

Development of the fishing and commercialization of the blue crabs in Bizerta and Ghar EL Melh lagoons: A case study of promotion opportunities of blue growth in Tunisia

Abstract

The blue crab, a species of crustaceans which originally came from the Red Sea through the Suez Canal, appeared, for the first time, in Tunisian waters in the cities of Skhira (governorate of Sfax) and Ghannouch (governorate of Gabes), at the end of 2014. After a year, this species adapted to the environment and proliferated throughout the Gulf of Gabes, to subsequently appear in the Gulf of Hammamet in 2016. In 2018, this invasive species emerged in the lagoons of Bizerte and Ghar EL-Melh. Coastal fishermen operating in crab-colonized areas have reported many problems associated with the appearance of this species in fisheries, including degradation of fishing nets, alteration of other caught species, time spent in its disentanglement, and the drop in stocks of many fish species of high commercial value in the invaded areas.

In view of these issues, the government has drawn up and funded a national plan to promote crab fishing, development and marketing in the Gulf of Gabes. Faced with the weakness of internal demand, the orientation towards the export of crab stands out as a pertinent alternative to explore.

Our project aims to develop an action plan in order to enhance the marketing of the blue crab on a national and international scale in the northern region of Tunisia, precisely in the lagoons of Bizerte and Ghar El Melh. The creation of new jobs and the improvement of incomes for the vulnerable populations of the two communes of MenzelAbderrahmen and Ghar El Melh are the main expected results of this project.

Keywords: blue crabs, invasion, bizertelagoon, ghar el melh lagoon, management, tunisia, blue growth

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Abbreviations: NIS, non-indigenous species; GFCM, general fisheries commission for the Mediterranean; GIPP, inter-professional grouping of fishery products; MSY, maximum sustainable yield; WP, work packages; LEK, local ecological knowledge

Introduction

In Tunisia, non-native crabs represent 70.58% of total alien decapoda.¹⁻¹⁸ The Lessepsian *P. Segnis* (Figure 1 B) is one of the first non-indigenous species (NIS) and is an active carnivorous predator^{19,15} with large populations recorded in the Gulf of Gabes (Southern Tunisia).⁴ Few months after its first entrance, the blue crab bloomed and became a threat to artisanal fishermen with serious socio-economic impacts. Thus, the Tunisian Ministry of Agriculture, Water Resources and Fisheries implemented a national plan for the exploitation and evaluation of the blue crab through grants for research, distribution of fishing gears to artisanal fishermen and launching tasting campaigns. This species is edible worldwide,⁸ and since its record in Tunisia, it has become frequent in all fish markets and in high demand from consumers. The expansion of the blue crab into southern Tunisian waters (Gulf of Gabes)¹³ has led to the development of fisheries addressed to catch this species. In this context, some new traps are experimented by the National Institute of Marine Sciences and Technologies for the capture of *Portunus. Segnis* and *Callinectesapudus* (Figure 1 A & B). With regard *C. sapidus*, although its range expansion in the Mediterranean Sea is very fast⁷

and its first appearance in Tunisia dates back to 2014.⁵ Mili *et al.*¹⁶ suggest the presence of *P. segnis* in Bizerte lagoon since August-September 2018.

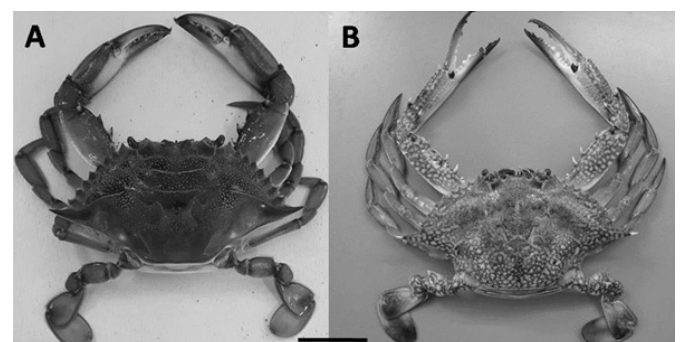


Figure 1 Specimen of *Callinectesapudus* (A) and *Portunussegnis*. (B) from Bizerte lagoon and Ghar El Melh lagoon, North Tunisian waters (September 2019). Scale bar: 25mm.¹⁶

Blue crabs were captured as a by-catch of trammel nets and invisible nets, targeting commercial shrimp species (*Penaeuskeraturus* Forskål, 1775) in northern Tunisian lagoons.

Records of these crab species in the vicinity of Bizerte port, suggests that the most probable introduction pathway is maritime traffic. Therefore, environmental conditions, larvae migration, recruitment

pattern and/or anthropogenic factors such as shipping activities, could be behind the spread of this bio-invasion in the north of Tunisia. The strong potential of expansion of *P. Segnis* to higher latitudes could be attributed in part to the water temperature rise in the Mediterranean Sea. The blue crab recognised as strong swimmers showed a rapid

proliferation and expansion of their biogeography. The existence of an important number of females as well as the high percentage of ovigerous ones leads to deduce that the blue crabs are well established and they form a well-structured population¹⁶ in Bizerte and Ghar El Melh lagoons (Figure 2).

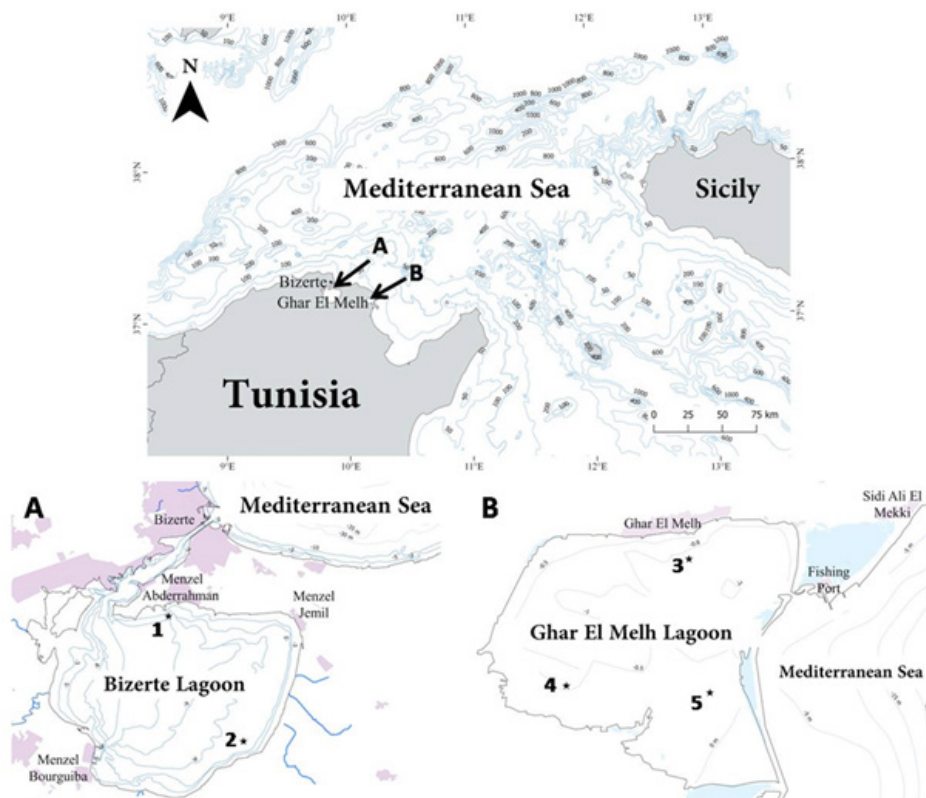


Figure 2 Localization of Bizerte Lagoon (A) and Ghar Melh Lagoon. (B) Mili et al., 2020.¹⁶

2,752 fishermen work in Bizerte lagoon and 1,460 others operate in Ghar Al-Melh lagoon.⁹ Fishermen in the two lagoons have noticed a drop in their income due to the blue crab invasion¹¹ which resulted a reduction in landings of stocks of high commercial value fish resources. On the other hand, the export of Tunisian fishery resources increased as a result of the expansion in the production of blue crab which rose from 770 tonnes in 2017 to 3355 tonnes in 2018 with an increase in value from 5.4 million dinars (2017) to 24.9 million dinars (2018).¹¹ It should be noted that the production of crabs over the last three years concerns only the southern region of Tunisia (Gulf of Gabes).

The aim of this project is to promote opportunities related to blue growth by the development of the blue crabs (*C. sapidus* and *P. segnis*) fishing activity and the commercialization of this resource. This activity will be developed in Bizerte and Ghar EL Melh lagoons which are situated in the North eastern Tunisian waters (Central Mediterranean Sea).

The purpose of this project is to develop new curricula and to increase employability in the study area, which is characterized by an overexploitation of autochthonous resources. The economic impact analysis of this new activity needs data in order to promote investment. The most important missing data are related to stock assessment and bio-chemical quality of this invasive species in Bizerte and Ghar El Melh lagoons. However, the fishing effort and the fishing technologies focused on this species are available and can be used as input in our

project. This work will constitute a basis and a first structure of data collection related to exploitation of NIS resources as recommended by General Fisheries Commission for the Mediterranean (GFCM).

Material and methods

Project description

The project makes it possible to provide a rapid response to the biological invasion of blue crab in the lagoons of Bizerte and Ghar El Melh and to support adaptive management of the problem by encouraging targeted fishing of this species with adequate fishing techniques. This target will be pursued through a series of specific actions, adapted to the local realities. Collaboration with several national partners should be established and it should allow an in-depth risk analysis, which will be fed by ecological and socio-economic information gathered through participatory approaches with the fishing community. The management of these resources is embedded in current governance through a tripartite commission composed by fishermen who will be connected to scientists and to policy makers. Geographic data combined with environmental data will also be used to model the potential geographic expansion of the species. The information gathered will be used to implement adaptive management practices. Communication strategy will target key players in the management of the species and potential end beneficiaries, by encouraging the natural responsiveness of civil society, through specific training.

Target groups involved at the project level

The target groups of this project are fishermen who are impacted by the blue crab invasion in the two lagoons under study, women who make the nets and the fishing gears in the study area, unemployed young people in Menzel Abderrahmen and Ghar El Melh who occasionally work as fishermen, as well as the support organizations that will benefit from the project activities by developing their capacities to support and set up a value chain specific to blue crab. The target group includes civil society which will be associated with the project as a partner. These partners will ensure the perpetuation and sustainability of the project results. The project will adopt a dialogue-

based approach in order to provide a better response to the problem of crab invasion and migratory challenges and to propose innovative alternatives.

Market opportunities for the blue crab in Tunisia

According to the inter-professional grouping of fishery products (GIPP) report,¹² crabs are sold fresh round, cooked, or frozen. The maximum sustainable yield (MSY) of blue crab is estimated at 1,500 tonnes/ year. This estimate of the potential is based on the catches made during the years 2015-2017 in the Gulf of Gabes (Medenine, Gabes and Sfax Governorates). The mapping of the blue crab sector in Tunisia is summarized in Figure 3.

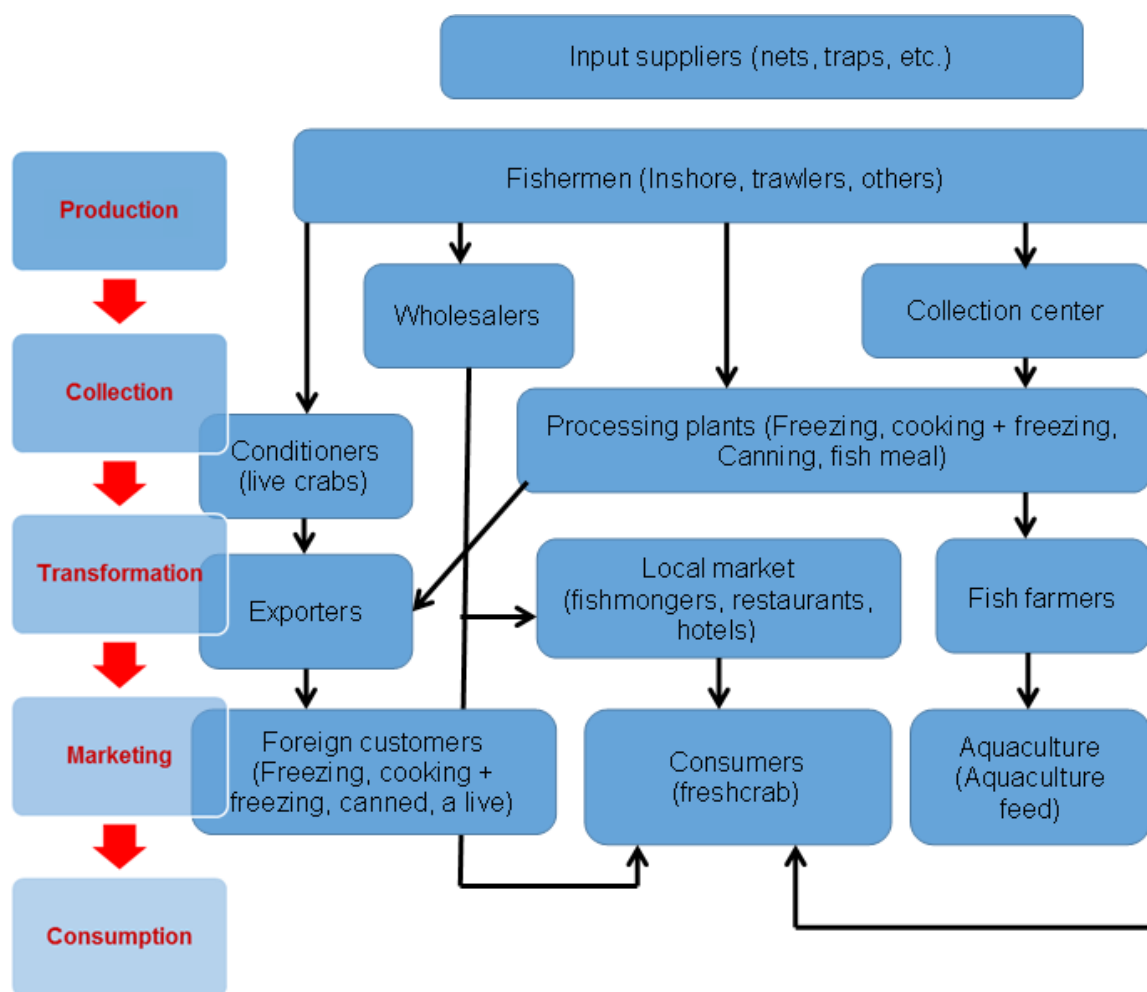


Figure 3 Mapping of the blue crab sector in Tunisia.

Production of the year 2017 is estimated at 1000 T and it is split between processed (75.5%) and fresh channels (24.5%). The majority of the crab caught is used by freezing units whose production is intended exclusively for export as frozen, frozen-cooked, preserved or live products. Small amounts are used by the canning industry (0.1%) and for the production of animal meal for fish farming (0.5%). The fresh channel is intended mainly for the local market.

The crab is drained on a short cycle due to the short shelf life. It is mainly done through fishmongers, markets and supermarkets and it usually goes through fishmongers as intermediaries. Sales on the local

market (in 2017) were of the order of 210 tons which represented 21% of the national production. This sale is detailed in Figure 4. Most of the crab catches in Tunisia are used by processing and packaging units to be subsequently exported in the form of frozen, frozen-cooked, preserved or live products. This channel concerned around 75% of catches in 2017 (Figure 5).

Crab-meal has been introduced into the crab production line since 2017 for use as a substitute in the manufacture of aquaculture feed for fish farms (Figure 6).

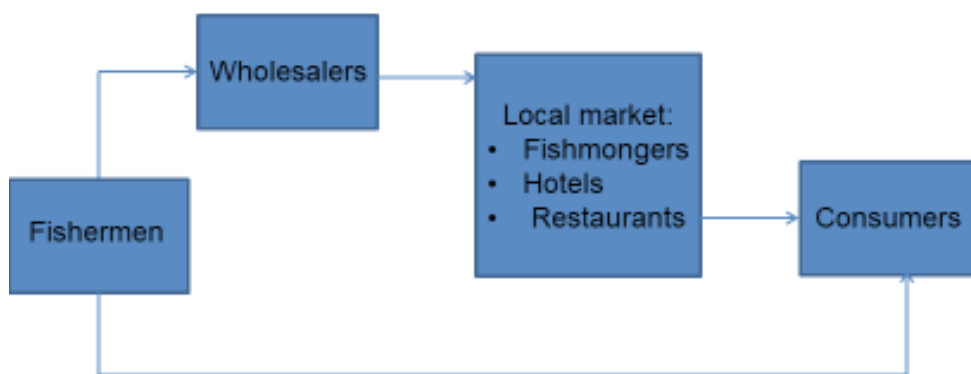


Figure 4 Blue crab sales channel in the local market.

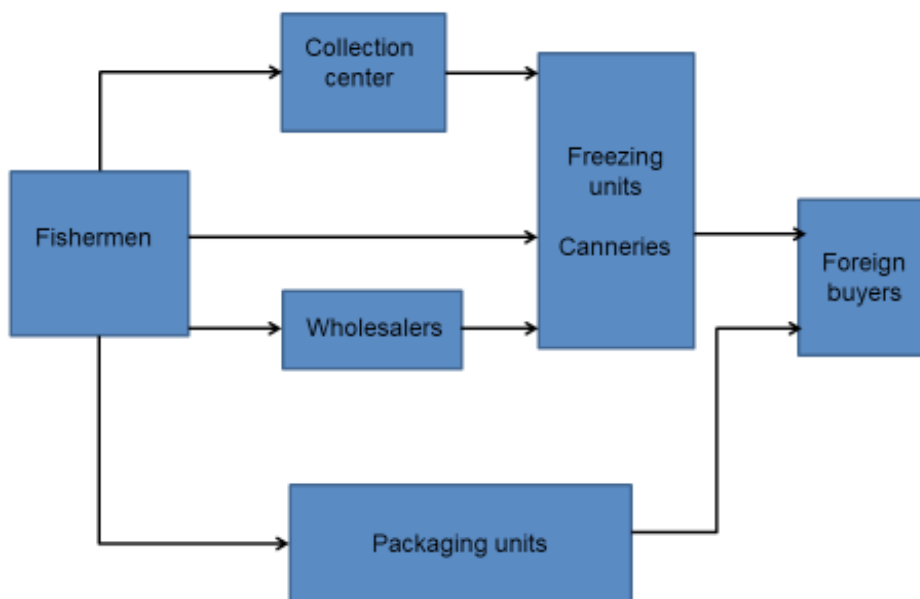


Figure 5 Blue crab sales channel in export.

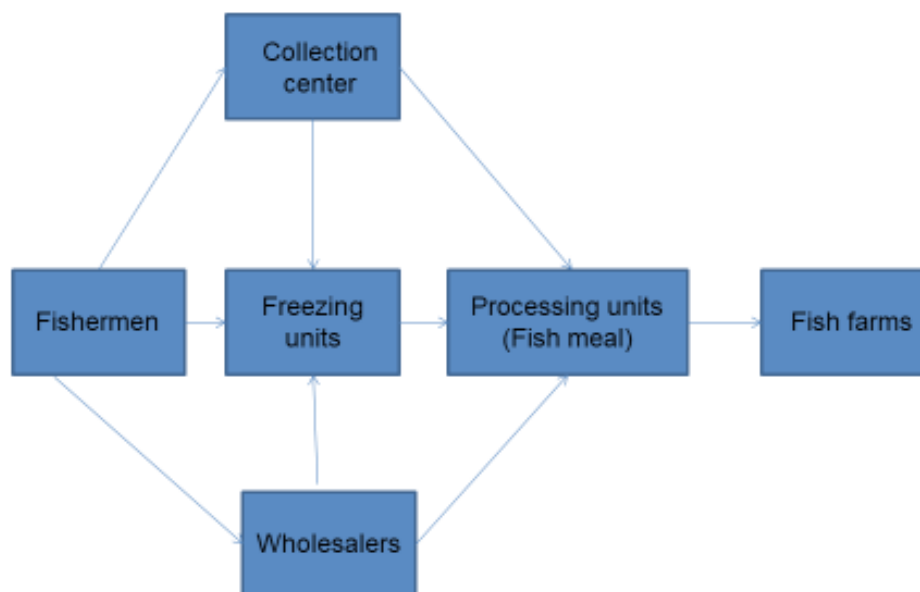


Figure 6 Channel of Blue crab-meal intended for pisciculture.

Analysis of the offer

Crab exports increased from 38.4 tons in 2015 to around 755.5 tons in 2017. This exponential development was related to both volumes and values (Table 1).

Table 1 Evolution of crab exports

Exports	2015	2016	2017
Value (Th D)	171.4	621.8	5243.1
Volume (Tons)	38.4	140.9	755.5
Average price (D/Kg)	4.5	4.4	6.9

Crab products are exported mostly in frozen (92.5%) and cooked-frozen (6.63%) forms. The destinations of exports are mainly Vietnam (37%) followed by Spain (19%), Malaysia (13%). The price of crab at production is 2 dt/kg while it is around 6.9 dt/kg when exported and 1.6 dt/kg when processed into flour.

Project activities

The project will be composed of 5 work packages (WP).

The first work package will be dedicated to management. The general objective of this WP is to set up a solid, coherent and transparent management structure which will ensure an adequate coordination of the tasks between the partners. It will follow up on the realization of the project and the evaluation of its progress in relation to the defined objectives related to the budget, resources and schedule.

The second WP will be devoted to communication. It will consist in creating thorough communication as well as a dissemination plan to help define and achieve the project objectives and the goals of the various activities and their outcomes. In addition, putting in place an appropriate communication strategy will make it possible to reach different target groups and transmit key messages. The communication plan must include a roadmap of activities; facilitate coordination between the various partners; and ensure a broad impact thanks to the full capitalization of stakeholders and partner contacts.

The third WP will be devoted to socio-ecological analysis, risk monitoring and assessment. We will model the risk of blue crab invasion in the project area through producing maps through the production of maps and highlighting introductory hotspots. This Task Group will be based on ecological sampling in the field, as well as Local Ecological Knowledge (LEK) obtained from local stakeholders, mainly fishermen. The vulnerability of the study area to blue crab invasion will be assessed using a spatial analysis of ecological data obtained by LEK.

LEK will provide researchers with field data and retrospective estimates of blue crab population trends in the study area. Ecological data gathered in the field and from stakeholders will produce three main results:

The first output is the production of a map illustrating the geographical distribution of blue crab in the study area which will show this species abundance spot and highlight potential source-sink systems. This map will be extremely important for a future blue crab management plan. It will especially help to locate crab harvesting areas and maximize commercial and ecological gains.

The second output is represented by the data set necessary for the production of the map. This dataset will integrate both LEK and field

data related to the presence of blue crab in the two lagoons (Bizerte and Ghar El Melh). These data will be available and will serve as a basis for policy development, communication campaigns and future research on the species.

The third result is vulnerability assessment which will show where and how fast the blue crab can currently spread in the study area as well as its distribution in the near future. The vulnerability assessment will include a detailed analysis of the pathways of invasion, a list of potential environmental and socio-economic impacts, and a risk map showing expected changes in the distribution of the species under various climate scenarios.

The fourth WP will be devoted to the development and testing of a blue crab invasion adaptation strategy for fishermen, scientists, fishmongers and civil society. The purpose of this working group will be to build the capacities of end beneficiaries and disseminate knowledge in relation to the blue crab invasion:

- Training on the notion of the crab invasion and its effect on the ecosystem and local fauna. This training is intended for fishermen from Bizerte and Ghar El Melh lagoons, civil society and unemployed young people from the two municipalities.

- Tasting campaigns for *Portunus segnis* and *Callinectes sapidus* blue crabs will be organized at the level of the two municipalities to encourage people to consume them and consequently encourage fishermen to exploit them. This fishing activity will constitute a new source of income for fishermen and fishmongers as well as women who make the fishing gears.

- Training and supporting women and young people in the implementation of best production practices (conservation techniques by freezing and packaging, quality and hygiene standards, better organization of the workspace, packaging, etc.).

- Operationalization of an action plan aimed at improving market access and sales conditions for blue crab.

- Establishing partnerships between the consortium and blue crab export factories located in Tunis and in the southern region of Tunisia and providing support for women to comply with the requirements of different markets.

- Identifying other potential buyers (e.g. supermarket channels, restaurants) and assisting the consortium in negotiating sales contracts.

- Training fishermen from the two lagoons, unemployed young people and women from the two municipalities on designing and making specific fishing gears to capture blue crab. The use of specific traps to catch crabs will be a useful asset in the fight against their propagation and multiplication in the two lagoons.

- Training fishmongers on the blue crab value chain by inviting wholesalers from Kerkennah region who have already started the blue crab marketing activity on a national and international scale. This training will aim to assist professionals in the development of an export plan. A second training course related to the development of a marketing strategy will be addressed to exporters wishing to develop an export plan for the blue crab.

WP 5 will be devoted to an eco-biological study of the two blue crabs *Portunus segnis* and *Callinectes sapidus* in the lagoons of Bizerte and Ghar El-Melh. As showed by Ben Abdallah-Ben Hadj Hamida *et al.*^{3,4}, some eco-biological parameters of these species will be studied in the new locations of introduction.

Biochemical analyses, as made by bejaoui *et al.*¹⁴ of the blue crab meat will be conducted in order to prepare a file for the zoosanitary classification in relation to these species. This classification is essential for the sustainability of the activity of exploitation and marketing of this resource. Additionally, this will be important for defining a preliminary protocol with ecological and economic info useful to develop a label and thereafter a certification. The label will increase market opportunities in term of value and possibility to access new markets.

Results

Highlight innovative aspects within sustainable blue growth

The two chosen lagoons face complex issues: socio-economic (low income from artisanal fishing, vulnerable young population threatened by illegal immigration) ecological (invasion by new species such as blue crab) and lack of alternatives or solutions to improve the living conditions of local residents.

The project will seek to adopt an approach based on dialogue and cooperation with fishermen from the communes of Manzel Abderahmen and Ghar-El Melh with a view to involve them in the various activities of the project as soon as it is launched. Their involvement in the project as a target group is a key success factor for the project because they would directly benefit from the blue crab adaptation and enhancement program, since these fishermen are currently the ones who are suffering the harmful effects of the bio-invasion.

Given the commercial potential of the blue crab, a series of pilot actions will be geared towards the promotion and development of the value chain of this species on national and international markets, involving all socio-economic players and even the general public. These actions aim to stimulate socio-economic dynamics around fishing activities for invasive species. This adaptation strategy will be a concrete and effective solution to tackle the blue crab problem and will constitute an effective model for its expansion into other fishing regions in Tunisia. All these activities and actions will contribute to the creation of new jobs in the blue economy.

Credibility and feasibility

Strengths	Weaknesses
<p>Blue crab marketing has been successful in the southern region of Tunisia (Kerkennah).</p> <p>The international market already exists for crabs caught in the southern region of Tunisia.</p> <p>Targeted blue crab fishing in the Gulf of Gabes (where this species has settled since 2014) has resulted in ecosystem resilience.</p> <p>The specific traps for catching the blue crab have already been tested and adapted to its capture.</p> <p>Involvement of civil society and the general public in other previous projects will have a positive impact on the success of the different project actions.</p> <p>The Tunisian consumer is beginning to appreciate the consumption of these invasive species</p>	<p>Lack of data relating to the eco-biology and the state of exploitation of crab stocks in the two lagoons of Ghar El-Melh and Bizerte.</p> <p>Lack of a relative value chain for crab fishing in the northern region of Tunisia.</p> <p>Lack of tradition of consuming crabs in Tunisia.</p> <p>Lack of zoosanitary classification related to this fish resource.</p>
Opportunities	Threats
<p>Creation of new jobs.</p> <p>Improvement of fishermen's income.</p> <p>Improvement of the income of women who earn their livings from making fishing gears.</p> <p>Resilience of the two weakened lagoon ecosystems due to the blue crab invasion.</p> <p>Valorization of consumption and export of blue crab.</p>	<p>Economic crisis in Tunisia.</p> <p>COVID19 pandemic.</p> <p>Reluctance of the beneficiaries of this project (fishermen, unemployed young people from the two municipalities, women) to join.</p> <p>Insufficient blue crab stocks for marketing and setting up a specific activity.</p> <p>Non-acceptance of the product by the Tunisian consumer or customer.</p>

Cross-cutting sustainable

The various actions programmed at the level of our project meet two objectives which have been set by the United Nations for sustainable blue development and which were mentioned in the report “The sustainable Development Report 2020”¹⁷. Indeed, this project is very important in supporting the implementation of sustainable development according to objective 14 “Life below water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development”. In addition, our project meets the first objective of sustainable development with regards to poverty; “No poverty: End poverty in all its forms everywhere” and the 5th objective “Gender equality: Achieve gender equality and empower all women and girls”. Based on these objectives, our project will involve

three pillars of sustainable development: “environment, social and economic issues.”

In order to support this fishing activity and to set a sustainable level exploitation of this resource stock assessment and eventually associated species and discards in relation with its ratio of exploitation and market will be monitored and updated regularly.

In addition, this project will facilitate joint reflection on the sustainable development strategy of the blue crab fishing industry, reconversion strategies, and slowing down the loss of biodiversity. On the other hand, common management strategies will allow the expansion of the market and the implementation of trade in this fish product.

Regarding social and economic aspects, our project will contribute to converting the danger presented by the blue crab invasion into opportunities through the creation of new professions for the vulnerable inhabitants of the communes of Menzel Abderrahmen and Ghar El-Melh. This project will primarily affect the fishermen of the two lagoons, the women who work in the fishing gear manufacturing sector and the unemployed young people affected by poverty and precariousness. The economic sector will be positively affected by this project through the income improvement of the fishermen and all the beneficiaries involved in this activity.

Regarding the environmental pillar, the targeted blue crab fishing component will allow the mitigation of its expansion, which will promote the restoration of the ecosystem of the two lagoons and the resilience of native species of commercial interest. The collapse, due to the invasion of the blue crab, of certain stocks of indigenous fishery

resources can thus be restored, which will have a positive impact on the resources and the two lagoon ecosystems.

The traps which will be used are selective and harmless compared to other gears targeting other species of high commercial value.

Discussion

The main objective of the project is the sustainable development of Bizerte and Ghar El-Melh lagoons which are subject to a blue crab invasion. This project will have a very significant environmental impact by ensuring resilience at the level in these ecosystems. Targeted blue crab fishing and its marketing will have a socio-economic impact on the local communities at the level of the communes of Menzel Abderrahmen and Ghar El-Melh. In addition, it will promote blue growth in these two lagoons. Figure 7, summarizes the novelties related to blue growth that we will introduce with our project.

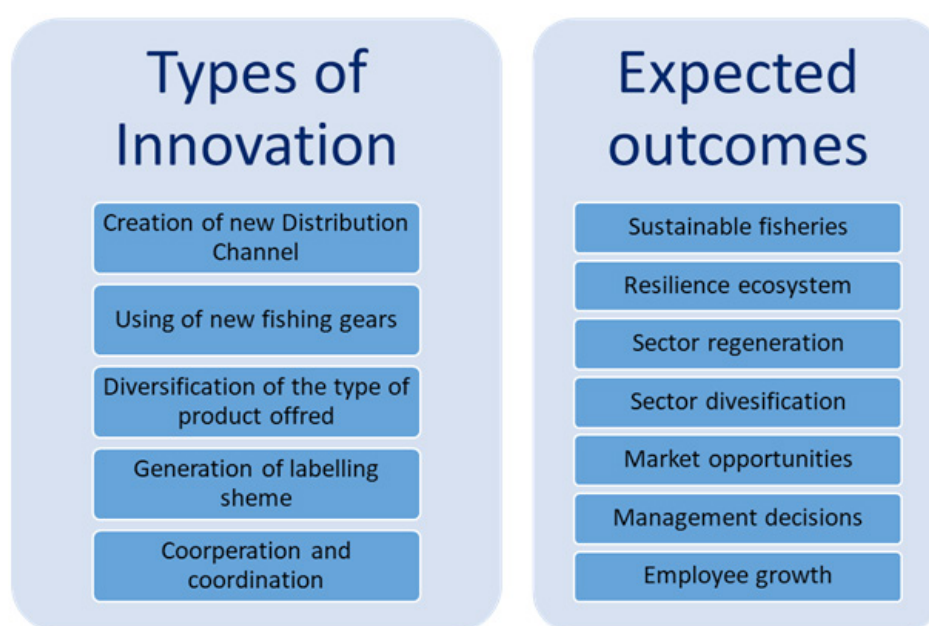


Figure 7 Novelties related to Blue growth.

Science impacts

Targeted blue crab fishing, which is starting to settle in the two lagoons of Bizerte and Ghar El-Melh,¹⁶ is a method of control, mitigation and protection of marine resources through the implementation of the strategy of adaptation to the bio-invasion by this species. The success of this strategy will allow the preservation of artisanal fishing in the two lagoon ecosystems invaded by blue crabs and the re-establishment of fish stocks in the two lagoons which are of economic, social and cultural importance.

In this project we will use innovative and solid methods for scientific and management analyses. These management methods, based on the use of new participatory tools for monitoring, management and mitigation of the impacts resulting from the introduction of invasive alien species in coastal areas, have already been adopted in other regions of the Mediterranean.

In fact, the environmental problems linked to the expansion of blue crab areas and the exposure of tropical species sensitive to climate change represent new pressures on fishing in Tunisia. The analysis of the impact of these pressures will be approached by methods developed through previous research in the Mediterranean.

The participatory approach and LEK protocols, in the cognitive phase of the project, have been tested by international experiments. In recent years, the LEK protocol has become increasingly adopted by researchers and environmental practitioners. The necessary input will come from the daily ecological experiences of local communities and stakeholders directly related to ecosystems and their surroundings.¹⁰ Individuals accumulate this information throughout their lives, making LEK an ideal tool to study large spatial and temporal scale ecological models, such as biological invasions. In this case study, fishermen and other local stakeholders will provide simple presence records,² as well as historical trends or categorical abundance estimates.⁶

LEK will be assessed using structured interview protocols involving fishermen and stakeholders in accordance with the study of Azzurro *et al.*¹ Interviews will be tailored after an initial pilot phase based on in-depth qualitative interviews with fishermen and group discussions with local decision-makers.

The eco-biological study will make it possible to collect all the data related to the dynamics of crab populations (reproduction, growth, diet, mortality, etc.) which will subsequently be used as input for stock assessment models. The rational exploitation of crab stocks

will allow the sustainability of the fishing activity of this resource as well as related resulting activities.

The resilience of the ecosystems studied (Bizerte Lagoon and Ghar El-Melh Lagoon) in this project will be an asset for scientific research and will make this work a pilot project whose results can be transferred to other coastal communities who have to deal with similar problems resulting from climate change.

Economy

Our project will promote the development and improvement of the economic situation of fishermen, women who make fishing nets and unemployed (vulnerable) young people who, in most cases, live in precarious conditions due to the scarcity of fish and marine resources following the proliferation of blue crab. The integration of new management measures will promote the improvement of the living conditions of local communities at the level of the communes of Menzel Abderrahmen and Ghar El-Melh, thus enabling their subsistence. A subsequent transversal benefit is intended for investors who will directly impact the socio-economic sector. The overall quality of life of the residents of these two lagoons will be improved following the results obtained.

The realization of this project will allow the creation of new jobs in the blue economy while preserving and improving the initial traditional fishing activity in the two lagoons. In fact, the fishermen will keep their original fishing activities through the integration of a targeted capture of the blue crab using specific traps that already exist on the Tunisian market. These fishermen will observe an increase in their income while fighting against the massive invasion of this species.

Women working in the fishing sector and who will benefit from economic empowerment leading to an improvement in their life conditions and those of their families and unemployed young people in the two communes are strong elements for the success of this project and need to be integrated from the start into the various activities. This group is vulnerable and it is the most affected by illegal immigration. The project will allow these young people to have stable jobs and sustainable income following the establishment of crab fisheries associated with the development and marketing of this resource.

The main objective of this action of the project is to train these two actors in new professions in relation to the marketing of the blue crab, both nationally and internationally. In addition, fishmongers will have a new source of income through the integration of this fish product into their commercial activity.

Society

The project will guarantee gender equality by involving the women who operate in making fishing gears used in the two lagoons invaded by blue crabs as it will guarantee their financial independence and their dignity. Young unemployed people will have an increased chance of working in their localities and more opportunities to earn a living. This will directly impact their living conditions and help reduce the rates of illegal immigration to Europe.

Future careers

The scientific results of this project will be the subject of oral communications, posters, articles in daily journals as well as scientific articles.

A seminar is planned after the end of the project in order to disseminate the main results, expose the methodologies used (performance, limits, etc.) and testimonials from people in the profession will be scheduled there.

End of study projects and masters, for regular follow-up, will be proposed by the project team. The supervision of students will boost the careers of supervisors, as researchers, in the field of fishery sciences.

Our commitment and the success of this project, which falls within the framework of the blue economy, will allow the team of our institution to familiarize themselves with this field and to be able to subsequently propose other projects in the field of sustainable development of the blue economy.

Conclusion

The main objective of the project is the sustainable development of the two lagoons which are subject to a blue crab invasion. Targeted blue crab fishing and its marketing will have a socio-economic impact on the beneficiaries of this project. In addition, this project will have a very significant environmental impact by ensuring resilience at the level of the two target ecosystems, which will promote blue growth in these two lagoons.

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Conflicts of interest

The author declares that there is no conflicts of interest.

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