Declining eastern rockhopper (*Eudyptes filholi*) and erect-crested (*E. sclateri*) penguins on the Antipodes Islands, New Zealand

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Abstract: New Zealand's subantarctic Antipodes Islands are of international significance for breeding seabirds. However, penguin populations on the islands are declining. Uncertainty about the extent of this decline has been accentuated by a lack of accurate information on the population size and nest distribution of the penguin species, and the absence of an appropriate methodology for their long-term monitoring. We surveyed the nest abundance and distribution of eastern rockhopper penguins (*Eudyptes filholi*) and erect-crested penguins (*E. sclateri*) on the Antipodes Islands from 22 October to 6 November 2011 and compared counts with historical censuses from 1978 to 1995. Presence or absence of colonies previously known to have existed was recorded and counts of all nests within colonies around the islands were undertaken. In total, 42 689 nests of both species were counted over 103 colonies. Of these, 86% of nests (2475 rockhopper and 34 226 erect-crested) were counted accurately from on land. Overall, 24 entire colonies have ceased to exist since 1978, and there was an estimated 23% decline in the number of penguin nests between 1995 and 2011. Despite differences in methodology between surveys, there appears to have been a significant decline in penguins nesting on the Antipodes Islands. Worldwide, most crested penguin species (*Eudyptes* spp.) are in decline. Since New Zealand is a world hotspot for endemic penguin species, a consistent monitoring system needs to be developed and a monitoring schedule put in place to allow quantification of the scale of these declines. The causes of the declines on the Antipodes also need to be investigated, as they are unlikely to be a result of on-land predation by introduced mammals and human habitat disturbance or destruction, as occurs on the New Zealand mainland.

Keywords: long-term monitoring; population; sampling methodology; subantarctic

Introduction

Over the last century, climate change and intense human exploitation of natural living resources have occurred in the Southern Ocean, potentially affecting its ecosystems (species distribution and abundance, habitat disturbance or destruction from fishing methods such as trawling), right up to the top marine predators, including seabirds (Lea et al. 2006; Ainley & Blight 2009; Ainley et al. 2010). The majority of crested penguin (*Eudypte*s spp.) populations around the world are currently in decline (Birdlife International 2010). The Antipodes Islands, which are located over 800 km south-east of the South Island of New Zealand on the edge of the Bounty Platform (49°41′ S 178°45′ E), are one of five island groups in the New Zealand subantarctic World Natural Heritage Area. The Antipodes Islands support approximately 65% of the world's population of erect-crested penguins (*Eudyptes sclateri*) and 1% of the world's population of eastern rockhopper penguins (*E. filholi*) (Birdlife International 2010). Consequently, this group is identified as an internationally significant seabird breeding area and is classified as an important bird area (IBA) by Birdlife International, as it supports significant populations of globally threatened species (Birdlife International 2013). Penguin colonies are found on the main Antipodes Island, Bollons Island, Archway Island, and the Windward Islands (Fig. 1).

Rockhopper penguins are the most widespread of the crested penguins, breeding on islands in the southern Atlantic, Indian and Pacific oceans (Marchant & Higgins 1990). Rockhopper penguin taxonomy is currently under review, but for the purposes of this research we have considered there to be three species: northern (*Eudyptes moseleyi*), western (*E. chrysocome*), and eastern (*E. filholi*), the last of which is found on New Zealand's subantarctic islands (Banks et al. 2006; de Dinechin et al. 2009). Recently, most breeding populations of eastern rockhopper penguin have declined substantially throughout the species' range (Birdlife International 2010). On Campbell Island/Motu Ihupuku, in New Zealand's subantarctic (52°33′ S, 169°09′ E), the eastern rockhopper penguin has declined by 94% since the 1940s (Cunningham & Moors 1994).

The erect-crested penguin is endemic to New Zealand, breeding predominantly (99%) on Antipodes and Bounties islands (47°45′ S, 179°00′ E; Birdlife International 2012). There has also been a decline in this species over the last two decades (Birdlife International 2012), although the reasons for this remain unclear.

Despite the significance of the Antipodes Islands to breeding colonies of penguins and the apparent decreases observed in penguin species on the islands, their population sizes and nest distributions have not been consistently quantified and no formal long-term methodology has been developed to monitor future trends. This is in part due to the extreme difficulty and cost of travelling to one of New Zealand's most remote subantarctic island groups.

Land-based photographs from the 1950s indicate that rockhopper penguins used to outnumber erect-crested penguins on Antipodes Island (Taylor 2006). The first systematic attempt at mapping the penguin colonies on the Antipodes Islands was undertaken by Rowley Taylor in 1978 and was repeated in 1989 (Taylor 2006), using a combination of boat and on-land surveys during November and December when

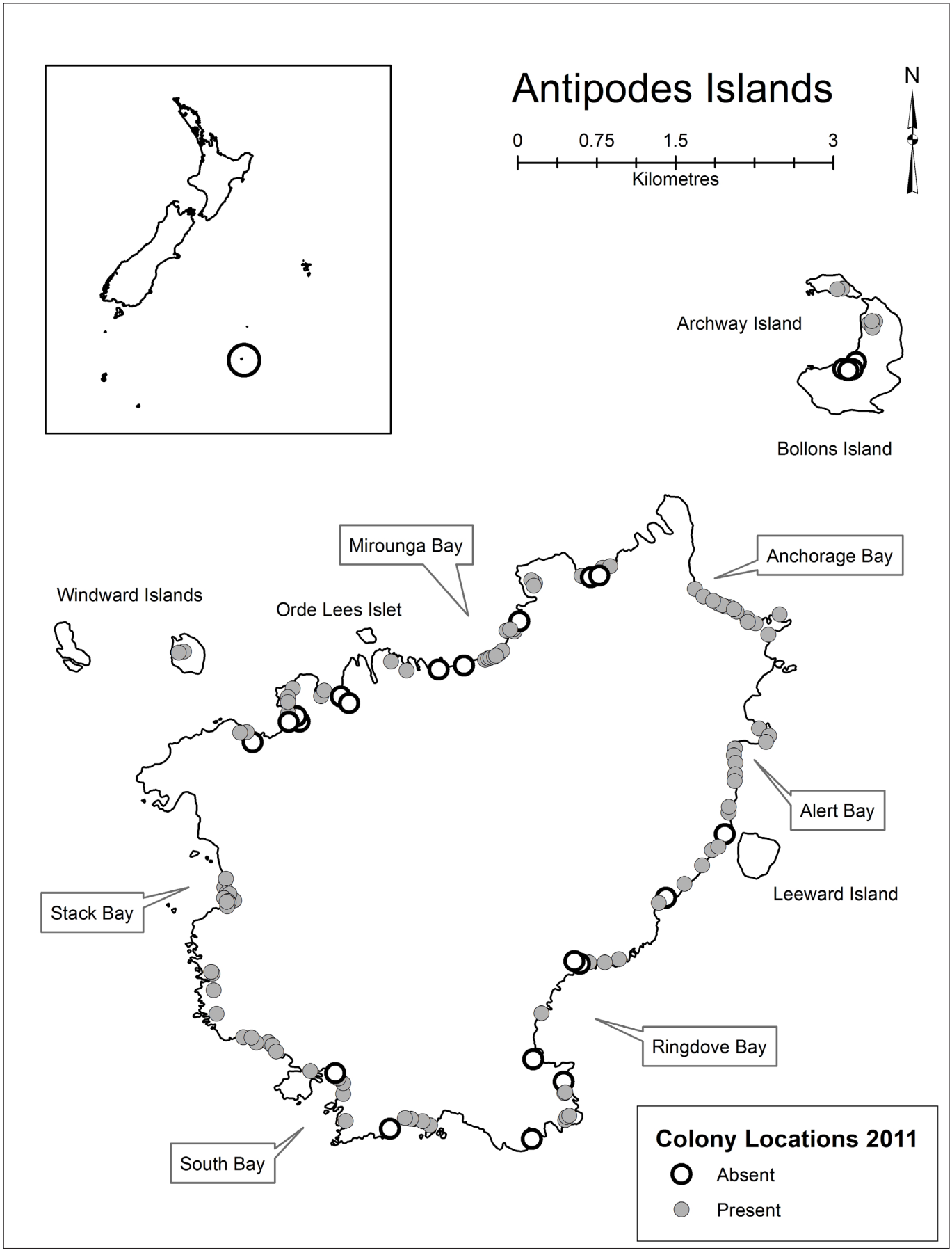

Figure 1. Map of the Antipodes Islands, showing their location in relation to the South Island of New Zealand and the other subantarctic islands. The location of penguin colonies present in 2011 are indicated.

chicks were present (Table 1). The next attempt to survey the penguins on the Antipodes Islands was completed in 1995, when a multidisciplinary expedition visited the islands in October–November and counts of nests were attempted at all colonies. At the bigger colonies, colony boundaries were measured and nest density estimates were used to calculate nest numbers. Many of the counts were conducted from vantage points both from the island and from the sea (Table 1) (McClelland et al. 2001).

The purpose of this paper is to document the methods used in a repeatable penguin census for the Antipodes Islands and obtain accurate baseline data on the population size of rockhopper and erect-crested penguins in 2011. These data were then compared with findings from previous surveys, where possible, to clarify population trends. The paper also aims to establish a formal, long-term standardised monitoring methodology that can be used to monitor penguin populations on Antipodes Island and other subantarctic islands in the future.

Methods

The survey of the Antipodes Islands was undertaken between 22 October and 6 November 2011 in four steps: (1) determining the location of current colonies and presence or absence of those recorded historically; (2) ground counts of nests in all accessible colonies; (3) binocular counts of inaccessible colonies; and (4) summation of an overall census estimate using data collected from ground counts and binocular counts. The timing, methodologies, and reported results from previous surveys are outlined in Table 1 for comparison.

Presence or absence of colonies

The presence or absence of colonies that had been identified in previous surveys was confirmed from the sea, from vantage points on land, or by visiting the colony ('ground counts'). The distribution of current colonies was compared with hand-drawn maps made by Taylor in 1978 and 1989 (R. Taylor unpubl. data), which had been digitised and the locations either given GPS coordinates or georeferenced, depending on the physical accessibility of the colony.

Initially, all islands were circumnavigated in a 15-m yacht with retractable keel to allow a broad check for colony persistence. However, boats cannot get very close to the south coast of the main island (between Stack and South bays; Fig. 1) due to underwater rocks, and therefore colonies in this area were checked from land. GPS coordinates were taken for all accessible colonies, and all colony locations are available for future comparisons to determine colony persistence (Hiscock 2013). Where possible, the presence of rockhopper and/or erect-crested penguins was noted in each colony; however, identification of the two species is often not possible from the sea. Colonies were distinguished from each other when they had observable boundaries and were separated by either a geographical feature such as a rock, ridge or vegetation, or by a distance greater than 10 m. However, rockhopper penguins often nest around the periphery of erect-crested penguin colonies, making differentiation of the two penguin species difficult.

Ground counts of colonies

Ground-count surveys of all accessible colonies were conducted in late October to early November during the middle of the incubation period for erect-crested penguins (Warham 1972) and early during the egg-laying period for rockhopper penguins (Richdale 1949). Ground counts were only conducted on the main Antipodes Island due to difficulty in landing on outlying islands and quarantine issues between islands. Ground counts were made of penguin nests, with a nest being defined as any nest bowl that was being defended by one or more penguins.

Counts were undertaken independently by two people, who each walked through the colony carrying two tally counters, one for erect-crested penguin nests (Fig. 2a) and the other for rockhopper penguin nests (Fig. 2b). For rockhopper penguins, one or more adults attending a nest were counted (i.e. either sitting or standing beside a nest whether it had an egg in it or not). This definition was taken because it was the very beginning of the rockhoppers' nesting season and this was considered a good indication of birds that were likely to nest. Observers made every possible attempt to identify rockhopper nests under and around rocks and boulders if there were signs of penguin activity. For the south-coast colonies,

Table 1. Comparison of survey timing and methods of surveys undertaken to count penguins at the Antipodes Islands since 1978.

Survey date	Methods	Reproductive stage	Colony counts	Nest counts	Reported results	Reference
1978 November–December	Boat- and limited land-based counts	Eggs and chicks	Hand-drawn maps of colonies	Breeding pair counts extrapolated from egg and chick counts	115 000 erect-crested and 50 000 rockhopper penguin breeding pairs 95 colonies identified	Taylor 2006
1989 November–December	Boat- and limited land-based counts	Eggs and chicks	Hand-drawn maps of colonies	NA	An estimate of breeding pair data not undertaken 85 colonies identified	Taylor 2006
1995 October–November	Boat- and land-based counts	Eggs	Written descriptions of locations	Direct counts and nest density estimates	52 000 erect-crested and 3392 rockhopper penguin nests Colony count data not available	McClelland et al. 2001
2011 October–November	Boat- and land-based counts	Eggs	GPS locations	Direct counts	Total of 42 689 penguin nests counted, 34 226 erect-crested and 2475 rockhopper nests 103 colonies identified	Present study

Figure 2. (a) Erect-crested penguin, *Eudyptes sclateri* and (b) rockhopper penguin *E. filholi* on nests.

this searching of boulder fields could take up to 25% of the count time. For erect-crested penguins, only nests with birds securely on the nest or standing beside a nest with an egg in the nest were counted. Those standing beside a nest without an egg were not counted because the nesting season for erect-crested penguins begins in late September and if penguins had not laid by late October – early November they were unlikely to nest. Small colonies were counted in one block, while larger colonies were divided into elongate smaller blocks, the totals for which were then added together; stock-marker spray paint was used to divide up blocks. Only one person counted a block at a time, to minimise disturbance to the nesting birds. All preparations for a count were made away from the colony to reduce disturbance.

Binocular counts

Where it was not possible to reach a colony by land, binoculars were used from the boat or a high vantage point on land nearby to count the penguins. Counts using binoculars were often too far away to identify species, and so the counts were of the total number of erect-crested and rockhopper penguin nests combined. For binocular counting, the bird's body posture was considered indicative of whether birds were sitting or attending nests. Because searches of boulders could not be undertaken, the number of rockhopper penguin nests was considered an underestimate.

Analysis and entire island census

In three instances, colonies that were counted from the sea were also ground-counted, with substantial differences recognised between counts. Therefore a correction factor was developed based on counts from the three colonies: Anchorage Bay, Mirounga Bay, and the North West Coast (Fig. 1; Table 2). The sea-based counts were 1.98 times lower than ground-based counts; therefore, when counts were summed to achieve an entire island nest census, sea-based binocular counts were multiplied by 1.98 ± 0.16 (Table 2). The 2011 ground counts were compared with ground counts from seven erect-crested penguin colonies and five rockhopper colonies that were carried out in 1995 (McClelland et al. 2001), as these are the only comparable ground counts of nests that have been undertaken previously.

Results

Presence or absence

A total of 103 colonies were identified in 2011 (Fig. 1). This included 30 newly recorded colonies and excluded the 24 colonies that were absent but that had been mapped on a hand-drawn map during Taylor's 1978 survey (unpubl.). The majority (28 of 30) of the newly recorded colonies identified in 2011 were in close proximity to previously identified colonies that were still present, and so may have been considered a single colony in 1978 or may have fragmented into several colonies since then. However, there were two clear cases where colonies were found high on a slope when traversing on foot that would have been missed from the Taylor 1978 and 1989 predominantly boat-based surveys. These colonies therefore may have existed in 1978, but would not have been seen or counted.

Ground counts and entire island census

A total of 42 689 penguin nests were counted on the entire Antipodes Islands census in 2011; 36 701 nests (86% of recorded nests) were counted from ground counts, 2222 using binoculars from viewpoints on land and 3766 ± 304 (corrected count) using binoculars from at sea. Of nests that were ground-counted, 34 226 were erect-crested penguin nests and 2475 rockhopper nests counted in 44 colonies. In contrast, 52 081 erect-crested penguin nests and 3392 rockhopper penguin nests were counted in the 1995 survey, giving a total of 55 473 nests.

For colonies that were clearly identified and ground-counted in both 1995 and 2011, there had been a 23% decrease in the number of erect-crested penguin nests counted and a 29% decrease in rockhopper nests (Tables 3 and 4). For colonies/areas that were not clearly defined in 1995 but were assumed to be similar to those observed in 2011, ground and binocular counts were compared and showed a 22% decrease in the number of erect-crested penguin nests and 21% decrease in rockhopper nests (Table 5).

Table 2. Comparison between ground and at-sea counts of erect-crested (*Eudyptes sclateri*) and rockhopper (*E. filholi*) penguin nests combined sighted on Antipodes Island, and correction factor for the at-sea counts. Total correction factor ± SE.

Colony	At-sea count	Ground count	Correction factor
Anchorage Bay	941	1752	1.86
Mirounga Bay	456	1049	2.30
North West Coast	185	328	1.77
Total	1582	3129	1.98 ± 0.16

Table 3. Comparison of ground counts of erect-crested penguin (*Eudyptes sclateri*) nests from the 1995 (McClelland et al. 2001) and 2011 surveys on the Antipodes Islands, New Zealand. Standard errors were only available for colonies that were double-counted; all other colony counts were undertaken by one person.

Colony location	1995 count	2011 count
Anchorage Bay	2779	2048 ± 5.1
Reef Point	713	578 ± 4.3
Stella Bay	330	251± 4.3
South Bay 6c	154	201
South Coast 5	72*	56
South Coast 6	150	106 ± 1.1
South Coast 10	300*	227
Total	4498	3467

* Estimates based on binocular counts

Table 4. Comparison of ground counts of rockhopper penguin (*Eudyptes filholi*) nests from the 1995 (McClelland et al. 2001) and 2011 surveys on the Antipodes Islands, New Zealand. Standard error was only available for Anchorage Bay, as all other counts were only undertaken by one person.

Colony location	1995 counts	2011 counts
Anchorage Bay	1095	816 ± 7.3
Stella Bay	11	3
South Bay 6a	101	54
South Coast 5	28	12
South Coast 10	7	0
Total	1242	885

Table 5. Comparison of erect-crested (*Eudyptes sclateri*) and rockhopper (*E. filholi*) penguin nests on Antipodes Islands from the 1995 and 2011 surveys from colonies whose boundaries could be identified from the 1995 data. Binocular counts were used unless indicated otherwise.

Colony location	Erect-crested penguin nests		Rockhopper penguin nests	
	1995	2011	1995	2011
Northern Bollons Island	107*	105	486*	0‡
Southern Bollons Island	0*	0	89*	0
Archway Island	1100	1014	< 50	0
Crater Bay South	95	105	0	0
Ringdove Stream Mouth	230	159	0	0
South Coast West of South Bay—MOAC	10,529†	5676*	475*	325*
Stack Bay	1800	3196*	>30	452*
Mirounga Bay	792	638	7	0
Point North of Mirounga Bay	559	1049*	27	170*
Point north-west of Hill 208	380	185*	30	21*
Bay north of Hill 208	124	95	30	0

* Ground count of nests
† Mixture of density counts and estimates
‡ None sighted but at-sea surveys only; would need to be ground-counted to confirm presence/absence

Discussion

In this study, we obtained quantitative population estimates for two globally threatened seabirds that breed on the Antipodes Islands and developed a methodology for repeated long-term monitoring of these populations. The estimates obtained indicate that the numbers of rockhopper and erect-crested penguins on the Antipodes Islands declined between 1978 and 2011 (McClelland et al. 2001; Taylor 2006) and that 24 previously known and clearly described colonies are no longer used. If previous estimates were reasonably accurate, the count of 42 689 penguin nests (both species combined) in 2011 represents a 74% decline in the number of nests estimated in 1978 (Taylor 2006), and a decline of 12 784 or 23% of nests since 1995 (McClelland et al. 2001).

Although it is difficult to compare population estimates from this study with previous studies due to differences in methodologies and survey timing, the findings from earlier studies are still useful for providing evidence of change. However, it should be noted that the reliability of these observed changes in population estimates depends on the accuracy and coverage of counts on each survey. It is also difficult to evaluate the survey methods we used to determine their accuracy relative to other, untested methods (e.g. aerial surveys) as these are not possible to perform at the remote Antipodes islands.

Our findings match the decreases in rockhopper penguin populations that have been observed on other islands. For example, the population of western rockhopper penguins on the Falkland Islands in the South Atlantic Ocean was estimated at ≈ 3 million breeding pairs in the early 1930s, but had declined to ≈ 275 000 pairs by the 2000/01 breeding season (≈ 91%; Pütz et al. 2002). Likewise, the population of northern rockhopper penguins breeding on Amsterdam Island in the Indian Ocean declined at a rate of 2.7% per year between 1971 and 1993, decreasing from 58 000 pairs to 24 890 pairs (57%; Guinard et al. 1998). A similar trend has also been observed in other New Zealand regions, with numbers of eastern rockhopper penguins breeding on Campbell Island/Motu Ihupuku declining from an estimated 1.6 million pairs in the early 1940s to 103 100 pairs in 1984–87 (93%; Cunningham & Moors 1994). There are currently no comparable published counts of erect-crested penguins at their other main breeding area, the Bounty Islands. However, from ground counts undertaken in 1997, 2004, and 2011 there appears to have been an approximate 6–8% decline in erect-crested penguin nests since 1997 on the Bounty Islands (J. Amey, Department of Conservation, unpubl. data).

The decline in rockhopper penguins on Campbell Island/Motu Ihupuku has been attributed to increases in sea temperature leading to changes in food distribution and abundance (Cunningham & Moors 1994). Penguins are generally thought to be sensitive to climate change (Barbraud & Weimerskirch 2001; Jenouvrier et al. 2005; Trathan et al. 2006; Boersma 2008; Ainley et al. 2010). Although gradual ocean warming may result in a poleward shift in the distribution of penguins (Forcada et al. 2006), increases in interannual variability in ocean temperature associated with global warming (particularly an increased frequency and intensity of changes in sea surface temperature; IPCC 2001) is also likely to have an impact on penguin populations. Studies investigating stable isotope ratios from a time series of feathers of rockhopper penguins from the Antipodes Islands dating back to 1861 have found a decreasing trend in $\delta^{13}C$, indicating that this population decline may have been related to a decrease in either ocean productivity or the availability of prey, possibly as a result of fisheries impacts (Hilton et al. 2006). Around the Falkland Islands and South Atlantic, penguin population declines have also been linked to the depletion of prey availability as a result of impacts from the commercial fishing industry, particularly when operations are close to penguin breeding sites (Bingham 1998; Ainley et al. 2010).

Population declines in penguin species on the New Zealand mainland have been linked to predation from introduced predators, habitat destruction of breeding areas (Moore 2001; Massaro & Blair 2003), and a reduction in foraging habitat quality (King et al. 2012). However, on-land impacts are less likely to be a factor in the decline observed on the Antipodes Islands because these islands have extremely limited human occupation (Taylor 2006) and are free from introduced predators, except mice (*Mus musculus*), which can impact on sea birds (Wanless et al. 2007) but usually to a much lesser extent than species such as stoats (*Mustela* spp.) or cats (*Felis catus*). It is currently unknown whether natural predators such as the subantarctic skua (*Catharacta lonnbergi*) could be causing this decline.

Long-term monitoring methodology

One of the objectives of this research was to describe a methodology for the repeated long-term monitoring of crested penguins. Previous surveys were less accurate than the 2011 survey due to the timing of the surveys (i.e. November–December; Taylor 2006), the resources, boat type and availability and time available at the islands (Taylor 2006) and the objectives of the expedition (McClelland et al. 2001). Our survey was more accurate because 86% of nest counts were ground counts (almost three times that of any of the other surveys) and, most importantly, all colonies were mapped accurately using GPS, making colony location and count comparisons repeatable with exact locations rather than hand-drawn maps or written descriptions as used in the other surveys (McClelland et al. 2001; Taylor 2006). Additionally, this survey used better boat resources, enabling small boats access into difficult locations that bigger boats used on previous surveys could not. The fieldworkers also spent a longer time at the island dedicated to penguin surveying rather than being a multidisciplinary survey as the 1995 survey was (McClelland et al. 2001).

The timing of this survey was appropriate for erect-crested penguins, but may have been a week early for rockhopper penguins, as the first rockhopper penguin egg was not seen until 25 October and not all birds intending to nest may have been present. Therefore, future surveys could be initiated at a similar time or 1 week later, at which time the erect-crested penguin eggs should not have hatched (the first erect-crested penguin chicks were recorded hatching on 10 November) and the majority of rockhopper penguins should be incubating (Warham 1972). The survey should not be completed after chicks have hatched, as, due to the predation of chicks by skuas, the number of failed nests would be disproportionately higher than when carried out at the egg stage.

Although the penguins may not show any obvious signs of disturbance when counters enter a colony, research has shown that even minimal disturbance can cause a stress response, e.g. increased heart rate (Holmes et al. 2005; Ellenberg et al. 2006). Therefore, any future monitoring should limit the number of people counting and the time spent in the colony and ensure that preparation for counts is carried out well away from the penguin colonies whenever possible.

In this research, both ground and at-sea counts were undertaken. Differences between binocular counts from sea and ground-based counts are expected, as many nests are obscured from view during the sea counts; this is particularly true for rockhopper nests, which are often located under rocks (J. Hiscock, pers. obs.). Boat movement may also hamper observations, depending on the weather conditions. Therefore calibration of binocular counts should be undertaken on each subsequent survey in a similar manner to the 2011 survey.

Conclusions

The findings of this study strongly indicate that the populations of rockhopper and erect-crested penguins on the Antipodes Islands are decreasing. The survey method outlined here provides baseline information, GPS locations of all known colonies, and a methodology for monitoring the population trends of these two globally threatened seabird species into the future. Due to the cost and logistical difficulties in censoring the Antipodes Islands, we recommend a census of the Antipodes Islands should be repeated every 5 years, during which the presence/absence of colonies should be determined, and both ground counts and binocular counts should be used to obtain a complete island census for comparability. We envisage that with the aid of GPS positions of colonies and a 5-yearly census, future surveys will be carried out more efficiently, and more accurate data and population trends could be established after several censuses. We also believe that the methodology outlined here could be used to monitor colonially nesting penguin populations on other subantarctic islands.

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