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Diet of the Australasian gannet (*Morus serrator*) at Farewell Spit, New Zealand

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Abstract The diet of the Australasian gannet (*Morus serrator*) at Farewell Spit, New Zealand, was studied by the analysis of 70 regurgitations collected from the 1995 to 2001 breeding seasons. Surface schooling pilchard (*Sardinops neopilchardus*) was the main prey, followed by anchovy (*Engraulis australis*). The composition of the diet was similar in most seasons examined except in 1996 in which anchovy was the main prey item. Such a change in diet could be linked with a pilchard mass mortality in New Zealand in August 1995. The estimated annual prey consumption by birds at the Farewell Spit gannetry was 852 tonnes. Although annual catches of pilchard and anchovy by commercial fisheries in the area are still relatively small, an increase may interfere with prey availability, and in turn, increase competition between marine predators and influence the breeding success. Our analyses of diet are consistent with previous studies showing that Australasian gannets as flexible foragers and they highlight their importance as bioindicators of fish stocks in New Zealand.

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INTRODUCTION

Breeding success and population growth in a number of species of seabirds has been demonstrated to be related to food availability (Lack 1968; Croxall 1987). However, commercial fishing can also influence seabird populations through a reduction of food resources (Burger *et al.* 1984; Croxall 1987; Tasker *et al*. 2000) and an increase in mortality from by-catch (Robertson *et al*. 2003). Information on the diet, foraging strategies, foraging sites and breeding cycles of seabirds is needed to increase our understanding of the potential for conflict with fisheries (Croxall 1987). Furthermore, long-term monitoring of the diet and foraging strategies of marine apex predators, including seabirds, provide valuable information on the health of the environment and in some fish stocks (Einoder 2009). The Australasian gannet (*Morus*

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Table 1. Overall composition of the diet of the Australasian gannet breeding at Farewell Spit, New Zealand, 1995-2001. Diet is described by percentage frequencies of occurrence (F%) and number (N%).

	F%	N%
Pilchard	62.8	37.6
Anchovy	44.3	50.2
Garfish	10.0	4.3
Arrow squid	4.3	1.8
Yellow-eye mullet	4.3	4.7
Barracouta	1.4	0.2
Saury	1.4	0.4

serrator) (hereafter gannet) is a marine apex predator endemic to Australia and New Zealand (Nelson 1978). The New Zealand population is estimated to be around 55,000 breeding pairs, distributed in 29 colonies and is considered to be increasing annually by 2.3 % (Robertson 1992; Nelson 2005; Stephenson 2005). Farewell Spit gannetry in Golden Bay, 1 of 4 breeding sites in the South I, was established in 1983 with *c.*75 breeding pairs (Hawkins 1988). Since then, the population has increased by an average of 11.5% per annum, and in 2011 was estimated at 3,900 pairs (R. Schuckard, *unpubl. data*).

Several studies have previously described the diet of gannets in other breeding colonies around New Zealand, reporting that they feed mainly on pilchard (*Sardinops* spp.), anchovy (*Engraulis* spp.), saury (*Scomberesox* spp.), jack mackerel (*Trachurus* spp.) and squid (*Nototodarus* spp.; Oliver 1955; Wingham 1985; Robertson 1992; Machovsky Capuska *et al*. 2011a, b). It has been suggested that the increase in inshore commercial fishing in New Zealand has positively influenced gannets by the increase in surface-schooling fish that are normally preyed on by commercial species (Robertson 1992). However, no data are available for the Farewell Spit gannetry to determine whether commercial fisheries have had any influence on this breeding population. Here we examine the diet of breeding adult Australasian gannets obtained from regurgitations collected at the Farewell Spit gannetry during 5 breeding seasons, to improve our knowledge of the foraging behaviour of this marine predator and to highlight possible overlap with fisheries in the region.

METHODS

A total of 70 gannet regurgitations from different breeding adults were collected at Farewell Spit gannetry, which is located at the northern end of the South I of New Zealand (40°33'S 173°02'E). All samples were collected between Oct and Jan during the chick-rearing period of the 1995/1996 (n = 18), 1996/1997 (n=7), 1997/1998 (n=17), 1999/2000 (n=26), and 2001/2002 (n=2) breeding seasons. Considering that gannets are sexually monomorphic in size and weight and behaviour is not a reliable method of sex-assignment (Nelson 1978), no sex differences were established for our samples.

Samples were collected in separate polythene bags from gannets in active nests that voluntarily regurgitated during handling. We then identified the species of prey in the field using published guides (Paulin *et al*. 1989). For each prey species, body length was measured as described in Meynier *et al*. (2008). Following Robertson (1992) samples were not weighed because birds from which they were taken had not always recently returned from feeding and thus partial digestion may have occurred. Data were analysed as the percentage of prey items of one type out of all prey items (Numerical Abundance percentage, N%) and as the presence or absence of prey on each individual regurgitation (Frequency of occurrence, F%) (Duffy & Jackson 1986). Frequencies of prey occurrence were compared using χ^2 tests. Data were initially tested using Levene tests for homoscedasticity and Shapiro-Wilk for normality and Kruskal Wallis tests for subsequent non-parametric comparisons. For statistical comparisons, data were analysed using *PAWS Statistics* version 19. We report data as medians and range.

To estimate Annual Food Consumption (AFC) by birds at the Farewell Spit gannetry, we assumed a daily food intake of 259 g per bird (Wingham 1985), and multiplied this by the number of breeding birds at the colony and the diet composition from Table 1.

RESULTS

A total of 7 species of fish and 1 species of squid were identified in gannet regurgitations. Surface-schooling pilchard (*Sardinops neopilchardus*) was the most frequent prey, followed by anchovy (*Engraulis australis*), garfish (*Hyporhamphus ihi*), squid (*Nototodarus* spp.), yellow-eye mullet (*Aldrichetta forsteri*), barracouta (*Thrysites atun*) and saury (*Scomberesox saurus*). However, *E. australis* was the most numerous prey followed by *S. neopilchardus* (Table 1).

Prey occurrence varied significantly across the 5 seasons studied (χ^2 = 41.7; df = 4 ; P < 0.001). From 70 regurgitations from 1995 to 2001, 50% contained 5 prey species, 37% contained 6 prey species, 10% contained 3 prey species and 3% contained 4 prey species (Table 2). *S. neopilchardus* (in 1995, 1997, 1999 and 2001) and *E. australis* (1996) were the most frequent prey. *E. australis* was the most numerous

Table 2. The composition of the diet of the Australasian gannet as reflected by the analysis of 70 regurgitations collected in 5 breeding seasons at Farewell Spit, New Zealand. Diet is described by percentage frequencies of occurrence (F%) and number (N%). Sample size in parentheses.

	1995 (n = 18)		1996 (n = 7)		1997 (n = 17)		1999 (n = 26)		2001 (n = 2)	
	F%	N%	F%	N%	F%	N%	F%	N%	F%	N%
Pilchard	55.5	32.3	14.3	3.4	58.8	52.2	80.8	53.2	100.0	30.0
Anchovy	50.0	53.0	85.7	95.4	35.3	44.1	34.6	23.8	50.0	35.0
Arrow squid	14.3	1.2	14.3	1.2	5.9	0.9	-	-	50.0	30.0
Garfish	-	-	-	-	11.8	1.8	15.4	12.7	50.0	5.0
Yellow-eye mullet	11.1	10.8	-	-	-	-	3.8	7.9	-	-
Barracouta	-	-	-	-	-	-	3.8	0.8	-	-
Saury	5.5	2.0	-	-	-	-	-	-	-	-

Table 3. Median total length (cm, and range) of prey in the diet of the Australasian gannet as reflected by the analysis of 70 regurgitations collected in 5 breeding seasons at Farewell Spit, New Zealand. The number of prey considered each year is presented in parentheses.

	1995 (n = 102)		1996 (n = 88)		1997 (n = 111)		1999 (n = 126)		2001 (n = 20)	
	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
Pilchard	12.0	11.0-19.0	15.0	11.0-19.0	14.0	10.0-21.0	15.5	10.0-19.0	15.0	13.0-17.0
Anchovy	12.0	10.0-12.0	10.0	9.0-10.0	11.0	10.0-12.0	11.0	10.0-12.0	-	-
Arrow squid	-	-	-	11.0	-	21.0	-	-	-	-
Garfish	-	-	-	-	22.5	22.0-23.0	17.0	15.0-20.0	-	-
Yellow-eye mullet	13.5	10.0-22.0	-	-	-	-	12.0	12.0-14.0	-	-
Barracouta	-	-	-	-	-	-	-	20.0	-	-
Saury	-	33.0	-	-	-	-	-	-	-	-

prey in 1995, 1996 and 2001, whereas *S. neopilchardus* was most numerous in 1997 and 1999 (Table 2).

The overall length of the prey species consumed ranged in size from 9-33 cm and varied significantly between years (Kruskal Wallis: $h = 227.6$, $df = 4$, $P < 0.0001$, Table 3). Thus, significant length variation was also observed in pilchard and anchovy between years (Kruskal Wallis: $h = 219.3$, $df = 4$, $P < 0.0001$, Table 3).

The total annual prey consumption by the Farewell Spit gannetry was also estimated (Table 4). Our analysis showed that more than 80 % of the biomass was represented by pilchard and anchovy, highlighting the importance of these species on the diet of gannets.

DISCUSSION

Our analysis provides the 1st report on the diet of breeding gannets at the Farewell Spit colony. Pilchard and anchovy were the main prey species, this being consistent with previous studies at other gannetries around New Zealand (Wingham 1985; Robertson 1992), including Waimaru colony during the summer of 1981-1982, in which pilchard and anchovy (90% and 10%, respectively) were the most important prey items (Robertson 1992). Additional diet studies from Australia revealed that Australasian gannets based their diet on high calorific value prey such as pilchards and to a lesser minor extent jack mackerel (*Trachurus novaezelandiae*) and saury (Bunce 2001).

The overall composition of the diet was similar in most of the seasons examined except for the samples collected in 1996 in which anchovy was the main prey item. Such a change in the diet could be linked with the pilchard mass mortality registered in New Zealand in Aug 1995 which is thought to have affected around 50% of the pilchard biomass (Whittington *et al*. 1997) and was suggested to have caused the biggest wreck of Australasian gannets ever recorded in New Zealand including at the Farewell Spit colony where hundreds of birds were found dead (Taylor 1997; R. Schuckard, *unpubl data*). This reduction in pilchard consumption and increase in anchovy was previously reported in

Australia, supporting the view that Australasian gannets are flexible foragers (Nelson 1978; Bunce & Norman 2000). Thus, our results confirmed that gannets increased the number of anchovies consumed when their diet was based mainly on this lower calorific prey species to satisfy their daily energetic requirements as suggested by Bunce (2001).

Our analysis also showed that gannets at Farewell Spit colony feed typically on fish of similar length to prey consumed by the same species in Australia (Brothers *et al*. 1993; Bunce 2001) and other colonies in New Zealand (Wingham 1985; Robertson 1992; Machovsky Capuska *et al*. 2011 a). Prey size was also similar in the related Cape gannet (*Morus capensis*) in South Africa (Berruti *et al*. 1993). It has been suggested that the size of these prey species are related to the size that adults deliver to young chicks during the breeding season (Waghorn 1982; Bunce 2001).

Australasian gannets are specialised hunters that forage by plunge-diving into the water with a high prey capture rate (72%, Machovsky Capuska *et al*. 2011b). It has been suggested that gannets have an average feeding range of 268 km in the Hauraki Gulf (Wingham 1985), however banded adults were found during the breeding season up to 400 km away from Farewell Spit colony (Hutzler 2009), although it is unknown if these were breeding birds. An aerial and boat survey for seabirds and marine mammals covering the whole of the Tasman and Golden Bay areas in Dec 2010 and Jan 2011 recorded gannets as the most widespread species in the study area (Handley *et al*. 2011a, b). This wide distribution could be related to pilchard availability. Pilchards are reported in the Marlborough Sounds and Tasman Bay throughout the year and from Oct to Apr are often visible as surface schools when diatoms bloom in nutrient-rich upwelling, coinciding with the gannet breeding season (Baker 1972, Paul *et al*. 2001).

The foraging range of gannets from Farewell Spit falls within Ministry of Fisheries Area 7 which encompasses the Marlborough Sounds, Golden and Tasman Bays, and the West coast of South I (Annala 1992). Although current estimates of biomass for pilchard and anchovy in New Zealand are not available, annual catches of 115 tonnes for anchovy and 165 tonnes for pilchard have been established (Paul *et al*. 2001; Chatterton 2002). Considering our estimation of prey annually consumed by gannets at Farewell Spit, and that other marine predators such as dusky dolphin (*Lagenorhynchus obscurus*), shearwaters (*Puffinus* spp.), terns (*Sterna* spp.), gulls (*Larus* spp.), shags (*Phalacrocorax* spp.), fur seals (*Arctocephalus forsteri*), spiny dogfish (*Squalus acanthias*) thresher shark (*Alopias vulpinus*), kahawai (*Arripis trutta*) and barracouta have also been reported to feed on pilchard and anchovy (Graham 1956; Baker 1972; Vaughn *et al*. 2007), an increase in commercial fishing may interfere with prey availability and result in increased competition between marine predators. This in turn could influence the breeding success of birds at the Farewell Spit gannetry.

Table 4. Estimated prey species consumption per year (AFC) by the Australasian gannet breeding at Farewell Spit, New Zealand.

	AFC (tonnes)
Pilchard	416.6
Anchovy	293.5
Garfish	66.3
Arrow squid	28.4
Yellow-eye mullet	28.4
Barracouta	9.5
Saury	9.5

Our study supports previous observations of gannets as flexible predators and we recommend the use of Australasian gannets as bioindicators of food availability and fisheries stocks in New Zealand. Decline of pilchard and anchovy can have serious effects on the overall food web, affecting not only the seabird populations dependent on these food sources but also important recreational and commercial fishing stocks. Further studies including the use of bird-attached data loggers are necessary to gain a better understanding of the foraging areas and site fidelity of these marine apex predators.

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