VIE ET MILIEU - LIFE AND ENVIRONMENT, 2018, 68 (2-3): 145-149

POPULATION STATUS OF *PINNA NOBILIS* IN FOUR PROTECTED AREAS OF FRANCE AND MONACO

S. TRIGOS[1], N. VICENTE[2]*

[1] *Innovation Network in Aquaculture Industries of the Valencian Community (RIIA-CV), Avda. Naranjos s/n. Edificio Colegio Mayor Galileo Galilei, Local 15, 46022, Valencia Spain*

[2] *Institut Méditerranéen de Biodiversité et d'Écologie marine et continentale (IMBE), Aix Marseille Univ, CNRS, IRD, Avignon Univ, France and Institut Océanographique Paul Ricard, Ile des Embiez, Six Fours les Plages, France*

Corresponding author: strigos@riia.es

BIVALVE
CONSERVATION
MONITORING
POPULATION
MEDITERRANEAN SEA

ABSTRACT. – Recent mortality events of *Pinna nobilis* registered in the western Mediterranean coasts highlight the need to monitor regularly populations of this endangered endemic bivalve. The present study has investigated a total surface of 6,400 m^2 of 4 protected areas from France and Monaco registering density of individuals and biometric data of each population. Herein, densities of 3.56 individuals·100 m^{-2} in the Embiez archipelago, 6.81 individuals·100 m^{-2} in the Natural Reserve of Scandola, 1.37 individuals·100 m^{-2} in the National Park of Port-Cros and 5.25 individuals·100 m^{-2} in the Underwater Reserve of Larvotto. These values, with great number of adults and juvenile individuals, support the healthy and consolidated status of these populations.

INTRODUCTION

The areas framed under different types of legal protection such as Marine Protected Areas (MPAs) aim to preserve natural habitats and its biodiversity. The main role of these legal protection figures consists in protecting a marine area from anthropogenic impacts thus ensuring the continuity of vulnerable species and its genetic load (Pujolar *et al*. 2013). Integrated coastal management and conservation initiatives are commonly known as a tool for fisheries management (Cooke *et al*. 2014, Metcalfe *et al*. 2015). However, since MPAs were shown to be effective in terms of ecological conservation (Halpern 2014, Pendoley *et al*. 2014), their interest has turned to be focused in the conservation of rare or endemic species (Margules & Pressey 2000, Roberts *et al*. 2003).

One of these species is the Mediterranean fan mussel *Pinna nobilis*. This endemic bivalve is a large suspension-feeder that can reach more than one meter of total shell length (Moreteau & Vicente 1982, Zavodnik *et al*. 1991, Butler *et al*. 1993) and live around 40 years (Rouanet *et al*. 2015). The species shows one of the fastest growths of all bivalves, reaching rates from 7 to 10 cm of total shell height (Ht) in one year (Moreteau & Vicente 1982, Richardson *et al*. 1999, Siletic & Peharda 2003). *Pinna nobilis* usually occurs at depths between 0.5 and 60 m, generally on soft-bottom areas overgrown by seagrass meadows (mostly *Posidonia oceanica* and *Cymodocea nodosa*), but also in rocky and maërl bottoms (Trigos & Vicente 2016) where they live with the anterior portion of their shell partially buried and attached by their numerous byssus filaments to different particles of the substrate.

Population density varies between 1 and 10 individuals·100 m^{-2} (De Gaulejac & Vicente 1990) although high densities up to 5-6 individuals·m^{-2} have been reported in some coastal lagoons (Vicente & Moreteau 1991, Catsiki & Catsikieri 1992). The regression of populations of *P. nobilis* has been reported for years (De Gaulejac & Vicente 1990) as a result of fishing, and/or accidental harvesting by trawling and shell breakage by anchoring (Katsanevakis 2005, Acarli *et al*. 2011). Consequently, it has been listed as an endangered species in the Mediterranean and is under strict protection according to the Habitats Directive 92/43/EEC (Annex IV), the Protocol for Specially Protected Areas and Biological Diversity in the Mediterranean of the Barcelona Convention (Annex II) and the national laws of most Mediterranean countries. Moreover, recent mortality events occurred in Spanish coasts which reached values up to 100 % (Darriba 2017) have considerably reduced local populations of this bivalve.

This fact among others is one of the reasons why monitoring populations of this species must be considered as the main tool to control density and healthy status of individuals. Herein, as a first step towards monitoring trends and a prerequisite for its conservation, the present study aimed to determine the spatial distribution of the species and mean total shell height (Ht) of the individuals to assess the current status of the fan mussel population in four Mediterranean areas under different figures of protection.

MATERIALS AND METHODS

With the aim to evaluate the current status of *P. nobilis* populations in four different locations in France (Embiez Island, Natural Reserve of Scandola and the National Park of Port-Cros) and Monaco (Underwater Reserve of Larvotto). In every location, tourism and recreational activities such as scuba diving is allowed, provided that proper authorizations are obtained. A total surface of 6,400 m^2 was monitored from 2012 to 2015. For each location a study surface of 1600 m^2 was estimated based on density surface modelling with 16 linear transects of 50 × 2 m via scuba diving (Katsanevakis 2007) in those places with greater population interest or with a noticeable need of conservation. This methodology was selected at the expense of other techniques also used to control the populations of this species, being the most indicated when it is necessary to cover large areas (García-March 2005).

The starting points for each transect were selected randomly always within seagrass meadows of *P. oceanica* and at depths varying from 5 m in the shallowest location of Port-Cros to 40 m in l'Imbutu (Natural Reserve of Scandola) thus covering the bathymetric range where *P. nobilis* inhabits (Basso *et al*. 2015).

Visual censuses were performed by a couple of scuba divers guided by a tape measure. After fixing the starting point with a pickaxe, the surface of each transect was studied heading a straight line with the help of a compass. Herein, the censuses were carried out in winter months where the size of the leaves of *P. oceanica* is shorter (Ott 1980) and consequently facilitates the location of the fan mussels. In certain cases where the size of these leaves avoided to realize the visual census, both divers were provided with a structure constructed in PVC that allowed to "brush" the *P. oceanica* leaves locating the hidden individuals (Fig. 1).

Every fan mussel observed was measured with a multicaliper to the nearest millimetre in "Hs" (shell height over the substrate) and "a" (shell width in the substrate) to calculate Ht (total shell height) according to the equation of García-March and Ferrer (1995):

$$Ht = (1.79 \cdot a + 0.5) + Hs$$

Using the SPSS® program, statistical analysis was carried out to determine significant differences among the Ht values registered in each location. A one-way ANOVA was calculated followed by the *post-hoc* (DHS-Tukey) comparison to detect possible differences among populations.

RESULTS

A total of 273 individuals were recorded in the 4 locations being most of them adults with a mean size of 45.04 ± 15.32 cm Ht (Fig. 2).

In Embiez island 58 specimens with an average size of 40.54 ± 15.51 cm Ht were observed presenting, therefore, an average population density of 3.56 individuals·100 m^{-2}. In the Natural Reserve of Scandola (Corsica), the number of fan mussels registered increased to 109 individuals with an average Ht of 45.90 ± 20.30 cm, thus obtaining an average density of 6.81 individuals·100 m^{-2}. In Scandola the heterogeneity of the population is even greater and in the strait of Gargalo, where population is known to be one of the most favorable places for the recruitment of juveniles, reaching the highest density values of the whole Reserve (21 individuals·100 m^{-2}). In contrast to this abundance of recruits in Scandola, it is necessary to mention the Imbutu population, with mean Ht (78.90 ± 6.08 cm) and a density of individuals (8.5 individuals·100m^{-2}) that

Fig 1. – Scuba divers searching individuals of *Pinna nobilis* in parallel using the "*brushing*" technique when *Posidonia oceanica* leaves are longer.

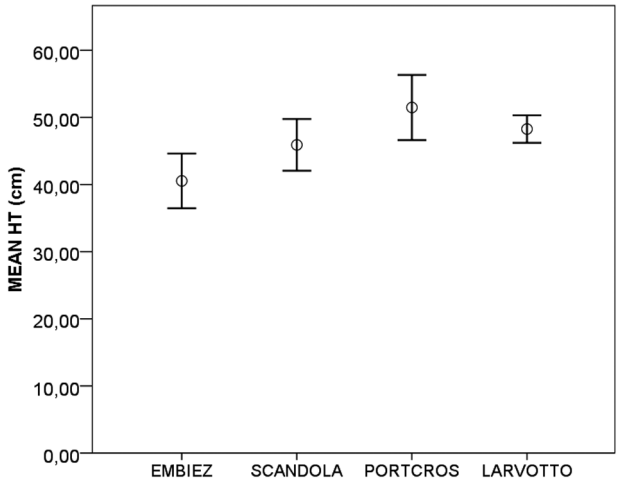

Fig 2. – Average total shell height (Ht) and standard deviation registered for *Pinna nobilis* in each studied area.

probably make it one of the oldest populations of all studied in the present study.

In the National Park of Port-Cros, only 22 specimens of *P. nobilis* were registered with a mean Ht of 51.47 ± 10.95 cm and an average population density of 1.37 individuals·100m^{-2}. In the Underwater Reserve of Larvotto, something similar is observed because in the shallower northwest, there were maximum densities of 13 individuals·100 m^{-2} while in the deepest zone and coinciding with the lowest limit of the *P. oceanica* meadow with severe regression symptoms, density is reduced to 1·100 m^{-2} individuals. Nevertheless, the Larvotto Underwater Reserve (Monaco) accounted for a total of 84 nacres with an average size of 48.26 ± 9.45 cm Ht and a population density of 5.25 individuals·100 m^{-2}.

The analysis of variance indicated the existence of significant differences between the Ht of the individuals registered in each area (ANOVA, $F = 3.850$; $p < 0.05$). The post-hoc analysis highlights that this difference was greater in the population of Embiez ($p < 0.05$) suggesting that this population is formed by a combination of adult and juvenile specimens that ensure the continuity of the species.

The population of Scandola appears to harbor areas of recruitment whereas for the other locations, populations seem to be older (Fig. 3). Herein, recruitment rates in these areas should be monitored annually in order to find out if conditions are favorable for the continuity of the local population or if it is necessary to apply corrective measures.

DISCUSSION

The widespread presence of adults (45.04 ± 15.32 cm Ht) in all the locations studied shows that these are well-established populations with high variability in the densities observed in the different areas. This heterogeneity is common in *P. nobilis* as its spatial distribution is usually "patched" (Richardson *et al*. 2004, Katsanevakis 2005) and generally entails the identification of areas with a large number of individuals that contrast with others displaying isolated individuals.

The average density of individuals observed in Embiez (individuals 3.56·100 m^{-2}) is similar to that described by Medioni & Vicente (2003) thus, this population appears to be stable in last decade. Despite Embiez archipelago is currently unprotected in terms of legal protection, the population density registered is comparable and even greater than observed in certain areas with protected areas (Trigos *et al*. 2013), and may be due to the anchoring prohibition existing in many places of the island as occurs in La Cauvelle (Embiez island) where the maximum values recorded for that population reach up to 7 individuals·100 m^{-2}.

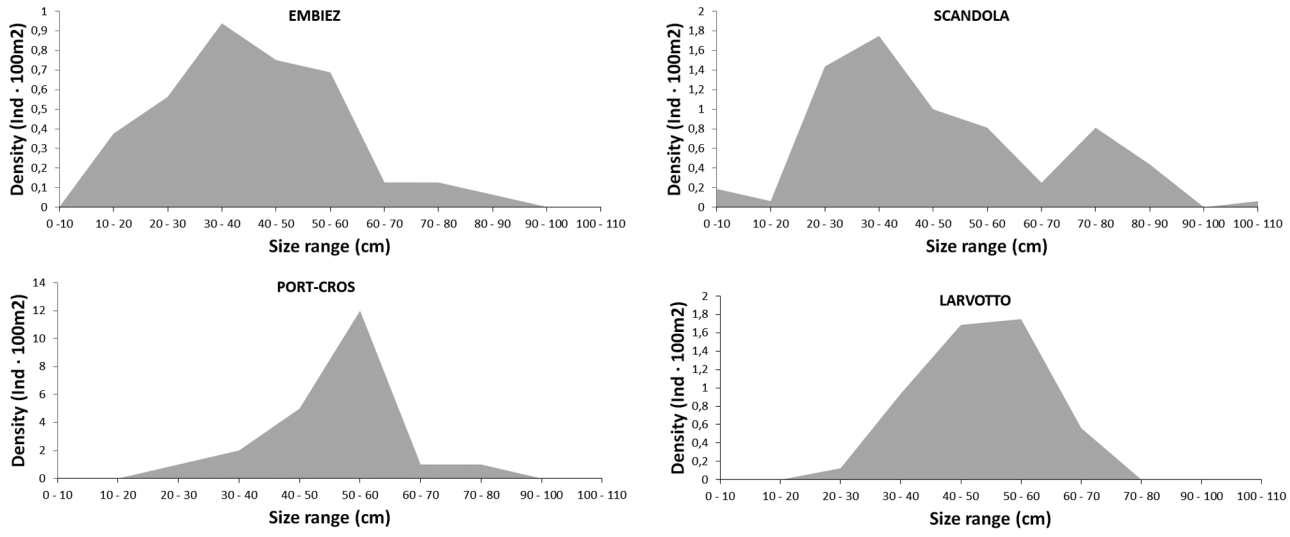

Fig 3. – Individual density according to size range (Ht) for each location.

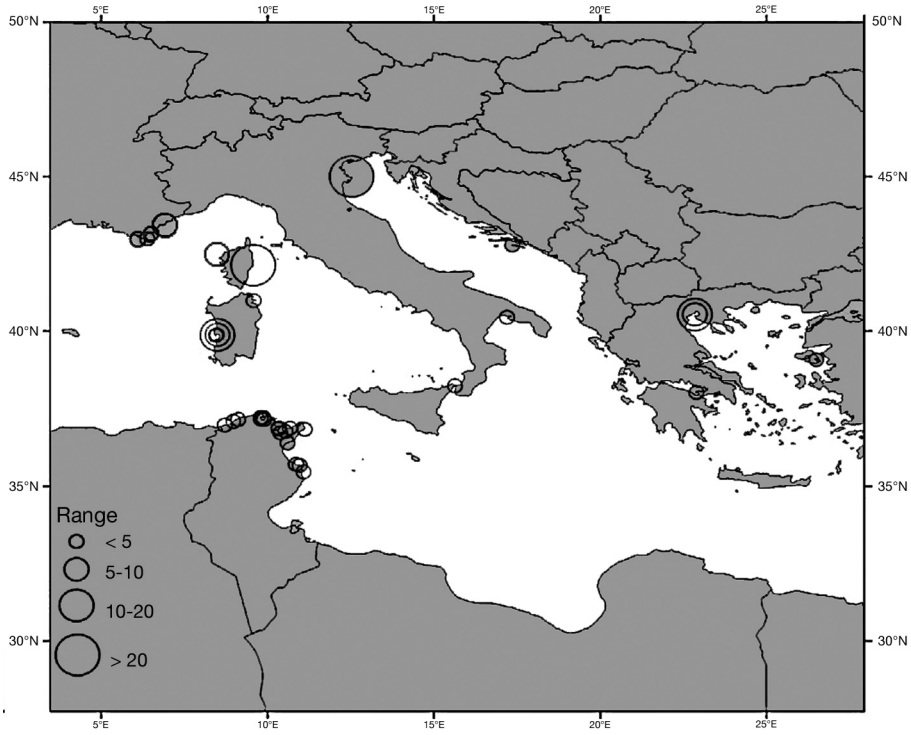

Fig 4. – Comparison among population densities (individuals·100 m^2) of *Pinna nobilis* in this study (solid black points) and densities observed in other Mediterranean locations according to the recent literature (Modified from Basso *et al*. 2015).

In Port-Cros and despite their long history as a protected area, the reduced number of fan mussels registered is mainly due to the exclusion of the shallowest area of La Palud underwater trail in the transects, where were observed the highest densities of up to 8 individuals·100 m^{-2} (Vicente *et al* 1980, Medioni & Vicente 2001), generally composed by young specimens. In the rest of the studied areas, the populations show lower density between 0 and 1.16 individuals·100 m^{-2}. Moreover, in certain zones such as the emblematic field of La Palud (Port-Cros) discovered by Commander Tailliez, the population has completely disappeared, including the last specimens of *P. nobilis* within ≈ 45 years (Rouanet *et al*. 2015), presumably due to the regression of the *P. oceanica* meadow in which it inhabited.

According to the literature, the minimum and maximum population density of *P. nobilis* ranges between 0.001 (Centoducati *et al*. 2007) and 600 individuals 100 m^{-2} (De Gaulejac & Vicente 1990, Catsiki & Catsikieri 1992) respectively, although the most common value is 1 individual·100m^{-2} (Šiletić & Peharda 2003). Therefore, it can be considered that population densities of Embiez, Scandola and Larvotto are higher compared to the rest of the locations surveyed in the Mediterranean in recent years (Fig. 4), then confirming the effectiveness of protection measures established in these areas.

ACKNOWLEDGEMENTS.- We are grateful to the crew of the different MPAs were this study was carried out, especially to Mrs J Gauthier Debernardi and Mr JM Dominici for their hospitality. We are also grateful to the Catholic University of Valencia for their support.

REFERENCES

Acarli S, Lok A, Acarli D 2011. Preliminary spat settlement of fan mussel *Pinna nobilis* Linnaeus, 1758 on a mesh bag collector in Karantina Island (Eastern Aegean Sea, Turkey). *Fresenius Environ Bull* 10: 2501-2506.

Basso L, Vázquez-Luis M, García-March JR, Deudero S, Alvarez E, Vicente N, Duarte Cm, Hendriks IE 2015. The pen shell, *Pinna nobilis*: a review of population status and recommended research priorities in the Mediterranean Sea. *In* Curry B.E. Ed, *Adv Mar Biol* 71. Oxford: Academic Press: 109-160.

Butler A, Vicente N, De Gaulejac B 1993. Ecology of the pterioid bivalves *Pinna bicolor* Gmelin and *Pinna nobilis* L. *Mar Life* 3(1-2): 37-45.

Catsiki VA, Catsikieri CH 1992. Presence of chromium in *Pinna nobilis* collected from a polluted area. *Fresenius Environ Bull* 1: 5.

Centoducati G, Tarsitano E, Bottalico A, Marvulli M, Lai OR, Crescenzo G 2007. Monitoring of the endangered *Pinna nobilis* Linné, 1758 in the Mar Grande of Taranto (Ionian Sea, Italy). *Environ Monit Assess* 131: 339-347.

Cooke SJ, Arlinghaus R, Bartley DM, Beard TD, Cowx IG, Essington TE, Watson R 2014. Where the waters meet: sharing ideas and experiences between inland and marine realms to promote sustainable fisheries management. *Can J Fish Aquat Sci* 71(10): 1593-1601.

Darriba S 2017. First haplosporidan parasite reported Infecting a member of the Superfamily Pinnoidea (*Pinna nobilis*) during a mortality event in Alicante (Spain, Western Mediterranean). *J Invert Pathol* 148*:* 14-19.

De Gaulejac B, Vicente N 1990. Écologie de *Pinna nobilis* (L.) mollusque bivalve sur les côtes de Corse. Essais de transplantation et expériences en milieu contrôlé. *Haliotis* 10: 83-100.

García-March JR, Ferrer Ferrer F 1995. Biometría de *Pinna nobilis* L., 1758: una revisión de la ecuación de De Gaulejac y Vicente (1990). *Bol Inst Esp Oceanol* 11: 175-181.

Halpern BS 2014. Conservation: making marine protected areas work. *Nature* 506(7487): 167-168.

Katsanevakis S 2005. Population ecology of the endangered fan mussel *Pinna nobilis* in a marine lake. *Endang Species Res* 1: 1-9.

Katsanevakis S 2007. Density surface modelling with line transect sampling as a tool for abundance estimation of marine benthic species: the *Pinna nobilis* example in a marine lake. *Mar Biol* 152: 77-85.

Margules CR, Pressey RL 2000. Systematic conservation planning. *Nature* 405: 243-253.

Medioni E, Vicente N 2001. Programme de recherches sur la grande nacre de Méditerranée *Pinna nobilis*. Rapport Contrat de recherches Total ELF Fina, Paris: 1-44.

Metcalfe K, Vaz S, Engelhard GH, Villanueva MC, Smith RJ, Mackinson S 2015. Evaluating conservation and fisheries management strategies by linking spatial prioritization software and ecosystem and fisheries modelling tools. *J Appl Ecol* 52(3): 665-674.

Moreteau JC, Vicente N 1982. Evolution of a population of *Pinna nobilis* L. (Mollusca, Bivalvia). *Malacologia* 22(1-2): 341-345

Ott JA 1980. Growth and production in *Posidonia oceanica* (L.) Delile*. *Mar Ecol* 1(1): 47-64.

Pendoley KL, Schofield G, Whittock PA, Ierodiaconou D, Hays GC 2014. Protected species use of a coastal marine migratory corridor connecting marine protected areas. *Mar Biol* 161(6): 1455-1466.

Pujolar JM, Schiavina M, Di Franco A, Melià P, Guidetti P, Gatto M, Zane L 2013. Understanding the effectiveness of marine protected areas using genetic connectivity patterns and Lagrangian simulations. *Divers Distrib* 19(12): 1531-1542.

Richardson CA, Kennedy H, Duarte CM, Kennedy DP, Proud SV 1999. Age and growth of the fan mussel *Pinna nobilis* from south-east Spanish Mediterranean seagrass (*Posidonia oceanica*) meadows. *Mar Biol* 133(2): 205-212

Richardson CA, Peharda M, Kennedy H, Kennedy P, Onofri V 2004. Age, growth rate and season of recruitment of *Pinna nobilis* (L) in the Croatian Adriatic determined from Mg:Ca and Sr:Ca shell profiles. *J Exp Mar Biol Ecol* 299: 1-16.

Roberts CM, Branch G, Bustamante RH, Castilla JC, Dugan J, Halpern BS, Lafferty KD, Leslie H, Lubchenco, McArdle JD, Ruckelshaus M, Warner RR 2003. Application of ecological criteria in selecting marine reserves and developing reserve networks. *Ecol Appl* 13: S215-S228.

Rouanet E, Trigos S, Vicente N 2015. From youth to death of old age: the 50-year story of a *Pinna nobilis* fan mussel population at Port-Cros Island (Port-Cros National Park, Provence, Mediterranean Sea). *Sci Rep Port-Cros Natl Park* 29: 209-222.

Siletic T, Peharda M 2003. Population study of the fan shell *Pinna nobilis* L. in Malo and Veliko Jezero of the Mljet National Park (Adriatic Sea). *Sci Mar* 67(1): 91-98

Trigos S, Vicente N 2016. Protocole pour la transplantation des nacres *Pinna nobilis* dans divers substrats. *Mar Life* 18: 55-61.

Trigos S, Vicente N, Garcia-March JR, Jiménez S, Tena J, Torres J 2013. Presence of *Pinna nobilis* and *Pinna rudis* in the Marine Protected Areas of the North Western Mediterranean. 3rd Int Mar Protected Areas Congress, 21-27 October. Marseille/Corsica.

Vicente N, Moreteau JC 1991. Statut de *Pinna nobilis* L. en Méditerranée (Mollusque Eulamellibranche). *In* Boudouresque CF, Avon M, Gravez V Eds, Les Espèces marines à protéger en Méditerranée. GIS Posidonie publ, Marsella: 159-168.

Vicente N, Moreteau JC, Escoubet P 1980. Étude de l'évolution d'une population de *Pinna nobilis* L. (Mollusque Eulamelibranche) au large de l'anse de La Palud. *Trav Sci Parc Natl Port-Cros* 6: 39-68.

Zavodnik D, Hrs-Brenko M, Legac M 1991. Synopsis on the fan shell *Pinna nobilis* L. in the eastern Adriatic Sea. *In* Boudouresque CF, Avon M, Gravez V Eds, Les Espèces marines à protéger en Méditerranée. GIS Posidonie, Marseille: 169-178.

Received on October 16, 2017
Accepted on March 14, 2018
Associate editor: Y Desdevises