

Comparison of population numbers of yellow-eyed penguins, *Megadyptes antipodes*, on Stewart Island and on adjacent cat-free islands

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Abstract: During a comprehensive survey in 1999, 2000 and 2001, we investigated the number of breeding yellow-eyed penguin pairs on Stewart Island, where cats are present, and on adjacent cat-free islands. We found 79 pairs of yellow-eyed penguin breeding in 19 discrete locations on Stewart Island (4.2 pairs per location), and 99 pairs breeding in 10 discrete locations on all cat-free islands (9.9 pairs per location). Large-scale human-induced habitat modifications have not occurred on Stewart Island, nor on any of its adjacent offshore islands. While the extensive coastline of Stewart Island (673 km) offers potentially large areas of breeding habitat for penguins, the highest number of breeding pairs were found on the smaller, predator-free Codfish Island (25 km coastline), where a total of 61 breeding pairs were recorded. On Stewart Island, where mustelids do not occur, only feral cats can pose a serious threat to penguin offspring. Results from this study suggest that feral cats may prey on yellow-eyed penguins on Stewart Island. Further work is necessary to investigate whether the observed low numbers of yellow-eyed penguins on Stewart Island are caused by feral cat predation. If so, it may be possible to develop appropriate measures to protect this penguin species from a population decline.

Keywords: Codfish Island; feral cat predation; hoiho; *Megadyptes antipodes*; population numbers; Stewart Island; yellow-eyed penguin.

Introduction

Introduced mammalian predators have been identified as a major cause of extinctions and population declines of native birds on islands (e.g. Diamond and Veitch, 1981; King, 1984; Holdaway, 1999). In many island ecosystems, the cumulative effect of predation by several introduced predator species causes bird diversity and abundance to decline drastically. This is also the case in New Zealand, where several introduced predators, such as mustelids (*Mustela* spp.), feral cats (*Felis catus*), rats (*Rattus* spp.) and brushtail possums (*Trichosurus vulpecula*) reduce native bird populations (King, 1984; Fitzgerald, 1988; Sadleir, 2000).

The yellow-eyed penguin (*Megadyptes antipodes*) is one of the rarest penguin species, and only breeds along the south-east coast of the South Island of New Zealand, on Stewart Island and its adjacent islands, and on the sub-Antarctic Campbell and Auckland Islands (Marchant and Higgins, 1990). Their decline in numbers on the South Island of New Zealand has mainly been attributed to predation by introduced mammals and to the degradation and destruction of their breeding habitat by grazing stock (Darby and

Seddon, 1990). However, on Stewart Island and its adjacent offshore islands, neither large-scale human-induced habitat modifications, nor the introduction of mustelids have occurred (King, 1990). Stoats, ferrets and cats are all known to prey upon yellow-eyed penguins on the South Island (Alterio and Moller, 1997). The impact of predation by cats alone has never been investigated. Remains of various species of penguin have been found in scats and stomachs of feral cats on Marion, Macquarie and Stewart Island (Jones, 1977; van Aarde, 1980; Karl and Best, 1982). While it is unclear from these studies whether cats killed or scavenged on penguins, a South African study reported that at least nine percent of all African penguin (*Spheniscus demersus*) chicks produced annually were killed by cats (Berruti, 1986). It has been suggested that cats shift to preying upon penguins if other food resources are scarce, possibly because cats have already reduced the availability of other prey species, such as smaller birds (Berruti, 1981). On Stewart Island, small bird species that are easily preyed upon by cats have either become extinct or their numbers have declined markedly since the introduction of exotic mammalian predators (Harper, 2002). Additionally, seasonal

declines in rodent numbers may also force cats to shift to alternative prey (Harper, 2002). While it has been suggested that the yellow-eyed penguin population on Stewart Island has probably been affected by cat predation (Harper, 2002), the size of the current breeding population is unknown (McKinlay, 2001).

The objective of this study was to compare the numbers of pairs of yellow-eyed penguins at breeding locations on Stewart Island, where cats are present, with the numbers at breeding locations on adjacent cat-free islands.

Methods

Searches for yellow-eyed penguin nests on Stewart Island (47°S, 167°E) were conducted in November and December of 1999 and 2000. This period of the

year usually coincides with penguins incubating their eggs or guarding their young offspring. Generally, adult yellow-eyed penguins return to the same breeding location from year to year (Richdale, 1957). In 1999, the entire north-east coastline between Long Harry and Halfmoon Bay was searched for yellow-eyed penguin nests (Fig. 1a, b). Bench, Weka, and the islands of the Bravo Group (Tommy, Crayfish, Groper, and Goat Island) were also visited to search for yellow-eyed penguin nests in 1999 (Fig. 1a, b). In 2000, the west coast of Stewart Island, between Doughboy Bay and Long Harry, Port Pegasus, from Broad Bay to the northern side of Whale Passage, and the east coast between Big Kuri Bay and Halfmoon Bay were searched for penguin nests (Fig. 1a, c). Noble and Anchorage Island in Port Pegasus were also searched for yellow-eyed penguin nests (Fig. 1c). The remaining south-east and south-west coast of Stewart Island was not searched,

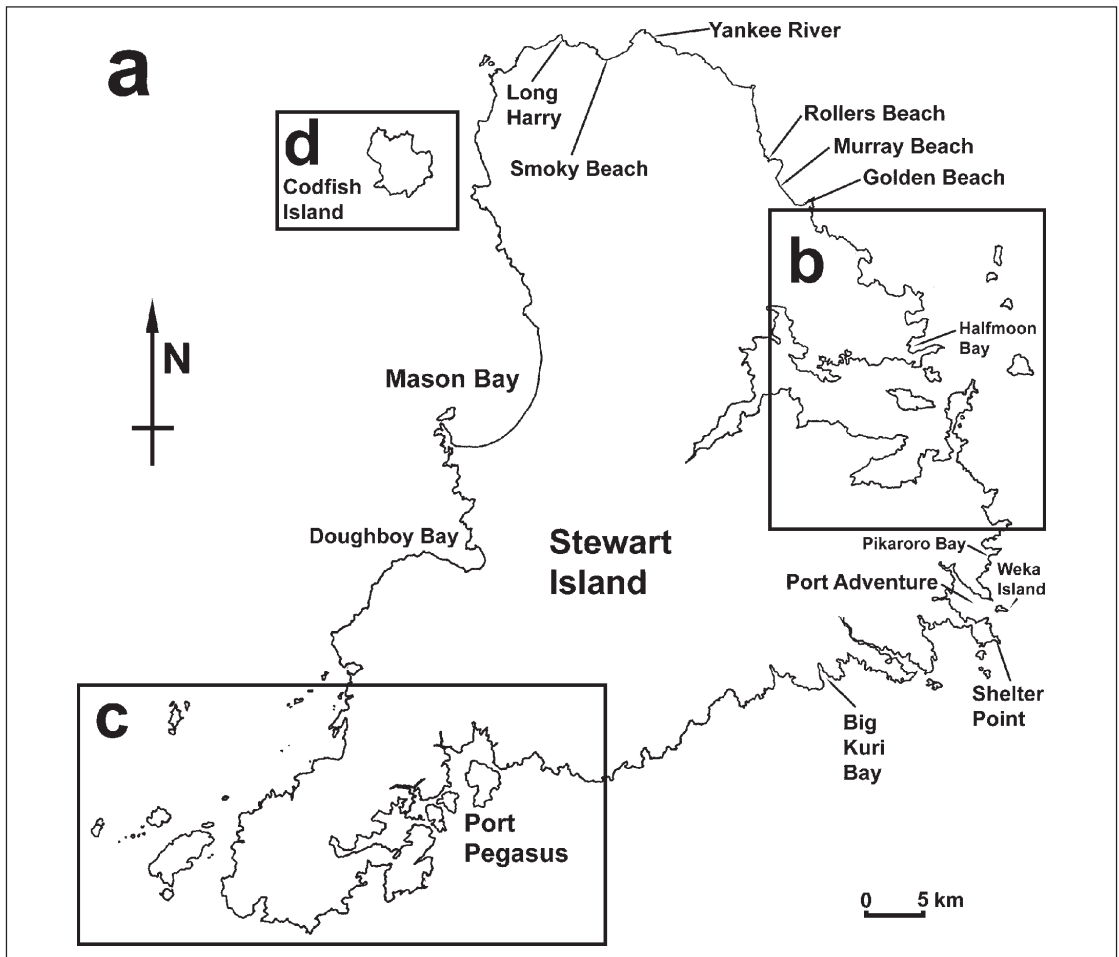


Figure 1.

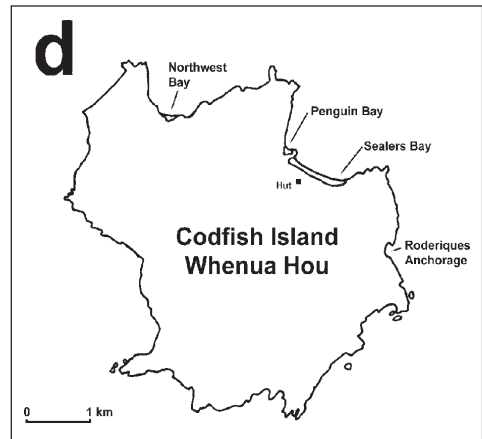
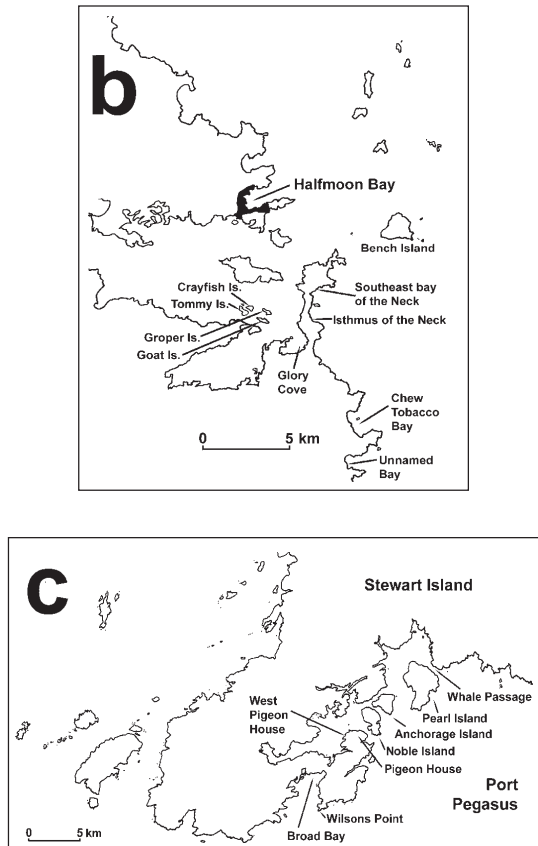


Figure 1. (a) Map of Stewart Island (see previous page), including the location of Codfish Island, Long Harry, Smoky Beach, Yankee River, Rollers, Murray and Golden Beach, Halfmoon Bay, Pikaroro Bay, Weka Island, Shelter Point, Big Kuri Bay and Port Pegasus. (b) North-east coast of Stewart Island showing the location of Bench Island, the islands in the Bravo Group (Tommy, Crayfish, Groper and Goat Island), the Neck, Glory Cove, Chew Tobacco Bay and Unnamed Bay. (c) South-east coast of Stewart Island, including the location of Broad Bay, Wilsons Point, Pigeon House, West Pigeon House, Noble, Anchorage and Pearl Island, and Whale Passage within Port Pegasus. (d) Codfish Island/Whenua Hou showing the location of Northwest Bay, Penguin Bay, Sealers Bay and Roderiques Anchorage.

as it generally consists of steep cliffs that are not suitable landing sites for yellow-eyed penguins, and they are unlikely to be breeding along this coast in any numbers. In November of 2001, a survey on Codfish Island/Whenua Hou (Fig. 1a, d) was conducted to search for yellow-eyed penguin nests.

All beaches or rocky shores that could be accessed by foot or boat along the coast of all islands were searched for signs that yellow-eyed penguins were coming ashore. Once signs of penguins (such as footprints, claw marks at access points, faeces and birds ashore) were found, a comprehensive search for nests was undertaken. Using both visual and olfactory clues, penguin tracks from landing sites were followed to the end and all sidetracks and the wider area surrounding penguin tracks and signs were thoroughly searched. In areas where anecdotal and historical records reported yellow-eyed penguins, extensive nest searches were undertaken even if no recent signs of penguins could be found. Bays or beaches were defined as breeding locations if breeding penguins were found.

Once a nest was located, the nest was marked to avoid recounting. A nest was defined as a nest bowl with eggs or chicks present, while empty nests attended by one or more adults were not considered as nest sites. We assumed that each nest found with eggs or chicks present was attended by one pair of breeding yellow-eyed penguins. To determine whether the number of breeding penguin pairs differed between cat-free breeding locations and locations on Stewart Island, where cats are present, a bootstrap test was carried out (Sokal and Rohlf, 1995). The data were randomly assigned to either the group of cat-free locations or to the group of locations where cats are present. The simulated means for both groups were calculated. The difference in number of breeding pairs between the simulated groups was compared with the observed difference between cat-free locations and locations where cats are present. This procedure was repeated 10 000 times and by counting the number of times the simulated difference matched or was greater than the observed difference, the probability of obtaining the

observed difference in number of penguin pairs by chance was calculated. Statistical significance is assumed if $P < 0.05$. Mean values are given ± 1 SE.

Results

We found a total of 79 yellow-eyed penguin pairs with eggs or chicks at 19 discrete locations on Stewart Island (Table 1). The largest aggregations of yellow-eyed penguins were found at the southeast bay of the Neck (10 pairs) and at Pigeon House at Port Pegasus (9 pairs) (Fig. 1b, c). On average, 4.2 pairs (± 0.6) per breeding location were found on Stewart Island.

A total of 61 yellow-eyed penguin nests with eggs or chicks were found on predator-free Codfish Island. At three out of four breeding locations on Codfish Island (Penguin Bay, Sealers Bay and Northwest Bay, Fig. 1d), we found large aggregations of yellow-eyed

penguins (Table 2). Although the nest search could not be completed on Bench Island due to dense vegetation and time limitations, 14 yellow-eyed penguin nests/pairs were located (Table 2). On Noble and Anchorage Island in Port Pegasus, we found seven and two penguin nests, respectively (Table 2, Fig. 1c). On the islands of the Bravo Group, we found 11 nests on Tommy and one nest on Crayfish Island, while none were located on Groper and Goat Island (Table 2, Fig. 1b). On Weka Island near Port Adventure we found three yellow-eyed penguin pairs (Table 2, Fig. 1a). A total of 99 penguin nests were found at 10 breeding locations on all cat-free islands. On average, 9.9 pairs (± 3.0) per breeding location were found on cat-free islands (Table 2).

There was a significant difference in the number of penguin pairs per breeding location on Stewart Island, where cats were present, and cat-free islands (bootstrap; $P = 0.009$).

Table 1. The number of breeding yellow-eyed penguin pairs for each breeding location on Stewart Island, where cats are present.

Breeding location	Coast/Area	Map	Coordinates (NZMG)	No. of breeding pairs
Long Harry	North coast	A	2111385 E, 5378130 N	7
Smoky Beach	North coast	A	2115545 E, 5377260 N	3
Yankee River	North coast	A	2119005 E, 5378280 N	3
Rollers Beach	North coast	A	2127085 E, 5370500 N	7
Murray Beach	North coast	A	2128120 E, 5368760 N	3
Golden Beach	North coast	A	2129685 E, 5366935 N	7
Glory Cove	East Coast	B	2142570 E, 5349285 N	3
Southeast bay of the Neck	East Coast	B	2142570 E, 5351980 N	10
Isthmus of the Neck	East Coast	B	2142675 E, 5350570 N	1
Chew Tobacco	East Coast	B	2145025 E, 5344830 N	7
Unnamed Bay	East Coast	B	2145055 E, 5342860 N	4
Pikaroro Bay	East Coast	A	2145675 E, 5341815 N	1
Port Adventure	East Coast	A	2144765 E, 5336615 N	3
Shelter Point	East Coast	A	2146780 E, 5335145 N	2
Big Kuri Bay	East Coast	A	2133370 E, 5332520 N	1
West Pigeon House	Port Pegasus	C	2103470 E, 5317880 N	2
Pigeon House	Port Pegasus	C	2104665 E, 5318305 N	9
Wilson's Point	Port Pegasus	C	2101895 E, 5313305 N	4
Broad Bay	Port Pegasus	C	2099620 E, 5314530 N	2
Total	Stewart Island			79
				Mean: 4.2 (± 0.6)

Table 2. The number of breeding yellow-eyed penguin pairs for each breeding location on cat-free islands.

Breeding location	Island/Location	Map	Coordinates (NZMG)	No. of breeding pairs
Penguin Bay	Codfish Island	D	2100435 E, 5368475 N	15
Sealers Bay	Codfish Island	D	2100965 E, 5368115 N	32
Roderiques Anchorage	Codfish Island	D	2101935 E, 5367175 N	1
Northwest Bay	Codfish Island	D	2098600 E, 5368900 N	13
Bench Island	East of Stewart Island	B	2147120 E, 5356140 N	14
Tommy Island	Paterson Inlet	B	2139000 E, 5350660 N	11
Crayfish Island	Paterson Inlet	B	2139360 E, 5350900 N	1
Weka Island	Port Adventure	A	2146250 E, 5339100 N	3
Anchorage Island	Port Pegasus	C	2106280 E, 5320740 N	2
Noble Island	Port Pegasus	C	2105250 E, 5319530 N	7
Total	Cat-free islands			99
				Mean: 9.9 (± 3.0)

Discussion

Despite the immense size of the Stewart Island coastline (total length: 673 km), we found 20 more yellow-eyed penguin pairs breeding on the small adjacent offshore islands, which have an entire coastline of only 53 km. Potentially, the extensive coastline of Stewart Island offers large areas of breeding habitat to penguins. Large-scale habitat modification has not occurred on Stewart Island, nor on any of the adjacent offshore islands, and it is unlikely that differences in habitat explain the large variation in penguin numbers between Stewart Island and its offshore islands. However, the size of the often exposed coastline of Stewart Island has made it difficult to obtain accurate population numbers for yellow-eyed penguins. The most recent survey prior to this study was conducted by the Department of Conservation in the late 1980s and early 1990s, when they concluded that there might have been a minimum of 395 pairs (Roberts, 1992). While previous estimates of penguin numbers relied heavily on extrapolations from partial surveys, this study was the first attempt at a full census. Locating dispersed breeding locations of penguins along the longer coast of Stewart Island may be more difficult than on small offshore islands and some may have been missed during this study. However, the difference in pair numbers per breeding location suggests there is a true variation in penguin numbers between Stewart Island and its offshore islands and not only an apparent difference generated by incomplete coverage.

The largest aggregation of breeding penguins was found on Codfish Island, which is entirely free of predators, including weka (*Gallirallus australis*). All other offshore islands are inhabited by rats (*Rattus exulans*, *R. rattus*, *R. norvegicus*), possums and weka, but are free of cats. While rats, possums and weka might prey upon abandoned penguin eggs and small chicks, it is unlikely that they are able to subdue guarding adults or large chicks, which weigh over three kilograms during the post-guard period (van Heezik, 1988). In contrast, feral house cats are opportunistic foragers that are able to prey upon a wide range of species (Bonner, 1984; Pearre *et al.*, 1998). The ability to shift to alternative prey, if one prey species is scarce, enables cats to maintain their abundance (Davis, 1957; Moors and Atkinson, 1984). A recent study on Stewart Island showed that feral cats feed mainly on rats throughout the year; however, each year rat abundance varied seasonally, with low abundance in early summer to early autumn (Harper, 2002). This period between December and March coincides with the post-guard period in yellow-eyed penguins when chicks are left alone at the nest. During the day, both parents spend long periods foraging at sea and return only for short intervals to feed their

chicks (Darby and Seddon, 1990). Unlike other penguins, yellow-eyed penguin chicks seldom form crèches for protection against predators (Darby and Seddon, 1990). Thus, chicks are defenseless against adult feral cats during the post-guard period. On Codfish Island many juvenile (one-year old) penguins were reported during beach counts (Blair, 2002). In contrast, only four juveniles were observed on Stewart Island. Since over 80 percent of juveniles return to breeding sites where they fledged (philopatry) (Richdale, 1957), the lack of juveniles on Stewart Island suggests that hardly any chicks fledge from Stewart Island or fledglings die before they reach one year of age.

Generally, in seabirds, the rate of mortality is the highest during the first year of life, mainly because young birds are inexperienced in locating and capturing prey (e.g. Harris, 1970; Chastel *et al.*, 1993). It is likely that penguins of Stewart Island use the same foraging grounds as penguins from the adjacent islands, considering the close proximity of those islands to Stewart Island. Any variation of marine food availability would be expected to affect penguins breeding not only on Stewart Island, but also on any of the cat-free islands. Thus, the low numbers of breeding pairs of yellow-eyed penguins on Stewart Island are unlikely to be explained by marine prey availability.

Human visitors to landing beaches or breeding locations might influence the number of breeding yellow-eyed penguins. A preliminary study on the Otago Peninsula on the South Island has shown that penguins avoid coming ashore if people are present on their landing beaches (Wright, 1998). On Stewart Island, some beaches along the north coast are frequently visited by people; conversely, other remote areas on Stewart Island, such as Port Pegasus, are rarely visited. On Codfish Island, ongoing conservation work for the last 20 years has meant a large number of people and planes visit and land at Sealers Bay (J. Joice, National Kakapo Team, Department of Conservation, Wellington, N.Z., D. Houston, Department of Conservation, Oamaru, N.Z., *pers. comm.*). Despite this disturbance, Sealers Bay had the largest breeding population of penguins recorded in this study. While the cumulative effect of frequent human presence at landing beaches and breeding locations may have some adverse impacts on the number of breeding yellow-eyed penguins, we argue that the low numbers of breeding yellow-eyed penguins on Stewart Island compared with cat-free islands cannot be explained by human-induced disturbance alone.

This study provides evidence that there were considerably fewer pairs on Stewart Island in 2000/2001 than previous estimates had suggested. While it is difficult to assess whether the yellow-eyed penguin population has been declining on Stewart Island in the last decade, or whether extrapolations from previous

partial surveys overestimated the population, this study clearly indicates that the number of breeding yellow-eyed penguins on Stewart Island is substantially lower than on cat-free islands. To determine causes of mortality of penguin offspring on Stewart Island, video cameras could be used to record predation events during incubation and the guard period (e.g. Sanders and Maloney, 2002); however, it would be very difficult to record predation events during the post-guard period when large, mobile chicks leave their nests. If feral cat predation does cause high offspring mortality on Stewart Island, reducing cat numbers during the period when offspring are most at risk, may protect this penguin species from a population decline on Stewart Island.

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