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RELATIONSHIP BETWEEN TUATARA *SPHENODON PUNCTATUS* AND FAIRY PRION *PACHYPTILA TURTUR* DENSITIES IN DIFFERENT HABITATS ON TAKAPOUREWA (STEPHENS ISLAND), COOK STRAIT, NEW ZEALAND

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Tuatara *Sphenodon punctatus* and Fairy Prions *Pachyptila turtur* both nest in burrows on 150-ha Takapourewa (Stephens Island), New Zealand. The birds form a major component of Tuatara diet (Moller 1985, Fraser 1995) and provide a source of food and moisture in the summer months when invertebrates are scarce (Walls 1981). As part of a broader systems study, the aim of this work was to investigate possible levels of Tuatara predation on Fairy Prions and determine if this feeding relationship was reflected in the distribution of the two species.

I used a Cohu 6700 series remote-head CCD miniature video camera to examine burrows in four different habitats on Takapourewa in 1994/95 (Markwell 1997). Two 100-m^2 quadrats were investigated in each of pasture, long grassland and forest habitats, and one in a scrub habitat. Burrows were selected opportunistically within each quadrat, and their contents determined with the camera. I calculated the proportion of burrows surveyed that was occupied by Tuatara in each quadrat. To estimate Tuatara density I multiplied the occupancy rates by surface counts of burrows in each quadrat. The density figure thus calculated was then corrected to account for the proportion of multiple chambered or entranced burrows discovered with the video camera (Markwell 1997).

Prions are only present on the island in any number over the breeding season (October–January, Falla *et al.* 1993). Data on Fairy Prion density were collected in November 1994 and January 1995. Prion densities were calculated in the same manner as Tuatara densities.

Adult Fairy Prions appear able to defend themselves against Tuatara (Newman 1987, Gaston & Scofield 1995), but the reptiles consume chicks (Walls 1978, Fraser 1995). Therefore, a measure of the effect on chicks was necessary to show the effect of Tuatara predation on Fairy Prion populations. I measured the survival rate of Fairy Prion chicks in different areas on Takapourewa and compared this rate with Tuatara density in these areas to ascertain if chick survival decreased as Tuatara density increased. To determine survival of chicks, I investigated the same burrows on two separate trips. Burrows empty in both November and January were not included in the analysis. In total, I studied 80 burrows during both incubation and prefledging times. I deemed the nest to be successful if a live chick was recorded in a burrow in January. Failures were scored when an empty nest or an unattended egg (i.e. without a parent) was found in January. Fairy Prions incubate eggs for *c*. 55 days and have a *c*. seven-week chick-rearing period (Falla *et al.* 1993). It was possible that some unattended eggs in burrows in January were still viable and would hatch. However, these would need to have been laid at the extreme end of the breeding season and were unlikely to be in any great number or affect the results significantly. On Takapourewa, Fairy Prion chicks begin to fledge in late January (Walls 1978), and so the possibility that empty nests in early January had previously contained chicks seems unlikely. Because Tuatara drag chicks away from their burrows before eating them (pers. obs.), I used empty burrows where previously an egg had been observed as an indication of the predation rate. Movement of prey is thought to be the prime stimulus triggering feeding by Tuatara (Falla 1935, Dawbin 1962) so chicks that died of causes other than predation are not likely to have been removed from the nest by Tuatara. A dead chick or unhatched egg was counted as a failure due to another cause (e.g. cold, malnutrition, abandonment).

Calculated Tuatara density ranged from nil in one grassland quadrat up to 0.40 Tuatara/m^2 in one forest quadrat (Table 1). In the same quadrats, Fairy Prion densities were up to *c*. 10 times greater than were Tuatara densities (Table 1). Because

TABLE 1

Burrow counts, occupancy rates and densities of Tuatara and Fairy Prions in different habitats on Takapourewa, 1994/95

Habitat type	% burrows containing Tuatara	% burrows containing prions	Burrow entrances /quadrat	Correction factor	Chambers /m^2	Tuatara /m^2	Prions /m^2
Pasture	9	67	192	1.05	2.02	0.18	1.34
Pasture	11	70	138	1.05	1.45	0.17	1.01
Grassland	0	65	193	0.88	1.70	0.00	1.50
Grassland	7	79	89	0.88	0.78	0.05	0.51
Scrub	13	88	124	1.00	1.24	0.17	0.98
Forest	25	69	164	0.98	1.61	0.40	1.10
Forest	20	63	56	0.98	0.55	0.11	0.35

of the significant imbalance in the numbers of Fairy Prions and Tuatara, large changes in Fairy Prion density are likely to lead to small changes in Tuatara density. To compensate for this, I carried out a logarithmic transformation on the Tuatara density data (Sokal & Rohlf 1981). Prion density was significantly positively correlated with *ln* Tuatara density ($r = 0.80$, $t_{[5]} = 3.04$, $P < 0.05$).

Adult prions were found sitting in most of the burrows observed during November. I attempted to nudge birds from the nests with the camera to see the egg, but this was not possible in 20 (27%) of cases. In the November samples, unattended eggs were found in five (6%) of the 80 burrows. In January, the only live prions found in the burrows were down-covered chicks. A burrow containing an egg or an unmoved sitting prion in November was occupied by a chick in January in 58 cases (73%). In two (2%) cases, empty burrows in November contained chicks in January. Eleven (14%) failures were shown by empty nests. One dead chick was found in a burrow and eight (10%) burrows contained unattended eggs.

TABLE 2

Percentage of Fairy Prion chicks successful and preyed upon in burrows in different habitats on Takapourewa, 1994/95

Habitat type	% nests successful	% nests preyed upon	No.
Pasture	88	13	8
Pasture	62	15	13
Grassland	79	14	14
Grassland	78	11	9
Scrub	86	7	14
Forest	58	33	12
Forest	80	10	10

In the different habitats, failure rate due to predation ranged from 7–33% (Table 2). I arcsine-transformed the chick predation data to maintain normality and homoscedasticity in percentage data (Sokal & Rohlf 1981). No significant relationship was found between arcsine predation rate and *ln* Tuatara density ($r = 0.43$, $t_{[5]} = 1.07$, $P > 0.05$).

Tuatara densities are positively correlated with seabird densities. This relationship indicates either that Tuatara are responding to the presence of prions or that both are responding to some other factor. Fairy Prions are an important food source for Tuatara (Moller 1985, Fraser 1995). The birds also deplete understorey vegetation in forested areas (Campbell 1967) and possibly increase the invertebrate biomass by nutrient addition (Dawbin 1962) thus potentially improving hunting conditions for Tuatara. For these reasons, it seems likely that the distribution and abundance of Tuatara is in some way influenced by Fairy Prions. If prion abundance was significantly affected by predation from Tuatara, Fairy Prion densities should be low at sites with high Tuatara densities and the correlation should be inverse, in contrast to my finding.

Because of the relatively small number of Fairy Prions thought to be taken by Tuatara, the lack of significant correlation between predation rate and Tuatara density provides only an indication that Tuatara do not have a great effect on Fairy Prion density. However, comparison of this study with other studies on petrel breeding success provides support for the conclusion that Fairy Prion numbers are not significantly influenced by predation. A total of 10 different studies was selected, based on a (non-exhaustive) literature search. The studies chosen reflected a range of species and geographic locations (Table 3). The studies on Marion Island (Schramm 1983, Fugler *et al.* 1987, Newton & Fugler 1989, Cooper *et al.* 1995) and Lavezzi Island (Thibault 1995) report data taken before and after the removal of predators from habitats on the islands (feral Domestic Cats *Felis catus* on Marion and Black Rats *Rattus rattus* on Lavezzi). The remaining data were

TABLE 3

Burrowing Petrel breeding success in localities with and without mammalian predators

Success (%)	Species	Locality	Reference
Without mammalian predators			
78	Cory’s Shearwater *Calonectris diomedea*	Lavezzi Island (Corsica)	Thibault 1995
76	Fairy Prion *Pachyptila turtur*	Takapourewa	Walls 1978
76	Fairy Prion	Takapourewa	This study
74	Fairy Prion	Poor Knights Island (New Zealand)	Harper 1976
49–71	Fairy Prion	Whero Island (New Zealand)	Richdale 1944
75	Manx Shearwater *Puffinus puffinus*	Skokholm Island (Wales)	Harris 1966
64	Great-winged Petrel *Pterodroma macroptera*	Marion Island (Subantarctic)	Cooper *et al.* 1995
64	Blue Petrel *Halobaena caerulea*	Marion Island	Cooper *et al.* 1995
22	White-chinned Petrel *Procellaria aequinoctialis*	Marion Island	Cooper *et al.* 1995
With mammalian predators			
26	Black Petrel *Procellaria parkinsoni*	Little Barrier Island (New Zealand)	Imber 1987
34	Cory’s Shearwater	Lavezzi Island	Thibault 1995
5	Great-winged Petrel	Marion Island	Schramm 1983, Newton & Fugler 1989
24	Blue Petrel	Marion Island	Fugler *et al.* 1987
36	White-chinned Petrel	Marion Island	Cooper *et al.* 1995
4	Westland Black Petrel *Procellaria westlandica*	Punakaiki (New Zealand)	Baker & Coleman 1977

gathered from areas with or without predators throughout the course of the study. In predator-free areas the breeding success rate is significantly higher than in predator areas ($t'_{[12.6]} = -5.46$, $P = 0.0001$). Although breeding success of some species (e.g. White-chinned Petrel *Procellaria aequinoctialis)* is not significantly improved by the removal of predators (Cooper *et al.* 1995), a clear pattern of success at over 60% in predator-free areas and 35% or lower in areas with predators can be seen. The value of 49% for Fairy Prion from Richdale (1944) was calculated one year on Whero Island in Foveaux Strait, New Zealand. Richdale (1944) noted that the climate was severe at this site, and chicks succumbed to excessively wet burrows. The survivorship pattern observed in my study matches the pattern seen for sites where predators are absent or in low numbers rather than situations where predators are having a significant impact on petrel breeding.

Although Tuatara numbers may be controlled by factors in addition to food supply, such as space for burrows and open areas for breeding (Thompson 1990), Fairy Prions may be important in allowing high Tuatara densities to be maintained, and higher Tuatara densities are found in areas with more prions. In contrast, Fairy Prion numbers do not appear to be significantly influenced by Tuatara. The proportion of chicks lost in a season does not seem any greater than that in areas without predators. The most likely factor controlling prion numbers is mortality while the birds are at sea.

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