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Assessing Potential Impacts of Offshore Fish Farming on Small-Scale Fishery in Monastir Bay (Eastern Shore of Tunisia)

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Abstract: The establishment of offshore aquaculture production areas that compete with traditional fishing activities is a potential source of conflict that needs to be assessed in coastal areas. Having little specific data available on the impacts of these farms, we aimed, through the present study, to gather information on this issue, especially regarding Monastir bay, a major zone of aquaculture production in the eastern shore of Tunisia. Hence, we have surveyed fishers' observations through a questionnaire-based methodology. A total of 78 fishermen were interviewed, in December 2016, in three different ports: Monastir, Sayada and Teboulba. Results revealed that 77 % of local fishing communities complained about the loss of fishing grounds and changes in the quantity and quality of catches. Net damage, caused by dolphin predation, was reported by 31% of fishermen. The most abundant and dominant fish and mollusc species around fish farms, as reported by 30% of inquired fishermen, were *Mugil cephalus*, *Octopus vulgaris* and *Sardinella aurita*, while 15% of fishermen interviewed reported the presence of marine turtles near cage fish farms. The present survey already provides an important data platform that will be useful to decision makers, to adopt appropriate strategies allowing harmonious coexistence between fish farms and fishing activities, in order to ensure ecological sustainability.
Keywords: Aquaculture, Coastal fishing, Marine species aggregation, Survey.

INTRODUCTION

Tunisia, occupying a central place in the Mediterranean, opens widely onto the sea, mainly on its eastern and southern shores.

It has a population of more than 11 millions [1] and more than 2 290 kms of coastline [2]. This long coast of Tunisia consists of 68 % continental linear, 20 % linear island and 12 % artificial linear [2]. The geographical distribution of the Tunisian waters as well as their stretch and the differences they have, brought about the development of very variable ecosystems.

The fishing and aquaculture sectors play a key role in the socio-economy of the country, providing food supplies and offering several employment opportunities in addition to international exchange earnings. Aquaculture benefits of an interest as a strategic activity supporting the fishing sector. The current national fish production is 131 705 tons in 2015 [3]. Over 35 977 people are directly and permanently employed in fishing and aquaculture sectors [3].

Aquaculture currently involves the farming of marine fish, freshwater fish, shellfish and blue fin tuna fattening. Tunisian aquaculture implementations have highly improved during the last ten years; indeed, the national production grew up from 2 956 tons in 2006 to 14 231 tons in 2015 [3]. In marine fish farming, the number of offshore farms has rapidly evolved to 21 farms producing fish, mainly sea bass and sea bream [2].

The main marine aquaculture production zone is in the governorates of Sousse, Monastir, Mahdia and Nabeul, all of them in the east of the country. In Monastir bay, the aquaculture sector has witnessed a turning point starting from 2008, with the setting-up of seven fish farms covering an overall marine surface area of around 70.000 ha, with around 400 ha surface of concession [2]. From this date, the bay of Monastir became a major zone of offshore aquaculture production, where all farms are rearing sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*). For both these species, an exponential growth of production has occurred, reaching 6 579 tons in 2015, which represented 24.37 % of the regional production in the same year. Conversely, the proportion of small-scale fishery landing did not stop decreasing: 37.4 % in 1998 to 7.1 % in 2014 and 6.53 % in 2015 [3, 4]. However, cuttlefish, squid, octopus and royal shrimp landings have been almost stable during the last 10 years, those of large pelagic fish have witnessed a

decline from 951 977 tons in 2006 to 379 095 tons in 2015 [3]. Despite a modest level of technological development, small-scale fishing did not give up its fundamental role in the sector of fishing in Tunisia. The prospects for increasing local production of fish through fisheries is limited, since the fishing grounds are almost fully exploited and overfishing of some species is frequent [5].

Significant research has been undertaken to examine the impacts of aquaculture on the environment, particularly water quality and disturbance effects on benthic community [6-9]. The impacts of these activities on the environment could be due to wastes offloads, introduction of alien species, genetic interactions, disease transfer, release of chemicals, use of wild resources and disturbance of wildlife.

As a primary food production sector in the bay of Monastir, aquaculture must remain an overriding priority and therefore should continue to grow. However, further aquaculture development in this region must ensure sustainability and balance the risks to public or environmental health with the substantial economic benefits. The local communities have long depended on local fishing grounds accessible by daily fishing trips, making the establishment of offshore aquaculture production areas that compete with traditional fishing activities a potential source of conflict that needs to be accounted for in coastal areas. Side effects related to aquaculture are obviously issues of importance and priority, but recent studies in Tunisia have addressed this issue [10]. However, reports are still scarce regarding attraction of fish, large predators and threatened species triggered by cage fish farming. Yet, to date and to our knowledge, there are no published studies on the conflict between fishermen and predators in areas where aquaculture was developed.

Taking all this into account, we attempted to investigate the impact of cage offshore aquaculture, especially interactions between coastal fishing, marine diversity, fish and predators attraction and sea pollution, using a survey study. The points raised, in this study, will provide a basis for establishing collaborative engagements between fishers, conventional scientists and managers, to deal with challenges in fisheries' management, socio-economic problems in the studied region and monitoring potential pollution generated by offshore aquacultures activities.

MATERIALS AND METHODS

Study area

The study was carried out in Monastir bay (eastern shore of Tunisia) where fish farms and fisheries co-occur (Figure 1). The study area includes about 50 square nautical miles of waters with a depth not exceeding 30 m at 10 km of the coast, with large and small islands and a complex shoreline. The islands of Kuriate are two emergent shoals, located off the bay of Monastir, north-east of the cape of Monastir and about 18 km from Monastir city (Figure 1). They include a small island (small Kuriate) about 70 ha and a larger island (big Kuriate) about 270 ha of area, a perimeter of 6.9 km and about 2.5 km from the first. These islands are the home of a remarkable terrestrial and marine flora and fauna [5], as well as a site of nesting of sea turtles (*Caretta caretta*) [11]. Both islands contribute to the activity of coastal fishing in this area. The region of Monastir accounts six fishing ports with a single deep-sea port (Monastir), two coastal ports (Sayada and Teboulba), two shelter sites (Bekalta and Ksibet El Mediouni) and a landing point (Khniss).

Questionnaire content

Our work aims to assess the eventual impact of offshore fish farming on local fishing activity and marine environment in the study area. The methodology was based on a questionnaire survey that targets fishermen, practising coastal fishing, to draw their overview to the new activity of offshore aquaculture, which will be, later, implemented within a scientific census.

Index cards of inquiries were prepared, which served as support to conducting the inquiry. Data collected concerned mainly the following two aspects: (1) Socio-economic, such as the profitability of fishing activity, quantitative and qualitative fish landings, as well as the current state of resources; (2) Environmental, such as their estimation of the impact of the offshore fish farming on their activities, in terms of pollution and ecological interactions and attraction of large predators.

For a maximum of parsimony, the work was conducted on the ground of questioning at least 10 % of the functional coastal fleets in every port (Monastir, Sayada and Teboulba) with the interviewed fishermen belonging to heterogeneous age classes. Besides, we considered to investigate a fisherman by boat, as a measure to avoid redundancies.

RESULTS AND DISCUSSION

Socio-demographic profile of questioned fishermen

Ages of fishermen varied between 17 and 66 years and the years of practice between 4 and 43 years (Table 1). Out of 78 interviewed fishermen, 18 were less than 30 years-old, about half were between 30 and 49 y-o, 18 were between 50 and 59 y-o and, 5 were 60 y-o or older.

The analysis of sources of income of the fishermen in this survey highlights that 91 % pull their income only of the fisheries exploitation, while only 9 % of them practise another activity to increase their income. The latter were mostly redeemed state employees who possess small boats intended to sailing with the aim of strengthening their yields.

As for the fishing zones, 77 % of questioned fishermen frequent fishing zones which do not exceed 10 miles, generally those using small boats with limited equipments. 50 % of fishermen go fishing at a distance that varies between 11 and 20 miles and only 8 % exercise their activity between 21 and 30 miles. Almost all the investigated fishermen declared that they go fishing near the coast and in the surrounding of Kuriate islands and few of them go fishing beyond the latter.

Potential effects of offshore fish farms on coastal fishing activity

The main problems of coastal fishing activities, as highlighted by fishermen were pollution caused by farms and/or other sources, space limitation for fishing, and net damage caused by dolphins. Additional concerns such as illegal fishing and fuel/maintenance costs were also cited (Figure 2). In Monastir bay, the rapid expansion of fish farming, during recent years, has caused conflicts between various users of the coastal zone. Approximately 77 % of local fishing communities near fish farming zones complained about the loss of fishing grounds and changes in the quantity and quality of catches. Monastir bay covers more than 70 000 ha, of which the farms occupy barely 400 ha. Therefore, the three poles of the system of actors, namely fishers (professionals and recreational fishers), aquaculture producers and tourist promoters share a conflict-sensitive territory, which is highly threatened with degradation, since the coastal fringe is no longer as spacious as it was previously, and its degradation is advanced. The balance that prevailed for a long time between traditional fishing and tourism has been disrupted, recently, by the implantation of the aquaculture projects, the number of which increased steadily, finally to "close the sea" making the small fishermen quartered at a small band between the polluted littoral fringe and the barrier of aquaculture cages.

Net damage because of dolphin depredation, which was reported by 31 % of fishermen, is a source of significant economic losses, especially since the costs of net are expensive. Previously, interviews, like ours, to small-scale fishermen have reported that depredation by dolphins also causes damage to fishing gear and disturbs fishing activities [12-14]. Therefore, the relationship between aquaculture cages on one hand, and the economic damage due to dolphins, on the other hand, cannot be ascertained, although for the fishermen, the size of the group of Delphinidae bordering the region before installation of aquaculture fish farms was very low, and depredation did not exist before the installation of the aquaculture farms.

Finally, above 32 % of fishermen reported that illegal fishing (by trawling and overfishing) is one of the main factors that reduced the livestock. When asked about the source of pollution disabling their fishing activity, the answers were divergent between the local fish farms (40 %) and urban and industrial wastewater (60 %). Additional issues were reported by 38 % of fishermen such us the profitability of the fishing fleets, which is very sensitive to fuel price variations.

Potential effects of offshore fish farms on ecological interactions and biodiversity

All fishermen interviewed (100 %) consented that local fish stocks have decreased significantly during the last years. However, there were some divergences among different age categories when fishermen were asked to identify the period in which that decline would have started (Table 2). A small fraction of the interviewed fishermen population (23%) indicated a precise period, as follows: 11 % (age average 40 ± 6) said that the decline started between 6 to 9 years, 8 % (age average 51.6 ± 7) answered 2-5 years and 5 % (age average 47,5 ± 7) answered 10-20 years. On the other hand, many fishermen (77%, age average 38 ± 12) did not mention any precise period of decline.

As for the most likely causes of livestock erosion, the fishermen assigned the decline of local stock to overfishing and pollution, followed by offshore aquaculture. As there was little Monastir bay-specific data available on changes in fish species, before and after the installation of fish farms, we compiled information from the reports of the Tunisian Fisheries and Aquaculture Department (DGPA), for the period from 2003 to 2015. Using this information, we concluded that the coastal catches of cuttlefish, squid, Octopus, and royal shrimp have been almost stable during the last 10 years, in contrast with those of the large pelagic fish, which have declined. We can explain that the decline of large pelagic fish could be due to the increasing of large predators, attracted by cages. Production of farmed fish (sea bream and sea bass), for the same period (2003-2015), increased with the installation of offshore fish farms as of 2008.

Offshore aquaculture operations are also known to impact the behaviour of wild fish as they aggregate around the cages to take advantage of the discharge of food and faeces [15]. The most abundant and dominant species around fish farms, reported by 30 % of inquiered fishermen, were *Mugil cephalus*, *Octopus vulgaris* and *Sardinella aurita* (Table 3). Further to the ecological effects of wild fish aggregation near sea cages, there is a suspected impact on the biology and physiology of wild fish. Indeed, it was reported that interference between wild fish species and farms diminishes their rate of survival, as they become farm effluents' feeders, feeding on commercial pellets and subsequently altering their fat deposition and their fatty acid composition [16]. The Mediterranean Sea may be a good example of where this could occur, as many of the species associated with farms are currently fully exploited or over-exploited [17]. Dempster *et al.*, highlighted that Mediterranean sea-cage fish farms attracted wild fish assemblages that had up to 30

different species (mainly *Mugil cephalus*, *Trachurus mediterraneus*, *Sardinella aurita* and *Boops boops*) and estimated that the aggregation biomasses ranged between 10 and 40 Tons at 5 of the 9 farms investigated [18,19]. The abundance of Mugilidae and the other small pelagic species near the cages for the direct consumption of feed pellets and to profit of the increase of primary production (phytoplankton and zooplankton) due to release in nutrients [20-22]. Many of the fish species that occur at farms in high numbers are commercially important to coastal fisheries and are already subject to heavy fishing pressure.

Higher-order predators, such as dolphins, turtles and shark, are also present at farms to feed on the aggregated wild fish [23]. Based on our survey, dolphin aggregation would occur year-round (according to 53 % of respondents), only in summer (3.12 %), only in spring (2.34 %). From these responses, it can be inferred that although there was an identical trend in responses to whether dolphins were noted in cage surrounding, there was a significant divergence when fishermen were asked in what season dolphins were seen most often, with 41.5% of them did not indicate any particular season (Table 3). The sea turtles also appeared to have been attracted by aquaculture (to feed on jellyfish), although only 15 % of fishermen interviewed have seen turtles and 85 % did not. This landscape may be induced by variations in the prey species distribution and abundance caused by the setting-up of fish farms in the study area. According to fishermen (30.42 %), jellyfish represent one of the marine populations that seem to be attracted by fish farms. The occurrence of jellyfish, near fish farms, seem be in all seasons (18.72 % of fishermen, Table 3). Jellyfish prey on zooplankton and may affect fish recruitment both directly (top-down control) and indirectly (through competition) [24]. Recent analyses of jellyfish population dynamics in Mediterranean coastal zones suggested increasing abundance and frequency of bloom formation [25, 26].

Feed and excrement draw sharks, which smell food from more than a mile away. According to fishermen, no shark has been observed in the area of the aquaculture farms, but it is possible that they occasionally transit through the site. Many reports of white sharks on the eastern coast of the country have been reported, but not documented. However, three observations were made from 2006 to 2012 (personal communication, Bechir Saidi). Record of Bechir Saidi can be summarized as follows: one specimen in Mahdia (01 July 2006, no measurements taken); a female of 0.5 m length (Mahdia, 04 December 2012) and a specimen of 5.44 m length was recorded in a tuna cage in Salakta (18 October 2009) with a stomach content of blue fin tuna (40 Kg).

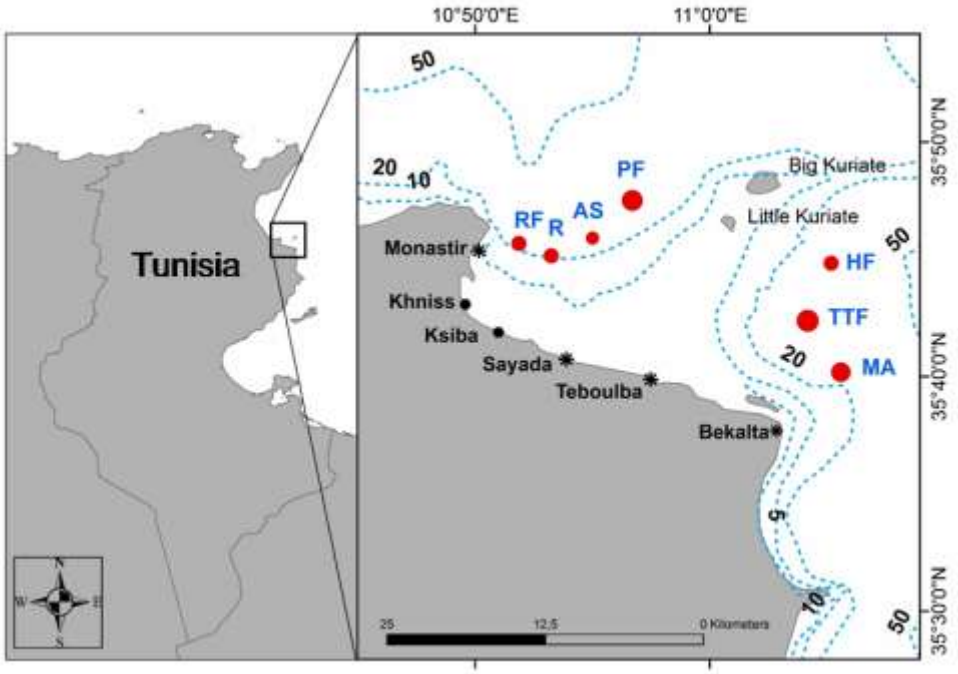

Fig-1: Map of the study area with a focus on coastal fishing zones and cage fish farm sites
✸: Ports; ●: Shelter sites; ●: Cages fish farms.

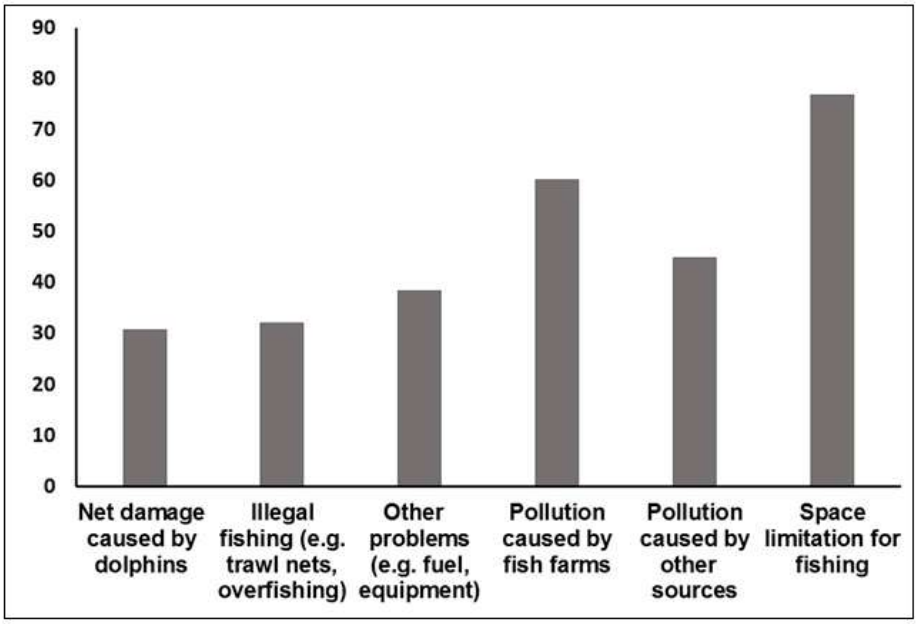

Fig-2: Main factors having a negative impact on small-scale fishery in Monastir bay, according to questioned fishers.

Table-1: Socio-demographic profile of questioned fishermen

	Monastir	Sayada	Teboulba	Total
Total number of fishermen	31	32	15	78
Age range	20 - 63	19 - 40	23 - 66	20 - 66
Primary engagement	27	29	15	71
Occasional engagement	4	3	0	7

Table-2: Perception of the questioned fishermen of the period since which the decline of local fish stocks would have started

Period since which the decline is believed to start (years)	Percentage of total fishermen providing this answer	Average age
2 to 5	8	51,6 ± 7
6 to 9	11	40 ± 6
10 to 20	5	47,5 ± 7

Table-3: Fishermen observations on marine species aggregated around cage fish farms

Answer / Observation	Percentage among total fishers	Period	Observed numbers
Dolphins	100%	• All seasons (53.04%) • Summer (3.12%) • Spring (2,34%) • No indication (41.5%)	• Several (32.76%) • Limited (3.9%) • No indication (63.34%)
Turtles	15%	• Summer (2.34%) • No indication (12.48%)	• One or two (15%)
Fish and molluscs (*Mugil cephalus*, *Octopus vulgaris*, *Sardinella aurita*)	30%	• All seasons (30%)	• Several (30%)
Jellyfish	30.42 %	• All seasons (18.72 %) • Summer (1.56%) • Spring (2.34%) • Autumn (3.12%)	• Several (20.28%)

CONCLUSIONS, RECOMMENDATIONS AND FUTURE PRIORITIES

How to balance the development of aquaculture, fishing activity and protect environment is a challenge that needs to be solved. Surveys, such as ours, are very important for screening the future of aquaculture with the aim to make it feasible for fish farms to coexist harmoniously with fishing. To this aim, appropriate measures should be taken, which seem to include: (1) Installing aquaculture cages away from coastal fishing, sensitive benthic habitats and major fish and mammal migration routes, in order to minimize the interaction between wild and cultured fish; (2) Rotating offshore farm sites, in order to minimize environmental impacts; (3) Improving pre/post-installation survey methodologies adapted to cage offshore systems, in order to assist project evaluations and risk assessment studies; (4) Integrating all actors, in particular those of the coastal fishing, within a management plan of the Monastir bay.

We realize that our results may be an over-simplification, due to the small sample of fishermen respondents to the survey and we look forward in the immediate future to undertaking more interviews and opinions from fishermen from others ports, and working with the industry sector to address the more difficult problems. The search for environmentally friendly control systems at marine fish farms requires cooperation, trust and transparency between the fish farm, fisheries and scientists. We think that this study will contribute a small but significant step to this direction, and that this report will be considered as an interim report of an ongoing study.

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Conflict of Interest

The authors declare no conflict of interest.

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