THE EX-SITU ADAPTATIVE POWER OF THE BLUE CRAB *CALLINECTES SAPIDUS* RATHBUN, 1896

Farida Becir, Asma Leulmi, Malek-Zakia Nessaifia, Samia Bouanani, Mostapha Beniddir

Abstract: In 2023, this study was conducted involving the capture of 115 blue crab (*Callinectes sapidus* Rathbun, 1896) specimens from the Mellah Lagoon, Ramsar site. The crabs were transported alive in clean containers to holding tanks to assess their adaptive capacity and to determine the optimal conditions for their survival.

Known by the nickname 'Dhaech', in the northwest of Africa, for its destructive nature, the blue crab consumes everything in its path, severely disrupting the environmental balance. Since 2019, this invasive species has posed a significant threat to the ecological equilibrium of the Mellah Lagoon. Despite its destructive impact, the blue crab is edible and offers economic potential for the local economy. Its shell contains chitin, a valuable material with multiple uses, including cosmetics, burn treatments, and the production of surgical sutures due to its strength and flexibility. Chitin is also used in wastewater filtration and has applications in the food industry, such as in juice production.

This study presents a solution to mitigate the impact of this destructive invasion on the lake while taking advantage of its economic potential. The approach involves extensive fishing followed by keeping crabs alive until they can be sold on the market. Therefore, we aimed to extend the crabs' survival time in ex-situ conditions for as long as possible.

Our findings show that blue crabs adapt more effectively to brackish water environments compared to freshwater. Notably, the population of crabs caught in the Mellah lagoon also demonstrates the ability to adapt ex-situ to a broad range of physical-chemical conditions, mirroring their adaptability in their natural habitat. The sardine was the best food in terms of cost and yield compared to shrimp and Fish meal. No parasitic forms were detected in the Callinectes sapidus specimens collected from the Mellah lagoon.

Keywords: *Callinectes sapidus*, blue crab, Mellah lake, ex-situ, adaptation

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Introduction

The Mellah Delta is home to various species, including Salicornia and Juncus, as well as a rich diversity of phytoplankton and zooplankton. It also serves as a nursery and feeding ground for many fish species, particularly eels preparing for their long migratory journeys. The lake supports an abundant population of fish such as sea bass, common sole, slap, marbled fish, and eels. Due to the abundance of food, the lake attracts numerous bird species, amphibians, and reptiles. It hosts a variety of waterfowl, including 14 migratory species, 10 breeding species, and 20 wintering species, such as the great cormorant, great crested grebe, and Eurasian eagle-owl. This ecological richness has earned it a place on the Ramsar list of wetlands of international importance.

Callinectes sapidus, commonly known as the blue crab, is native of the western Atlantic Ocean. It has been introduced into the eastern Atlantic, the northern and eastern Mediterranean, Japan, the French Mediterranean lagoons, and the Ebro Delta in Spain, where it is considered an invasive species [3-4]. In Algeria, the blue crab was officially reported on August 26, 2018, in Jijel and later observed in El-Kala (El-Taref department) on November 19, 2019, at Oued Mafragh, and in Mellah Lake [5-7].

The ecology of blue crabs varies by size: larger crabs can inhabit depths ranging from 0 to -35 meters and even as deep as -90 meters, while smaller crabs are typically found in deeper waters [1]. They thrive in temperatures between 3 °C and 35 °C and can survive up to 45 °C for short periods [2]. Although primarily a coastal species, blue crabs are also found in freshwater environments, lakes, estuaries, and mangrove forests [8-9].

Blue crabs, a newly introduced exotic species in Mellah Lake, consume everything in their path, disrupting and impoverishing the local ecosystem. This study proposes an alternative approach to managing this invasion by leveraging the economic potential of the species. The objective of the study is to explore the feasibility of cultivating blue crabs in Mellah Lake and maintaining them alive in controlled conditions. To achieve success in ex-situ cultivation, it is crucial to find the right balance between food quality, population density, and water quality. This balance will help reduce intraspecific competition for food and reproduction, as well as interspecific interactions, such as parasitism, thus significantly lowering the primary causes of mortality.

Materials and Methods

The study was carried out at El-Kala National Park. In 2023, a total of 115 blue crab specimens were gradually caught from Lake Mellah, a brackish lagoon connected to the sea by a 900-meter-long canal. Designated as a Ramsar site on December 12, 2004, Lake Mellah spans nearly 5600 hectares and is situated in El-Kala National Park at coordinates 36° 53' N, 08° 20' E, in the far northeast of Algeria (El Tarf department) [8].

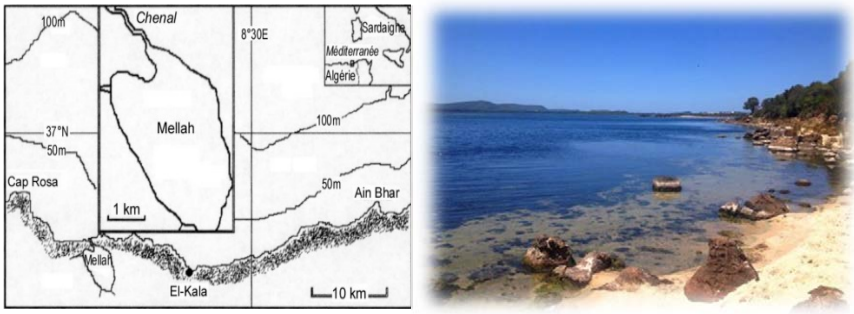

Figure 1 – Location of the Mellah lagoon [10] (left) and a partial view of Mellah Lake (right).

This study was conducted in two phases:

i. At Mellah Lagoon, where:
   - 115 specimens of *Callinectes sapidus* were caught, with fish traps,
   - With the U-50 multiparameter analyser from HORIBA, we were able to simultaneously measure 11 key water parameters of the Mellah lagoon (Fig. 2),
   - Crab measurements (weight, length, and width) were taken (using a calliper and a precision scale), and the sex ratio was calculated.

ii. At the aquaculture farm, where:
   - The crabs were kept alive in ex-situ, and their behaviour was monitored.

Since the invasion of El-Kala National Park by the blue crab (Callinectes sapidus) in 2019, its populations have successfully stabilized in wadis, coastal waters, and most notably in Lake Mellah, thriving in both freshwater and brackish environments. After analysing the physical-chemical variations across the different habitats affected in the region, we opted to establish four types of tanks for ex-situ experiments, and we gradually increased crab density and observed their behaviour. The basins were set up as follows:

- Freshwater (tap water) without sand,
- Freshwater (tap water) with sand,
- Brackish (sea water) without sand,
- Brackish (sea water) with sand.

The purpose of this study is to achieve two main objectives related to crab farming. Each of these steps is crucial for the success and sustainability of our aquaculture project. The aims are as follows:

Ensure the survival of crabs

i- Maintain a clean and stable aquatic environment: control parameters such as temperature (20 °C÷25 °C), pH (7÷8), salinity (25 ÷ 32 psu), and a good oxygenation.

ii- Provide a balanced diet: ensure the diet is adapted to the nutritional needs of crabs to promote their health and growth.
iii- Create a suitable habitat: develop a habitat that mimics their natural conditions, allowing crabs to behave naturally and reducing stress.

Successfully fatten the crabs

i. Crab feeding: Three different types of feed were tested to identify the most suitable and cost-effective option (non-GMO fish feed, shrimp, and sardines).
ii. Population density: The number of males and females in each tank was gradually increased to determine the minimum territorial size and ideal sex ratio. The sex ratio represents the proportion between the number of males and females in the population. The territory size refers to the minimum area in which each male establishes its personal space (with reduced interaction, indicated in crabs by a decrease in agitation).
Sex ratio = Number of females / Number of males.
Territory size = Total area of the habitat / Number of males ; under conditions of ecological equilibrium (absence of stress).
iii. Continuous monitoring: The crabs' ex-situ behaviour was continuously observed, including aspects such as feeding patterns, activity levels, and territorial boundaries.

Figure 2 – Ways to catch blue crabs in Lake Mellah.

The crabs were shipped alive in tanks offering the best conditions to aquaculture ponds located 30 km from an aquaculture station. The ponds were already prepared before receiving the harvested crabs.

Figure 3 – Aquaculture ponds.

Results and Discussion

Crab biometry

The easiest way to determine a crab's gender is by examining its abdomen. Males have a more prominent 'T'-shaped abdomen, while females have a triangular abdomen that becomes more pronounced and semi-circular after maturity. The average length of crabs from Lake Mellah is 138.29 mm, with a width of 64.52 mm and a weight of 153.89 g. In terms of size, male blue crabs are consistently larger than female blue crabs, a characteristic clearly observed in the population of Lake Mellah.

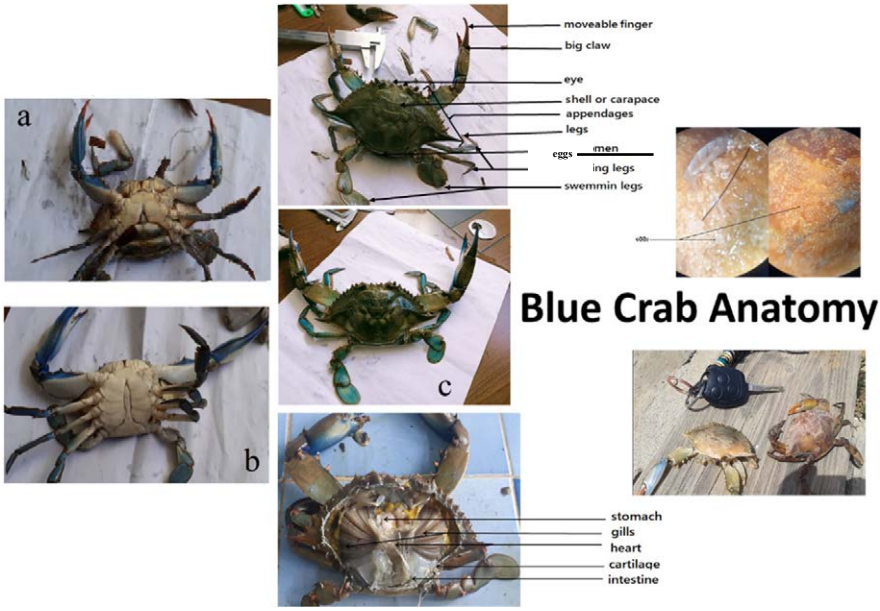

Figure 3 – Lake Mellah's *Callinectes sapidus* population and its anatomy.

The measurements of crabs from Lake Mellah are similar to those of their counterparts sampled in other regions. The species has adapted well after three years of settlement. Our study also revealed that female blue crabs outnumber males at Lake Mellah, with a consistent ratio of four females to every male throughout the year.

Table 1 – Crab measurements.

		Length (mm)	Width (mm)	Weight (g)
Male	Average	144,74	71,76	200,68
	Max	176,26	79,73	292
	Min	127,02	64,6	117,5
Female	Average	136,01	61,96	134,61
	Max	168,62	72,73	189,5
	Min	119,28	10,96	83,5

➢ ***Feeding Trials:*** this study assessed three types of feed to identify the most effective and cost-efficient option for sustaining blue crabs (Callinectes sapidus):

- ♦ Fish Meal (Natural, Non-GMO): This feed showed limited effectiveness, as it did not sufficiently attract the crabs or satisfy their feeding needs, resulting in low consumption rates,
- ♦ Rose Shrimp: Known to be a highly preferred food source, particularly during the reproductive season, pink shrimp were readily consumed by the crabs. However, their introduction led to increased aggression and agitation among males, which resulted in physical injuries such as shell fractures, loss of body mass, and in some cases, mortality.
- ♦ Sardines: Sardines, a locally abundant and nutritionally rich resource, proved to be a more favourable option. They provided high nutritional value at a reasonable cost, making them a sustainable choice for feeding.

Feeding was replenished in each basin as needed, allowing for continuous observation and calculation of the average daily intake per crab. This approach enabled precise monitoring of feeding behaviour and consumption rates, ensuring an optimal feeding regime.

Table 1 – Crab's feeding

Food	Consumed portion	Quantity/crab/day
Fish Meal	-	-
Rose Shrimp	the abdomen	3 ± 1
Sardines	trunk and tail	0,1

Sardines were unanimously identified as the most effective feed tested. However, if not consumed promptly, it contributes to increased water turbidity,

necessitating water replacement every two to three days. The farm's proximity to the sea, located approximately 100 meters away, facilitates efficient water renewal.

- ***Habitat selection:*** Initially, tanks were filled only with water, two tanks with freshwater and two with seawater. In the freshwater tanks, the crabs exhibited frequent agitation, and their food consumption was consistently two to three times higher than in the seawater tanks. In the seawater tanks, the crabs became agitated in our presence, leading us to suspect that the species exhibits shy behaviour. To simulate the lakebed environment, we added sand (collected from the lake) to one seawater tank and one freshwater tank, covering the tank bottoms. The addition of sand significantly reduced agitation, with 100 % of the crabs burying themselves in the sand. As a result, all crabs became immobile, and their food consumption dropped to nearly zero at temperatures ranging between 17 °C and 20 °C. No crab mortality was recorded under these conditions over the course of four months.

- ***Couple formation*****:** at aquaculture ponds the sex ratio balance is four to five females for each male. The imbalance causes a strong agitation of males and a lot of aggressiveness that can cause even the death of the less competitive one. The male even outside the laying period spends his days protecting its females by standing on these last and attacking all those who come close to it. However, no ovigerous females were observed during the breeding period.

- ***Mortality*****:** the main cause of crab mortality in ex situ was intraspecific interactions for territory and/or female protection and/or foraging. We were able to determine the mean area of occupancy of an ex-situ male crab by analysing its behaviour, which showed an average surface area of 0.4 m^2. This minimum average surface area ensures population stability, minimizing crab losses to nearly zero and eliminating any signs of agitation.

- ***Parasitism:*** during this study, we recorded the loss of five crabs (one male and four females). According to the literature, parasitism is a major cause of mortality in *Callinectes sapidus*. The deceased specimens, and more than 30 additional dead crabs collected from the lake, were examined at the university laboratory using to identify any potential parasites. The trematode (*Spelotrema nicolli*) is the parasite known to infect *Callinectes sapidus* [11-12]. In the laboratory, crabs were first inspected with the naked eye to detect macro-parasites, followed by detailed examination under the binocular microscope for internal micro-parasites. No signs of parasitism were found in any of the examined specimens.

Conclusion

The blue crab (*Callinectes sapidus* RATHBUN, 1896) was native of the temperate and tropical coasts of the western Atlantic. Known for its remarkable adaptability [13], this species has successfully established itself in its new biogeographical range, the Mellah Lagoon. This environment was stabilized by the lake's physical-chemical and biological conditions [14], and the morphometric characteristics of crabs from Mellah remain consistent with those observed in other populations.

The ex-situ maintenance of live blue crabs was successfully achieved at the aquaculture facility using seawater tanks with sand bottoms, maintained at temperatures between 17 °C and 20 °C. The operational costs were limited to seawater transportation, electricity to run the structure, and food supplies. During winter, blue crabs naturally reduce their activity and food intake, a behaviour also observed in the aquaculture environment, where the crabs move only when absolutely necessary.

Males establish territorial boundaries and protect their mates by covering the females with their bodies. Each male tends to guard a group of four to five females, shielding them from potential threats.

Increased agitation among crabs in the tanks is associated with heightened mobility and aggression, which may be triggered by insufficient space (less than 0.4 m² per crab), competition for food, or perceived dangers.

Parasitological analysis revealed no signs of parasitism, suggesting that the crabs in this population are free from parasitic infection.

While this invasive species disrupts the ecological balance of Lake Mellah, a Ramsar Site, it is highly valued and appreciated in other regions. There is an urgent need to stabilize the species' presence and transform it into a sustainable economic resource. This study demonstrates the feasibility of this approach at a low cost, where the commercialization of the species could offset the expenses of restoring the invaded areas.

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