Antarctic Science 23(4), 332–336 (2011) © Antarctic Science Ltd 2011 doi:10.1017/S0954102011000071

Continued increase in numbers of spectacled petrels *Procellaria conspicillata*

PETER G. RYAN[1] and ROBERT A. RONCONI[2]

[1]*Percy FitzPatrick Institute, DST/NRF Centre of Excellence, University of Cape Town, Rondebosch 7701, South Africa*
[2]*Department of Biology, Dalhousie University, 1355 Oxford St, Halifax, Nova Scotia, Canada*
pryan31@gmail.com

Abstract: Until recently, the spectacled petrel *Procellaria conspicillata* Gould was listed as Critically Endangered due to its small population size and ongoing incidental mortality on fishing gear. Surveys at its sole breeding locality, Inaccessible Island in the central South Atlantic Ocean, indicated that the population increased from 1999–2004, resulting in the species being down-listed to Vulnerable. We repeated the census of breeding spectacled petrels during the early incubation period in October–November 2009. Numbers of burrows increased by 55% from 2004–09, with increases in all count zones, and the greatest changes in peripheral populations. Burrow occupancy estimates remained high, averaging 81% during one-off checks. Our best estimate of the population in 2009 was 14 400 pairs, continuing the *c*. 7% per year increase inferred since the 1930s following the disappearance of introduced pigs. This confirms the rapid recovery of this species despite ongoing mortality on fishing gear. Our results suggest that at least some procellariiforms are able to sustain strong growth rates in the face of fishing mortality when colony based threats are removed.

Received 23 April 2010, accepted 23 September 2010, first published online 22 February 2011

Key words: fishing mortality, Inaccessible Island, population trend, Procellariiformes, Tristan da Cunha

Introduction

Many albatrosses and large petrels are threatened by mortality on fishing gear (BirdLife International 2004, 2008). In the Southern Ocean and adjacent temperate oceans, the large petrels of the genus *Procellaria* dominate the bycatch of most fisheries (e.g. Barnes *et al*. 1997, Nel *et al*. 2002a, Delord *et al*. 2005, Waugh *et al*. 2008, Petersen *et al*. 2009) and all five species are listed as Threatened or Near Threatened (BirdLife International 2008). Mitigating the impacts of fishing gear on these birds is complicated by their proficiency as divers (Robertson *et al*. 2006). Among *Procellaria* petrels, two species have widespread breeding ranges, whereas three are confined to one or a few sites. The spectacled petrel or ringeye *Procellaria conspicillata* Gould only breeds on Inaccessible Island (37°18'S, 12°41'W), one of three main islands in the Tristan da Cunha archipelago in the South Atlantic Ocean (Ryan 1998, Ryan & Moloney 2000, Ryan *et al*. 2006). It is well protected at its breeding island, which lacks introduced predators and is a nature reserve and natural world heritage site (Ryan & Glass 2001, Ryan 2007), but spectacled petrels regularly are killed on longlines, mainly off the east coast of South America (Bugoni *et al*. 2008a, 2008b, Jiménez *et al*. 2010), but also occasionally off South Africa (Ryan *et al*. 2006). Catch rates generally are low (Bugoni *et al*. 2008a, Jiménez *et al*. 2010), despite spectacled petrels being the most abundant bird attending fishing vessels off Brazil (Bugoni *et al*. 2008a), but they are the species killed most frequently on handlines off Brazil and are also killed by vessels trolling for tunas (Bugoni *et al*. 2008b). The species was listed as Critically Endangered (BirdLife International 2000, 2004) until successive surveys using the same techniques in 1999 and 2004 showed that the population had increased at roughly 7% per year (Ryan *et al*. 2006). Indeed the population appears to have increased at this rate since the 1930s, following its near extinction due to predation by introduced pigs (Ryan *et al*. 2006). Fortunately the pigs died out, probably between 1900 and 1930 largely due to hunting pressure (Fraser *et al*. 1988, Ryan & Glass 2001), before they were able to extirpate the petrels.

The spectacled petrel remains listed as Vulnerable given its small breeding range confined to a single island (BirdLife International 2008). Proposed conservation measures include ongoing monitoring of the species' population (BirdLife International 2008), which is necessary to confirm that the population continues to recover. In this paper we report a third successive five-yearly survey of spectacled petrels at Inaccessible Island in 2009.

Methods

We visited Inaccessible Island from 5 October–1 December 2009. The total number of spectacled petrel burrows was estimated during the early incubation period between 29 October and 4 November. The survey was led by PGR,

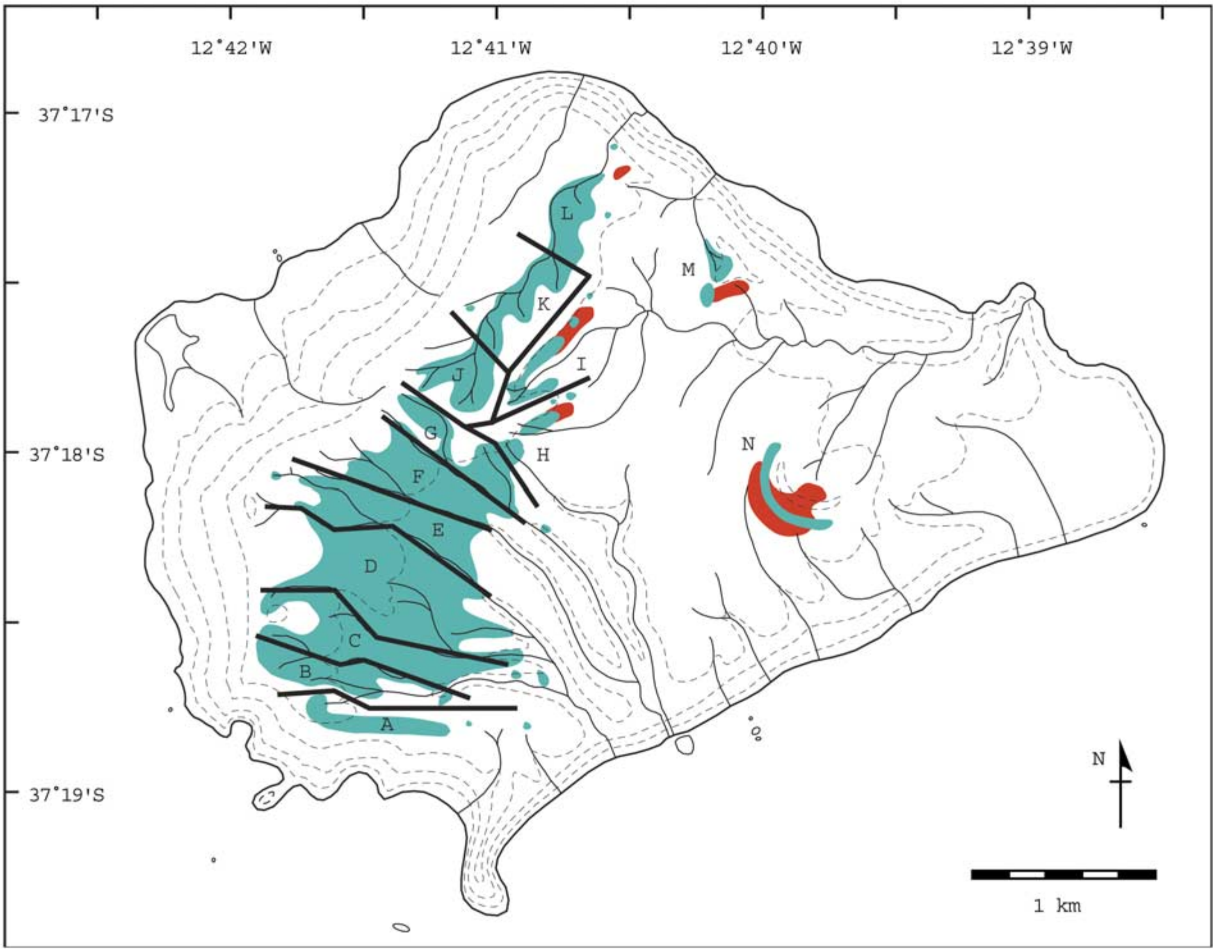

Fig. 1. The distribution of spectacled petrel burrows at Inaccessible Island. Red represents areas where marked range expansions occurred between 2004 and 2009. Count areas reported in Table I are labelled A–N. Dashed lines are *c*. 100 m contours.

who also led the 1999 and 2004 surveys, ensuring consistency in survey techniques. We surveyed all areas where spectacled petrels are known to breed (Ryan & Moloney 2000, Ryan *et al*. 2006). Counts were divided into the 20 count areas proposed by Ryan (2006), but results are reported for the 14 zones used in both previous

Table I. Counts of spectacled petrel burrows at Inaccessible Island (see Fig. 1 for count areas).

Count area		Number of burrows		
		1999	2004	2009
A	'Dune Hills' (seaward slopes)	180	370	490
B	'Molly Bog River'	375	650	815
C	'Swales Fell'	195	275	495
D	Gony Ridge	1125	1510	2230
E	'Boulder Hill River' to 'Twin Falls River' west	225	660	1040
F	'Twin Falls River' west to 'Twin Falls River' east	610	705	1150
G	Eastern drainage into 'Twin Falls River' west	610	625	1060
H	South-eastern slopes of 'Cairn Peak'	617	925	1285
I	South-eastern slopes of Long Ridge	50	325	670
J	'Ringeye Valley' - top	380	970	1210
K	'Ringeye Valley' - middle	568	620	1020
L	'Ringeye Valley' - bottom	795	940	1400
M	'Denstone Hill'	50	90	210
N	Round Hill	120	205	690
Total		5900	8870	13 765

https://doi.org/10.1017/S0954102011000071 Published online by Cambridge University Press

Table II. Population estimates for breeding spectacled petrels in three successive five-yearly surveys at Inaccessible Island.

Parameter	1999	2004	2009
Number of burrows counted	5900	8870	13 765
Correction for count bias*	6960	10 560	15 050
Correction for missed nests+	7650	11 090	15 800
Number of occupied burrows			
1. based on one-off occupancy rate	5900	8540	12 800
2. assuming 91% occupancy	6970	10 090	14 400

*based on careful checks of subsets of the count area, see methods for details.
+assumes 5% missed in 2004 and 2009, based on data from repeat surveys of study areas in 2004, and 10% missed in 1999, given later census period (when adults are less vocal) and reduced observer experience.

surveys (Fig. 1). Spectacled petrel colonies are readily detected because the birds regularly arrive and depart from their burrows during daylight (Ryan *et al*. 2006). Most burrows are easily distinguished from those of other petrels at Inaccessible Island by their large size, often with an entrance pool or moat (Rowan *et al*. 1951, Hagen 1952, Ryan & Moloney 2000). Most burrows are concentrated in distinctive 'ringeye bogs', marshy areas dominated by *Scirpus sulcatus* Thouars that are created by the birds' burrowing activity. However, some breed along stream banks or under dense vegetation where burrows are easily overlooked unless the adults call (Ryan *et al*. 2006).

After completing the burrow survey, we checked observer accuracy on 6 November 2009 by independently estimating the number of burrows at five colonies in different count zones to assess the relationship between estimated and actual numbers of burrows (see Ryan & Moloney 2000, Ryan *et al*. 2006 for details). Nest occupancy was assessed at the same sites using the criteria used in previous surveys (Ryan & Moloney 2000, Ryan *et al*. 2006). Spectacled petrel calls were played down the burrow entrance for 10–30 sec, ceasing if a response was obtained. The recording used was of a pair of birds giving a combination of rattles, wheezes and groans (Ryan 1998), and so should elicit responses from a high proportion of incubating birds (a combination of wheezy and rattle calls elicited responses among 89% of incubating white-chinned petrels, *Procellaria aequinoctialis* L., Berrow 2000). If there was no response (24% of burrows), an arm was inserted down the burrow as far as could be reached (*c*. 1 m), and the burrow scored as occupied (adult and/or egg felt, or adult called), empty, or uncertain (where nothing was detected, but the burrow was too long to be checked completely). Comparisons of numbers of birds responding in different periods were made using chi-squared goodness of fit tests with Yates' correction for continuity.

Results

Spectacled petrel burrows were found in all areas where they were previously recorded to breed, but their range had expanded, especially around 'Denstone Hill' and Round Hill, isolated colonies on high points on the eastern plateau (Table I, Fig. 1). Smaller range expansions also were recorded around the periphery of core breeding areas on the western plateau. The total breeding range was slightly $> 2\ km^2$. A total of 13 765 burrows was counted, 55% more than in 2004 (Table I). Numbers of burrows increased in all sectors. The greatest proportional increases (two- to threefold) occurred at Denstone Hill, Round Hill and the south-eastern slopes of Long Ridge (Table I), all at the eastern edge of the species' breeding range (Fig. 1).

The five count validation areas contained 146 burrows ($n = 18$–36, Table II). The two observers estimated 89% (PGR) and 94% (RAR) of the total number of burrows (average 91%), with estimates within each area ranging from 77–113% of the actual number of burrows. Combined count accuracy was $90.2 \pm 5.4\%$ ($\pm$ s.e., $n =$ ten estimates). Adjusting for counter bias suggests that the total number of burrows was 15 050 (95% confidence interval 13 500–16 600, Table II). This estimate fails to account for burrows not detected amongst dense vegetation. Assuming that at least 5% of nests are overlooked (Ryan *et al*. 2006), there are probably 15 800 (14 200–17 400) spectacled petrel burrows on Inaccessible Island.

Response to playback during one-off occupancy surveys was uniformly high in the five study areas (average 76%, range 69–85%), with an additional 5% (0–9%) of nests proving to be occupied when birds were detected when an arm was inserted into the burrow. Coupled with a few known breeding failures (broken eggs in burrow entrances), average occupancy was 81% (range 72–85%). Most other burrows were confirmed empty (14%), with only 5% of burrows too long to check their contents. The occupancy rate was slightly higher than the one-off estimate in 2004 (77%), but the difference was not significant ($\chi^2 = 0.70$, df = 1, $P > 0.2$). The increase in the proportion of burrows where there was a response to playback was more marked between 2009 (76%) and 2004 (68%, $n = 311$, $\chi^2 = 2.81$, df = 1, $P < 0.1$), which might be expected given that the check in 2009 occurred slightly earlier (6 November) than in 2004 (11 and 12 November). Response to playback decreases throughout the breeding season after egg laying in late October (Ryan *et al*. 2006).

If 81% of burrows were occupied, the population of spectacled petrels in 2009 was 12 800 pairs (Table II). However, multiple checks of marked burrows in 2004 indicated that occupancy was 91%, 14% greater than that recorded during one-off surveys (Ryan *et al*. 2006). Assuming a 91% occupancy rate in 2009 gives a total population of 14 400 breeding pairs (Table II) and an annual average growth rate from 2004–09 of just over 7% per year. It gives a total population of roughly 30 000 adult birds in 2009.

Discussion

The 2004 spectacled petrel survey suggested that the population was increasing at about 7% per year (Ryan *et al*. 2006).

https://doi.org/10.1017/S0954102011000071 Published online by Cambridge University Press

However, this growth rate may have been inflated in part by improved observer experience and greater search effort in 2004 (Ryan *et al*. 2006). A simple deterministic model suggested that numbers of spectacled petrels could increase at around 7% per year, but it was sensitive to the magnitude and timing of fishing mortality as well as the way in which fishing mortality changes in relation to the population size and density of spectacled petrels at sea (Ryan *et al*. 2006). Given these uncertainties, it was important to conduct another survey to confirm that the population was indeed increasing despite ongoing mortality on fishing gear.

The 2009 survey confirms that the population of spectacled petrels has continued to increase, and the 7% per year growth rate over the last five years is the same as that estimated for the period 1999–2004. Observer biases are unlikely to account for the increase from 2004–09, given that all three surveys were led by the same observer. The increase was apparent in the larger numbers of birds visiting the island in 2009 compared to 2004 and 1999. In the late afternoon it was not unusual to see up to 50 birds sitting outside their burrows on a single ringeye terrace, and to have thousands of birds soaring over the island's ridges. Estimates of the numbers of burrows increased throughout the species' breeding range, but the fact that the increases were greatest at the periphery of its range suggest that favoured breeding sites may be limited in core areas.

The accuracy of burrow estimates and burrow occupancy rates were similar to those obtained in 2004 (Ryan *et al*. 2006). Our trials confirm that a large proportion of *Procellaria* adults respond to playback during the early incubation period (Berrow 2000, Ryan *et al*. 2006), which is the best time to conduct surveys of these species. Berrow (2000) found marked differences in response rates of white-chinned petrels in successive years at Bird Island, South Georgia, but this apparently was due to differences in occupancy linked to colder weather and heavy snow cover in one year. Such interannual differences are less likely to occur at temperate Inaccessible Island, but a larger sample of years is necessary to confirm that occupancy rates are consistently high in all years.

The growth of the spectacled petrel population apparently results from the recovery of the species after its population was impacted by an introduced predator (Ryan *et al*. 2006). The elimination of introduced predators, in this case pigs, is essential for the recovery of many endangered seabird species (e.g. Rayner *et al*. 2008). However, the rate of recovery is perhaps surprising given ongoing mortality of spectacled petrels on fishing gear mainly off the east coast of South America (Bugoni *et al*. 2008a, 2008b, Jiménez *et al*. 2010). The marine distribution of spectacled petrels is concentrated along the shelf break and deeper offshore waters off Brazil and Uruguay (Camphuysen & Van der Meer 2000), where they overlap extensively with pelagic longline fisheries (Bugoni *et al*. 2009). One reason for their relatively rapid growth may be a rather low susceptibility to capture on longlines. Despite being the most abundant seabird attending longline vessels off Brazil, spectacled petrel capture rates are low in comparison to white-chinned petrels (Bugoni *et al*. 2008a). The absence of juvenile spectacled petrels possibly also contributes to low capture rates in this region, given that juveniles may be more prone to being caught on longlines (Bugoni & Furness 2009). Bycatch rates of spectacled petrels in Uruguayan longline fisheries also are low, and total seabird catch rates in this region have decreased over the last decade (Jiménez *et al*. 2010). For other populations of Procellariformes, population growth and stability has been attributed to decreased fishing effort and associated bycatch rates (Nel *et al*. 2002b, Rolland *et al*. 2009, Rivalan *et al*. 2010) emphasising the importance of fisheries management in the recovery of endangered albatross and petrel populations. The preponderance of spectacled petrels in handline bycatch (and, to a lesser extent, trolling fisheries) off Brazil (Bugoni *et al*. 2008b) remains cause for concern.

Despite the larger population recorded in 2009, the spectacled petrel still qualifies as globally Vulnerable under criterion D2 (population very small or restricted), because the entire breeding population is confined to a single location, with an area $< 10\,km^2$. Our results suggest that at least some procellariiforms are able to sustain strong growth rates despite limited mortality on fishing gear.

Acknowledgements

We thank the Administrator and Island Council of Tristan for permission to visit Inaccessible Island. Logistical support was supplied by the South African National Antarctic Programme (SANAP), and Tristan's Conservation Department; we especially thank Captain Clarence October and the crew of the MV *Edinburgh* and Norman Glass. Financial support was provided by SANAP, the European Commission's EDF-9 through the South Atlantic Invasive Species project, and the University of Cape Town. RAR was supported by the Killam Trust, Dalhousie University.

References

Barnes, K.N., Ryan, P.G. & Boix-Hinzen, C. 1997. The impact of the hake *Merluccius* spp. longline fishery off South Africa on procellariiform seabirds. *Biological Conservation*, **82**, 227–234.

Berrow, S.D. 2000. The use of acoustics to monitor burrow-nesting white-chinned petrels *Procellaria aequinoctialis* at Bird Island, South Georgia. *Polar Biology*, **23**, 575–579.

BirdLife International. 2000. *Threatened birds of the world*. Cambridge: BirdLife International, 864 pp.

BirdLife International. 2004. *Threatened birds of the world*. Cambridge: BirdLife International (CD ROM).

BirdLife International. 2008. *Threatened birds of the world*. Cambridge: BirdLife International (CD ROM).

Bugoni, L. & Furness, R.W. 2009. Age composition and sexual size dimorphism of albatrosses and petrels off Brazil. *Marine Ornithology*, **37**, 253–260.

https://doi.org/10.1017/S0954102011000071 Published online by Cambridge University Press

Bugoni, L., D'Alba, L. & Furness, R.W. 2009. Marine habitat use of wintering spectacled petrels *Procellaria conspicillata*, and overlap with longline fishery. *Marine Ecology Progress Series*, **374**, 273–285.

Bugoni, L., Mancini, P.L., Monteiro, D.S., Nascimento, L. & Neves, T.S. 2008a. Seabird bycatch in the Brazilian pelagic longline fishery and a review of capture rates in the southwestern Atlantic Ocean. *Endangered Species Research*, **5**, 137–147.

Bugoni, L., Neves, T.S., Leite, N.O., Carvalho, D., Sales, G., Furness, R.W., Stein, C.E., Peppes, F.V., Giffoni, B.B. & Monteiro, D.S. 2008b. Potential bycatch of seabirds and turtles in hook-and-line fisheries of the Itaipava Fleet, Brazil. *Fisheries Research*, **90**, 217–224.

Camphuysen, K.C.J. & van der Meer, J. 2000. Notes on the distribution of the spectacled petrel *Procellaria conspicillata* in the Southern Ocean. *Atlantic Seabirds*, **2**, 13–18.

Delord, K., Gasco, N., Weimerskirch, H. & Barbraud, C. 2005. Seabird mortality in the Patagonian toothfish longline fishery around Crozet and Kerguelen islands, 2001-2003. *CCAMLR Science*, **12**, 53–80.

Fraser, M.W., Ryan, P.G. & Watkins, B.P. 1988. The seabirds of Inaccessible Island, South Atlantic Ocean. *Cormorant*, **16**, 7–33.

Hagen, Y. 1952. Birds of Tristan da Cunha. *Results of the Norwegian Scientific Expedition to Tristan da Cunha 1937–38*, **20**, 1–248.

Jiménez, S., Abreu, M., Pons, M., Ortiz, M. & Domingo, A. 2010. Assessing the impact of the pelagic longline fishery on albatrosses and petrels in the southwest Atlantic. *Aquatic Living Resources*, **23**, 49–64.

Nel, D.C., Ryan, P.G. & Watkins, B.P. 2002a. Seabird mortality in the Patagonian toothfish longline fishery around the Prince Edward Islands, 1996–2000. *Antarctic Science*, **14**, 151–161.

Nel, D.C., Ryan, P.G., Crawford, R.J.M., Cooper, J. & Huyser, O.A.W. 2002b. Population trends of albatrosses and petrels at sub-Antarctic Marion Island. *Polar Biology*, **25**, 81–89.

Petersen, S.L., Honig, M.B., Ryan, P.G. & Underhill, L.G. 2009. Seabird bycatch in the pelagic longline fishery off southern Africa. *African Journal of Marine Science*, **31**, 191–204.

Rayner, M.J., Parker, K.A. & Imber, M.J. 2008. Population census of Cook's petrel *Pterodroma cookii* breeding on Codfish Island (New Zealand) and the global conservation status of the species. *Bird Conservation International*, **18**, 211–218.

Rivalan, P., Barbraud, C., Inchausti, P. & Weimerskirch, H. 2010. Combined impacts of longline fisheries and climate on the persistence of the Amsterdam albatross *Diomedea amsterdamensis*. *Ibis*, **152**, 6–18.

Robertson, G., McNeill, M., Smith, N., Wienecke, B., Candy, S. & Olivier, F. 2006. Fast-sinking (integrated weight) longlines reduce mortality of white-chinned petrels (*Procellaria aequinoctialis*) and sooty shearwaters (*Puffinus griseus*) in demersal longline fisheries. *Biological Conservation*, **132**, 458–471.

Rolland, V., Nevoux, M., Barbraud, C. & Weimerskirch, H. 2009. Respective impact of climate and fisheries on the growth of an albatross population. *Ecological Applications*, **19**, 1336–1346.

Rowan, A.N., Elliott, H.F.I. & Rowan, M.K. 1951. The 'spectacled' form of the shoemaker *Procellaria aequinoctialis* in the Tristan da Cunha group. *Ibis*, **93**, 169–179.

Ryan, P.G. 1998. The taxonomic and conservation status of the spectacled petrel *Procellaria conspicillata*. *Bird Conservation International*, **8**, 223–235.

Ryan, P.G. 2006. Inaccessible Island seabird monitoring manual. *Royal Society for the Protection of Birds, Research Report*, **16**, 1–32.

Ryan, P.G. 2007. *Field guide to the animals and plants of Tristan da Cunha and Gough Island*. Newbury, UK: Pisces Publications, 162 pp.

Ryan, P.G. & Glass, J.P. 2001. *Inaccessible Island nature reserve management plan*. Edinburgh, Tristan da Cunha: Government of Tristan da Cunha, 65 pp.

Ryan, P.G. & Moloney, C.L. 2000. The status of spectacled petrels *Procellaria conspicillata* and other seabirds at Inaccessible Island. *Marine Ornithology*, **28**, 93–100.

Ryan, P.G., Dorse, C. & Hilton, G.M. 2006. The conservation status of the spectacled petrel *Procellaria conspicillata*. *Biological Conservation*, **131**, 575–583.

Waugh, S.M., MacKenzie, D.I. & Fletcher, D. 2008. Seabird bycatch in New Zealand trawl and longline fisheries, 1998-2004. *Proceedings of the Royal Society of Tasmania*, **142**, 45–66.