MAF Fisheries Marine Research, Box 297, Wellington, New Zealand.

DIET OF THE AUSTRALASIAN GANNET *MORUS SERRATOR* (G.R. GRAY) AROUND NEW ZEALAND

Summary: Collections of gannet regurgitations at most of New Zealand's gannetries allowed the identification of major components in the gannet diet and an estimate of the total annual consumption of the most important prey species. Major species were pilchard *(Sardinops neopilchardus),* anchovy *(Engraulis australis),* saury *(Scomberesox saurus),* and jack mackerel *(Trachurus novaezelandiae).*

Keywords: Gannets, feeding, New Zealand, pilchard, anchovy, saury, jack mackerel.

Introduction

The New Zealand gannet *Morus serrator* (G.R. Gray) population has more than doubled since the first census was made in the summer of 1946-47, from an estimated 21 115 breeding pairs to 46 004 breeding pairs in 1980-81 (Wodzicki *et al.,* 1984). The mean annual rate of increase for the population over this period was 2.3%.

Reasons for this increase are unknown but are possibly related to food availability. Furness (1982) found that changes in seabird numbers in different parts of the world were apparently in response to changes in food abundance. This supports the general belief (e.g., Lack, 1966) that the breeding success and population growth in seabirds are directly related to food availability.

The relative ease of counting the entire breeding population of the New Zealand gannet provides opportunity to examine the relationship between food availability and gannet numbers. As a result of increased fishing effort, the total reported inshore demersal and pelagic commercial fish catch increased by a factor of five over the period of the censuses (MAF Fisheries unpublished data). However, no quantitative data exist on the availability of those species which might be expected to be important in the gannet diet, and only one quantitative study on the feeding of gannets (Wingham, 1985) has been completed.

I set out to answer some of the questions basic to the population growth-food availability relationship; i.e., on what quantities of what species does the New Zealand gannet population depend? Much more difficult to answer but of equal importance is the consideration, in the broader context of fisheries management, of the degree of competition that might exist between fishers and seabird populations. Examples of such connections are common in scientific literature. For instance Schaefer (1970) showed that the precision of estimating the maximum sustainable yield for the Peruvian anchovy fishery could be improved by 40% if he included seabirds in the model. The model showed that reduction in seabird numbers would maximize yield to the fishery. When the anchovy fishery collapsed, the Peruvian seabird population declined from 30 million to 1 million.

Methods

To define the range of prey species important in the diet of gannets, 11 gannetries were visited in the summer of 1981-82 (Fig. 1) and 307 regurgitations were collected. This was done by approaching the birds which would often vomit (onto the ground) when disturbed or handled. Regurgitations were not weighed for these samples because birds from which they were taken had not always just returned from feeding. Samples were preserved in 8% formalin and identified in the laboratory.

In the summer of 1982-83 Gannet Island and Cape Kidnappers, two of the largest and more geographically distinct gannetries, were selected for more detailed measurements of dietary composition, weight of each prey species consumed per feed, and number of feeds per breeding pair per day through the summer. Six visits were made to Cape Kidnappers and three to Gannet Island. A total of 360 regurgitations were collected from birds returning from feeding at sea. Food species were immediately identified and weighed to ± 5 g and the degree of digestion noted. If digestion were advanced, the sample was not included in the study.

On each visit, observations were made on groups of 15-35 marked birds to determine the number and

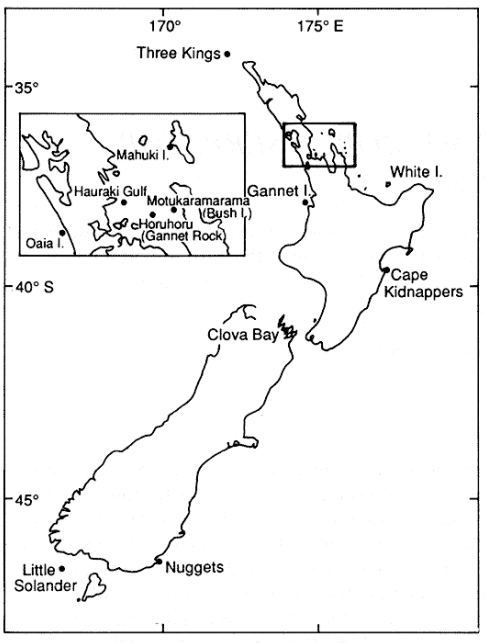

Figure 1: *Place names mentioned in the text*

duration of feeding flights per pair per day by recording departures and arrivals over a 24-36 hour period (excluding hours of darkness) and assuming that all departures from the colony resulted in feeding at least once. No attempt was made to measure stomach fullness. The mean weight of prey regurgitated per pair per day was estimated from the mean number of feeding trips per pair per day and the mean prey weight per regurgitation.

To provide a crude indicative estimate of total prey consumption annually by the Australasian gannet population in New Zealand, some simple assumptions are applied to the results of this study.

Combined prey weight percentages from the 1982-83 summer for both the Cape Kidnappers and Gannet Island colonies, were used to estimate approximate quantities of fish and squid which might be expected to be consumed around New Zealand on an annual basis by the population estimated to be present at the time of the last census; i.e., 46 004 breeding pairs in 1980-81 (Wodzicki *et al.,* 1984). Thirty days were subtracted off the year to allow for periods of wind greater than force 8 (34-40 knots) when gannets cease feeding (K. Wodzicki, *pers. comm.).* It is assumed that the observed adult diet accommodates both adult and chick requirements, that all feeding at sea is being detected, that feeding rate is constant throughout the year and that the results from Gannet Island and Cape Kidnappers apply to all colonies.

Results

Number of species per regurgitation

In 84% of all 667 regurgitations from 1981-82 and 1982-83 over all colonies, only one prey species was present per regurgitation. Two prey species were present in 14%, three species in 1 % and four species in 0.3% of regurgitations.

Composition of prey species

Prey occurrence ranged widely for a similar group of species for most gannetries visited in the summer of 1981-82 (Table 1) and for the series of observations made at Cape Kidnappers and Gannet Island in the summer of 1982-83 (Tables 2 and 3).

For both seasons' observations the same four fish and one squid species were predominant in the diet: pilchard *(Sardinops neopilchardus* Steindachner), anchovy *(Engraulis australis* (White)), saury *(Scomberesox saurus* (Walbaum)), jack mackerel *(Trachurus novaezelandiae* Richardson) and squid *(Nototodarus* spp). The mean percentage occurrence of squid *(Nototodarus* spp.) in both seasons was similar to the value for jack mackerel. The main differences in prey species' presence in the two data sets were the occurrence of sprat *(Sprattus muelleri* Klunzinger) in the 1981-82 samples exclusively from the small colony at Nugget Point south of Dunedin, and of red cod *(Pseudophycis bachus* Bloch and Schneider) in the 1982-83 samples from Cape Kidnappers.

Between visits in 1982-83 the percentage species occurrence varied (Tables 2 and 3). At Cape Kidnappers anchovy dominated in October and November initially with replacement by pilchard in December then saury in January, February and March.

At Gannet Island, presence of pilchard and anchovy declined from December to January while saury increased.

Prey composition by weight

Prey composition by weight varied (Tables 4 and 5) in a similar way to percent species composition. There were also differences between gannetries in averaged figures for anchovy (12.6% at Cape Kidnappers, 33.0% at Gannet Island) and saury (34.3% at Cape Kidnappers, 14.0% at Gannet Island).

Food consumption

Measurements averaged over all visits to both gannetries (Table 6) give a value per regurgitation of

Table 1: *Percentage prey species occurrence per total number of prey items in gannet regurgitations from some New Zealand gannetries, summer 1981-82 (see Fig. 1. for locations). Occurrence = Number of times a species occurs/total number of prey items. Yellow eyed mullet* = Aldrichetta forsteri *(Cuvier and Valenciennes), Cubiceps* = Cubiceps caeruleus *Regan, Blue mackerel* = Scomber australasicus *(Cuvier and Valenciennes), and Garfish* = Hyporhamphus ihi *Phillipps*.

Area	Pilchard	Anchovy	Jack Mackerel	Saury	Squid	Kahawai	Cubiceps	Blue Mackerel	Garfish	Sprat	Yellow-eyed mullet	No. of prey items
Three Kings	8.7		34.8	34.8			21.7					23
Mahuki Is.	86.0		8.8		1.8				3.5			57
Bush Is.	66.8	13.0	5.8		10.0	0.8		3.6				113
Gannet Rock	63.6	31.8				4.5						22
Horuhoru	78.9		10.5		1.8	5.3			1.8		1.8	57
Gannet Is.	27.8	50.0	5.6		5.6	5.6					5.6	18
Oaia Is.	38.5	46.2	7.7			7.7						13
White Is.	14.6	11.9	7.1	45.2	16.7	2.4						41
Cape Kidnappers	57.1			14.3		14.3	14.3					7
Clova Bay	90.0	10.0										10
Nuggets										100.0		2
All areas combined	59.0	11.9	9.5	7.7	5.8	2.5	1.7	1.1	0.8	0.6	0.6	363

Table 2: *Percentage species composition by occurrence for fresh regurgitations from visits to Cape Kidnappers colony between 21 October 1982 and 27 March 1983. Prey item numbers in Table4.*

Date	Pilchard	Anchovy	Jack Mackerel	Saury	Garfish	Yellow-eyed Mullet	Squid	Red Cod	Others
21-22 Oct	20.0	43.3	6.7	6.7	0	5.1	0	2.0	16.0
20-22 Nov	28.1	64.1	0	0	1.6	0	1.6	4.7	0
29-31 Dec	25.0	23.1	1.9	5.8	1.9	5.8	23.1	9.6	3.9
22-24 Jan	17.9	11.9	6.0	26.9	0	0	16.4	0	20.9
23-25 Feb	35.2	3.7	7.4	53.7	0	0	0	0	0
25-27 Mar	17.2	17.2	1.7	58.6	0	0	0	0	5.2
All samples combined	24.0	26.5	3.7	26.5	0.6	0.9	7.4	2.5	5.8

Table 3: *Percentage species composition by occurrence for fresh regurgitations from visits to Gannet Island colony between 2 December 1982 and 1 February 1983. Prey item numbers as in Table 5.*

Date	Pilchard	Anchovy	Jack Mackerel	Saury	Kahawai	Squid	Others
2-4 Dec	43.5	46.8	3.2	0	0	6.5	0
18-19 Dec	23.0	37.0	1.0	28.0	0	6.0	5.0
30 Jan-1 Feb	15.2	26.0	19.6	30.4	6.6	2.2	0
All samples combined	27.4	37.5	5.8	20.2	1.4	5.3	2.4

Table 4: *Percentage species composition by weight for fresh regurgitations from visits to Cape Kidnappers colony between 21 October 1982 and 27 March 1983.*

Date	Pilchard	Anchovy	Jack Mackerel	Saury	Garfish	Yellow-eyed Mullet	Squid	Red Cod	Others	No. of prey items
21-22 Oct	14.1	25.9	17.5	15.1	0	7.2	0	9.4	10.7	30
20-22 Nov	58.1	37.6	0	0	0.1	0	0.4	3.7	0	65
29-31 Dec	18.9	8.1	3.4	10.4	1.9	9.5	25.6	17.6	3.9	52
22-24 Jan	20.2	3.1	10.8	36.1	0	0	10.3	0	19.4	67
23-25 Feb	39.1	0.7	8.7	51.2	0	0	0	0	0	54
25-27 Mar	12.4	5.3	1.6	79.1	0	0	0	0	1.6	58
All samples combined	30.9	12.6	5.7	34.3	0.3	1.8	5.7	4.0	4.8	326

Table 5: *Percentage species composition by weight for fresh regurgitations from visits to Gannet Island colony between* 2 *December 1982 and 1 February 1983.*

	Pilchard	Anchovy	Jack Mackerel	Saury	Kahawai	Squid	Other	No. of prey items
2-4 Dec	51.5	43.7	2.2	0	0	2.5	0	62
18-19 Dec	28.8	38.9	2.1	17.4	0	6.9	6.0	100
30 Jan-l Feb	25.8	15.1	25.9	21.5	9.4	2.3	0	46
All samples combined	34.0	33.0	9.3	14.0	2.8	4.4	2.6	208

245g (9.9% of post-regurgitation adult body weight), an average of 2.4 feeding trips per pair per day and an average weight of food consumed per day of 288g per bird. The mean post-regurgitation body weights of 36 birds weighed throughout the season was 2470g. Thus the average weight *of* food consumed per bird per day was 11.7% of body weight.

The data are insufficient to allow an estimate of chick feeding or to determine if all feeding at sea is being detected.

An increase in daily total food consumption from October to March might be expected due to chick demand during growth, but the small number of samples (Tables 4 and 5) and variability in mean weight of regurgitation and mean numbers of regurgitations per day make it difficult to detect (with any certainty) a seasonal trend in food collection by adults during the summer.

Annual Consumption

Estimates of the approximate quantities of fish and squid which might be expected to be consumed on an annual basis (Table 7) by the whole New Zealand Gannet population can be made using the prey weight percentages from the 1982-83 summer (see Discussion).

Discussion

Observations presented here indicate that New Zealand gannets feed predominantly on four species of fish and one species of squid. The fish species, pilchard, anchovy, saury and jack mackerel are all surface schooling. All except saury occupy coastal waters out to the shelf edge. The saury has a more oceanic distribution which normally extends inshore to about the shelf edge but can sometimes occur closer to the coast when slope water extends up onto the outer shelf (Robertson, *unpub. data).* Ten other species were consumed but apparently on a more opportunistic basis. These observations conform with those of Wodzicki and Moreland (1966) who described the contents of 18 regurgitations collected from three gannetries between 1947 and 1964. Additional species in their study included flying fish *(Cypselurus* sp.), puffer fish *(Spheroides* sp.) and telescope fish *(Mendosoma lineatum).* The latter is a southern fish species and was from a single gannet specimen from Little Solander colony south east of Stewart Island, not visited in the present study.

Wingham (1985) concluded that pilchard was the most common species item in the diet of gannets at the Motukaramarama gannetry in the Hauraki Gulf both numerically and by weight. The next most common

Table 6: *Gannet food consumption for Cape Kidnappers and Gannet Island colonies. Standard deviation is in brackets. (Sample sizes as in Tables 4 and 5.) * = Regurgitation.*

Colony	Mean weight per feed* per bird(g)	Mean no. of feeds per pair per day	Mean weight of food per pair per day
Cape Kidnappers			
21-22 Oct 82	162 (120)	3.8 (2.6)	616
20-22 Nov 82	168 (86)	2.9	487
29-31 Dec 82	273 (128)	1.6 (0.8)	437
22-24 Jan 83	270 (122)	2.4 (1.5)	648
23-25 Feb 83	376 (159)	2.5 (1.1)	940
25-27 Mar 83	283 (151)	2.4 (1.4)	679
Gannet Island			
2-4 Dec 82	172 (81)	2.0 (0.9)	344
17-19 Dec 82	240 (117)	1.6 (0.6)	384
30 Jan-2 Feb 83	261 (162)	2.5 (1.1)	653

Table 7: *Estimated average prey species consumption per year by the Australasian gannet population in New Zealand at 1980-81 population size.*

Prey species	Estimated Annual Consumption (tonnes)
Pilchard	2880
Anchovy	2020
Jack mackerel	670
Saury	2140
Squid	450
Others	720

species were, numerically, anchovy, and by weight, jack mackerel. She reported an average regurgitation weight of 11 % of adult body weight and 2.3 trips per pair per day. Her data can be used to estimate mean daily food consumption (assuming one feed per trip away) of 298 g per bird per day or 12.7% of adult body weight per day which is similar to the value observed in the present study. Jarvis (1970) observed a value of 11.2% of adult body weight per bird per day for the Cape gannet *(Sula capensis)* off South Africa. Cooper (1978) showed that hand-reared Cape gannet chicks could be maintained on a daily diet of 12.4% of their body weight.

The estimate of annual food consumption (Table 7) is not intended to be definitive, but to give an approximation of quantities involved in annual maintenance of the Australasian gannet population at the size present in New Zealand in the early 1980s. Similar estimates could be derived from Wingham's (1985) data.

The indicative consumption weights of prey species (Table 7) are similar in size to annual catches in some local inshore commercial fisheries; however for pilchard, anchovy and saury there is negligible commercial fishing around New Zealand. For the species of jack mackerel utilised by gannets there is a commercial catch of at least 5000 tonnes per year and for arrow squid *(Nototodarus* spp.), the annual catch varies from 40 000 tonnes up to about 114 000 tonnes (Annal a, 1992).

Data do not exist for abundance or abundance changes for any of these prey species in the gannet feeding areas and any comments concerning possible links with changes in gannet abundance are speculative. However, the increase in inshore commercial fishing activity over the last 20 years has included species such as barracouta, *Thyrsites atun* (Euphrasen), kahawai, *Arripis trutta* (Bloch and Schneider), gemfish, *Rexea solandri* (Cuvier and Valenciennes), skipjack, *Katsuwonus pelamis* (Linnaeus) and albacore tuna, *Thunnus alalunga* (Bonnaterre), which prey on the fish and squid species predominant in the gannet diet. It is possible that the gannet population size has been influenced by increases in abundance or availability of those surface schooling pelagic species such as anchovy, pilchard, jack mackerel and saury which are normal prey for the above listed commercial species.

Acknowledgements

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