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Structure and spatio-temporal dynamics of the artisanal small-scale fisheries at the future MPA of "Taza" (Algerian coast, SW Mediterranean)

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Abstract

Artisanal Small-Scale Fisheries (SSFs) are a primordial and very diverse activity in the Mediterranean, also within Marine Protected Areas (MPAs). This diversity is explained in terms of target species, gears, and fishing strategies. The main objective of this work was to investigate the spatio-temporal dynamics of artisanal SSFs of the future MPA of "Taza" (Algeria, SW Mediterranean). Data were collected through direct assessment of daily landings and using questionnaires. They were the subject of multivariate analyses that allowed us to identify the *métiers* practiced by artisanal fishers. During the one year (May 2013 to April 2014) field work period, 1330 fishing trips and 1613 fishing operations in 16 fishing grounds were recorded in the Ziama fishing harbor, where 15.2 tons of total catch was assessed. Our results show that, in the study area, the boats are predominantly gillnetters and that among the five *métiers* characterized by target species, gear type, fishing grounds, and fishing seasons, two *métiers* ("*Mullus surmuletus* trammel net" and "Sparids monofilament gillnet") are practiced throughout the year, while the remaining three ("*Sarda sarda* driftnet", "*Merluccius merluccius* set gillnet", and "*Pagellus* set gillnet") are specific to a determined period of the year. The '*Mullus surmuletus* trammel net' *métier* represents 40% of the total fishing operations, of which 57.5% are carried out in the coastal sector at - 25 m. This study could contribute to defining the appropriate management approaches for SSFs in the future MPA of "Taza" by providing baseline information to build a sound management plan. In Algeria, it will certainly serve as a scientific reference in terms of zoning, protection of biodiversity, and specific monitoring at particular locations and periods of the year for the sustainable management of MPAs.

Keywords: Marine protected areas; Algeria; Taza; Mediterranean; small-scale fisheries.

Introduction

Artisanal fisheries represent more than 46% of global catches (including inland catches) and employ about 90% of the 120 million full-time and part-time commercial catchers (FAO, 2016a), the same source indicating that 90% of artisanal fisheries operate in developing countries. There is currently almost no common and universal definition of this activity. Generally, the term "artisanal" is difficult to define, its criteria varying according to the spatio-temporal and socio-cultural context (Griffiths *et al*., 2007; Carvalho *et al*., 2011). Artisanal fisheries are defined in the FAO glossary (FAO, 2005) as "*Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20 m trawlers, seiners, or long-liners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. Sometimes referred to as small-scale fisheries*". One of the most commonly used definitions refers to vessels less than 12 m in length corresponding to about 85% of the world's fishing vessels in 2014 (FAO, 2016b). Diverse terminology is used to define this fishing activity as it varies from region to region. Thus, "artisanal fisheries" are often referred to as "small-scale fisheries", although as Di Franco *et al*. (2014) report, some subtle differences between the two definitions are sometimes underlined. The term "artisanal" refers to the little technology used on fishing trips without reference to vessel size, while the term "small-scale" refers to the small size of the vessels without any implication of the degree of technology used (Di Franco *et al*., 2014).

In the Mediterranean context, with a considerable proportion of small vessels (<12 m) using basic technology, the term "artisanal small-scale fisheries" could be employed (Griffiths *et al*., 2007).

Throughout this article, we will refer to the term "artisanal small-scale fisheries" because of the common use of this term in both Mediterranean and Algerian contexts.

Artisanal small-scale fisheries and the Mediterranean MPAs

In the Mediterranean Sea, the artisanal small-scale fisheries (SSFs) have a high socio-economic relevance for the local communities as they represent an important share of the fish caught and constitute about 80% of the fisheries in terms of fishing vessels (Maynou *et al*., 2013). They are characterized by a diversity of target species, gear, and fishing tactics. As a result, this activity is very variable in time and space (Farrugio & Le Corre 1993; García-Rodríguez *et al*., 2006; Maynou *et al*., 2013; Moutupoulos *et al*., 2014; Grati *et al*., 2018). Despite the fact that SSFs are a primordial activity around the Mediterranean, including within Marine Protected Areas (MPAs) (Francour *et al*., 2001), the diversity and the great variety of their *métiers* create great uncertainty from the perspective of the protection and sustainable management of marine resources. Pelletier & Ferraris (2000) consider that the *métiers* correspond to fishing practices at the scale of the fishing operation, defined as the combination of four variables: one or more target species, a fishing gear, a fishing ground, and a period of the year (Biseau, 1998). Therefore, the identification of the main *métiers* practiced, as well as the distribution of effort and the catches associated with them, are essential elements for characterizing such fishing activity.

The establishment of zoned MPAs attempts to best meet the relative needs of the multiple user-groups (Francour *et al*., 2001). MPAs, coupled with other management tools, can fulfil biodiversity conservation and fisheries management objectives (Hilborn *et al*., 2004; Di Franco *et al*., 2016). Thus, the creation of an MPA may initially result in the displacement of fishing effort to the surrounding areas (Halpern *et al*., 2004) and the direct benefits to fishers are observed only after a sufficient amount of time (Claudet *et al*., 2008). In the Mediterranean MPAs, these benefits have been documented in a few studies and explained through three main phenomena: 1) an increase in abundance, biomass, and average size of fish (Ojeda-Martinez *et al*., 2007; García-Charton *et al*., 2008; Guidetti *et al*., 2014; Harmelin-Vivien *et al*., 2015; Giakoumi *et al*., 2017), 2) an enhancement of fisheries yields within the MPA (Goñi *et al*., 2010; Guidetti & Claudet, 2010), and finally 3) an increase in fishing catch, but also effort near the boundaries of the no-take MPAs due to the fish "spillover" effect (Stelzenmüller *et al*., 2007). The latter is defined as the net emigration of juveniles, subadults, and adults beyond the boundaries of the MPA resulting in fishery benefits in neighboring areas (Harrison *et al*., 2012; Colléter *et al*., 2014; Di Lorenzo *et al*., 2016). However, such benefits could be achieved if only adequate fisheries management rules and strategies are implemented. Following Di Franco *et al*. (2016), the presence of a SSF management plan is one of the five key attributes that can increase an MPA's performance in terms of fisheries management.

In the northern Mediterranean, several studies have investigated SSFs in the context of MPAs, most of which have described the structure of the different *métiers* practiced by small-scale fishers (i.e. Stergiou *et al*., 2006; Tzanatos *et al*., 2006; Forcada *et al*., 2010; Maynou *et al*., 2011; Leleu *et al*., 2014) and their impacts and pressure on fish stocks and habitats (i.e. Seytre & Francour, 2008; Cadiou *et al*., 2009; Guidetti *et al*., 2010). Other aspects of SSFs linked to MPAs have also been studied, such as: the socio-economic and socio-cultural dimensions (Himes, 2003; Ünal, 2003; Battaglia *et al*., 2010; Ünal & Franquesa, 2010; Maynou *et al*., 2013), the catch species composition (Stergiou *et al*., 2006; Forcada *et al*., 2009; Rocklin *et al*., 2009; Dimitriadis *et al*., 2015), and the potential bio-economic value (Merino *et al*., 2008 & 2009).

Studies of SSFs in the context of MPAs are scarce in the southern part of the Mediterranean. Tunisian coasts have been the focus of a few studies carried out mainly in the waters of the Gulf of Gabes by Jabeur *et al*. (2000) and in the North of the country by Abdessalem (1995) and Romdhane (1998). These studies focused respectively on the typology of the fleet and fishing techniques. In Algeria, the limited number of studies on artisanal fisheries has focused on the bio-economic modeling of small pelagic fish in the bays of Ziama in Jijel (Chakour, 2008) and Bou-Ismail in Tipaza (Maouel *et al*., 2014).

Small-scale artisanal fisheries are considered to be the dominant type of fishing in Algeria (Olivier & Franquesa, 2005; Chakour & Guedri, 2014). This activity is practiced by small boats three to nine meters long with between five and 40 horsepower and a crew of two to eight fishers depending on the gear used (Sahi & Bouaicha, 2003). With 2972 boats in 2007, the artisanal small-scale fleet in Algeria represents almost three quarters of the Algerian fishing fleet (MPRH *in* Bouzourène, 2009). Between 1999 and 2007, the growth rate of artisanal small-scale fishing boats reached 92% while that of purse-seiners and trawlers did not exceed 51% and 34% respectively (Bouzourène, 2009). This dissimilarity is related to the topography of the restricted and rugged continental shelf as a whole limiting fishing grounds to the coastal areas (Coppola, 2006; Derbal, 2007). In recent years, the artisanal SSFs in Algeria have been facing several challenges such as declining yields, pollution, habitat degradation, illegal and illicit fishing systems (Belhabib *et al*., 2012; Chakour & Guedri, 2014). That is why Algeria, like many countries, tries to protect its marine living resources, ecosystems, and related fisheries. In the context of the future establishment of MPAs along the Algerian coast, there is a need to systematically collect SSF data in order to characterize this activity and therefore provide a baseline that could be extremely valuable to set up sound management plans.

Given the future establishment of the "Taza" MPA and its potential impact on SSFs (Boubekri & Djebar, 2016), the present study aims to describe and analyze the artisanal SSF activity in the study area. To this end, given the lack of administrative monitoring and the declarative catches system for artisanal SSFs, landings were observed on a daily basis to describe fishing activities which is useful for understanding the spatio-temporal patterns of effort allocation and the resulting catches (Griffiths *et al*., 2007; Merrien *et al*., 2008).

The list of caught species and observed fishing yields for each *métier* will be useful for subsequent comparisons between the pre- and post-MPA periods.

Materials and Methods

Study area

The study area is located within the future MPA of Taza (Algeria, South-Western Mediterranean). In 2009, with the support from the network of MPA managers in the Mediterranean (MedPAN), Taza National Park began a process to include its adjacent marine area covering 9603 ha (Fig. 1). It is located in the West of the province of Jijel and extends along the three municipalities of Jijel, El-Aouana, and Ziama Mansouriah (Fig. 1). The shallows, Banc des Kabyles and Salamandre reef (Fig. 1), form abrupt ascents of the seafloor, which passes from - 100 m to - 50 m, and even to - 13 m, very quickly. The bottom relief in this area is mostly rugged, with deep falls or slopes and steep canyons with a sandy facies at a depth of - 50 m then beyond a mud facies at a depth of - 200 m (Leclaire, 1972). However, in the East of the Gulf of Béjaia (Fig. 1), between - 100 and - 500 m deep, there is a facies of coastal mud where *Pennatula phosphorea* and *Pennatula rubra* are found at depths of up to - 200 m and deep mud where *Funiculina quadrangularis* and *Kophobelemon leuckartii* are found at depths greater than - 350 m (Refes, 2011). However, the presence of shallows in this area justifies the catch of *Scorpaena* spp. species in soft bottoms.

The future MPA of Taza comprises 2 no-take zones (Fig. 1). The regulatory proposal for the no-take zones stipulates the authorization of vessel navigation without mooring and scientific research, while prohibiting commercial and recreational fisheries as well as all the other extractive uses (e.g. extraction of aggregates for construction). Two fishing ports are located near the future MPA: Boudis (36.81833° N, 5.774167° E) and Ziama (36.67694° N, 5.478889° E) pending the completion of work to build a third port in the municipality of El-Aouana (Fig. 1).

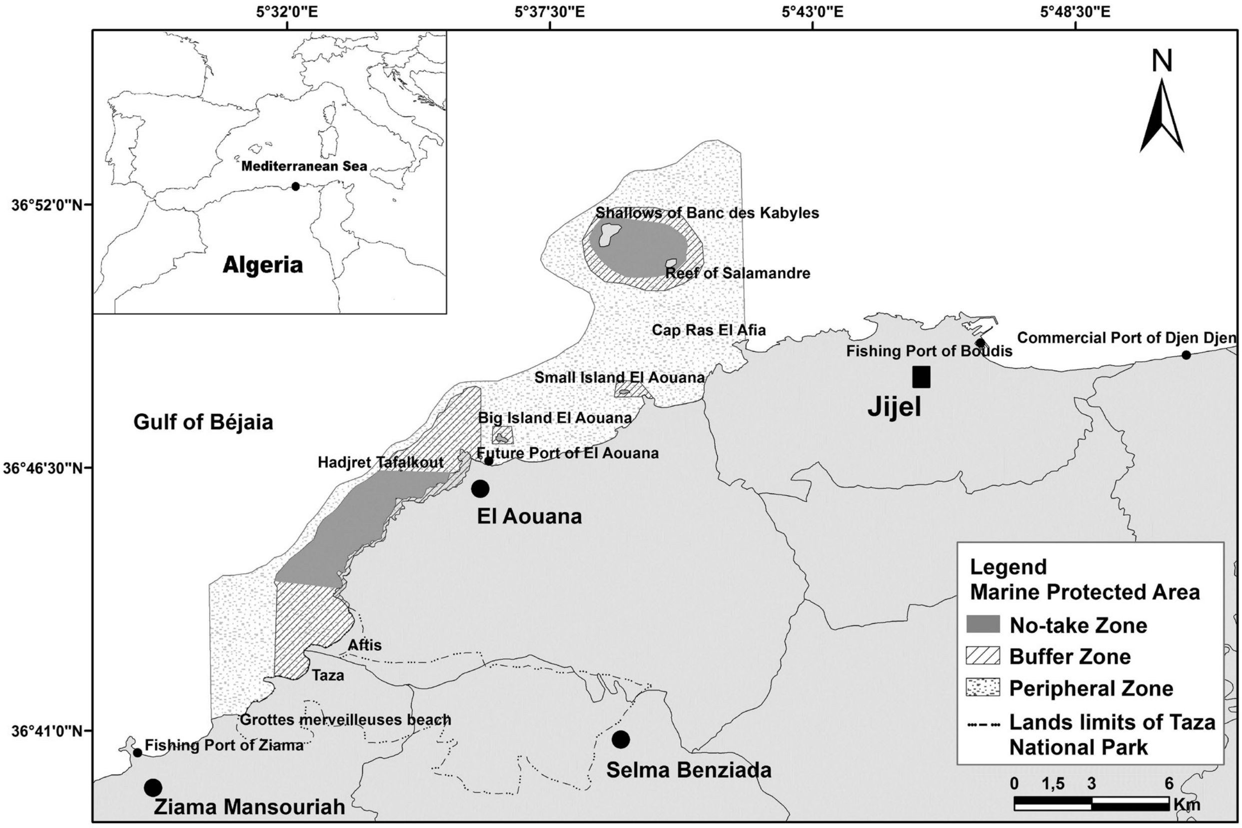


Fig. 1: Map showing fishing harbors, location and zoning plan of the future MPA of "Taza", Algeria. Source: Boubekri & Djebar (2016).

Experimental design and data collection

Official fleet data (length, horse power, and tonnage) were provided by the local Directorate of Fisheries and Aquaculture (DPRH of Jijel). In the study, catch data were collected via a direct observation method of landings on a daily basis between May 2013 and April 2014. Given the lack of administrative monitoring and the declarative catches system of artisanal small-scale fisheries, direct observations are commonly used to evaluate the effort and catches of this activity (Griffiths *et al*., 2007, Merrien *et al*., 2008). This methodology was suited to our case, so we drew inspiration from Ifremer's (French Research Institute for Exploitation of the Sea) Fisheries Information System - SIH (Merrien *et al*., 2008).

In order to characterize the artisanal small-scale fishery activity in Ziama harbor, during an annual cycle, daily observations were made with the help of two observers from the DPRH of Jijel. As vessels returned to the harbor to land their catch, the following data was collected: 1) vessel name by direct observation and 2) catches by interviewing fishers after sale to the operators which is carried out immediately after the vessels return to the harbor. When interviews with fishers were not possible in some cases, operators were surveyed. It should be noted that each vessel has some kind of informal contract with a well-defined operator whereby the sale of fish is exclusively reserved for her/him. Also, an operator may have several contracts with several vessels. Since the price of each species is different, the fishers classified the catch before landing operations while the operators weighted it (kg). However, for some caught fishes (e.g. seabreams, dentex, and scorpionfish), different species were landed together in the same fish crate and sold at the same price, in which case the weights recorded were grouped at a higher taxonomic level (i.e. genus or family) (please see the Appendix for more details about the concerned species). Catches were recorded for all the active vessels. Each day was thus characterized by an exhaustive record of catches for all fishing operations carried out by fishers.

In addition, weekly surveys were conducted using questionnaires to obtain information on the target species, the gear used (length, mesh size, and soak time), and the fishing ground (depth, location, and habitat characteristics). For the latter, map-based interviews were conducted with fishers, for which the interviewer and the informant used a hard copy map (Close & Hall, 2006). Once these data had been transformed from paper into a GIS (Geographic Information System), it was possible to draw the 16 locations frequented by the artisanal fishers of Ziama. In addition to the information provided by the fishers during the weekly surveys, some sea trips were organized to verify this information and limit the spatial uncertainty related to our cartographic representation. The drawings were obtained using the different reference marks and geographic coordinates, if any, provided by the fishers. It should be noted that fishers' Traditional Ecological Knowledge (TEK) is recognized as an effective tool for the management of artisanal fisheries and MPAs in the Mediterranean (Coll *et al*., 2014; Léopold *et al*., 2014; Pita *et al*., 2016).

Interview data show that this approach can produce a lot of useful information for assessing fisheries (Neis *et al*., 1999; Rocha *et al*., 2004). This method has already been used in the Mediterranean to assess landings and the fishing effort (Stelzenmüller *et al*., 2007; Merino *et al*., 2008; Cadiou *et al*., 2009; Forcada *et al*., 2010; Leleu *et al*., 2014; Falautano *et al*., 2018).

The choice of the harbor of Ziama allowed us to overcome logistical constraints while targeting a fleet that is mainly operational in the perimeter of the future MPA and which represents the largest segment in this area. For the small-scale boats of El-Aouana and Jijel, the widespread geographical dispersion of their places of landing made it impossible to conduct field observations.

In total, 1330 fishing trips and 1613 fishing operations in 16 fishing grounds were recorded, while 24 small-scale active boats out of the 28 observed were considered in this study. This is the set of boats that use nets as the main fishing gear. For these boats, all fishing trips were taken into account, even those taking place outside the zoning proposed for this future MPA. The remaining 4 observed active boats use lines and hooks as their main fishing gear. The data for the fishing operations of these boats were excluded in the statistical analysis because of their very small number.

Data analysis

The structure of the artisanal fleet by gear used and by: 1) tonnage, 2) horsepower, and 3) boat length was evaluated for Ziama harbor.

A Multiple Correspondence Analysis (MCA) was applied to the data from the active variables: target species, gear type, fishing ground, and fishing period. Then, the main factorial axes were kept for the Hierarchical Cluster Analysis (HCA) (Pelletier & Ferraris, 2000) based on Ward's criterion. The latter provided us with a scree plot to which a partition was applied. The cutoff level of the scree plot is determined by the number of clusters that should not be too large for the typology to be interpretable and by the inter-cluster inertia/total inertia ratio that must be high to reflect the structure of the fishing operations (Benzecri, 1982). The statistical analysis was carried out with the software Excel STAT®.

Each cluster obtained from the multivariate analyses is considered as a *métier*. Each *métier* is characterized by target species and/or groups of target species (5 categories), fishing gear (4 categories), depth (3 categories), and season (4 categories). Each cluster was further defined by: 1) fishing period, 2) main habitats, 3) depth and distance to the harbor, 4) soak time, and 5) stretched mesh size from the characteristic of the fishing operations included in it.

The number of species in the total landed catch was raised from the family to the higher taxonomic level. Regarding the target species, we retained in our study the approach of declarations by the fishers. This information was obtained when weekly surveys were carried out.

Also, the mean catch per 100 m of nets was calculated, for all species together and for the 5 most common species (in terms of frequency of occurrence) of each *métier*.

Fishing grounds were manually reported using geographic information system software (ArcGIS 9.3®). Each polygon was then considered as a fishing ground and the distance to the harbor was calculated from its center. The spatial distribution of the fishing effort of the various *métiers* is represented on the basis of the number of fishing operations carried out in the different fishing grounds observed.

Results

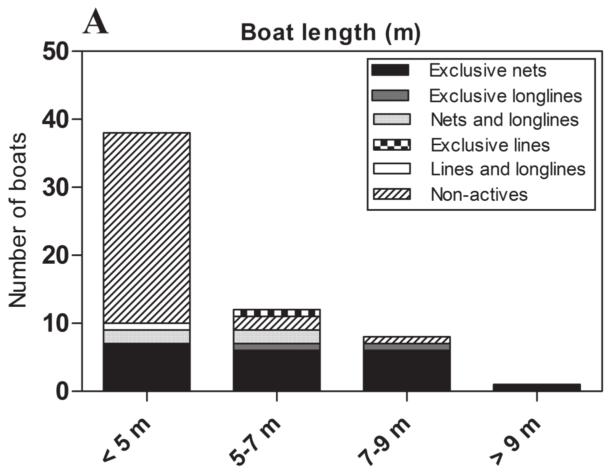
Fleet structure

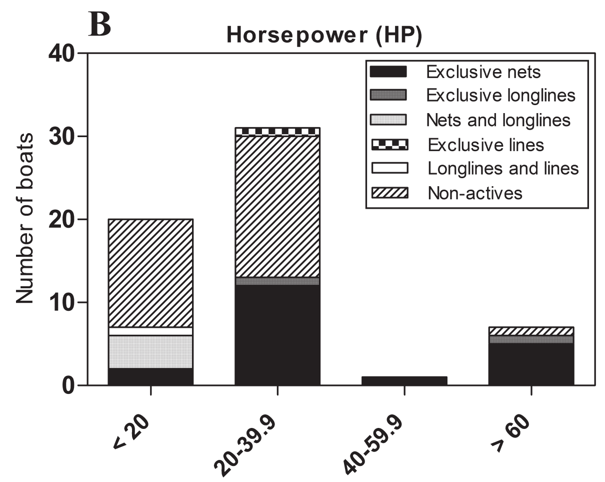
The fishing fleet present in the study area is mainly artisanal. In 2013, the category of small-scale boats accounted for approximately 77% of the total fleet registered in the department of Jijel (DPRH of Jijel, 2014), with 84 small-scale boats registered at Ziama harbor. If the small-scale boats operating as "purse-seiners" and the vessels outside this fishing harbor are excluded, only 59 remain. Of these, only 28 vessels were active between May 2013 and April 2014.

Gillnetting is common on all boats regardless of their length (Fig. 2). However, boats less than 7 m long represent 85% of the small-scale boats in Ziama harbor. The average length of the 28 active boats is 6.53 m, with lengths ranging between 4.80 and 10 m (Fig. 2A). In the category of <5 m boats, 90% were found to be inactive during the study period (Fig. 2A). The average engine power of active boats is 46.07 horsepower (HP), with engine powers ranging from 15 to 180 HP (Fig. 2B). The inactive boats have an average engine power of 24.67 HP, the average of exclusive gillnetters is higher than the global average with 51.15 HP. The total engine power of the active fleet is 1290 HP, or about 63% of the overall small-scale fleet (Fig. 2B). The average gross registered tonnage (grt) of the boats is 0.90 grt and the active boats are the largest, the widest, and the most powerful (Fig. 2C).

Métiers identification

Nine axes were needed to describe the entire inertia of the dataset (Table S1). The first 5 axes represent 81.28% of the inertia. Axis 1 with 24.94% of inertia is represented by the target species "*Sarda sarda*" with a 13.09% contribution to its construction (Table S2; Fig. S1). The representative gear of this axis is the driftnet with 13.09%, the "summer" season, and a depth of >40 m (16.57%). Axis 2 with 18.70% of inertia is represented by the group of target species "Sparids" with 21.67% and the monofilament gillnet (Table S2). Axis 3, with 17.80% of inertia, is characterized by 3 species and/or groups of target species: "Sparids" with 9.93%, "*Sarda sarda*" with 9.44%, and "*Mullus surmuletus*" with 9.44%. Axis 4 represents 11.48% of inertia, their 2 target species are "*Pagellus* spp." and "*Merluccius merluccius*", while these species constitute almost all of its construction with respectively 26.73% and 24.54% (Table S2).





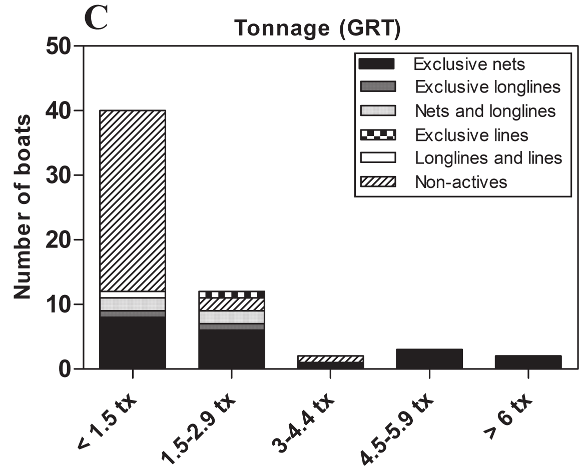


Fig. 2: Structure of artisanal small-scale fleet in the harbor of Ziama per gear used and per: A, boat length, B, horsepower, and C, gross registered tonnage over the studied year. Source: DPRH of JIjel.

The level of partition chosen from the dendrogram according to the gain of inertia between two levels of successive cuts gives 5 different clusters (Fig. S2). The inertia gain at the selected partition is 2.07 accounting for 69.26% of the total inertia of the dataset (Table S3). Thus, five clusters (hereafter called *métiers*) were obtained from the HCA. Each *métier* was named after the species and/or group of target species with which it was strongly related. Each *métier* is also characterized by a single gear: 1) the set gillnet for *Pagellus* (*Pagellus* spp.) and hake (*Merluccius merluccius*), 2) the driftnet for bonito (*Sarda Sarda*) , 3) the trammel net for surmullet (*Mullus surmuletus*)", and 4) the monofilament gillnet for Sparids (Table S4).

With regard to the depths at which the fishing operations are carried out, 96% of the fishing operations of the "Sparids monofilament gillnet" *métier* take place in depths ≤25 m, whereas the "surmullet trammel net" *métier* operates almost exclusively at depths of less than 40 m (i.e. 99.5%) (Table S4). 88.9% and 72.7% of the fishing operations of the "*Pagellus* set gillnet" and "hake set gillnet" *métiers* take place at depths >40 m respectively while the fishing operations of the "bonito driftnet" *métier* take place exclusively at depths >40 m (Table S4).

Each identified *métier* is characterized by a fishing period called the "season". "*Pagellus* set gillnet" fishing operations are characterized by the period from May to September and "bonito driftnet" from May to August, thus they are more frequently in summer (Table 1). Conversely, the "hake set gillnet" *métier* (December - April) is characterized by two seasons, spring and winter (Table 1). The "surmullet trammel net" and "Sparids monofilament gillnet" *métiers* are characterized primarily by the summer season (May - August); however, they can also be practiced in winter and spring (Table 1). Thus, the seasonality of the *métiers* is well marked in Ziama's small-scale fisheries.

Regarding the habitats frequented, the "*Pagellus* set gillnet" and "hake set gillnet" *métiers* are exclusively practiced on sandy substrates (Table 1). As for the "surmullet trammel net" and "Sparids monofilament gillnet" *métiers*, they mainly fish above rocky habitats near to *Posidonia* seagrass meadows (Table 1). However the "bonito driftnet" *métier* is also practiced on sandy and rocky substrates.

Regarding to the average distances to the fishing harbor, the "*Pagellus* set gillnet" and "bonito driftnet" *métiers* operated in the most remote locations compared to the other *métiers* at respectively 5855 and 5760 m, whereas the fishing operations of "hake set gillnet" and "Sparids monofilament gillnet" *métiers* take place in the first 2000 m with the respective percentages of 78% and 87% of their number (Table 1).

Each net was characterized by a length of 150 to 2000 m maximum and a mesh size of 22 to 45 mm according to the targeted species (Table 1). The net lengths observed varied considerably according to the *métier* practiced by the SSFs of Ziama. Thus, the "Sparids monofilament gillnet", "surmullet trammel net", and "hake set gillnet" *métiers* more frequently use nets of lengths <500 m, whereas for the "*Pagellus* set gillnet" and "bonito driftnet" *métiers*, they use lengths between 500 and 1000 m (Table 1). The "*Pagellus* set gillnet" *métier* is the one that uses the widest range of lengths, ranging from 150 to 2000 m (Table 1). The observation of the soaking times of the nets by fishing operation shows the existence of 3 distinct categories: 1) the category of "*Pagellus* set gillnet" and "hake set gillnet" *métiers*, the latter having long soaking times, with minimum durations of 24 h and maximums of 74 h and 72 h respectively (Table 1), 2) the category of "Sparids monofilament gillnet" and "surmullet trammel net" *métiers*, characterized by mid-range soaking times (i.e. between 20 and 26 h), and finally 3) the category that represents the shortest average soaking time (i.e. 5.3 h), characterizing the "bonito driftnet" *métier* (Table 1).

Catch composition and target species

A total of 40 taxa belonging to 27 families were observed in the catches of the 28 small-scale boats of the harbor of Ziama between May 2013 and April 2014, comprised of 36 species (or higher taxonomic level) of fish (31 Actinopteri and 5 Elasmobranchii), 1 species of crustaceans *Palinurus elephas*, and 3 species of cephalopod molluscs *Loligo vulgaris*, *Octopus vulgaris*, and *Sepia officinalis*. In total, 15,215 tons of catch were landed, of which 85.80% consisted in the 14 main and accessory target species (see Table 1). The data obtained are summarized in Appendix where the list of species (or higher taxonomic level) caught and their total catches per *métier* are reported.

The evolution of monthly landings of the main target species of the five *métiers* (Fig. 3) shows that the Axillary seabream (*Pagellus acarne*) fishing period is from May to August (Fig. 3A), that of the European hake (*Merluccius merluccius*) from March to October (Fig. 3B), and that of the Atlantic bonito (*Sarda sarda*) from May to August (Fig. 3E), thus marking a seasonal fishing activity. On the other hand, the striped red mullet (*Mullus surmuletus*) and the different species of seabreams (*Diplodus* spp.) are landed throughout the year (Figs 3C, D).

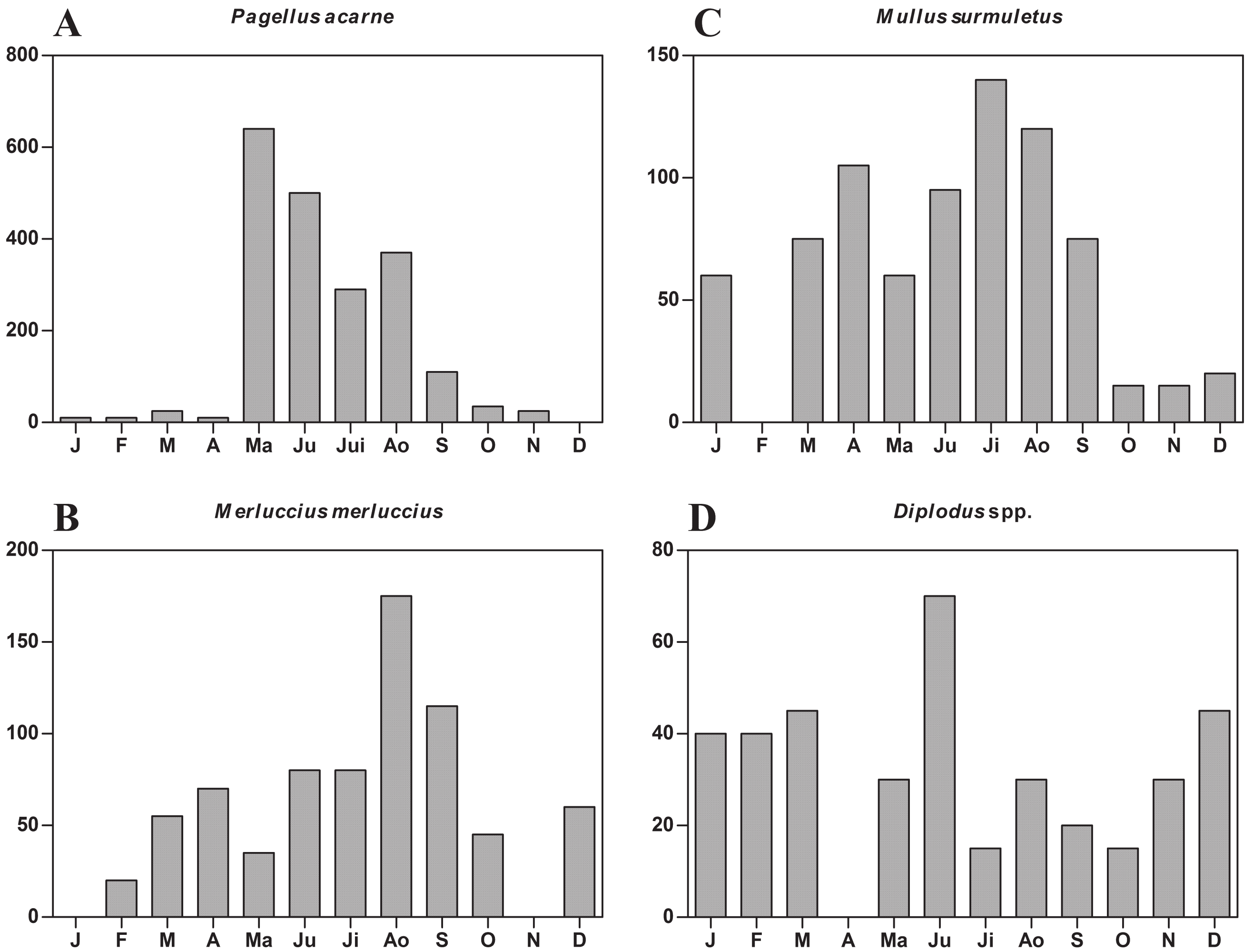
CPUE

The average values of the biomasses captured per 100 m of net or Catch Per Unit Effort (CPUE) of all *métiers* are greater than two kg (Fig. 4). The lowest CPUEs are those of the "*Pagellus* set gillnet", "hake set gillnet", and "surmullet trammel net" *métiers* (Fig. 4), while the overall CPUE of the "Sparids monofilament gillnet" *métier* is 2.5 kg/100 m net.

Species with the highest CPUE are often the main target species for the different *métiers* (Table 2). Thus, for the "*Pagellus* set gillnet" *métier*, *Pagellus acarne* represents the highest CPUE with 1.07 kg/100 m of net. In the same way, for the "hake set gillnet" *métier*, *Merluccius merluccius* represents the largest CPUE with 2.76 kg/100 m

Table 1. Description of the *métiers* according to the characteristics of the fishing operations included in each cluster. Each *métier* is described through its target species (main and accessory), its fishing period, the habitat visited (P, *Posidonia oceanica* meadow; R, rocky substrata; S, sandy substrata), the fishing ground (fishing depth and distance from the fishing port), and the net characteristics (mesh size, length, and soak time). Fishing period of each *métier* corresponds to the gray shading; no shading: less than 5% of the whole fishing operations observed during the specific month; light gray shading: between 5 and 10%; dark gray shading: more than 10% (sensu FAO, 1980).

Métier and gear (FAO code)	Target species: Main	Target species: Accessory	Fishing period (month): J	F	M	A	M	J	J	A	S	O	N	D	Habitat	Fishing ground: Depth (m) Range (mean ± sd)	Fishing ground: Distance to the fishing port (m) Range (mean ± sd)	Net characteristics: Mesh size (mm) Range (mode)	Net characteristics: Length of net (m) Range (mean ± sd)	Net characteristics: Soak time (h) Range (mean ± sd)
Pagellus Set gillnet 07.1.0	*Pagellus acarne*	*Squalus acanthias* *Scyliorhius canicula* *Merluccius merluccius*													S	24 - 450 225.6 ± 136.8	609 - 10470 5854.6 ± 2213.8	30 - 40 30	150 - 2000 1211 ± 681.4	24 - 74 49.1 ± 11.2
Hake Set gillnet 07.1.0	*Merluccius merluccius*	*Scorpaena* spp. *Pagellus acarne*													S	20 - 240 49.4 ± 20.9	609 - 6936 1702.4 ± 1159.3	30 - 30 30	150 - 2000 376.8 ± 465.4	24 - 72 37.8 ± 15.5
Bonito Driftnet 07.2.0	*Sarda sarda*	*Auxis rochei* *Euthynnus alletteratus*													S, R	45 - 400 103.9 ± 46.4	979 - 10470 5760.1 ± 3815	45 - 50 45	200 - 1600 590 ± 374.2	2 - 8 5.3 ± 2.1
Surmul-let Trammel net 07.5.0	*Mullus surmuletus*	*Sepia officinalis* *Mullus barbatus barbatus* *Diplodus* spp.													R, P, S	10 - 48 24.4 ± 7.8	609 - 1047 2424.3 ± 2096.9	22 - 40 22	200 - 800 362.8 ± 215.2	10 - 44 22.7 ± 8.9
Sparids Monofilament gillnet 07.9.1	*Diplodus* spp.	*Sarpa salpa* *Sarda sarda* *Seriola dumerili*													P, R, S	5 - 110 18 ± 16.8	609 - 7938 1571.3 ± 1564.8	45 - 45 45	200 - 300 202.6 ± 15.7	18 - 26 20.6 ± 2.6



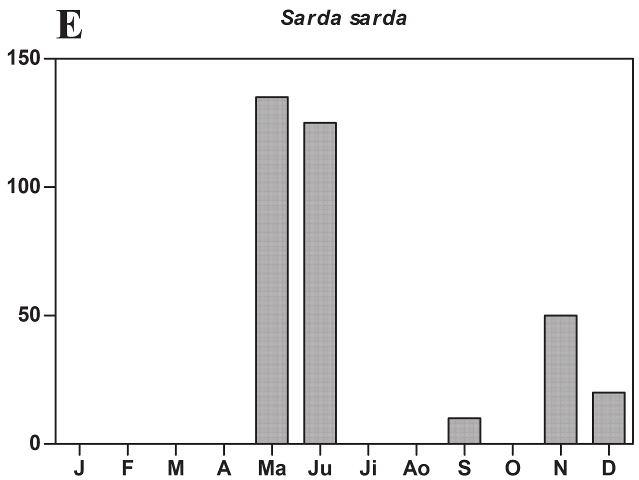


Fig. 3: Monthly landings (in kg) for the five main target species: A, *Pagellus acarne*, B, *Merluccius merluccius*, C, *Mullus surmuletus*, D, *Diplodus* spp. and E, *Sarda sarda* of the small-scale fishery from Ziama bay (Southwestern Mediterranean) between May 2013 and April 2014.

of net, while scorpionfish *Scorpaena* spp., the accessory target species for this *métier* (see Table 1), ranks second with 1.92 kg/100 m of net (Table 2). The 3 species of the family Scombridae, *Euthynnus alletteratus*, *Auxis rochei*, and *Sarda sarda*, have the highest CPUEs within the "bonito driftnet" *métier* with respective values of: 4.73, 4.12, and 3.72 kg/100 m of net. The CPUE of the striped red mullet *Mullus surmuletus* is the highest among the other species caught by the "surmullet trammel net" *métier* with an average value of 1.80 kg/100 m of net (Table 2). As for the "Sparids monofilament gillnet" *métier*, and even if the different species of the Sparidae family represent the majority of the species most fished in terms of frequency of occurrence (in particular the *Diplodus* genus), the greater amberjack *Seriola dumerili* and the Atlantic bonito *Sarda sarda* record the highest CPUE for this *métier* (Table 2).

Fishing effort distribution

The area of the future MPA of "Taza" is mostly exploitable by the fishing fleet of Ziama harbor. The fleet of the harbor of Boudis (trawlers and purse-seiners) is active almost exclusively in the bay of Jijel (Fig. 1). The 16 fishing grounds used by the small-scale fishing vessels of Ziama are mainly concentrated in the western perimeter of the future MPA (Fig. 5) while the eastern sector remains potentially exploitable, notably by the fishers of El-Aouana and some of the small-scale fishers of Jijel. Thirteen of the fishing grounds are mainly at depths <100

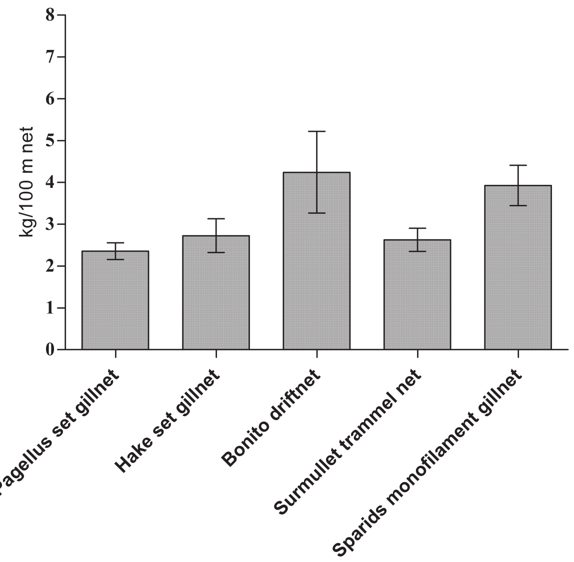


Fig. 4: Mean CPUE of the five *métiers* calculated as kilogrammes per 100 m of net from the fishing operations.

m (Fig. 5) while five of them are located within the perimeter of the future MPA (Fig. 5). The fishing grounds located inside the future MPA represent almost half of the total fishing effort (i.e. 47.42% of total fishing operations) (Fig. 6). The patterns of activity show a high concentration of the fishing effort within the proposed no-take zone, especially for the *métiers* recording the highest CPUEs (see Fig. 4). This is the case for the "bonito driftnet" (Fig. S5) and "Sparids monofilament gillnet" *métiers* (Fig. S7).

The fishing effort of the "*Pagellus* set gillnet" *métier* is concentrated in the Large Sec Bara fishing ground (Fig. S3). As a consequence, more than three quarters of its fishing effort (83.47%) is outside the MPA. The "hake set gillnet" *métier* largely shares the fishing grounds of the "*Pagellus* set gillnet" *métier* (Fig. S4). The "bonito driftnet" *métier* is used mainly inside and around the proposed MPA (Fig. S5). More than half of the fishing effort (57.80%) of this *métier* takes place in the grounds inside the MPA and is deployed exclusively beyond 40 m deep (Fig. S5). The "surmullet trammel net" *métier* has the highest fishing effort (i.e. 40.3% of global fishing operations, Table S4). It is used mainly in the most coastal fishing areas and shows the highest values around the harbor

Table 2. Mean CPUE (biomass landed in kg per 100 m of net) and standard error (s.e.) for the five first species and/or groups of species most fished (in terms of frequency of occurrence) for the five *métiers*. Parenthetically, the number of productive fishing operations for each *métier*.

1. *Pagellus* set gillnet (182)			**2. Hake set gillnet** (81)			**3. Bonito driftnet** (188)			**4. Surmullet trammel net** (313)			**5. Sparids monofilament gillnet** (70)		
Species	CPUE	s.e.	Species	CPUE	s.e.	Species	CPUE	s.e.	Species	CPUE	s.e.	Species	CPUE	s.e.
Pagellus acarne	1.07	0.07	*Merluccius merluccius*	2.76	0.23	*Auxis rochei*	4.12	0.54	*Mullus surmuletus*	1.80	0.07	*Diplodus* spp.	2.68	0.12
Squalus acanthias	0.87	0.06	*Scorpaena* spp.	1.92	0.33	*Euthynnus alletteratus*	4.73	1.45	*Diplodus* spp.	1.55	0.11	*Sarpa salpa*	2.69	0.19
Scorpaena spp.	0.54	0.03	*Pagellus acarne*	1.55	0.50	*Sarda sarda*	3.72	0.76	*Sepia officinalis*	1.56	0.11	*Seriola dumerili*	3.86	0.61
Scyliorhinus canicula	0.75	0.06	*Loligo vulgaris*	2.30	0.39	*Balistes carolinensis*	1.40	0.10	*Mullus barbatus barbatus*	1.68	0.11	*Sarda sarda*	3.50	0.40
Loligo vulgaris	0.45	0.04	*Pagellus erythrinus*	2.35	0.39	*Sciaena umbra*	2.90	0.40	*Pagellus erythrinus*	1.64	0.12	*Pagellus erythrinus*	2.50	0.20

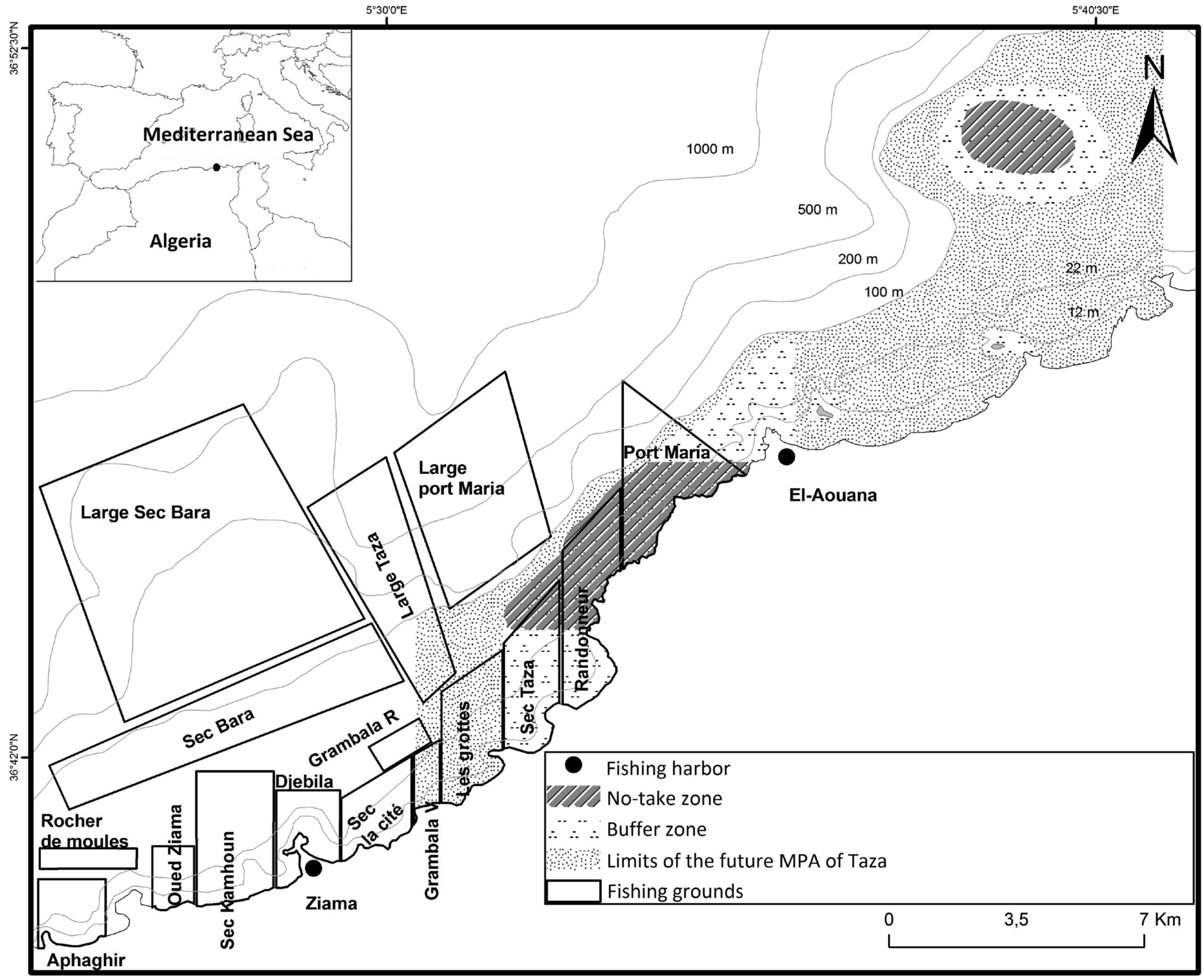


Fig. 5: Position of the fishing grounds used by the artisanal small-scale fishers of Ziama harbor (Jijel, Algeria).

and one of the two future no-take zones, targeting all five fishing grounds situated inside the perimeter of the future MPA (Fig. S6). The fishing effort of the "Sparids monofilament gillnet" *métier* is distributed mainly inside the perimeter of the future MPA with almost three quarters (71.35%) of the fishing effort of this *métier* within one of the two future no-take zones (Fig. S7).

Discussion

As in other Mediterranean artisanal fisheries (i.e. Farrugio & Le Corre, 1993; Stergiou *et al*., 2006; García-Rodríguez *et al*., 2006; Rocklin *et al*., 2009; Maynou *et al*., 2011; Leleu *et al*., 2014), the artisanal fishery of Ziama is characterized by SSFs by means of boats of small sizes and powers, as well as by the use of passive fishing gear. This activity is carried out mainly in the first three nautical miles off the coast, in areas that can be reached within 1 to 2 hours of navigation from the harbor. A total of five *métiers*, using four different gears and targeting 5 main species and/or groups of species, were identified in the Ziama artisanal small-scale fisheries. Such a variety of fishing gear and target species has also been reported in the western (Maynou *et al.,* 2011; Leleu *et al.,* 2014), central (Colloca *et al.,* 2004), and eastern (Tzanatos *et al.,* 2005) sectors of the northern Mediterranean shore. In terms of fishing gear, gillnets, which account for 59.7% of total fishing operations, are the more common gear used by the Ziama small-scale fleet. However, trammel nets are more common within Mediterranean SSFs and the prevalence of gillnets could be related to the limited rocky bottoms in the study area.

Observation of the monthly landings showed that the fishing of the target species is distinctly seasonal, demanding that fishers tend to rotate between various *métiers* throughout the year and adapt to variations in resource availability. This seasonal rotation of fishing gear, a specific characteristic of the Mediterranean artisanal small-scale fisheries (García-Rodríguez *et al*., 2006, Leleu *et al*., 2014), is determined not only by the abun-

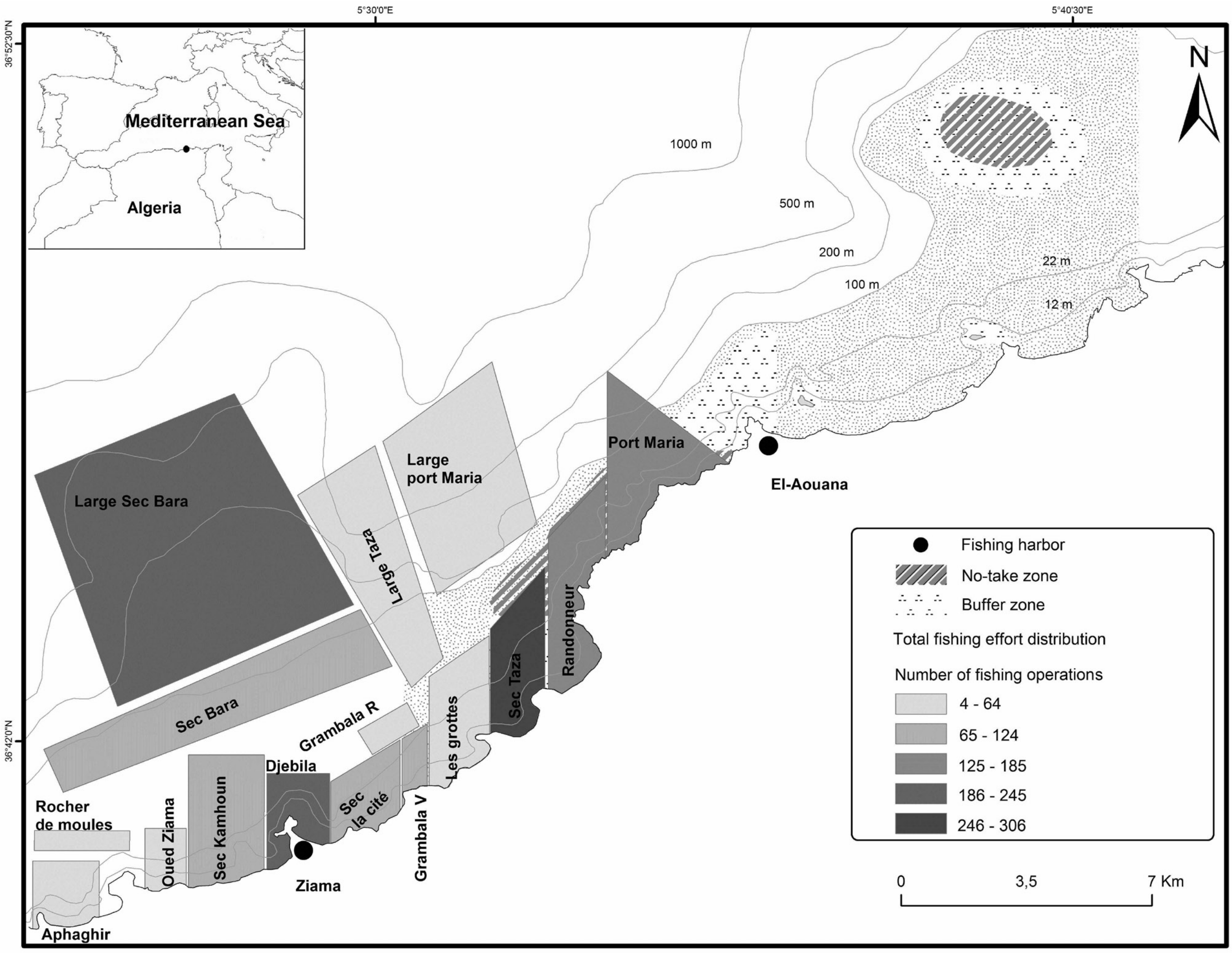


Fig. 6: Spatial distribution of the total fishing effort. Effort was represented on the basis of the number of fishing operations carried out in the different fishing grounds.

dance and availability of fisheries resources but also, and most importantly, by the breeding season of the majority of target species as reported by Forcada *et al*. (2010) or Maynou *et al*. (2011). When individuals gather in large numbers to reproduce, they become, as explained by Pelletier & Magal (1996), vulnerable to fishing. It is therefore a form of adaptation of fishing tactics to the ecology and dynamics of the species.

The temporal dynamics found in the study area are not comparable to that found in some northern Mediterranean small-scale fisheries. Indeed, our results do not agree with those obtained for the fisheries of Scandola (Le Diréach *et al*., 2008), Port Cros (Bonhomme *et al*., 2010), or Bonifacio (Rocklin *et al*., 2009) in France, for which, these authors have reported the presence of a season without activity (i.e. winter). However, our results are in agreement with those of Forcada *et al*. (2010) for the Tabarca MPA in Spain as well as for the Marine Park of the Côte Bleue near Marseille (Leleu *et al*., 2014). These disparities in the dynamics of the *métiers* practiced are due to the dissimilarities of the natural, historical, and cultural characteristics of the environment of each fishery (Farrugio & Le Corre, 1993; Forcada *et al.,* 2010).

Although there is evidence of the rotation of *métiers*, and consequently of the gear, throughout the year in order to favor the optimization of fishing yields, the fishing activity during the breeding periods of the target species could, as shown by Tzanatos *et al*. (2005), have negative effects on the state of the stocks. This is the case of *Diplodus* spp. off eastern Algerian coasts, where most species of this genus breed in the spring period (Benchalel & Kara, 2013; Derbal & Kara, 2013), which corresponds to the peak in the activity of the "Sparids monofilament gillnet" *métier* targeting this range of species. The spatial distribution of the fishing effort is a crucial element in the spatialization of pressures and impacts on the environment (Costello *et al*., 2010; Parnell *et al*., 2010). The creation of maps, as well as the knowledge of the spatial distribution of the fishing effort, provides valuable elements to the managers of this future MPA for the identification of the most frequented areas in order to estimate the pressures and impacts on the fishing habitats. The fishing grounds observed are characteristic of the *métiers* practiced, and therefore suitable habitats for the capture of the targeted species. Thus, the fishing zones drawn from the information provided by the fishers during the field surveys and our trips to sea can contribute to the development of management measures intended to spatially limit the pressures and the impacts of small-scale fisheries in this area.

The spatial distribution of the fishing effort of the five *métiers* needs to be monitored more closely in order to detect any potential effects related to the creation of an MPA in this area such as the displacement of the fishing effort to its surrounding areas (Halpern *et al*., 2004). However, the Catch Per Unit Effort (CPUE) results and spatial distribution of the *métiers* show an interesting correlation. Thus, the *métiers* for which the highest CPUEs were recorded (i.e. "bonito driftnet" and "Sparids monofilament gillnet") are practiced intensively in one of the proposed no-take zones. This argues for a strengthening of controls in this area once the MPA is established.

This study provides a baseline on which to judge the future impact of the MPA by disaggregating the CPUEs for the fishing fleet to *métier* level which will certainly make it easier to monitor the effects of the MPA on different *métiers* once the "Taza" MPA is established.

Indeed, MPAs have attracted much attention as a tool for sustainable fisheries management, restoring depleted fisheries stocks, and maintaining ecosystems. When studies suggest that an MPA may not benefit fish productivity or recovery, extenuating factors such as insufficient time since MPA creation, poor enforcement, inadequate design, and poorly defined management objectives are generally blamed rather than the failure of the MPA concept itself (Gruss *et al*., 2014). We often forget that not all species are equally vulnerable to fishing, nor are all species likely to recover at the same rate. Takashina & Mougi (2014) found that MPAs can have either a positive effect or almost no effect on the recovery of depleted fishing stocks, depending on fish migration patterns and fishing policies. Thus, unsuitable MPA planning might result in low effectiveness or even deterioration of the existing condition.

Many meetings between members of the Project Working Group of the future MPA of "Taza", experts, scientific researchers, fishers associations, municipalities, NGOs, the local population, and the press were held in the three coastal municipalities of Jijel, El-Aouana, and Ziama Mansouriah between 2009 and 2011 (Boubekri & Djebar, 2016). The aim of these meetings was to discuss the zoning proposal through a participatory process that preceded finalization of the zoning plan. The latter was conceived with support from the network of MPA managers in the Mediterranean (MedPAN) within the MedPAN South Project (MSP). Data from the MSP conducted between 2009 and 2012 in the area which assessed marine biological diversity (Ramos-Espla, 2010), fisheries (Kacher, 2010), and socio-economic aspects (Chakour, 2012; Grimes, 2010) served as a basis to achieve the final proposal which was subject to a wide consultation process within the different user-groups of this future MPA.

However, non-professional fishing appears to be causing most conflict in the area of the future MPA of "Taza". According to Kacher (2010), the current economic difficulties of the local population are now leading to unfair competition between the many illegal fishers and artisanal fishers because their fishing activity is conducted in contravention of national laws. Thus, they use the same fishing gear as the professional fishers and also target the same species, but sell their catch illegally.

Conclusions

Artisanal fishing is the main socio-economic activity in the area of the future MPA of "Taza". The activity of the boats is concentrated in the coastal sector, where 57.3% of fishing operations are carried out at <40 m. Moreover, our results show a strong coincidence between 3 features: 1) the fishing grounds; particularly littoral, 2) the seasonal fishing periods of the main target species, and 3) the breeding seasons of the main target species.

Despite it still being rather early to judge the proposed zoning on the basis of CPUE results and the spatio-temporal distribution of *métiers*, onboard data could provide additional information (e.g. estimation of discards). However, and for a more relevant assessment, it would be interesting to estimate discards and bycatch by participating in the trip at sea as part of the regular monitoring of the 2 no-take zones of the future MPA. In addition, a strong illegal fishing activity is present in the area of the future MPA of "Taza". This activity should be addressed in future studies because of its diverse impacts: 1) biological, through the significant fish mortality, 2) ecological degradation and fragmentation of habitats, and finally 3) socio-economic because the fishing effort of non-professional vessels is underestimated, leading to an overexploitation of fishing resources and compromising the role of any management decisions based on biased data in a context of a data-poor situation.

Our results show that the spatio-temporal dynamics of artisanal SSFs is a crucial component for the effective management of the future MPA of "Taza". Understanding the dynamics of the fishery and the behavior of the fishers are two fundamental elements that must be integrated into the management approach, strictly conditioned by close collaboration between scientists, fishers, and local managers.

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Appendix

List of caught taxa and their total weight (kg) per *métier* in the catches of the 28 small-scale vessels considered for this study.

Species	Pagellus	Hake	Bonito	Mullets	Sparids	Total (kg)
Elasmobranchii						
Dasyatidae	10.00	-	-	5.00	-	**15.00**
Rajidae	15.00	15.00	-	165.00	-	**195.00**
Scyliorhinidae						
Scyliorhinus canicula	730.00	20.00	-	-	-	**750.00**
Squalidae						
Squalus acanthias	1135.00	-	-	-	-	**1135.00**
Torpedinidae						
Torpedo spp.	5.00	10.00	-	-	-	**75.00**
Actinopteri						
Balistidae						
Balistes carolinensis	-	5.00	20.00	130.00	-	**155.00**
Carangidae						
Seriola dumerili	-	-	-	-	90.00	**90.00**
Congridae						
Conger conger	5.00	-	-	15.00	-	**20.00**
Gadidae						
Phycis spp.	40.00	15.00	-	-	-	**55.00**
Lophiidae						
Lophius spp.	165.00	5.00	-	-	-	**170.00**
Merlucciidae						
Merluccius merluccius	460.00	205.00	-	70.00	-	**735.00**
Moronidae						
Dicentrarchus labrax	-	-	-	5.00	-	**5.00**
Mugilidae	-	-	-	25.00	30.00	**55.00**
Mullidae						
Mullus barbatus barbatus	45.00	5.00	-	225.00	15.00	**290.00**
Mullus surmuletus	-	-	-	775.00	5.00	**780.00**
Muraenidae						
Muraena helena	-	-	-	30.00	-	**30.00**
Sciaenidae						
Sciaena umbra	5.00	-	25.00	10.00	-	**40.00**
Scombridae						
Auxis rochei	30.00	-	4010.00	-	-	**4040.00**
Euthynnus alletteratus	-	-	1180.00	-	-	**1180.00**
Sarda sarda	-	-	260.00	10.00	70.00	**340.00**
Scorpaenidae						
Scorpaena spp.	595.00	65.00	-	160.00	5.00	**825.00**
Serranidae						
Epinephelus costae	-	-	-	15.00	-	**15.00**
Epinephelus marginatus	5.00	-	-	-	-	**5.00**

(continued)

Appendix continued

Species	Pagellus	Hake	Bonito	Mullets	Sparids	Total (kg)
Soleidae	10.00	15.00	-	10.00	-	**35.00**
Sparidae						
Dentex spp.	5.00	-	-	-	5.00	**10.00**
Diplodus spp.	10.00	10.00	5.00	210.00	145.00	**380.00**
Lithognathus mormyrus	10.00	-	-	15.00	25.00	**50.00**
Oblada melanura	-	-	-	5.00	15.00	**20.00**
Pagellus acarne	1850.00	35.00	-	140.00	-	**2025.00**
Pagellus bogaraveo	35.00	5.00	-	5.00	5.00	**50.00**
Pagellus erythrinus	20.00	35.00	-	190.00	45.00	**290.00**
Pagrus spp.	20.00	-	-	20.00	10.00	**50.00**
Sarpa salpa	10.00	-	-	145.00	70.00	**225.00**
Sparus aurata	-	-	-	-	5.00	**5.00**
Trachinidae						
Trachinus draco	-	15.00	-	70.00	-	**85.00**
Triglidae						
Trigla lucerna	75.00	40.00	-	-	-	**115.00**
Cephalopoda						
Loliginidae						
Loligo vulgaris	280.00	35.00	-	-	-	**315.00**
Octopodidae						
Octopus vulgaris	30.00	5.00	35.00	65.00	-	**135.00**
Sepiidae						
Sepia officinalis	15.00	10.00	-	220.00	15.00	**260.00**
Malacostraca						
Palinuridae						
Palinurus elephas	165.00	-	-	-	-	**165.00**
Total (kg)	**5780.00**	**550.00**	**5535.00**	**2795.00**	**555.00**	**15215.00**