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Number, fate, and distribution of kakapo (*Strigops habroptilus*) found on Stewart Island, New Zealand, 1979–92

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Abstract This paper documents the number of kakapo (*Strigops habroptilus*) found dead or alive and their distribution on Stewart Island, New Zealand, between 1979 and 1992. In total, 91 birds were found, 85 alive (56 males and 29 females) and six dead. Of the 85 initially found alive, 61 (72%) were subsequently transferred to safe sites (Maud, Little Barrier, Codfish, and Mana Islands), 11 were not found again, and 13 were later found dead. Of those found dead, most had been killed or scavenged by feral cats. From a radio-tagged sample of 13 adults, annual mortality in 1981–82 was estimated at 56%; after the instigation of a cat-control programme in April 1981, mean annual mortality during 1982–89 was 2.4%. Most (76%) birds were located in a 4000 ha block about the southern end of the Tin Range. Similarly, 59% of 150 track-and-bowl systems found were within the same block of land. From the distribution of kakapo and of track-and-bowl systems in 1979–92, and the vulnerability of the species to predation by cats and rats, we conclude that the population had been in decline for some time.

Keywords kakapo; *Strigops habroptilus*; Stewart Island; number; distribution; track-and-bowl system

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INTRODUCTION

The kakapo (*Strigops habroptilus*) is a unique parrot that is nocturnal, flightless, and lek-breeding (Merton et al. 1984; Powlesland et al. 1992). It is the heaviest parrot known (♀ ≤ 2.4 kg, ♂ ≤ 3.6 kg) and feeds on the buds, leaves, roots, rhizomes, bulbs, nectar, fruit, and seeds from a wide variety of species (Best 1984).

Kakapo were once widespread over the two main islands of New Zealand (Williams 1956; Millener 1981), but by 1976 fewer than 15 known birds remained, apparently all males, with a fragmented distribution in Fiordland (Fig. 1) (Merton et al. 1984). Thus, the species seemed effectively extinct. However, in January 1977, a New Zealand Wildlife Service expedition rediscovered kakapo in southern Stewart Island (Russ 1978). By capturing and banding individuals, and mapping the distribution of occupied male courtship sites, the total population of kakapo on Stewart Island in January 1981 was estimated to be between 70 and 200 birds (H. A. Best pers. comm.; D. V. Merton pers. comm.).

The first suggestion that feral cats (*Felis catus*) might be killing kakapo arose when one of eight cat scats collected in January 1977 was found to contain kakapo feathers (Karl & Best 1982). In 1981, several dead kakapo were found that had been eaten by feral cats, including seven of 13 adults radio-

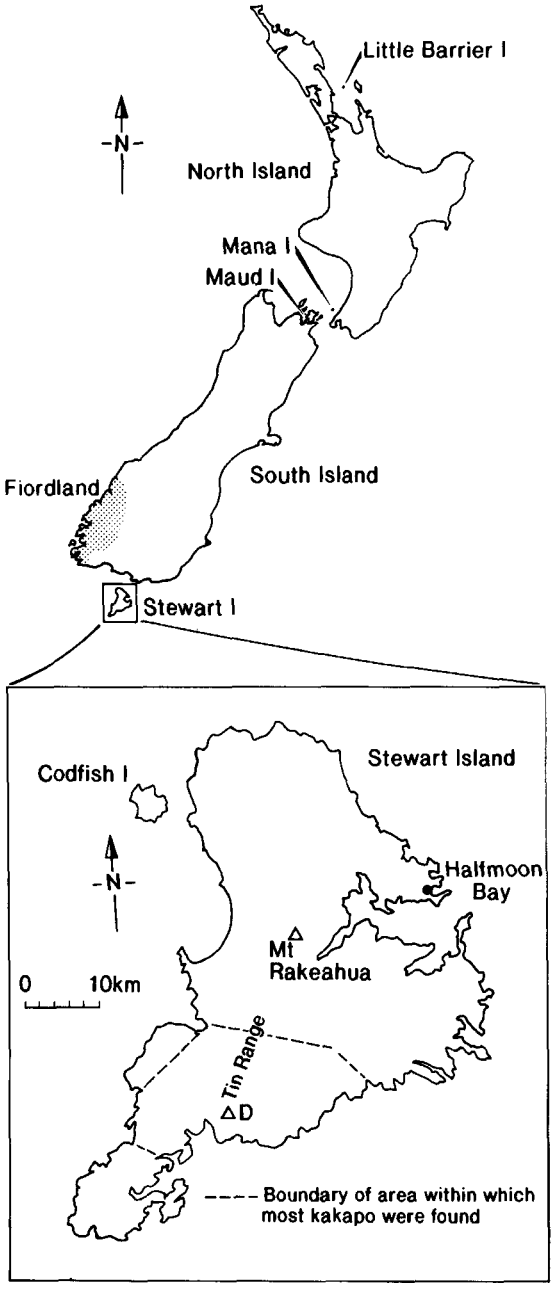

Fig. 1 New Zealand locations mentioned in the text supporting living kakapo during this century, and the boundaries of the former distribution of kakapo on Stewart Island.

tagged the previous year (Lloyd & Powlesland 1994), and cats were assumed to have killed them. Therefore, a cat-control programme began in April 1981: after cat numbers had been reduced, few kakapo were killed. With the methods and funds available at the time it was determined that cat eradication would be impractical, but that the few kakapo remaining were very vulnerable to cat predation. Therefore, in 1982 it was decided to transfer some kakapo to Little Barrier Island, an island free of cats (Fig. 1) (Moorhouse & Powlesland 1991), and to maintain the rest in situ. The high cost of cat control, the impossibility of ensuring the survival of every individual kakapo, and the population's very low productivity (Powlesland et al. 1992) prompted the decision in 1987 to transfer the remaining Stewart Island kakapo to Codfish Island, a second island free of cats (Fig. 1) (Lloyd & Powlesland 1994). By 1993, no kakapo were known on Stewart Island. All had been transferred to islands that are free of introduced predators, except for kiore (*Rattus exulans*) on Little Barrier Island and Codfish Island (Lloyd & Powlesland 1994). Because all known kakapo have now been removed from Stewart Island, the Department of Conservation will not carry out further searches for them unless new evidence suggests that survivors remain.

It is therefore now appropriate to summarise the information relating to kakapo captures since 1979 in the final remnant of their natural range. In this paper we document the number of male and female kakapo found on Stewart Island, their distribution, the proportion that were transferred to safe sites, and the number and distribution of male courtship sites.

STUDY AREA

Stewart Island (172 060 ha) is 30 km south of the South Island (Fig. 1), and is mostly covered by native forest and scrublands (Wilson 1987). Most of the 400 people live at Halfmoon Bay (Fig. 1) or nearby. Visiting trampers and deerstalkers rarely venture south along the Tin Range (Fig. 1) and into the adjacent country where most kakapo were found. Much of the island was searched for kakapo and their sign, but most searching was concentrated in the area south of Mt Rakeahua (Fig. 1), where the land rises to 500–600 m a.s.l. The climate is maritime—mild to cool, windy, and wet (1250 mm/yr of rainfall along the east coast to 3750 mm/yr on the peaks and ranges (Leamy 1975).

Much of Stewart Island is covered by cool temperate rainforest dominated by rimu (*Dacrydium cupressinum*), kamahi (*Weinmannia racemosa*), and southern rata (*Metrosideros umbellata*). Large areas, influenced by wind, altitude, and/or poorly drained

predominantly peat soils, are occupied by low forest or scrub in which manuka (*Leptospermum scoparium*), yellow-silver pine (*Lepidothamnus intermedius*), leatherwood (*Olearia colensoi*), and other species are variously predominant (Meurk & Wilson 1989). A more detailed description of the island's vegetation is given by Wilson (1987). The southern end of the Tin Range (Fig. 1) is one of the more human-modified areas of Stewart Island. Fire-modified vegetation, the result of periodic burning to assist mining activities from the 1880s to 1940s, covers >1500 ha (Sansom 1982). Browsing by the brush-tailed possum (*Trichosurus vulpecula*), released in the 1890s, and white-tailed deer (*Odocoileus virginianus*), introduced in 1905, has significantly changed the coastal rata-kamahi-rimu forest, particularly its understorey (Veblen & Stewart 1980).

Cats were introduced to Stewart Island in the early 1800s (Karl & Best 1982), and their scats have been found throughout the island, from the coast to the tops of the ranges. Six (5.1%) of 118 scats collected during 1977–80 from areas where kakapo were evident contained kakapo feathers (Karl & Best 1982). Three *Rattus* species inhabit Stewart Island: *R. exulans* was present before Europeans arrived (Karl & Best 1982); *R. norvegicus* colonised by 1874; and *R. rattus* colonised by 1911 (Atkinson 1973). The diets of these omnivorous rats overlap with that of the kakapo (Best 1984; Sturmer 1988; James et al. 1991). In addition, all three species of rat eat nestling birds (Atkinson 1978).

METHODS

Individual kakapo were located from sign and the calls of males in summer. For most of the year kakapo rarely call and their sign (faeces, feathers, and evidence of feeding), even in an area inhabited by a known bird, can be difficult to find. Characteristic feeding sign included "chews" (expectorated, compressed, crescent-shaped, masticated plant fibre) and evidence of grubbing for bulbs, rhizomes, and roots (Best 1984). Feeding sign left by kakapo could not always be distinguished from that of possums and deer, but most kakapo feathers and faeces were distinctive (Powlesland 1989).

Male kakapo call and display in summer at traditional courtship sites called track-and-bowl systems, that are distinctive and often recognisable several years after they were last used (Powlesland et al. 1992). Most of Stewart Island was searched for track-and-bowl systems, especially the subalpine and alpine habitats on hills and ridges during 1977–81 (A. Cox pers. comm.) and where males were found or heard booming in summer (Powlesland 1988). On still nights, or when downwind of a calling male in light winds, the booming call (Powlesland et al. 1992) can be heard from up to several kilometres away. Since males on Stewart Island in January–February of some summers gave a series of booms every few minutes throughout much of the night, the general location of booming males was determined by listening from prominent landforms.

Baited and non-baited walk-through cage traps were initially used to capture kakapo, but were discontinued because they proved impractical and their capture rate was too low (Butler 1989). A more effective method of capturing kakapo required using a trained, muzzled dog, and then capturing by hand (Lloyd & Powlesland 1994). Occasional finding of sign suggested that a bird was inhabiting a particular area. If dogs failed to locate a kakapo there, baits, such as apples and kumara, were set out at 50 m intervals along tracks and marked routes. The baits were checked daily and, once kakapo feeding sign was evident, a dog was taken to the sign to locate the bird. To determine the sex of dead birds, measurements of major bones, particularly the skull, were compared with those from birds of known gender. An alternative or additional method was to note the colour pattern on the five outer primaries (males have faint yellow-cream markings near the tip of the inner vane, but females lack them; Powlesland 1989).

Until 1983, kakapo caught for transfer were banded and measured, and then carried in open-weave hessian sacks to individual pens (3 m^2 open-topped enclosures built of plywood 1.2 m high), where they were held overnight until transferred in purpose-built cages by helicopter and scheduled jet flights (Lloyd & Powlesland 1994). From 1983, instead of being held captive, birds were radio-tagged and released to reduce stress to them. The transmitters, weighing about 30 g, were mounted on the bird's back with a harness placed around the base of the wings. The radio-tagged kakapo were recaptured either on the day of transfer, or the day before, by radio-tracking on foot or from a helicopter. (For details of the methods of transfer and release, see Lloyd & Powlesland 1994.)

The cat-control programme began in April 1981 and finished in January 1989 (Roberts 1992). It consisted of distributing poison fish baits by hand from a helicopter and on foot, and trapping. During 1981–

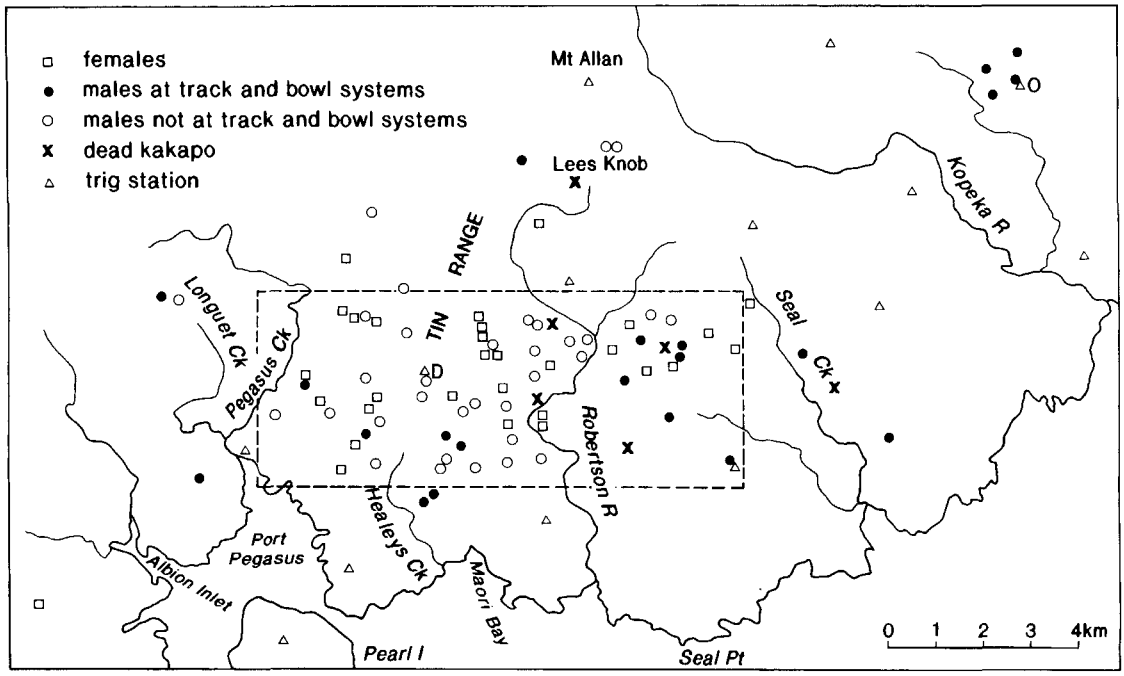

Fig. 2 Kakapo study area of southern Stewart Island showing the positions where each female, male, and dead kakapo was first located during 1979–92. Dashed boundary indicates the 4000 ha block within which most kakapo were found.

84, the baits (25 mm^3 injected with sodium monofluroacetate "1080") were spread from a helicopter on to ridges and hills of the kakapo area on three occasions. On four occasions during this period, baits were placed at 15 m intervals beside tracks throughout the main study area. The baits were retrieved after a week, or sooner if it rained, to prevent cats getting sub-lethal doses from diluted baits. Similarly, Lanes Ace leg-hold traps were set out for cats four times during 1981–84 in the coastal podocarp forest from Albion Inlet to the mouth of the Robertson River (Fig. 2). Seven traplines, each consisting of about 20 traps set 50 m apart, were operated. Roberts (1992) gives details of how the traps were set. In 1984, the aerial spreading of baits was discontinued, mainly because of the poor quality of baits available, but the ground application of baits and trapping was continued. Although this meant that baits were spread over a smaller area, baits were distributed more frequently in the main kakapo study area where most birds lived. Every second month from November 1984 to January 1989, the cat-control team was in the field for a month distributing fresh poison baits each week and operating the traplines throughout. At least 146 cats were trapped and six poisoned during the almost 8-year duration of the programme (Roberts 1992).

RESULTS

Number found

Although kakapo were rediscovered on Stewart Island in January 1977, it was not until June 1979 that the first bird was captured. Since then a total of 91 individual kakapo have been found, 85 alive and six dead. This total does not include one bird banded as a nestling in 1981, but which has not been found again. Of the 85 birds initially found alive, 83 were located by dogs. The other two, both males, were caught in cage traps.

Of the live birds, 56 were males and 29 were females (a ratio of 2:1), of which three were juveniles (2♀♀ and 1♂). Five of the six dead birds were found by chance. The sixth was first found as a very malnourished nestling on 26 May 1985, and when relocated c. 20 m from the nest 12 days later had starved to death. Three of the dead birds were determined

to be males and one a female. Too few skeletal fragments of the fifth bird were found to determine its gender.

Fate of kakapo

Sixty-one (72%) of the 85 birds initially found alive were transferred to safe sites (Table 1). Eleven were transferred to Maud Island (1♂ and 3♀♀ in 1980–81, 1♀ in 1985, and 4♂♂ and 2♀♀ in 1989–91), 18 to Little Barrier Island (11♂♂ and 7♀♀ in 1982), 30 to Codfish Island (20♂♂ and 10♀♀ in 1987–92), and two to Mana Island (2♂♂ in 1992) (Lloyd & Powlesland 1994). Of the other 24 kakapo, 13 were found dead and 11 were not found again (Table 1). One bird was killed by a cat in August 1983, and two died after being injured when located by a dog in 1990. In total, at least nine of the 13 birds (69%) found dead had been torn apart, the major leg and wing bones broken and sometimes the back of the skull chewed off (H. A. Best pers. comm.), indicating that cats had killed or scavenged them. Eight of the birds not relocated were last seen alive before the start of the cat-control programme in April 1981. The last of the above eight birds was captured and released in March 1983. Although time of death could not be accurately determined from skeletal remains, at least four died before the cat-control programme began, and four died between April 1981 and June 1982. Females were not more susceptible than males to predation by feral cats; 21% of 29 females died or disappeared compared with 32% of 56 males ($\chi^2 = 0.738$, $P > 0.05$).

Distribution of kakapo

One male kakapo was found at a track-and-bowl system on Mt Rakeahua (Fig. 1), at least 17 km north of any other known birds. Another outlying group of four males was at their track-and-bowl systems near Trig O (Fig. 2). However, most kakapo (65 alive and four dead; 76%) were found within a 4000 ha block about the southern end of the Tin Range (Fig. 2) over a 14-year period (1979–92). We did not census the population in any single year: however, if we assume that all adults initially found alive (39♂♂ and 23♀♀) within the 4000 ha were present in 1981, then the mean density would have been one kakapo per 64.5 ha. Although a few males moved >4 km from their non-breeding season ranges to track-and-bowl systems, most males used systems that were inside their home ranges or within 2 km of them (Powlesland et al. 1992). Therefore, the concentration of kakapo within the 4000 ha block is not a result of males concentrating at track-and-bowl systems within the block during summer, but reflects the dispersion of the population in 1979–92.

Table 1 Fate of male and female kakapo initially found alive on Stewart Island, 1979–92.

	Not found again	Dead when relocated	Transferred	Total
Male	8	10	38	56
Female	3	3	23	29
Total	11	13	61	85

Distribution of track-and-bowl systems

In total, 150 track-and-bowl systems were found (Fig. 3). Most were on prominent landforms, such as ridge crests and hilltops where the vegetation was low-growing and sparse. In addition, a disused track-and-bowl system was found on Trig U (47°03′S, 168°00′E), 8 km north-east of Trig O (Fig. 3), plus several other probable systems nearby (A. Cox pers. comm.). The bowls are depressions in the soil c. 50 mm deep and 450 mm wide, and usually two or more bowls are interconnected by tracks, 300–600 mm wide and clipped clear of vegetation. Characteristically, such systems are found on the tops of sparsely vegetated ridges and hills. When in use, the bowls are grubbed each night, and freshly clipped vegetation, along with other kakapo sign, is usually evident at the system or nearby. Of these systems, 88 (59%) were within the 4000 ha block (Fig. 3). Typically, the systems were 50–100 m apart. Occupied systems were also found near the southern end of the Tin Range 1–2 km from other occupied systems (Fig. 3). These latter systems were occupied each summer that males boomed, even though unoccupied systems were available within 100 m of occupied systems. Of 45 systems checked in the 1980–81 breeding season, at least 28 (62%) were occupied. In contrast, in the 1984–85 breeding season, after 12 males had been removed, only six (13%) of the same 45 systems were occupied.

DISCUSSION

Number found

In total, 91 kakapo were found on Stewart Island between 1979 and 1992. Six of them were dead, unbanded kakapo. Given that kakapo inhabited c. 110 km^2, much of it thickly forested, the remains

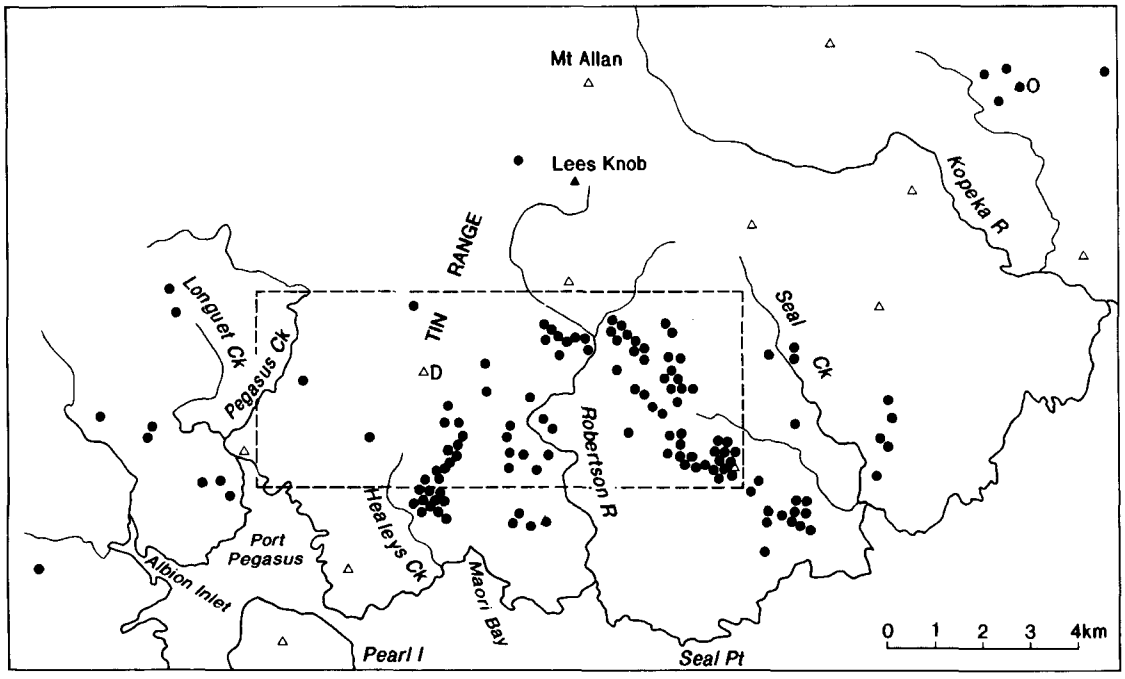

Fig. 3 Kakapo study area of southern Stewart Island showing the positions of kakapo track-and-bowl systems found during 1977–92. Dashed boundary indicates the 4000 ha block within which most kakapo were found.

of other kakapo must have gone undetected. Therefore, the number of kakapo that inhabited Stewart Island in 1982 probably fell into the mid-range of the estimates (70–200 birds) given by D. V. Merton (pers. comm.) and H. A. Best (pers. comm.).

The sex ratio of the 85 live kakapo was two males to one female. Armstrong (1947) suggested that the populations of some other lek species contained more males than females, but his evidence was based mainly on observations at arenas (a feature of which is their highly skewed sex ratios in favour of males). Other lek species, such as the magnificent bird of paradise (*Cicinnurus magnificus*) (Beehler & Foster 1988) and sharp-tailed grouse (*Tympanuchus phasianellus*) (Oring 1982) had a population sex ratio of 1:1. Whether the skewed sex ratio of the kakapo population on Stewart Island was a natural feature of the species or was a result of differential mortality as a consequence of predation is unknown. No females were captured in Fiordland (where mustelids and feral cats are present) during the 1960s to 1980s (when 24 males were found), but males survived until at least 1987 (Merton et al. 1984; Powlesland et al. 1992), which suggests females had a shorter longevity than males or were more vulnerable to mammalian predators. However, on Stewart Island (no mustelids), females were not more susceptible than males to predation by feral cats.

Fate of kakapo

Seventy-two percent of the 85 kakapo that were initially found alive on Stewart Island were transferred to other islands. Although no one saw a feral cat killing or eating a kakapo, the evidence is fairly compelling that cats killed the birds, rather than just scavenged carcasses of birds that died for other reasons. Eight (73%) of the 11 kakapo not found again were initially located before the start of the cat-control programme in April 1981. During 1981–82, seven of 13 adult radio-tagged kakapo died, giving an estimated 56% annual mortality (Lloyd & Powlesland 1994). Once the control programme had been in operation for a year, the mortality rate of 18 remaining kakapo averaged 2.4% per annum during 1982–89 (SD = ±0.002).

There are several features of the kakapo that render it particularly vulnerable to cat predation. Kakapo have a strong characteristic scent, and spend much time on the ground roosting and foraging. Breeding would increase their vulnerability to cat

predation, because each adult male spends most of each night for at least 3 months calling noisily at his track-and-bowl system, and each female that rears chicks spends much time over 4 months at her nest on the ground (where large chicks can be noisy and the smell of their accumulated faeces quite evident) (Powlesland et al. 1992). It is probably no coincidence that the kakapo is the only flightless lek species, and that it evolved in the absence of mammalian predators. Kakapo rely on their cryptic plumage and on remaining motionless to avoid detection; this behaviour may have protected them against predatory birds but is unlikely to be effective against cats. Even when approached closely (<1 m) by us, roosting kakapo moved away only slowly and without any attempt to defend themselves aggressively until captured.

Given this vulnerability to cat predation, and that cats have been on Stewart Island since the early 1800s (Karl & Best 1982), it is surprising that kakapo survived there until the 1980s. One explanation suggested for the sudden increase in kakapo mortality in 1981–82 was that access tracks cut by Wildlife Service staff through the thick vegetation of the main kakapo area, and the resulting human scent trails, enabled cats more readily to find kakapo than previously. However, tracks and a tramline constructed during mining activities in the 1880s and 1890s were still visible from the mouth of Pegasus Creek to Trig D (Fig. 2), and tracks created during the 1920–30s by E. Carrington, a miner, were also evident between Trig D east to the Robertson River and out to the coast at Maori Bay (Fig. 2). Several cat-eaten kakapo and recently abandoned track-and-bowl systems were found well outside the main kakapo study area in a locality (Seal Creek catchment) very rarely visited, with no tracks within a kilometre (Butler 1989).

We hypothesise that the kakapo population survived for so long after cats were introduced to Stewart Island because cat predation of adult kakapo was irregular and involved only a few cats. Although feral cats are opportunistic hunters and scavengers (Turner & Meister 1988), they are primarily predators of small mammals (Fitzgerald 1988). Studies have shown that cats hunting Norway rats and European rabbits (*Oryctolagus cuniculus*) concentrated on individuals that were less than half grown, apparently because the mature ones were too aggressive or too large to be readily killed (Jones 1977; Childs 1986). Also, studies of feral cat diet broken down by cat age suggest that learning through experience is very important in finding and killing prey (Turner & Meister 1988), and as a result cats are well-grown before they tackle larger prey, such as rats and rabbits (Fitzgerald 1988). From this information, we assume that cats on Stewart Island would have normally preferred small prey, such as rats (100–400 g) (Karl & Best 1982), rather than adult kakapo (1–3 kg), and that the high kakapo mortality in 1981–82 was the result of a few cats learning to kill kakapo during a period when rats were scarce. Support for this latter suggestion comes from the observation during 1983–87 that a few cats were still living in the kakapo study area, as evident from scats found on each field trip, often close to where kakapo regularly fed or a male had its track-and-bowl system. The sharp reduction in kakapo mortality soon after the cat-control programme began may have been the effect of early removal of most of the cats which had learnt to kill kakapo. If rat densities at that time were sufficient, the remaining cats could survive without having to kill large prey, such as kakapo. Rat populations do fluctuate markedly on Stewart Island, as was evident after a good fruiting season of pink pine (*Halocarpus biformis*) and yellow-silver pine (*Lepidothamnus intermedius*) in summer–autumn 1985 (Powlesland et al. 1992). Index trapping of rats (Cunningham & Moors 1993) gave combined index results for all rat species (*Rattus exulans*, *R. rattus*, *R. norvegicus*) varying from 1.3 to 5.7 captures/100 trap-nights between June 1982 and December 1985, except that in June 1985 the index was 13.7 captures/100 trap-nights (D. M. Cunningham pers. comm.). We suspect that the irregular mast-fruiting of podocarps (Podocarpaceae) on Stewart Island (Powlesland et al. 1992) supports temporarily increased rat densities, and as a consequence cat densities increase, in much the same manner that irregular beech (*Nothofagus* spp.) mast-seeding in Fiordland promotes house mouse (*Mus musculus*) population irruptions, which in turn lead to increased stoat (*Mustela erminea*) densities (Fitzgerald 1978; King 1983).

Distribution of kakapo and track-and-bowl systems

Most kakapo and their track-and-bowl systems on southern Stewart Island (Fig. 2, 3) were found in a centrally located 4000 ha block of habitat. The mean area per kakapo within the block was 65 ha; the home ranges of each of four radio-tagged kakapo were: 2♂♂: 15–30 ha, 2♀♀: 35–50 ha (Best & Powlesland 1985). The home ranges of neighbouring kakapo often overlapped considerably, and not all the 4000 ha provided suitable habitat for kakapo. In favoured areas of southern Stewart Island, the

density may therefore have been much greater than one bird per 65 ha. By comparison, the present mean density of kakapo on Codfish Island (n = 30 birds) is one bird per 47 ha, on Maud Island (n = 5) it is one bird per 62 ha, and on Little Barrier Island (n = 21) it is one bird per 147 ha, assuming even distribution.

Williams (1956) wondered if the Stewart Island kakapo population originated from a release of Fiordland kakapo in Port Pegasus during the 1890s. However, three museum specimens collected from Stewart Island in the early 1880s (Dawson 1962; Russ 1978) suggest that the species reached the island when it was connected to Southland during the last glaciation (Butler 1989). Also, it seems highly unlikely that a few released birds could have increased to as many as 100 resident birds within 80 years in the presence of rats and cats. It is strange, given the considerable human activity in the Port Pegasus – Tin Range area during the 1880–1940 period, that the presence of kakapo there went almost unrecorded until 1977. There is too little information about the pre-1977 distribution of kakapo on Stewart Island to assess its status then. Cockayne (1909) reported a dog killing one at Port Pegasus; Russ (1978) quoted H. Vipond's report to the Department of Internal Affairs of a kakapo treed by a dog near Seal Point in 1949; and N. MacDonald found a live kakapo in 1970, although where it was found is not stated (Butler 1989). Given the impact of cat predation on Stewart Island kakapo in 1981–82 and the impact of mammalian predators generally on South Island kakapo (Merton 1975; Lloyd & Powlesland 1994), it seems likely that the Stewart Island kakapo population had long been in decline. A few track-and-bowl systems were found beyond the range of the population in 1977–92, and many systems found within the range had been unused for several years.

The assumption of prolonged decline is supported by the distribution of track-and-bowl systems on Stewart Island. Although some unoccupied systems remained unchanged for at least 7 years, one occupied system was not recognisable as such 3 years later (A. Cox pers. comm.). Most of the outlying birds were males living close to their traditional leks, as in Fiordland in the 1970s, not long before the species went extinct there (Merton 1975). Given the critically endangered status of the kakapo, with its skewed sex ratio in favour of males, and the continued presence of cats in the kakapo habitat despite the cat-control programme, the risk of predation on adult kakapo was considered unacceptable. Therefore, all kakapo found after 1987 were removed from Stewart Island (Lloyd & Powlesland 1994), and now the long-term survival of the species depends on the intensively managed populations on Little Barrier (Powlesland & Lloyd 1994), Codfish, and Maud Islands.

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