DENSITY AND POPULATION STRUCTURE OF *PINNA NOBILIS* (MOLLUSCA, BIVALVIA) IN THE GHAR EL MELH LAGOON (N-E TUNISIA)

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ملخص

الكثافة و التّركيبة السّكانية لصدفة"*Pinna nobilis*" في بحيرة غار الملح : يهتمّ هذا البحث بدراسة الكثافة و التّركيبة السّكانية لصدفة"*Pinna nobilis*" في بحيرة غار الملح أجريت دراسة ميدانية في الموقع سنة2007 في أربع محطات وتتوزع هذه المحطات من البحر الى البحيرة. تبيّن أنّ هَذا النوع من الرّخويات تعيش وسط معشّبات" *Cymodocea nodosa* و*Ruppia* و*Nanozostera*" كما لاحظنا أنّ الكثافة تقلّ كلّما ابتعدنا عن منطقة إلتقاء البحيرة بالبحر يبلغ العمر الأقصى للصدفة 9,7سنة وقد استنتجنا أن هذا يتوافق مع فترة فتح القناة بين البحر و البحيرة في سنة 1996حيث تحسنت نوعيّة مياه البحيرة.
كلمات مفاتيح: البحر الأبيض المتوسط، بحيرة غار الملح، تونس، الرخويات.

RESUME

Densité et structure de la population de *Pinna nobilis* (Mollusque, Bivalve) au niveau de la lagune de Ghar El Melh (N-E Tunisie): Ce papier s'intéresse à l'étude de la densité et la structure de la population de *Pinna nobilis* au niveau de la lagune de Ghar El Melh. Le travail de terrain a été mené *in situ* en 2007 au niveau de 4 stations selon un transect allant du Boughaz (communication mer-lagune) vers l'intérieur de la lagune. La population de *P. nobilis* étudiée est localisée au niveau d'un herbier mixte de *Cymodocea nodosa*, *Ruppia* et *Nanozostera*. Un gradient de la densité de population a été observé en s'éloignant de la rencontre mer-lagune (9,63 ind.100m^{-2}) vers l'intérieur de la lagune (0,07 ind.100m^{-2}). L'âge maximal est estimé à 9,7 ans, et semble être lié à l'amélioration de la qualité de l'eau dans la zone sous influence marine après l'ouverture du canal de communication entre la mer et la lagune en 1996.
Mots clés : Méditerranée, lagune de Ghar El Melh, Tunisie, Mollusque.

ABSTRACT

This paper focuses on the study of *Pinna nobilis* population density and structure on Ghar El Melh lagoon. Fieldwork was conducted in 2007 in 4 stations distributed from the sea toward the lagoon. Population of *P. nobilis* inhabits *Cymodocea nodosa* meadows mixed with *Ruppia* and *Nanozostera*. A gradient in the population density, decreasing from the sea (9.63 ind.100m^{-2}) to the internal lagoon (0.07 ind.100m^{-2}), has been noted. Maximal age is estimated to be 9.7 years, and seems to be related to the improvement of water quality in the area under marine influence after the opening of a communication channel between sea and lagoon in 1996.
Key words: Mediterranean Sea, Ghar El Melh lagoon, Tunisia, Mollusc.

INTRODUCTION

The fan mussel *Pinna nobilis* Linnaeus, 1758 is a bivalve mollusc endemic to the Mediterranean Sea. It is one of the largest bivalves present in the world and the largest of the Mediterranean Sea, attaining lengths up to 120 cm (Zavodnik *et al*., 1991). It occurs at depths between 0.5 and 60 m, mostly in soft bottom areas overgrown by seagrass meadows of *Posidonia oceanica*, *Cymodocea nodosa*, *Zostera marina* or *Nanozostera noltii* (Zavodnik *et al.,* 1991; Richardson *et al.,* 1999). However, it could also be present in sandy or algae substrate (Katsanevakis, 2006). *P. nobilis* shell has a triangular shape with a wider surface area on the posterior side, and a much narrower surface on the anterior side. The fan morphology of the shell permits the animal to live in soft sediments, buried up to one third of its sharp anterior apex (Zavodnik *et al*., 1991; Richardson *et al*., 1999; Templado, 2004). *P. nobilis* is a filter-feeder which feeds mainly on phytoplankton, bacteria and suspended particulate mater (Kennedy et *al*.,

2001).

P. nobilis populations have been greatly reduced during the past few decades as a result of recreational and commercial fishing, use of its shell for decorative purposes, and incidental killing by trawling and anchoring (Richardson *et al*. 2004). In the European Union, it has been listed as an endangered species and is under strict protection according to the European Council Directive 92/43/EEC.

Ghar El Melh lagoon represents one of the most important ecosystems in Tunisia on both economical and ecological plans. It was declared as Ramsar site and wetland of international importance in 2007. However, this site is subject to several human disturbances, which have originated the regression of the seagrass meadows (Shili *et al*., 2002) as well as *P. nobilis* populations. A wide distribution of *P. nobilis* was reported in the Ghar El Melh lagoon by Romdhane (1985) and was observed during an investigation of benthic communities. Studies conducted in the lagoon before 2003 indicated that the species had disappeared (Kraiem, 2003; Rabaoui *et al*., 2008). However, the *Cymodocea nodosa* survey in Ghar El Melh lagoon during 2006 and 2007 (Sghaier *et al.*, 2011) allowed the observation of an important population of *P. nobilis* in the northeast part of the lagoon. The aim of the present study is to provide new data about distribution, densities and size structure of the shallow (<0.5 m depth) *P. nobilis* population found in the Ghar El Melh lagoon.

MATERIAL AND METHODS

Study area

Ghar El Melh is a coastal lagoon located in the Northeast of Tunisia. It is sheltered, on the North side, by Ennadhour Mountain and is encircled on the West and the South by the alluvial and swampy plain of Medjerda. The Eastern side is separated from the sea by an offshore belt of variable length, which is interrupted by channels allowing some communication with open waters. Since 1996, this belt had a single opening called "El Boughaz" situated at the Northeast extreme of the lagoon (Fig 1). Due to anthropogenic activities, the lagoon ecosystem has suffered a progressive deterioration. This deterioration has led to a reduction in biodiversity and a decrease in fish production. To remedy to this decrease of the biodiversity and the halieutic productivity, and to improve maritime traffic and water quality inside the lagoon, "El Boughaz" opening was dragged in 1996 (Moussa *et al*., 2005). Presently, the lagoon is hyper-eutrophic with an annual average concentration of total phosphorus of 350 mg/m^3. The depth varies from 0.2 to 3.8 m with an average of 0.8 m. The water volume is estimated to be 25 Mm^3. Salinity ranges between 36 and 51 psu (Moussa *et al*., 2005).

A preliminary survey of the fauna and flora of the Ghar el Melh lagoon carried out in the framework of WADI (Sustainable management of Mediterranean coastal fresh and transitional water bodies: a socioeconomic and environmental analysis of changes and trends to enhance and sustain stakeholder's benefits INCO-CT2005-015226) project allowed us to observe a population of the endangered species *P. nobilis*. A field survey was conducted *"in situ"* in February 2007 when the density and the growth of the vegetation in the lagoon are minimal to better observe the *P. nobilis* shells. Four sampling stations, distributed along the Northeast side of the lagoon were chosen according to the distance from El Boughaz (Fig 1, Tab I).

The method adopted to evaluate density of individuals consists in counting the number of life *P. nobilis* in a circle of 20 m of diameter subdivided into 8 equal sectors. In each sector, the number (N) of live and dead *P. nobilis* was counted. A total surface of 5024 m² was prospected. Estimated density is the ratio of live individuals per prospected surface reported in 100 m². A mean density was calculated for each station between the eight prospected sectors.

Percentage of mortality is assumed as the rate of dead individuals observed per station. Mortality can be attributed to three reasons through traces on the shell, 1) trampling by fisherman's and persons collecting mollusks from the lagoon such as *Hexaplex trunculus* (Linnaeus, 1758) and *Ruditapes decussatus* (Linnaeus, 1758), 2) predation by *H. trunculus* and *Octopus vulgaris* and 3) natural death when shells remain intact.

According to the technical method described by Moreteau and Vicente (1982) and Garcia-March & Ferrer-Ferrer (1995), the following parameters on a sample of 80 individuals distributed in the four station (36 individuals in the station I, 30 in station II, 3 in station 3 and 1 in station 4) were measured *"in situ"*: the shell height above the sediment (Hs), the width of the shell at the sediment level (Ls), the biggest width (L) and the shell orientation (Fig 2). The total shell height (Ht) is calculated according to the equation by Garcia-March & Ferrer-Ferrer (1995): $Ht = (1.79Ls + 0.5 \pm 0.2) + Hs$.

Age of *P. nobilis* is estimated using the model proposed by Rabaoui *et al*. (2007) for marine and

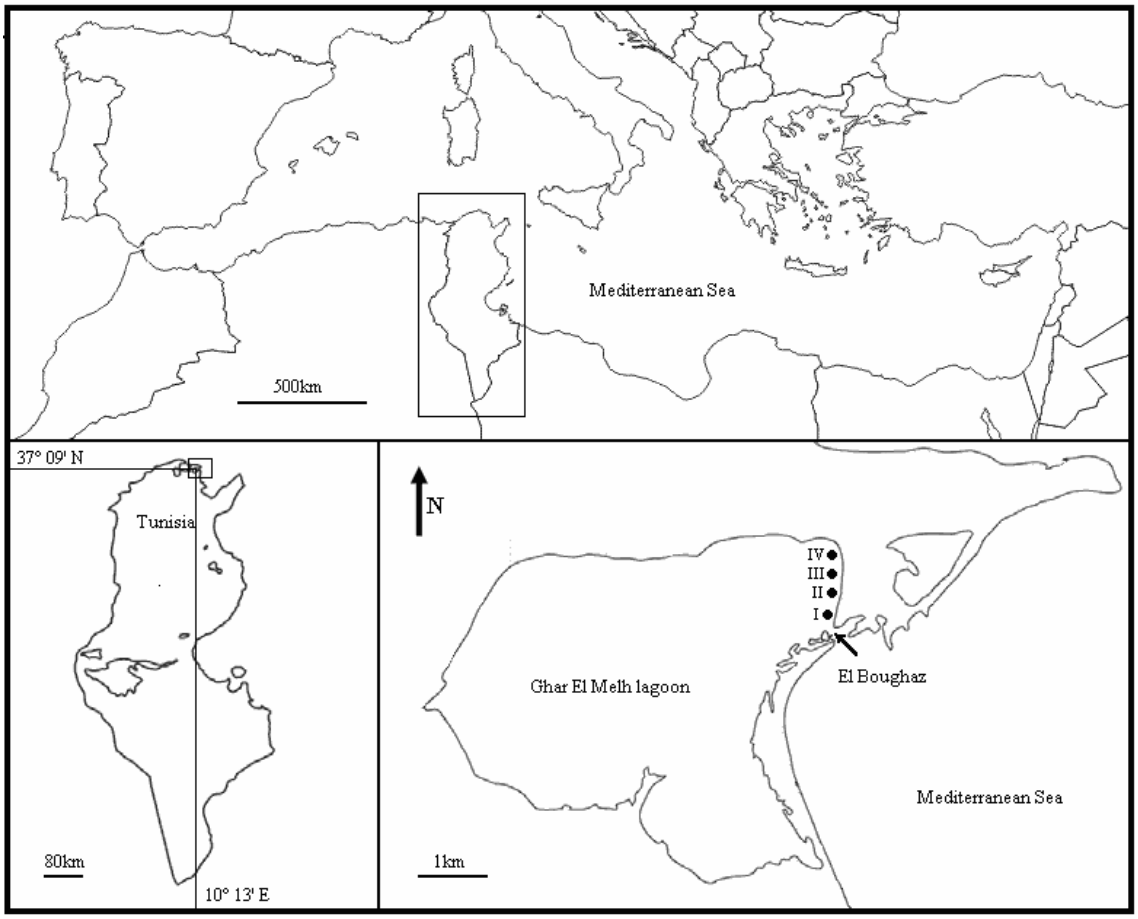

Figure 1. Study area and sampling stations in Ghar El Melh lagoon.

Table I. Location of the stations in Ghar El Melh lagoon

Stations	GPS coordinates	Depth in cm	Distance from El Boughaz
SI	N 37°09'20.30'' E 10°13'13.50''	20-50	150m
SII	N 37°09'23.25'' E 10°13'04.98''	20-50	250m
SIII	N 37°09'40.82'' E 10°13'20.45''	20-50	600m
SIV	N 37°09'52.38'' E 10°13'21.85''	20-50	1000m

lagoon Tunisian populations: Ht (t) = 104.3 x (1-$e^{-0.0526(t-0.714)}$) (t in year, Ht in cm).

To preserve the population, only the dead shells were collected and analyzed at the laboratory. Shells were separated into three categories: intact shells, shells carrying predation tracks (holes on valves) and broken shells. Only the well-preserved valves were used for the biometric study. The following meristic parameters were measured, total shell height (Ht) and the biggest width (L) (Fig 2).

RESULTS

P. nobilis was found only in the Northeast part from the opening of El Boughaz to 1 km inside the lagoon, mostly within *Cymodocea nodosa*, *Ruppia maritima*, *R. cirrhosa* and *Nanozostera noltii* meadows (Tab II) and aggregated in shallow water (-20 to -50 cm of water column). A total of 204 shells of *P. nobilis* were inventoried in the four stations. 52 were found dead, of which 30 were useful for biometric analysis.

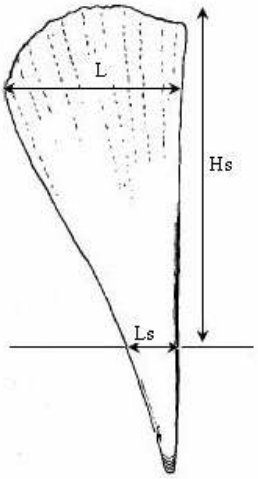

Figure 2. Parameters measured on *Pinna* shell
(Hs : hight from sediment ; L : largest width ; Ls : width at the sediment).

Table II. Substrate, population size (N), mortality percentage and mean density of *Pinna nobilis* individuals in the four sampling stations (±SD)

Station	Substrate	N	Mortality %	Mean density per 100m²
SI	Muddy sediment, dense meadows of *Nanozostera noltii*, *Ruppia maritima* and *Ruppia cirrhosa*	157	22.92	9.63 (±6.00)
SII	Muddy to sandy substrate with dense meadows of *N. noltii*, *R. maritima* and *R. cirrhosa* mix to *Cymodocea nodosa*	43	37.20	2.14 (±3.02)
SIII	Sandy substrate with dense meadows of *C. nodosa* mix to *N. noltii*, *R. maritima* and *R. cirrhosa*	3	***	0.23 (±0.44)
SIV	Sandy substrate with sparse meadows of *C. nodosa* associated with *N. noltii*	1	***	0.07 (±0.21)

Density and percentage of dead fan-shells

The density of *P. nobilis* varies from 0.07±0.21 ind.100 m^{-2} at SIV to 9.63±6.00 ind.100 m^{-2} at SI, indicating a gradual decrease from the sea-lagoon communication. An important variation of density was observed between studied sectors in the same station.

The mortality percentage is evaluated only for the two first stations (SI and SII) where a high number of *P. nobilis* was observed (Tab II). The most important percentage was recorded at station II. Trampling (47%) is the first cause of mortality, followed by the predation (23%). The causes of mortality for the rest of shells were unknown (30%).

Biometric analysis

The total height (Ht) and the largest width (L) of the 30 dead shells range between 16-31.5 cm and 7-14 cm respectively. The *in situ* study reported 80 individuals belonging to the different stations.

The largest width (L) varies between 4 and 16 cm, ranging between 10 and 15 cm in 78.75% of shells (Fig 3). The total height varies from 6 to 39 cm (Fig 4), and 48.75% have a total height between 20 and 25 cm; maximal total height recorded is 39 cm for the single *P. nobilis* collected at station IV. Maximum age estimated does not exceed 10 years and 75% is 5 to 8 years old (Fig 5). Concerning the shell orientation, valves mainly have a north, northeast and northwest orientation (Fig 6).

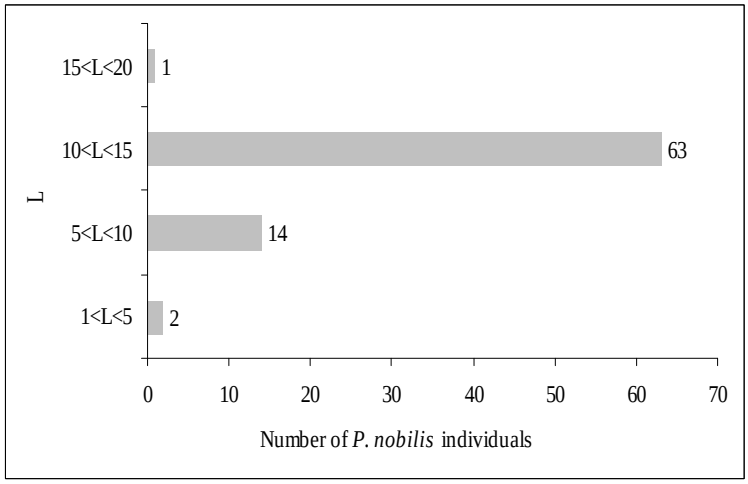

Figure 3. Different classes of individuals using largest width.

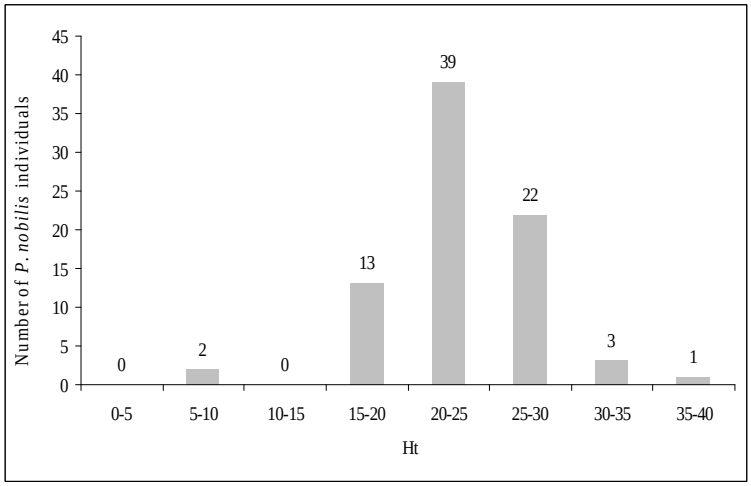

Figure 4. Size classes of individuals using shell height.

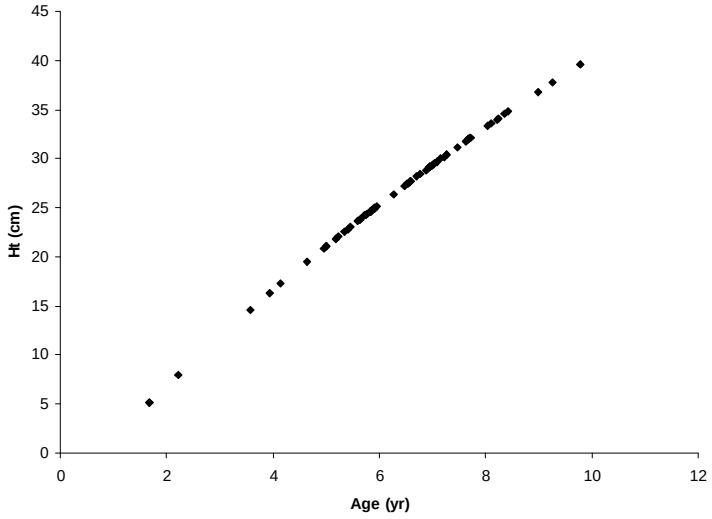

Figure 5. Age of individuals of *Pinna nobilis* population in Ghar El Melh lagoon estimated according to the model of Rabaoui *et al*., 2007.

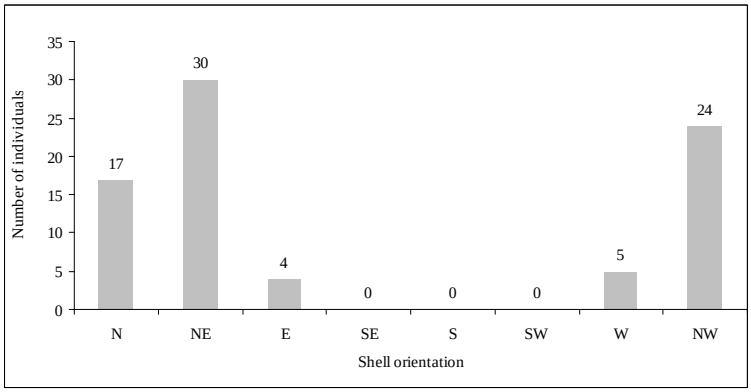

Figure 6. Orientation of *Pinna nobilis*; N, north; E, east; S, south; W, west.

DISCUSSION AND CONCLUSION

The species occurs in mixed meadows of the seagrasses *Cymodocea nodosa*, *Nanozostera noltii*, *Ruppia maritima* and *R. cirrhosa* in shallow water (-20 to -50 cm). Its absence in the rest of the lagoon is certainly due to the deterioration of the water quality and the eutrophication of the lagoon caused by the urban and agriculture discharges, and the lack of marine current (Moussa *et al*., 2005) at the origin of the disappearance of its natural habitat. *C. nodosa* meadows are substituted by algae such as *Ulva rigida*, *Enteromorpha intestinalis* or *Chaetomorpha linum*, which are bioindicators of eutrophic states (Kamer *et al*., 2004; Viaroli *et al*., 1992). Mean density of *P. nobilis* is 3.01±4.41 ind.100m^{-2}, however, if we consider only the station I, the mean density is 9.63±6.00 ind.100m^{-2} indicating an average value when compared to density recorded in the Tunisian coasts (Rabaoui *et al*., 2008) and a high value if compared to the Mediterranean Sea (Combelles *et al*., 1986; Butler *et al*., 1993). The important standard deviation observed can be explained by the aggregated distribution of the population. Thus, in some sectors, there are many individuals and in the following sector no individual is observed.

According to the model by Rabaoui *et al*. (2007) based on five populations of *P. nobilis* (two from the Bizerte lagoon, one from the Gulf of Tunis and two from the Monastir Bay), 75% of the studied population is between 5 and 8 years old. The size structure showed that the populations are characterized by the predominance of small sized individuals as in other populations studied in Tunisian coasts (Rabaoui *et al*., 2008). Maximal height of 39 cm indicates a maximal age of 9.7 years. Two hypotheses can be advanced, first that the population is recently settled in this part of the lagoon, where the water is constantly renewed, the second hypothesis it could indicate that there is a high level of renovation that animals die before reaching older ages. The release of the communication sea-lagoon through El Boughaz in 1996 and the improvement of the water quality have probably favoured the reappearance and the establishment of this species in this part of the lagoon.

The circulation of the seawater entering the lagoon is towards the North, North-East and North-West (Moussa *et al*., 2005). The observation of a common shell orientation is in accordance with the hypothesis that animals are directing the opening towards the food gradient (Combelles *et al*., 1986) and that only those with an orientation reducing the hydrodynamic stress survive (Garcia-March *et al*., 2007).

The abiotic parameters (shallow depth, exposure to strong winter and autumn swells as well as the important variations of water temperature and salinity) makes Ghar El Melh lagoon an unfavourable site to the development of the species *a priori*. Despite these unfavourable conditions, a young population of *P. nobilis* is settling down in a part of the lagoon where the environmental conditions are less extreme. In conclusion, the results of the present study indicate a recovery of *P. nobilis* population in Ghar El Melh lagoon, but also suggest an important mortality by trampling due to the lack of protection of this endangered species in Tunisia. This population remains very sensitive to the trampling which is the reason of 50% of mortality. To protect this young population, the local people (mainly fisherman and mollusc collectors) must be informed about the status of this endangered species. Furthermore, a regular monitoring program is necessary for the conservation of this species in Ghar El Melh lagoon.

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