A review of the biology and ecology and an evaluation of threats to the Westland petrel *Procellaria westlandica*

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A Westland petrel. Photo by Kerry-Jayne Wilson

Executive summary

The Westland petrel (*Procellaria westlandica* Falla 1946) is an endemic seabird that breeds during winter in broadleaf/podocarp rainforest on coastal hills near Punakaiki on the South Island West Coast (Waugh & Bartle 2013, Wood & Otley 2013). Prior to human arrival 16 species of Procellariiformes (albatrosses, petrels, shearwaters and storm petrels) bred on the New Zealand mainland (Holdaway *et al*. 2001) but only the Westland petrel was large enough and feisty enough to survive in lowland habitats where almost all introduced predators are common.

The Westland petrel colonies are the best remaining mainland examples of a seabird dominated ecosystem. In these ecosystems the seabirds are keystone species; enriching the soils with their guano plus dead eggs, chicks and adults, resulting in high levels of soil nitrogen and phosphorous; these elements then move through the terrestrial and freshwater food chains (Harding *et al*. 2004, Hawke & Holdaway 2005, Warham 1996). Seabird dominated ecosystems were once common on the New Zealand mainland but, other than the Westland petrel colonies, these lowland ecosystems remain only on offshore islands. The Westland petrel colonies are crucial in understanding the role seabirds have played in soil ecology in New Zealand (see Hawke & Vallance 2015 and references therein). Westland petrel conservation is about more than just the species; also at risk is the last lowland example of a seabird dominated ecosystem on the mainland.

Quantifying the threats to petrels, particularly burrow-breeding species is fraught with difficulties. Due to their demographic features of a long life expectancy, delayed breeding, a single egg each breeding season, tendency to skip breeding seasons and naturally high adult survival, even a small increase in adult mortality can tip a population into decline. In order to determine population trends and thus recognise threatening processes, long-term monitoring of key demographic parameters is required. For burrow breeding species obtaining those demographic parameters is at best challenging. For most New Zealand species estimates of population size are so inaccurate that a population could be reduced by quarter or more and the threat operating for some years before that decline was recognised. Petrels are subject to multiple potential threats on both land and at sea. Most species, including the Westland petrel, regularly move between the EEZs of several nations and spend time on the high seas, further complicating their conservation management.

In comparison to most New Zealand burrow breeding petrels the Westland petrel is in a better position that most when it comes to identifying threats. Their restricted breeding range has allowed their breeding distribution to be mapped and breeding numbers estimated (Baker *et al*. 2011, Wood & Otley 2013) with better precision than for most other New Zealand breeding petrels. For Westland petrels there is a 40+ year history of population monitoring and breeding biology research. While there are gaps in the data during those 40 years and data collection has not always been consistent, a robust demographic analysis has been published (Waugh *et al*. 2015a) which indicates that the largest colony at least has increased by about 1.8% per year between 1970 and 2012.

Breeding success in burrow breeding petrels varies from near zero in the presence of introduced predators to over 80%, with 40-50% being common (Warham 1990). Breeding success for Westland petrels has been determined for a number of seasons since 1970 and this shows breeding success (percentage of eggs laid resulting in fledged chicks) to have increased from lows in the early 1970's when muttonbirding still occurred to 50-60% in recent decades, which should be sufficient to maintain the population (Waugh *et al*. 2006, 2015a). Annual survival of adults, at least in the Study Colony, is high, 0.96/year for breeding birds and 0.73 per annum for those that skipped breeding (Waugh *et al*. 2006). Breeding success within this range, in combination with the high adult survival rates, suggests that predation at the nest is unlikely to be influencing population dynamics in the large Study Colony (Waugh *et al*. 2006). So long as high adult survival rates continue little management work appears to be needed at that breeding colony (Waugh *et al*. 2006, 2015a). More data on mate tenacity from season to season are desirable.

Research by Sandy Bartle between 1969 and 1995 indicated that breeding success and population dynamics in smaller colonies may be different from that in the large colony where that demographic analysis was carried out. More information on population trends and breeding success in smaller colonies is desirable. Currently only one of the smaller colonies (Rowe Colony) is monitored.

In any one year half or more of breeding age Westland petrels do not breed, including birds that had bred successfully in previous years (Waugh *et al*. 2015a). The reasons for the low numbers breeding and the relatively low rate of burrow occupation are not known and need investigation. As non-breeding birds had a lower survival rate than breeding birds, sustained losses of non-breeders due to changes on the marine environment could result in a smaller pool of potential breeding birds once conditions again became favourable (Waugh *et al*. 2015a). Adult survival was negatively correlated with sea surface temperature anomalies in New Zealand but positively correlated with sea surface temperature anomalies in Chile (Waugh *et al*. 2015a). Further research into the environmental influences on adult survival and why adults switch between breeding and non-breeding is important.

Land-based threats have been well documented and most addressed to some degree at least. The major land-based unknowns are mortality due to disorientation by lights, the impact of landslides and storm events, and the impact goats have on the breeding habitat. In the past dogs have killed both adults and chicks but there is no recent evidence of them accessing the colonies. A single dog entering a colony could kill dozens of birds in a single night. It is important to ensure locals are aware of the issue and keep dogs under control. Feral dogs must be dealt to immediately.

Pigs are an even greater threat to the petrels as they can destroy breeding habitat as well as killing adults, chicks and eggs. Pigs have been released into the area on several occasions in order to establish a population for hunting. With the current level of visitation by researchers or conservation workers an incursion by pigs could do enormous damage before it was noticed and the pigs culled.

Changes in land use on the Barrytown Flats and privately owned land adjacent to the breeding areas has the potential to impact on the petrels. For several decades there were plans to mine the Barrytown Flats and site the processing plant beneath the Scotsman's Creek flyway. Lights from the processing plant and the noise from machinery would have had a huge impact on the birds. Those plans have been cancelled and the planned processing site is now undergoing habitat restoration. However, there has been recent interest in mining on the flats. Any changes in land use on the Barrytown Flats, in the Punakaiki River valley and other land adjacent to the specially protected area or close to flyways must consider their potential impact on the petrels.

Westland petrels are disorientated by the lights of Punakaiki and to a lesser extent Westport, Greymouth and Hokitika. These birds land beside lights in places where they are unable to take flight again. Apparently both recently fledged chicks on their maiden flight and birds that have successfully been at sea are grounded by lights. However neither the number of birds grounded, their fate nor the locations and dates of groundings have been systematically recorded and rectifying this should be a priority. This research could involve volunteers in the search, collection and reporting of grounded petrels. Considering the distance between West Coast towns, public participation in the study would be especially desirable and thus would also serve to raise awareness and appreciation of the birds. Due to likely annual variation in numbers affected I propose an initial three year study starting in 2017 which would include setting up ongoing monitoring of fallout at key locations. Ideally large numbers of chicks would be banded on the colonies prior to fledging and all unbanded chicks handled would be banded on release.

Marine based threats may influence seabird populations by affecting adult, juvenile or pre-breeding survival, breeding success, age of first breeding, the ability of adults to attain breeding condition or any combination of these factors. The data most often collected, and some of the best data we have to assess threats to Westland petrels is breeding success. It is possible that breeding success may be high, but few pairs commence breeding, thus the population may decline while breeding success is high. The data available do not allow a robust comparison of numbers of chicks fledged in recent seasons with numbers produced in previous decades.

While the documentation of terrestrial threats is relatively straight forward, marine based threats are poorly documented and difficult to quantify. The two studies on the foods of Westland petrels show that they are adaptable, take a moderately wide range of near surface fish and squid species, as well as scavenging from fishing vessels (Freeman & Wilson 2002). Satellite tagged birds had longer foraging trips than non-tagged birds, presumably due to the extra work of carrying the unit, but they all successfully fledged chicks of normal weight (Freeman *et al*. 2001) indicating that Westland petrels were able to compensate for variations in food supply. As the hoki season finished two months before chicks fledged it showed that parents could satisfy the demands of growing chicks without recourse to fisheries waste (Freeman & Wilson 2002). It should be noted that it is now 20 years since the field work for those studies was undertaken.

Threats analyses indicate that the Westland petrel is the 10th most threatened seabird from commercial fisheries in New Zealand (Richard & Abraham 2013), an increase in threat ranking since the previous assessment in 2013 and current research on at sea distribution may well raise the threat ranking further (S. Waugh *pers comm*. May 2016). The fisheries posing greatest risk to Westland petrels have been identified by Richard & Abraham (2013). Of the trawl fisheries the hoki fishery poses the greatest risk to Westland petrels with most petrels being caught off the South Island West Coast. The inshore trawl and flatfish trawl fisheries also pose some risk to Westland petrels (Richard & Abraham 2013).

The numbers of Westland petrels killed by bottom long-liners is not well documented, confidence limits for the Annual Potential Fatalities (APF) remain large however; the hapuka fishery and minor long-line fisheries appear to be the bottom long-line fisheries from which this petrel is most likely at risk (Richard & Abraham 2013).

As opposed to bottom long-line fisheries, the risks posed by surface long-line fisheries to Westland petrels is more certain, confidence levels for APFs are smaller. Vessels less than 45 m in length seeking southern bluefin tuna appear to pose a greater threat to Westland petrels than any other single surface long-line fishery with bigeye and swordfish long-line fisheries also posing some risk (Richard & Abraham 2013).

Given that the ecology of Westland petrels is better researched than that of many other species the Department of Conservation has only one research project, a population census in 2018/19 funded through the Conservation Services Programme (2016).

For Westland petrels the Conservation Services Programme (2016) has identified greater observer coverage to be required for the hoki trawl, hapuka bottom long-line and minor bottom long-line fisheries, and recommends observer coverage be increased for the flatfish trawl and inshore trawl fisheries. Greater use of mitigation measures to protect Westland petrels is required for those vessels less than 45 m in length using surface long-lines in pursuit of southern bluefin tuna, and recommended for the hoki trawl, hapuka bottom long-line, minor bottom long-line and swordfish surface long-line fisheries (Conservation Services Programme 2016).

There is limited information available for inshore trawl fisheries in the Karamea, Cook Strait, South Westland and Marlborough areas where bycatch of Westland petrels is possible. The extent of bycatch of Westland petrels by recreational fisheries in New Zealand is unknown.

Virtually nothing is known about bycatch of Westland petrels while in South American seas and this is potentially the most serious threat to the species. Documenting bycatch in South America is the highest priority research recommendation and steps to mitigate South American bycatch are the highest priority management recommendations to come out of this report.

There is no information on how or even if changes to the food chain caused by fishing may impact Westland petrels. There is no anecdotal evidence to suggest this is occurring but equally so, no reason to believe it does not. Possible trophic shifts in the foods taken by Westland petrels are being examined by Sue Waugh at Te Papa by comparing stable isotopes in samples from museum specimens with those taken from live birds.

Climate change and the associated changes in marine conditions will impact many species of seabirds but this is very poorly studied in New Zealand. There is no data to help predict ways in which climate change and associated changes in the marine environment will affect Westland petrels. Sea surface temperature in those seas around NZ used by Westland petrels is likely to increase which will probably impact negatively on Westland petrels (Waugh *et al.* 2015a). Research into the ways climate change may affect New Zealand seabirds, not just Westland petrels is urgently required.

Introduction

The Westland petrel (*Procellaria westlandica* Falla 1946) is an endemic seabird that breeds during winter in broadleaf/podocarp rainforest on the coastal hills between the Punakaiki River and Lawsons (Waiwhero) Creek[1], just south of Punakaiki on the South Island West Coast (Waugh & Bartle 2013, Wood & Otley 2012). Prior to human arrival 16 species of Procellariiformes (albatrosses, petrels, shearwaters and storm petrels) bred on the New Zealand mainland (Holdaway *et al*. 2001) but only two still have substantial mainland colonies. The other mainland survivor, Hutton's shearwater (*Puffinus huttoni*) remains only at high altitude in the Kaikoura Mountains. All others are now extinct or very rare on the mainland following the arrival of introduced mammalian predators. Only the Westland petrel was large enough and feisty enough to survive in lowland habitats where almost all introduced predators are common.

The Westland petrel colonies are the best remaining mainland examples of a seabird dominated ecosystem. In these ecosystems the seabirds are keystone species; enriching the soils with their guano and to a lesser extent, dead eggs, chicks and adults, resulting in high levels of soil nitrogen and phosphorous; these elements then move through the terrestrial and freshwater food chains (Harding *et al*. 2004, Hawke & Holdaway 2005, Warham 1996). By digging their nesting burrows the birds turn over and aerate the soils while the trampling action of thousands of tiny feet restrict seedling growth and influence vegetation composition. Seabird dominated ecosystems were once common on the New Zealand mainland but, other than the Westland petrel colonies, these lowland ecosystems remain only on offshore islands. Local extinction of petrel colonies following the introduction of terrestrial mammals by Polynesian and then European settlers has resulted in significant changes to soil chemistry (Hawke & Powell 1995) and understanding how soils have been influenced, first by the presence of seabirds, and then by their localised extinctions is important in a country dependant on agriculture. The Westland petrel colonies are crucial in understanding the role seabirds have played in soil development and soil ecology in New Zealand (see Hawke & Vallance 2015 and references therein). Westland petrel conservation is about more than the just species; also at risk is the last significant mainland lowland example of a seabird dominated ecosystem.

Like most burrow-breeding petrels they are nocturnal on land, returning to their colony after dark and departing for sea shortly before dawn. They lay a single egg in May or June which both parents take turns to incubate. The chick is brooded by one or other parent for up to six weeks, thereafter chicks are left alone in their burrow, parents visiting only to feed them, until they fledge in November or December. During the March to November breeding season Westland petrels feed mostly over shelf waters around the South Island and Cook Strait. Westland petrels migrate to South American seas between breeding seasons, most remaining off Chile with some rounding Cape Horn into Argentinian waters (Brinkley *et al*. 2000, Landers *et al*. 2011a).

The most thorough review of Westland petrel biology is in the Handbook of Australian, New Zealand and Antarctic Birds (Marchant & Higgins 1990) although this is now largely out of date. Recent but less comprehensive reviews are ACAP (2012) and Waugh & Bartle (2013). The latter is an online resource also containing photos and sound files. The Department of Conservation fact sheet (DOC 2016) is a useful introduction to the species.

The Department of Conservation has produced a recovery plan for the species (Lyall *et al*. 2004) with reviews of progress in 2005 and 2010 (DOC 2005, 2010). These reviews provide detailed information on those research and management recommendations identified by the recovery plan, few of which have been addressed.

[1] This creek is named Waiwhero on the current topo map but is labelled Lawsons Creek in many Westland petrel papers and reports.

Status

The Westland petrel is classified as naturally uncommon by the Department of Conservation (Waugh & Bartle 2013) and vulnerable by IUCN (ACAP 2012). The population trends have been uncertain as it has been difficult to assess the reliability of the various estimates that have been made. The species has generally been thought to be in decline following earlier population increases (Bartle 1974, Marchant & Higgins 1990), Bartle (1985a) even suggesting that the population doubled prior to the 1980's, although in retrospect such a large increase seems unlikely. More recent estimates based on transect surveys and burrow occupancy rates suggest the species, or at least the Scotsman's Creek[2] Study Colony, is slowly increasing (Waugh *et al*. 2015a). That study colony represents 25.4% of the total breeding population (Wood & Otley (2013); observations suggest that the trends in smaller colonies may be quite different. Baker *et al*. (2011) and Wood & Otley (2013) estimate the total population to be about 3000 breeding pairs. Breeding frequency appears to be a major factor limiting population growth, with birds that have previously bred often skipping a breeding season (Waugh *et al*. 2015a). They estimated that only about half of the birds bred in any given year. The total Westland petrel population is probably at least 6,000 - 10,000 birds.

About 75% of known burrows occur within a Specially Protected Area within Paparoa National Park; about 20% are in the Dick Jackson Memorial Reserve owned by the Royal Forest and Bird Protection Society, with the remaining 5% on private land (Figure 1).

Access to the Specially Protected Area is by permit only and restricted to people engaged in research or management of the petrels; this effectively also applies to the Dick Jackson Reserve. A low impact eco-tourism venture provides stringently controlled visitor access to a colony on private land owned by Denise Howard and Bruce Stuart-Menteath (http://www.petrelcolonytours.co.nz).

Justification for this project

Breeding on land and feeding at sea Westland petrels are exposed to a wide variety of both land-based and marine-based threats including predation by introduced mammals, weka, free-roaming dogs, feral pigs, powerline strike, disorientation by lights, habitat destruction through farming, mining and forestry, landslides, habitat modification by browsing mammals, trampling of burrows by people and feral goats, bycatch in longline trawl and set-net fisheries (Lyall *et al*. 2004, Rowe & Taylor 2006). Proposals to mine the Barrytown Flats for titanium ore and process the ore at a plant beneath the Scotsman's Creek flyway were shelved after decades of discussion.

Uncertainty remains over the status of the Westland petrel and, while the species faces numerous real or potential threats, the actual impact posed by each has not been systematically assessed. Thus conservation management has been limited and few attempts made to quantify, let alone address, any threats to the species. In the last decade there have been three DOC reviews of the species (Lyall *et al*. 2004, DOC 2005, 2010) yet due to uncertainty of the actual impact posed by the numerous potential threats, management of them has been limited. Uncertainty over the effectiveness of any proposed management has been a common justification for inaction.

[2] This is called Scotchman's Creek in many reports and papers concerning Westland petrels.

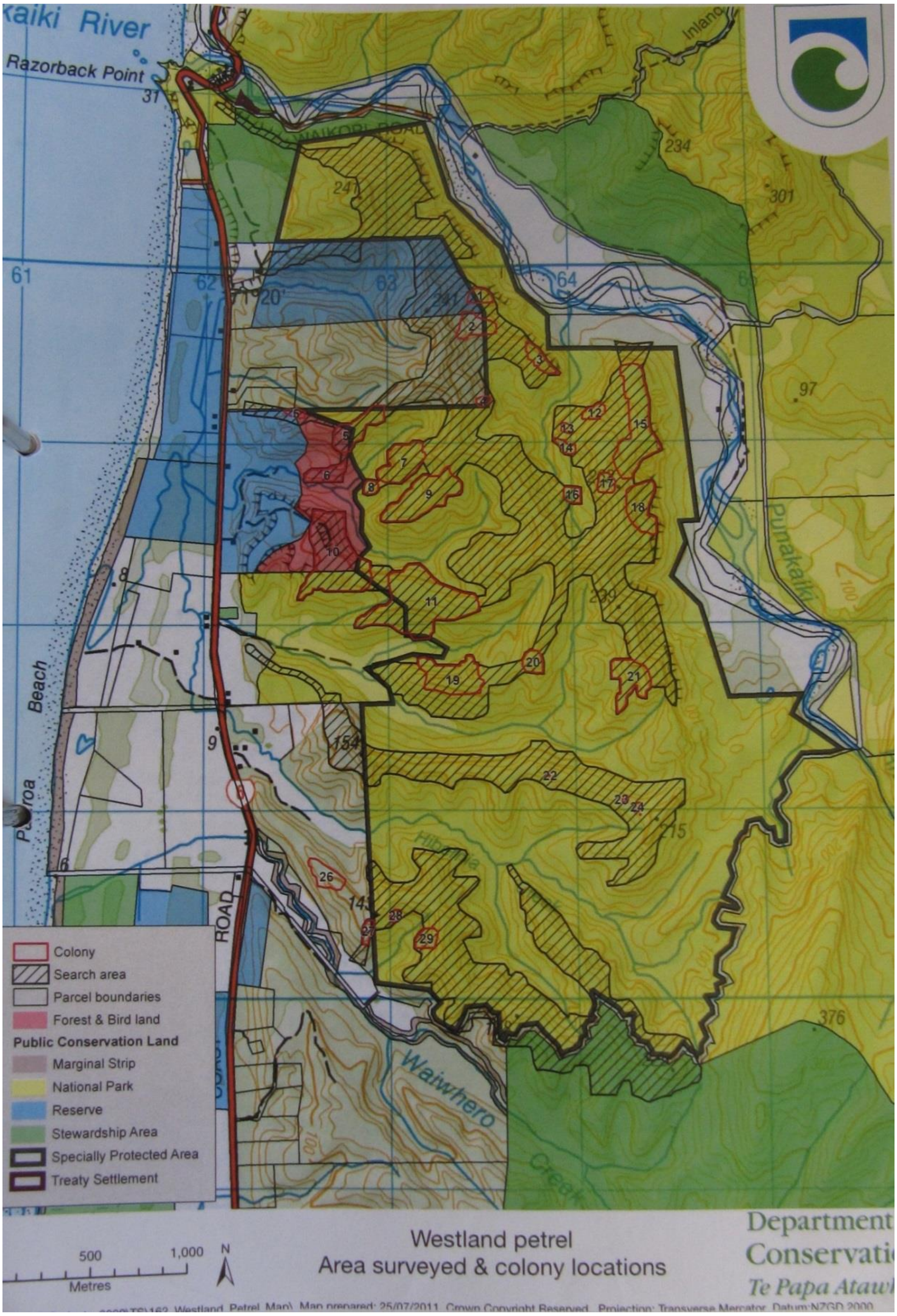

Figure 1. Distribution of Westland petrel colonies showing the Specially Protected area and surrounding land tenure.

Objectives of this study

This study is a rigorous attempt to determine which threats to the petrels are, or are likely to be, the most important. This report reviews relevant published and unpublished studies of the species, lists all threats that have been suggested and assesses the evidence for and against each. It identifies research and management priorities for protection of the species.

The first section of this report reviews the information available on the biology and ecology of the Westland petrel, in order to identify important gaps in our knowledge and secondly to provide the information needed to assess threats. The second part of this report lists actual and potential threats to the species and assesses the likely impact of each. The final section lists the research and management priorities identified in approximate order of priority. Some are more practical than others; unfortunately those of highest priority tend to be the most challenging and expensive.

Westland petrel biology; a review

Taxonomy and history

The species was bought to the attention of scientists in 1945 by the pupils of the Barrytown School. The children had listened to a nature talk by Dr R.A. (later Sir Robert) Falla on National Radio, in which he described Maori muttonbirders taking fledgling sooty shearwaters (*Puffinus griseus*) in April and May. The children wrote to Falla pointing out that their fathers went muttonbirding (illegally) in November. Falla, aware of no petrel that fledged young in November, visited Barrytown and was escorted to the colony of these then unknown birds by the muttonbirders. Falla initially treated the Westland petrel as a subspecies of the black petrel (*Procellaria parkinsoni westlandica*) but by 1953 it had been accorded its present full species status (Gill *et al*. 2010).

The Westland petrel is one of the largest of the burrow-breeding petrels; for sexed birds weighed during incubation, females 1230 g (N=86, SD 106 g), males 1320 g (N =109, SD 133 g) (S. Waugh unpublished data). Head length and bill depth are the only reliable measurements for sexing most individuals (Landers *et al*. 2011b).

Figure 2. Part of the Rowe Colony where in 1945 muttonbirding fathers of Barrytown school children introduced Dr R.A. Falla to the Westland petrels. Photo by Kerry-Jayne Wilson

Distribution and abundance

On land

Westland petrels breed in 21 to 29 colonies (different observers have drawn differing boundaries, some linking, others separating adjacent colonies) between the Punakaiki River and Lawsons Creek the two just 4.5 km apart (Figure 1). Colonies range from 50-200 m above sea level; all are in broadleaf/podocarp rainforest in coastal hills (Jackson 1958, Wood & Otley 2013). The breeding colonies are all on steep, densely forested, mudstone hills, a challenging environment for people attempting research or management of the birds.

The breeding range of Westland petrels was apparently always restricted to the Punakaiki area; the only verified records from outside their current breeding range are Quaternary fossils from Cairns Tomo, Bullock Creek, just north of Punakaiki and a single bone from Tory Canyon Cave in the Tiropahi Catchment south of Charleston (Worthy & Holdaway 1993, 2002). Quaternary fossils from caves near Punakaiki indicate that at least five other species of burrow-breeding petrel probably also bred in the area, including the congeneric black petrel (*Procellaria parkinsoni*) and Scarlets shearwater (*Puffinus spelaeus*) a second species that bred only on the West Coast (Worthy & Holdaway 1993, 2002).

There have been two recent estimates of the total breeding population. The population in the years 2002-2005 and 2010 was estimated to be between 2954 and 5137 breeding pairs (Wood & Otley 2013). Baker *et al*. (2011) estimated there to be 2,827 (95% CI, 2,143—3,510) breeding pairs during the 2007 to 2011 period. Differing methodology probably accounts for the difference between these two estimates, the Baker estimate probably the most reliable. The colonies were mapped by Baker *et al*. (2011).

Westland petrels follow well defined flight paths when moving between sea and colony (Figure 3) and these have been mapped by Best & Owen (1976). The major flight path was up Scotsman's* Creek (NZTM E1462230 N5332900) and Carpenteria* Creek (NZTM E1462150 N5332030), with a secondary flight path following the south bank of the Punakaiki River and just a few flying up Lawsons*[3] (Waiwhero) Creek (NZTM E1462330 N5330810) (Best & Owen 1976).

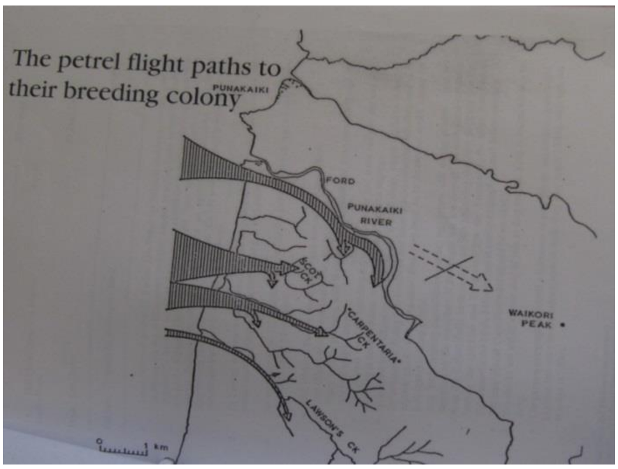

Figure 3. The flightpaths used by Westland petrels when moving between the sea and their breeding colonies, from Best & Owen 1976.

[3] * These place names do not appear on the current NZ Topo 50 map or the 260 K30 Topomap.

At sea

During the breeding season Westland petrels mostly forage in continental shelf waters <1000m deep (S. Waugh, J. Arnould unpublished) north of the sub-tropical convergence off the West Coast of the South Island (from Haast north to the Challenger Plateau), in Cook Strait, off Kaikoura and eastwards to the Mernoo Bank and Chatham Rise (Bartle 1974, Freeman *et al*. 1997, 2001, Landers *et al*. 2011a) (Figures 4 and 5). They are less often recorded seaward of Fiordland, rarely to Stewart Island and sometimes north to Cape Egmont, and on the east coast between Banks Peninsula and East Cape (Bartle 1974, Marchant & Higgins 1990). During winter they are the most common large, dark petrel in Cook Strait and the northern half of the South Island (Bartle 1974). Several Westland petrels were seen near the Chatham Islands in December 1983 (Clark 1989). A few adults and juveniles are seen off eastern Australia.

Current tracking studies by Te Papa scientists who are deploying miniature GPS units on adults during the breeding season, are providing more detailed information on foraging zones and movements. Their research is not yet published but some preliminary data appear in several blogs including one that shows a bird circumnavigating the South Island (Waugh 2012a). That blog contains an animation showing the movements of tracked birds by day and by night.

Westland petrels mostly fed along the shelf break and continental slope in water depths of 200-800 m (Freeman 1997a, Freeman & Wilson 2002). During observations at sea none were seen during nine counts in waters 800-1500 m deep or ten counts in waters less than 200 m deep (Freeman 1997a).

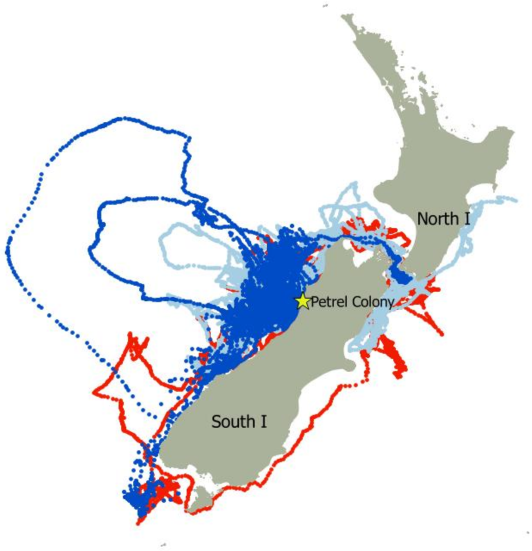

Figure 4. Tracking data from breeding Westland petrels fitted with GPS units during pre-breeding and incubation periods in 2011 (red); incubation and chick rearing in 2012 (light blue) and incubation and chick rearing in 2015 (dark blue). Susan Waugh and John Arnould unpublished data. Figure copyright Te Papa.

Between breeding seasons Westland Petrels migrate to southern South American seas most feeding in the Humboldt Current off Chile with a few rounding Cape Horn to the Patagonian Shelf off Argentina (Brinkley *et al*. 2000, Landers *et al*. 2011a) (Figure 5). Of eight birds tracked year round, six (3 males, 3 females) remained in the Humboldt Current while two (both males) rounded Cape Horn onto the southern Patagonian Shelf (Landers *et al*. 2011a). Fraser (2009) estimated there to be about 400 in the Golfo de Penas and 850 on the Canal Messier, both in the outer parts of the southern Chilean fiords on 17 November 2005.

Of the eight petrels tracked during migration the post breeding (eastward) migration began between 30 September and 30 November 2007 (mean 7 November, five of the eight during November) (Landers *et al*. 2011a). For most birds the return migration back to New Zealand began in March (mean 28 March, range 16 March to 9 April) (Landers *et al*. 2011a). The eight tagged birds took a mean of 6 days (range 4-7) to migrate between New Zealand and South America and 10 days (range 8-13) for the return trip (Landers *et al*. 2011a). On both migratory legs those that departed early tended to take longer to migrate than late leavers (Landers *et al*. 2011a). All tracked birds were breeding in 2007 when tagged and in 2008 when the tags were recovered. A large number of Westland petrels are in attendance at the colonies in March, but the breeding status of these early arrivals is unknown.

In the Humboldt Current System seaward of Peru and Chile, Westland petrels were most common over the Continental shelf (200-1000 m depth) with few in shallower or deeper waters, apparently preferring areas of upwelling (Spear *et al*. 2005). Although they were recorded from southern Peru (20^{o}S) south to 50.72^{o}S they were most common in sub-Antarctic waters south of 40^{o} (Spear *et al*. 2005). With only 20 Westland petrels seen during 1020 hours of observation between 1980-1995, covering 9688 km^{2} and ranging from the coast out to 1725 km offshore, they were much less common than white-chinned petrels (*Procellaria aequinoctialis*) (2114 birds) or even black petrels (179 seen) (Spear *et al*. 2005). Black petrels occurred in warmer more saline waters than the other two species. Spear *et al*. (2005) estimated there were about 3500 (95% CI 2053-6388) Westland petrels in the Humboldt Current System during the Austral Spring and Summer but very few during their breeding season.

Westland petrels appear to undergo their annual moult between October and February while in South American waters, immatures perhaps moulting before older birds (Brinkley *et al*. 2000, Fraser 2009).

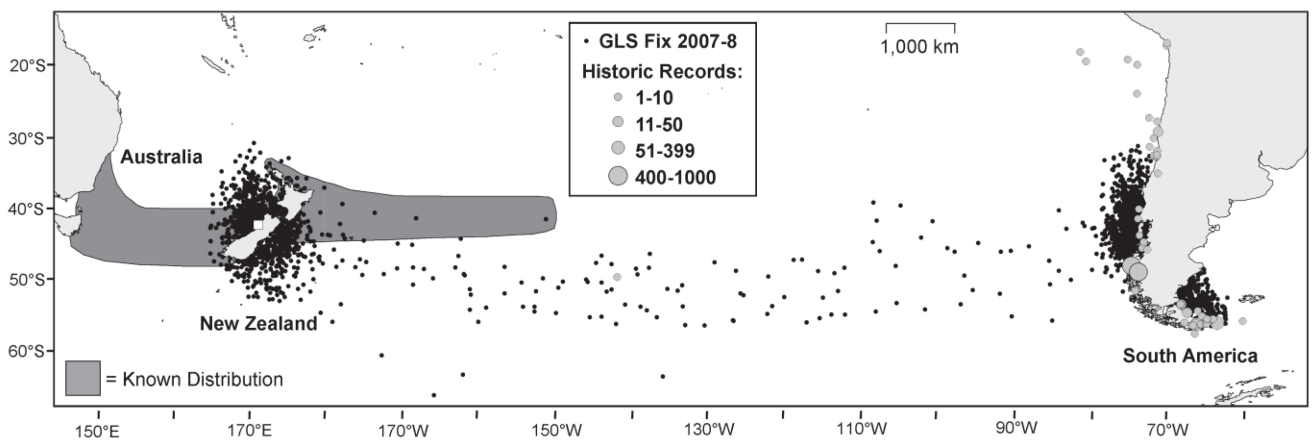

Figure 5. Geolocation (GLS) fixes (black dots) of Westland Petrels from July 2007 to July 2008 with known distribution according to Marchant & Higgins (1990) shown in grey, and previous records (grey dots) from Brinkley et al. (2000) and Fraser (2009). The white square shows their breeding colony in New Zealand. Map from Landers *et al*. (2011a).

Breeding

Westland petrels tend to mate with the same partner in the same burrow year after year. They arrive at their breeding colonies between March and May to prepare previously used burrows or dig new ones. Most burrows are 1-1.4 m long, (mean 1.2 m, range 0.2-2.8 m) (Waugh *et al*. 2003). Their breeding biology and various other aspects of their ecology were studied by Sandy Bartle from 1969 to 1995, much of which remains unpublished. As with all other Procellariiformes a female can lay just one egg each breeding season and they cannot lay a replacement clutch if that egg is lost (Warham 1990). The egg is large in proportion to the size of the female (mean 81.1 x 55.6 mm, 130 gm) (Baker & Coleman 1977).

There is a pre-laying exodus of about 15 days, the first eggs are laid about 12 May and the last laid in early June the peak lay date being 23 May. Incubation takes 57-68 days (mean 64 days) with most eggs hatching between 20 and 26 July (Lyall *et al*. 2004, Waugh & Bartle 2013). As with other petrels, both parents take turns incubating the egg and both feed the chick by regurgitating food they caught at sea. The breeding attempt will fail if either of the parents is killed.

The chick is guarded by one or other parent for between two and six weeks after hatching. The mean length of foraging trips of satellite tracked adults while feeding chicks was 4.1 days (range 1-8 days with out-layers of 13 and 14 days); birds not carrying trackers made shorter trips (mean 1.8 days, range 1-6 days) (Freeman *et al*. 1997, 2001). The first chicks fledge 120-130 days after hatching, the earliest in early November and the last in mid-January, the peak fledgling date is 20 November.

Breeding success, the percentage of eggs laid from which chicks fledge, has generally increased since the 1970's (Table1). The very low success rate recorded by Baker & Coleman (1977) in 1970 and 1971 was caused by losses to muttonbirders, without that breeding success would have been greater. Prior to 1990 fewer than half of the eggs laid resulted in chicks fledgling (Table 1). Since then breeding success has generally been 50% or greater, averaging 60% since 1995 (Waugh *et al*. 2006, 2015a) but with pronounced variations, the best being 84% in 2000, the worst 46.7% the following year (McClellan & Wood 2004). In recent years breeding success has been similar to the congeneric black petrel and higher than that recorded for white-chinned petrels (ACAP 2012). Sandy Bartle (*pers comm.* February 2016) found breeding success was higher in isolated burrows than in those burrows closer to their nearest neighbours.

Between 1997 and 2003, 73.5% (range 53.3-84.0) of eggs laid hatched and 86.9% (range 77.3-100) of hatched chicks fledged, indicating that most breeding failures occur at the egg stage (McClellan & Wood 2004).

Most of these studies have been conducted in Study Colony which is the largest of all Westland petrel colonies. Breeding success in smaller colonies, thus for the species overall may be different.

Year range	Breeding success (fledglings/eggs laid)	Reference
1970	5.7%*	Baker & Coleman 1977
1971	3.0%*	Baker & Coleman 1977
1976-1991	39% (range 20-63%	Bartle 1993
1983-1989	27%**	Bartle 1993 in Lyall *et al*. 2004
1990-1994	59%	Bartle in Lyall *et al*. 2004
1991-1996	50% (range 38-63%)	Freeman & Wilson 2002
2000	84%	McClellan & Wood 2004
2001	46.7%	McClellan & Wood 2004
1995-2003 and 2010	60.7% (+/- 1.19% SD)	Waugh *et al*. 2006, 2015a

Table 1. Breeding success in Westland petrels from 1970 to 2010. *These very low chick survival rates were due to muttonbirding. **The figure of 27% does not appear in Bartle (1993) as indicated by Lyall *et al*. (2004)

Burrow occupancy (percentage of suitable burrows in which eggs are laid) in Westland petrel colonies is low, with fewer than half the available burrows being used in any one year. In the first ever study of this species Jackson (1958) reported that many burrows were unoccupied. Bartle (1985b) recorded burrow occupancy in Study Colony of only 19% in 1983, 52% in 1984 and 42% in 1985; mean occupancy was 48% (range 41-58%) between 1995 and 2003 (McClellan & Wood 2004). Burrow occupancy at Study Colony has increased since 2001 when it was just 21% (+/-2.8) (Waugh *et al*. 2003). Burrow occupancy was highest at 52% (+/- 0.08) in 2012 but declined to 43% in 2013 and 2014 (+/- 0.11 and 0.07) (Waugh *et al*. 2015a). On average eggs were laid in 51% (range 41-59%) of the 60-61 study burrows followed annually from 1995-2001 (DOC unpublished data in Waugh *et al*. 2003). These two estimates are not strictly comparable; the DOC data comes from a subset of burrows followed year after year, while Waugh obtained her estimate by burrowscoping virtually all burrows on Study Colony.

Sandy Bartle (*pers comm*. February 2016) found that a number of males held burrows for consecutive years but never bred. Waugh (*et al*. 2015a) estimated that in any one year 54% of the breeding age population does not bred.

Even at 50% the occupancy rate is lower than that recorded in studies of many other species of petrels. The low rate of burrow occupation may suggest a population decline, alternatively it could be due to a large proportion of burrows being used by non-breeding birds. A population decline seems an unlikely explanation as both Bartle (1974 and unpublished data) and more recently Waugh (*et al*. 2015a) show the population to have increased since the 1970's and is currently stable or increasing slowly (see next section).

Study birds did not breed every year (Bartle 1983, McClellan & Wood 2004) with no apparent pattern to breeding frequency; individual birds appearing to have a run of good, then a run of bad years (Waugh *et al*. 2006). In that study about a third (0.39) of those pairs that bred one year would skip breeding the following year, conversely a third (0.38) of those that skipped breeding one year would breed the following year. A subsequent paper with additional data gives these values as 0.232 (95% CI: 0.156-0.330) breeding to non-breeding and 0.295 (95% CI: 0.190-0.426) non-breeding to breeding (Waugh *et al*. 2015a). Females tended to be less likely to breed in two consecutive years (0.608, 95% CI: 0.524-0.687) than males (0.722, 95% CI: 0.662-0.774). Males were less likely to breed following a non-breeding year than non-breeding females (Waugh *et al.* 2015a). Some birds bred for nine consecutive years (Waugh *et al*. 2006) although this was unusual (McClellan & Wood 2004).

Westland petrels have a strong tendency to use the same burrow and mate with the same partner year after year, although between 1995 and 2003, 7% were found in more than one burrow with occasional changes in partner (McClellan & Wood 2004). Between 1995 and 2003, an average of 0.3% of the individuals on Study Colony changed burrows each year, compared with 1% between 2010 and 2013 (Waugh *et al.* 2015a).

Population trends

It is difficult to determine how the Westland petrel population has changed over time as the early estimates used differing and sometimes poorly described methodologies. In 1955 Jackson (1958) estimated the population to be between 3,000 and 6,000 birds and assumed, due to the large number of unoccupied burrows, there had been a recent decline in their numbers. The number of occupied burrows in the Rowe colony declined during Jackson's three year study. Bartle (1974) estimated the population to be 6,000 - 10,000 birds in 1972. He attributed that apparent increase to fewer disturbances, due to a reduction in logging and mining, and since 1966 the availability of fisheries discards from vessels off the West Coast (S. Bartle *pers comm.* February 2016). Based on 1982 data Bartle estimated that an average of 2,000 pairs bred each year, with a total population of about 14,000 birds (Bartle 1983, 1985b, McClellan & Wood 2004). Numbers on Study Colony increased each year from 1972 until 1988 with the total population peaking at an estimated 20,000 (+/-5,000) birds (Bartle 1985b, 1987, 1993). Bartle (1987) suggested that the increase began as early as 1955 and increases were in the order of 5%/year. Bartle (1987) suggested that a slowdown in population growth after 1979 was a result of a reduction in chick production and survivorship, as the availability of fisheries waste declined. Subsequent mark/recapture studies by Bartle showed numbers on Study Colony continued to increase through to the mid 1990's and the area occupied by that colony increased while burrow density remained stable (S. Bartle *pers comm*. February 2016). Monitoring of a grid within the Study Colony indicated that the population continued to increase between 1997 and 2002 (McClellan & Wood 2004).

A recent paper on Westland petrel demography provides a much more robust analysis of population change (Waugh *et al*. 2015a). They conclude that the Study Colony population averaged a growth rate of 1.8% per year between 1970 and 2012, thanks to high adult survival, moderately high fecundity, strong recruitment of juveniles, very low emigration, and the positive effect of several environmental variables (Waugh *et al*. 2015a). This conclusion was supported by increases in nest occupancy since 2001 and nest density since 2007 (Waugh *et al*. 2015a). The rate of population growth during these four decades is unlikely to have been constant; with rapid population growth during the 1970's and 1980's coupled with the rapid increase in industrial scale fishing during those decades (Bartle in Waugh *et al*. 2015a).

Two recent estimates of the total breeding population are in the same ballpark as estimates of total numbers made by Sandy Bartle in the 1980's. The population in the years 2002-2005 and 2010 was estimated to be between 2954 and 5137 breeding pairs (Wood & Otley 2013). Baker *et al*. (2011) estimated there to be 2,827 (95% CI, 2,143-3,510) breeding pairs during the 2007 to 2011 period. Differing methodology probably accounts for the difference between these two estimates and Baker's estimate is probably the most reliable. These counts are of breeding pairs only whereas Bartle's earlier estimates also included non-breeding birds.

No colonies known to Bartle in the 1970's have disappeared while small colonies have formed since then (S. Bartle *pers comm*. February 2016). He suggested that between the 1970's and the 1990's the southernmost colonies in the Lawsons (Waiwhero) Creek catchment declined while the northern colonies in the Scotsman's Creek area increased.

Another estimate of less than 900 occupied burrows (Best and Owen 1976) cannot be reconciled with other estimates.

Demography

The birds present on the colonies include breeders, failed breeders, burrow-holding non-breeding birds and non-burrow holding pre-breeders. Non-breeding birds out number breeders but there is uncertainty about the ratio of breeding to non-breeding birds. Bartle suggested of the total population non-breeders outnumbered breeders by about five to one (Bartle in Lyall *et al*. 2004) and of those birds on the colony Bartle (unpublished notes) suggested about 30% were non-breeders. The reliability of these estimates is questioned.

Westland petrels are long-lived (20-40 years). On average they first return to the colony when 7.7 years of age; a few when only four or five years old, most will be six or older and a very few were first recorded on the colony when at least 12 years of age (Waugh *et al*. 2015a). The minimum age of first breeding is 5 years (Waugh *et al*. 2006).

Bartle's data (1987, 1993) suggested females suffered higher mortality than males. More than twice as many males than females were captured on the breeding colony and of his 1976 and 1977 study pairs, more than 12 times as many males than females were known to still be alive ten years later (Bartle 1987). However, subsequent research utilising a larger data set found that Bartle's apparent differential mortality was an artefact of catchability and found no difference in survival of the two sexes (Waugh *et al*. 2015a). As with other petrels one bird alone can neither complete incubation nor chick rearing, and the first breeding attempt by a newly formed pair is less likely to be successful than that for established pairs (Warham 1990). Thus the death of a reproductively active adult can reduce the breeding output of its mate for one or two years.

The survival rate for breeding birds was the same for both sexes although breeding birds had a higher survival rate than non-breeders, and non-breeding females tended to have a lower survival rate than non-breeding males (Waugh *et al*. 2015a). Between 1995 and 2003 Waugh *et al*. (2006) found mean survival rates of breeding birds to be 0.96/year (range 0.87-1.00 se 0.04) and those that skipped breeding 0.73 per annum (range 0.46-0.92, se 0.17). The lower rate for those that skipped breeding may be an artefact of birds breeding elsewhere on the colony during the year they were not recovered. Adult survival was influenced by annual variation in the size of the hoki catch, negatively by sea surface temperature anomalies in New Zealand waters and positively by sea surface temperature anomalies in southern Chile (Waugh *et al*. 2015a). Adult survival was higher than that of two congeners the black petrel and white-chinned petrel (ACAP 2012).

There was almost no inter-colony movement of banded birds, of 1516 birds banded as fledglings only two (both males) were later found breeding in a colony different from the one in which they were banded (Waugh *et al*. 2015a). No inter-colony movements of adults have been recorded.

For long-lived species with delayed breeding and a low reproductive rate, changes in population growth rates are most sensitive to changes in adult survival.

Behaviour

There is only one comprehensive study of the on-colony behaviour of Westland petrels (Landers *et al*. 2011c). This paper includes an ethogram for the species and reports on nocturnal and seasonal behavioural rhythms of the birds.

Foods and foraging

Westland petrels can dive to depths no greater than 15 m (Freeman 1998) so are restricted to near surface prey, obtained by surface seizing, surface diving and occasionally pursuit-plunging (Marchant & Higgins 1990). As with other species in the genus *Procellaria* Westland petrels are avid scavengers which readily take discards from fishing vessels. There have been two studies of the foods taken by Westland petrels, each using different methods with quite different biases. The first by Imber (1976) sampled stomachs obtained from 12 dead birds, while the second study (Freeman 1998, Freeman & Smith 1998) sampled petrels within minutes of landing at the colony by inducing regurgitation. Imber mostly recovered indigestible hard parts, mainly squid beaks, that had accumulated in the gizzard, while Freeman (1998) could only obtain food still in the proventriculus (see diagram in Warham 1990 page 6), most of which would have been consumed during the last 12 hours of a foraging trip that lasted several days. Fish otoliths can be digested by seabirds, further over emphasising the importance of squid in Imber's (1976) study. Iso-electric focusing of semi-digested fish remains allowed the identification of partly digested fish, a technique not available in previous studies of seabird diet (Freeman & Smith 1998).

The food species found by the two studies are listed in Tables 2 to 4. As expected Imber's samples mostly contained squid with few fish and no crustaceans, whereas Freeman found a predominance of fish, with fewer cephalopods (including one small octopus) and even a few crustaceans (Imber 1976, Freeman 1998). Imber found 10 species of cephalopods from nine families, whereas Freeman recorded eight species from six families. The cephalopod species found by the two studies were quite different, with no more than four species (some cephalopods and fish could only be identified to genus) in three families in common (Table 2). Imber recorded only six fish species from five families, in contrast Freeman found at least 14 species from 12 families (Table 3). Seven of the fish species identified by Freeman were deep water species obtained from fish waste thrown overboard from fishing boats.

The food brought back to the colony during the chick rearing period between 1993 and 1996 was predominantly fish (present in 92% of samples, comprising 78.8% of the diet by weight), with lesser use of cephalopods (in 32% of samples, 18.7% by weight) and crustaceans (4% of samples, 2.4% by weight) (Freeman 1998). Two-thirds of samples contained only fish, with discards from the hoki (*Macruronus novaezelandiae*) fishery accounting for 80% of the fish during the hoki season (Freeman 1998). Fisheries discards still made up 31% of the fish and comprised a quarter of the total diet after the hoki season, as the petrels switched to a more natural diet and presumably scavenged behind smaller inshore vessels.

The fish ranged in size from 20 to at least 230 mm in length and cephalopods 38-197 mm mantle length (Freeman 1998). Of the 12 fish families identified by Freeman (1998) Macrouridae (rattails) and Myctophidae (lantern fish) were the most common, and of six Cephalopod families remains of Histioteuthidae and Cranchiidae were the most commonly found.

The natural prey consisted mainly of small species, common over the continental shelf and slope (Freeman 1998). Westland petrels probably take most of their natural prey at night. Many of the prey species either perform daily vertical migrations, immatures are found in near surface waters whereas adults occur at greater depths, are bioluminescent, or are deep water squids which float to the surface after death (Freeman 1998, Imber 1976).

There is no information on diet during the non-breeding season. Westland petrels are usually solitary when at sea except when attracted to fishing vessels.

	Imber 1976, samples collected July 1969		Freeman 1998, samples collected August to October 1993-1996		
	No.	Estimated weight g.	No.	Occurrence	Estimated mantle length
Ommastrephidae *Nototodarus sloani*	11	75			
Onycheteuthidae *Moroteuthis ingens*	1	2000			
Gonatidae *Gonatus antarcticus*	3	200	2	2	197
Brachioteuthidae *Brachioteuthis ?picta*	1	-			
Enoploteuthidae *Abralia sp*	1	-			
Octopoteuthidae *Octopoteuthis sp*	1	-			
Histioteuthidae *Histioteuthis macrohista* *H. atlantica* *H. sp.*	 57	 100	 4 6	 3 4	 38, 55 53, 53, 77, 78
Chiroteuthidae *Chiroteuthis sp*	15	100			
Cranchiidae *Taonius pava* *T. sp.* *Teuthowenia pellucida*	 3 29	 250 115	 1 4	 1 4	
Mastigoteuthidae *Mastigoteuthis sp*.			1	1	
Spirulidae *Spirula spirula*			2	2	55
Octopodidae *Octopus cordiformis*			1	1	157

Table 2. Cephalopods (squid and octopus) identified from beaks found in food samples obtained from Westland petrels by Imber (1976) and Freeman (1998). Occurrence is the number of samples containing that prey species. *Megalocranchia richardsoni* listed by Imber (1976) has been renamed *Teuthowenia pellucida* and *Enoploteuthis* beaks listed by Imber have been identified as *T. pellucida*.

	Imber 1976	Freeman 1998		
	No.	No.	Source	Estimated length
Macrouridae *Lepidorhynchus denticulatus* *Caelorinchus sp* Unidentified species	 2 2 	 2 2 1	 fish waste fish waste fish waste	 200-500 172 200-300
Argentinidae *Argentina sp*	 5			
Gonostromatidae Unidentified species	 1			
Myctophidae *Lampanyctus australis* Unidentified species	 1	 2 2	 natural natural	 50-100
Trichiuridae/Gempylidae Unidentified species	 1	 1	 fish waste	
Ophichhthidae *Muraenichthys sp.*		 1	 natural	 230
Clupeidae ?*Sprattus sp*		 1	 natural	 84 FL
Engraulidae ?*Engraulis australis*		 1	 natural	 80-140
Photichthyidae *Photichthys argenteas*		 1	 natural	 200-250
Moridae *Auchenocerous punctatus* *Pseudophycis sp*		 1 1	 natural fish waste	 119 400
Merlucciidae *Macruronus novaezelandiae*		 2	 fish waste	 323-325
Zeidae/Oreosomatidae Unidentified species *Cyttus sp*		 1 1	 ? natural	 20
Scorpaenidae ?*Helicolenus sp*		 1	 natural	 60
Triglidae ?*Chelidonichthys kumu*		 1	 fish waste	 180 FL

Table 3. Fish identified from otoliths found in food samples obtained from Westland petrels by Imber (1976) and Freeman (1998). Estimated length given here is the total length except where FL indicates that it was measured from head to tail fork.

	No.	Occurrence	Estimated length mm
Euphausiidae			
Nyctiphanes australis	1076	4	13-17
Thysanoessa gregaria	5	1	15
Caridea			
Unidentified species	1	1	26
Notostomus auriculatus	1	1	47
Cymothoidae			
Unidentified species	2	1	40

Table 4. Crustaceans identified from exoskeletons found in food samples obtained from Westland petrels by Freeman (1998). Occurrence is the number of samples containing that prey species.

Land based threats

Human disturbance and trampling

People walking through the colonies can disturb the birds and collapse burrows, burrow collapse is especially likely in wet weather when soils are soft and people are more likely to fall. This is currently a minor threat as colony visits are restricted. Other than the Howard/Stuart-Menteath tourist colony, other colonies are only visited by researchers, people directly involved with conservation of the species and occasionally by goat cullers, the later always outside the breeding season. Tourist visits to the Howard/Stuart-Menteath colony are strictly controlled. Tourist or other recreational visits to other colonies need to be strictly controlled.

Human take

Illegal muttonbirding (the taking of nearly fledged chicks for food) has occurred in some Westland petrel colonies in the past but this has become much less common since Baker and Coleman (1977) recorded the disappearance of large chicks from the Rowe Colony in 1970 and 1971. Inspection hatches in their study burrows were removed in pursuit of the chicks. It was the Rowe Colony where muttonbirders took Falla in 1945 and Sandy Bartle has evidence indicating that Westland Petrel chicks continued to be harvested from that colony up to 1974 by local miners and farmers (Bartle 1983) with no Maori involvement (S. Bartle *pers comm.*). Contrary to the suggestion in Heather & Robertson (2015) and Lyall *et al*. (2004) there is no evidence to suggest that this species was traditionally muttonbirded by Maori. Dr Bruce McFadgen (unpublished) did not find any Westland petrel bones in the Maori middens he excavated on the Barrytown flats in the 1970's.

Sandy Bartle suggests that Westland petrel chicks were probably harvested from 1865 until about 1955 by gold miners. Chinese gold-miners apparently lived on the Rowe Colony terrace in the early 20th century and would likely have eaten petrels.

On two occasions in the last few years we have found study lids removed and chicks missing from Rowe and Study Colonies, suggesting that a few muttonbirds may have been taken (S. Waugh and authors unpublished observations).

Natural disaster

Westland petrels breed on steep forested slopes, mostly on mudstone, in a region subject to strong winds with high rainfall where rain showers can be intense. Single trees within the colonies blow down from time to time and inevitably result in the destruction of a few close by burrows and, depending on the season in which tree-fall occurs, possibly the death of a few adults, chicks or eggs. There is no data on the frequency of tree-fall in Westland petrel colonies. This is a natural process; a consequence of their breeding habitat and is unlikely to pose any significant threat to the species.

On 17 April 2014 the West Coast was hit by ex-tropical cyclone Ita, wind was from the south east, a rare wind direction for the West Coast, peak gusts at Westport Airport were 126 km/hour, with torrential rain causing widespread damage to forests in Paparoa National Park (Waugh *et al*. 2015b). There was extensive blowdown of trees and landslides causing significant damage to all six of the Westland petrel colonies surveyed by Waugh's team. For instance, on Study Colony all trees were blown down in one sector of the colony, although the soils there remained intact. Where the petrels had nested under a tall broadleaf/podocarp canopy they were now in an open clearing. There was a major landslide on the very steep upper half of the Rowe Colony which left bare mudstone bedrock where there had been tall forest with deep soil into which the birds burrowed (Waugh *et al*. 2015b). In Study Colony 25 of 91 (27%) and in Rowe Colony 27 of the 64 (42%) monitored burrows were lost as a result of the storm. Damage to forests was most intense on steep slopes and ridges where most petrel colonies occur (Waugh *et al*. 2015b). An aerial reconnaissance of the petrel colonies found landslides and or tree-falls in many colonies with landslides causing major damage in the Middle Bluff, Fucawe, Dougies Bluff, East and Back of Beyond Colonies (S. Freeman unpublished photos and notes), all colonies not surveyed by Waugh *et al*. (2015b).

Landslides are known to have occurred in at least three different colonies between the 1960's and 2013, including one that destroyed about 50 burrows (McClellan & Wood 2004) but the impact of these on the petrels was not recorded (Waugh *et al*. 2015b). There was a major landslide on the Carpentaria Colony in 1982 (S. Bartle *pers comm.* February 2016) and Rowe Colony in 1994 (A. Freeman and K-J. Wilson unpublished). Based on this limited information destruction of a large part of at least one Westland petrel colony has occurred at approximately decadal intervals since the 1960's.

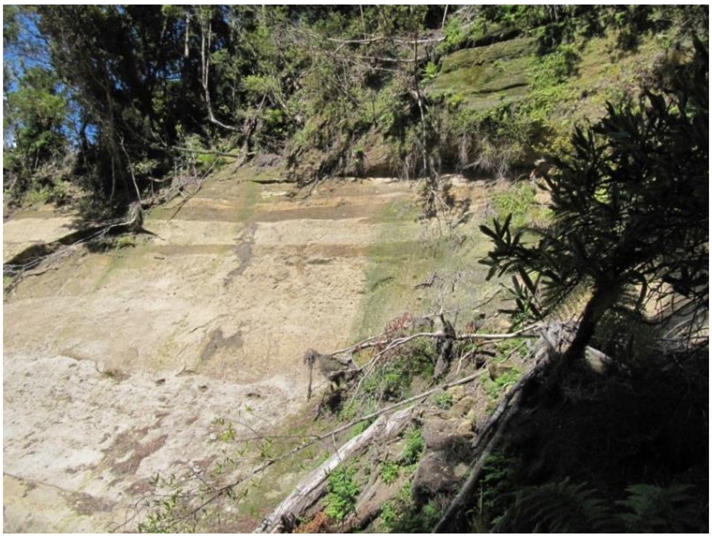

Figure 6. Prior to Cyclone Ita this area of bare rock was the upper part of the Rowe Colony. Photo by Kerry-Jayne Wilson

With climate change the frequency of severe storms is predicted to increase. The impact of storm events on Westland petrels has not been quantified, while they do result in loss of breeding habitat, habitat itself is not limiting, but with such strong site fidelity we do not know if, or how quickly breeding birds will shift to new sites. Some adults were killed by landslides caused by Cyclone Ita but the numbers of birds lost is unknown. We could see dead birds in the landslide debris, but the site was too unstable for us the safely search for dead birds.
Occasionally adult petrels get caught up in vegetation, either caught by the leg or wing in branch forks when landing, or tangled in tree roots when burrowing (Jackson 1958 and author's personal observations). These deaths are natural consequences of their rainforest nesting habitat.

Seabird vegetation dynamics

There is a dynamic relationship between seabirds and their influence on the soils and vegetation of their colonies. The affects are both positive and negative. On the positive front, the seabirds transfer nutrients from marine to terrestrial environments, resulting in soils on petrel colonies being rich in nitrogen, phosphorous and other nutrients from guano, dead chicks, eggs and adults (Hawke & Holdaway 2005, Warham 1996). Their burrowing activities aerate soils and by dragging nesting material into their burrows they take leaf litter underground. However, on the negative side petrels crash land into the canopy, the trampling of seedlings by thousands of tiny feet inhibits plant establishment and their burrows can undermine trees and precipitate treefall. The digging of burrows can increase soil erosion, particularly on the steep slopes favoured by Westland petrels. These natural dynamics may mean that any particular colony has a finite lifespan, the birds eventually increasing erosion to the point that reduction in soil depth and, or landslides render locations unsuitable and new colonies form nearby. While there is an extensive literature on the relationship between seabirds, soils and vegetation (Roberts *et al*. 2007 and references therein), there is little information on the longevity of colonies. Although Westland petrels have bred in the area for at least the duration of the Holocene (Worthy & Holdaway 1993), dating of soils showed one Westland petrel colony to be no older than 740-960 calendar years (Hawke 2004). Colony initiation at a particular site will require adequate soil depth and the life of the colony is perhaps terminated by landslides and soil loss (Hawke 2004), the landslides precipitated by catastrophic events such as earthquakes or major storms. This could be of long term importance for Westland petrels where breeding is limited to such a small geographic range in a tectonically active region with high rainfall.

A second cause of erosion is known to occur but has not been measured. This is soil loss due to burrow excavation and other activities of the birds. This will enhance soil loss from other natural processes and is likely to make colonies more prone to landslides during storm events.

Habitat loss and degradation

Feral goats (*Capra hircus*) and brushtailed possums (*Trichosurus vulpecula*) are common throughout the western Paparoa Range. Since 2011, goats have been seen at least once during each two-week visit by Te Papa researchers, despite periodic culls in and around the Westland petrel colonies. DOC (2010) includes maps and tables describing the extent of goat control between 2006 and 2010. Both goats and possums browse vegetation, in so doing modify habitat and possibly make the colonies more susceptible to erosion. Goat hooves can penetrate through the soil into petrel nest chambers. This reduces the thermal insulation and waterproofness of burrows and allows weka (*Gallirallus australis*) to prey on unguarded chicks. Some nestling loss is probably attributable to the presence of goats.

Pigs (*Sus scrofa*) would be especially destructive, their rooting increasing erosion rates and destroying burrows as well as their predation on adults, chicks and eggs. Pigs have been illegally released in the area several times in order to establish a population for hunting. Feral pigs are currently absent from the area and illegal releases must be dealt with immediately.

In the past cattle (*Bos taurus*) have entered Westland petrel colonies from private land along the Punakaiki River valley, some penetrating as far west as colonies in the Scotsman's Creek catchment (S. Bartle 1983 and *pers comm.* February 2016). To prevent incursions by farm stock DOC maintains a fence at Liddys Creek. The private land along the Punakaiki River and in Scotsman's Creek is no longer stocked. Fences at Waihwero and Hibernia Creeks are checked from time to time by DOC (S. Freeman *pers. comm*. May 2016).

Predators

Weka, rats (*Rattus* sp) and stoats (*Mustela erminea*) are all present in the Westland petrel colonies, but they do not appear to present significant threats to the petrels (S. Bartle *pers comm.*, S. Waugh and author's personal observations). None the less, both Jackson (1958) and Baker & Coleman (1977) reported chicks being consumed by rats or stoats, but the cause of death could not be ascertained; scavenging of already dead chicks was just as likely as predation. Baker & Coleman reported one incidence of a weka removing and killing a petrel chick from a shallow burrow. A similar observation was made at Rowe Colony by S. Waugh (*pers comm.*). Weka have been seen patrolling colonies, inspecting burrows looking for any eggs or chicks within reach; the chicks being at risk if they wait near the burrow entrance for their returning parents (C. Wood file notes). Most burrows are too long for weka to catch the chicks.

In 1990 25 birds, in 1991 36 birds and in 1992 nine birds were found dead as a result of predation (McClellan & Wood 2004). Some were chicks 2-3 days old, while most were found in November and December when chicks emerge from their burrows at night. Weka were seen attempting to extract chicks from shallow burrows, while most deaths were attributed to feral cats (*Felis catus*) (McClellan & Wood 2004). Predation by dogs (*Canis familiaris*) was recorded in 1992 when burrows in a remote colony were dug out and four petrel chicks apparently killed (McClellan & Wood 2004). In 2000 at least 12 adults were killed by dogs at the Howard/Stewart-Menteath colony (McClellan & Wood 2004). While these dog kills were isolated incidents, a single dog can kill many petrels in just a few days.

In the past cage traps for dogs have been set in the Liddys Creek area and alongside the track leading to Study and Rowe Colonies (McClellan & Wood 2004). These have not been set in recent years.

Parasite, pathogens and disease.

The prevalence of disease and parasites in New Zealand seabirds is poorly studied. Avian cholera (*Pasteurella multiocida*) has been found in rockhopper penguins (*Eudyptes filholi*), avian diphtheria and avian malaria in yellow-eyed penguins (*Megadyptes antipodes*) and avian pox in three species of Procellariiformes including the closely related black petrel (Rowe & Taylor 2006). There are no reports of diseases affecting Westland petrels. Avian pox has caused the death of some black petrel chicks, hence it is a potential threat to Westland petrels (Rowe & Taylor 2006).

Powerline strike

Adult Westland petrels flying to and from their breeding colonies have occasionally collided with power lines running alongside the coastal highway. Electricity and communications lines have been placed underground where they cross the Scotsman's Creek flight path. However, they remain above ground across all other flyways including a single span from beside the Punakaiki River to the top of the Razorback where petrels could possibly strike the lines. Powerlines cross over open fields under the minor Liddys Creek and Waiwhero Creek flight paths.

Lights

Petrels, in particular fledglings on their maiden flight and for some days thereafter, are attracted to lights and land ashore in well-lit areas. Disorientation by lights has been shown to be a significant cause of mortality of young petrels of various species in the Canary Islands, Balearic Islands (western Mediterranean), Hawaii, La Reunion (Indian Ocean), Phillip Island (Australia) (Rodrıguez *et al*. 2012, 2014, 2015, Telfer *et al*. 1987) and closer to home with Hutton's shearwater at Kaikoura (http://www.huttonsshearwater.org.nz/crash-landing-huttons-shearwater-chicks/). Many of the petrels grounded in those studies were captured and released, but others died through collision with manmade structures, dehydration, starvation, predation or subsequent roadkill.

Westland petrels are also attracted to lights and some are found grounded every year. The data collected by the Department of Conservation between 2007 and 2015 was made available by Guinevere Coleman with some additional records from Julie Leighton, Pete Lusk and the West Coast Penguin Trust. This has been summarised in Tables 5 and 6. The quality of the data is poor, it has not been collected systematically, search effort has varied year to year, not all birds found grounded were recorded, an unknown number were grounded but not found, it is possible a few birds have been entered into the database more than once and some records are incomplete. However, the data available do allow a preliminary assessment of the problem to be made.

Most grounded birds have been found between mid-November and mid-January, peaking in the first half on December, Table 5. The earliest chicks fledge in early November and the last in mid-January with the peak fledgling date being 20 November (Waugh & Bartle 2013), at least 10 days earlier than the period when most petrels were found grounded. A few Westland petrels have been found between March and October and these would have been adults, but their breeding status is unknown.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov 1-15	Nov 16-30	Dec 1-15	Dec 16-31	Jan 1-15	Jan 16-31
2007											6			
2007						1						1		
2008	1									2	9			
2009										1	7	8	2	1
2010		1								2	24	3	1	
2011			3			1					7	1		
2012					1	1			1	1	3	3	2	3
2013						1		1		1	4	1		
2014										2		1	3	
2015				1		1				1	12	4		
Year not recorded												1		
Total	**1**	**1**	**3**	**1**	**1**	**5**	**0**	**1**	**1**	**10**	**72**	**23**	**8**	**4**

Table 5. Months in which Westland petrels have been found grounded, most as a result of disorientation by lights.

Of the 141 records for which there is location data (Table 6), 91 were recovered at or near Punakaiki. Of those Punakaiki groundings at least 40 were in the immediate vicinity of well-lit areas in the village and 33 between their colonies and the sea. Not all of those 33 found between the colonies and the sea were necessarily casualties caused by lights. Six records from the resort stated they were 'storm cast' so their deaths may not have been caused by lights. Twenty-three and 21 have been found near Westport and Greymouth respectively, four in Hokitika with two from towns further inland, all in well-lit areas (Table 6). Most found between November and January would have been fledglings; those found in Punakaiki presumably on their maiden flight from the colony to the sea, while those found in Westport, Greymouth, Hokitika and the two inland records must have made it to sea successfully only to be attracted to the bright lights of town some time later. Any influence moon phase, weather or other factors may have on the grounding of Westland petrels has not been assessed. The influence of these factors will be determined in a proposed study planned to commence in 2017.

	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	Year unknown	Total
Punakaiki village/Tavern	1		2		12							15
Punakaiki resort			3	1		6*		1		1	1	13
Café/DOC area	1		2		1	8						12
Punakaiki no location	1						7			4		12
Punakaiki River area	1	2		3	3	2				2		13
Pororari to Trumans	1			4					1			6
Rio Tinto/ Conservation Volunteers site			1		2	3	2	4				12
Pakiroa Beach Barrytown flats and SH6				2	2	1			3			8
Punakaiki total												**91**
Greymouth town centre				3	4	1		2				10
Cobden & North Beach				2	1		3	1				7
Paroa/ Camerons			1	1								2
Rapahoe/ Rununga				1					1			2
Greymouth area total												**21**
Westport town	1		1	2	2					9		15
Holcim works					2		1	1		4		8
Westport area total												**23**
Hokitika			1	1	1				1			**4**
Stillwater							1					**1**
Kaniere				1								**1**

*Storm cast and may not be light related.

Table 6. Westland petrels found grounded at various locations on the West Coast. Most groundings are assumed to be a result of disorientation by lights.

During the November to January fledging period 92 of the Westland petrels found grounded were released from coastal cliffs, a few after veterinary care, and 26 were found dead or died in care. Of those found between March and October eight were found dead and four were released. As birds were not banded there is no data on the survival of released birds.

Department of Conservation files contain a number of emails and memos recommending that light brightness and light spill be restricted. One such email recommended that luminosity not exceed 0.18 lux two metres from the light source and external lights not exceed 60 watts (D. Carden email 1 July 2004). It was also recommended that curtains be drawn between April and January. The Buller District Plan requires buildings in the Scenically Sensitive Commercial Zone, between Dolomite Point and the Punakaiki River to have all fixed, external lighting for utility and services hooded to contain light spill. The Grey District Plan has no specific requirements for lighting south of the Punakaiki River but would impose appropriate restrictions on an *ad hoc* basis (Katrina Lee, Grey District Council email 4 May 2016).

Lights along the paths, carparks and in front of the units at the Punakaiki Resort are of low brightness and hooded, so that there is no light spill skywards and almost none seawards (Figure 7), and indoor lighting appears dull when viewed from outside (Figure 7). Given the proximity of such a large facility at a beach, so close to Westland petrel flightpaths, it is reassuring that so few petrels apparently become grounded there.

Figure 7. Left, the Punakaiki Resort at night showing the low light levels facing seawards. The room on the left is the main communal area including restaurant. Right, one of the path lights hooded to prevent light spill skywards, four of these can be seen in the photo on the left. Photos by Kerry-Jayne Wilson

The threat posed by lights to Westland petrels has been known for decades. Indeed in the 1950's, the only records of Westland petrels anywhere other than their breeding grounds were a few that flew aboard the nightly Lyttelton-Wellington ferry (Bartle 1974), presumably attracted by the on board lights. There are no recent records of Westland petrels flying onto ships at night but presumably this still happens.

Land development, mining, forestry and farming

Changes in land use on the non-DOC land adjacent to the petrel's breeding range could pose threats to the petrels, in particular if new subdivisions resulted in higher levels of lighting and an increased number of dogs and cats. Should new subdivisions be proposed close to the petrels breeding colonies or beneath their flyways light spill skywards and seawards should be restricted and the developments be pet-free. The Buller District Plan does place restrictions on light spill in Punakaiki township but the breeding colonies are south of the Punakaiki River in the Grey District.

A major threat that hung over the petrels from the 1970's until the 2000's was the proposal to mine ilmenite on the Barrytown Flats. First proposed by Carpentaria Exploration, the prospecting licence went through several changes of ownership until taken over by Rio Tinto Ltd. New Zealand's largest ilmenite deposits in are on the Barrytown flats and the site chosen for the processing plant was right under the major Scotsman's Creek flyway. While mining on the flats would not itself affect the petrels, to be economic the plant would operate 24 hours a day. Machinery noise and lights burning all night would have posed a serious threat to the birds passing overhead. In 2010 Rio Tinto, having shelved plans to mine in the area, transferred their land to DOC. Conservation Volunteers began restoring native forest on this land in 2008 and this habitat restoration continues. The Barrytown Flats have deposits of ilmenite, gold and other several other minerals, mining is currently in abeyance however a different mining company did investigate the prospects for mining in the southern part of the Barrytown Flats in 2014.

There is a history of forestry, bush clearance and drainage on land adjacent to the Specially Protected Area. By 1969 Lawson Creek had been cleared of native forest and the land drained for farming. There were logging roads up both Scotsman's Valley and Liddy's Valley (S. Bartle *pers comm.* Feb 2016). When Sandy Bartle started work in 1969 the hillsides of Scotsman's Valley were all but completely covered by pasture or gorse. These hills are now densely covered with second growth forest. In the 1970's regenerating yellow silver pine (*Lepidothamnus intermedius*) and kahikatea (*Dacrycarpus dacrydiodes*) forest on farmland in Liddy's Valley was felled and the creek straightened with a dragline that extended into the Reserve (S. Bartle *pers comm.* Feb 2016).

The impact forest clearance, farm development and mining had on the petrels is unknown. It is possible some lower altitude colonies were destroyed. While farming was contained in the valleys where few petrels breed, some forestry, and in the 19th and early 20th century mining, occurred on ridges and the higher slopes where most petrels nest.

By in large the threats posed by farming, have been addressed, and forestry and mining are not currently taking place in areas where they pose a direct threat to the petrels.

A Petrel Protection Zone

The now defunct Westland Petrel Protection Group recommended that there be a Petrel Protection Zone, within which there be restrictions on lighting (exterior lights to be hooded so that light spill be <0.18 lux two metres from source), that all power and communication lines crossing flight paths be buried, that building height be restricted to seven metres, that there be controls on pets and stock, that noise levels not exceed 45 decibels measured 20 m from the source and there be no aircraft activity between an hour before sundown and an hour after sunrise (Westland Petrel Protection Group, submission to Grey District Council April 2004).

A petrel protection zone would bridge two District councils, Buller north of the Punakaiki River and Grey south of the river. The Grey District Council does not have any rules in place to protect Westland petrels but they are aware of the importance of the birds and, working in conjunction with DOC, would impose appropriate restrictions on an *ad hoc* basis (Katrina Lee, Grey District Council email 4 May 2016). The Buller District Plan requires buildings in the Scenically Sensitive Commercial Zone, between Dolomite Point and the Punakaiki River to have fixed, external lights hooded to contain light spill.

Sea based threats

Bycatch in commercial fisheries in the New Zealand EEZ

Both commercial and recreational fishing may impact petrels through bycatch, by depleting the petrels' food species, or through changes to the marine food chain. Conversely, fisheries may benefit seabirds through the discharge of offal and other fish scraps, making available foods that the birds could not otherwise access. For Westland petrels there is moderately good information on their relationships with large (>28m) commercial fishing vessels within the New Zealand EEZ, but virtually no information on interactions with any fisheries in South America or recreational fishing in New Zealand. Fisheries which seldom carry observers and operate within the Westland petrel's range, including inshore trawl, set-net, purse-seine, and troll fisheries report little if any seabird bycatch, yet based on studies from other jurisdictions, have the potential to catch seabirds including Westland petrels.

Like other petrels in the genus *Procellaria* Westland petrels are aggressive foragers around fishing vessels, they can dive up to 15 m and often feed by night, all factors that render them vulnerable to bycatch (Waugh *et al*. 2006). Furthermore there is extensive overlap in the distribution of Westland petrels with commercial fishing effort (Figures 8 and 9). Until mathematical models were developed by the Dragonfly Team (see Richard & Abraham 2015 and references therein) information on the numbers of Westland petrels caught as bycatch was sketchy as only about 5% of vessels had observers on board, the observer coverage varied between different fisheries, some with no observers and not all birds killed or injured by fishing gear were recovered. Until recently no estimate of the total number of Westland petrels killed could be made, although the limited data available suggested that there was greater bycatch of females than males (Waugh *et al*. 2008).

Of the 18 observed captures of Westland petrels by trawl vessels between 2002/03 and 2012/13, ten were dead and eight released alive, most captures were made between July and September and most during hours of darkness (Abraham & Thompson 2014a). Fifteen were caught by vessels fishing for hoki, 12 off the South Island West coast, two on the Chatham Rise and one in Cook Strait (Figure 8). Vessels targeting hake, barracoota and Jack mackerel each caught one Westland petrel, all off the South Island West Coast (Abraham & Thompson 2014a). This information was not available for all 27 captures shown in Figure 8.

Of the nine observed captures of Westland petrels by surface long-line vessels between 2002/03 and 2012/13, (Figure 9) all were dead, caught in either May or June and all during daylight hours (Abraham & Thompson 2014b). Six were captured by vessels targeting southern bluefin tuna, two seeking albacore tuna (the two East Coast North Island captures) and one broadbill swordfish.

One Westland petrel was observed captured by commercial bottom long-liners targeting school shark off the West Coast (Abraham & Thompson 2014c). Three Westland petrels caught in commercial set-nets fishing for moki near Kaikoura in November 2007 were released alive (Abraham & Thompson 2014d).

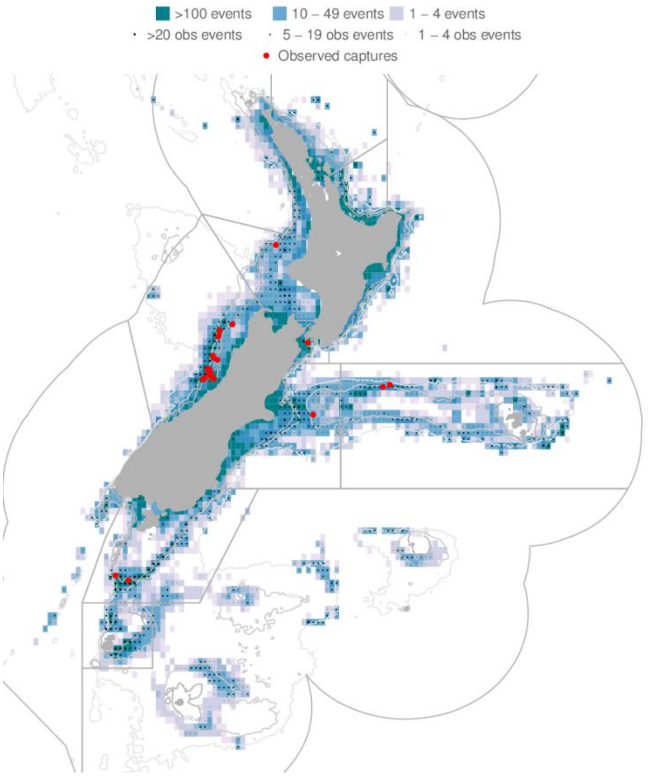

Figure 8. Map showing trawl fishing effort and the 27 observed captures of Westland petrels in commercial trawl fisheries from 2002/03 to 2013/14. From Abraham & Thompson (2014a) plus 2013/14 data not publically available at the time of writing.

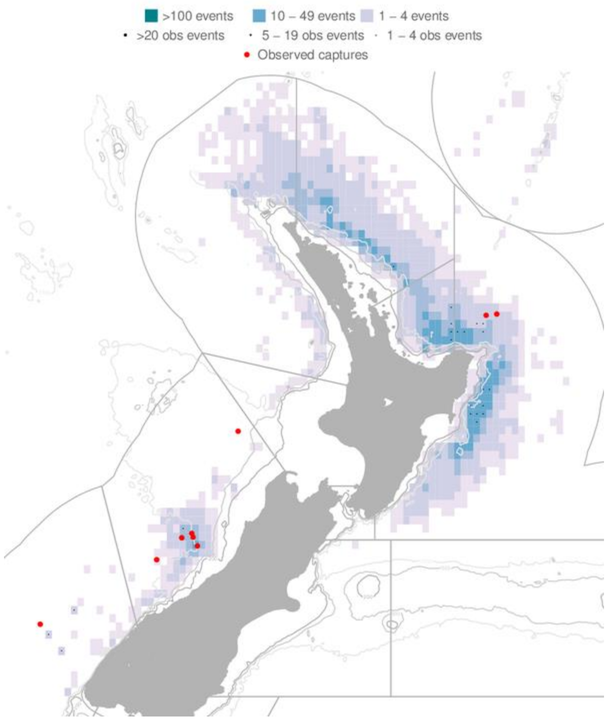

Figure 9. Map showing fishing effort and the 9 captures of Westland petrels in commercial surface long-line fisheries from 2002/03 to 2013/14. From Abraham & Thompson (2014b)

The risk commercial fisheries pose to each species of seabird has been calculated by Richard & Abraham (2015). This is the latest in several risk assessment documents produced by the Dragonfly Team under contract to the Ministry of Primary Industries, each incorporating additional years of data and refining their mathematical models as new biological and fisheries data came to hand. Their method of calculating risk is complex, incorporating demographic data, population size, behaviour around vessels, at sea distributions, plus bycatch and fishing effort data from each different fishery making allowance for the proportion of vessels in each fishery with observers on board. Their calculation of risk for each species is ultimately based on two figures; Potential Biological Removal (PBR) which is a measure of the reproductive capacity of the species, and the Annual Potential Fatalities (APF), an estimate of the maximum number they estimate to be killed by bycatch in the New Zealand EEZ (Richard & Abraham 2015). The methodology of calculating these figures from the relatively small numbers observed and the uncertainties inherent in each data set is complex, described in detail in that publication, but need not concern us here. Confidence levels are large for some species and in some fisheries, but these are by far the best estimates of seabird bycatch by commercial fisheries for the New Zealand EEZ.

Richard & Abraham (2015) estimate the Westland petrel to be the 10th most at risk species, an increase in assessed risk compared with earlier estimates, and one of four species in the *high risk* category. The 11 species in either the *very high risk* or the *high risk* categories were all albatrosses, *Procellaria* petrels or large shearwaters, their low reproductive rates and delayed maturity rendering them susceptible to population decline whenever adult mortality is elevated (Richard & Abraham 2015). They calculated the PBR for Westland petrels to be 157 (95% confidence level 84-234) and the APF as 88 (37-181). These calculations are based on there being 3520 (3110-3720) breeding pairs and a total population of 11600 (8640-16600) individuals. These estimates were just for commercial fisheries in the New Zealand EEZ; others may be killed by recreational fishers in New Zealand and by fisheries in South America. Their risk assessment for Westland petrels increased markedly between the 2013 and 2015 editions of the risk assessment, due to improved information about the petrels foraging distribution. As current research produces more detailed data on the petrels overlap with fisheries at different stages of their annual cycle, it is likely that the risk assessment for Westland petrels will increase further (S. Waugh *pers comm.*).

The annual potential fatalities (APF) calculated for each of the commercial fisheries are shown in Tables 6 -10.

Trawl fisheries	Bottom long-line (BLL) fisheries	Surface long-line (SLL) fisheries	Set-net fisheries	Total
30 (9-92)	24 (1-91)	31 (8-70)	3 (0-6)	88 (37-181)
Medium risk	Medium risk	Medium risk	Low risk	High risk

Table 6. Estimated annual potential fatalities (APF) (range in brackets) of Westland petrels in commercial fisheries in the New Zealand EEZ from Richard & Abraham (2015).

Westland petrels are at medium risk from commercial trawl, bottom long-line and surface long-line fisheries with very few killed in set-net fisheries (Table 6), together putting the species at high risk from commercial fisheries in the New Zealand EEZ (Richard & Abraham 2015).

Inshore trawl	Squid trawl	Hoki trawl	Scampi trawl	Middle depth trawl	Flatfish trawl	Ling trawl	Hake trawl	Jack mackerel trawl	Deep-water trawl	SBW trawl
6 (0-35)	0 (0-1)	14 (5-32)	1 (0-6)	2 (0-7)	4 (0-28)	0 (0-1)	2 (0-2)	1 (0-3)	0 (0-2)	0 (0-0)

Table 7. Estimated annual potential fatalities (APF) (range in brackets) of Westland petrels in commercial trawl fisheries in the New Zealand EEZ, from Richard & Abraham (2015).

Of the various trawl fisheries where seabird bycatch was assessed, the hoki fishery poses the greatest risk to Westland petrels (Table 7). Inshore and flatfish trawl fisheries pose a secondary risk to this species.

Snapper BLL	<45m vessel, ling BLL	Bluenose BLL	Hapuka BLL	Minor BLL	>45m vessel, ling BLL
1 (0-10)	3 (0-20)	2 (0-17)	9 (0-38)	9 (0-39)	0 (0-3)

Table 8. Estimated annual potential fatalities (APF) (range in brackets) of Westland petrels in commercial bottom long-line (BLL) fisheries in the New Zealand EEZ, from Richard & Abraham (2015).

There remains uncertainty over the risks posed by the various bottom long-line fisheries to Westland petrels (Table 8) however, the hapuka fishery and minor long-line fisheries appear to be those from which this petrel is most likely at risk.

Bigeye SLL	<45m vessel, southern bluefin tuna SLL	Swordfish SLL	>45m vessel, southern bluefin tuna SLL	Minor SLL	Albacore SLL
6 (1-15)	17 (4-41)	8 (1-28)	0 (0-1)	0 (0-1)	0 (0-0)

Table 9. Estimated annual potential fatalities (APF) (range in brackets) of Westland petrels in commercial surface long-line (SLL) fisheries in the New Zealand EEZ, from Richard & Abraham (2015).

As opposed to bottom long-line fisheries, the risks posed by surface long-line fisheries to Westland petrels is more certain, confidence levels for APFs are smaller and of the six fisheries, three pose little if any threat. Vessels less than 45 m in length seeking southern bluefin tuna appear to pose a greater threat to Westland petrels than any other single fishery with bigeye and swordfish long-line fisheries also posing some risk (Table 9).

Shark set-net	Flatfish set-net	Minor set-net	Grey mullet set-net
1 (0-3)	1 (0-2)	1 (0-2)	0 (0-1)

Table 10. Estimated annual potential fatalities (APF) (range in brackets) of Westland petrels in commercial set-net fisheries in the New Zealand EEZ, from Richard & Abraham (2015).

Very few Westland petrels appear to be taken in commercial set-net fisheries (Table 10) although observer coverage of these fisheries in areas frequented by this species has been poor.

Other *Procellaria* species are also frequent victims of bycatch (Waugh *et al*. 2008), the black petrel being assessed as the most at risk species, the white-chinned petrel the 13th most at risk and the grey petrel (P*rocellaria cinerea*) 20th out of the 70 species assessed (Richard & Abraham 2015). The mean APF for white-chinned petrels was 1440, so many more of them are killed than Westland petrels (88); more even than black petrels (1130) but, because their population is so much larger, their risk assessment is lower.

The Department of Conservation uses Richard & Abraham's (2015) risk assessments, plus some additional information to determine research and management priorities to address seabird bycatch in the New Zealand EEZ. Their latest five year plan is currently in draft form (Conservation Services Programme 2016). In their five year research plan the only research scheduled for Westland petrels is a population estimate to be done in 2018/19, although they also consider a mark-recapture study to estimate demographic parameters and routine colony monitoring to determine population trends, to also be required. Current research led by Dr Susan Waugh from Te Papa includes mark-recapture of breeding birds and population trends in Study and Rowe Colonies, but how long Te Papa wishes to sustain this work is uncertain.

The Conservation Services Programme (2016) also identifies those fisheries where greater observer coverage is required. For Westland petrels, the hoki trawl, haupuka bottom long-line and minor bottom long-line fisheries are of high priority, and flatfish trawl and inshore trawl fisheries of secondary priority for increasing observer coverage. Greater use of mitigation measures to protect Westland petrels is required for those vessels less than 45 m in length using surface long-lines in pursuit of southern bluefin tuna, and recommended for the hoki trawl, haupuka bottom long-line, minor bottom long-line and swordfish surface long-line fisheries (Conservation Services Programme 2016).

There is limited information available for inshore trawl fisheries in the Karamea, Cook Strait, South Westland and Marlborough areas where bycatch of Westland petrels is possible.

Bycatch in recreational fisheries in New Zealand

Boat-ramp surveys indicate that petrels, probably mostly shearwaters, are the group of birds most often caught by recreational fishers in New Zealand (Abraham *et al*. 2010). These boat-ramp surveys were conducted along the north east coast of the North Island and in Otago, not areas where Westland petrels commonly occur. Seven banded Westland petrels have been recovered by fishers, four caught in nets and three on lines, but whether they were caught by recreational or commercial fishers was not determined (Abraham *et al*. 2010). Their surveys suggest that in New Zealand recreational fishers may catch more seabirds than commercial fishers, although in contrast to commercial bycatch, most caught by recreational fishers were released alive (Abraham *et al*. 2010).

Bycatch in South American fisheries

Westland petrels are also at risk from bycatch while in South American waters. There is no reliable information on the bycatch of Westland petrels in South America, but fisheries likely to catch them are poorly observed and bycatch poorly reported (Karen Baird and Esteban Frere *pers comm.*). At least 1160 seabirds are killed by the fishing vessels on the Patagonian Shelf each year and 20% of these are black-coloured petrels in the genus *Procellaria* (Favero *et al.* 2003). They were assumed to be white-chinned petrels (Favero *et al.* 2003) but, as this is an area known to also be frequented by Westland petrels and as the two species are so similar, it is possible some were Westland petrels. White-chinned petrels and black petrels were seen attending fishing vessels in the Humboldt Current System (Spear *et al.* 2005) and presumably Westland petrels do so also.

Of concern is the developing small vessel (<45 m) longline fishery catching Patagonian toothfish (*Dissostichus eleginoides*) over the continental slope (500-2000 m) off Chile (Spear *et al*. 2005) where interactions between Westland petrels and the fishery are likely (ACAP 2012). The distribution of Westland petrels overlaps with the pelagic longline swordfish fishery, but as that fishery operates between March and December (ACAP 2012) when most Westland petrels are in New Zealand it is perhaps of lesser concern.

The Chilean authorities are aware of seabird bycatch and measures are being taken to document the level of bycatch and develop and implement mitigation measures (for example see Suazo et al. 2014 and PAN-AM/CHILE undated). Both these reports discuss the likely impact of bycatch of seabirds and describe Chile's plan of action to reduce bycatch, but only Suazo *et al*. (2014) makes specific reference to Westland petrels. Westland petrels are known to be taken by industrial level demersal longline fisheries south of 41^{o} 47'and in the Chilean fiords (Suazo *et al*. 2014) but they do not give any information on numbers caught. Conversely Oli Yates (*pers comm*. May 2016) who has been working on bycatch issues off the South American coast between Chile and Ecuador since 2007 is not aware of any Westland petrels caught in trawl, longline, purse seine or gillnet fisheries. There has been little consideration of the interactions between local fishers using small vessels and seabirds in either New Zealand or South America. Although no mention is made of Westland petrels the approach taken by Suazo (*et al.* 2013) could be adapted for small boast fisheries in New Zealand.

Use of offal and discards

Fisheries may also benefit those seabirds that scavenge on offal and other fisheries waste discharged from vessels and Westland petrels are avid scavengers. In the late 1950's few Westland petrels appear to have feed on fishery waste. Their numbers on the Cook Strait trawling grounds increased greatly during the 1960's (Bartle 1974) and in October and November 1975 up to 500 were seen feeding on fishery discards during exploratory fishing off Greymouth (Vooren 1977).

The New Zealand hoki fishery developed in the early 1970's but remained relatively small until 1985 with landings of less than 50,000 tonnes. From 1986 it expanded, peaked at 255, 000 tonnes in 1987/88, after that catches were stable at about 210,000 tonnes per year (Freeman & Wilson 2002). In the late 1980's, 160,000-190,000 of those tonnes were caught off the South Island West Coast, about 80 km from the Westland petrels' breeding colonies, catches in that area reducing to 100,000 tonnes by the mid 1990's with an additional 40,000 tonnes in Cook Strait, another area frequented by the petrels (Freeman & Wilson 2002). Westland petrels habitually follow vessels fishing for hoki with up to 150 seen near a vessel off the South Island West Coast (Freeman & Wilson 2002).

The hoki fishery generated huge quantities of waste, estimated at 23,000 tonnes in 1986, increasing to 47,000 tonnes by the mid 1990's, all between June and September, coinciding with the incubation and early chick rearing periods of the Westland petrels (Freeman 1998, Freeman & Wilson 2002). It has been suggested that the increase in Westland petrel numbers in the 1970's and 1980's resulted from their use of hoki fishery waste (Bartle 1985a, 1987). They also scavenge from other fisheries with which their at sea distributions overlap but there is no data on their use of discards from those fisheries.

In her PhD research Amanda Freeman (1997b) assessed the importance of the hoki fishery to Westland petrels in three ways; at sea observations (Freeman 1997a), radio and satellite tracking to determine the overlap with fishing vessels (Freeman *et al*. 1997, 2001) and dietary studies, (Freeman 1998, Freeman & Smith 1998). The final paper in that series (Freeman & Wilson 2002), integrated the findings from each of these approaches. They concluded that the petrels made opportunistic use of fishery waste, but the birds were not dependent on that abundant food source (Freeman & Wilson 2002).

Systematic at sea observations were made on and around the hoki fishery grounds between 2 and 14 August 1993 from a research vessel and the degree of overlap between Westland petrels and fishing vessels plotted using GIS (Freeman 1997a). While at sea observations can estimate the number of petrels in the vicinity of fishing vessels, they do not distinguish between breeding and non-breeding birds, or estimate the amount of time any single bird spends near fishing boats.

To determine the proportion of a foraging trip breeding Westland petrels spent near fishing vessels we first tried radio tracking adults with dependent chicks, however the petrels spent much of their time beyond the radio horizon (Freeman *et al*. 1997). In 1995 and 1996 adults were tracked using satellites and their positions compared with the locations of hoki trawls (Freeman *et al*. 2001). Fishing vessels longer than 43 m were required to report the positions of each trawl and many smaller vessels did so as a matter of course.

Both the hoki spawning grounds (hence the location of the fishery) and the Westland petrels preferred foraging zone coincided with the 200 m depth contour thus, we would expect the petrels to feed along this shelf break whether or not the fishery was there (Freeman *et al*. 2001). It was not possible to separate the relative role of the shelf break (200 - 800 m depth) and the hoki fishery in influencing the distribution of the petrels. However, the presence of fish waste in petrel food samples showed that their use of this zone was to some degree influenced by the fishery (Freeman *et al*. 2001).

Although fishing vessels influenced the distribution of the petrels, only a small proportion of the population appears to use this food source at any one time (Freeman & Wilson 2002). On average, satellite tracked birds spent about a third of their foraging trip within 5 km of fishing vessels, some birds spending half their time at sea near fishing vessels, while three of the 12 petrels tracked associated little with fishing boats (Freeman *et al.* 2001, Freeman & Wilson 2002). The two tracked birds that visited Cook Strait did not associate with the hoki vessels fishing there (Freeman *et al*. 2001). The proportion of the time spent in the vicinity of fishing vessels actually spent feeding on discards could not be determined, but as flight speeds indicated by satellite tracking were lower when close to fishing vessels, than when distant from vessels, they were probably feeding (Freeman *et al*. 2001). In 68% of tracked flights the petrels visited the hoki fleet in the 12 hours prior to their return to the colony (Freeman *et al*. 2001). The time spent near fishing vessels was not related to sex, length of foraging trip, time of day or night, or month of observation (Freeman *et al*. 2001).

Diet was studied between August and October 1993-1996 using regurgitations and by samples obtained through water offloading, taken as adults returned to the breeding colony at night to feed their chicks (Freeman 1998). These methods only sample foods taken during the last 12 hours or so of foraging trips which averaged 4.1 days (range 1-7 days) (Freeman *et al*. 2001). As the hoki fishery is within a few hours flight of the colony, and the petrels forage over a much larger area, the importance of fishery discards was probably over estimated by these methods.

Fish were found in 92% of samples (Freeman & Wilson 2002); waste from the hoki fishery accounted for 80% of the fish found and made up 63% of the total volume of food brought back to the colony during the hoki season (Freeman 1998). After the hoki season ended, fisheries discards continued to make up 31% of the fish in their diet, and 25% of the total amount of food bought back to the colony, as the petrels switched to a more natural diet while also scavenging behind smaller inshore vessels (Freeman 1998).

Fishery waste would appear to be so abundant and sufficiently close to their breeding colonies that the petrels could meet all their needs feeding on this alone. However, despite this handy source of food the birds continued to forage on natural prey further afield. None the less, if changes in fishery practice resulted in significantly less waste being available it could possibly affect Westland petrel breeding success or population size (Freeman & Wilson 2002). Changes in fishing practice could include changes in location if new hoki grounds are discovered, a change from large surimi vessels to smaller vessels which fillet fish on board, or a move to processing waste into fish meal rather than discarding it over board. Albatrosses (*Diomedea* and *Thalassarche* spp.) and giant petrels (*Macronectes* spp), all larger and dominant over Westland petrels also scavenge behind fishing vessels and their numbers may affect how much waste is available to Westland petrels.

Climate change

There has been very little research into the impact climate change will have on New Zealand seabirds. An assessment of the impact climate change is likely to have on Australian birds showed that seabirds are particularly vulnerable to changes in food availability due to changes in the marine environment resulting from climate change (Garnett & Franklin 2014). New Zealand seabirds including Westland petrels will no doubt also be vulnerable.

Westland petrels found dead on beaches

Birds washed up dead on beaches can provide additional information on at sea distributions and mortality. The Ornithological Society of New Zealand maintains records of seabirds found dead on beaches and records for petrels in the genus *Procellaria* from 1960 to 1986 were reviewed by Powlesland (1987). Between 1960 and 1986, 86 Westland petrels were found on New Zealand beaches with 5-10 reported each year; the maximum in any one year being 11 found after a poor breeding season in 1978. As expected most were found on the Wellington south coast and the north coast of the South Island and numbers peaked in December and January soon after the young fledged (Powlesland 1987). Paper based records are currently being digitised which will eventually allow an analysis of records from the last 30 years.

Oil spills

Westland petrels are not known to have been victims of oil-spills however, as more of the New Zealand EEZ is made available for oil prospecting and ever larger vessels visit New Zealand, the chance of spilt oil impacting this species will increase.

Plastics

The amount of plastic waste accumulating in the marine environment is increasing year by year (Lavers *et al*. 2014, Wilcox *et al*. 2015 and references there in). This is a global problem, in Hawaii plastics continue to kill albatross chicks when adults have mistaken plastic debris for food and on-fed it to their chicks. In Australia plastics have been implemented in the continuing decline of flesh-footed shearwaters (*Puffinus carneipes*) (Lavers *et al*. 2014). However, to date ingestion of plastics appears to have been a minor threat to New Zealand seabirds and did not warrant consideration in Rowe & Taylor's (2006) review of New Zealand seabird priorities. The only West Coast record appears to be one small piece of plastic found in the stomach of one of the 60 blue penguins (*Eudyptula minor*) found dead on the West Coast (R. Lane unpublished data). Ingestion of plastics can block the gut inhibiting food intake sometimes killing the bird, or organs may be damaged by chemicals that leach from the plastic (Lavers *et al*. 2014, Wilcox *et al*. 2015). Seabirds can also become entangled in plastic debris.

The presence of plastics in the ocean is now ubiquitous and a global review of the impact of plastics on seabirds (Wilcox *et al*. 2015) makes sobering reading. The production of plastics is doubling every 11 years and they predict that by 2050, 99% of all seabird species and 95% of all individuals of those species will have ingested plastic (Wilcox *et al*. 2015). Impacts are expected to be greatest where high plastic concentration and high seabird diversity coincide, and one of those areas is the boundary between the southwestern Pacific and Southern Oceans in the southern Tasman Sea (Wilcox *et al*. 2015).

Other possible threats

Heavy metals and other contaminants enter the marine environment through a variety of natural and anthropogenic sources. Seabirds being at the top of the marine food chain are likely to exhibit high levels of heavy metals and other contaminants which can reduce breeding success and cause eggshell-thinning. To date there is no known instance of heavy metal or chemical contaminants adversely affecting New Zealand breeding species although there has been very limited research on New Zealand seabirds (Rowe & Taylor 2006).

Toxic algal blooms occur around New Zealand from time to time and they have the potential to kill a variety of marine organisms and perhaps even seabirds. Marine biotoxins may have been responsible for die-offs of blue penguins and common diving petrels (*Pelecanoides urinatrix*) (Rowe & Taylor 2006).

Research priorities in approximate order of priority

The colony based research that is recommended below requires periods of intense research over several weeks. This is challenging given the lack of infrastructure at the colony, and the often inclement weather. The campsite used by previous researchers has been destroyed by treefall. A small research hut would enable a greater quality and consistency of work to be achieved. It would reduce the likelihood of accident and reduce damage to the access track; currently researchers come and go daily often when tired after late night vigils on the colony.

- Determine which South American fisheries take Westland petrels as bycatch and the level of bycatch in each fishery. Identified as essential research by ACAP (2012) but virtually no progress has been made. This is probably the one threat that has the greatest potential impact on Westland petrels.

- Determine the degree of overlap between Westland petrel foraging ranges with South American fisheries.

- Continue demographic monitoring of productivity, recruitment, age at first breeding and breeding frequency in Study Colony and Rowe Colony, plus some smaller colonies to determine population trends. The minimum requirement is to check burrows about 1 June and 1 November each year

- Further tracking at sea of breeding and non-breeding petrels at all stages in the annual cycle, including migration to identify hotspots of petrel activity. Identified as a priority by ACAP (2012), Rowe & Taylor (2006) and Waugh (2012b). Tracking of breeding adults during the breeding season continues but there is no information on juvenile dispersal, on non-breeding birds and limited information on distribution while in South American seas.

- Assess the impact climate change is likely to have on Westland petrels. At present there is virtually nothing known about the effect of climate change on New Zealand seabirds in general or Westland petrels in particular.

- Investigate why only about half of breeding age birds breed each year and why birds that have bred previously skip breeding seasons.

- Determine overlap in foraging range with fisheries. There is good data for the South Island West Coast Hoki fishery (Freeman & Wilson 2002) although that field work was undertaken 20 years ago, but very limited information available for other fisheries.

- It is possible that breeding success may be high, but few pairs commence breeding, thus the population may decline despite breeding success remaining high. The data available do not allow a robust comparison of numbers of chicks fledged in recent years with numbers produced in previous decades.

- Study of foods and foraging both within the New Zealand region and while in South America to better understand how changes to the food chain caused by fishing and climate change may affect the petrels. This to include trophic shifts if diet has changed over time.

- Systematic recording of fallout of fledglings and adults due to disorientation by lights primarily at Punakaiki but also in Westport, Greymouth and Hokitika. A proposal for research addressing mortality due to lights is likely to be submitted by the West Coast Penguin Trust. This research could involve volunteers in the search, collection and reporting of grounded petrels. Considering the distance between West Coast towns, public participation in the study would be especially desirable and thus would also serve to raise awareness and appreciation of the birds. Due to likely annual variation in numbers affected I propose an initial three year study starting in 2017.

- Determine if there is bycatch of Westland petrels in inshore trawl fisheries in the Karamea, Cook Strait, South Westland and Marlborough areas.

- Census of all breeding colonies for three consecutive years every decade with more frequent population estimates for Study and Rowe Colonies.

- Install motion activated cameras in colonies, preferably colonies seldom visited by people, to determine the presence of introduced mammals and their impact on the petrels.

- Determine bycatch in recreational fisheries in New Zealand in particular those fishing inshore using set-nets.

- Analysis of gut of birds found dead to determine the level, if any of plastic ingestion by Westland petrels.

- Monitor survival in both males and females.

- Record localised causes of mortality such as treefalls, landslides and habitat destruction. Of particular importance is the frequency at which landslides occur and the areas of colony lost in these events. Record treefall frequency and number of burrows affected in Study and Rowe Colonies.

- Band chicks each year in Study and Rowe Colonies to determine productivity and movement between colonies. Annual banding of chicks and adults was part of DOC's management programme for the species (Lyall *et al.* 2004).

- Stable isotope studies to assess the fit with other species in the New Zealand seabird assemblage. Work in progress (S. Waugh *pers comm*.)

- Analysis of carcases, blood or feather samples (as appropriate) to determine the level of heavy metal contamination in Westland petrels.

- Search for banded birds from colony areas lost during cyclone Ita.

- Establish soil depth markers and soil pits in Study and Rowe colonies to measure soil loss through localised erosion.

- Burrow longevity studies to determine how stable burrows are and how often birds abandon burrows or start new burrows. This is needed to better interpret transect and quadrate data. Data on these aspects have been collected but money is required to support its analysis and write up.

Management priorities in approximate order of priority

As with other petrels population changes are influenced more by adult survival than any other population factor. Management that affects adult survival (i.e. fisheries by catch) is more effective at influencing population growth than factors affecting chick survival (i.e. disorientation by lights).

- Increase observer coverage on fishing vessels in South American waters, ensure observers can distinguish Westland and black petrels from the more common white-chinned petrels and ensure bycatch data is shared with New Zealand authorities. Perhaps this could be done through ACAP.

- Recommend mitigation measures be taken to reduce bycatch in those South American fisheries where bycatch of Westland petrels is greatest.

- Feral pigs are currently absent from the area and illegal releases must be dealt with immediately. The establishment of feral pigs is probably the greatest risk to the survival of the Westland petrel colonies, as adults and chicks would be killed and colony habitat destroyed. It is essential that DOC be prepared and have mitigation measures in place in case this should occur.

- Breeding success and adult survival suggest that most of the time predation on the colonies is of minor consequence. However cats and dogs could decimate Westland petrel colonies. Stray dogs can cause the death of dozens of petrels in just a few days so dog incursions must be dealt to quickly. With the current level of visitation by researchers and DOC staff, pig and dog incursions could go unnoticed for weeks or months. In the past cage traps have been set alongside the Scotsman's valley track to catch dogs and two sand tracking pits on the track would record the footprints left by people or animals using the track.

- Increase targeted seabird observer coverage in hoki trawl, hapuka bottom long-line and minor bottom long-line (high priority), and flatfish trawl and inshore trawl fisheries in New Zealand.

- Better application of mitigation measures in small vessel southern bluefin tuna (high priority) and hoki trawl, hapuka bottom long-line, minor bottom long-line and swordfish surface long-line fisheries in New Zealand.

- Fisheries which carry few observers and operate within the Westland petrel range, including inshore trawl, set-net, purse-seine, and troll fisheries report little if any seabird bycatch, yet based on studies from other jurisdictions, have the potential to catch seabirds including Westland petrels.

- Possum and goat control to keep their populations at low levels to protect vegetation and thus stabilise slopes. Remove carcasses from colony areas to avoid attracting predators. This has been recommended in the Westland petrel recovery plan (Lyall *et al*. 2004) and its updates (DOC 2005, 2010).

- Systematic recording of Westland petrels grounded by lights in Punakaiki and elsewhere. Record the precise locality of each grounding and the fate of each grounded bird.

- Ensure lights at Punakaiki are shielded to prevent light spill skyward and seaward to reduce the incidence of the grounding of petrels. Currently this is required only for buildings in the Scenically Sensitive Commercial Zone between Punakaiki River and Dolomite Point.

- Maintain the fences along the boundaries of private land in Liddys, Hibernia and Lawsons Creeks to keep stock out of the Westland petrel breeding areas.

- Encourage the Buller and Grey District Councils to put in place restrictions on land use, building height, lighting in those areas adjacent to the Westland petrel breeding areas and beneath flyways to protect the birds.

- Ensure all power and communication lines crossing Westland petrel flight paths are underground.

- Continue to keep visits to the colonies by people to those essential for conservation, research and advocacy.

Advocacy

A major impediment to the conservation of petrels of any species is lack of public awareness, hence little concern for them. Almost all New Zealand breeding petrels are nocturnal on land and spend most of their lives at sea, furthermore they are vulnerable to introduced mammalian predators thus almost all of the 16 species that would once have bred on the North or South Island mainlands are now confined to islands free of introduced predatory mammals. Thus, petrels are perhaps the group of birds least familiar to the lay person. Westland petrels are one of the most easily viewed of the New Zealand breeding species and offer unparalleled opportunities for public viewing. Their major flyway crosses the West Coast highway 3.8km south of Punakaiki and the birds pass low overhead each evening from March to November. Denise Howard and Bruce Stuart-Menteath have a colony on their private land and they operate low key, ecologically sensitive tourist visits to their colony. In 2015 Punakaiki business-people, keen to create a local event in the tourist shoulder season, ran the 'Return of the Westland Petrel Festival' which probably did more than anything else to raise the profile of the petrels. This was repeated in 2016 and may become an annual event. Low impact petrel viewing could be good for the local economy at a time when the West Coast has lost several major employers.

As the petrels are nocturnal on land, they can only be viewed in the evening as they fly from sea to colony or just before dawn as they return to sea, thus visitors must find accommodation locally; even freedom viewing has economic spinoffs.

Greater advocacy is not only advantageous for the local economy it would also help address the main land-based, human induced threats to the petrels identified in the previous sections. Those threats are, wandering dogs, feral cats, poorly fenced stock, illegal releases of pigs and bright lights in coastal communities, yet each can be easily mitigated if local people take simple steps to reduce petrel mortality. Locals will only take these steps if they know of and value the birds.

Promotion of the Howard/Stuart-Menteath tourist operation, provision of a safe off road viewing area on the Conservation Volunteers site and local advocacy of the birds, are easy steps to increase local awareness of the birds and enhance their contribution to the local economy. In the hour before dusk the petrels raft up about one kilometre off the beach at McMillans Road (2.2 km south of Punakaiki) but binoculars or preferably a spotting telescope is required to see them.

There are two options for a viewing area on the Conservation Volunteers site. The simplest and cheapest is a fenced area near their building merely providing safe off road parking and viewing as the birds fly overhead. Seating and information panels would enhance the viewing experience. A viewing platform on the ridge to the south side of Scotsman's Creek has been mooted. This is controversial; the access track must be routed away from the colonies so that predators do not use the track to locate the birds, and viewers would be tempted to use bright lights which could disorientate the birds. A less controversial site on a hilltop on the north side of Scotsman's Creek could be investigated. Hilltop viewing requires greater infrastructure, it does allow people to view the birds as they fly by at eye-level as opposed to viewing birds flying overhead from the Conservation Volunteers carpark. Hilltop viewing would probably require onsite supervision.

The Westland petrel display at the DOC Punakaiki visitors centre has not been updated for decades, it is looking a bit tired. A leaflet with photos and basic information on the petrels should be produced. The West Coast Penguin Trust could do this perhaps seeking sponsorship from Rio Tinto.

In the past there have been suggestions that supervised visits to the Study Colony on the hills at the head of Scotsman's Creek be permitted. While occasional visits by ornithologists or other specialist interest groups may be appropriate, access to this colony is steep and challenging and there is little reason for this when tourists can visit the more easily accessible Howard/Stuart-Menteath colony.

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