specifically designed microwave cavities may solve this problem. Second, the precise quantities of α-particle emitting isotopes must be determined. These isotopes belong to the uranium and thorium decay chains. However, their concentration in quartz lies normally in the parts-per-billion range which is difficult to measure. The authors suggest comparing the natural ESR signal from quartz of known age with neutron-induced signals, but this approach seems unsuitable for investigation of samples of unknown age.

Third, as already pointed out by Kislyakov *et al.*[6], the number of E′-centres per unit of radioactive elements may vary depending on the variety of the quartz under investigation. This dependency and also saturation effects would have to be studied. Lastly, the defects seem to be thermally stable for around 10^9 years. This should be confirmed, because the concentration of centres reaches a steady state in samples older than the mean life of the defects. It was previously reported[7] that the point defects which lead to the E′ paramagnetic centre have a mean life in the range of 10^8 years (at 20 °C).

Although the investigation of these problems is not a trivial task, it seems now very likely that in the near future, ESR dating can be extended from the Quaternary to the whole geological timescale and that ESR dating will be applied to many chronological problems which could not be solved with established dating techniques. □

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CONSERVATION BIOLOGY

Nine hundred kiwis and a dog

Jared M. Diamond

INTRODUCED predators are thought to be a leading cause of the extinction of island species. Yet the evidence for this is inferential in many cases, with few or no direct observations of predation. It remains baffling how victim species can disappear so quickly, and how a predator species can eradicate a victim species completely before its own numbers collapse. Thus, the recently documented collision between one dog and a population of 900 kiwis is likely to become cited as a classic case study in conservation biology (Taborsky, M. *Notornis* **35**, 197–202; 1988).

New Zealand has lost a high proportion of its native bird species in the few centuries since Europeans arrived. Introduced weasels, cats and dogs may be responsible, but firm proof is lacking even for well-known endangered species such as the kiwi, New Zealand's national bird. The three species of kiwi are all large, flightless birds confined to New Zealand and adjacent islands, but it is not known why one (the little spotted kiwi) has vanished from the New Zealand mainland.

Until recently, the 11-square-mile Waitangi State Forest supported the largest-known and counted population of brown kiwis (*Apteryx australis*). Between June and October 1987, biologists marked some individuals of this population and followed them using radio transmitters. On 24 August 1987, a large female kiwi was found freshly dead. Over the next 6 weeks more fresh carcasses were located, usually buried under leaves and soil. Of the 23 marked birds, 13 died during this period and were discovered through their radio transmitters. Despite the very low chances of detecting a buried kiwi carcass without the help of a transmitter, 10 carcasses of unmarked individuals were also discovered. By the end of September many fewer kiwi calls were being heard, and a dog trained to locate kiwis (but not kill them) could find none.

Tooth marks and footprints showed that all the dead kiwis had been killed by a dog, which had buried but not eaten them. All parts of Waitangi Forest that were searched yielded dead kiwis, dead possums, dog footprints, or dog faeces containing kiwi feathers or possum remains. The footprints and faeces all appeared to be from the same dog. On 30 September, a German shepherd dog was found in the forest and shot. Thereafter no marked kiwis disappeared and no further dog signs were found.

How many kiwis did the dog kill? The 13 deaths among the 23 marked birds would mean 500 deaths in the whole population of 900, if marked and unmarked birds were at equal risk. In fact, the population may have suffered greater losses, because the proportion of marked birds killed was nearly twice as high outside than inside the main study of 0.5 square miles, where the biologists' presence may have deterred the dog. Five hundred killings in 6 weeks would mean about 12 kiwis killed per night. That kill rate may at first appear unbelievably large, but kiwis have a very strong distinctive smell, forage and call noisily, so are particularly vulnerable to predators.

The Waitangi incident illustrates many points relevant to the extermination of island species by introduced predators. Kiwis evolved in the absence of mammalian predators and are entirely defenceless against dogs. They breed so slowly that the Waitangi population will require an estimated 8–20 years to recover even if no such incident recurs. It took just one dog to halve the size of the largest-counted brown kiwi population in 6 weeks, yet the cause of that decline would have remained unknown but for the coincidence that some of the buried carcasses had been radio-tagged. Hence it becomes less surprising that New Zealand's abundant feral cats and weasels could have exterminated other native species without being identified as the culprits.

Bruce Coleman

The brown kiwi is defenceless against introduced predators.

The kiwi incident also illuminates the paradox of how a predator could exterminate its prey without exterminating itself first. Like most other introduced pests, dogs are 'switching predators' for which kiwis are just one of several potential prey species: this particular dog did not even eat the kiwis that it killed.

Finally, the Waitangi incident emphasizes the importance of control of introduced pests. Responsibility for the forest was recently transferred from the New Zealand Forest Service to a timber corporation, which abandoned the previous policy of keeping the forest free of dogs. As Taborsky says, "The disappearance of kiwis from other populated parts of New Zealand during the last decades underlines the general importance of the issue to the protection and management of kiwis". □

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