THREATS AND THREAT STATUS OF THE WESTLAND PETREL *PROCELLARIA WESTLANDICA*

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ABSTRACT

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Threat status assessments provide a benchmark for identifying priorities for conservation and related research for special-status species. We review data about an endemic New Zealand seabird, the Westland Petrel *Procellaria westlandica*, and provide information to assist future threat assessment reviews. A range of threats have potential or have already contributed to reductions in population growth at a level that may exceed 10% over 10 years (ranked "High" or "High potential" threats). The realised (observed) threats include landslips and extreme climate events that degrade nesting habitat; bycatch mortality in commercial, recreational, and high-seas fisheries; attraction of fledglings to lights; and the potential encroachment of pigs *Sus scrofa* and dogs *Canis familiaris* into breeding areas. Low-ranked threats (which may contribute <10% to population reduction over 10 years) include habitat degradation by browsing introduced mammals and land development; death of individuals by striking wires or buildings; disturbance at colonies; the petrels' consumption of fisheries waste and plastics; human harvest; and naturally occurring mortality such as predation by native species or entrapment in tree branches and vines. Population size estimation, demographic modelling, and trend information indicate that the population is small (~2 800 breeding pairs), with very low productivity and therefore potential vulnerability to stochastic events. Recent surveys show that the area of breeding habitat occupied by the birds is only about 0.16 km^2. Storm events in 2014 severely reduced habitat quality, destroyed large parts of some colonies, and increased the likelihood of further erosion and landslip for at least 75% of the global breeding population. Storm impacts at other colonies have not yet been assessed. In light of this information, we recommend immediate review of the threat status of the species and initiation of mitigation to reduce the severity of threats. The information available indicates that a relisting to IUCN Endangered status may be warranted, and that the Agreement on the Conservation of Albatrosses and Petrels threat assessments should be revised to include two high-level potential threats: pig predation and dog predation.

Key words: habitat degradation, New Zealand, predation, threat assessment, Westland Petrel

INTRODUCTION

Threat assessments are useful in prioritising conservation activities and research actions related to special-status species. All methods of conducting threat assessments, however, have shortcomings and are difficult to apply across a broad range of taxa. Species may be of conservation concern but data needed to assess the magnitude of specific threats may be lacking, or the species are assumed to have a healthy status because they are commonly seen or found in accessible locations. In general, seabirds are highly vulnerable to stochastic or site-based threats (Ricketts *et al.* 2005). We review information relating to the conservation status of the Westland Petrel *Procellaria westlandica*, a species for which little quantitative population information was available until the first decade of this century. Recent research has provided the first detailed assessments of the population size, area of occupancy, population trends, productivity, and current and potential threats.

Paradoxically, for a species that nests close to human habitation, within a kilometre of a main highway, and on the mainland of New Zealand, its natural history is poorly known. It was first described as a species in 1945 (Falla 1946). Demographic research began in the 1970s but was not published in detail until the first decade of the 2000s (Waugh *et al.* 2006, 2015a). It revealed that, over that 40-year period, the population at the largest colony had a stable or slightly increasing population (an increase of up to 1.8% per year); high adult survivorship (~95%); and low breeding frequency (an estimated 46% of adult birds breed annually). The population size was first assessed using quantitative analyses during the first decade of the 2000s (Baker *et al.* 2011), but population trends across all surveyed colonies remain unknown.

By the late 1990s, interactions between Westland Petrels and fisheries were identified as problematic, as diet and tracking studies revealed frequent interactions with the nearby trawl fishery for hoki *Macruronus novaezelandiae* (Freeman 1998). Soon thereafter, the New Zealand Department of Conservation (DoC) developed a Threatened Species Recovery Plan (Lyall *et al.* 2004), which identified a range of threats and conservation priorities. However, since the plan was established, few attempts have been made to address those threats. A recent, comprehensive review of the threats affecting the species documented actual and potential causes of habitat degradation and mortality, as well as indirect threats to the population (Wilson 2016). That assessment prioritised management and research actions. Here, we provide an assessment of the severity and likelihood of the threats, as well as other information relevant to a review of the threat status for Westland Petrels. On the basis of the threat-classification systems of the DoC, the ACAP, and International

Union for the Conservation of Nature (IUCN), we recommend reclassifying the species' status to the endangered category.

METHODS

We reviewed all available information about the threats to Westland Petrels from both published and unpublished sources. Using DoC criteria for threat classification (Townsend *et al.* 2008), IUCN assessment criteria for threat status (IUCN 2012), and the threat matrix developed by ACAP (2011, 2014, Phillips *et al.* 2016), we presented an assessment in a format suitable for any upcoming review of the species' conservation status by these agencies. The threat matrix developed by ACAP (2014), modelled on the IUCN threat assessments (2012; summarised in Table 1), ranked threats

TABLE 1
Risk assignment criteria based on likelihood and consequence of threats as used by ACAP[a]

Severity (likely percentage reduction of affected population within 10 years)	Scope (% population affected)	
	High (11%–100%)	Low (1%–10%)
High (11%–100%)	High and High potential unquantified	Low
Low(1%–10%)	Low	Low

[a] Definition of scope and severity follow those set out in ACAP (2016). Scope indicates the percentage of the population potentially affected by the threat and severity indicates the percentage of reduction in the affected population within 10 years, as a result of a current or potential threat.

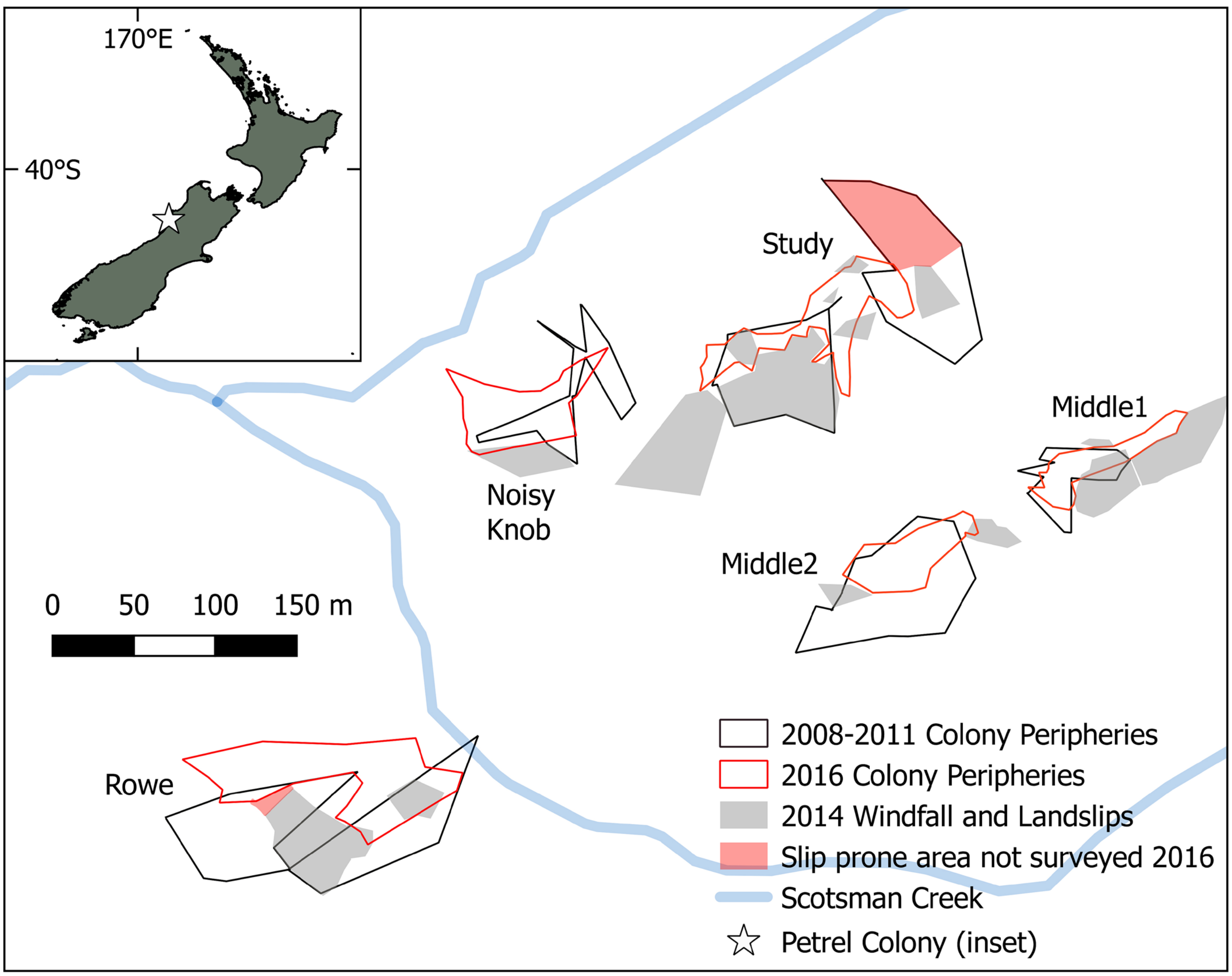

Fig. 1. Westland Petrel colonies in the Scotsman Creek Catchment (star on the inset map) mapped with GPS in 2008–2011 (black peripheries) by Baker *et al*. (2011) and in 2016 (red peripheries; this study, S. Waugh unpubl. data). The areas shown in grey shading are those that contained burrows in the 2008–2011 or earlier surveys and were affected by landslips, erosion, and tree windfall following tropical storm *Ita* in 2014. No burrows or soil remain in these areas. Two areas (red shading) have not been eroded but were not surveyed in 2016 as they are considered unsafe to enter due to the risk of landslips.

identified in our earlier publications (Waugh *et al.* 2015 a,b; Wilson 2016). This methodology assesses the scope of each threat in relation to the proportion of the population exposed and the severity of the threat to indicate the likely reduction in population that would result from the actual or potential threat. The scope and severity were assessed by expert opinion. Threats were ranked as High if they were considered to have a probability of causing a >10% reduction in population size over 10 years (High severity) or of affecting >10% of the population (High scope); or low, if they were likely to cause a <10% reduction in population over 10 years or affect <10% of the population. We added "High potential", for both scope and severity, if a threat was not known to be operating currently but had a high likelihood of becoming evident within a 10-year time frame. Threats assessed as Negligible were likely to affect only a very small number of individuals.

We present some demographic data (e.g., breeding success) based on visits to two research colonies, Rowe and Study Colony, three times per year during 2014–2016. Breeding pairs with eggs, chicks, and fledglings were identified in marked, lidded burrows—a total of 8–11 burrows at Rowe and 24–31 burrows at Study Colony each year in which eggs were laid. This sample is small because,

TABLE 2
Assessment of terrestrial threats to Westland Petrels considered to be at such a level to affect the survival of individuals, colonies, or to influence breeding habitat or feeding opportunities [a]

Terrestrial threat	Severity	Scope	Notes and references
Predators (feral pigs)	High potential	High potential	Pigs have the ability to extirpate whole colonies or, at worst, the whole population. Feral populations currently occur about 20 km north of the Petrel Colonies, they may arrive at any time, and they have been released by hunters close to the petrel colonies on occasions during the last 20 years.
Predators (vagrant dogs)	High potential	High potential	Dogs have entered the petrel colonies infrequently over the last 20 years and killed petrels, but could invade at any time, with Punakaiki village only 2.5 km from the colonies.
Landslide and windfalls leading to erosion of nesting substrate	High	High	Likelihood increased by storm damage in 2014, with erosion fronts currently at the periphery of major colonies leading to ongoing erosion of nesting areas (Waugh *et al*. 2015b).
Habitat damage by introduced mammals	Low	High	Possums and goats are always present, degrading breeding habitat and destroying burrows.
Predators (weka, possums, stoats, rats)	Low	High	Weka, possums, stoats, and rats are all present at breeding colonies but do not appear to be affecting the colony dynamics in measurable ways.
Land development (mining, farming, housing)	Low	High potential	Currently, no land development is planned adjacent to the colonies, but development and changes in land use on and adjacent to flight paths remains possible. There is some housing intensification on the margins of the Specially Protected area.
Attraction to lights (fallout)	Low	Not quantified	Each year, some young petrels are found grounded near lights in Punakaiki and other West Coast settlements. Mitigation, low light levels, and recovery and release of grounded birds may assist in reducing numbers of birds affected. There are restrictions on lighting in nearby Punakaiki village and developed areas near some flyways. The frequency is moderate, with birds recovered most years, but with high uncertainty around the numbers of individuals affected.
Powerline strikes	Low	Low	Mitigated by underground wires across the major flight path, but wires remain across all secondary flight paths.
Harvest (human take)	Low	Low	Mitigated by restricted access, but occasionally appears to affect >20% of chicks in monitored colonies. If unchecked, this could lead to a >10% reduction in population growth over 10 years, but is unlikely to be carried out at this severe level without being reported.
Tree captures	Low	Low	A natural threat affecting adults of breeding age, but ongoing at a low level annually.
Pathogens, parasites	Low	Low	Not identified for Westland petrels, although the potential exists.
Soil loss through burrowing	Low	Low	Ongoing natural process resulting from the birds' nest-building activity.
Human disturbance and trampling	Low	Low	Mitigated by restricted access.

[a] All threats are discussed in Wilson (2016) or Waugh *et al.* (2015a or b), except where otherwise noted. Threat levels are aligned to those described in Table 1, and are listed as High, High potential, Unquantified, Low, or Negligible for severity and scope.

although greater numbers of burrows at each colony (n = 50 at Rowe, n = 130 at Study Colony) were monitored in these and previous years, many were not used by breeding pairs. As well, 42% and 27%, respectively, of study nests at the two colonies were unfortunately destroyed in a major storm in 2014. Breeding success was defined as the number of eggs present in early July that led to fledgling young in September of the same year. Between-colony differences in breeding success were tested using paired *t*-tests, with significance set at $P = 0.05$.

Colonies where we conducted our demographic research within the Scotsman Creek catchment (42.147°S, 171.339°E; Fig. 1) were resurveyed in 2016 following the methodology of Baker *et al.* (2011). In addition, the colony boundaries were mapped following our transect surveys once the researchers had a clear understanding of each colony's extent. Mapping was accomplished using Quantum geographic information system (GIS; QGIS Development Team 2016), and results were compared with those defined by Baker *et al.* (2011) based on the end points of all transects that contained burrows in the earlier survey series (Baker, unpubl. data). Two areas covered in 2008–2011 were not resurveyed in 2016 because they presented a risk of landslide, either due to overhanging, unsupported mud cliffs, or due to soil cracks, indicating possible land movement. The areas that had been subject to landslip in 2014 were partially mapped, including edges safely accessible using global positioning system (GPS) points (Garmin GPS Map 64), as well as inaccessible edges estimated based on knowledge of the terrain. The spatial extent of each colony was estimated using the QGIS "identify features" tool to estimate the area of mapped polygons and does not take into account slope. Data relating to colony extent from 2016 are provisional and included only as indicative values to show where slips have occurred and colony boundaries have changed. Further detailed surveys are desirable to confirm these preliminary assessments.

RESULTS & DISCUSSION

We reviewed all available data on population size, area of occupancy, and threats, using those identified by Wilson (2016), with additional demographic information from Waugh *et al.* (2015a). See Table 2 for terrestrial threats and Table 3 for marine threats.

Species population size

The estimated population size in 2011 was 2827 breeding pairs in 26 colonies (95% CI = 2143–3510; Baker *et al.* 2011). The population size assessment from this comprehensive quantitative survey was broadly similar to that provided by more qualitative surveys (Wood & Otley 2013), which estimated 3000–5000 breeding pairs in 2005, in 29 colonies. The difference in colony number may be a result of variation in colony boundary definition and does not indicate that Baker *et al.* (2011) missed three colonies. However, as Wood & Otley (2012) did not provide accurate maps, it is difficult to assess where these differences in colony boundaries occurred.

TABLE 3
Assessment of marine threats to Westland Petrels[a]

Marine threat	Severity	Scope	Notes and references
Bycatch in commercial fisheries, New Zealand Exclusive Economic Zone (NZ EEZ)	High	High	Analyses for the Ministry for Primary Industries (Richard & Abraham 2015) place the species 10th most likely to suffer adverse population effects as a result of commercial fishing within the New Zealand Exclusive Economic Zone, with "High" risk ranking.
High-seas and out of NZ EEZ fishery captures	Unquantified	High	Possibly occurring during non-breeding migration. Although data relating to Westland Petrels are sparse, capture of *Procellaria* petrels is common in the areas occupied between breeding seasons.
Bycatch in recreational fisheries	Unquantified	High	The level of capture in recreational and customary fisheries within New Zealand waters is unknown, but some band returns from fishers indicate some mortality.
Climate change and consequent changes in the marine environment	High potential	High potential	May increase difficulty in finding food.
Fishery discards as food source	Unquantified	High	Fishery changes within the petrels' foraging zone could lead to reduced chick production, but is unquantified. Analyses of the influence of fishery activity and climatic influences on diet indicate that climate has equal or greater influence (Waugh *et al.* unpubl. data).
Plastic entanglement or ingestion	Low	High potential	No plastics have yet been reported in diet samples collected 20 years ago (Freeman 1998), nor has plastic debris been observed at the colonies. However, as the incidence of plastics in areas occupied by the Petrels will increase, the threat to the birds will increase.
Storm wrecks	Negligible	Low	Not considered to affect Westland Petrel populations adversely at current levels, as no Westland Petrels were observed killed in extensive storms in 2011 (Miskelly 2011a, b *in* Jamieson *et al.* 2016).

[a] Details as for Table 2.

Area of occupancy

The area occupied by the species for nesting is variously reported: 16 km^2 by Lyall *et al.* (2004) and 3 km^2 by BirdLife International (2016), with no explanation of the survey method for either record. However, the species occupies only a small proportion of the 16 km^2 protected area identified by Lyall *et al.* (2004), with concentrations of burrows in localised areas (termed "colonies") within a rugged, heavily dissected landscape. The petrel's occupancy of the 16 km^2 protected area is best described as fragmented. Few burrows (perhaps only a few dozen) are found outside the boundaries of the protected area.

The area of occupancy reported by Wood & Otley (2012) was 73 ha, but this figure is difficult to reconcile with data from GPS-mapped transect surveys (Baker *et al.* 2011), in which the total area of burrowed terrain was reported as 0.16 km^2, made up of 26 discrete colonies. Baker *et al.* (2011) reported the first rigorous and repeatable transect survey that estimated colony surface areas and conformed to a recognised survey methodology (ACAP 2011). We consider that 0.16 km^2 reported in that survey is the most robust, global estimate of the actual area of breeding habitat that Westland Petrels occupied in 2011. No subsequent all-colony surveys have been conducted.

Our own GPS mapping and transect surveys conducted in 2016 of four colonies in Scotsman Creek catchment (Study Colony, Rowe, and two others—Middle and Noisy Knob) showed that the petrels occupied 26 860 m^2. Two additional areas that could not be surveyed due to land instability covered an estimated 7 073 m^2. The areas surveyed were comparable to those mapped by Baker *et al.* (2011), and, based on our GPS mapping, totalled 41 713 m^2. The differences between the Baker *et al.* (2011) estimate and our survey was 7 780 m^2. This provisional estimate provides an indication of the minimum area of burrowed terrain lost in 2014 as a result of storm damage and attendant land slips at these four colonies (Fig. 1). Aerial surveys by DoC showed that slips and tree-falls occurred across the whole area containing the Westland Petrel colonies (DoC, unpubl. data *in* Wilson 2016). Landslips and ongoing erosion remain a concern. Landslips have occurred about once each decade, but before 2014 probably affected just one colony on each occasion (Wilson 2016). Estimates of the population size, the extent of colonies, and density of burrows following the 2014 storm event are needed to assess the stability of the population and its current zone of occupancy. The ongoing erosion caused by landslips and uprooting of trees also needs to be considered in determining the level of ongoing habitat degradation, or whether mitigation actions can prevent further erosion of nesting areas. More detailed assessments of the survey data and additional surveys are required to provide estimates of the changes in colony size and habitat stability.

Population trends and demographic information

Surveys of burrow density and burrow occupancy were conducted at Study Colony, whose numbers of petrels contribute ~27% of the petrel's global population; both measures indicated a slow increase (density at 0.67% per year during 2007–2014, and occupancy at 0.95% per year from 2001 to 2014; Waugh *et al.* 2015a). Demographic modelling of mark–recapture data from Study Colony indicated an average increase in population size of ~1.8% per year since 1970. Key parameters for examining the impact of threats for the species were adult survivorship (0.917 and 0.954 for non-breeding and breeding birds, respectively) and breeding frequency (averaging 0.46 of adult birds breeding in a given year).

The large Study Colony may not be representative of the other, smaller colonies, which may be subject to different pressures due to predation or habitat quality. Surveys in colonies of different sizes and habitat features are needed. Preliminary analyses indicate that breeding success did not differ significantly in 2014–2016 between Rowe ($n = 8$–11 pairs, average 0.72 ± SD 0.13) and the Study Colony ($n = 24$–31 pairs, average 0.64 ± 0.11), albeit with small sample sizes. Many more nests ($n = 50$ at Rowe, $n = 130$ at Study Colony) are currently monitored. However, due to low breeding frequency in study burrows (only ~0.33 of burrows are used for breeding; Waugh *et al.* 2015a), few eggs are laid annually. Further, major landslips at both colonies in 2014 reduced the number of study nests dramatically (Waugh *et al.* 2015 b). Other small colonies should be monitored for breeding success. The low breeding frequency across colonies should be monitored to understand why productivity from the species is so low, and to assess the ongoing impact of this on population growth. In addition, site- and pair-fidelity should be assessed to determine whether meta-population dynamics might explain the apparent low frequency of breeding.

Threats

In the following sections, we detail the threats that have greatest potential to cause mortality and influence population growth rates (see Tables 2 and 3).

Terrestrial threats: The Westland Petrel nests on steep, densely forested hills of 20–250 m altitude. Burrows are usually concentrated in areas where the ground is relatively open, with adjacent take-off areas (Waugh & Bartle 2013). This is one of the few petrels that still nests on mainland New Zealand, possibly because its large size helps it aggressively resist attacks from land-based predators.

The breeding habitat was severely affected by tropical storm *Ita* in 2014, leading to the damage or destruction of up to half the area of those colonies inspected, together containing up to 75% of the breeding population (Waugh *et al*. 2015 b). Surveys to quantify the impacts are needed, with aerial photography showing damage across the entire petrel habitat (DoC, unpubl. data). The most accessible colonies were surveyed for colony area, burrow density, and occupancy in 2015 or 2016, with analysis ongoing. Tropical storm *Ita* occurred before the laying period, so only those adults visiting their burrows at the time would have been killed. Breeding birds do visit burrows during the pre-laying period, but the number is variable from night to night.

It would be beneficial to assess whether birds were killed during the storm. Knowing the numbers killed would help assess the population level impact of this event. From our field observations, it is probable that breeding birds on the ground at night were killed in the landslips, which occurred during months when birds attend colonies. We do not have direct evidence that birds were killed, and we do not know the time of day that the land damage occurred; thus, we cannot estimate the mortality. The debris fields have not been accessed to identify any bird remains, as these areas remain dangerous to visit.

One could ask whether birds that were not killed, but that lost their burrows and surrounding segment of the colony, could adjust to habitat loss. It seems clear that such long-lived birds could relocate and establish new territories. Indeed, two individual banded birds that had previously bred at a heavily affected small colony (Rowe) were recovered at the larger Study Colony, some 2 km from their previous nesting areas. However, the impact on breeding frequency for affected birds is likely to be substantial, with up to 50% of the area of at least three major colonies affected by severe erosion (in which all substrate was removed), or by uprooted trees destroying or reducing access to burrows. From our observations to 2017, many of these areas remain inaccessible to the petrels, as the resulting massive volumes of tree trunks and rotting vegetation completely obstruct the bird's access to the soil, and upturned tree-root systems have removed all substrate in areas. This environment also provides a hazardous landscape in which to land or move about for the petrels. The lowland podocarp forest present in the colonies is composed of canopy trees of around 15 species, each of which can measure 20–60 m in height and 1–4 m in diameter (Plant Conservation Network 2017); each tree in this temperate rain forest could almost be called an ecosystem, with many hanging vines and epiphytes. The volume of the tree, its foliage, branches and root system, once toppled, is huge. In the affected colonies we have visited, very large volumes of plant material and soil are disturbed and unable to be used by nesting petrels.

The ongoing nature of the erosion is a cause for concern. The 2014 storm caused severe erosion, including parts of some colonies being reduced to exposed bedrock. As most canopy trees were removed from the two monitored colonies, future heavy rainfall events, common in this region with over 2 m rainfall per year, are causing further soil erosion, which threatens a significant proportion of remaining burrows. During the 2014 storm, over 200 mm of rain fell in 24 h, but this is not an uncommon event in this region.

We have yet to find any indication that the number of birds breeding at the two closely monitored colonies has increased as a result of within-colony movement. Monitoring the response of the population—in terms of the distribution of nests, the nest density, and the breeding frequency and reproductive output of birds—should be a high priority for data collection in the future.

Predation by pigs *Sus scrofa* and dogs *Canis familiaris* remains a potentially high-risk threat because of the proximity of these two invasive species to the petrels' nesting habitat. Vagrant dogs have killed petrels at the colonies in the past, and pigs have been liberated nearby by people seeking to establish a pig population for hunting. Dogs killed all Little Penguins *Eudyptula minor* monitored at a small colony 2.5 km from Study Colony in 2016 (K.-J.W., pers. obs.). In 2016, there was an established population of feral pigs within 20 km (J. Washer, pers. comm.; Wilson 2016). Either of these predators has the potential to extirpate entire colonies and should be considered a major threat to the petrel population. Pig invasion is considered more severe than dog predation, as pigs are likely to be more pervasive, more persistent, and harder to eradicate than vagrant dogs. DoC is monitoring only Study Colony on a monthly basis to check for the presence of these introduced species (S. Freeman, pers. comm. in February 2017), but additional solutions, such as fencing, toxic bait stations, or management of buffer land to avoid the arrival of pigs and dogs should be implemented without delay. These threats remain the most pervasive and potentially destructive that we have documented.

Being attracted to lights at night (also called fallout; Rodrigez *et al*. 2017) and striking powerlines may be important threats for the species. The fallout of fledglings appears to lead to higher mortality than powerline collisions. These are assessed as being low risk, with unquantified scope for fallout, as the extent of mortality is unknown (Wilson 2016). Awareness-raising among the local residents is ongoing (Wilson 2016, Westport News 2017) so that many downed petrels may be recovered and released. However, robust planning of housing or industrial development and enforcement of standards around lighting and structures, are necessary to avoid an increase in deaths from these causes.

Human harvest may have taken place since 2010 (Wilson 2016). There has been evidence of unauthorised visits to monitored colonies, as equipment used to extract chicks from burrows was found at Study Colony in 2011. However, it is not known whether these visits were by curious local residents, or to harvest birds at the end of their fledging period. Ongoing monitoring, for example by surveillance cameras, is warranted to assess any such unauthorised access. As this threat affects only the most accessible (albeit, large) colonies, and is unlikely to cause a >1% per annum population decline, it is assessed as low severity and low scope.

Other important but low-severity threats that are likely to affect the entire population (therefore having high scope) include browsing by introduced goats *Capra hircus* and brushtail possums *Trichosurus vulpecula*, which reduces plant cover and increases erosion potential. Goat trampling creates holes in burrows and can increase access to nestlings for the native, but predatory, weka *Gallirallus australis.* Predatory introduced mammals sighted in and around the colonies during 2010–2016 include brushtail possums, stoats *Mustela erminea*, and rats *Rattus* spp., but breeding success (ca. 65% of eggs laid fledge chicks; Waugh *et al*. 2015 a, this study) suggest that their presence may not hinder breeding success at Study Colony. The effects of these predators and browsers at smaller colonies are unquantified.

"Naturally occurring" sources of mortality that may affect adult survival include the entrapment of adult birds in tree branches and vines, which kills a few birds at monitored colonies each year. Pathogens and soil loss through the birds' burrowing activities are considered low-risk threats in terms of both severity and scope. Human impacts on the colony, through visits by researchers and tourists, are monitored. While potentially damaging, these impacts are managed through strict controls on access.

Marine threats: Bycatch remains an important threat to Westland Petrel throughout its range in both breeding and non-breeding periods. It can affect all breeding stages and age groups, so is considered high scope. Fishing mortality occurs throughout the foraging range during breeding, April–October (Richard & Abraham 2015), and probably in their non-breeding range off South America, November–March (Landers *et al.* 2011, Brinkely *et al.* 2000; see below for more details). These fishing mortality threats are considered high risk, due to their potential to increase adult mortality to a point that could lead to a decline of the population of >1% per year (Tuck *et al.* 2001). In models of the Westland Petrel population, adult survivorship differed between breeding and non-breeding birds (those that had breed at least once but not engaged in breeding in a particular year). Non-breeders showed significantly lower survivorship (0.917) compared with breeders (0.954; Waugh *et al.* 2015a). One possible explanation is that the non-breeding birds spend more time in a particular environment than breeders, either during out-of-breeding migration or when in New Zealand waters, and are thus exposed to factors that reduce their survivorship, such as high fishing mortality or low food availability. We therefore do not exclude the possibility that fishing mortality could have a significant impact on the species, to the level of 4% per year on average, and higher in some years (Waugh *et al.* 2015).

These birds feed mainly within 200 km of the coast around central New Zealand during the breeding season (Landers *et al*. 2011). During the non-breeding season, they migrate to South American waters, where they occur as far north as Peru (Brinkley *et al*. 2000) and as far south as Patagonia (Landers *et al*. 2011). Westland Petrels are strongly attracted to fishing vessels and feed readily on baits and discards (Freeman & Smith 1998, Freeman 1998, Freeman & Wilson 2002). They may be captured in a range of commercial, artisanal, and recreational fisheries. Assessment of the likelihood of capture by New Zealand commercial fisheries indicates that trawl, bottom longline, and surface longline fisheries account for 88 (95% confidence interval 37–183) fatalities annually (Richard & Abraham 2015). The species is considered at high risk of adverse population effects from New Zealand commercial fisheries (Richard & Abraham 2015), ranking 10th among 80 species assessed. The level of capture in non-commercial New Zealand fisheries and fisheries outside of New Zealand is unquantified.

Other marine threats assessed as of lower severity and scope include the prediction that storms will become more extreme and more frequent (Rhein *et al.* 2013), leading to further erosion at breeding colonies. Through changes in the marine environment, storms may reduce foraging returns for breeding petrels (high potential severity and scope). Changing fisheries practices may lead to a reduction in food supply, as the petrels frequently feed on discards from trawl fisheries during the breeding period. The impacts of future changes are unquantified, but may affect a large proportion of the population. Such impacts require complex data to interpret, but should be considered for future fisheries management and research on petrel threat assessment. Plastic ingestion or entanglement has not been noted for Westland Petrels at their colonies to date, and is rated as low severity, but has high potential scope. Storm wrecks were assessed as having negligible severity and low scope, as very few deaths have been reported for Westland Petrels, while other species, such as prions *Pachyptila* spp., have been heavily affected by storm events in recent years in southern New Zealand (Miskelly 2011a, b, cited *in* Jamieson *et al.* 2016).

Threat assessments

Threat assessments for the species were undertaken by DoC in 2016 (Robertson *et al*. 2017), and a review was initiated for the IUCN Redlist in 2016, both within reviews of multiple species. These assessments are useful in providing a generic overview of conservation and research priorities when applied to many different taxa. As such, they may have limited scope in assessing the specific circumstances of particular species. For example, those with particular life-history traits or particular spatial distributions may have additional vulnerabilities, poorly captured by one-size-fits-all classification systems (Master *et al*. 2012).

Our analysis points to several threats that may result in population declines for Westland Petrel, which are not included in threat assessments completed before 2017. Information on population distribution and size used in these generic threat assessments is out of date. This may influence the level of severity of threat recognised for the species. A final factor to consider is the potential threats to the species from two introduced predators—dogs and pigs—that have strong potential to quickly decimate the Westland Petrel population. While neither currently (in 2017) occur within the petrels' breeding colonies, both could reach the colonies unobserved at any time. The threat classification systems and conservation priority-setting systems appear to deal poorly with potential threats, rather than measured or observed threats, regardless of how serious they may be.

Department of Conservation threat classification: A review of the national threat classifications (Townsend *et al*. 2008) for New Zealand seabirds was conducted in 2016 (Robertson *et al*. 2017). The information available in July 2016 was reviewed, excluding detail provided by Wilson (2016). The DoC panel recommended that the threat assessment of At Risk, Naturally Uncommon be retained for the species.

IUCN threat assessment: The latest review of the threat status of Westland Petrels undertaken in 2016 (IUCN 2017) reused information from the 2012 assessment, without incorporating more recent information, and listed the threat status as Vulnerable. Based on our assessment of a revised area of occupancy (0.16 km^2) and significant ongoing degradation of habitat, we submit that a revision of the threat status from Vulnerable to Endangered is warranted (IUCN 2012). This assessment is based on criteria B (<500 km^2 of occupied area), B2a (fragmented occupancy, with 20 or more colonies totalling 0.16 km^2 within the single site), and 2biii

TABLE 4

Suggested revision of threats for the ACAP assessment (ACAP 2011), showing a summary of known threats causing actual or potential population-level changes of greater than 10% over 10 years at the breeding site of the Westland Petrel[a]

Breeding site	Human disturbance	Human take	Natural disaster	Parasite or pathogen	Habitat loss or degradation	Predation by alien species	Contamination
2008 assessment (ACAP 2011)	No	No	No	No	No	No	No
2016 assessment (this study)	No	Occurring but not a threat [b]	Yes [c]	No	Yes [c]	Yes [d]	No

[a] These ratings are based on the assessment of threats in this study, and those described in Wilson (2016) and Waugh *et al.* (2015a).

[b] Human take is suspected in the past 5 years, as burrow lids removed at two monitored colonies and muttonbirding equipment was found at one colony.

[c] Habitat loss through landslips and windfall of trees has resulted in the loss of breeding habitat, reduction in habitat quality, and some adult mortality at two major colonies, with ongoing erosion at these and others.

[d] There is a strong potential threat of dog and/or pig predation.

(ongoing decline of habitat quality due to erosion at the slips and windfall sites documented following the 2014 storm). Data required to provide a population trend assessment are currently lacking and should be a high priority.

ACAP threat assessment: The information presented herein has been assessed according to the ACAP threat severity and scope matrix (ACAP 2014). This information was presented in summary form for all ACAP species by Phillips *et al.* (2016), but the information herein is more up-to-date and accurate. Our assessments using the ACAP system are presented in Table 4. We included three terrestrial threats that present observed or potential risk to the population stability, at a severity level of High (Table 2). Two of these most severe threats relate to potential predation by dogs and pigs.

Some threats are known to kill tens to hundreds of individuals annually (fallout, fishing mortality) or to adversely affect the breeding habitat (storm damage and ongoing erosion of nesting substrate at major breeding colonies). Currently, however, the data required to assess the impact of these threats to the petrel population are lacking to enable these to be included in the ACAP assessment.

CONCLUSIONS

We conducted a comprehensive review of the threats affecting the endemic Westland Petrel, restricted to breeding at one locality on the mainland of New Zealand. Our review showed that a number of threats have not been considered in the existing threat classifications for the species, prompting the need for reviews of the Westland Petrels threat status under the DoC, IUCN, and ACAP systems.

On the basis of the information reviewed, we suggest that the ACAP species threat assessment warrants revision, with some evidence of minor human take in the last five years, extensive degradation of limited breeding habitat, and potential predation all posing population-level threats. Indeed, the extinction risk for species occupying a single site is particularly high (Ricketts *et al.* 2005), with conservation action needed before these species reach the brink of extinction.

The New Zealand threat classification system places little priority on species that number >5 000 mature individuals, ranking the Westland Petrel as At Risk, Naturally Uncommon—the seventh of the Threatened or At Risk categories of threat, and just one rank above Not Threatened. At a national scale, with many pressing priorities for conservation and species recovery, this ranking may be understandable. At a global scale, however, New Zealand has more threatened endemic seabirds than any other nation (Croxall *et al.* 2012). It is therefore irresponsible to wait until a species declines to <5 000 individuals, or suffers a 10–30% decline—the criteria for changing the conservation status to a more severe one—before increasing its priority for monitoring, research, or recovery. Allowing a population to decline to such small numbers, increases the risk that stochastic events will cause rapid population declines or that genetic bottlenecks will negatively affect population productivity (Briskie & Macintosh 2004, Jamieson 2011).

The resources required for estimating population changes, range contractions, or habitat degradation are difficult to obtain. Thus, many important conservation priorities may be overlooked and remain undocumented for this species. Baseline estimates of population sizes for this species have only recently been established, and further work is needed to understand whether the populations are stable, declining, or recovering. With good baseline surveys completed in 2011 for this species, the research and conservation management groups are in a good position to secure the species recovery to non-threatened status, using an evidence-based approach. We commend efforts to improve the knowledge base for this species and encourage resource managers to continue the good work started 10 years ago by completing repeat surveys and investigating areas where potential threats may be operating. It is crucial that we move beyond the "ambulance at the bottom of the cliff" approach and instead create appropriate resource-monitoring frameworks for the threatened and endemic wildlife of New Zealand.

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