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Reintroduction of the highly endangered mollusk *Patella ferruginea* Gmelin, 1791 in an MPA: A novel approach to achieve high survival rates☆

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ABSTRACT

Patella ferruginea is the most endangered marine invertebrate of western Mediterranean rocky shores. After a study of one of its most important populations in the Zembra Archipelago National Park (Tunisia), a new protocol for the translocation of the species (size: 4–8 cm) was adopted. The first translocation was made in June 2014 in the same archipelago, where 94 specimens were moved from Zembretta to Zembra Island and marked (62 protected by cages, 20 with no cages and 60 as controls). The second translocation was performed in August 2014 (110 specimens) from Zembra to La Galite Island (185 km away). High mortality was registered during transport. The remaining individuals (39) were marked and placed in cages on the rocky shores of Galite Island, then monitored until November 2015. Growth and survival rates were measured in both translocated and control populations. The highest mortality rates were observed during the initial three days after translocation, especially for individuals with no cage protection. After a 697-day survey on Zembra Island, survival rates of 58%, 25% and 85% were observed for cage, no-cage and control populations, respectively. After a 457-day survey on La Galite Island, the survival rate was 18%. Limpets>6 cm in size had the highest survival rate among Zembra-translocated populations, whereas translocated limpets of 4–6 cm in size showed the highest survival rate in La Galite. The growth rates for both translocated populations were higher than the rate observed for controls. Our translocation experiment shows the importance of cage protection and initial limpet size for survival.

1. Introduction

Patella ferruginea (Gmelin 1791) is a large Mediterranean endemic limpet found at the intertidal (for details about its biology see Espinosa and Rivera-Ingraham, 2017), that faced an extreme contraction of its distributional range throughout the last century (Espinosa et al., 2014; Laborel-Deguen and Laborel, 1991a,b). Due to this critical situation, the European Directive 92/43/EEC classified the species as the most endangered marine endemic invertebrate on the Western Mediterranean coasts and the species was catalogued as "strictly protected" by the Berne Convention (Annex II, 1979), as a "species in need of strict protection" (Annex IV of the Habitats Directive 92/43/CEE), and as an "endangered or threatened species" by the Barcelona Convention.

Templado (2001) noted that the reintroduction *of Patella ferruginea* in protected areas, that had formerly been part of their range, would be of value. Here, translocation is defined as one of the major management measures and an efficient method for the restoration and conservation of endangered species (Fischer and Lindenmayer, 2000). However, translocation projects involve difficult management decisions that need to be based on study and scientific monitoring (Rout et al., 2009).

The first reported attempts of translocation of *P. ferruginea* were made in the 1980s. The first one was in 1983 in Italy, where 3

☆ A successful new way for *Patella ferruginea* translocation.

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individuals of *P. ferruginea* (size > 6 cm) were translocated from Mortorio Island (northeast of Sardinia) to a new site in the Arzachena Gulf, at a distance of 10 nautical miles, and were still alive after two years (Aversano, 1986). The second one was performed in 1987 in France by Laborel-Deguen and Laborel (1991c). The aim was to translocate 222 individuals (sized from <1 cm to 5 cm) from a healthy population situated in Galeria (Corsica) to a site 200 km away where the species had disappeared, an island in the Port Cros National Park. This experiment showed high mortality rates during its different phases, but preluded further translocation experiences motivated by the construction of maritime structures (Espinosa, 2006; Espinosa et al., 2008a; Guallart, 2014; Paredes-Ruiz et al., 2014). Another conservation approach is the release of individuals of this endangered species held in captivity under laboratory conditions (Guallart, 2010, 2014). Indeed in 2003, an important population of *P. ferruginea* in Ceuta was translocated due to the extension work in the harbour and so 420 individuals were translocated to an adjacent site. A few days after the translocation, high mortality was recorded and the survival rate was 50%. However, in some stations the survival rate was 30–35% after one year and 18% after two years (Espinosa, 2006; Espinosa et al., 2008a).

From 2008 to 2013 various studies described *P. ferruginea* population in the Chafarinas islands in Spain; many parameters such as survival rate, sex ratio, genetics, reproduction and behaviour were measured (see Guallart, 2006, 2010, 2014). Thus, some breeding individuals were collected, placed in aquaria and then translocated to other sites in the archipelago at the end of these studies. Parts of this translocation were done using artificial substrates of different natures and textures. Those substrates were first placed in aquaria, after which *P. ferruginea* individuals were allocated on them and controlled until their shell was well adapted to the substrate. Then the specimens were translocated with these artificial substrates to a natural site in the Chafarinas archipelago. The results of this translocation were mostly positive but as very few individuals of *P. ferruginea* benefited from this experience, this precludes general conclusions (Guallart, 2010).

Another translocation of many individuals was done in 2013 in Muelle Chico Harbour in the Chafarinas islands and described by Guallart (2014) and Paredes Ruiz et al. (2014). Part of the harbour, where 591 individuals (391 adults and 200 recruits) of *P. ferruginea* had been reported, had to undergo urgent rehabilitation works. The translocation of the limpet population was made using expensive and heavy logistics. Indeed, whole blocks on which the limpets were living were displaced to an adjacent site. Guallart (2014) and Paredes Ruiz et al. (2014) indicate that approximately 75% of the population was translocated using this method. A 10% mortality rate was registered during translocation. Eight months after the translocation, Paredes Ruiz et al. (2014) indicate a survival rate of 45.6% for adults and Guallart (2014) indicate a survival rate of 35.9% for the whole translocated population.

In 2014, two other translocations were made in Spain and described by Guallart (2014). The first case concerned one individual that was collected from Motril Harbour, maintained in an aquarium and then translocated to a new site, although the individual was lost a few days after translocation. The second case concerned 10 individuals (8 originally collected from the Chafarinas islands and 2 obtained from controlled reproduction in laboratory) which were maintained during a long period in a laboratory for scientific studies then translocated to the Hormigas islands (SE Spain). Two specimens were lost during translocation as the result of wave damage and only 6 remained the second day. Recently, in June 2016 only one specimen remained (Guallart pers. comm.). All these translocation operations have provided very important knowledge of the ecology and biology of *P. ferruginea* and, especially, its response to habitat and environmental changes.

Espinosa et al. (2006a) hypothesized that the use of a cage during the earliest days could be an effective technique for future translocations of *P. ferruginea*. Taking into account the several problems related to developing a successful protocol for moving specimens of *Patella ferruginea*, the current work aimed: 1) to perform a protocol with relatively low associated mortalities that could be applied in the future, due to threats caused by habitat destruction or in reintroduction and/or reinforcement programs, and 2) test the viability of translocation (within the same habitat) and transplantation (between different habitats) procedures. Therefore, as regards the first aim the hypothesis was that the use of cages could reduce the mortality associated with translocation, whereas for the second aim the hypothesis was that specimens of *Patella ferruginea* could be transplanted either long or short distances.

The translocation procedure was implemented in the Zembra National Park archipelago, which hosts one of the most important populations of the species (see Zarrouk et al., 2016), where specimens were moved from Zembretta to Zembra island. For the transplantation procedure the specimens were moved from Zembra island to La Galite island (within the Specially Protected Area for Mediterranean Interest of the La Galite archipelago), where the species has been absent for more than 30 years.

2. Material and methods

2.1. Study areas

The study was carried out in the Zembra and La Galite archipelagos, which are located on the central Mediterranean Sea in Tunisia (Fig. 1). The two archipelagos are separated a distance of about 185 km. The Zembra archipelago was the first National Park in Tunisia, established in April 1977, one month after being classified as a Biosphere Reserve by UNESCO. In 2001, it was classified as a Specially Protected Area of Mediterranean Importance (SPAMI). All fishing activities are totally prohibited 1.5 nautical miles around the archipelago and the whole MPA is considered a “no take zone”.

The La Galite archipelago is a nature reserve that was established 0.5 nautical miles around the Galiton Islet and, in 1995, a ban on fishing was established within the 1.5 nautical miles surrounding the whole archipelago. In 2001, as with the Zembra archipelago, it was classified as a Specially Protected Area of Mediterranean Importance. Several shells of *P. ferruginea* are found in the archipelago either in geological strata or scattered on the main island. Some shells are also found at Punic tombs and probably were part of funeral rites at the time (pers. obs.). Thus, unlike the Zembra archipelago, the Galite Island was alternately populated and deserted several times throughout the centuries. The last major occupation dates from 1860 and continued until 1970. It is probable that *P. ferruginea* was heavily consumed during this period and, even if some individuals could have survived, the low remaining densities probably made any successful reproduction impossible causing the species over time to eventually become extinct. The old residents of the archipelago and local fishermen estimate that the extinction of the species was around the 1960s (pers. com.). During all marine biodiversity investigations in the archipelago (Andromede, 2010; Bonhomme et al., 2010; Dutrieux et al., 2001; Harmelin et al. 2008, 2010; Ramos Espla and Azzouna, 1999) the species has never been found.

2.2. Sampling and translocation sites identification

Two surveys were done in the La Galite archipelago. The first was done in June 2012 and concerned the intertidal zone of the whole archipelago to determine if there were still living