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POPULATION ESTIMATES AND BREEDING BIOLOGY OF THE PETRELS *PTERODROMA EXTERNA* AND *P. LONGIROSTRIS* ON ISLA ALEJANDRO SELKIRK, JUAN FERNANDEZ ARCHIPELAGO[1]

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Abstract. The Juan Fernandez Petrel (*Pterodroma externa externa*) and Stejneger's Petrel (*P. longirostris*) are respectively confined as a breeding race and a breeding species to Isla Alejandro Selkirk in the Juan Fernandez archipelago. The mixed upland colony of the two species was mapped and the density assessed by quadrat methods. The 1985–1986 world breeding population of the two species was estimated as 1,131,000 ± 209,000 pairs, comprising 1,000,000 pairs of *P. e. externa* and 131,000 pairs of *P. longirostris*. Predation by introduced cats fell disproportionately on the smaller *P. longirostris*.

Both species bred in the southern summer, laying in late December and early January. Incubation spells were lengthy averaging about 3 weeks. In other respects the petrels' breeding biology was typical of *Pterodroma* species.

Key words: *Juan Fernandez Petrel; Stejneger's Petrel;* Pterodroma; *population estimate.*

INTRODUCTION

This paper presents population estimates for the two petrel species breeding on Isla Alejandro Selkirk (33°45'S 80°45'W) in the Juan Fernandez archipelago. The species concerned, the Juan Fernandez Petrel (*Pterodroma e. externa*) and Stejneger's Petrel (*P. longirostris*) are, respectively, confined as a breeding race and a breeding species to the island. Although past reports (Lönnberg 1921, Bourne 1983) suggested the birds are abundant—as would be anticipated from their density at sea (Ainley 1980, pers. observ.)—this is the first attempt to quantify that abundance and so provide world population estimates for the two forms. In addition the paper includes data on the breeding biology of the two species. The eggs of Stejneger's Petrel have not been described previously.

The Juan Fernandez Petrel is closely allied to the White-necked Petrel (*P. e. cervicalis*). The latter, endemic to the western Pacific Kermadec Islands, has a breeding population of 5,000 to 10,000 pairs (Robertson and Bell 1984). In fact Imber (1985) has proposed that the two forms be separated as full species, principally on the basis of differences in intestinal structure. Regardless of whether the separation proves justified the Juan Fernandez Petrel is the more numerous. It migrates as far north as Costa Rica (Murphy 1936) after breeding in the austral summer.

Stejneger's Petrel, now widely accepted as a good species, (Harrison 1983, Croxall et al. 1984) has long been known from its North Pacific wintering grounds (Stejneger 1893). But in the early part of the present century the petrels breeding on Isla Alejandro Selkirk, previously assigned to *P. cookii* (Lönnberg 1921) or *P. leucoptera* (Murphy 1936), were not recognized as identical to those wintering in the North Pacific. The connection is now established (Harrison 1983).

Lönnberg (1921) gave no information on the breeding season of Stejneger's Petrel. Millie (in Johnson 1967) failed to find the birds on Isla Alejandro Selkirk in October 1955. Harrison (1983) gave egg dates from November, roughly compatible with Bourne's (1983) report of recently-vacated nest holes in June. However Araya Modinger (1985) mentioned, without further substantiation, a July/August nesting season. The present study aimed to resolve this uncertainty.

METHODS

In order that the population estimate could take place against an established breeding timetable 30 study burrows were opened for inspection between 17 and 19 January 1986 in a grassland area near the campsite (Fig. 1). Breeding adults in the burrows were measured, as were the eggs. The occupied burrows were inspected daily from opening until 4 February and then again on 14

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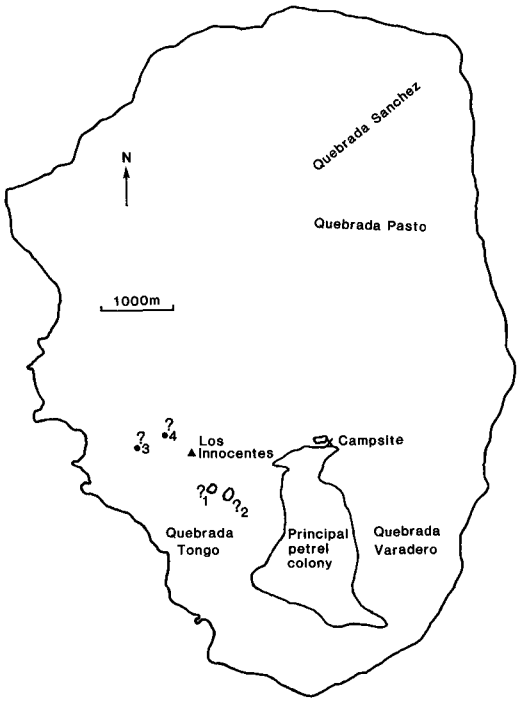

FIGURE 1. The distribution of *Pterodroma* spp. petrels on Isla Alejandro Selkirk. In addition to the mapped principal colony there were possibly small pockets of petrels on the inaccessible slopes at $?_{1-4}$. There were also small (see text) numbers of Juan Fernandez Petrel burrows in the upper reaches of Quebradas Pasto and Sanchez.

February. Petrels were marked with a permanent marker pen so that incubation changeovers could be recorded with minimum disturbance.

More than 95% of petrels nested in a mixed colony in the southern half of the island (Fig. 1). The colony very closely coincided with that part of the island swathed in the tree fern *Dicksonia externa,* the exception being that the lower altitudinal limit of the petrel colony, around 850 m, was generally somewhat above the lower limit of *Dicksonia* forest. Using a 1:25,000 map the colony was carefully mapped in the field. Minor corrections to the field map were subsequently made using aerial photographs supplied by the Chilean Air Force and the knowledge of the coincidence of nesting burrows and *Dicksonia* forest. Photocopies of the completed map were then made. From each photocopy, the colony was cut out as was a square equivalent to 100 ha. The two pieces of paper were weighed on a Sartorius balance sensitive to 0.001 g, allowing the colony area to be estimated. The procedure was repeated five times and the mean value taken as the planar area of the colony. The five estimates did not differ by more than 1%. Since the terrain was sloping a correction is required to discover the surface area of the colony. From the east in Quebrada Varadero the colony rises from 850 m to the ridge at 1,050 to 1,100 m that runs north-south and divides the watersheds of Quebradas Varadero and Tongo. This rise is of about 200 m in a horizontal distance of 750 m. West of the ridge the colony slopes steeply down for some 150 m in a horizontal distance of 200 m. The minimum gradient, a rise of 200 m in 750 m, is a slope of 15°. The gradient west of the ridge, a rise of 150 m in 200 m, is 37°. These figures take no account of the fact that the ground is dissected and further steepened by river courses. Conservatively, I consider the minimum average slope to be 20° and so increase the mapped planar area by the secant of 20° (=1.064).

Burrows within the colony, apparently occupied because their entrances were clear of debris and showed evidence of recent bird trampling, were counted in 30 quadrats measuring 5 × 5 m each. Quadrat positions were determined as follows. I marked 60 points within the colony by dotting the map with eyes closed. The 60 points were then numbered and 30 of the 60 numbers drawn from a tin can. These formed the 30 quadrats to be visited. Each quadrat position was located in the field as accurately as map, compass, and dense fern forest allowed. I then walked 25 paces in a randomly determined compass direction. The point reached was the northeast corner of the quadrat which was marked on the ground by string with sides running north–south and east–west. Burrows within the quadrat were counted.

Burrows of Juan Fernandez and Stejneger's petrels were intermingled and the two species were both incubating (see below) when the quadrats were visited 23 to 27 January 1986. Several lines of evidence were used to estimate the proportion of the two species:

(a) Within quadrats certain burrows were clearly too small to accommodate the larger Juan Fernandez Petrel. A count of such burrows gave a minimum estimate of the proportion of burrows occupied by Stejneger's Petrels, since larger burrows could have belonged to either species.

(b) The 30 study burrows, opened for regular inspection near the campsite, contained either species.

TABLE 1. The mean dimensions (±SE) of Juan Fernandez Petrel eggs on Isla Alejandro Selkirk.

	Length mm	Breadth mm	Length/breadth ratio	Volume index
Burrow eggs				
$n = 19$	67.2 ± 0.74	48.0 ± 0.20	1.40 ± 0.016	155.0 ± 2.25
Surface eggs				
$n = 40$	67.5 ± 0.41	47.0 ± 0.19	1.44 ± 0.010	149.4 ± 1.54
t	0.34	3.18	1.94	2.05
Significance	>0.10	<0.005	$0.05 < P < 0.10$	<0.05

Note: Volume index = length in cm × breadth in cm².

(c) Between 17 January and 2 February, 68 eggs of both species were found on the colony surface. Judging by their position some eggs had been laid outside burrows while others had probably been pushed out. Only eggs sufficiently whole to be measured, and so identifiable by size, were counted.

(d) Between 15 January and 17 February, 183 carcasses of petrels killed during the current breeding season were found on the island and counted.

(e) On 25 January and on 31 January, 110 and 105 petrels respectively were mist-netted at the campsite. These two samples, netted in the first hour of petrel activity after dusk, included both species.

(f) On 15 January a large vessel was moored approximately 250 m offshore from the settlement on Isla Alejandro Selkirk. At dusk a small proportion of the petrel throng flew between the vessel and the shore. The birds in this sample were easily assigned to species by sight and counted until 200 Juan Fernandez Petrels had been tallied.

All means are given ±1 SE.

RESULTS

BREEDING BIOLOGY: JUAN FERNANDEZ PETREL

Of the 30 burrows opened from 17 to 19 January, 22 contained incubated eggs, 20 laid by Juan Fernandez Petrels, and two laid by Stejneger's Petrels. Another burrow contained the fragments of an egg, probably a Juan Fernandez Petrel egg, laid during the current season. The remaining seven were empty and, despite checks about every fourth day, no egg was observed in them.

The Juan Fernandez Petrel egg was a typical white procellariiform egg. Nineteen incubated eggs (burrow eggs) were measured as were 40 intact eggs found outside burrows on the ground (surface eggs: Table 1). The surface eggs were significantly less broad and consequently had a higher length/breadth ratio and lesser volume than the burrow eggs. They had probably been laid by younger females (Richdale and Warham 1973, Brooke 1978). Since some of the eggs were clearly laid outside burrows—they could not have reached the location of their discovery by ejection from a burrow—it seems that younger females may particularly fail to lay inside burrows.

Thirty-six breeding Juan Fernandez Petrels of unknown sex had mean wing length 319 ± 1.1 mm, bill length 38.2 ± 0.19 mm, and tarsus length 40.1 ± 0.25 mm.

Of 20 Juan Fernandez Petrel eggs found in the burrows 13 remained at the last check on 14 February when one was chipping. If laying was completed by 17 January and hatching about to commence on 14 February then, assuming an incubation period of 55 days (Schramm 1983), laying took place between about 20 December and 10 January.

Continuous incubation was maintained in 15 burrows between opening (17 to 19 January) and 4 February. No complete incubation shifts were monitored in this period. Thirteen incubation changeovers occurred in 253 burrow-nights, suggesting a mean incubation shift of 19.5 days. There were no checks at burrows between 4 and 14 February. At the 13 burrows where incubation continued between these dates there were six changeovers, suggesting a mean incubation shift length of 21.7 days.

BREEDING BIOLOGY: STEJNEGER'S PETREL

The egg of Stejneger's Petrel was also a typical white procellariiform egg. Two in study burrows were 50.1 × 37.5 mm and 52.6 × 37.0 mm. In addition nine eggs found outside burrows had a mean length 51.7 ± 1.30 mm, mean breadth 37.5 ± 0.27 mm, mean length/breadth ratio 1.38 ± 0.030, and mean volume index (length in cm × breadth in cm²) 73.0 ± 2.74.

TABLE 2. Six methods for estimating the proportions of Juan Fernandez and Stejneger's petrels in the population breeding on Isla Alejandro Selkirk.

	No. of Juan Fernandez Petrels	No. of Stejneger's Petrels	% of Stejneger's Petrels
(a) Quadrats	423	50	10.6
(b) Study burrows	20	2	9.1
(c) Intact eggs on ground	56	12	17.6
(d) Corpses	101	82	44.8
(e) Mist-netting			
25 January	101	9	9.3
31 January	94	11	
(f) Dusk sea count	200	26	11.5
$\chi^2 = 133.7$, df = 5, $P < 0.001$			

Four Stejneger's Petrels of unknown sex had a mean wing length 216.8 ± 1.03 mm, bill length 24.1 ± 0.33 mm, and tarsus length 28.8 ± 0.49 mm.

Of the two eggs in study burrows one hatched between 28 and 31 January. The chick, covered in grey down, was brooded continuously until the night of 3 February when the parent departed. The chick had disappeared by 14 February. The second egg was not chipping on 4 February and had also disappeared by 14 February. These data suggest a laying period in late December and early January, very similar to that of the Juan Fernandez Petrel.

At both study burrows there was only one incubation (or brooding) changeover between opening on 18 January and 4 February. Incubation shifts were probably of the order of 2 or 3 weeks.

CENSUS RESULTS

The mean number of burrows in each 25-m^2 quadrat was 15.8 ± 1.87. Of the 30 study burrows 23 (76.7 ± 7.72%) were certainly occupied by breeding pairs. Others may also have been so occupied, only to lose their eggs before I opened the burrows. Thus multiplying the number of burrows by 0.767 may underestimate the breeding density. However using this factor the density of breeding pairs was 0.484 ± 0.0753 m^{-2}. The planar area of the colony (Fig. 1) was 219.8 ha and, including a correction for slope (Methods), the surface area was calculated as 233.9 ha. There is no statistical basis for assessing the error in this area estimate and I can only guess a standard error of 10%. Multiplying density by area, the estimated breeding population of the principal petrel colony was 1,131,000 ± 209,000 pairs.

In addition to the principal colony the vegetation, *Dicksonia* forest, of two small (each 1 to 2 ha) areas to the south and two lesser pockets to the northwest of Los Innocentes (Fig. 1) suggested outlying groups of burrows. Due to inaccessibility this was not confirmed. In the grassland in the upper reaches of Quebradas Pasto and Sanchez several clusters of up to 50 Juan Fernandez Petrel burrows were found at an altitude of 600 to 800 m. These clusters were not censused in detail. The total number of burrows might exceed 1,000 but would not exceed 10,000, a figure substantially smaller than the error term for the burrow estimate of the principal colony.

Several means of assessing the proportions of the two species were used (Table 2). Excluding the value derived from corpses (see Predator section below) the mean of the five remaining values for the proportion of Stejneger's Petrels was 0.116. Thus on Isla Alejandro Selkirk the breeding population of the Juan Fernandez Petrel was about 1,000,000 pairs and of Stejneger's Petrel about 131,000 pairs.

The quadrat data yielded no significant evidence of habitat or altitudinal differences in the nesting areas of the two species.

Neither the Juan Fernandez Petrel nor Stejneger's Petrel is known to breed on Isla Robinson Crusoe, the second major island of the Juan Fernandez group lying 180 km east of Isla Alejandro Selkirk. However a freshly-killed Juan Fernandez Petrel was found on that island on 12 December 1985. The inland position of the corpse in a nesting colony of Pink-footed Shearwaters *Puffinus* (*carneipes*) *creatopus* raises the possibility that Juan Fernandez Petrels breed in small numbers on Isla Robinson Crusoe, a possibility also mooted by Lönnberg (1921).

GENERAL OBSERVATIONS

The petrels were strictly nocturnal in their activity at the colony. During the study period birds were first heard calling at the campsite between 21:40 and 22:10 local time (= GMT − 3). Calling then continued until about 06:00.

There was some evidence that Stejneger's Petrels arrived at the colony earlier in the night than Juan Fernandez Petrels. The number of Stejneger's Petrels included in the first 50 birds to fly over or within 30 m of the campsite was counted on 30 January, 2 and 3 February. The

counts began about 21:55 and lasted some 10 min. The samples included 42, 22, and 32 Stejneger's Petrels, a higher proportion than in the breeding population (Table 2). Comparable counts could not be continued into the night because, after the first 50 birds, it became too dark to separate the species by sight.

Juan Fernandez Petrels flying over the colony gave a prolonged sighing whistle, particularly when birds were involved in aerial chases. Sometimes this whistle was followed by a harsh bark or 'wowk.' A call given by both flying birds and those on the ground walking through the fern forest was a booming 'boo-booo-boo.' Grounded birds also uttered a chattering call which occasionally was given from within burrows. The only call positively identified as coming from Stejneger's Petrels was a rapid 'ti-ti-ti,' a vocalization similar to but higher than the comparable call of the Great-winged Petrel *P. macroptera* (Warham 1956, pers. observ.).

The featherlice *Halipeurus kermadecense* and *H. leucophryna* were collected from breeding Juan Fernandez and Stejneger's petrels respectively on Isla Alejandro Selkirk on 18 January 1986.

PREDATORS

During fieldwork at the petrel colony feral cats were seen four times, a rat (dead) once, and buzzards *Buteo polyosoma exsul* daily.

A large proportion (over 50%) of freshly-killed petrels had been eaten by cats as evidenced by gnawed sterna and ribs. Since the petrel corpses included a significantly higher proportion of Stejneger's Petrels than is present in the population (Table 2) it appears that cat predation fell disproportionately on Stejneger's Petrels. However, in the absence of prior surveys, there is no evidence that Stejneger's Petrels have declined. Moreover I would not echo Reed (1874) who mentioned that the island 'swarmed' with cats. It seems plausible that the winter period, when all the breeding petrels quit the island, is important for limiting cat numbers.

The winter period may also serve to limit rat numbers. I have no data concerning the level of rat predation on petrel eggs and small young. The fact that entire uneaten eggs of both petrel species litter the colony suggests such predation may not be heavy.

I saw only one petrel, probably Stejneger's, in the talons of a buzzard. As the petrels are presumably difficult to catch in flight in darkness or when beside their burrows under the fern forest canopy, such predation may not be heavy.

CONCLUSION

Approximately 1,000,000 pairs of Juan Fernandez Petrels and 131,000 pairs of Stejneger's Petrels bred on Isla Alejandro Selkirk in 1985–1986. The colony is therefore of the highest international importance. Cat predation fell disproportionately on Stejneger's Petrels. This gives cause for concern and should be monitored by the appropriate conservation organizations.

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