (in hours)		4.28 ± 1.98	4.90 ± 1.70	3.71 ± 0.94
Mean fishing experience (in years)		21.50 ± 14.60	22.0 ± 16.10	21.70 ± 13.30
No-kill practice (in %)	Yes	90.00	56.67	Not concerned
	No	10.00	43.33	Not concerned
Preferred fishing season (in %)	Annual	55.00	63.33	41.18
	Summer	0.00	6.67	0.00
	Winter	10.00	6.67	0.00
	Spring	0.00	0.00	11.76
	Autumn	5.00	0.00	0.00
	Spring–summer	0.00	6.67	17.65
	Except summer	25.00	10.00	23.53
	Except winter	0.00	3.33	5.88
	Except summer and winter	5.00	3.33	0.00
Preferred day (in %)	Indifferent	65.00	73.33	76.47
	Week	10.00	0.00	0.00
	Weekend	25.00	26.67	23.53
Preferred hours (in %)	Indifferent	30.00	36.67	17.65
	Morning	30.00	53.33	52.94
	Afternoon	5.00	0.00	0.00
	Day	0.00	3.33	17.65
	Evening	30.00	0.00	5.88
	Morning–evening	5.00	6.67	5.88
Relationship with other users of the sea (in %)	Good	85.00	83.33	64.71
	Indifferent	0.00	0.00	0.00
	Conflicting	15.00	16.67	35.29
Awareness of regulations for recreational fishing (in %)	Good	60.00	70.00	70.59
	Medium	25.00	20.00	29.41
	Bad	15.00	10.00	0.00
Loss of equipment at sea (in %)	Yes	75.00	80.00	35.29
	No	25.00	20.00	64.71

et al. 2010; Gordoa et al. 2019). Another characteristic often shared by recreational fishers is the duration of fishing trips; the duration varies slightly among fisheries, but the overall average trip duration (between 3.71 h/day and 4.8 h/day) correlates with the range previously estimated in the Mediterranean (Morales-Nin et al. 2005; Lloret et al. 2008; Unal et al. 2010; Veiga et al. 2010; Font and Lloret 2011; Gordoa et al. 2019). Spearfishing trips are slightly shorter as previously observed by Gordoa et al. 2019. Shore fishers reported practicing no-kill fishing more than boat fishers. There are two main categories of no-kill: regulatory no-kill as a response to management regulations and voluntary no-kill where fish that legally could be kept are released deliberately (Arlinghaus et al. 2007). According to discussions we had with fishers, shore fishers voluntarily release fish mainly when the species caught does not interest them for consumption, often rockfish (authors' unpublished data). On the other hand, boat fishers practice no-kill more because of the regulations. Indeed, the catches of boat fishers are generally species with a high commercial value and they do not particularly wish to release them. Boat fishers are also confronted with problems related to barotrauma of the fish, as they fish at greater depths

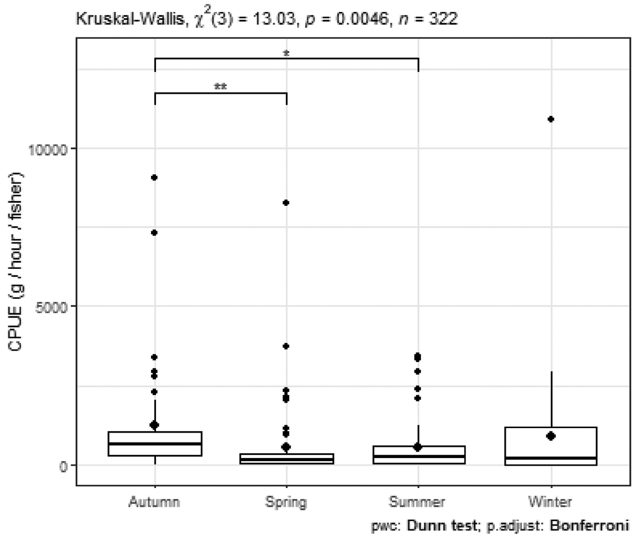

FIGURE 8 Catch weight per unit effort of boat fishers (in g/day/fisher) according to seasons, with mean (diamond symbol), median (horizontal line in the box), first and third quartiles (bottom and upper line of the boxes), the 5th and 95th percentiles (black whiskers), and outliers (black dots). The asterisk symbols represents significant differences between seasons (one asterisk: $p < 0.05$, two asterisks: $p < 0.01$, three asterisks: $p < 0.001$, and four asterisks: $p < 0.0001$).

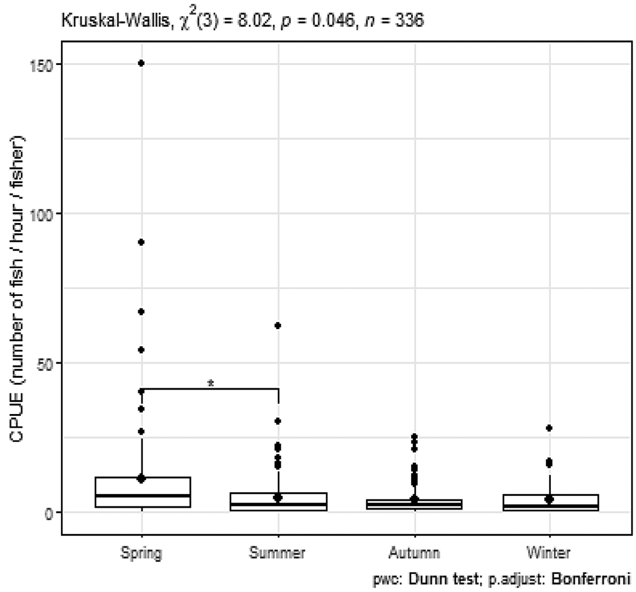

FIGURE 9 Catch per unit effort of boat fishers (in number of fish/day/fisher) according to seasons, with mean (diamond symbol), median (horizontal line in the box), first and third quartiles (bottom and upper lines of the boxes), the 5th and 95th percentiles (black whiskers), and outliers (black dots). The asterisk symbols represents significant differences between seasons (one asterisk: $p < 0.05$, two asterisks: $p < 0.01$, three asterisks: $p < 0.001$, and four asterisks: $p < 0.0001$).

than shore fishers and do not know how to release fish effectively (authors' unpublished data).

Lastly, a majority of both shore and boat fishers declared losing equipment regularly during their fishing trips (e.g., lead; hooks; line; and, more rarely, fishing rods and floating anchors). As a result of the issues related to mercury poisoning (Goddard et al. 2008; Pokras et al. 2009; Watson et al. 2009; Lloret et al. 2014), various devices that are frequently lost while fishing, such as floats or lines (nylon), are made of various types of plastic that are highly resistant to degradation and therefore can remain for decades (Ryan et al. 2009; Serra-Gonçalves et al. 2019). Pieces of nylon have been found in fish stomachs (Boerger et al. 2010; Possatto et al. 2011). Fishing lines can also impact sessile organisms (e.g. gorgonians, sponges, corals) by causing abrasions, strangulation, or a reduction of sunlight, leading to a consequent weakening of organisms (Chiappone et al. 2002; Asoh et al. 2004). In view of our results, and according to Lloret et al. 2014, specific studies are needed to quantify and to determine the real impact of the loss of recreational fishing gear at sea.

In the Balagne region as a whole, the spatial distribution of the activity is heterogeneously distributed and shows hot spots of frequentation, mainly around the ports of Calvi and L'Ile-Rousse but also along the coast in places without vertical drop that are easily accessible by foot or car (particularly for shore and spear fishers). It has been shown that the choice of a fishing site depends on various attributes of the site, namely proximity, fishing quality, environmental quality, facilities, encounter levels, and fishing regulations (Hunt 2005). The fact that fishers choose fishing sites for a variety of reasons, other than simply fishing quality, could allow managers to influence distribution of fishers, for example by closing car access to certain locations. In addition, coastal zone managers could establish zoning plans according to the identified hot spots.

In addition, 6.75% of fishing trips were made in offshore areas, more than 6 nautical miles from the coast. The furthest fishing trip recorded during our study was up to 50 nautical miles offshore. There is little information on recreational fishing offshore, and in most studies this type of practice is not considered (Font and Lloret 2014; Lloret et al. 2020). However, some studies have shown that most recreational fishing offshore targets vulnerable species; therefore, this type of fishing needs to be studied and monitored more closely (Lloret et al. 2020; Panayiotou et al. 2020).

Boat fishing

Regarding seasonal variability of the CPUE, only 1 year (2019) could be sampled across all seasons, which did not allow us to draw solid conclusions. Our results bring

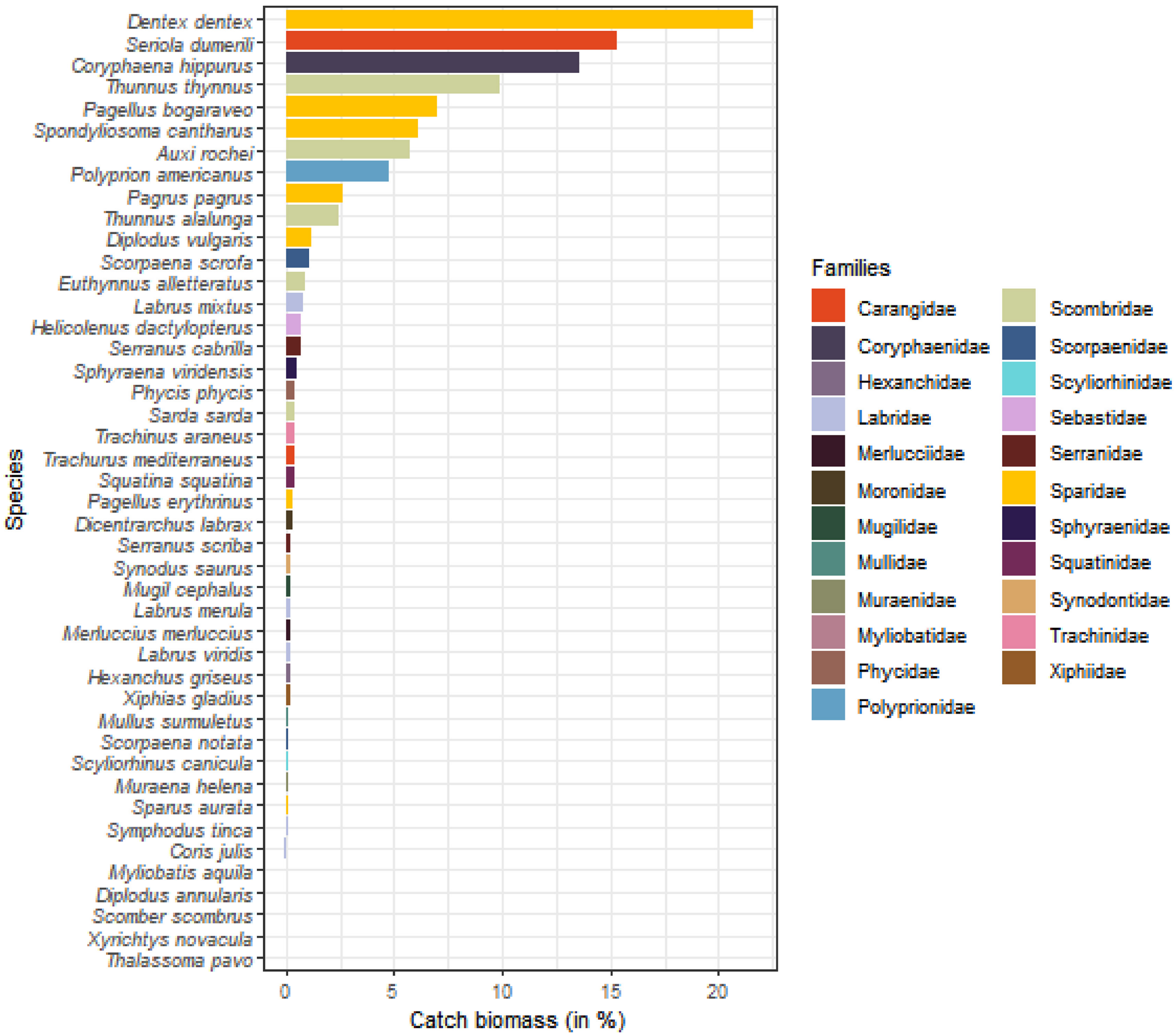

FIGURE 10 Percentage of total biomass caught per species.

therefore a first rough estimate that will have to be confirmed by further studies. Nevertheless, seasonal variability seems to mainly result from an abundance of targeted species and variations in the fishing techniques used based on the weather conditions.

Differences observed between the CPUEs calculated from logbooks, photographs, and boarding can be explained by the method of data acquisition and rigor of fishers in systematically filling out or sending information about their fishing activity. Indeed, we noted throughout the study that although fishers tended to note in their logbooks or to send us photos of their catches regularly, they forgot to report on their fishing trips when they did not catch anything. These biases are well recognized in the scientific literature (Lewin et al. 2021, 2023 and references therein). Despite the methods we implemented to mitigate these biases (see below), it is possible that the CPUE calculated from logbooks and photographs may be overestimated. Nonetheless, CPUE values between 222 and 789 g/h/fisher obtained in this study are within the ranges of those observed elsewhere in the Mediterranean. Indeed, the highest value of CPUE for boat fishing was estimated to be 2770 g/h/fisher in Turkey (Unal et al. 2010), while other CPUEs for boat fishing vary between 200 and 1000 g/h/fisher depending on the study considered (Font and Lloret 2014 and references therein). Research has demonstrated that boat fishing has the greatest extractive potential compared to spearfishing or shore fishing (Luna-Pèrez 2010; Charbonnel et al. 2011; Lloret and Font 2013; Font and Lloret 2014).

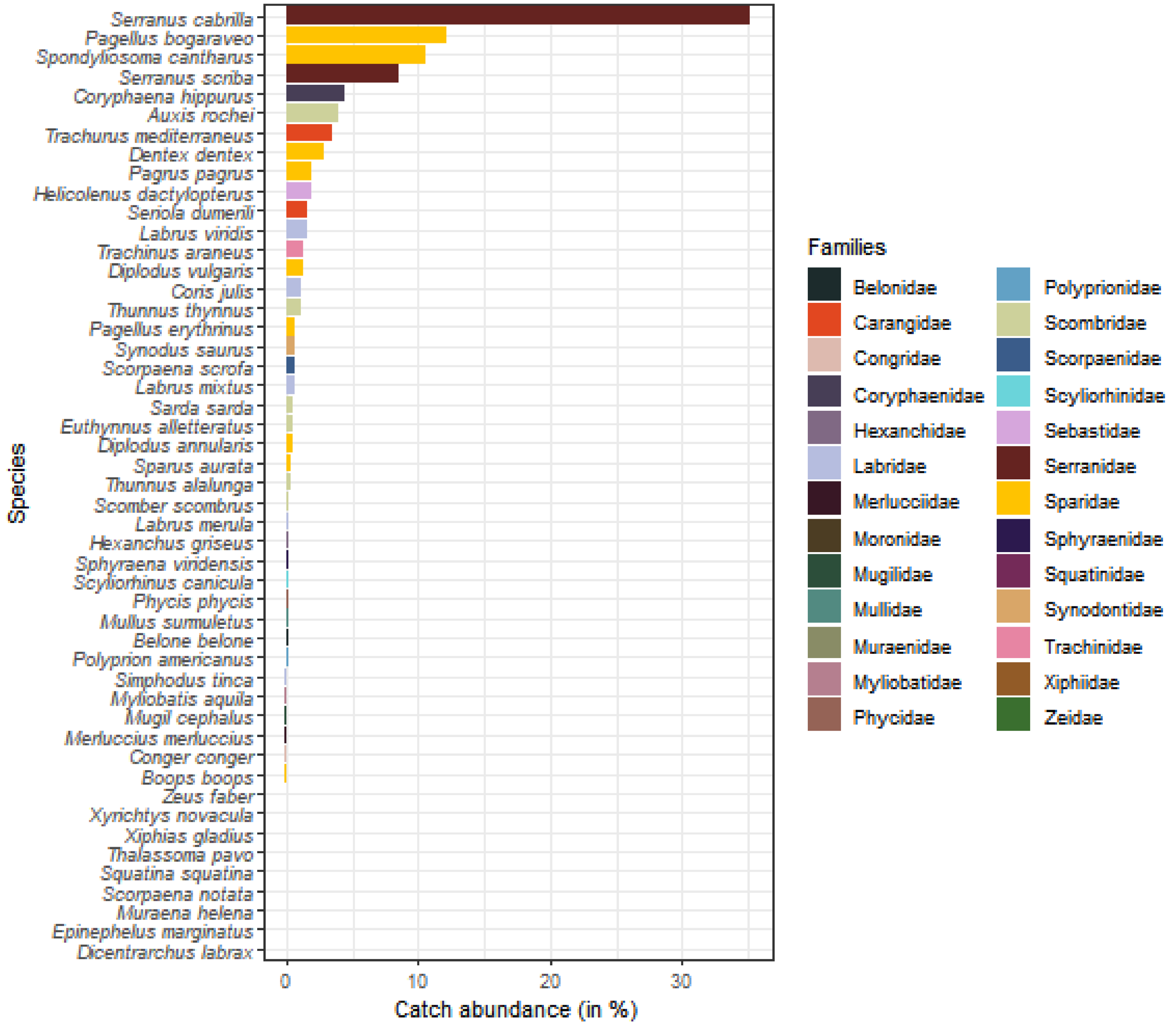

FIGURE 11 Percentage of total number of individuals caught per species.

Despite the high diversity of the species caught, the main marine fish species caught by boat fishers were Comber, Blackspot Seabream, Black Seabream, and Painted Comber by number and Common Dentex, Greater Amberjack, Dolphinfish, and Bluefin Tuna by weight. Effects of boat recreational fisheries on pelagic species appear to be important since several pelagic species are targeted by fishers and are among the most frequently caught (Greater Amberjack, Dolphinfish, and Bluefin Tuna). Moreover, these species are highly migratory and Bluefin Tuna is classified as endangered in the Mediterranean (Di Natale et al. 2011). As has been shown in many studies, catchability of species depends greatly on the fishing technique used and fishing depth (Morales-Nin et al. 2005; Lloret et al. 2008; Gordoa 2009; Vega and Licandeo 2009; Font and Lloret 2014). Although in this study we did not specifically study the relationship between fishing technique used and species caught, during the boardings carried out we were able to observe that pelagic species (Dolphinfish, Greater Amberjack, and Bluefin Tuna) were caught by trolling and Comber, Black Seabream, and Painted Comber were caught with fishing rods on shallow bottoms (<50 m) while Blackspot Seabream was mainly caught by deep fishing (>50 m) at the beginning of Calvi canyon. Species targeted by boat fishers also explain the spatial distribution of the activity around and in Calvi Bay. Indeed, hot spots for recreational fishers are located around Calvi aquaculture farm, around Algajola hazard (beacon), and along the Revellata Cap, where several marker buoys are present. This is explained by the fact that the species sought, such as Dolphinfish, Greater Amberjack, Bullet Tuna, or Bluefin

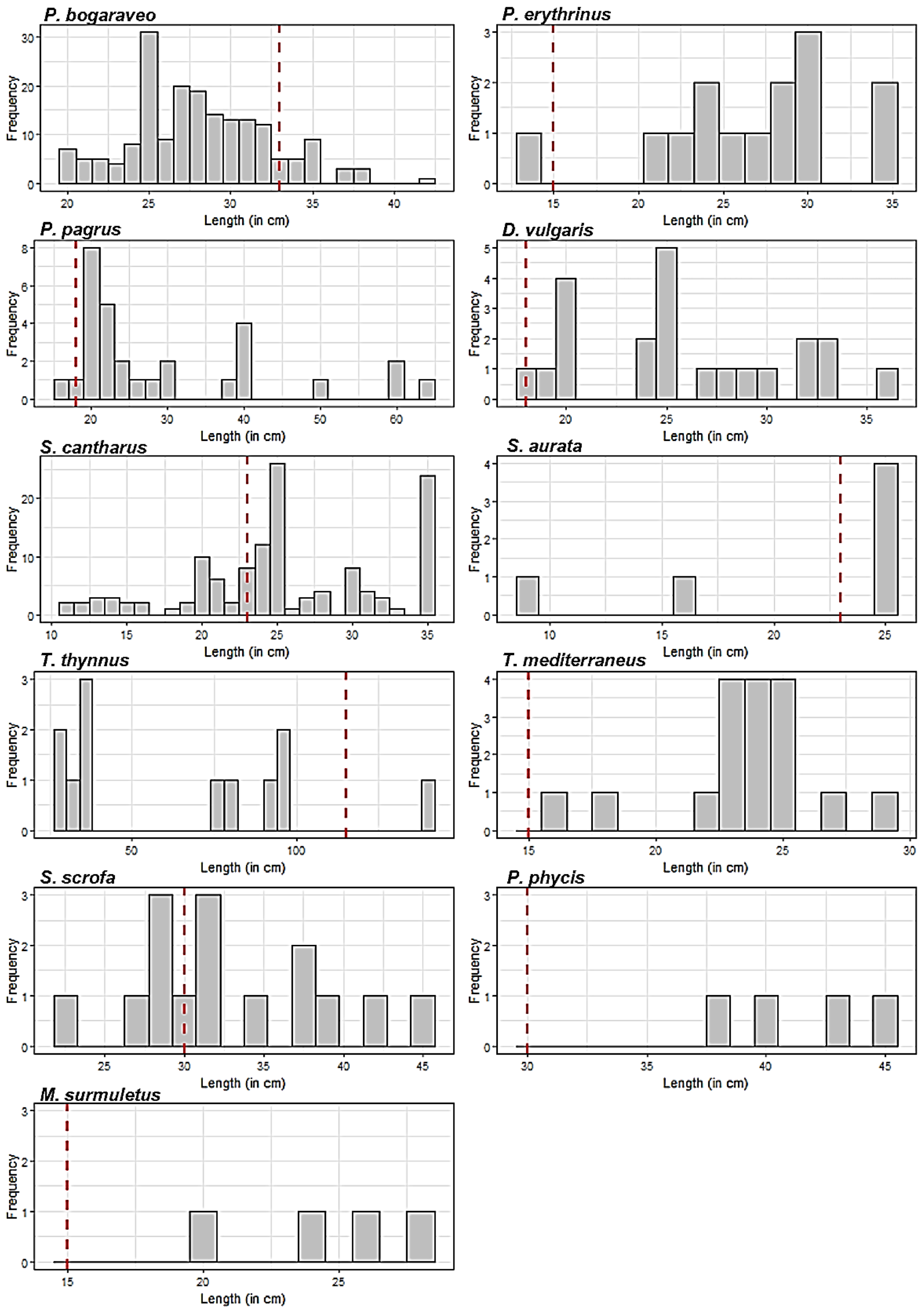

FIGURE 12 Catch size distribution of Mediterranean regulated species sampled between 2018 and 2020 ($n=439$). Minimum catch sizes are indicated by the red dashed line.

Tuna, are caught mainly by trolling near the surface (authors' personal observation) and near artificial structures or floating objects. Indeed, these species are known for their aggregative behavior around fish-aggregating devices or marine aquaculture farms (Andaloro et al. 2007; Arechavala-Lopez et al. 2015; Relini et al. 1994; Šegvić Bubić et al. 2011; Taquet 2004; Taquet et al. 2007a, 2007b; Iborra et al., submitted).

The absence of data from spearfishing and shore fishing, the constraints of the survey method to reliably estimate fishing effort, and the lack of a registry or license listing all recreational fishers in Balagne are among the limitations of this study. A scoping survey conducted across the entirety of Corsica could have facilitated the determination of socioeconomic characteristics within the parent population of recreational fishers. This approach would have enabled us to weight the data obtained in this study, striving for a fisher sample that is as representative of reality as possible.

Our results indicate that the biological effects of recreational boat fishing on fauna are relatively large compared with commercial fishing. As a matter of fact, for Corsica as a whole, commercial landings were estimated to be about 378 metric tons in 2019 (all species) and 50.5 metric tons for the Balagne region (DACOR Project 2019). However, these estimates are certainly underestimated since only net fishing is considered and not longline and pot fishing, which are also widely practiced in Corsica. If 611 boat recreational fishers are considered (calculated as 29.91% boat fishers of the 2046 fishers in Balagne), then the total annual production of boat fishers would be 42 metric tons. This estimation derives from calculated values of CPUE per trip (expressed as total catch per hour of fishing and per fisher) and annual fishing effort (average duration of trips multiplied by the average number of trips per year). The proportion of harvest attributed to boat recreational fishery in Balagne would therefore be approximately 11% of the total production of professional fishery in Corsica or 83% of the total production of professional fishery (net fishing only) in the Balagne region. These results appear to be consistent with those obtained by Lloret et al. 2008, who estimated total annual production of boat fishers in a smaller area in Spain (355 ha, Marine Protected Area of Cap Creus) of about 20 metric tons per year, i.e., about 40% of the total production of professional fishery. In other Mediterranean marine areas, the contribution of the recreational fishery in total catch ranges from 10% to 50% of total commercial catches (Morales-Nin et al. 2005; Lloret et al. 2008; Colella et al. 2010; Unal et al. 2010; Hussein et al. 2011; Lloret and Font 2013). However, at the global scale, Cooke and Cowx (2004) estimate that recreational fishery is responsible for approximately 14% of total commercial fishery production.

Compliance with legal sizes of Mediterranean species

In our study, about 50% of catches (all species) did not respect legal minimum catch sizes. Species most affected are Bluefin Tuna, Blackspot Seabream, Red Scorpionfish, and Black Seabream. In the Mediterranean, several studies have already shown that for some species (mainly White Seabream *D. sargus*, Common Two-banded Seabream, or Red Porgy), the size of individuals caught is smaller than the minimum catch size, which means that some recreational fishers land immature fish. This is of real concern since age and size at sexual maturity are fundamental variables that deeply influence the reproductive potential of a fish stock (Trippel et al. 1997; Marteinsdottir and Begg 2002). If reproductive potential is impaired, then the ability of a fish stock to produce viable offspring that can be recruited to the adult population or fishery will also be impaired (Trippel 1999). In addition, in France, Bluefin Tuna is subject to specific regulations with an obligation to tag and declare catches; however, in the great majority of cases, this is not done by recreational fishers (authors' personal observation).

Limitations and potentials biases of the study

During telephone surveys, nonresponse and refusal by respondents generate an unknown bias in the sample estimates and extrapolation of the results (O'Neil 1979). The main problem posed by nonresponse is assessing whether nonrespondents differ significantly from respondents (Lewin et al. 2021). This bias can arise from the limited coverage of a study or voluntary nonresponse by participants. In our study, we encountered three types of nonresponse: (1) no telephone response, accounting for 51% of the telephone numbers used; (2) incorrect or unassigned numbers (33%); and (3) individuals who declined to participate, comprising 1.24% of the numbers called. Furthermore, it required 2576 calls to obtain 387 respondents, resulting in a completion rate of 14.95%.

In the case of telephone nonresponse, it is particularly challenging to determine whether nonrespondents are similar to respondents as various factors may contribute to nonresponse. Firstly, the sampling plan used for the telephone surveys did not exhaustively cover the entire target population of recreational marine fishers. In France, the latest telephone directories for individuals date from 2017, and no new directories have been published since then. While a paid-for telephone database (including both landline and mobile numbers) could have helped address this issue, the budget allocated to this study did not allow us to utilize it.

Secondly, it is known that some landline telephone numbers were unlisted and therefore not included in the phone book used. However, despite growing concerns about the use of land-based telephone directories as a sampling source due to the increasing prevalence of exclusively mobile households, Teixeira et al. (2016) demonstrated that there was no significant difference between the fishing activity of fishers listed in the telephone directory and that of unlisted fishers. Thirdly, it is possible that sampled individuals were not at home during the survey calls. However, to address this type of nonresponse bias, each nonrespondent number was called back three times, on different days and at different times. This sampling plan aimed to ensure that each household had an equal probability of being reached, thereby increasing the likelihood that the group of respondents would be similar to that of nonrespondents. Additionally, the COVID-19 pandemic led to strict home confinement measures in France from March 17 to May 11, 2020, significantly limiting people's movements. This restriction likely improved the response rate. Furthermore, the low percentage of households that refused to respond (1.24%) suggests that the potential bias from this aspect of the survey was likely minimal.

Declarative and voluntary investment in scientific research can introduce certain biases as highlighted in the literature (Levrel et al. 2010). To address these biases, we implemented several strategies: (1) printing and distribution of guidelines in each logbook to explain how to complete the logbook and provide practical examples; (2) organization of numerous communication events to explain the study objectives and best practices for completing the logbook (Iborra 2022); (3) provision of direct telephone access to the scientist in charge of the study, encouraging fishers to call at any time if they encountered any problems; and (4) development of photographic protocols and distribution of measuring sticks aimed at reducing biases (e.g., enabling visual control of captured species and sizes).

Furthermore, it is known that fishers who agree to provide their data are often the most involved and passionate about fishing (Thomson 1991; Lewin et al. 2023). This bias can lead to overestimating the total results obtained. One approach to mitigate this effect is to divide the sample into different strata based on factors such as fishing frequency hierarchy and type of fishing. Weighting factors assigned to each fisher can then compensate for the overrepresentation of certain strata in the sample compared with the total population of fishers (Dorow and Arlinghaus 2011). However, due to the limited number of fishers in this study, we were unable to utilize this method. Instead, we chose to assess the total annual production only for boat fishing, based on data acquired by fishery observers, as explained earlier in the discussion.

Finally, we utilized CPUE, considering the duration of fishing as the unit of effort, without accounting for the specific gear used, such as the number of hooks or the length of the net. Our objective was to compare catches among different categories of fishers rather than assessing the effectiveness of individual gear types. However, comparing CPUE across different gear types, using metrics like the number of hooks as a unit of effort, could enhance our understanding of recreational fishing techniques and characteristics. Additionally, collecting and analyzing additional data on factors such as boat size, engines, presence of GPS, fish finders, electric reels, bait used, etc., would provide valuable insights. These details were not available in our study, limiting our ability to assess these characteristics. Future studies incorporating such data will be necessary to comprehensively understand these variables.

CONCLUSION

This study highlights that socioeconomic and biological implications of recreational fishing are important and should therefore be considered in fish stock assessments and in overall management strategies of Mediterranean coastal areas. In addition, a more sustained enforcement of regulatory measures is recommended, as our results emphasize that many recreational fishers do not comply with the regulations about the activity, either in terms of species caught or in terms of minimum catch sizes that are not respected for some species. Furthermore, it is advisable to implement additional regulations that mandate fishing licenses in France and other countries. This requirement would enable more regular and effective monitoring of fishing activities. Studies on recreational fishing must continue to refine results, to totalize catches of all recreational fishing modalities, to identify catches related to tourist fishers, and finally to allow a fair and equitable treatment of the recreational fishing sector. In addition, it is expected that climate change will induce changes in distribution and abundance of species, which could increase competition for marine resources and lead to tensions between recreational and commercial fisheries. Measures could then be taken to encourage catches of some species over others, to recommend the use more selective gear, or to promote times or locations more conducive to the development of vulnerable species. Some management measures can be very unpopular; therefore, it is important to build trust with the recreational fishing community to encourage voluntary cooperation and minimize noncompliance. Recreational fishers are also sentinels of the sea who have years of knowledge about the species observed, the changes in distribution, and the behavior of fish in their local area. This local knowledge can be very valuable (Azzurro et al. 2019) and could even help scientists to monitor and understand climate change effects and how to best address them.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

This study meets the ethical guidelines outlined by the American Fisheries Society.

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APPENDIX: Additional Data

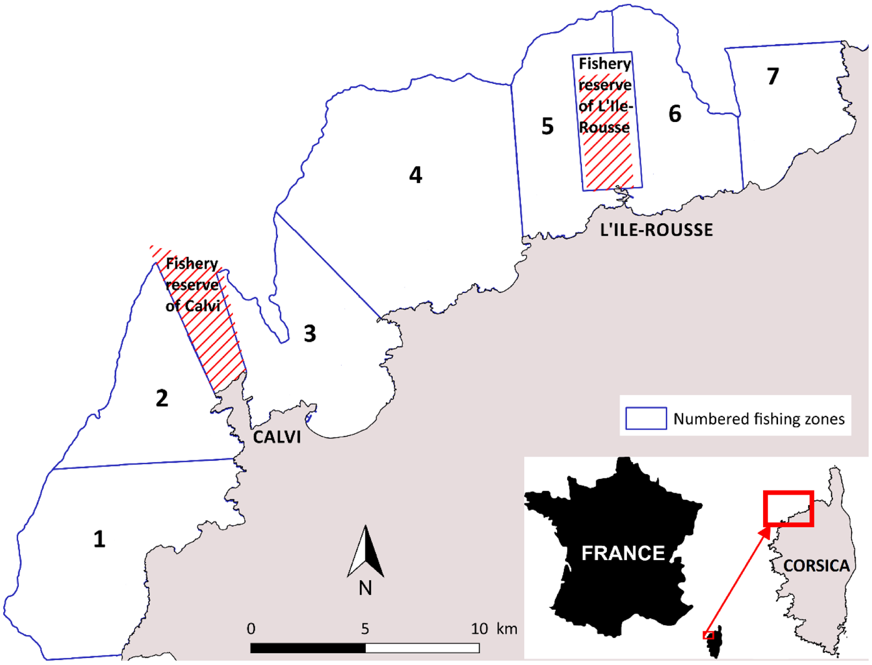

FIGURE A.1 Map of in situ sampling zones along the entire coastline of the Balagne region (northwestern Corsica). The striped areas represent fishery reserves, where professional and recreational fishing are prohibited.

TABLE A.1 Characteristics of our sample after adjustment compared with the Balagne population as a whole.

Variable	Modalities	INSEE Balagne population (%)	Interviewees (%) ($n = 387$)
Gender	Women	50	50
	Men	50	50
Age	15–29	17	17
	30–44	22	22
	45–59	24	24
	60–74	23	23
	75 and over	14	14

TABLE A.2 Summary table indicating the sample size for each group of fishers interviewed according to the different protocols used.

Survey protocol	Total number of fishers sampled	Number of boat fishers sampled	Number of shore fishers sampled	Number of spear fishers sampled	Number of mixed fishers sampled
Telephone survey	18	7	7	3	1
Field survey	8		8		
Opportunistic surveys (e.g., events, opportune meetings)	28	11	10	7	0
Logbook	4	4 (196 fishing trips carried out with 4 different fishers)			
Boarding	5	5 (35 fishing trips carried out with 5 different fishers)			
Photograph sent by fishers	4	4 (95 fishing trips carried out with 4 different fishers)			
Total of surveys	67	31	25	10	1