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The effect of cat *Felis catus* predation on three breeding Procellariidae species on Marion Island

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Breeding success of *Pterodroma macroptera, Procellaria aequinoctialis* and *Pachyptila vittata salvini* in three cat-free and three control areas were used to evaluate the effects of cat *Felis catus* predation on the avifauna of Marion Island. Breeding success of all three species was significantly higher in the combined cat-free areas than in the combined control areas. However, breeding success in one cat-free area failed to show a significant difference from its particular control area, probably as a result of higher skua (*Catharacta antarctica*) predation inside the cat-free area. Chicks of *P. macroptera* and *P. aequinoctialis* were especially vulnerable to cat predation, since cats can enter their nesting burrows. *P. macroptera* was seriously affected by cat predation because it is the most abundant of only two winter-breeding petrels. Significant changes in the number of nest visits by these petrels during their breeding season followed hatching dates, which in turn were concomitant with, or were followed by significant differences in the combined breeding success between the cat-free and control areas. The cat-free areas show that an elimination of cat predation would still favour the recovery of the petrel population.

Broeisukses van *Pterodroma macroptera, Procellaria aequinoctialis* en *Pachyptila vittata salvini* in drie katvrye- en drie kontrole-gebiede is gebruik om die effek van katpredasie (*Felis catus*) op die avifauna van Marioneiland te evalueer. Broeisukses van die drie spesies was in die gekombineerde katvrye-gebiede betekenisvol hoër as in die gekombineerde kontrole-gebiede. Broeisukses in een van die katvrye-gebiede het egter nie 'n betekenisvolle verskil met sy spesifieke kontrole-gebied getoon nie, waarskynlik weens 'n hoër roofmeeu- (*Catharacta antarctica*) predasie binne die katvrye-gebied. Kuikens van *P. macroptera* en *P. aequinoctialis* was veral vir katpredasie kwesbaar, omdat katte hulle nestonnels kon betree. *P. macroptera* is ernstig deur katpredasie beïnvloed omdat dit die volopste van slegs twee winterbroeiende stormvoëls is. Betekenisvolle veranderinge in die aantal nesbesoeke deur die stormvoëls gedurende hulle broeiseisoene het gevolg op uitbroeidatums wat op hulle beurt deur betekenisvolle veranderings in broeisukses tussen die katvrye- en kontrole-gebiede gevolg is. Die katvrye-gebiede het getoon dat 'n uitskakeling van katpredasie die herstel van die stormvoëlbevolking sal bevoordeel.

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During 1982 the Marion Island cat *Felis catus* population comprised 615 ± 107 individuals, survivors of a biological control programme through the introduction of feline panleucopaenia (FPL) virus in 1977 (van Rensburg, Skinner & van Aarde 1987). Prior to the introduction of FPL, the 1975 cat population of 2139 ± 290 cats consumed an estimated 450 000 burrowing petrels (Procellariidae) and the distribution and density of the cats were influenced by the distribution of their prey (van Aarde 1979, 1980). The introduction of FPL resulted in a population decrease of 29,0% per year, from a calculated 3400 cats in 1977 (van Rensburg *et al.* 1987).

Cats are opportunistic predators with predation being a factor of prey availability rather than prey selection (Jones 1977; Fitzgerald & Karl 1979; van Aarde 1980; Jones & Coman 1981; Karl & Best 1982; Apps 1983; Liberg 1984; van Rensburg 1985). Since the cat population on Marion Island was reduced artificially and changes in diet were noted (van Rensburg 1985), it was necessary to quantify the present effect of cat predation on the burrowing petrel species. Breeding success of great-winged petrels *Pterodroma macroptera,* white-chinned petrels *Procellaria aequinoctialis* and Salvin's prions *Pachyptila vittata salvini* were used to evaluate the effect of cat predation at the present population density.

Study area

Marion Island (46°54′S / 37°45′E) is a sub-Antarctic island with a tundra biome, 290 km^2 in area and volcanic in origin, with high precipitation, low mean temperature and strong winds (Huntley 1967; Schulze 1971; Verwoerd 1971). Van Aarde (1979) recognized six habitat types utilized by cats, namely vegetated black lava, bare black lava, grey lava slopes, grey lava ridges, volcanic cones and *Cotula* hillocks.

Study areas were chosen according to cat and petrel densities and their distribution in the different habitat types. These areas were situated at Skua's Ridge (grey lava slopes), Junior's Kop (volcanic cone) and Nellie's Humps (vegetated black lava) (Figure 1).

Methods

A cat exclosure was erected in each of the study areas using 0,9 m chicken mesh wire (25 mm) with the top strand electrified with a 'Prakelek' energizer (Department of Electrical Engineering, Rand Afrikaans University, Johannesburg, Republic of South Africa). The

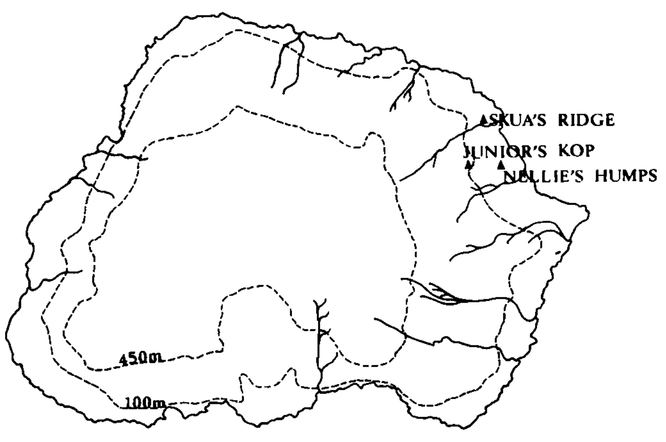

Figure 1 Locations of cat exclosures on Marion Island.

Skua's Ridge, Junior's Kop and Nellie's Humps exclosures were 6,6; 6,7 and 9,9 ha in area respectively. The areas adjacent to the cat exclosures served as controls and represented the same habitat type as the exclosures.

Cats were eliminated from the exclosures by night hunting and all signs of cats (prey remains and faeces) destroyed. The exclosures were subsequently checked on an irregular basis for cats and signs of cats whereas the fences and energizers were inspected regularly for openings and working condition respectively.

Nest visits by the three petrel species were determined monthly for the duration of their respective breeding seasons. These visits could not be qualified and were only used to indicate breeding success and to correlate differences in breeding success between the cat-free and control areas with cat predation. Visits were detected by planting a row of matchsticks upright at the nest entrances, which were then inspected on alternative days for two weeks' duration (inspection period). Matchsticks were treated with formalin to prevent mice from chewing and removing them. Displaced matchsticks were assumed to indicate that a bird had entered or exited through the entrance, and was therefore still breeding. In addition, burrowing activity and calls were taken as additional confirmation that the birds were still breeding. Signs of cats (tracks and prey remains), as well as the absence of nest visits during an inspection period, were considered indicative of breeding failure. Breeding success is expressed as the percentage of actively used nests during an inspection period of the total number of nests which were monitored. The breeding success of a species in all the study areas together is referred to as the combined breeding success.

Nest density of *P. aequinoctialis* was determined from the initial count of all actively used nesting burrows inside an exclosure. Nest densities of *P. macroptera* and *P. vittata* were recorded in 30 m wide transects inside the exclosures, and for *P. macroptera,* also in the control areas.

Results

The laying, hatching and fledging dates of the three Procellariidae species and their nest densities are given in Tables 1 and 2 respectively. Significant differences occurred in the breeding success of *P. macroptera* at Skua's Ridge, and *P. aequinoctialis* and *P. vittata* at Junior's Kop between the cat-free and control areas (Table 2).

A significant difference in the combined breeding success of *P. aequinoctialis* was only evident between the cat-free and control areas after about 9/10 (March) through their breeding season (χ^2 = 5,88; $P < 0,05$). With *P. macroptera* and *P. vittata* this was already evident after about 3/5 (September and January respectively) through their respective breeding seasons (χ^2 = 11,78 and 4,12 respectively, $P < 0,05$). With the latter two species these differences were still significant at the end of their breeding seasons (χ^2 = 22,7 and 4,04 respectively, $P < 0,05$) (Figure 2).

The mean number of nest visits for *P. vittata* during an inspection period increased significantly from December to January. Visits of *P. macroptera* and *P. aequinoctialis* decreased significantly from August to September and January to February respectively (Table 3). These significant changes in the number of visits for every month followed hatching dates, which in turn were concomitant with or were followed by significant differences in the combined breeding success between the cat-free and control areas (Figure 2).

Discussion

Electrified fences have been used successfully in reducing mammalian predation on birds (Patterson 1977; Dorrance & Bourne 1980; Lokemoen, Doty, Sharp & Neaville 1982). Observations on two tamed and two feral cats showed that cats rather tried to get underneath through the electric fence. When the tamed cats attempted to climb over, they received a shock and then kept about 10 m away from the fence (pers. obs.). The electrification of the fence therefore served as a deterrent and these exclosures could be considered cat

Table 1 Breeding cycle of three Procellariidae species on Marion Island

Species	Laying	Hatching	Fledging
Pterodroma macroptera	Late May[1]	Late July[1]	Late Oct – early Nov[2]
Procellaria aequinoctialis[3]	Early November	Mid-January	Early August
Pachyptila vittata	Late November[4]	Early January[4]	Early March[3]

[1] Schramm (1983); [2] I. Newton (pers. comm.); [3] M. Schramm (pers. comm.); [4] Berruti & Hunter (1986).

Table 2 Breeding success (%) and density (nests/ha) of three Procellariidae species in cat-free and control areas on Marion Island during 1982–1983

	Pterodroma macroptera						*Procellaria aequinoctialis*						*Pachyptila vittata*					
	Skua's Ridge			Junior's Kop			Junior's Kop			Nellie's Humps			Junior's Kop			Nellie's Humps		
	Cat-free n^1=32	Control n=36	χ^2_1	Cat-free n=7	Control n=6	χ^2_1	Cat-free n=14	Control n=13	χ^2_1	Cat-free n=14	Control n=14	χ^2_1	Cat-free n=37	control n=25	χ^2_1	Cat-free n=47	Control n=35	χ^2_1
Breeding success (%)																		
24–29 May	100	100																
14–19 Jun	100	88,9	2,04	100	100													
12–17 Jul	96,9	86,1	2,44	100	66,7	0,79												
2–8 Aug	90,6	80,6	1,37	100	66,7	0,79												
6–12 Sep	65,6	25,0	11,34 [2]	71,4	50,4	0,05												
5-16 Oct	59,4	5,6	20,54 [2]	57,1	16,7	0,85												
2–14 Nov	50,0	0	22,99 [2]	57,1	16,7	0,85												
1–13 Dec							100	100		100	100							
19 Des–2 Jan													100	100		100	100	
18–30 Jan							100	100		100	100		100	84,0	3,96 [2]	97,9	94,3	0,07
15 Feb–1 Mar							100	100		78,6	64,3	0	59,5	28,0	5,93 [2]	72,3	65,7	0,42
14–26 Mar							100	46,2	7,571 [2]	71,4	64,9	0,16						
Density (nests/ha)	71,1 [3]	80,0 [3]		11,7 [3]	10,0 [3]		2,1	[4]		1,4	[4]		30,8 [3]	[4]		26,1	[4]	

[1] Sample size for breeding success; [2] $P<0,05$; [3] Transects went mainly through possible breeding hahitat; [4] Density estimates not possible owing to opportunistic nest sampling.

Table 3 Number of nest visits/nest of three Procellariidae species on Marion Island during the breeding season

	Pterodroma macroptera [1]							*Procellaria aequinoctialis* [2]				*Pachyptila vittata* [3]		
Month	M	J	J	A	S	O	N	D	J	F	M	D	J	F
$\bar{x}$	2,00	2,27	2,03	1,92	1,11	1,04	1,60	3,24	4,89	3,83	3,64	2,70	3,40	3,38
S.D.	0,70	0,78	0,96	0,84	0,80	0,65	0,82	1,25	0,31	1,22	1,46	1,44	1,58	1,25
n	54	74	73	71	38	27	20	46	55	47	39	110	139	86
t		2,05 [4]	1,66	0,73	4,95 [4]	0,39	2,52 [4]		8,73 [4]	5,80 [4]	0,65		3,65 [4]	0,10

[1] Nest visits monitored every second day over a six-day-period; [2] Nest visits monitored every second day over a 10-day-period; [3] Nest visits monitored every second day over a 12-day-period; [4] $P < 0,005$.

proof, provided that such a fence is impenetrable at the bottom.

The shortcomings of the technique used to determine breeding success are the assumptions that the birds used a burrow for breeding, abandoning it soon after a breeding failure, and that only one breeding pair used a burrow. Since breeding success of *P. macroptera* agreed with the findings of Schramm (1983), and owing to the differences in the results between the control and cat-free areas, the technique could be considered reliable for comparative purposes.

The effect of cat predation is illustrated by the difference between breeding success of petrels in the control and cat-free areas. Schramm (1983) found a zero breeding success of *P. macroptera* at Skua's Ridge during both 1979 and 1980. However, breeding success of this species was 20,4% (n = 49) during 1982 away from the study area (I. Newton pers. comm.) This could be due to a lower density of *P. macroptera* there, which would reduce the probability of cat predation. This 20,4% breeding success, however, was still significantly lower than the combined breeding success of *P. macroptera* in the exclosures (χ^2 = 12,16; $P < 0,05$). Although there was a non-significant difference in breeding success between the cat-free and control areas of Junior's Kop, a similar trend as at Skua's Ridge was exhibited and the non-significant difference found is therefore attributed to small sample sizes.

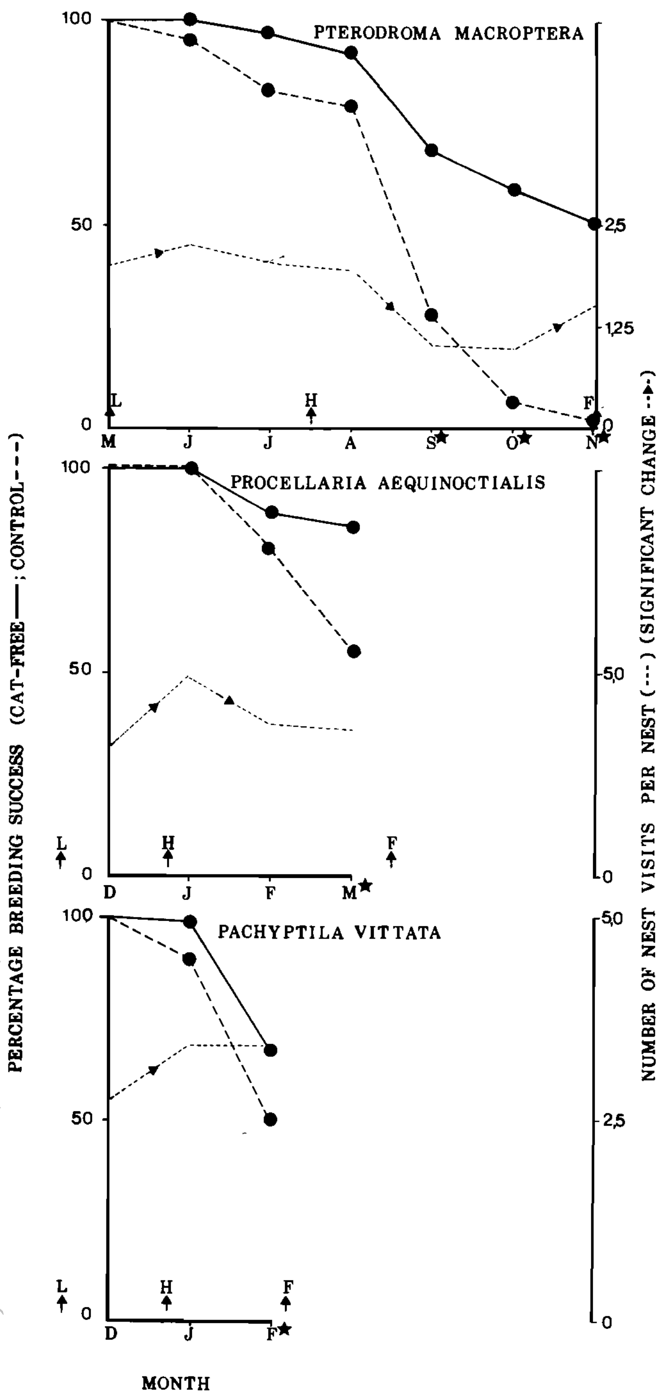

Figure 2 Combined breeding success and number of nest visits/nest of three Procellariidae species on Marion Island during the 1982 breeding season (L = Laying, H = Hatching, F = Fledging, * = significant difference in breeding success between cat-free and control areas.

The susceptibility of *P. macroptera* to cat predation is ascribed to their long breeding season (Table 1) and also to their large nesting burrows which allow cats free access. Furthermore, *P. macroptera* is the most abundant of only two winter-breeding petrel species on Marion Island. Since the significant difference in breeding success of *P. macroptera* became evident in September after hatching it is apparent that chicks were most vulnerable to cat predation. In contrast, adults were relatively safe during incubation, probably owing to their large size and aggressiveness. Therefore, the higher frequency of nest visits during August rather than later in the breeding season, probably acts in part as an initial protection by the visiting adults to the chicks against cats. On the other hand, the increase in activity during November (Table 3) could be attributed to fledgling movement for exercising their wings outside the burrow. Since *P. macroptera* chicks fledge from late October (Schramm 1983), some chicks could have been fledged before the November inspection period. This would result in an underestimate of breeding success at fledging, while the October inspection could be an overestimate.

Prions form the major prey item of the cat population, and an estimated 76 000 prions were consumed by cats during 1982 (van Rensburg 1985). Burrows of prions are normally too small for cats to enter and adults are therefore more vulnerable than chicks to cat predation. The observed decrease in post-hatching breeding success could be the result of increased nest visits, making adult prions more available as prey for cats. The last inspection period was just prior to fledging and breeding success during this period is probably close to breeding success at fledging.

The low frequencies of *P. aequinoctialis* observed in prey remains of cats (van Aarde 1980; van Rensburg 1985), may be attributed to their large size and aggressive nature together with their low availability (density). Nest visits after hatching also decreased and chicks were therefore unprotected for longer periods. Thus it is possible that chicks of this species are affected more by cat predation. Since fledging occurs in early April, breeding success during the last inspection period (late March) could be an overestimate of breeding success at fledging.

Four of the five breeding failures of *P. aequinoctialis* in the control area of Nellie's Humps could be ascribed directly to cat predation and two breeding pairs of skuas *Catharacta antarctica* were also present in the cat-free area. Furthermore, this species increased significantly in the diet of skuas since 1975, owing to predation on fledglings. This was a result of changes in relative abundance of petrels owing to cat predation (van Rensburg 1985). Therefore, skua predation may be responsible for the non-significant difference in breeding success of *P. aequinoctialis* and also prions between the control and cat-free areas at Nellie's Humps.

Depredation and extinction of petrels owing to cats has previously been described for other sub-Antarctic islands (Derenne 1976; Derenne & Mougin 1976; Jones 1977; Brothers 1984). Cats have already been implicated in the extinction of the common diving petrel *Pelecanoides urinatrix* at Marion Island when the cat population numbered only an estimated 200 individuals (van Aarde 1980). In addition, van Rensburg (1985) noted that Kerguelen petrels *Pterodroma brevirostris* were disappearing during 1982 in a specific area on Marion Island as a result of cat predation. In the present study, the effects of cat predation on the breeding success of the three species investigated were conspicuous. The winter-breeding *P. macroptera* in particular is under severe pressure. The increased predation pressure on larger sized petrels (*P. aequinoctialis* and *P. macroptera*) by skuas as a result of cat predation, compounds the already precarious position of these species (van Rensburg 1985). Despite the marked decline in cat numbers, the burrowing petrel population is still endangered. However, the cat-free area on Marion Island shows that presently an elimination of cat predation would favour a recovery of the petrel population irrespective of the increased predation pressure by skuas on larger sized petrels.

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