Experimental Release of Endemic Partula Species, Extinct in the Wild, into a Protected Area of Natural Habitat on Moorea

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Experimental Release of Endemic *Partula* Species, Extinct in the Wild, into a Protected Area of Natural Habitat on Moorea[1]

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Abstract: Extinction of tree snails of the genus *Partula* on Moorea, following introduction of the predatory snail *Euglandina rosea*, has challenged conservation biology during years of successive captive breeding of small rescued populations. An experimental release of three *Partula* species into a predator-proof patch of native forest on Moorea was designed to test effectiveness of physical and chemical methods of predator exclusion and to evaluate behavior of animals bred for up to six generations in highly artificial environments. At the close of the experimental release, there had been multiple incursions of *E. rosea*, and too few *Partula* spp. remained to assess effects of captive breeding on ecological responses. However, results demonstrated the effectiveness of the exclosure under ideal maintenance and monitoring. Captive breeding methods were validated by reproduction and growth to sexual maturity in the wild as well as retention of genetic variability in the form of persistent color polymorphism in one species.

The ultimate objective of captive breeding programs is the reintroduction of viable populations of endangered species into their natural habitats. Even thriving captive populations are susceptible to novel pathogens (Cunningham and Daszak 1998) and to changes in gene frequency in response to artificial culture conditions.

The land snails of the genus *Partula* have been particularly hard hit by a series of extinctions in the wild (see Cowie 1992 and Hickman 1999 for reviews and references). Species on many Polynesian islands have been extirpated by the introduction of the predaceous land snail *Euglandina rosea* in an ill-advised attempt at the biological control of the giant African snail, *Achatina fulica*. However, more than 30 species of *Partula* have been rescued and perpetuated in captive breeding populations in 18 zoos and laboratories throughout the world (Pearce-Kelly et al. 1997). Because *E. rosea* remains a threat in the wild, there is no question of direct reintroduction in the immediate future.

Based on promising results of a release of captive-bred *Partula* spp. on native French Polynesian plants in the controlled conditions of a botanic garden (Pearce-Kelly et al. 1995), an experimental predator-proof forest reserve, first proposed by Clarke and Wells (1986), was constructed on the island of Moorea, Society Islands, French Polynesia (17° 30′ 5″ S, 149° 49′ 5″ W). The reserve was situated at 210 m elevation in the Afareaito Valley, immediately below the Belvedere and the ridge connecting Mt. Tohiea

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Figure 1. Predator-proof snail reserve in Afareaito Valley, Moorea.

and Mt. Mouaputa, in nearly pristine forest dominated by *Hibiscus tiliaceus*, *Freycenetia impavida*, and *Angiopteris evecta* (Figure 1). Reserve design and habitat choice were keyed to questions of interest to both conservationists and ecologists concerned with microhabitat partitioning of sympatric species under natural conditions.

The exclosure was intended to answer three main questions: (1) Could an effective barrier be erected to exclude the predatory *E. rosea* and retain the reintroduced species of *Partula?* (2) Would a cost-effective monitoring and maintenance system be feasible? (3) Would the captive population of *Partula* spp. have retained the genetic and ecological traits necessary for survival in natural conditions?

The third question is crucial, not only to the reintroduction of partulid snails, but also to the general theory of the maintenance of captive populations.

MATERIALS AND METHODS

Construction

The exclosure (Figure 2), constructed in July 1994, surrounded a 20 by 20 m square of natural vegetation. It consisted of a barrier of galvanized iron roof panels 75 cm in height, anchored to wooden posts set in concrete. *Euglandina rosea* was excluded by two lines of defense, each of which had proved capable of stopping the snails. At the base of the barrier a plastic trough was filled with salt ($CaCl_2$ or NaCl). Near the top a pair of electric wires, powered by a 12-volt battery, were so arranged that an approaching snail would complete the circuit. Internally the exclosure was partitioned into four 10 by 10 m quadrants by galvinized iron fence, providing clear structural delineation without chemical and electrical defenses.

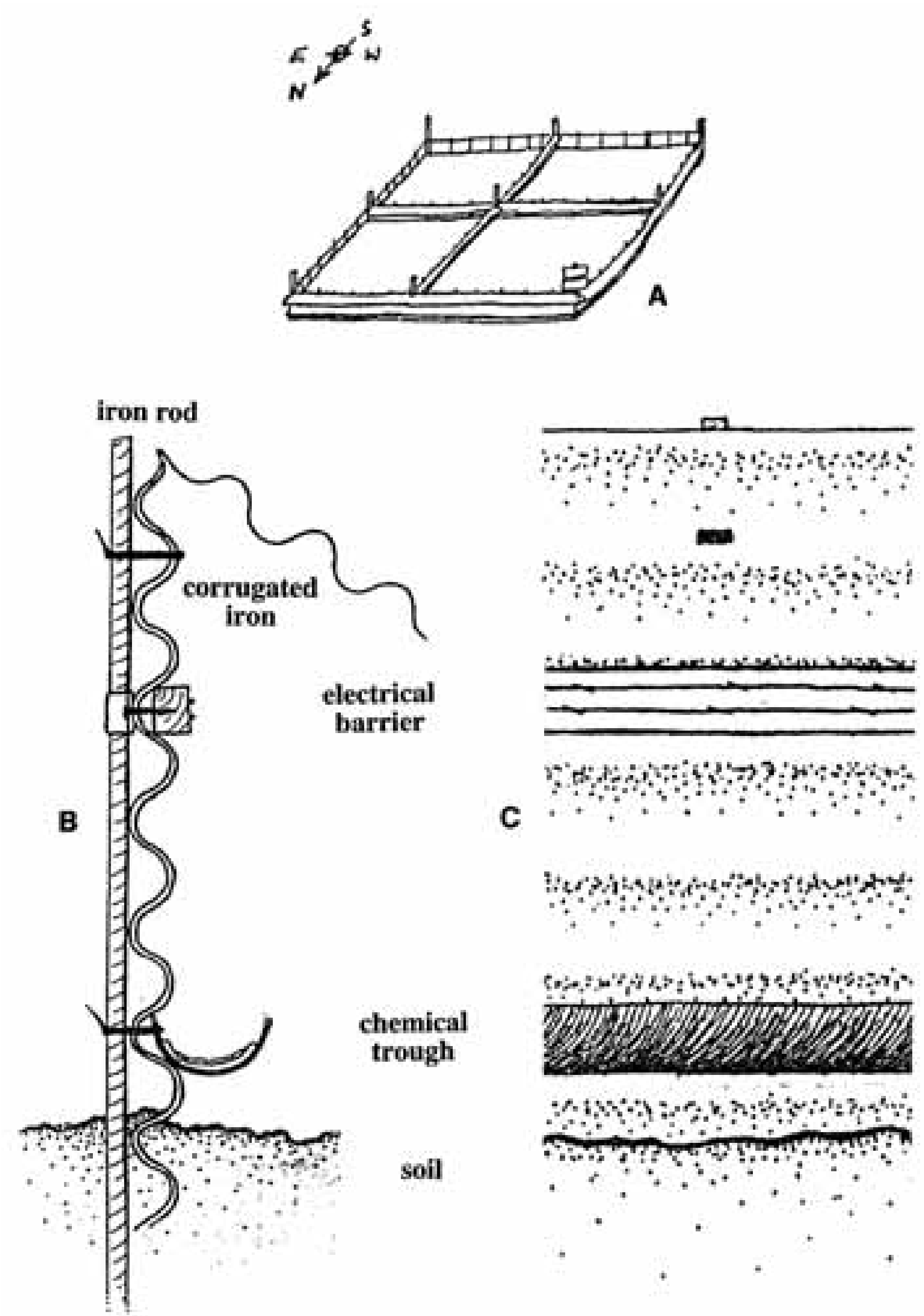

FIGURE 2. *Partula* reserve on Moorea. *A*, reserve view, enclosing 400 m^2 of natural vegetation; *B*, cross-sectional view through the outer barrier of galvanized iron panel, electrical barrier, and chemical trough at a point of attachment to iron support rod; *C*, exterior view of panel, electrical barrier, and chemical trough (bent overhang shown in *B* is removed). Height of vertical walls, 75 cm.

Stocking

The exclosure was stocked in September 1994 with three species of *Partula* indigenous to the area in which it was constructed (Afareaito Valley, Moorea). Each of three quadrants received 75 adult individuals of a single species: *P. suturalis*, *P. teaniata*, or *P. tohiveana*. The fourth received 25 adult individuals of each of the three species. Density was therefore equal in all quadrants. Each snail was marked by tiny holes drilled in the lip of the shell to indicate the locality from which the stock originated and the quadrant into which it was released (see Clarke et al. 1984, showing persistence of marked snails from 1962 to 1967).

The intent of this design was to allow detection, at the close of the 1-yr trial period, of any differences in the choice of microhabitat sites by the individuals of a species alone or in the presence of other sympatric species.

Monitoring

Weekly monitoring and associated maintenance was arranged through the Gump Biological Station and the Centre de l'Environnement, Moorea. Monitors were responsible for removing fallen branches forming bridges into the area, closing any gaps under the barrier, renewing the chemical troughs, and recharging the batteries. The monitors were also responsible for filing weekly reports of the condition of the exclosure and the numbers of partulids seen in the reserve.

RESULTS AND DISCUSSION

The arrangements for monitoring and maintenance proved to be more difficult than we had anticipated. A visit to the exclosure in July 1995, for interim censusing of the populations, determined that the security of the exclosure had been breached and that *E. rosea* had eliminated the entire population (except for three individuals that were found much later). This failure was especially disappointing because the presence of unmarked adult shells indicated that reproduction and rapid growth had taken place before the breakdown. The initial reintroduction had been successful, and two of the initial questions were therefore answered. It is indeed possible to exclude *E. rosea* effectively from an area long enough for reproduction to occur, and the captive populations of partulids had not lost their ability to reproduce under natural conditions.

A decision was reached to repair the exclosure and to restock it as soon as practicable. The electrical system was replaced with stainless steel wiring and staples to simplify maintenance. Potential bridging foliage was cut and holes beneath the barrier were plugged.

On 5 May 1996 the exclosure was restocked at a slightly reduced level, using 80 individuals of each species, all that could be spared from the captive breeding populations. The distribution was the same as in 1994: 60 individuals in each of three single-species quadrants and 20 of each in the fourth. At that time further repairs were carried out. Where a large fallen branch had damaged the galvanized coating, rust spots were treated with rust preventer and holes filled with silicone glue. The bottom of the barrier was reinforced with rocks and netting. A careful search of the area was made to eliminate all *E. rosea*, paying close attention to the bases of large ferns of the genus *Angiopteris* where *E. rosea* has a tendency to deposit its eggs. Care was taken to avoid damage to the foliage.

During the period of the second stocking, problems of supervision and communication resulted in lapses in population monitoring and reserve maintenance. After 6 months an incursion of *E. rosea* had taken place in each of the quadrants. Only one individual each of *P. taeniata* and *P. tohiveana* remained, although there was still a relatively healthy population of *P. suturalis*. Further serious problems with maintenance were encountered over the next 18 months, and in June 1998, almost 4 yr from the initial release, the decision was made to conclude the experiment without further restocking.

At that time eight living partulid snails remained in contrast to the total of 320 individuals released. It is important, however, that all of the eight were born in the wild. Their

TABLE 1

Comparison of Shell Dimensions of the Four Surviving Adults from the Reserve and Snails Collected by Crampton (1932) from Same Valleys of Origin as Reserve Founder Stock

Valley	*n*	Yr	Range (length)	Mean ± SE (l)	Range (width)	Mean ± SE (w)
Fareaito Valley	166	1923	18.95–22.85	20.81 ± 0.45	9.7–12.3	11.02 ± 0.24
	29	1924	19.85–23.85	21.32 ± 0.11	10.3–12.1	11.31 ± 0.52
Haapiti Valley	190	1907	17.15–21.65	19.08 ± 0.38	9.5–11.7	10.52 ± 0.18
	225	1923	17.15–21.35	19.07 ± 0.39	9.3–12.1	10.63 ± 0.20
Reserve mixed	4	1998	17.50–22.20	19.47 ± 1.45	9.7–11.4	10.80 ± 0.55

survival is noteworthy because *E. rosea* was also found in three of the four quadrants.

To assess the condition of the surviving individuals we compared their size and color polymorphism with those reported by Crampton (1932). Table 1 shows the measurements of the four surviving adults and similar measurements of animals from the valleys from which our stocks were obtained (Haapiti and Fareaito). Although the sample size is too small for a statistical comparison, there is no indication that up to six generations in the captive breeding program have resulted in any change of size.

More surprising is the retention of color polymorphism by the residual population of the reserve. Several of the captive populations have lost this visible expression of genetic polymorphism over the years. Both *P. taeniata* and *P. tohiveana* have been reduced to a single color morph. Molecular methods confirm the general reduction of genetic diversity (Goodacre 2001). By contrast *P. suturalis* has retained its color polymorphism, and four color morphs (frenata, cestata, strigata, and atra [see Crampton 1932, Johnson et al. 1993]) were included in the releases. It is noteworthy that among the animals bred in the exclosure three color morphs appeared (frenata, strigata, and atra), demonstrating that there was no notable founder effect reducing genetic variation.

The method of entry of *E. rosea* into the exclosure remains uncertain. In addition, it cannot be stated for sure that there were no escapes of *Partula* spp. (however, see Clarke et al. 1984, who determined that *Partula* spp. on Moorea rarely move more than 1 m in a year). The barriers were tested and found effective during the initial installation and no direct entry of the predator was ever observed. In at least 14 instances dead *E. rosea* were found lying in the salt troughs. Most probably entry was effected by way of fallen branches, overarching fern fronds, or erosional gaps that were not detected sufficiently rapidly by the monitors. There also remains a possibility that the *E. rosea* had hatched from undetected eggs within the area and had grown up without being detected by the monitors.

CONCLUSIONS

The ecological experiment that we hoped to carry out in conjunction with our conservation program was unsuccessful. We were never able to obtain measurements of the microhabitat choices of the introduced snails that would have enabled us to determine the effects of species interactions. However our experience with the reintroduction of partulids into the exclosure on Moorea has allowed us to answer the conservation questions with which we began:

(1) Effectiveness of the exclosure. It is clear that a defended exclosure can afford protection to a population of land snails under essentially wild conditions. The metal fence, protected by chemical and electric barriers, proved to be an effective means of excluding *E. rosea* and providing suitable native habitat for *Partula* spp. as long as the exclosure was monitored and maintained in a regular and consistent manner.

(2) Importance of monitoring. Our expe-

rience demonstrated that the most important element in maintaining a population in these protected, yet natural, conditions is an effective monitoring program. It also became clear that the coordination of efforts with multiple observers and distributed supervision remains the largest hurdle for such a program to surmount.

(3) Viability of populations. Finally, the most important result of this experiment is to have established that the captive populations of *Partula*, even after as many as six generations of captive breeding, retain sufficient genetic and ecological properties to allow at least some individuals in a small population to breed successfully under natural conditions. This result represents a validation of the methods employed in the captive breeding program and a justification for the time and resources expended to maintain these populations in the laboratory.

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