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# Survey based proxy-localisation techniques for spatial distribution assessment of small-scale fishing activity: the case study of the Banc d'Arguin National Park (Mauritania)

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## Abstract

In recent years, the sustainable exploitation of the natural resources policy started to be implemented in Africa. In many cases, artisanal fishing is still permitted around Marine Protected Areas and sometimes even inside with particular rules such as in Mauritania's Banc d'Arguin National Park (BANP) where only sailing boats are allowed to fish with restricted fishing gears. In the context of control and conservation of the resource exploitation, evaluating the spatial distribution of fishing pressure is a key issue. Unfortunately, the lack of VMS and GPS, particularly in developing countries, makes the task difficult. Since 2006, in Mauritania, a small-scale fisheries information system mainly based on fishermen statements is operational. The main goal of our work was to use all fishermen's geographical statements to map the fishing activity and catch. For a given fishing trip, the monitoring survey provides information on landing sites localization, canoes' course back, time travel between the fishing zone and the landing site as well as the distance of the fishing zone from the coast. Finally a few self-reported GPS positions let us assess the vessels' speed ranges which were computed with the time travel to obtain a distance. From the reported azimuths, a cone was identified from a landing site. The travel time and lower and upper speeds were then used to calculate two distances subdividing the cone extent. Thus, the final result helped to identify areas likely associated with catches. The catch and fishing effort related to subdivided cones were compiled into two grids. These results showed contrasting behaviors of the two fleets operating in the Gulf of Arguin: sailing boats inside and motorized boats outside the BANP. It also let us map the quantity caught by 5.5 x 5.5 kilometer cells. Finally, it will be implemented as a tool of the Mauritanian survey to help managing the fisheries with spatial information.

## Keywords

*Artisanal Fishery, Declarative Survey, Geographic Information Systems, Marine Protected Area, Spatial distribution assessment.*

## 1. Introduction

During the world summit in Johannesburg (2002) the vital role of Marine Protected Areas (MPA) as a tool in the biodiversity conservation was reaffirmed. In developing countries, these MPAs are often established in important and rich fishing zones (Klein *et al.*, 2008). As a result, substantial legal or illegal fishing pressure can be observed around and sometimes even inside MPAs. It concerns generally small-scale fisheries which are an important source of protein and revenue for the local population (FAO, 2003; Moberg and Folk, 1999). Nevertheless, the authorities must try every possible means to monitor these fisheries, taking into account that the main goal of MPAs is the biodiversity conservation (Klein *et al.*, 2008).

Moreover, some authors have argued for the importance of understanding the spatial aspects of the fisheries (Booth, 2000; Gillis, 2003; Hutchings and Myers, 1994; Wilen *et al.* 2002). The increasing interest in spatial management measures, including MPAs, highlights the relevance of assessing the spatial distribution of fishing activity and catch to fisheries management (Moustakas *et al.*, 2006; Walters and Martell, 2000). For instance, the evolution of catch-per-unit-effort (CPUE) should take account of changes in the spatial distribution of fishing effort (Jennings *et al*., 2001; Walters, 2003).

As these fisheries are small-scale and thus informal activities, it is very difficult to get an accurate assessment of fishing pressure distribution and catches. In some cases, monitoring surveys exist on these fisheries but the data collected do not easily allow a spatial representation of the effort and catches. As well, motor canoes are not equipped with Vessel Monitoring Systems (VMS) nor with recording GPS that could be used to draw fishing zones maps.

Nevertheless, some declarative data collected during the landings give information about the spatial extent of the fishery. In this paper we put forward a method using this information to estimate an approximate cartography of the fisheries. The main challenge is to use every data available in the database to plot the maps of the most important fishing zones in the North of Mauritania. Our method is based on the case study of the Banc d'Arguin National Park (BANP) in Mauritania.

# 2. Case study presentation

## 2.1 Region

The case study is situated in Mauritania, a West African country where a huge upwelling, operating between November and the end of May (which is called "cold water season"), contributes to large fish production. The upwelling stops between June and October (which is called "warm water season") (Arfi, 1985; Leroux 1996). The richest zone is the Gulf of Arguin, situated in the north third of the country (Figure 1). Nouadhibou, which is situated in the north of this zone, is an important landing site with fish processing capacities. Dozens of industrial fishing vessels coming from all around the world and hundreds of motor canoes are concentrated in this harbor. The case study zone also includes the Banc d'Arguin National Park (BANP), a large MPA created in 1976 (Anonymous, 2001a) to preserve the flora and fauna (in particular migratory birds). In 1993, a government's decree added an assignment of socio-economic development to its first preservation goal. This development mainly concerns fishing activity, which is at this point allowed but severely restricted (Anonymous, 2001b).

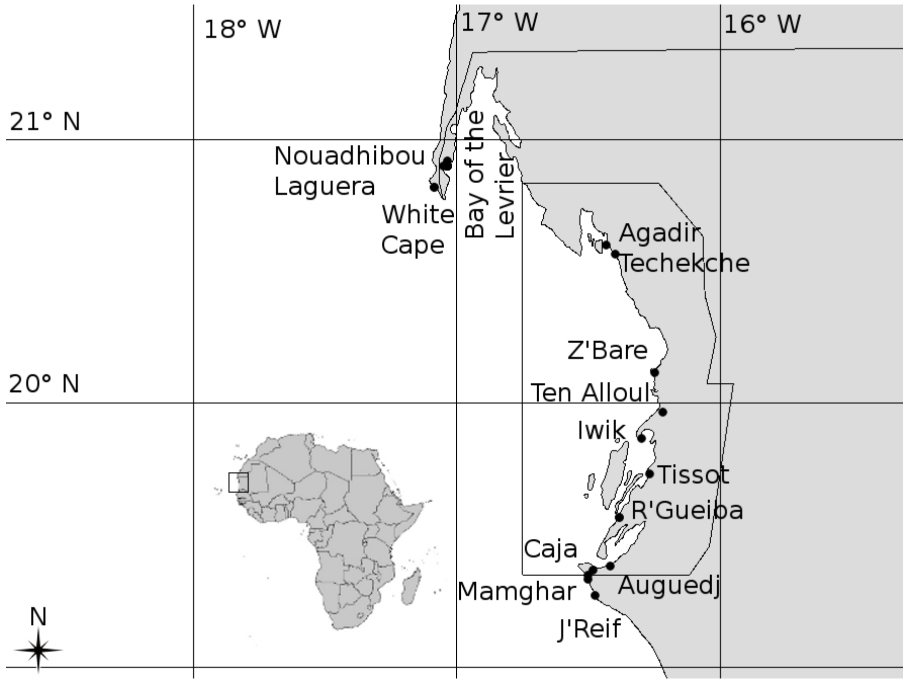



*Figure 1. Case study location (Gulf of Arguin, North Mauritania in West Africa) with the landing sites in the monitoring survey and the Band d'Arguin National Park boundaries identified.*

## 2.2 Fleets

The small-scale fishery in the Gulf of Arguin is composed of two fleets. The first one is the motor canoes fleet (canoes length is in a 10 to 12 meters range), equipped with one 40 horsepower outboard engine. These small-scale vessels, built of wood or aluminum have a standard shape and homogenous behavior during navigation. The crew of this type of vessel is generally Mauritanian inhabitants with Senegalese origins. In the landing site of Nouadhibou, in the north of the Gulf of Arguin there are 1934 canoes. In Mamghar, in the south of the BANP, there are only 58 canoes.

The second fleet is composed by traditional sailing vessels called “lanches”. They are only based in the landing sites inside the BANP (Figure 1). These vessels are between 8 and 10 meters long. The crew is composed only of native Mauritanians called “Imraguens”. A limited number of 115 lanches are allowed to fish in the BANP and only non-destructive gears can be used for fishing endangered species such as sharks. In the following text we will further distinguish the two types of fleets.

### 2.3 The monitoring system

The Mauritanian Institute for Oceanographic and Fishery Research (IMROP) developed a small-scale fishery monitoring survey in partnership with the French Research Institute for Development (IRD). This survey was displayed in 2005 on all Mauritanian landing sites. The main goal of this survey was to collect regular fishing statistics on the small-scale fishery: total and per-species production, effort, prices etc. This system was based on fishermen surveys collecting data on catches, activity of the fleet, selling prices, technical features of the fishing journeys (navigation duration, rest duration, gears used, spatial localization…).

## 3. Data and Methodology

### 3.1 Proxy-localisation method

This study was based on the declarative data provided by the small-scale monitoring system of the IMROP. More precisely, we used: (1) geographical coordinates of the landing sites, (2) the proximity from the fishing zone to the coast (less or more than 5 nautical miles which is the limit beyond that the fisherman cannot see the shoreline), (3) travel course from the last fishing zone to the landing site, and (4) duration of the way back travel. The latter data was converted into a distance using a speed factor.

To assess this speed factor, for each type of vessels, we used a data subset provided by artisanal fishermen using personal GPS. The calculations were based on 150 observations for the motor canoes and 688 for the sailing lanches.

As trips returning to port are generally in straight line, we could calculate the speed factor for each reported observation. The results were plotted on a normal distributed graph. Lower and upper speeds based on the 20 % and 80 % observations were defined with the quantiles of the observed distribution. This method wiped out the two extreme parts of the distribution and the dummy data. The speed factor was assessed for each type of vessel (outboard motor canoes, 4 and 11 knots and sailing lanches, 3.6 and 5.3 knots).

We used the landing site as the center of the proxy-localization cone. As the fisherman reported the course of his trip back to port (North as in the Figure 2, South, East or West), a 45 degrees cone was drawn on each side of the course. The lower and upper speeds, combined with the travel time, allowed us to delimit a distance range (Figure 2a). The defined zone was then cut by the coast line (Figure 2b). To take into account the last data (proximity to the coast) we created a buffer zone between the coast line and the 5 nautical miles offshore; if the fisherman declares he was close to the coast (he saw the coast) the polygon was intersected with the buffer (Figure 2c); if not (he did not see the coast), it was cut by the buffer (Figure 2d).

To obtain a synthetic and convenient representation, data affected to each proxy-localisation cone were broken down onto a grid (cell size is 0.05 degrees so 5.5 km). To do this, the weight of each quantitative catch data $Y_i$ associated to the cone i (e.g., catch realised during a journey i) was spread off on each n cells intersecting the cone i with a $y_{x,y}$ value per cell defined as $y_{x,y} = Y_i / n$. For each $_{x,y}$ cell, the data set values of the whole journeys were then added, in order to obtain a statistical map of the variable. So, it was possible to draw up the spatial distribution of all raw or extrapolated data associated to the journeys.

## 3.2 Data: selection and exclusion

There are 2027 observations for the motor canoes (august 2005 to august 2007) and 6075 observations for the sailing lanches (January 2006 to august 2007). These were processed with two variables: effort (1 trip = 1 unit of effort) and catches (kg of fish).

Concerning the motor canoes, some selections had to be made in order to get consistent results. So we had to exclude the time travels standing outside of the 0 - 24 hours range. This range was defined to cancel missing data which were noted “-1” in the database. Concerning the 3 data which journey durations were more than 24 hours, results were inaccurate and too far from the main fishing zones we were interesting in. Finally, in the database, if the fisherman declares more than one fishing zone, there is no information to know which one was the last fishing zone and which catch we can map. So we also cancelled journeys with more than one fishing zone.

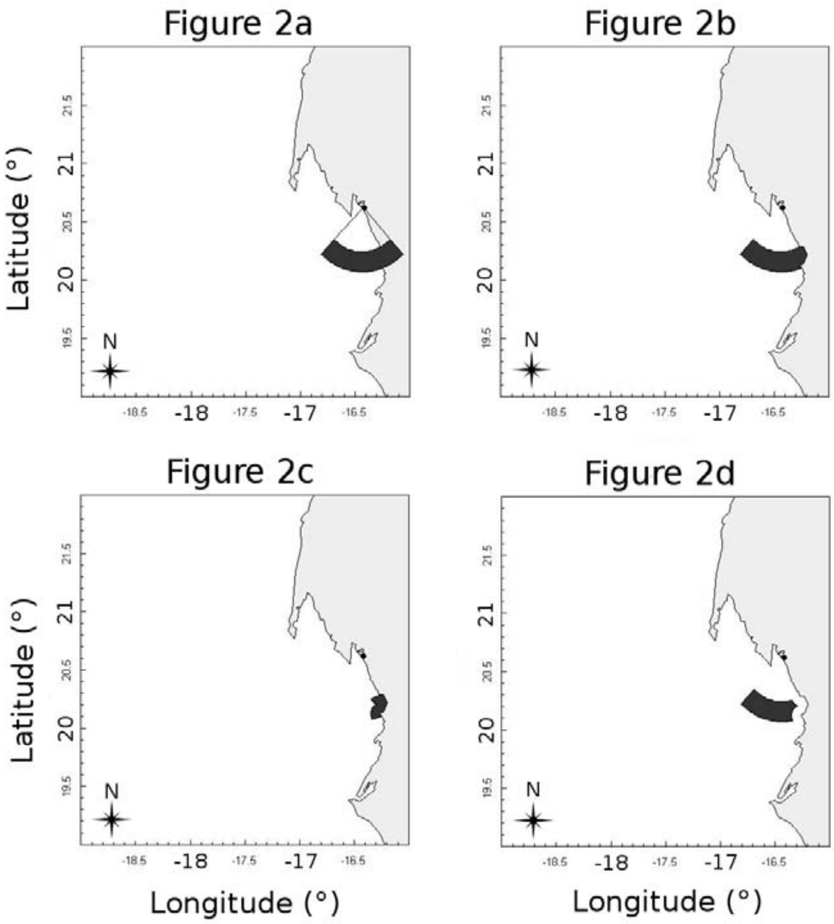
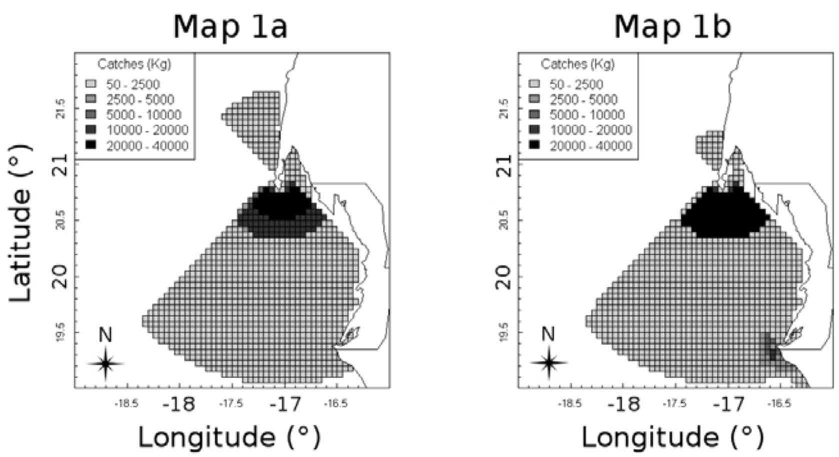



*Figure 2. The four steps of the cone creation: (a) cone boundaries (b) cancellation of the shore (c) intersection with the coastal zone and (d) difference with the coastal zone.*

# 4. Results

## 4.1 Motor canoes

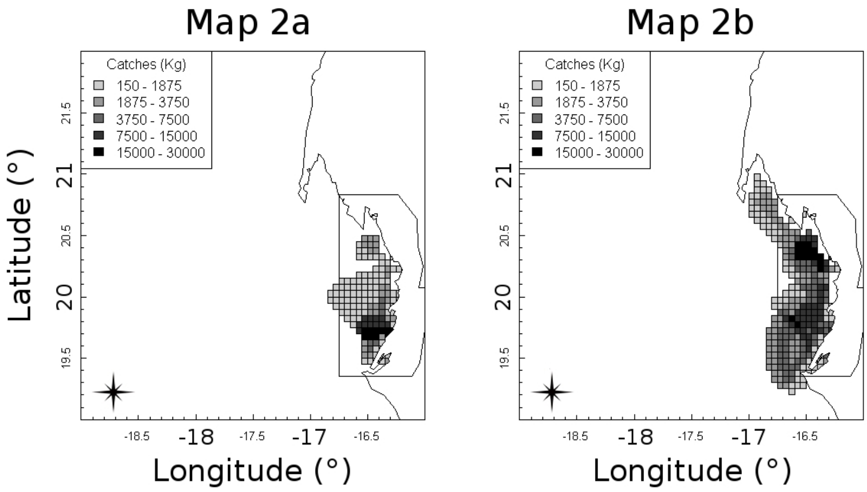
Fleets of motor canoes working in the Gulf are based in only two landing sites. The first location is the large harbor of Nouadhibou in the north sheltered from the White Cape and in front of the Bay of the Levrier and to a lesser extent, Mamghar, situated near the south boundary of the BANP (Figure 1). The application of the method lets us obtain Map 1 where we can see that motor canoes can go very far from the two landing sites but always by traveling to the north or the south, more or less parallel to the coast. For the fleet based in Nouadhibou, zones of high fishing density are concentrated throughout the year in the south of the White Cape, although some motor canoes from Nouadhibou go fishing in the north during the warm water season (Map 1a). Moreover we can notice that 58 percent of the motor canoes declare a course to the north to return to the landing site. In addition we can observe the increasing spatial distribution of high catch quantity during the upwelling season. For the small fleet of Mamghar, fishing activity is intensive only during the cold water season with a small dispersal, essentially limited to the coastal waters situated close to the south boundary of the BANP. For the complete sample of study, results reveal that the fishing catch increases and slides to the south during the cold water season (Map 1b).




*Map 1. Spatial distribution of the catches (in kg) realised by the motor canoes in the warm water season (a) and in the cold water season (b).*

### 4.2 Sailing lanches

Lanches primarily fish in the BANP. The vessels are based at several landing sites along the shore of the MPA. Catch zones cover the major part of the MPA (Map 2). During the warm water season, catches zones are closer to the shore line and are concentrated in one spot (Map 2a) in front of Iwik and R'Gueiba (Figure 1). During the cold water season, catch zones are widely spread and cover all the BANP waters area (Map 2b). They are concentrated in two spots. The primarily one is in the North of the BANP off Agadir and the secondarily one in the West of Iwik and R'Gueiba (Figure 1).




*Map 2.* *Spatial distribution of the catches (in kg) realised by the lanches in the warm water season (a) and in the cold water season (b).*

## 5. Discussion

### 5.1 Coherence of the results with the existing knowledge on the Gulf of Arguin ecosystem

The climatic system of this region is governed by the trade winds causing a huge upwelling along the shore line. The upwelling index is at the maximum between December and April (the cold water season) and it is at the minimum between July and October (the warm water season) (Arfi, 1985; Leroux, 1996). During the cold water season, the fish abundance is at its maximum and our results show that the catches realized by lanches have an increasing spatial dispersion. The fishing hotspots highlighted in the results correspond to two fishing seasons. On the one hand, the warm water season is favorable for the Flathead grey mullet (*Mugil cephalus*) catch. This species represents 14 % of the annual biomass landed and is primarily fished in the south of the BANP between July and October where shallow waters can be found (Anonymous 2009). On the other hand, the cold water season lets the Imraguens fish the Meagre (*Argyrosomus regium*), a métier which was developed as a replacement for the shark fishing. This species represents 15 % of the annual biomass landed and it is mainly fished between February and May. It is primarily fished in the North of the BANP where sea is deeper than in the south zone (Anonymous 2009).

Concerning the motor canoes catch, they are landed in the landing sites of Nouadhibou and Mamghar. The fishermen from Nouadhibou have to find a compromise between the distance (related with the fuel quantity used) and the fish quantity caught as it was showed by Walters (2004) in other fisheries, so they generally do not go further than south of the White Cape where the main fishing effort is concentrated. It can be observed that, during the warm water season (July to October), there is a decrease of the spatial distribution in the south of the White Cape. Moreover, results seem to show a behavior modification of some motor canoes which go fishing along the shore line of the Western Sahara, to North of the White Cape. It could correspond to the northward sliding of the upwelling during this warm season, a well known phenomenon (Arfi, 1985). Concerning the motor canoes working from the Mamghar landing site, their catches are mainly realized near the south and west boundaries of the BANP, a zone where this type of vessel is not allowed to fish.

It must be reminded that the preliminary results obtained and presented above are, for the moment, only based on survey data collected on landing sites without taking account of sampling rate or fleet size. So there may be some bias and above all, a magnitude factor certainly exists between the calculated values and the real catches converted per cell into the grid.

## 5.2 Method efficiency and limits

It can be observed that the visual quality of the mapping obtained depends on the data quantity. In our case, the large quantity of data and the multiplicity of landing sites, especially in the lanches' case, have certainly played a favorable role in displaying interesting spatial patterns.
Concerning the cell size, we used intermediate resolution scales (5.5 x 5.5 km) that allow a good observation of the data distribution. Considering that these data are self-reported, and consequently not extremely

accurate, it is not effective to increase the resolution. Thus, it clearly appears that, if this method lets us assess the spatial behavior of the two fleets studied, it cannot be considered as an efficient method to provide an accurate map of the fishing sites.

The method utilized can be improved in several ways. Firstly, the database used here provides only self-reported data for the course back (only four choices). The accuracy of this data can be improved by giving eight choices (N, NW, W, SW, S, SE, E, NE) to the fishermen instead of four, supposing that fishermen can give this accuracy.

Additionally, speed data have been assessed by using self-reported GPS data. In the case of the lanches with a large quantity of data collected, the speed range calculated is pretty good. However, the speed range calculated for the motor canoes is larger and leads to an inaccuracy in the results, particularly for the travel time greater than 3 hours. So, it may be interesting to conduct some field experiments in various winds, swells and loads conditions to determine the real speed range of the vessels.

We also noted measurement error in the self-reported time data on the BANP lanches which are approximated to the hour. It results an inaccuracy in the spatial assessment of the fishing zones. This is the consequence of the Imraguen's imprecision in assessing the time.

## 6. Conclusion and perspectives

The method proposed, based on four information types collected by the standard procedure at the landing site of the Mauritanian artisanal fishermen allows us to observe the various patterns of the spatial distribution of catches between the two seasons. With this method it is possible to map other statistical figures collected with this monitoring system as, for example, the presence of a particular species or fishing effort could be mapped in a similar fashion. The final goal is to implement this tool into the statistical monitoring survey of IMROP in order to follow up the evolution of the catch or effort distribution and the behavior of every other variable provided by the monitoring survey.

In order to improve this method, it is possible to add other types of information as Belkhaouad *et al.* (1999). For instance, we can use sedimentology or bathymetry data which can be computed with the already exploited data. These data will be available at the end of the PACOBA project and implementing a method to exploit them will improve the spatial assessment of these small-scale fisheries.

Finally, we note that the method proposed here is one of the available methods to study the spatial distribution of the small-scale fisheries, like the ethno-geographic survey which lets us create an accurate toponimic map of the fishing sites or the vessel count by aerial survey. These various methods present advantages and disadvantages and we propose to use them as alternative or complementary options depending on the choice of objectives as well as available resources and data. These information might be used to increase the accuracy of this method in other more complex exploited ecosystems as coral reefs fisheries or island archipelago with complex chain of reefs as it was done by Guillemot *et al*. (2009) in New Caledonia (South Pacific).

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