

there were two inshore feeders <2 km from Long Point in water 30-60 m deep, three mid-zone feeders around the 90 m contour, 6-17 km out, and five other birds scattered out to 10-30 km offshore in water 100-120m deep. In 1993 there were also two inshore feeders, seven mid-zone feeders, two of which had been offshore feeders the previous season, leaving only one bird foraging in water >100 m deep.

4.4 Dive depth

Dive data from the time-depth recorders was graphed to interpret diving behaviour. Dives with flat bottomed profiles were assumed to be foraging dives to the sea floor, zig-zag profiles were probably mid-water dives and shallow curved dives were probably when birds were travelling. In December and January, birds carrying dive-depth recorders were simultaneously radio-tracked, so that the position of the bird at sea could be matched with depths recorded. While travelling offshore, penguins dived to the bottom to forage. Deep dives were interspersed with mid-water dives (sometimes for long bouts) or rest periods. Diving continued (on average 254 dives per day, maximum 603) during daylight and then birds returned to the breeding area, mainly by travelling dives, or stayed at sea overnight without diving.

The maximum depth reached on each dive is summarised in Fig. 11. This represents 74 days of foraging on 62 foraging trips, mostly day-trips to sea, but also overnight trips (up to five days). Both areas showed a bimodal distribution of dive depths. The first peak from 5-30 m depth is probably a combination of travelling dives, foraging dives in shallow water and mid-water dives in deep water. The second peak at 40-60 m (maximum 66.2 m) of the Otago Peninsula and 80-110 m (maximum 127.9 m) off the Catlins represents foraging dives at or near the sea floor. These depth zones correspond to the wide areas of continental shelf in the respective areas (Fig. 1).

4.5 Diet

Between February 1991 and July 1993, 185 stomach contents from 85 penguins were collected from the Otago Peninsula (n = 115) and Catlins (n = 70).

From these samples, 21949 prey items in 37 species groupings were identified (see Appendix 1 for species names). Ten species (nine fish and one squid) constituted 95% of the estimated biomass and 67% of the total prey number. Fish comprised 86% of diet biomass and 78% of prey number. The mean number of prey items per stomach was 119.

The biomass of the main prey types are shown in Table 3. For example the average opalfish was equivalent in weight to 1004 krill, and the average blue cod was equivalent to 36 red cod. These relationships are reflected in Fig. 13 and 14; i.e. prey that are eaten in large numbers, do not necessarily contribute much to the total percentage weight of prey eaten or to the total food value of the diet.

Opalfish featured prominently in terms of occurrence (Fig. 12), number (Fig. 13) and weight (Fig. 14). Blue Cod and Arrow Squid were also important in terms of weight, but these were relatively large food items (Table 3) taken in low numbers, as were Lamprey. Silverside and Ahuru were taken at medium frequency and number, whereas

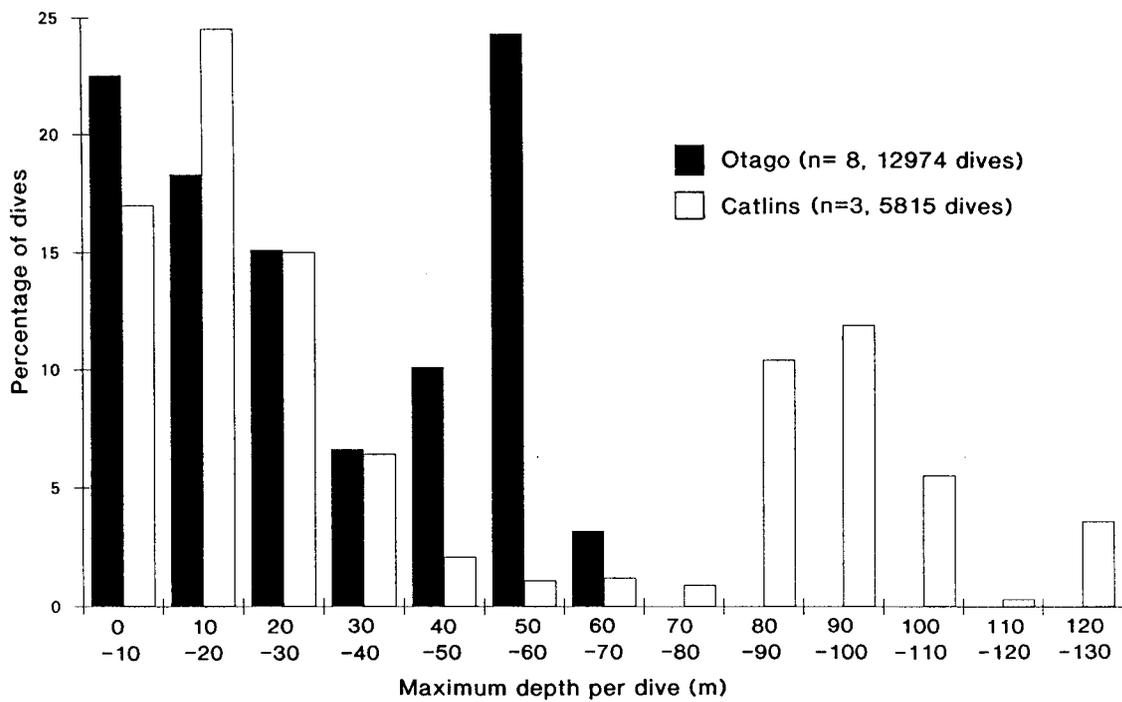


Figure 11 Frequency distribution of maximum depth of dives during the 1992-93 breeding season at Otago Peninsula and February 1993 at Catlins.

Table 3 Mean weight of prey in Yellow-eyed Penguin stomachs, 1991-93, from intact specimens or calculated from weights of unworn fish otoliths and lengths of squid beaks.

Prey Type	Mean calculated weight (g)	S.D.	No. weighed	Lifestyle*
Krill	0.023	0.006	100	pelagic
Arrow Squid	51.1	71.5	450	pelagic
Ahuru	7.7	2.3	719	demersal?
Opalfish	23.1	26.2	2119	demersal
Silverside	16.1	6.7	768	demersal
Blue Cod	94.3	74.4	247	demersal
Red Cod	2.6	10.2	3828	pelagic and demersal
Sprat	2.2	2.4	1436	pelagic
Lamprey	101.3	15.8	3	demersal?

* indications of lifestyle. Available information from Ayling (1982), Paulin *et al.* (1989) and Murdoch (1991), is mainly for adults, rather than the juveniles or subadults preyed on by Yellow-eyed Penguins. Demersal = bottom dwelling; pelagic = lives in the water column.

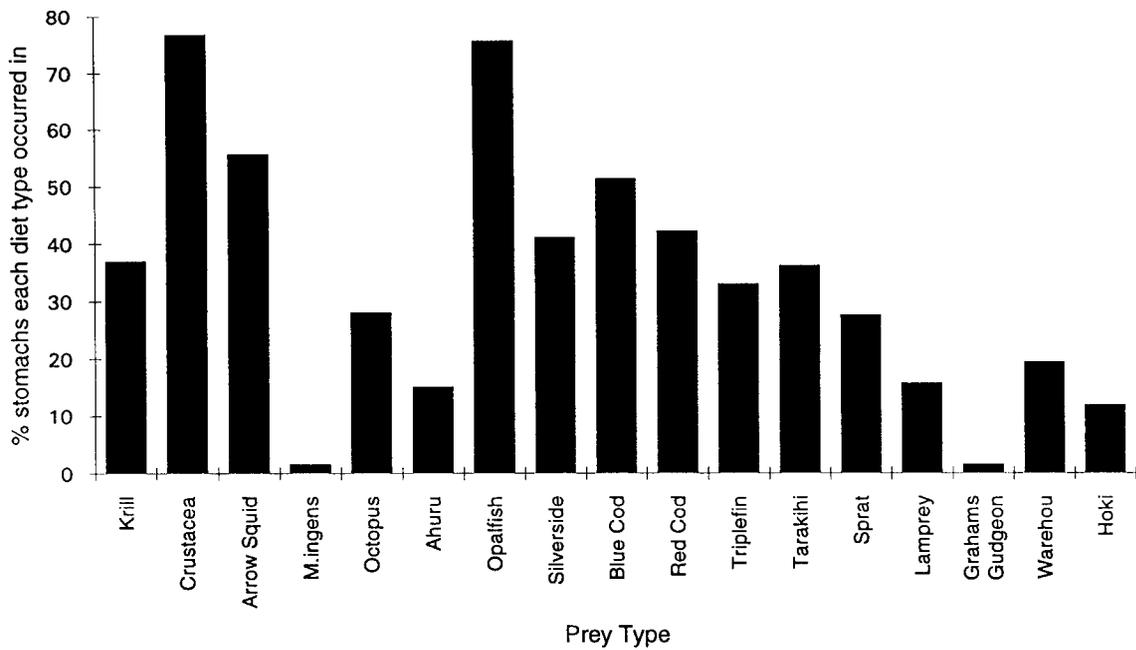


Figure 12 Percent occurrence of main prey in Yellow-eyed Penguin stomachs (i.e. % of stomachs that each diet type occurred in), Otago Peninsula and the Catlins, 1991-1993.

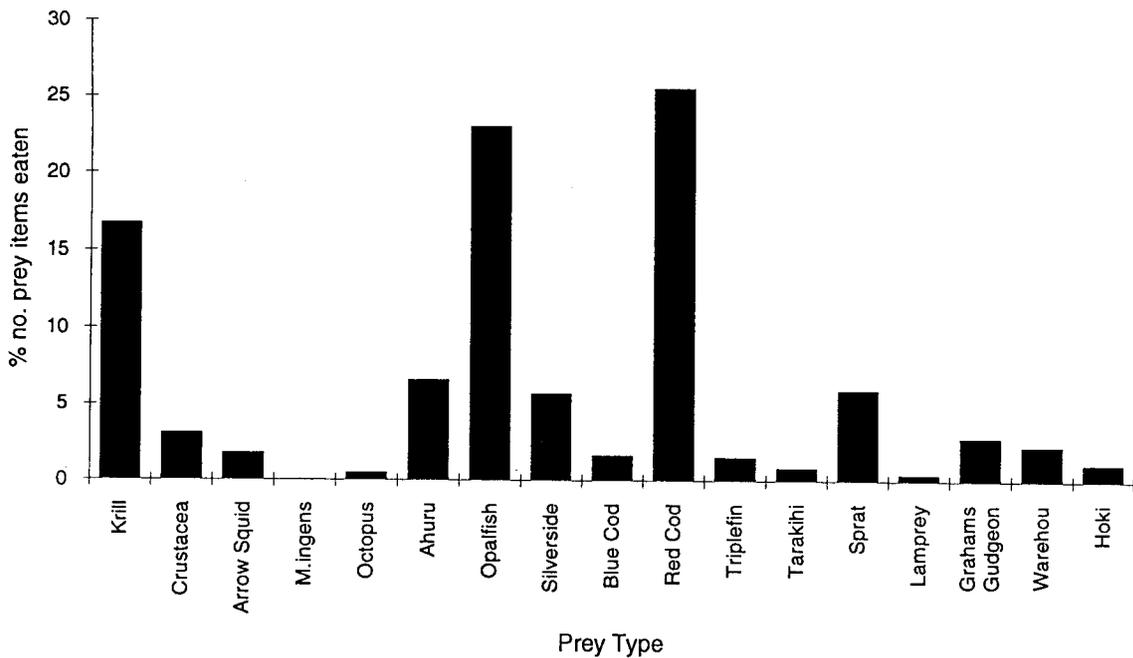


Figure 13 Percent number of main prey in Yellow-eyed Penguin stomachs (i.e. % of each diet type as a proportion of total number of prey items eaten), Otago Peninsula and the Catlins, 1991-1993.

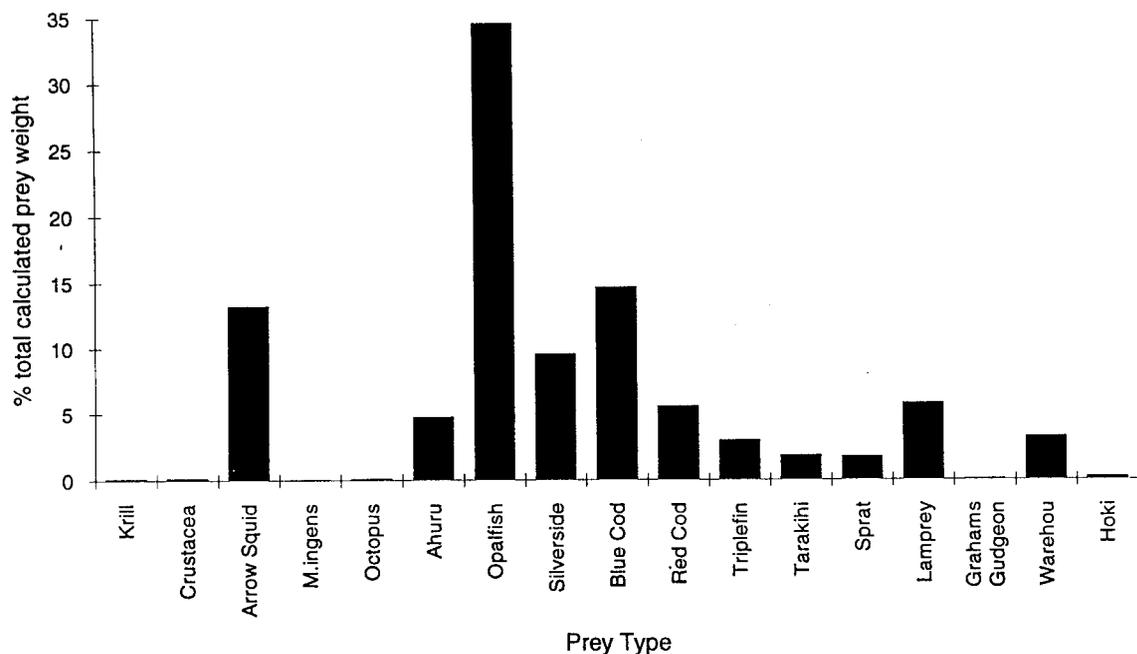


Figure 14 Estimated percent weight of main prey in Yellow-eyed Penguin stomachs (i.e. % of each diet type as a proportion of the total calculated prey biomass), Otago Peninsula and the Catlins, 1991-1993.

Red Cod were taken in the highest number of any species at high frequency, yet their small size (Table 3) relegated the species to sixth on the percent weight list (Fig. 14). Similarly, Sprat were taken in medium numbers and frequency but rated low in terms of estimated biomass. Krill and other crustacea (demersal and pelagic) were taken in high numbers and frequency but were insignificant in terms of biomass. Most krill came from a small number of samples that contained hundreds or thousands of individuals. Other prey which were frequently taken but were relatively small or few in number were octopus, Triplefin (demersal), Tarakihi (demersal), Warehou (mid-water) and Hoki (mainly demersal).

Looking at weight alone (Fig. 14), the most important species were Opalfish, Blue Cod, Arrow Squid and Silverside.

4.5.1 Variation in diet between sites The estimated percent weight contribution of each prey type to the diet of Yellow-eyed Penguins was similar at both localities (Fig. 15). Both sites had high proportions of Opalfish and similar proportions of Silverside, Red Cod and Warehou. However, Ahuru was the second most important component of the diet at the Catlins and almost absent at Otago Peninsula. Lamprey was also more important at Catlins, while Arrow Squid and Blue Cod were more so at Otago Peninsula. Small quantities of Triplefin and Tarakihi were taken at Otago Peninsula but rarely at Catlins.

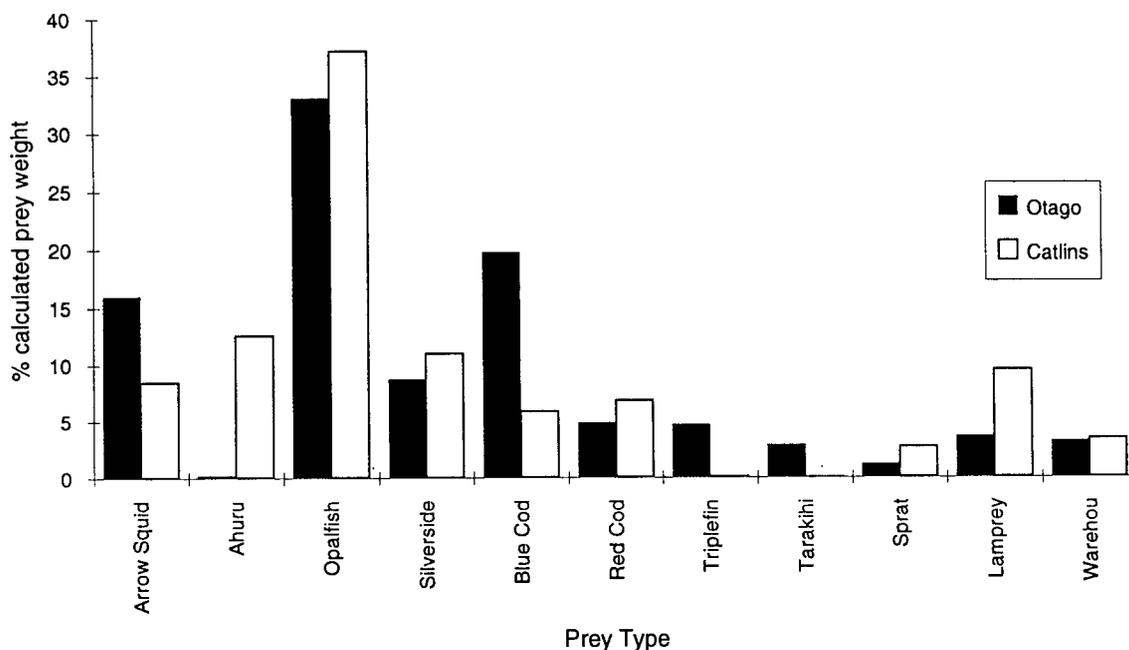


Figure 15 Estimated % weight of main prey in Yellow-eyed Penguin stomachs (i.e. % of each diet type as a proportion of the total calculated prey biomass), comparison between Otago Peninsula and the Catlins, 1991-93.

Mean weight of all prey was 9.3 g at Otago Peninsula and 5.5 g at the Catlins but mean prey number per stomach was 97 and 155 at the two respective areas; i.e. Catlins birds ate smaller prey but in greater numbers.

4.5.2 Annual variation in diet Stomach contents were collected during four breeding seasons (1990-91 to 1993-94), although only in 1991-92 and 1992-93 were samples collected from each stage of the season (July, October, December, January-February).

The proportion of prey types eaten in terms of weight were similar in the two fully sampled seasons (Fig. 16). Changes in the second (1992-93) season included an increase in Opalfish, the main prey in both years, and proportionally large increases in Red Cod, Triplefin, Sprat, Warehou, and Hoki. In contrast, Arrow Squid, Ahuru, and Lamprey decreased.

Mean prey size decreased from 9.1 to 6.1 g between 1991-92 and 1992-93 but mean prey number increased from 94 to 149 g; i.e. birds in the second season ate smaller prey in greater numbers.

4.5.3 Variation in diet with stage of the breeding cycle Differences in weight of prey eaten at different breeding stages (Fig. 17) reflected the seasonality of percent occurrence and percent by number of prey in the diet. Arrow Squid was most important in January-February (post-guard stage), Ahuru and Lamprey in July-August (pre-season) and Warehou in October-December (incubation and guard stages). Other major prey showed less marked changes between stages of the breeding season, although there

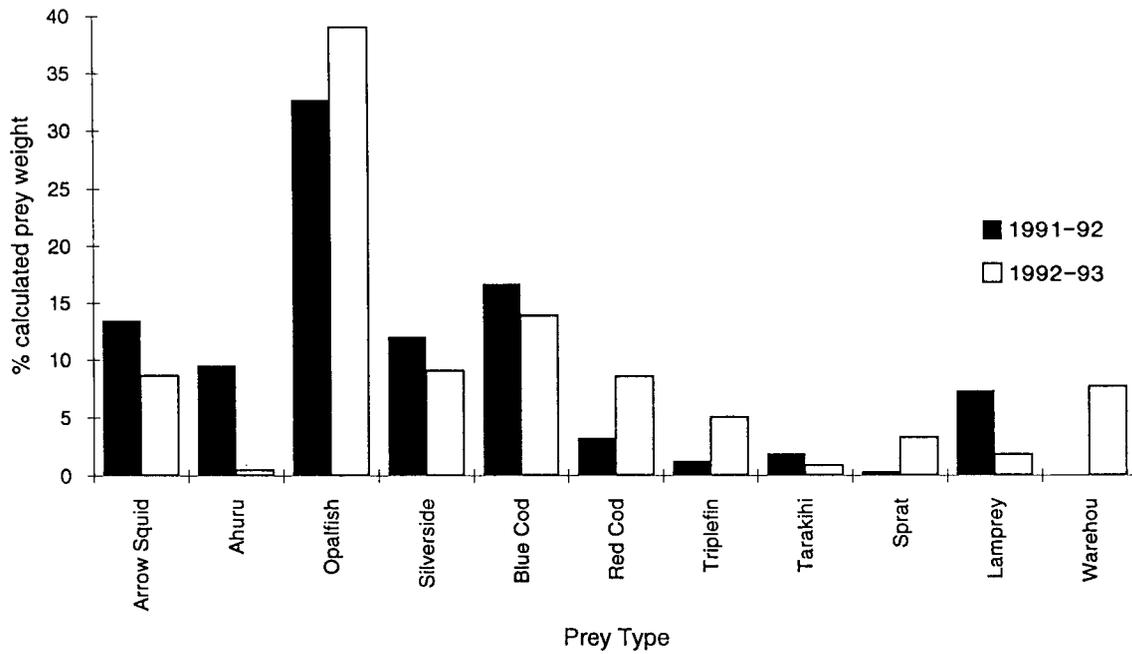


Figure 16 Estimated percent weight of main prey in Yellow-eyed Penguin stomachs (i.e. % of each diet type as a proportion of the total calculated prey biomass) during two breeding seasons, 1991-92 and 1992-93.

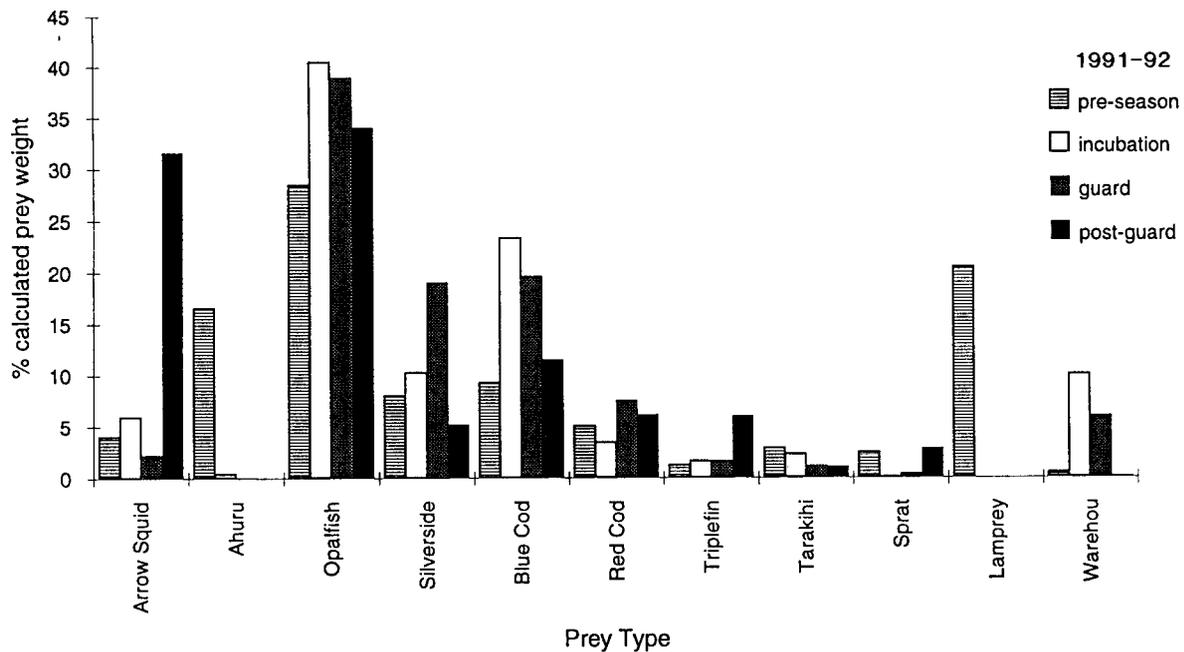


Figure 17 Estimated percent weight of main prey in Yellow-eyed Penguin stomachs (i.e. % of each diet type as a proportion of the total calculated prey biomass) at different stages of the breeding cycle, 1991-93.

was a trend for Opalfish, Silverside and Blue Cod to be more important in October-December.

Mean prey weight decreased from 12.4 to 4.0 g between July-August and December but mean prey number had a reverse trend of 65 to 178.

4.6 Breeding success

Most areas monitored during this study had twice as many nests in 1991-92 (Table 4) than were found in the previous season. In 1990-91, the year after the population crash, only 26 nests were found in the three Otago localities and 23 in the three Catlins areas (Moore *et al.* 1991). The least increase in 1991-92 occurred at A1 and Hayward Point. In 1992-93 nest numbers had levelled off at Otago Peninsula, but continued to increase at Long Point in the Catlins. Total chick production from the six areas monitored (Otago Peninsula and Catlins) increased from 25 chicks in 1990-91 to 86 in 1991-92 and 126 in 1992-93.

As a general guide to penguin nesting success, a mean of >1.2 chicks/nest is relatively high, 0.8-1.2 is moderate and <0.8 is low success (pers. obs.).

At Otago Peninsula, Highcliff and Sandfly Bay were successful areas of chick production. Although five (9%) chicks died between banding and fledging in 1991-92, there were no late deaths the following season. There was particularly high success at Sandfly Bay in 1992-93 with 11 of 15 nests successfully rearing two chicks. In 1991-92, most chick losses were by starvation at different stages of the rearing period. Predation was known or suspected in some other cases despite predator control (trapping of cats, ferrets and stoats by DOC staff). In 1992-93 all the chick losses occurred during the first week, seven were found dead in the nest, presumably from natural causes, and three disappeared.

Table 4 Yellow-eyed Penguin Nesting Success 1991-93

Breeding Area	1991-92		1992-93	
	No. Nests ¹	Mean No. Chicks Produced/Nest ³	No. Nests ²	Mean No. Chicks Produced/Nest ³
A1	10	0.7	11	1.0
Highcliff	16	1.38	16	1.25
Sandfly Bay	15	1.27	15	1.67
Otago Total	41	1.17	42	1.33
Nugget Point	8	0.5	8	1.0
Hayward Point	8	1.0	7	1.86
Long Point	22	0.73-0.95	31	1.45
Catlins Total	38	0.76-0.87	46	1.43

¹ Nests found during incubation. Two others were found during chick rearing in Otago and 3 in Catlins.

² Nests found during incubation. Two nests were found during chick rearing at Catlins.

³ Number produced to fledging stage at Otago, and to banding stage (c.80 days) at Catlins.

Breeding success at the Catlins (Table 4) was low in 1991-92. Most chick losses were early or late in the rearing period, from probable trampling, starvation and predation (there was no predator trapping that year). In 1992-93 there was much higher success, with low levels of predation (partly because of predator control) and less unexplained disappearances early in the rearing period.

Breeding success for three seasons at Otago and Catlins (this study) and for two seasons at Codfish Island and Campbell Island is tabulated in Appendix 2. In 1990-91, chick production was low at the South Island sites monitored (down to only 0.3 chicks per nest in the Catlins), partly because of egg removal. This had been a response by DOC to indications that another "bad season" was occurring (J. Darby pers. comm.). By reducing clutch size, it was hoped to prevent a repeat of the high mortality which occurred the previous season. In 1991-92 Otago nests were successful, but all areas to the south did poorly. In 1992-93 all four localities had high levels of success.

The possible influence of different types of disturbance on penguin breeding success is tabulated in Appendix 3. Although disturbance may have affected some nests and caused lower success in A1 of Otago Peninsula, adults that were disturbed the most (with radio-tags, multiple handling and diet samples) were more successful than birds that were sampled for diet once or twice only. Nests where adults were diet sampled had the lowest success, except for the Catlins sites in the second year. It was rare for a breeding failure to coincide with a handling of an adult, although stress may have predisposed birds to later failure from the disturbance of nest visits or predation because of changes to their parenting behaviour. As there is wide variation in success between localities (Table 4), it is probable that disturbance was only one of the factors involved in lowering breeding success at A1.

Mean banding and fledging weights of chicks at Otago and Catlins were about 0.5-1.0 kg higher in 1992-93 than in 1991-92 (Appendix 4). There was a similar increase at Campbell Island but no difference between years on Codfish Island (Appendix 2).

5. DISCUSSION

Environmental and dietary factors which may influence Yellow-eyed Penguin survival and breeding success are poorly understood. As early as the 1940's, Richdale (1957) suggested that poor breeding success or high mortality of juveniles and adults in some years were caused by "some unusual event at sea affecting the food supply." In 1985-86 there was poor reproductive success, low fledging and adult weights, delayed moult and subsequent high adult and juvenile mortality (van Heezik and Davis 1990) apparently caused by a dietary shift from favoured fish species to squid and less favoured prey (van Heezik 1990). The most dramatic event at Otago occurred in 1989-90, when about 150 adult penguins died over a short period. Although there was some evidence of food shortage (e.g. squid was possibly being eaten more than usual, most chicks were underweight, moulting was delayed) none of 13 autopsied birds had starved, nor had they died from obvious pathogens or toxins. Because "red tides" of algae had been observed at the time it was suggested that an unidentified toxin may have been involved in the deaths (Gill and Darby 1993). Some of the possible correlations between Yellow-eyed Penguins, other seabird population parameters and environmental changes are being studied at Otago University (L. Peacock pers. comm.).

Since the population crash in January 1990, the three subsequent breeding seasons we have studied have been increasingly productive. Nest numbers doubled after 1990-91 and further increased slightly in 1992-93. This appears to have been caused by new breeders and previous breeders returning. The increase in breeding success to over 1.2 chicks reared per nest occurred also at other monitored areas in Otago, Catlins (Ratz *et al.* 1992, Fechney *et al.* 1993), Codfish and Campbell Islands (Appendix 2), although some localities such as Banks Peninsula (P. Dilks, pers. comm.) and Green Island (C. Lalas, pers. comm.) had low success.

Although there was some inshore foraging, <2 km from shore in water <30 m deep, most activity off the Otago Peninsula appeared to be centred on the wide part of the continental shelf SSW from Boulder Beach, up to 50 km away (but generally <25 km). This outer zone covered the 50-70 m depth contours, which were 10-30 km from the nearest shoreline.

Some individual penguins were regular inshore feeders while others ranged further offshore. Although there was not a consistent variation between stages of the breeding cycle, some birds foraged progressively closer to shore as a season progressed, possibly because of the increased quantities of food required by chicks. Variation in food availability probably influenced changes in foraging ranges, e.g. in October 1991-92 birds were at sea for longer and travelled further out to sea than in any other tracking period. In the following October, by contrast, there was an unusual period of foraging very close to the coastline. The Catlins results were similar to those of the Otago Peninsula, with individual differences in ranges being retained during the tracking periods, and between years. There was less offshore activity in 1993 than had been seen in the previous year.

Foraging behaviour and ranges of penguins vary with the biology of the species, environmental conditions and the nature of the food supply. For example, different foraging strategies amongst *Pygoscelis* species (Gentoo, Chinstrap and Adelie Penguins) have probably adapted to the conditions prevailing at the centre of their distributions. The Gentoo Penguin (*P. papua*), which experiences mild subantarctic conditions (cf. Adelies and Chinstraps in the antarctic), is an inshore deep diver, shows non-migratory behaviour, short nest reliefs, non-fasting, and slow growth of chicks (Trivelpiece *et al.* 1987). These characteristics are shared by the Yellow-eyed Penguin, which occupies the same "inshore" niche in the New Zealand region (Croxall and Lishman 1987). However, Gentoos feeding on krill and rearing chicks in Antarctica made foraging trips averaging 10.5 hours and had a mean maximum foraging distance of 17 km (Trivelpiece *et al.* 1987); i.e. shorter duration and more inshore than Yellow-eyed Penguins.

Dive depth data has added an extra dimension to this study, showing that Yellow-eyed Penguins forage at or near the sea floor for much of the time. This is true even at the Catlins, where the sea floor slopes steeply to a wide shelf 80-120 m deep. Seddon & van Heezik (1990) used capillary tubes on birds at Boulder Beach, Otago Peninsula, in October 1988 to estimate a mean maximum dive depth per day of 34 ± 8 m (range 19-56, n = 43). Assuming that this related to foraging on the sea floor, they extrapolated this to a foraging range of 7-13 km by reading, in error, a bathymetry chart scale as metres (Fig. 1, Seddon and van Heezik 1990) instead of fathoms (Brodie 1967). They should have extrapolated their recordings of 34 m dives to give a foraging range of about 3 km offshore. Our data from the same locality for mean maximum dive per day was 56 ± 10 m (range 22-66, n = 42). The difference between the studies may have been a result of the techniques used, although repeated immersions of capillary tubes would most likely result in overestimates rather than underestimates of maximum depth (Burger and Wilson 1988). Alternatively, birds in 1988 were feeding temporarily inshore, as seen in October 1992. For example, one of our birds with a dive recorder attached in October 1992 consistently had maximum dives per day of 57-59 m except for one trip when 22 m was the deepest dive. Another habitual inshore feeder had dived to a maximum depth per day of 29-49 m.

Our maximum recorded dive depth of 128 m is probably well within the Yellow-eyed Penguins's capabilities, since the slightly larger Gentoo Penguin has been recorded at 156 m (Williams *et al.* 1992). The published record depth of 304 m is held by the larger King Penguin (*Aptenodytes patagonicus*) (Kooyman *et al.* 1992). A bimodal, pattern of shallow and deep dives, as seen in the Yellow-eyed Penguin, has also been noted in other species. Shallow dives can be for travelling, searching and foraging on prey migrating up the water column at dusk, and deep dives are predominantly for foraging (Williams *et al.* 1992, Kooyman *et al.* 1992). Some species, e.g. King and Macaroni Penguin (*Eudyptes antipodes*), which feed on migrating prey, forage at shallow depths during the night (Croxall *et al.* 1988), whereas Yellow-eyed Penguins and most other species appear to be inactive at night. Diving to the sea floor must be an important foraging strategy for Yellow-eyed Penguins because of the obvious energy investment involved in deep dives, and therefore this activity must reflect the distribution of the main prey (Chappell *et al.* 1993).

Possible influences on Yellow-eyed Penguin feeding zones include:

1. Bathymetry. The continental shelf is widest to the SSW of Otago Peninsula, where water is 40-80 m deep (Carter 1986, Fig. 18) and birds spread out in this direction. Similarly, at the Catlins birds moved offshore to the wide part of the continental shelf, which is 80-120 m deep (Hughes 1987).
2. Water Masses. There is low salinity water directly offshore from the Otago coast. In the mid-outer continental shelf zone, subtropical water of the Southland Current moves along the coast (schematically shown in Fig. 18). Further offshore there is water of subantarctic origin (Jillett 1976). A productive zone occurs at the front between these two water masses. This moves seasonally, as reflected in the activity of the squid fishery. The front's seasonal pattern is being studied at Otago University (A. Shaw pers. comm.).
3. Food Supply. There is a wide area of ocean bed comprised of medium-sized pebbles in the mid continental shelf region, 10-30 km SW of our Otago Peninsula study area (Andrews 1973, Fig. 18). This has a distinctive benthic faunal community, rich in species, dominated by bryozoans which are suited to the lack of fine sediment and the continuous flow of the Southland Current (Probert and Batham 1979, Probert and Wilson 1984). The zone occurs within the area of main foraging activity of penguins in our study and must be particularly productive for their bottom-dwelling prey.

There are several problems in quantifying penguin diet, a major one being erosion of hard parts of diet items, such as otoliths (Gales 1988). It was assumed that otoliths in a Yellow-eyed Penguin stomach represented the remains of fish eaten during the day preceding capture, since an experiment involving feeding otoliths of Opalfish, Red Cod and Sprat and squid beaks to captive Yellow-eyed Penguins showed that most were completely digested within 24 hours (van Heezik and Seddon 1989). However, differential digestion and size effects make this assumption invalid; e.g. small otoliths such as Sprat were digested in 8 hours, yet Opalfish otoliths lasted 36 hours. Squid beaks showed signs of wear after 16 hours (van Heezik and Seddon 1989), so we only used intact beaks for our diet analysis.

The prey weight equations (Lalas 1983) which we and van Heezik (1988, 1990) have used make no allowance for the effects of digestion in reducing otolith weight, and thus under-estimate fish size. Fortunately, 63% of otoliths from all our samples were apparently unworn. Further analysis of our data is planned, where fish size will be calculated using the weight of undigested otoliths from each sample, as suggested by Gales (1988). Other errors which may have occurred in our study include not extracting the whole sample from the bird, small prey remains being overlooked during sorting and "secondary" prey being released from the stomachs of fish and squid and counted as "primary" prey. Since the writing of this report, we have discovered that the Opalfish equation that we used, and van Heezik (1988) used for most of her study, overestimated fish size for the larger otoliths. Our opalfish otoliths appear to be predominantly *Hemerocoetes monoptygius*, but a small proportion of relatively large otoliths are probably from *H. artus* or *H. pauciradiatus* (C. Lalas pers. comm.). It is hoped to

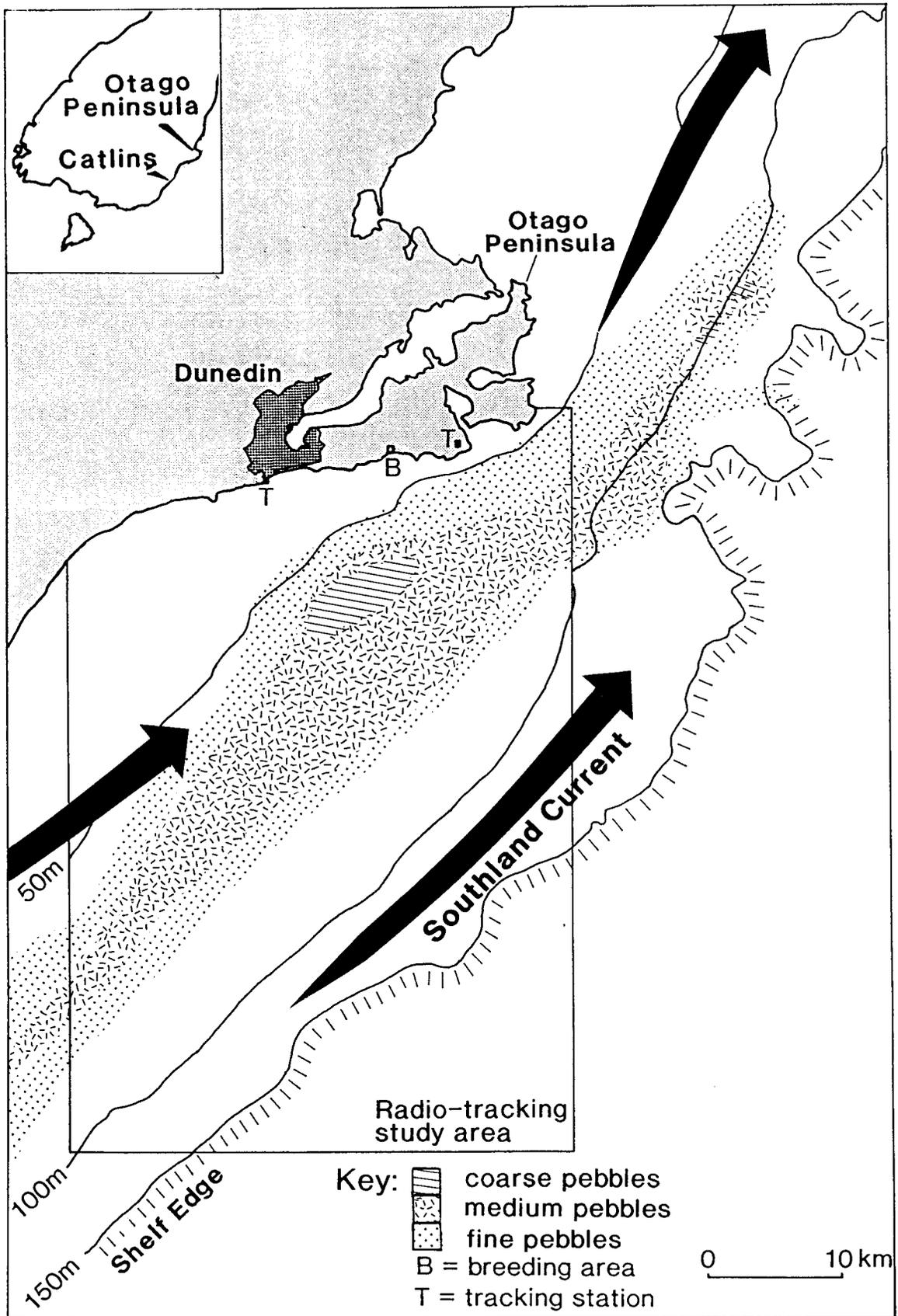


Figure 18 Sediments (after Andrews 1973) and direction of the Southland Current, Otago Peninsula.

improve the equations with data supplied by C. Lallas in further analyses. Preliminary adjustments suggest that the estimated Opalfish biomass should decrease by about 5% in Figs. 14-17, still leaving it as the most important weight component.

Yellow-eyed Penguins at Otago Peninsula and the Catlins ate a small range of prey species, the most important in terms of percent weight, number and occurrence being Opalfish, a demersal (bottom dwelling) fish. Little is known of the ecology of penguin prey, particularly of the juvenile and small size classes that they eat (Murdoch 1991). Therefore, the extent that particular prey types are demersal or pelagic is uncertain. Nevertheless, our data suggests that demersal or near-bottom prey are important for Yellow-eyed Penguins. This contrasts van Heezik's (1990) suggestion that they feed mainly in the upper portion of the water column, although she also stated elsewhere that demersal feeding was important (Seddon and van Heezik 1990).

The diet composition in 1990-93 was similar to that described from seven areas in 1984-86 by van Heezik (1990), who recorded 26 prey types (four not found in our study), with six fish and one squid species making up 94% of the weight and 97% of the prey items. In 1990-93, the same seven prey types constituted 84% of the weight and 70% of the prey number. Van Heezik found that Red Cod was the most important species, followed by Opalfish and Sprat. This was the case for most areas she studied, although at Boulder Beach (our Otago Peninsula study area) Opalfish was the most important species. The most surprising difference between van Heezik's study and ours, was her lack of krill and other crustacea, yet in 1990-93, krill (mainly *Nyctiphanes australis*) was found in 37% of all stomachs and constituted 17% of prey number, and other crustacea (including *Munida gregaria*) occurred in 77% of samples. In our study, small numbers of krill occurred in most individual samples, but one particular bird, which was sampled five times, took up to 1352 krill, accounting for 78% of our total krill numbers. Possibly, small numbers of krill in 1984-86 would have been discounted as secondary prey, and our one krill-eating bird biased our results.

Each of Van Heezik's two penguin breeding seasons were markedly different in diet, with large proportional decreases in Red Cod, Sprat and Opalfish and increases in Squid and fish such as Blue Cod. This dietary shift was implicated in causing poor breeding success and fledging weights in the second season, particularly the lack of Sprat with its high fat levels (van Heezik 1990). Although annual differences were less apparent in our study, the high reproductive success in 1992-93 may have been influenced by increased availability of more favoured species such as Red Cod, Sprat and Warehou, and a more abundant food supply than previous seasons.

5.1 Future work

It is hoped to repeat the intensive research during a "bad season" for Yellow-eyed Penguins. Years of poor breeding success and/or adult survival have occurred in recent times, so possibly we will be able to record some of the changes and interactions of foraging behaviour, breeding success and survival. By monitoring key indicators of penguin breeding behaviour and activity (e.g. laying dates, nesting numbers, beach counts) we may be able to predict if the season will be a successful one or not before "management decisions" such as egg removal have to be made.

6. ACKNOWLEDGEMENTS

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APPENDIX 1

**Species of prey identified from stomach contents of Yellow-eyed Penguins,
1990-93, mean weights of prey and formulae used for calculating prey weight**

Group or Order	Family	Common Name	Species	Weight formula
Euphausiid		Krill	<i>Nyctiphanes australis</i> mainly rarely 2+ others	0.023 g (n = 100)
Other Crustacea		Munida, isopods, crabs, shrimps, mantis shrimp	<i>Munida gregaria</i> mainly	0.27 g (n = 20 various)
Cephalopoda		Arrow Squid Warty Squid octopus	<i>Nototodarus sloani</i> <i>Morotheuopsis ingens</i> ?	lnW = 1.79+2.41lnr lnW = -0.068+3.50lnr lnW = -0.812 = 3.95lnh
FISH				
Agnatha	Geotriidae	Lamprey	<i>Geotria australis</i>	101.27 (n = 3)
Anguilliformes?	Congidae?	Conger Eel?		c.300 g
Clupeiformes	Clupeidae	Sprat	<i>Sprattus antipodum</i> , rarely 2nd sp.?	$4.4 \times 10^{-6} (77.6 \times \text{ow}^{0.45})^{3.08}$
Salmoniformes	Argentinidae	Silverside	<i>Argentina elongata</i>	$3.1 \times 10^{-6} (44.2 \times \text{ow}^{0.40})^{3.15}$
	Retropinnidae	Smelt	<i>Retropinna retropinna</i>	$9.9 \times 10^{-7} (91.6 \times \text{ow}^{0.37})^{3.44}$
Gadiformes	Moridae	Ahuru	<i>Auchenoceros punctatus</i>	$5.5 \times 10^{-6} (31.6 \times \text{ow}^{0.45})^{2.98}$
		Rock Cod?	<i>Lotella sp.</i>	$3.4 \times 10^{-4} (24.9 \times \text{ow}^{0.44})^{2.43}$
		Red Cod	<i>Pseudophycis bachus</i>	$5.9 \times 10^{-6} (19.6 \times \text{ow}^{0.52})^{3.09}$
	Merlucciidae	Hoki	<i>Macruronus novaeseelandiae</i>	$2.3 \times 10^{-6} (53.5 \times \text{ow}^{0.36})^{3.08}$
	Macrouridae	Rattail	?	$5.9 \times 10^{-7} (22.3 \times \text{ow}^{0.50})^{3.35}$
	?	?	?	c.3 g
Ophidiiformes	Ophidiidae	Ling	<i>Genypterus blacodes</i>	$1.2 \times 10^{-6} (29.9 \times \text{ow}^{0.54})^{3.22}$
Syngnathiformes	Syngnathidae	Sea Horse	<i>Hippocampus abdominalis</i>	0.01 g (n = 2)
		Short-snouted Pipefish	<i>Lissocampus filum</i>	2.32 g (n = 1)
Scorpaeniformes	Scorpaenidae	Sea Perch	<i>Helicolenus percoides</i>	$3.5 \times 10^{-6} (28.6 \times \text{ow}^{0.44})^{3.30}$
		Scorpion Fish?	<i>Scorpaena cardinalis</i>	c.2 g
Perciformes	Pinguipedidae	Blue Cod	<i>Parapercis colias</i>	$1.2 \times 10^{-5} (25.1 \times \text{ow}^{0.71})^{3.04}$
	Percophidae	Opalfish (main sp.)	<i>Hemerocoetes monopterygius</i>	$4.4 \times 10^{-6} (53.1 \times \text{ow}^{0.54})^{2.99}$
		Opalfish (rarely)	<i>H. pauciradiatus</i>	$4.4 \times 10^{-6} (53.1 \times \text{ow}^{0.54})^{2.99}$

Appendix 1 (Continued)

Group or Order	Family	Common Name	Species	Formula
Perciformes ctd.	Cheilodactylidae	Tarakihi	<i>Nemadactylus macropterus</i>	$6.0 \times 10^{-6} (56.9 \text{ow}^{0.48})^{3.22}$
	Creediidae	Sand Diver	<i>Tewara cranwellae</i>	2.14 g (n = 1)
	Leptoscopidae/ Uranoscopidae	Stargazer	?	$8.8 \times 10^{-6} (24.0 \text{ow}^{0.51})^{3.01}$
	Tripterygiidae	Triplefin	<i>Forsterygion sp.</i>	$1.1 \times 10^{-5} (49.2 \text{ow}^{0.50})^{3.01}$
	Eleotrididae	Grahams Gudgeon	<i>Grahamichthys radiata</i>	$2.2 \times 10^{-8} (44.5 \text{ow}^{0.27})^{4.50}$
	Gemphylidae	Barracoutta	<i>Thyrsites atun</i>	$1.3 \times 10^{-6} (66.3 \text{ow}^{0.43})^{3.25}$
	Centolophidae	Warehou	<i>Seriolella punctata?</i>	$2.3 \times 10^{-7} (62.1 \text{ow}^{0.41})^{3.80}$
<i>Seriolella brama</i>			$1.1 \times 10^{-5} (50.8 \text{ow}^{0.41})^{3.10}$	
Gonorynchi-formes	Gonorynchidae	Sandfish	<i>Gonorynchus gonorynchus</i>	3.0 g
Pleuronecti-formes	Pleuronectidae	Lemon Sole	<i>Pelotretis flavilatus</i>	$2.8 \times 10^{-7} (22.7 \text{ow}^{0.77})^{3.68}$
		Sole	<i>Peltorhamphus novaezeelandiae</i>	$4.0 \times 10^{-6} (36.1 \text{ow}^{0.53})^{3.13}$
Tetradonti-formes	Monacanthidae	Leather Jacket	<i>Parika scaber</i>	$1.9 \times 10^{-5} (183 \text{ow}^{0.79})^{2.96}$
?	?	Unknown L	?	c.2g
?	?	Unknown O	?	c.2g

Formula Key:

Cephalopods W = fresh weight of animal
r = rostral length of lower beak (mm)
h = hood length in cephalopods (mm)

Fish ow = Paired otolith weight (mg)

Equations are a combination of the otolith weight-fish length relationship (inside brackets) and the fish length-weight relationship.

Formulas for fish were for the same species, or most closely related species, from Lalas (1983), except for Silverside calculated from van Heezik's (1988) raw data. Formulas for cephalopods from Clarke (1986). Individual weights or mean weights are given if a prey type was taken only once or in low numbers and a (fairly) intact specimen was recovered.

APPENDIX 2

Comparison of Breeding Success of Yellow-eyed Penguins in different seasons and localities

Success Category	1990-91		1991-92				1992-93			
	Otago 3 areas	Cat- lins 3 areas	Otago 3 areas	Cat- lins 3 areas	Cod- fish Is.	Camp -bell Is.	Otago 3 areas	Cat- lins 3 areas	Cod- fish Is.	Camp -bell Is.
No. nests found in incubation	22	22	41	37	10	36	42	46	18	26
Nest Success										
Nests that hatch chicks % of total nests	86	77	90	92	100	89	91	89	94	96
Nests that fledge chicks % of total nests	64	32	71	49	50	39	79	80	67	81
2-chick broods reared % of total nests	5	0	46	24	0	19	55	63	50	69
Egg Success										
Eggs that hatch % of total eggs	86	71	83	82	90	86	81	84	86	92
Eggs that fledge chicks % of total eggs	54	23	60	60	26	30	68	75	58	75
Fledging Success										
Chicks alive early Feb. banding time % of chicks hatched	71	45	80	46	29	37	85	89	71	81
Chicks assumed fledged % of chicks hatched	63	32	73		29	35	85		68	
Reproductive Success										
Mean no. chicks/nest early Feb.	0.8	0.5	1.3	0.7	0.5	0.6	1.3	1.4	1.2	1.5
Mean no. chicks/nest	0.7	0.3	1.2		0.5	0.6	1.3		1.2	
Mean hatch date (Nov.)	16	16	13			22	14	15	14 N	20
Mean fledge date (F = Feb, M = March)	1 M	27 F	2 M			13 M	25 F			13 M
Mean fledge age (days)	104	101	111			108	103			108
Mean chick weight (g) early Feb.	5.1	4.8	4.5	5.0	5.2	4.1	4.8	5.5	4.7	5.3
Mean final or fledge weight (g)	5.6	5.3	5.2		5.4	5.1	5.0		5.4	

Otago Peninsula: Boulder Beach Highcliff and AI, Sandfly Bay (monitored by Dean Nelson, DOC, Otago Conservancy, this study).

Catlins: Nugget, Hayward and Long Points (monitored by Brian Murphy, DOC, Otago Conservancy, this study).

Codfish Island: Northwest Bay, Penguin Beach and Sealers Beach (monitored by Rhys Buckingham, DOC contract worker, Southland Conservancy).

Campbell Island: Sandy Bay (monitored by Jacinda Amey, DOC, Southland Conservancy).

APPENDIX 3

Possible Effects of Disturbance on Yellow-eyed Penguin Nesting Success, 1991-93

Breeding Area	1991-92		1992-93	
	No. Nests	Mean No. Chicks Produced / Nest	No. Nests	Mean No. Chicks Produced / Nest
Otago: 3 areas				
Nests with adults radio -tagged ^{1a} , diet sampled ^{2a} , nests visited &/or chicks weighed ³	8	0.75	8	1.25
Nests with adults diet sampled ^{2b} , nests visited &/or chicks weighed ³	3	0.67	7	0.43
Nests with adults handled ⁴ , nests visited &/or chicks weighed ³	22	1.45	21	1.67
Nests visited and/or chicks weighed ³	8	1.0	6	1.33
Catlins: Long Point				
Nests with adults radio -tagged ^{1b} , diet sampled ^{2c} , nests visited &/or chicks weighed ³	4	1.5	5	1.8
Nests with adults diet sampled ^{2c} , nests visited &/or chicks weighed ³	6	0.17-0.67	9	1.56
Nests with adults handled and or visited &/or chicks weighed ³	12	0.75-0.92	17	1.29

- Key:
- ^{1a} three radio-tracking sessions, birds handled at least six times
 - ^{1b} one radio-tracking session, birds handled twice
 - ^{2a} 1-4 diet collections/bird/year
 - ^{2b} 1-2 diet collections/bird/year
 - ^{2c} 1-3 diet collections/bird/year
 - ³ approx. weekly visits, most chicks weighed if accessible
 - ⁴ adults handled 1-2 times for measuring or weighing.

APPENDIX 4

Yellow-eyed Penguin Banding and Fledging Weights 1991-93

Breeding Area	1991-92				1992-93			
	Banding Weight ¹		Final Weight ²		Banding Weight ¹		Final Weight ²	
	Mean (kg)	s.d., N	Mean (kg)	s.d., N	Mean (kg)	s.d., N	Mean (kg)	s.d., N
A1	4.01	0.75, 11	4.83	0.50, 8	5.05	0.43, 11	5.56	0.67, 11
Highcliff	4.9	0.60, 19	5.30	0.66, 19	5.46	0.58, 20	5.83	0.51, 20
Sandfly Bay	4.5	0.85, 22	5.19	0.72, 19	5.42	0.71, 25	5.80	0.68, 25
Otago Total	4.54	0.80, 52	5.18	0.67, 46	5.36	0.63, 56	5.76	0.62, 56
Nests with tx	3.93	0.60, 8	4.84	0.40, 6	4.89	0.54, 10	5.53	0.74, 10
Other A1 nests	4.24	0.90, 5	4.73	0.59, 4	5.19	0.22, 4	5.59	0.33, 4
Other Highcliff nests	4.97	0.58, 17	5.38	0.65, 17	5.59	0.47, 17	5.89	0.48, 17
Nugget Point	4.62	0.84, 5			5.38	0.27, 8		
Hayward Point	4.79	0.54, 8			5.37	0.57, 13		
Long Point	5.2	0.81, 16			5.55	0.44, 44		
Catlins Total	4.99	0.77, 29			5.50	0.45, 65		

¹ Weight at banding time, usually early February or approx. 80 days of age.

² Final weight before fledging.