

I thank the late G.W. Johnstone (Antarctic Division, Australia) for confirming the identification of the penguin from photographs, Robert Jones and Jeremy Smith for helping to measure and weigh the penguin and commenting on the manuscript, and Peter Dann for commenting on the manuscript.

LITERATURE CITED

- MARCHANT, S.; HIGGINS, P.J. 1990. Handbook of Australian, New Zealand and Antarctic Birds. Vol.1(A). South Melbourne: Oxford University Press.
 NAPIER, R.B. 1968. Erect-crested and Rockhopper Penguins interbreeding in the Falkland Islands. Br. Antarct. Surv. Bull. 16:71-72.
 REILLY, P.N.; CULLEN J.M. 1982. The Little Penguin *Eudyptula minor* in Victoria. III. Dispersal of chicks and survival after banding. Emu 82:137-142.
 TUCK, G.S.; HEINZEL, H. 1980. A Field Guide to the Seabirds of Australia and the World. London: Collins.
 WATSON, G.E. 1975. Birds of the Antarctic and Subantarctic. Washington D.C.: Amer. Geophys. Union.

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Weka predation on eggs and chicks of Fiordland Crested Penguins

Between July and October 1989, we studied the breeding biology of Fiordland Crested Penguins (*Eudyptes pachyrhynchus*) on Taumaka, the larger of the Open Bay Islands (43° 52' S, 168° 53' E), 5 km west of Haast. The Fiordland Crested Penguin is the rarest of the six crested penguin species, breeding only on the rugged coasts of South Westland and Fiordland, and on Solander and Stewart Islands and offshore islands. Like its congeners, it lays a clutch of two different-sized eggs and only one of these, usually the larger, results in a fledged chick (Warham 1975). Displacement and desertion account for most of the natural egg mortality, whereas chick mortality most often results from starvation or exposure to bad weather. These penguins appear to have no native, naturally occurring land predators (Warham 1974), but introduced rats, cats and stoats may take eggs and chicks in some areas.

The Open Bay Islands have no introduced mammalian predators and so are an important breeding place for several species of seabird. Although no formal census has been made, the breeding population of Fiordland Crested Penguins may be in the order of 300 - 400 birds on the island of Taumaka. Among the nests watched in our study, predation by the introduced Weka (*Gallirallus australis*) was the greatest single cause of egg mortality and contributed significantly to chick loss.

We monitored the contents of 61 nests daily and determined the cause of egg loss by the nature and location of shell remains and by the presence

or absence of incubating adults. If adults were absent when we began daily checks of a nest, we assumed the nest had been deserted, regardless of the presence or condition of shell remains. In contrast, adults that had displaced eggs or lost eggs to predation typically remained at the nest site for several days. Weka predation was indicated by transverse openings in the shell remains.

Of 115 eggs laid, 57 failed to hatch. Twenty-two (38%) of these were taken by Wekas, 13 (23%) were abandoned, 4 (7%) were displaced, and 5 (9%) were addled or infertile. The remaining 13 (23%) were missing during the daily checks, no shell remains were found, and so their fate was unknown. Early in incubation, when penguins were least tenacious at incubation, our presence in the colonies sometimes made penguins leave their nests temporarily, thereby creating opportunities for Weka predation. In addition, it is possible that some of the egg loss we attributed to Weka predation was of eggs displaced by incubating penguins and then eaten by Wekas.

We once saw a Weka attack an egg while the parents were at the nest. It pierced the egg while the breeding pair stood dozing beside it. In general, crested penguin species stand over but do not incubate the first egg until the second is laid (Warham 1975). At the sound of the shell breaking the pair awoke and drove the Weka from the nest. The penguins did not recover the damaged egg from where it had rolled during the brouhaha.

A small but substantial proportion of chick mortality also was due to Wekas. Of the 55 eggs that hatched at nests we visited daily, 11 chicks (20%) were taken by Wekas. Another 7 (13%) were abandoned or displaced, 13 (24%) starved, and 3 (5%) were missing. Only 21 (38%) of the chicks were alive by the end of the study, 6-8 weeks before fledging. Nine of the 11 chicks taken by Wekas were taken after they had entered the creche stage, the period during which chicks are left unguarded by day while both parents forage. Chicks entered the creche stage as early as 14 days after hatching in 1989, younger than has been reported previously (Warham 1974; S. Phillipson, pers. comm.) and this may have made them more vulnerable to Weka predation. Several of the chicks taken appeared to be large and healthy; the heaviest was 620 g and 17 days old. It appeared to have been killed by repeated beak blows to the head in a manner similar to the territorial fights we observed between breeding adult Wekas. Flesh was torn from the back, neck and abdomen of the chick, although it was still alive when we reached it.

Chick predation did not appear to be associated with our disturbance; most chicks were taken while we were away or watching from a distance. On two separate occasions, I. McLean saw a Weka take a live chick from within a few centimetres of its brooding parent. Apart from direct observation, we distinguished Weka predation by chick remains and by the behaviour of parents. Those birds that had lost a chick usually returned to the nest site for long periods, apparently waiting for the chick to return. Breeding birds with live chicks tended to return only during the evening or night for short feeding visits and were seldom seen by day.

Most penguins were indifferent to the movements of Wekas, which could easily move between nests. However, some pairs, mainly those from which a Weka had previously attempted to take an egg or chick, were clearly hostile

and actively drove Wekas from the vicinity of their nests. Of the nests we watched regularly, there was not a single nest location that Wekas did not visit at least occasionally.

Wekas were introduced to Taumaka early in this century, probably between 1905 and 1912 (Stirling & Johns 1969). A smaller, probably self-introduced, population is on the island of Popotai, about 100 metres southwest of Taumaka. They were introduced to Taumaka and other offshore islands apparently to be food for shipwreck survivors. Douglas was prophetic when he wrote, circa 1899, that there were

...numbers of uninhabited islands on which shipwrecked mariners often die of starvation, or at least live miserably. Why not put Maorie [*sic*] hens [Wekas] on those islands? They would have no enemies in such places, they are easy to catch, good healthy food, and will live and thrive anywhere eating and digesting anything.... (Pascoe 1957)

From a small initial population, Wekas have increased on Taumaka to an unusually high density. They occupy every conceivable niche from the intertidal zone to seemingly inaccessible cliff ledges. They seemed highly territorial throughout our study, although territories were much smaller than reported for a mainland population (Beauchamp 1987). We could often see up to five birds patrolling a small area and squabbles were common.

Wekas appear to have greatly altered the characteristics of the vegetated areas. Ground cover was continually uprooted by Wekas foraging for insects and other prey. Burrows (1972) reported that extensive areas of vegetation, particularly rock plants, were severely harmed by Weka activity.

The effects of Wekas on native fauna area also severe. We found the remains of at least seven Fairy Prions (*Pachyptila turtur*) in and around Weka lairs. Wekas routinely entered the small burrows and holes where prions, Sooty Shearwaters (*Puffinus griseus*) and Blue Penguins (*Eudyptula minor*) were known to nest or roost. The New Zealand land leech (*Hirudobdella antipodum*), known only from Open Bay and Snares Islands, may also be eaten by Wekas (Stirling & Johns 1969).

Wekas were capable of climbing to heights of 2 m among the kiekie (*Freycinetia banksii*) that covers most of the island. Kiekie flowers appeared to be the only food sought, but C. Miskelly (pers. comm.) has seen Wekas take tree wetas (*Hemideina thoracica*) from the leaf bases of kiekie on Taumaka. Tree-nesting birds and a gecko species (probably *Hoplodactylus granulatus*) may also be vulnerable to predation as a result of this behaviour.

Although Wekas have clearly affected the populations of native species on Taumaka, the severity of this impact has not been assessed. Stirling & Johns (1969) believed that Wekas were modifying the natural fauna so greatly that they should be removed. Most likely, Weka numbers and damage have increased since the 1960s.

Removing Wekas from Open Bay Islands, as has been done on Codfish and other islands, could restore native populations. However, Wekas have disappeared from much of their natural range and are elsewhere declining. Recent attempts to re-establish the North Island Weka (*Gallirallus australis greyi*) in the Waitakere

Therefore, removal of Wekas from Open Bay Islands could mean the loss of a potentially important reservoir.

Nonetheless, Weka predation on Taumaka may be nearing the threshold at which other species cease to co-exist. We believe that a detailed study of the effects of Wekas on the flora and fauna of the Open Bay Islands is urgently needed. These effects must then be balanced against the value of the islands' otherwise pristine nature, the importance of native populations that will require protection if they are to remain, and the value of a thriving Weka population. Removal of Wekas, possibly only to the adjacent mainland where they are reported to have declined in recent years (B. Glubb, pers. comm.) may be an ideal and relatively inexpensive solution.

ACKNOWLEDGEMENTS

Financial and logistical support for research on Open Bay Islands was provided by the Department of Zoology, University of Canterbury; the New Zealand Lottery Grants Board; the Ornithological Society of New Zealand; the Stocker Scholarship of the Royal Forest and Bird Protection Society; and the World Wide Fund for Nature (WWF) - New Zealand. We thank I. McLean and J. Schieck for help in the field, B. and P. Glubb for providing radio contact during the study, and B. Heather, I. McLean, C. Miskelly, H. Robertson and C. L. St. Clair for improving the manuscript.

LITERATURE CITED

- BEAUCHAMP, A.J. 1987. The Social structure of the Weka (*Gallirallus australis*) at Double Cove, Marlborough Sounds. *Notornis* 34: 317-325.
 BURROWS, C.J. 1972. The flora and vegetation of Open Bay Islands. *J. Roy. Soc. NZ* 2: 15-42.
 MacMILLAN, B.W.H. 1990. Attempts to re-establish Wekas, Brown Kiwis and Red-crowned Parakeets in the Waitakere Ranges. *Notornis* 37: 45-51.
 PASCOE, J. 1957. Mr. Explorer Douglas. Wellington: A.H. and A.W. Reed.
 STIRLING, I.; JOHNS, P.M. 1969. Notes on the bird fauna of Open Bay Islands. *Notornis* 16: 121-125.
 WARHAM, J. 1974. The Fiordland Crested Penguin. *Ibis* 116: 1-27.
 WARHAM, J. 1975. The crested penguins. Pages 189-269 in *The Biology of Penguins*. Stonehouse, B., ed. London: MacMillan.

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Unique, dark olive-green moa eggshell from Redcliffe Hill, Rakaia Gorge, Canterbury

Moa eggshell is known from many, widely distributed localities throughout New Zealand, having been most frequently found in dunesand and loess deposits and beneath rock overhangs which have been used as nesting sites. It also occurs on archaeological sites and in swamps and caves. Most is buff or creamy white, but pale green moa eggshell has also been collected, notably from Otago (see Hutton 1876, White 1886). This pale green shell is similar