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Conservation of the Dark-rumped Petrel *Pterodroma phaeopygia* of the Galápagos Islands, 1982–1991

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Summary

Early work on the Dark-rumped Petrel *Pterodroma phaeopygia* of the Galápagos Islands, Ecuador, identified colony sites and population status and alerted wildlife managers to an alarming decline in nesting numbers. Predation by introduced mammals, such as rats, cats, pigs and dogs, is the chief concern, followed by loss of nesting habitat to agricultural development. Programmes to reduce predation through poisoning and hunting, begun in 1983, increased the number of chicks fledged from the main breeding colony in eight out of nine years. Pre-breeding adults were lured by tape-recordings to 'safe' sites where they successfully raised chicks in artificial nests. Tape-luring offers hope for establishing new colonies on predator-free islands.

Introduction

Dark-rumped Petrels *Pterodroma phaeopygia* were once abundant in both the Hawaiian and Galápagos archipelagos. Today they are endangered in both locations mainly due to intense predation by introduced mammals and loss of nesting habitat (King 1978–1979, Collar and Andrew 1988). *Pterodroma p. phaeopygia* is endemic to the Galápagos Islands, where relic populations nest in the humid highlands of at least four islands in the Galápagos National Park: San Cristóbal, Santa Cruz, Santiago and Floreana (Figure 1). Petrels probably nest on Isabela Island as well, but the location of breeding colonies remains unknown.

Land used for agricultural purposes has restricted nesting habitat on Santa Cruz, Floreana and San Cristóbal, while predation has eliminated the petrels from all but the most protected nest-sites, such as lava tubes and stream banks, on all of the islands. Here we review the studies and contributions to the conservation of the Dark-rumped Petrel up to 1991.

Early efforts

Harris (1970) documented the breeding chronology of the petrel on Santa Cruz in 1968–1969 and suggested that predation on eggs and young chicks by introduced rats *Rattus rattus*, pigs *Sus scofra* and dogs *Canis familiaris* were

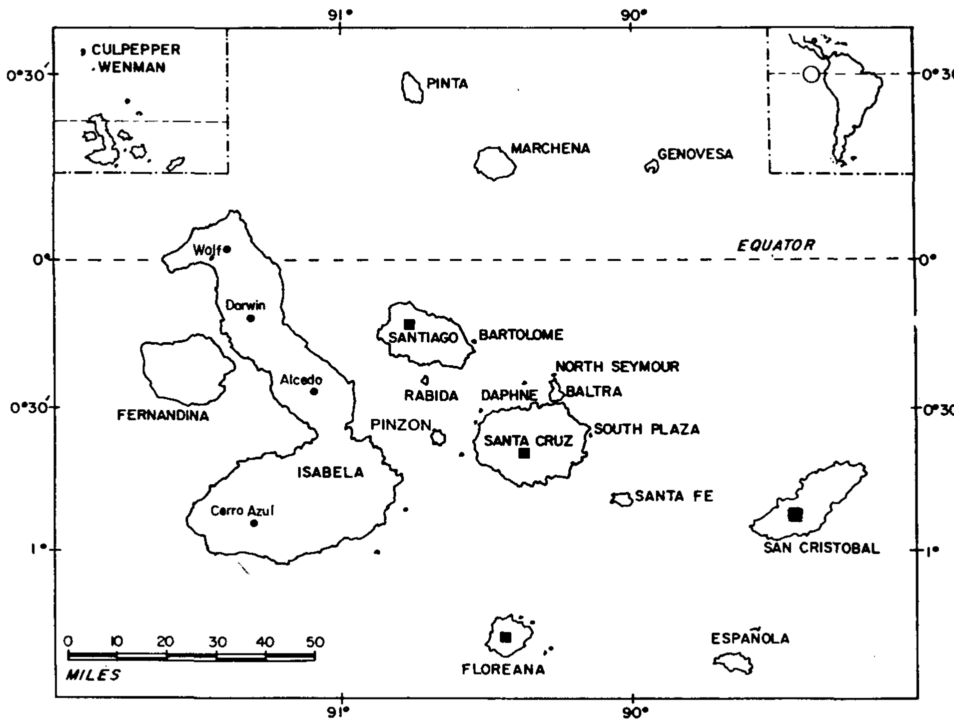

Figure 1. Map of the Galápagos archipelago. Open circle in upper right inset depicts location of the archipelago; black squares indicate location of Dark-rumped Petrel colonies.

primarily responsible for low petrel reproductive success (0–10%). Tomkins (1985) also documented predation on adults and chicks by cats *Felis catus*. Surveys by the Galápagos National Park Service (GNPS) and the Charles Darwin Research Station (CDRS) estimated the numbers of breeding pairs through the early 1980s (Jacobs 1972, Baker 1980, Bass 1980, Coulter *et al.* 1981b, Tomkins 1985) and documented a decline of the Santa Cruz population at the alarming rate of 33% per year.

Petrel colonies on other islands in the archipelago were located and observed by Tomkins (1985) in 1978–1979. He suggested that petrels on San Cristóbal were preyed on by rats, dogs and cats, while on Floreana Island rats, cats and pigs contributed to nest failure, and on Santiago Island pigs were the principal cause of mortality. Later studies confirmed these observations and also found that on Floreana introduced goats *Capra hircus*, burros *Equus asnus*, and cattle *Bos taurus* destroyed habitat and trampled nests (Coulter *et al.* 1981a, 1982). On Santiago the Galápagos Hawk *Buteo galapagoensis* killed petrel chicks and adults while goats destroyed nesting habitat (Cruz and Cruz 1987b).

Coulter *et al.* (1981a) suggested that the number of breeding pairs in the largest known colony (Cerro Pajas, on Floreana) might be declining by as much as 33% annually. Based on these studies, World Wildlife Fund–U.S. (WWF) decided to establish conservation priorities to control the predators in the petrels' breeding colonies. Recommendations from J. Keith, Denver Wildlife Research Center, U.S. Fish and Wildlife Service, and B. Bell, New Zealand Wildlife Service, were that initial efforts be concentrated in the Cerro Pajas breeding colony on Floreana. In 1982, WWF funded CDRS and GNPS to initiate a five-year conservation effort targeted at controlling introduced rats, cats, pigs, goats and burros in the Cerro Pajas colony.

The WWF petrel conservation project

I. Floreana 1982–1984

An estimated 2,000 pairs of Dark-rumped Petrels return to Cerro Pajas at 300–640 m above sea level to breed annually. Egg-laying extends from mid-December through March, and both parents incubate until the chick hatches after about 50 days. Chicks develop thermoregulatory capacities within a few days of hatching (Simons and Whittow 1984). Thereafter, both parents forage at sea, returning with food every three or four days. As with other procellariids, Dark-rumped Petrels exhibit high levels of breeding-site tenacity and mate fidelity (Cruz and Cruz 1990).

Because black rat predation on eggs and young petrels was severe, the rat was the first species targeted in control efforts. We tested two anti-coagulant rodenticides which were readily available in Ecuador: coumatetralyl in commercially prepared bait formulation (0.0375% active ingredient mixed with ground corn and rice), and brodifacoum, commercially prepared in wax blocks of 0.0005% active ingredient in a cereal base (Dubock and Kaukeinen 1978). Both baits were accepted by captured and wild rats and consumed in similar quantities during feeding tests, but coumatetralyl killed the rats more quickly (Cruz and Cruz 1987a). Brodifacoum was more toxic, distributed more easily, and weathered better, but disadvantages included the difficulty of measuring consumption when bait blocks were not secured, and the possible secondary hazards to owls and other raptors (Bell and Keith 1983). Coumatetralyl was chosen for rodent control in Cerro Pajas, although it was found to be damaged easily by heavy rains.

To effect control we distributed 200 poison feeders (50 cm long sections of four-inch diameter polyvinyl chloride tubing) at approximately 50 m intervals in the crater of Cerro Pajas. Later, we enlarged the feeders to 80 cm to protect the bait from rain damage. We used the same feeders each season (1983 to 1991). We distributed 100–250 g of commercially prepared coumatetralyl bait mixed with ground corn and rice (0.075% active ingredient) to each feeder and replaced damaged or consumed bait twice weekly. We assessed bait consumption by weight, but adsorption of water during heavy rains made some measurements unreliable. We set snap-traps over three successive nights (300 trap-nights) prior to poison distribution, then three to four weeks later, and at the end of the programme, to determine if the resident rodent population had decreased.

We controlled larger mammalian predators and pests by hunting with a .22 calibre repeating rifle and three trained hunting dogs. The amount of hunting varied annually (up to 14 man-days per year) because we hunted only when we found evidence of pigs, cats, goats and burros in the colony.

Table 1. Number of rats (*Rattus rattus*) caught as a result of trapping in the Cerro Pajas colony 1983–1986. Trap-nights are in parentheses below.

Year	Pre-control (tn)	After knock-down (tn)	Mid-season (tn)	Post-control (tn)
1983	16 (271)	0 (261)	–	3 (288)
1984	19 (273)	0 (284)	2 (286)	1 (268)
1985	4 (290)	0 (298)	0 (300)	1 (298)
1986	4 (294)	0 (278)	1 (295)	4 (277)

tn, trap-nights (the number of active traps × the number of nights set).

We monitored petrel nests from January to September, checking 104 nests in 1983 and 100 nests in 1984. During the incubation period nests were usually checked weekly and details recorded through to fledging. Success was evaluated as the ratio of young fledged to eggs laid.

In 1983, pre-control trapping in the Cerro caught 16 rats; 19 were caught in 1984 (Table 1). We caught no rats three to four weeks after control began, but low numbers were caught in the post-control trapping: three in 1983, and one in 1984. This suggests that during the petrel breeding season control measures maintained the site relatively free of rats.

The quantity of poisoned bait consumed varied between years. The 1983 petrel breeding season coincided with an El Niño–Southern Oscillation and precipitation increased nine-fold, damaging much of the grain-based bait. In 1984 bait consumption was initially high but dropped to consistently low levels for the remainder of the control period. This pattern was repeated in succeeding years. Probably a low level of migration from non-control areas, as well as the presence of mice *Mus musculus* in the Cerro, contributed to the continuing low consumption observed.

We had no problems with secondary poisoning during either of these seasons. The few Short-eared Owls *Asio flammeus* which hunted in the Cerro remained in the area and increased in numbers. We observed no deaths to non-target species. Small granivorous birds inhabiting the Cerro ignored the feeders during both seasons. Two pigs, several wild burros, six cats and about 25 goats were killed by hunting in the colony during the first two years.

Before control measures, in 1981 and 1982, nesting success was approximately 31% (Coulter *et al.* 1982). Of the 104 eggs monitored in 1983, 48 (46%) fledged young successfully, and we found no losses of either eggs or young to rodent predation (Table 2). Similarly in 1984 we observed no losses to predation and 72% of the nestlings fledged.

II. Santa Cruz, Santiago and Floreana 1985–1986

On Santa Cruz, petrel nests are widely scattered through the humid highland zone of the island (400–800 m). The majority of nests were restricted to areas

Table 2. Reproductive success of the Dark-rumped Petrel on Floreana Island 1981–1987.

Year	Eggs laid	Young fledged successfully	Fledglings from eggs laid (%)	Nests lost to predation (%)[a]
1981[b]	42	13	31	31
1983	104	48	46	0
1984	100	72	72	0
1985	100	23	23	49
1986	100	70	70	10
1987	83	66	80	0

[a] Predation by cats and rats; non-predation losses were due to nest abandonment, egg infertility, collapse of nesting burrows, chick starvation and undetermined causes.
[b] Results of prior assessments (Coulter *et al.* 1982).
Incomplete data from 1992 are omitted.

above 600 m owing to farming at lower altitudes. The burrows were easily dug up by dogs and pigs; cats and rats were abundant. Few problems were encountered from burros and cattle in the national park, although these animals were the principal cause of nest destruction on private property. Nests in agricultural areas were most affected, but low reproductive success continued even within the Galápagos National Park. Predation, principally by rats, but also by dogs, cats and pigs, was identified as the most urgent problem.

Petrel nests on uninhabited Santiago were scattered in small clusters over approximately 35 km^2 of the highlands (400–900 m). We followed the history of 205 nests from February to August and October 1985. During a 14-day visit in June 1986, we monitored 50 nests: this coincided with a pig-control campaign by GNPS. Their programme included hunting and poisoning with 1080 (sodium monofluoroacetate) and was aided by a severe drought.

On Santiago we found that pigs and hawks were the principal predators of adult and nestling petrels, with 55% of monitored adult birds (n = 510) being killed in one season. Our best estimate is that there were less than 500 (± 200) breeding pairs of petrels in 1985. A reduction in the pig population by 80% (L. Calvopiña and H. Ochoa, verbally) may have been reflected in the low incidence of predation found in 1986, when we recovered only six dead petrels.

On Floreana we continued to follow a sample of 100 nests each year in Cerro Pajas. Because rat numbers were lower in 1986, we reduced the number of active feeders from 200 to 75, distributing the poison in feeders which encircled the petrel colony. Feeders were checked weekly and maintained with 100–200 g of bait. To control an increase in cat predation in 1985 we used a combination of hunting (trained dogs, shooting) and poisoning (1080). Baits were distributed at 100 m intervals in a cordon around the Cerro and in other areas where there was evidence (e.g. scats) of cats. We also injected 1080 into petrels killed by cats when we suspected that cats would probably return to finish consuming them. In 1986, cat predation was also reduced through the use of traps set at 500 m intervals in a cordon around the exterior base of the mountain.

Bait consumption in 1985 and 1986 followed a similar pattern to that observed in 1984, being initially high and then rapidly falling to consistently low levels. However, in 1985 we observed bait being consumed by non-target species such as finches and cockroaches. Cockroaches consumed about 70% of the bait. We observed no apparent ill-effects or deaths of these species due to the poison, but the effects on fecundity or other life-history variables are unknown.

Rodent control remained effective at Cerro Pajas and petrel losses due to rats during 1985 and 1986 were negligible. Once the control area had been cleared of rats, distribution of poison in a cordon around the Cerro was effective in maintaining low rat numbers and in reducing labour and material required. In addition, over 500 goats were eliminated by hunting in this two-year period. Petrel reproductive success was 70% in 1986, higher than in 1985 when losses were due to cats. In 1985 and 1986, 66 and 23 cats respectively were destroyed by hunting: effects of poisoning could not be assessed (see also Rauzon 1985).

Rodent, cat and pig control measures appeared to be effective in increasing petrel reproductive success and in reducing adult mortality, but the financial and logistic implications of a continuous poisoning schedule were prohibitive. In 1985 we began experiments to determine the effectiveness of a reduced poison distribution schedule.

In an area similar to Cerro Pajas we laid out four quadrats, 200 m^2, with poison feeders spaced 50 m apart containing 200 g of coumatetralyl mixed with rice (active ingredient 0.0375%). We did not replace the consumed bait but set snap-traps at two-weekly intervals to assess rodent numbers (emigration test). We also tested the bait over periods of up to 120 days (persistence tests).

Rats found weathered bait palatable after 120 days of exposure, during which coumatetralyl remained effective as a toxic agent. Results from the quadrat study indicated that a single poisoning would effectively prevent a build-up of rodent numbers for several weeks. We repeated both the persistence and emigration experiments in 1986 and obtained similar results.

Based on these results and experience in Cerro Pajas, we recommended to GNPS that: (1) rodent control be continued for at least 10 years, employing a three-man team to distribute a rodenticide during the petrels' egg-laying, incubation and early chick periods on Cerro Pajas (February–June); (2) 20-day control periods be scheduled for January, March and May using 150 g of bait distributed in 200 feeders at the beginning of each period; (3) 500 g of bait be distributed in each feeder and left for the interim at the end of each control period; (4) all larger predators and pest species be removed from Cerro Pajas by hunting during control periods; (5) if evidence of cats was found in the Cerro, 100 traps be set in a perimeter around the exterior of the mountain and checked daily for the duration of control; and (6) at least 50 Dark-rumped Petrel nests be monitored during each control period, and in July to assess reproductive success.

III. Floreana 1987–1991

In 1987 the GNPS assumed responsibility for continuing petrel conservation on Floreana with support from CDRS. Additionally, long-term funding for continued conservation was obtained from WWF–Sweden. A five-man team implemented the above recommendations in 1987 and successful reduction in rat numbers has been achieved during each control period since then (S.

Naranjo, verbally). Hunting and trapping have continued to eliminate cats and goats on Cerro Pajas. Petrel reproductive success has also been high: 80% of 83 nests monitored in 1987 produced fledglings and no predation by rats or cats on petrel nests was observed, while in 1988 78% of the monitored nests fledged successfully. Figures are not available for more recent years.

The Audubon-CDRS petrel conservation project 1988–1991

With the concerns described above in mind, the National Audubon Society (NAS), GNPS and CDRS initiated a joint restoration programme to lure pre-breeding adults to predator-free, artificial nest sites on Santa Cruz. The project was modelled on the successful attraction and restoration of Leach's Storm-petrel *Oceanodroma leucorhoa* colonies on islands off the Maine coast (Podolsky and Kress 1989). S. W. Kress and R. H. Podolsky suggested that Dark-rumped Petrels breeding for the first time may use the stimuli of sight and sound provided by an established colony to locate a breeding-site. Therefore, by imitating colony sounds, they hoped to induce Dark-rumped Petrels to nest in areas cleared of predators prior to stimulation.

In 1988 they tested the relative attractiveness of seven different Dark-rumped Petrel calls ranging from single calls to full colony sounds. Double- and triple-intensity tapes were prepared, played on a random schedule during the night and broadcast through two speakers set in the middle of six mist-nets in the Media Luna petrel colonies of Santa Cruz Island. Relative attractiveness of different calls was measured by the number of birds captured in the nets and the number of passes over them. More petrels were netted when colony sounds were played (single, double- and triple-intensity) than when other calls were broadcast. The tape with greatest attraction was the double-intensity recording of colony sounds.

The first phase of a colonization project was also begun in 1988, in the crater of a small cerro known as Mirador (600 m). The experiment tested the role of artificial burrows enhanced by petrel calls (Anon. 1988): 80 burrows were dug within the crater and four speakers played the double-intensity petrel tape continuously from 22h00 to 06h00 each night from mid-June to mid-August 1988. The burrows were checked for activity each morning.

Petrels prospected at 68% of the 80 artificial burrows in Mirador, and 17 birds were found during the day in these burrows. By chance, active burrows were half a metre closer to the speakers than expected (Podolsky and Kress 1988). These results indicate that Dark-rumped Petrels were attracted to play-back recordings of several calls and also that they occupied artificial burrows close to speakers broadcasting their calls.

In the second year of the restoration project (1989), a further 80 artificial burrows were constructed and stimulated with taped calls in the Mirador crater. Petrel activity at the artificial nests more than doubled in 1989, from 14 birds remaining overnight (1988) to 39 overnights in 1989 (Anon. 1990). A breakthrough came in 1990 when petrel activity at the burrow increased to 257 overnights with four pairs of petrels laying eggs in artificial nests. Despite rodent control efforts, however, three of the four chicks hatching in man-made nests were lost to predation; rats were suspected in each case.

Despite the loss of chicks, the nestings demonstrated that petrels can be influenced to nest in designated areas using tape-recordings and artificial burrows. However, the project failed to create a truly predator-free environment within the confines of Santa Cruz. Therefore, in 1991, Kress and Podolsky decided to test the attraction method on a true island – one selected for its absence of exotic mammals – where petrels have not been known to breed previously. Uninhabited and remote, Pinta was selected for this trial.

A team of three worked for two months on Pinta searching for Dark-rumped Petrel burrows and playing petrel tapes at night. No petrel activity on the island was reported during their stay (R. H. Podolsky, verbally), but petrels did visit the surrounding waters. The effectiveness of tape-lures to augment recruitment into an already or recently occupied site is evidently greater than it is when attempting to establish birds at a previously unused site. Stimulation of birds to colonize predator-free Pinta may therefore have to proceed for several years before success is achieved.

Conclusions

With continued commitment on the part of local conservation agencies, predator control should be successful in increasing recruitment into the Dark-rumped Petrel population on Cerro Pajas. As successful as these methods have been, however, they remain temporary measures. More permanent methods, such as fencing out predators, may reduce long-term investment costs and increase the level of protection. Again, the methods employed on Floreana will not be entirely applicable to petrel colonies on other islands where there is predation by domestic animals, or where petrel nests are scattered over broad areas.

Results of the attraction experiments indicate that luring Dark-rumped Petrels with tapes is a viable management option which can influence nest-site selection. Combining an attraction programme with predator eradication, predator control or exclusion and vegetation rehabilitation would increase survival of pre-breeders and adults, thereby increasing reproductive success, and help in maintaining a viable population size on islands with human settlements. Attracting Dark-rumped Petrels to predator-free, uninhabited islands holds great promise for the survival of this endangered species over the long term.

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