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Westland petrels and hoki fishery waste: opportunistic use of a readily available resource?

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Abstract The importance of fisheries waste in the diet of Westland petrels (*Procellaria westlandica*) was assessed using 3 different techniques. Dietary studies showed that during the hoki (*Macruronus novaezelandiae*) fishing season (mid June - early September), fish waste formed *c.* 63% of the solid food brought back to the colony and fed to chicks. After the hoki season, fisheries waste contributed only *c.* 25% to the diet. A survey of Westland petrels at sea found that, although vessels fishing for hoki influence the petrels' distribution, only a small proportion of the population appears to use this food resource at any one time. Satellite tracking showed that, on average, birds spent 1/3rd of each foraging trip near vessels, but they foraged over much wider areas than those occupied by the fishing fleets. Although fishery waste now forms a substantial component of the Westland petrel's diet, the situation suggests opportunistic use of a readily available resource, rather than dependence.

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INTRODUCTION

The use of fishery waste by scavenging seabirds has received increasing attention in recent years and several studies have found waste to be an important component of the diet of certain seabirds which have learnt to exploit this abundant and readily available food source (e.g., Hudson & Furness 1988; Jackson 1988; Thompson 1992; Camphuysen *et al.* 1995). Although variation in food availability has been mooted regularly as a cause of population change, it is difficult to demonstrate clear links between changes in seabird populations and fisheries. The demographic characteristics of the Procellariiformes (low reproductive rates, high adult survival rates, delayed maturation) coupled with their pelagic habits, make it very difficult to study population regulation in these birds. By the time significant changes have been detected, the factors underlying those changes must have operated for years (Croxall & Rothery 1991). Nevertheless, seabird biologists have expressed concern that, if a large enough proportion of a species' population comes to depend on scavenging at fishing vessels, the species could experience a food crisis if fishing operations changed (e.g., Bartle 1974; Abrams 1983). Studies that have recorded a decrease in the reproductive performance of gull species following a trawling moratorium in the Mediterranean provide compelling evidence for this effect (Oro *et al.* 1995; Oro 1996; Oro *et al.* 1996).

Westland petrels (*Procellaria westlandica*) breed only near Punakaiki on the West Coast of New Zealand's South Island (Turbott 1990). Capture-recapture analysis of banded birds has indicated that the total population of Westland petrels expanded at an average of c. 5% per annum between 1953 and 1985, when it peaked at 20 000 ± 5 000 birds. Population modelling indicates a subsequent decline (Bartle 1987; Department of Conservation 1996). The long period of population growth has been attributed partly to increased food in the form of waste from fisheries, especially the West Coast South Island (WCSI) hoki (*Macruronus novaezelandiae*) fishery (Bartle 1985, 1987). It has been postulated that the subsequent decline in the Westland petrel

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population could have resulted from a reduction in trawling on the West Coast (Bartle 1987).

Previously published research sought to determine the importance of fishery waste in the diet of Westland petrels during the chick-rearing period and whether foraging patterns of Westland petrels were influenced by commercial fishing activity, particularly the WCSI hoki fishery. In this paper we further interpret and integrate the different aspects of this research and present arguments in support of the contention that changes in fishing practices could be expected to have little impact on the breeding success of Westland petrels. For reasons of completeness, this paper cites some information from sources that are not readily obtainable.

METHODS

Fisheries reports and published studies were examined for information relating to observations of Westland petrels, fishing areas, annual landings, and discard rates in the WCSI and Cook Strait hoki fisheries and other fisheries along the West Coast of the South Island of New Zealand. This information was used to assess: (a) the volume of waste available to seabirds; (b) the potential for Westland petrels to come into contact with fishing vessels; (c) the timing of the hoki fishing season relative to the Westland petrel's breeding season; and (d) the expansion of the hoki fishery relative to the expansion of the Westland petrel population.

Dietary studies, a survey at sea, and satellite-tracking were used in this study and the methods are described in full in the papers cited below.

Regurgitation and water offloading (Wilson 1984) were used to sample the diet of Westland petrels at the Scotchman's Creek sub-colony in August-October 1993-1996, inclusive. Traditional means of identifying hard parts in the samples allowed some fishery waste to be identified and improved knowledge of the range of prey in the Westland petrel's natural diet (Freeman 1998). Early in the study, however, it became apparent that, because fishery waste typically does not contain many identifiable hard parts, conventional analysis was insufficient. Therefore, iso-electric focusing, an electrophoretic technique, was used to identify fish species from pieces of flesh in diet samples.

A survey of Westland petrels at sea off the West Coast of the South Island from 2-14 August 1993 (Freeman 1997) complemented the land-based diet studies. Ten-minute counts of seabirds visible through 8 × 40 binoculars all around the vessel were made every 0.5 h during daylight hours. The survey included areas intensively worked by hoki trawlers over waters 200- 800 m deep along the edge of the continental shelf and inner continental slope. Comparing the positions of Westland petrels and fishing vessels in a Geographical Information System (GIS) enabled the relationship between the Westland petrels' distribution at sea and the positions of fishing vessels to be determined.

Although the at-sea survey provided information on the petrels' relationship to the WCSI hoki fishery on a species-wide scale, it could not reveal whether or not birds differed in their attraction to fishing vessels, when during a foraging trip they visited the fishery, the proportion of time that birds spent foraging around vessels, or locations outside of the survey area where Westland petrels forage. Nor could the survey differentiate between non-breeders and the breeding birds of most interest. It was necessary to track individual birds at sea. VHF radio tracking proved unsatisfactory because birds travelled too far and spent little time within tracking range (Freeman *et al.* 1997) but satellite tracking allowed the foraging movements of breeding birds to be followed. Three male Westland petrels were tracked for a total of 6 foraging trips between 11 August and 19 September 1995. Four female and 5 male Westland petrels were tracked for a total of 16 foraging trips between 6 August and 3 September 1996. All birds had dependent chicks ashore. Using GIS to compare the positions of birds obtained from satellite tracking with those of fishing vessels obtained from catch processing returns, enabled the proportion of time that Westland petrels spent in the vicinity of fishing vessels to be assessed (Freeman *et al.* 1997; Freeman *et al.* 2001).

RESULTS

The WCSI hoki fishery is New Zealand's largest commercial fishery in terms of total catch (MAF Fisheries 1993). It operates about 80 km offshore from the Westland petrel colony, concentrated over localised hoki spawning grounds around the 200 m depth contour of the continental shelf break. Most Westland petrel eggs are laid in May and hatch in July; chicks fledge in November/December. The WCSI hoki fishing season from mid June to early September therefore coincides with the Westland petrel's incubation and early chick rearing period.

The hoki fishery developed in the early 1970s but remained relatively small up to 1985, with annual landings of < 50 000 t. After 1986, the fishery expanded with estimated landings reaching a maximum of 255 000 t in the 1987/88 fishing year (October-September) and since then has remained relatively constant at about 210 000 t (Horn & Sullivan 1996). However, the proportion of hoki caught outside of the main West Coast fishing area increased during the 1990s and the WCSI catch reduced from *c.* 160 000-190 000 t in the late 1980s to *c.* 100 000 t in the mid 1990s.

The proportion of non-target fish species caught, and hence discarded, in the WCSI hoki fishery is low. For example, in 1991, other commercial species

— predominantly hake (*Merluccius australis*) and ling (*Genypterus blacodes*) — accounted for no more than 10% of the total catch (Sullivan & Cordue 1992). Small numbers of rattails (Macrouridae) and dogfish (Squalidae) are also caught but, being non-quota species, are largely unrecorded (pers. obs.). The waste discharged from the (WCSI) hoki fishery consists, therefore, mainly of hoki, with small amounts of other mid-water fish, which would not otherwise be available to seabirds.

The quantity of waste discharged from the hoki fishery varies depending on the composition and characteristics of the fishing fleets from year to year. Livingston & Rutherford (1988) estimated that 48% of the catch of vessels fishing for the surimi (fish paste) trade was dumped as waste compared to 25% of the catch of other vessels. The volume of waste discharged from the WCSI hoki fishery may, therefore, have decreased in the 1990s with both the reduction in catch and the withdrawal of surimi vessels in favour of filleting vessels, which produce less waste. In 1991, for example, the surimi component of the WCSI catch was only 39% of the total compared with 60% in 1986-1990 (Sullivan & Cordue 1992).

Using Livingston & Rutherford's (1988) estimates of the proportion of catch discharged as waste, Sullivan & Cordue's (1992) 1991 ratio of surimi to non-surimi catch in the WCSI fishery, and the 1994-95 total catch figure of 175 000 t, the total volume of waste discharged from the hoki fishery in the mid-1990s would be *c.* 47 000 t per annum. This represents a very large potential food source for seabirds.

During the breeding season, Westland petrels feed mostly over the continental shelf and upper continental slope. At this time they are found north of the subtropical convergence east and west of New Zealand (Marchant & Higgins 1990) where they can come into contact with fishing vessels.

In the late 1950s, few Westland petrels fed on trawl waste from fishing boats, but the number feeding on the Cook Strait trawling grounds increased greatly during the 1960s (Bartle 1974). In October and November 1975, large numbers of Westland petrels were observed feeding on fishery waste during exploratory fishing off Greymouth, West Coast (Vooren 1977). Since then, Westland petrels have regularly been observed scavenging behind WCSI hoki trawlers and other fishing vessels. The number of birds seen has seldom been recorded accurately but the few counts show that 1 or 2 individuals up to *c.* 150 may follow a single vessel (pers. obs.; P. Langlands pers. comm.). Although most observations of scavenging are from the WCSI hoki fishery, other fisheries within the Westland petrel's foraging range, such as the Cook Strait hoki fishery, and the small, inshore set net, trawl, and long line fisheries are also potential food sources. Among these are vessels fishing for red cod (*Pseudophycis bachus*), barracouta (*Thyrsites atun*), and gurnard (*Chelidonichthys kuma*), which are caught in comparatively small quantities (a few hundred to a few thousand tonnes) off the West Coast of the South Island (Annala & Sullivan 1996).

Fish were present in 92% of Westland petrel diet samples and formed 78.8 ± 6.5% by weight of the solid food brought back to the colony. Cephalopods were found in 32% of samples and contributed 18.7 ± 6.2% of solid food by weight. Crustacea occurred in 4% of samples and contributed only 2.4 ± 2.4% of solid food by weight. Myctophids were the commonest "natural" fish found in the diet samples. Histioteuthids and cranchiids were the most common cephalopods and *Nyctiphanes australis* (an euphausiid) was the only crustacean species present in large numbers in the diet samples (Freeman 1998).

During the hoki fishing season, fishery waste accounted for *c.* 63% of the solid food brought back to the colony. After the hoki season, fishery waste contributed *c.* 25% of the solid food brought back to the colony as birds increased the proportion of "natural" prey, and scavenged a wider variety of fish species, presumably from smaller, inshore fishing vessels (Freeman 1998). Iso-electric focusing enabled us to identify 10 samples (6 positively, 4 tentatively) of fish tissue from 40 Westland petrel diet samples that would otherwise have been indeterminable. This technique revealed that fishery waste is more prominent in the diet of Westland petrels than was indicated by analysis of hard prey remains alone (Freeman & Smith 1998).

The survey of Westland petrel distribution at sea showed that vessels in the hoki fishery influenced the distribution of Westland petrels (Freeman 1997). Despite the proximity of the fishing grounds to the petrel's breeding colony, however, only a small proportion of the Westland petrel population appeared to be using this food resource at any time. During the survey at sea, Westland petrels were observed only over water depths of 250-780 m and were not seen near fishing vessels in shallower (100-200 m) water. However, shallower waters were not adequately sampled by the at-sea survey and subsequent satellite tracking showed that, on occasions, birds may spend substantial time inshore.

The proportion of time that Westland petrels spent in the vicinity of hoki fishing vessels was not influenced by the time of day (Freeman *et al.* 2001). Satellite-tracked birds varied considerably in the length of time they spent in the vicinity (i.e. < 5 km) of hoki fishing vessels (Freeman *et al.* 1997; Freeman *et al.* 2001). The mean length of foraging trips of satellite-tracked birds was 4.1 days. On average, tracked birds spent 1/3rd of the duration of a foraging trip near vessels. Some birds spent as much as half their foraging trip near the WCSI fishing fleet, and 9 of 12 birds satellite-tracked spent at least 25% of their foraging trip there. However, 3 birds, 2 of which visited Cook Strait, associated little with vessels. Most tracked birds concentrated on the waters of the shelf break and slope (water depth *c.* 200-800 m).

The time spent in the vicinity of vessels did not appear to be related to sex, length of foraging trip, or time in August and September when birds were tracked. The values provided an upper limit on the amount of time birds could have spent scavenging at vessels, because the methodology was not precise enough to determine when birds were coincident with vessels. Although the at-sea survey could not distinguish the breeding status of the Westland petrels associating with vessels, only breeding birds were tracked using satellite telemetry. The results, therefore, were not directly comparable.

DISCUSSION

Fishery waste would appear to be so abundant that Westland petrels could meet all their needs by visiting the hoki fishery for a short time. Nevertheless, Westland petrels continued to forage on natural prey. Sampling indicated that during the hoki fishing season *c.* 63% of food brought back to the colony was fishery waste. However, the importance of fisheries waste in the diet may have been overestimated if recently consumed waste from the nearby fishery was over-represented in the regurgitations collected (Freeman 1998; Freeman *et al.* 2001). The satellite tracking results also indicated that some individuals may seldom scavenge around hoki fishing vessels. Nevertheless, as the WCSI hoki fishery is the fishery most used by Westland petrels during their breeding season, changes which result in less waste from this fishery could affect their breeding success.

Changes which result in less waste could include movement of vessels to other fishing grounds (such as the movement to Cook Strait following the discovery of other hoki spawning grounds there), reduction in the number of surimi vessels in favour of smaller filleting boats, or an increase in the number of vessels processing waste into fish meal for fertiliser, or a combination of these factors. Indeed all these factors probably reduced the volume of fishery waste discharged from the WCSI hoki fishery during the 1990s. Future changes that could reduce the volume of waste are reduction in quotas or economic factors affecting the profitability of WCSI hoki fishing.

The impact that a reduction in fisheries waste would have on Westland petrels would depend on several factors. Firstly, the ease with which Westland petrels can obtain waste may depend on their hierarchical status among species attending vessels. Presumably smaller, or less aggressive, scavenging species would be out-competed by larger, or more aggressive, species as observed in seabird assemblages around Shetland (Hudson & Furness 1988). Off the West Coast in winter the larger albatrosses (*Diomedea* spp.), mollymawks (*Thalassarche* spp.) and giant petrels (*Macronectes* spp.) tend to dominate the Westland petrels, but Westland petrels dominate the smaller petrels (pers. obs.). In addition, the ease with which different species can obtain fishery waste may also depend on the size of waste debris discharged. A change in the size composition of waste discharged could be associated with an overall reduction in fishery waste if caused by a change in fishing practices. There are no data on the place of Westland petrels in the dominance hierarchy of species scavenging at fishing vessels or on the success of Westland petrels at scavenging in the hoki fishery.

Interspecific competition may also play an important role in the responses of seabird populations to changing fishing practices. For example, the volume of waste consumed by great skuas (*Catharacta skua*) in Shetland varied with the availability of sandeels (*Ammodytes* spp.), their preferred prey. When sandeels were scarce and skuas took a disproportionate share of available discards, gulls were thought to turn to other food sources (Furness & Monaghan 1987). Therefore, consumption of fishery waste by Westland petrels may be affected not only by changes in their own food supply, but also by changes in the food supply of competing scavengers.

The WCSI hoki fishery could also have secondary effects on the food available to Westland petrels. The large amount of hoki removed by trawling each year could result in Westland petrels being released from competition with hoki whose diet also includes myctophids (Kuo & Tanaka 1984). This is unlikely, however, because outside of the spawning season most adult hoki reside on the Southern Plateau (away from the Westland petrel's foraging grounds) and hoki do not appear to feed while spawning (Livingston 1990).

Whether or not Westland petrels would be negatively affected by a decline in the availability of fishery waste may depend on the availability of alternative food sources. Several factors suggest that this might not be difficult. After the hoki fishing season, when Westland petrels are feeding larger, more demanding chicks, they feed on larger quantities of natural prey, and scavenge at smaller, inshore fishing vessels, suggesting that Westland petrels are adaptable and able to find adequate natural foods. The closely-related white-chinned petrel (*Procellaria aequinoctialis*) uses diverse foraging techniques; they feed by day and night, by surface seizing and deep plunging, display aggressive behaviour at limited food sources, and associate with vessels and cetaceans (Ridoux 1994), all behaviours that suggest an ability to take advantage of different feeding opportunities.

Although the foraging trip lengths of satellite-tracked birds were, on average, twice as long as those of un-tracked birds, presumably because it took them longer to obtain food, only 1 bird lost weight between when the transmitter was attached and its recovery (Freeman *et al.* 2001). Hence, in general, the satellite-tracked birds fed successfully during their foraging trips although the weights of satellite-tracked birds were not compared with untracked birds. All chicks of satellite-tracked birds fledged with normal weights and wing lengths (Freeman *et al.* 2001). These results suggest that Westland petrels may be able to sustain longer foraging trips that could accompany a reduction in available food through decreased volumes of fishery waste, without detriment to their breeding success.

White-chinned petrels have been shown to forage up to *c.* 1200 km from their nests while breeding (Ridoux 1994). Satellite tracking showed that breeding Westland petrels can travel similar distances, allowing them to forage over much wider areas than that occupied by the WCSI hoki fishery (Freeman *et al.* 2001).

It is possible that fishery waste is most important to Westland petrels in 'poor' years. It could, for example, help to even out annual variations in breeding success. The Westland petrel's breeding success (% eggs from which chicks fledged) has varied considerably over the years. An earlier study found that breeding success in 1970 and 1971 was only 5.7 and 3%, respectively (Baker & Coleman 1977). However, the authors attributed this to chicks being 'birded' (taken for human consumption) in the late chick stage and this, coupled with predation by cats, dogs, and weka (*Gallirallus australis*), whose numbers are now controlled at the colony, are more likely to explain poor breeding success than is poor food supply.

In the years 1976-1991, breeding success averaged 39% (range 20-63%) (Department of Conservation 1996) and in 1991-96 it averaged 50% (range 38-63%) (pers. obs.). Breeding success was relatively high during the early to mid-1990s even though the amount of waste discharged from the WCSI hoki fishery presumably decreased over the same period as a result of the reduced catch on the West Coast and changes in the composition of the fishing fleet. Therefore, it appears that other factors, perhaps environmental factors affecting natural prey abundance or foraging efficiency, or just the removal of predators at the breeding colony, are more important to breeding success than the quantity of fishery waste available.

Finally, the hoki fishing season finishes 2 months before Westland petrel chicks fledge in November and December. All young birds must, therefore, learn to feed on "natural" food and do not have access to the waste provided by this large-scale fishery. Although hoki fishery waste is now a substantial component of the Westland petrel's diet, the above factors indicate that Westland petrels could compensate for a reduction in the amount of waste by switching to waste from other fisheries or increasing the quantity of 'natural' prey caught, or both, without affecting their breeding success. The situation appears to be an opportunistic use of a readily available resource rather than dependence.

The implications of scavenging on fishery waste for the Westland petrel population are unknown. The present study suggests that a reduction in hoki fishery waste would not affect breeding success, but there are several other parameters, for example fledging weights, adult and immature survival rates, extent of non-breeding among adults, and age at first breeding, which may affect population size (Croxall & Rothery 1991). All of these parameters could be affected by the availability of waste but were not investigated during this study. Comparing changes in the Westland petrel population with catch levels in the hoki fishery suggests, however, that there is no positive relationship between the size of the fishery and the size of the Westland petrel population which is thought to have peaked in 1985 (Bartle 1987; Department of Conservation 1996) even though the hoki fishery did not expand markedly until after that time. If expansion of the hoki fishery caused the increase in the Westland petrel population, it would be expected that the population would have continued to increase through the 1980s and 1990s.

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