CCSBT-ERS/1503/11

Ministry for Primary Industries
Manatū Ahu Matua

Evaluation of the diets of highly migratory species in New Zealand waters

New Zealand Aquatic Environment and Biodiversity Report No. 116

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ISSN 1179-6480 (online)
ISBN978-0-478-42300-6 (online)

November 2013

New Zealand Government

Growing and Protecting New Zealand

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EXECUTIVE SUMMARY

Horn, P.L.; Ballara, S.L.; Sutton, P.J.H.; Griggs, L.H. (2013). Evaluation of the diets of highly migratory species in New Zealand waters.

***New Zealand Aquatic Environment and Biodiversity Report No. 116.* 141 p.**

Data were available from 97 101 stomachs of highly migratory species examined by observers on surface longline trips from 1994 to 2012. The prey samples were from 65 taxonomic groups (i.e., species, genus, or family). However, 52% of examined stomachs were empty, and 13% contained only bait or parasites, leaving 33 978 stomachs (35%) containing non-bait food items. Most of the prey items were identified only into the broad categories ‘fish’, ‘crustacean’, ‘squid’, ‘salp’, and ‘other’, but some items were identified more precisely. The dietary items were tabulated for 26 species where more than 10 non-empty stomachs were available. More comprehensive descriptions of diet were produced for the 12 species sampled most frequently (mako shark, *Isurus oxyrinchus*; porbeagle shark, *Lamna nasus*; blue shark, *Prionace glauca*; longsnouted lancetfish, *Alepisaurus ferox*; moonfish, *Lampris guttatus*; Ray’s bream, *Brama* sp.; butterfly tuna, *Gasterochisma melampus*; albacore, *Thunus alalunga*; yellowfin tuna, *Thunnus albacares*; southern bluefin tuna, *Thunnus maccoyii*; bigeye tuna, *Thunnus obesus*; swordfish, *Xiphias gladius*), and the shortsnouted lancetfish, *A. brevirostris* (to enable a comparison between the short and longsnouted species)). Spatial distributions are presented for the samples of each of these predators relative to the area fished by the surface longline fishery in New Zealand waters, as are comparisons of the distributions of predators with and without items in their stomachs. Diet compositions (expressed as mean percentage volume of various prey categories) were determined for each predator species overall and by various categories (i.e., by predator length class, sample area, month, and year). Identified fish prey were combined into a series of categories, generally small mesopelagic species, large mesopelagic species, and other fish, but sometimes into more concise categories like ‘tunas’ or ‘dealfish’ when these sub-groups comprised more than about 2% of the recorded items. Similarly, sub-groups of the ‘squid’ (e.g., nautilus) and ‘other’ (e.g., anthropogenic rubbish, plant material, bird remains) categories were introduced for some predator species.

Ontogenetic changes in diet were apparent for most of the 13 predator species examined in detail, and some distinct within-species dietary differences were also apparent between the northern (centred on the Bay of Plenty) and southern (centred on the west coast South Island) areas. Temporal differences in diet were less obvious. The diets determined from the current study were compared with literature reports for the same species elsewhere. A discussion is presented on how the differences in diet between the main predator species might reduce any conflicts in resource use between them.

1. INTRODUCTION

The new National Fisheries Plan for Highly Migratory Species (Ministry of Fisheries 2010) has identified the importance of using an ecosystem approach to fisheries management. In particular Objective 7 of the Fisheries Plan aims to implement an ecosystem approach to fisheries management and aims to maintain food chain relationships and conserve trophic linkages.

The first step in attempting to maintain food chain relationships and conserve trophic linkages is determining what they are. The research reported here aims to evaluate ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in New Zealand waters. The key database that forms the basis for this research is the data on stomach contents of highly migratory fish, which comprises over 97 000 samples collected by observers on surface longline vessels between 1994 and 2012. These data have potential biases and weaknesses that are described below, but it is still expected that appropriate analysis will yield important information on food chain relationships and trophic linkages among these species and their immediate trophic associates.

The research follows a specific sequence where firstly we evaluate the constraints on the raw data and establish diet composition for all fish in the database. Secondly, we assess the suitability of the resulting data for evaluating spatio-temporal patterns in diet, and will select the most suitable species for analysis and description of those patterns. Concurrently, we assess and determine the potential linkages with wider biological and oceanographic characteristics and processes. The results of those analyses will indicate the feasibility of developing a focussed ecosystem model centred on the Highly Migratory Species, their key prey species and the ecosystem resources necessary to support their prey. In this sequence of tasks there is a clear progression of uncertainty, with the chosen method and results of the last objective being dependant on the quality of data and analysis that arises from earlier objectives.

This document reports on Objectives 1–2 of Project ZBD2011-01 “Evaluation of ecotrophic and environmental factors affecting the distribution and abundance of highly migratory species in New Zealand waters”. Project objectives are as follows:

1. Assess the dietary composition of highly migratory teleosts and elasmobranches using the data collected by the Observer Services.
2. Assess spatio-temporal patterns in dietary composition and changes in food utilisation with fish size.
3. Identify biological and physical environmental forces that can be used to explain highly migratory species distribution.
4. Develop an ecosystem model for the pelagic environment in New Zealand waters.

Objective 3 will be reported in an AEBR by McGregor and Horn. An examination of the results from Objectives 1–3 will determine if it is viable to complete Objective 4, and, if so, what methods will be used to complete it, and what the desirable outcome will be

2. METHODS

2.1 Fishery data

Data collected by observers on surface longline vessels is stored in the *cod* database administered by NIWA for the Ministry for Primary Industries. Sampling of individual fish involves the roughly random selection of an individual as it is caught. The length is collected for almost all specimens and most have additional data collected, e.g. sex, weight, maturity stage, and stomach contents. The data available for this analysis comprised stomach content information from 97 101 fish (44 509 tuna, 6 261 billfish, 31 850 sharks, and 14 481 other species) collected between 25 March 1994 and 28 August 2012. Date and time the fish was brought on-board is also recorded.

Vessel location at approximately hourly intervals (to the nearest 0.1 degree of latitude and longitude) is provided, so the landing location for each sampled fish can be taken as the vessel location at the time nearest to the catch time. However, for the analysis of diet by area, locations were binned into one of four broad areas as defined in Figure 1. A value for sea surface temperature was derived for each landing location, as described in Section 2.2. Hook depth was derived for each longline set as the mean of the estimated maximum and minimum depths of hooks set, as recorded by the vessel skipper.

Some example data, and the data collection form used by observers, are shown in Figure 2 to illustrate the variety of available information. The stomach contents data were of varying quality and were mostly in the form of presence-absence data in six categories (fish, crustacean, squid, bait, salps, and other), with estimated proportions by volume, and sometimes additional information to further qualify the category components. Any plastics associated with the fish, either internally (I) or externally (E), can be noted. Four ‘office code’ columns allow the NIWA data administrator to record further information on the components of fish, crustacean, bait, or other categories. The trip number, set number, and sample number allow the stomach contents information to be linked to the biological data of the fish (e.g., species, length, weight, sex) and its location in space and time.

Each row on the example form in Figure 2 represents an individual sampled fish. Fish 1 had squid, salps, and some ‘other’ prey in its stomach, with squid comprising 90% of the prey volume, and with no additional information on the ‘other’ component. Fish 2 had an empty stomach. The stomach of fish 3 contained bait (20% of the contents volume) and bird remains. Fish 4 contained only prey in the ‘other’ category of which the main component (and possibly the entire component) was octopus. The stomach of fish 5 contained ‘fish’, ‘crustacea’, and ‘other’ prey categories; the major or entire components of each of these three categories were dealfish, prawns, and plastic, respectively. The plastic was identified as clear plastic wrap (‘W’). The stomach of fish 6 was 80% full of unidentified fish, with the remaining 20% primarily comprising octopus, but also with a small component of clear plastic wrap. Fish 7’s stomach contained only fish, which were predominantly Ray’s bream. The stomach of fish 8 also contained only fish, comprising Ray’s bream and hoki, but with no indication of the relative volumes.

In these examples, the data administrator will have made some assumptions about the fish components of the diet to allow the recording on the electronic database of more detailed dietary information in the ‘office codes’ columns. It may be assumed that the stomachs of fish 7 and fish 8 contained mainly Ray’s bream (probably valid for fish 7 based on the comments, but not necessarily so for fish 8 where Ray's bream was simply the first fish species noted in the comments). In both cases, however, while the primary fish component is more precisely identified, the information on the secondary fish components (i.e., lanternfish and hoki) cannot be recorded in the database. Clearly the disadvantages with data recorded in this way are that categories that comprise multiple prey species will only (at best) be identified as the most abundant prey species, and there is no option to classify squid or salp prey more specifically. Octopus and nautilus (when identifiable) were generally recorded in the 'other' category, rather than as 'squid'.

Suggested improvements to the Stomach Samples Log form are presented later in this document (Appendix D).

2.2 Environmental data

A value of sea surface temperature (SST) for each catch location was derived from the Reynold's Optimum Interpolation (OI) Sea Surface Temperature Analysis. This analysis is produced daily on a ¼ degree latitude and longitude grid using *in situ* and satellite SSTs. Before the analysis is computed, the satellite data are adjusted for biases using the method of Reynolds (1988) and Reynolds & Marsico (1993). A description of the OI analysis can be found in Reynolds & Smith (1994). The bias correction improves the large scale accuracy of the OI. The version used here (OI.v2) has an improved sea-ice simulation as described in Reynolds et al. (2002). The SST value relevant to the fisheries data was found by finding the nearest SST data point to the fisheries location for the same day. The ¼ degree SST grid means effectively 25 km resolution.

Because moon phase is known to influence the dietary composition and feeding behaviour of some pelagic species, including southern bluefin tuna and Ray's bream (Kemps et al. 1998, Horn et al. 2013), the date-time of fish capture was referenced to moon phase as follows. The mean lunar cycle of 29.5 days was divided into four equal bins, each about 7.4 days long using a moon phase calculator at: http://www.timeanddate.com. Bin 1 was the 7.4 days centred on the actual date-time of the full moon, bin 2 encompassed the 7.4 days around the third quarter, bin 3 encompassed new moon, and bin 4 the first quarter.

2.3 Data summaries and analyses

Several different summaries of the available data are described below. First, the numbers of fish of each species or species group that were sampled for stomach data are tabulated. Second, detailed stomach contents are provided by species for all species where at least ten stomachs containing food were available. The resulting descriptions and tables take no account of predator size or location in space and time. Finally, detailed dietary descriptions are provided for 13 species, including an examination of ontogenetic, spatial, and temporal differences in diet. The 13 species were chosen by the Aquatic Environment Working Group, and comprise the 14 most commonly sampled species excluding school shark.

Ideally, the detailed dietary analysis would have used a distance-based linear model procedure, available in PRIMER software (Clarke & Gorley 2006), to identify which biophysical predictors explained most of the variability in diet response. This multivariate procedure applies a multiple regression technique to select predictor variables based on permutation tests, and has been used to analyse diets of numerous fish species found on the Chatham Rise (e.g., Dunn et al. 2010a, Horn et al. 2013). However, owing to the general lack of resolution of the prey data (i.e., 'fish', 'crustacean', and 'squid' were seldom identified in any more detail), the 'analyses' presented here were limited to summary tables showing the influence on dietary composition of predator size, sample area, month, and year. For the 13 predator species to be analysed in detail, the percentage of fish prey that were identified in any more detail ranged from 8 to 53% (mean of 28%). Consequently, it was not logical to ignore the 'unidentified fish' component (as this would strongly bias the diets towards non-fish components), or to scale the unidentified prey items up to the identified values (as the identified samples were not necessarily random or complete, the identified proportions were generally too low, and any scaling would be likely to obscure any real ontogenetic, spatial, or temporal effects).

Available data from the 13 predator species to be analysed in detail were examined to determine suitable classes of fish length, area, month, and year for each species, thus enabling the identification of any changes in diet over predator size, space, and time. The length classes for the "long" and "short" fish of each species were determined by selecting at least the 100 shortest and longest fish with stomach contents. The remaining fish were divided into approximately equal size classes, with the number of size classes dependent on the sample size and the range of remaining lengths. No length class sample size was less than 100. All species were divided into four or five length classes, except for shortsnouted lancetfish, which had three length classes owing to an overall small sample of stomachs (n = 381). The sample sizes of the area classes were determined by catch location (see Figure 1); data were tabulated if there were at least 12 stomachs from an area. The chosen month classes did not equally divide the year for any species, because catches of each species were generally concentrated over one or two short periods during the year. The year was divided into four classes, each at least one calendar month long, for all species, with an aim of having at least 100 fish per class. However, Ray's bream and albacore had only three classes and shortsnouted lancetfish had only two. For year classes, data from adjacent years were grouped with the aim of having minimum sample sizes of about 100. Data for most species were split into three to five year classes.

Once the fish length, area, month, and year classes had been determined for each species, diet compositions (expressed as mean percentage volume of various prey categories) were determined for each species and class. Identified fish prey were combined into a series of groups, generally small mesopelagic species, large mesopelagic species, and other fish. (Note that 'mesopelagic' groups will sometimes comprise species that are most commonly found in the epipelagic zone within 200 m of the surface, e.g., saury, flying fish). Sometimes, groups were created for sharks, tunas, or lancetfish if combined species in these groups accounted for more than about 2% by number of all prey items recorded for a predator. Similarly, individual species were allowed to comprise a group on their own if records of them accounted for more than about 2% by number of all prey items recorded. Appendix B shows the groups that all identified fish species were allocated to. The difference between "small" and "large" prey fish was determined using the adult size of the species. It is clear that the group of small mesopelagic species will always comprise small fish. The large mesopelagic species group, however, could comprise either small or large specimens of the component species (e.g., hoki is in this group, but the actual hoki prey items could range in size from a few centimetres to over one metre). No information was ever recorded to allow the evaluation of the size of individual prey items. Sub-groups of the cephalopods (e.g. nautilus) and other (e.g, anthropogenic litter, plant material, bird remains) categories were introduced for some predator species, again where these sub-groups comprised more than about 2% of the recorded items. Salps and crustaceans were retained as single groups in the analyses of all predator species.

The detailed analyses for each predator species also included depictions of the spatial distribution of the predator relative to the area fished by the surface longline fishery in New Zealand waters, and a comparison of the distributions of predators with items in their stomachs relative to those with empty stomachs. The distributions of sampled fish were also compared with the distributions of observed fish caught, in four groups of years (i.e., 1994–1998, 1999–2003, 2004–2008, and 2009–2012). Correlations between sample descriptor variables (year, month group, fish sex, fish length, moon phase, latitude, longitude, SST and mean hook depth) were examined using lattice plots.

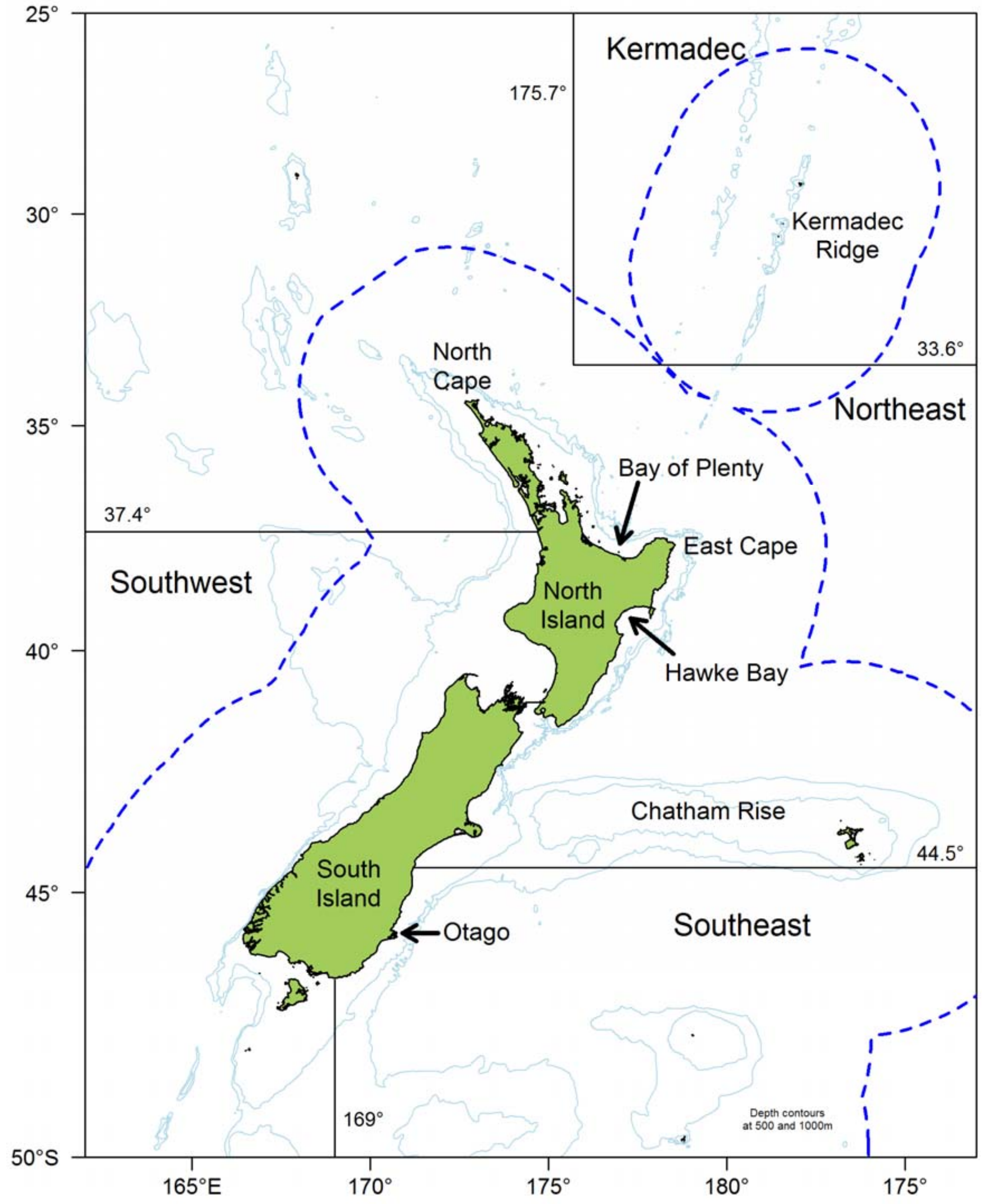
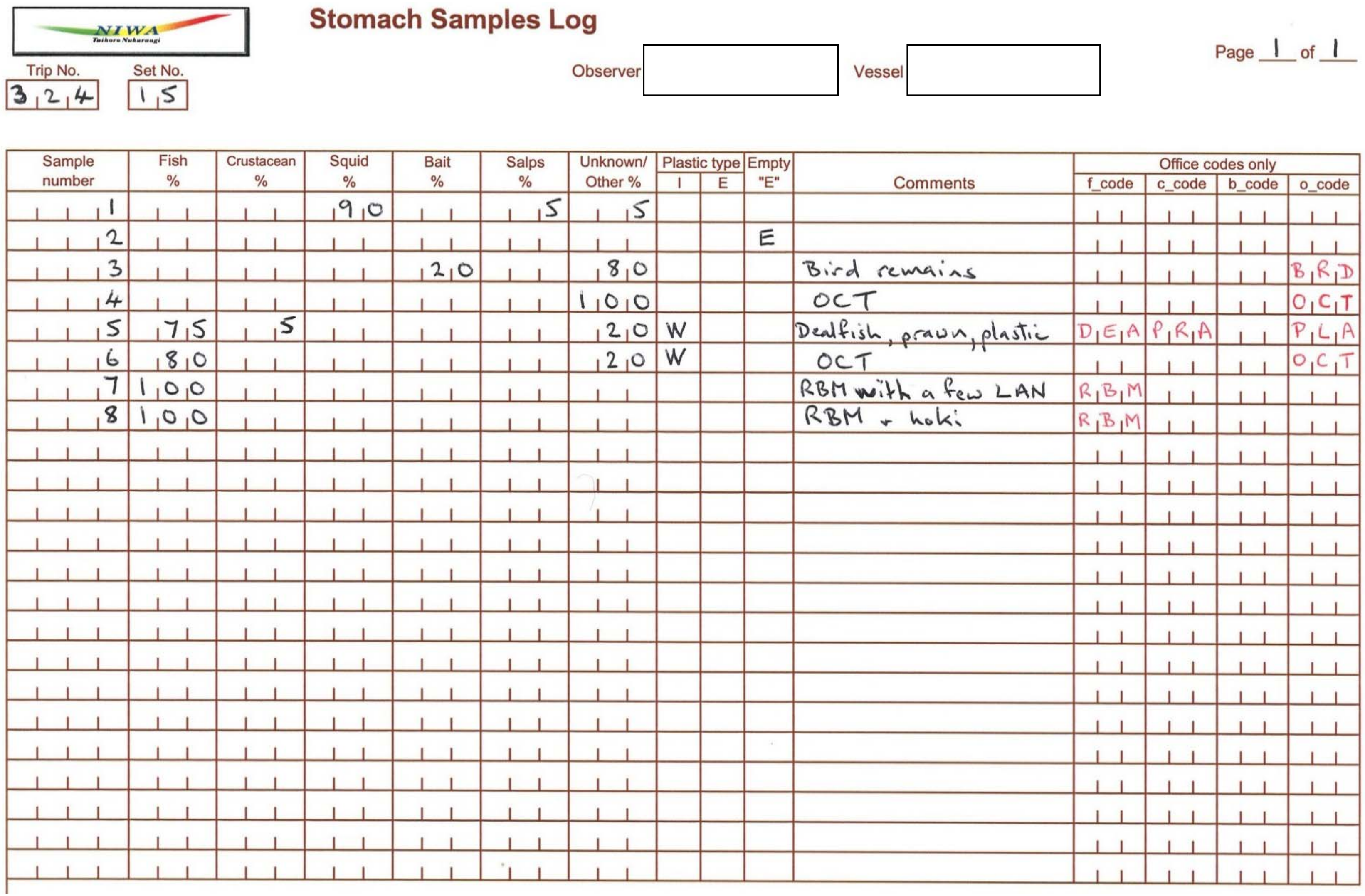


Figure 1: Boundaries of the four areas (Kermadec, Northeast, Southwest, and Southeast) used to examine spatial differences in dietary composition. Locations mentioned in the text, and the New Zealand EEZ boundary (dashed blue line) are also shown.



NIWA Taihoro Nukurangi

Stomach Samples Log

Trip No. 3 2 4 Set No. 1 5

Observer Vessel

Page 1 of 1

Sample number	Fish %	Crustacean %	Squid %	Bait %	Salps %	Unknown/ Other %	Plastic type I	Plastic type E	Empty "E"	Comments	Office codes only f_code	c_code	b_code	o_code
1			90		5	5								
2									E					
3				20		80				Bird remains				BRD
4						100				OCT				OCT
5	75	5				20	W			Dealfish, prawn, plastic	DEA	PRA		PLA
6	80					20	W			OCT				OCT
7	100									RBM with a few LAN	RBM			
8	100									RBM + hoki	RBM			

Figure 2: Log sheet used by observers to record data on stomach contents of sampled fish, with some dummy example data inserted to illustrate the available information. Each line represents a single examined fish. Black writing is recorded by the observer, red writing is added later by the NIWA database administrator.

3. RESULTS

3.1 Overall diet composition by species

Data were available from 97 101 examined stomachs (Table 1). Sixty-five taxonomic groups were represented in the diet (species, genus, or family), with one additional group comprising unidentified fish. Of the stomachs examined, 52% were empty, and a further 13% contained only bait or parasites. That left 33 978 stomachs (35%) containing non-bait food items (Table 1).

Table 1: Summary of data available on stomach contents, by species, ordered by the number of stomachs containing non-bait food items.

Common name	Scientific name	Stomach contents			Total
		Empty	Bait and/or parasites only	Other items	
Southern bluefin tuna	*Thunnus maccoyii*	21 767	3 680	9 966	35 413
Blue shark	*Prionace glauca*	10 610	4 023	8 584	23 217
Swordfish	*Xiphias gladius*	2 406	325	3 494	6 225
Moonfish	*Lampris guttatus*	1 319	422	1 565	3 306
Ray's bream	*Brama* sp.	5 107	384	1 560	7 051
Porbeagle shark	*Lamna nasus*	1 728	1 239	1 489	4 456
Bigeye tuna	*Thunnus obesus*	1 654	307	1 169	3 130
Mako shark	*Isurus oxyrinchus*	576	320	993	1 889
Yellowfin tuna	*Thunnus albacares*	887	296	967	2 150
Butterfly tuna	*Gasterochisma melampus*	654	422	949	2 025
Longsnouted lancetfish	*Alepisaurus ferox*	375	109	849	1 333
Albacore	*Thunnus alalunga*	659	259	694	1 612
School shark	*Galaeorhinus galeus*	736	292	423	1 451
Shortsnouted lancetfish	*Alepisaurus brevirostris*	117	44	381	542
Rudderfish	*Centrolophus niger*	59	62	177	298
Big-scale pomfret	*Taractichthys longipinnis*	290	75	113	478
Hoki	*Macruronus novaezelandiae*	152	180	102	434
Thresher shark	*Alopias vulpinus*	82	25	102	209
Smooth skin dogfish	*Centroscymnus owstoni*	171	270	76	517
Dealfish	*Trachipterus trachypterus*	196	95	56	347
Pacific bluefin tuna	*Thunnus orientalis*	80	25	47	150
Escolar	*Lepidocybium flavobrunneum*	184	8	22	214
Ribbonfish	*Agrostichthys parkeri*	3	3	22	28
Flathead pomfret	*Taractes asper*	37	5	21	63
Sunfish	*Mola mola*	3	4	21	28
Striped marlin	*Tetrapturus audax*	9	4	20	33
Oilfish	*Ruvettus pretiosus*	54	4	11	69
Dolphinfish	*Coryphaena hippurus*	9	3	10	22
Slender tuna	*Allothunnus fallai*	10	1	10	21
Shortbill spearfish	*Tetrapturus angustirostris*	7	2	8	17
Barracouta	*Thyrsites atun*	13	23	7	43
Bronze whaler shark	*Carcharhinus brachyurus*	16		7	23
Bigeye thresher shark	*Alopias superciliosus*	3	3	6	12
Wingfish	*Ptercalis velifera*	2	1	6	9
Frostfishes	Trichiuridae	10	3	5	18
Kingfish	*Seriola lalandi*	1	1	5	7
Unidentified	–	10	2	4	16
Opah	*Lampris immaculatus*	2	1	4	7
Ocean whitetip shark	*Carcharhinus longimanus*	2		4	6
Hapuku	*Polyprion oxygeneios*	5	7	3	15
Deepwater sharks/dogfish	Squalidae		5	3	8

Skipjack tuna	*Katsuwonus pelamis*	4	1	3	8
Galapagos shark	*Carcharhinus galapagensis*			3	3
Hake	*Merluccius australis*	8	1	2	11
Cubehead	*Cubiceps* sp.	9		2	11
Blue marlin	*Makaira mazara*	1		2	3
Black barracouta	*Nesiarchus nasutus*	61	15	1	77
Portugese dogfish	*Centroscymnus coelolepis*	19	17	1	37
Zameus squamulosus	*Zameus squamulosus*	7	8	1	16
Seal shark	*Datatias licha*	5		1	6
Pelagic stingray	*Pteroplatytrygon violacea*		3	1	4
Fanfish	*Pterycombus petersii*	2		1	3
Unicornfish	*Lophotus capellei*	1	1	1	3
Lyconus sp.	*Lyconus* sp.	2		1	3
Plunket's shark	*Proscymnodon plunketi*		1	1	2
Gemfish	*Rexea solandri*		1	1	2
Laternfish	Myctophidae			1	1
Southern spiny dogfish	*Squalus acanthias*	2	2		4
Bass groper	*Polyprion americanus*	3			3
False frostfish	*Paradiplospinus gracilis*	3			3
Leafscale gulper shark	*Centrophorus squamosus*	2			2
Frostfish	*Lepidopus caudatus*	2			2
Broadnose sevengill shark	*Notorynchus cepedianus*	2			2
Deepwater dogfish	*Centroscymnus* sp.		1		1
Hammerhead shark	*Sphyrna zygaena*	1			1
Wahoo	*Acanthocybium solandri*	1			1
Totals		50 140	12 983	33 978	97 101

Of the 20 560 occurrences of fish prey recorded in the stomachs of all species examined, only 6 999 (34%) were identified in more detail than 'fish'. Only 130 (8%) of the 1 538 occurrences of crustaceans were identified as other than 'crustacean', 'prawn', 'shrimp', or 'krill'. There were 11 144 occurrences of 'squid' with no further qualification, plus 929 records in the 'other' category with comments indicating that these items comprised octopus, nautilus, or cuttlefish. Of the remaining 2 659 non-cephalopod 'other' prey occurrences, 947 (36%) had comments giving more information on their composition. Note, however, that observers were not instructed to provide any additional comments on prey composition before 1996.

There were 29 species for which at least 10 stomachs containing prey were available. Detailed stomach contents for each of these species are listed in Appendix A, with frequencies of occurrence (%) of each item identified by observers. Summaries of the diets of these 29 species are provided below (*n* is the number of stomachs that contained prey).

Smooth skin dogfish (*Centroscymnus owstoni*)
A small sample of stomachs (*n* = 76) indicated that over two-thirds of the diet of this predator comprised cephalopods (primarily squid), with a smaller component of fish, and occasional crustaceans (Table 2, Table A1).

Thresher shark (*Alopias vulpinus*)
A moderate sample of stomachs (*n* = 102) indicated that thresher sharks fed almost exclusively on fish. The fish prey, when identified, were mesopelagic teleost species, with Ray's bream dominating the diet (Table 2, Table A2)

Mako shark (*Isurus oxyrinchus*)

A large sample of stomachs (*n* = 993) indicated a diet strongly dominated by fish, both elasmobranchs and teleosts. Virtually all the identified fish prey were mesopelagic species, with Ray's bream and albacore being the most abundant (Table 2, Table A3). One instance of cannibalism was recorded. Squid made up most of the non-fish component.

Porbeagle shark (*Lamna nasus*)

A large sample of stomachs (*N* = 1 489) indicated that fish comprised about two-thirds of the diet of porbeagle sharks, primarily mesopelagic teleosts, with dealfish and Ray's bream dominating the identified fish component (Table 2, Table A4). Cephalopods, primarily squid, made up most of the non-fish component.

School shark (*Galaeorhinus galeus*)

A moderate sample of stomachs (*n* = 423) indicated that fish comprised about half the diet (Table 2, Table A5). The few identified fish prey were all mesopelagic species. Cephalopods (primarily squid) made up most of the remainder, with a very minor crustacean component.

Blue shark (*Prionace glauca*)

A very large sample of stomachs (*n* = 8 584) indicated that the diet of blue sharks was split approximately equally between cephalopods (primarily squid) and fish (Table 2, Table A6). The identified fish tended to be medium-sized pelagic species, both teleost and elasmobranch. Ray's bream and dealfish dominated the identified fish component, but albacore, squaretail, rudderfish and jack mackerel were frequently identified. Twenty-four instances of cannibalism were recorded, which equates to about 40% by number of the elasmobranch prey recorded for this species. Remains of birds and marine mammals made up about 1% of the prey records.

Shortsnouted lancetfish (*Alepisaurus brevirostris*)

A moderate sample of stomachs (*n* = 381) indicated that pelagic crustaceans comprised about 60% of the diet, with an additional 16% made up of fish. Fish were dominated by small mesopelagic species (Table 3, Table A7). Three instances of cannibalism were recorded. Cephalopods (squid and nautilus, at a ratio of about 3:1) and salps each accounted for a small component.

Longsnouted lancetfish (*Alepisaurus ferox*)

A large sample of stomachs (*n* = 849) indicated that longsnouted lancet fish had a diet spread across all five prey groups (Table 3, Table A8). The 'other' prey group was the largest component (36% by volume); just over half of these records were identified as nautilus, with the remainder being predominantly unidentified. Fish comprised the next most frequent prey group (32%), and where identified these tended to be lancetfish (both *A. ferox* and *A. brevirostris*) and small mesopelagic species (with light organs). Just over 5% of all prey occurrencess were cannibalised *A. ferox*. Salps comprised about 21%, unidentified squids a further 9%, and crustaceans 3%. Plastic items made up about 1% of prey occurrences. Note, however, that some of the lancetfish examined in 1996–97 and recorded as *A. ferox* may have been *A. brevirostris*, as the two species were not distinguished by observers before 1998.

Hoki (*Macruronus novaezelandiae*)

A moderate sample of stomachs (*n* = 102) indicated a diet dominated by fish, particularly myctophids (Table 3, Table A9). The remaining 22% was split predominantly between squid and pelagic crustaceans, at a ratio of about 2:1. There was one record of cannibalism.

Moonfish (*Lampris guttatus*)
A large sample of stomachs (*n* = 1565) where fish was the dominant prey group, accounted for over one-third of the prey. Identified fish prey were dominated by lancetfish and small mesopelagic species (with light organs) (Table 3, Table A10). Cephalopods, primarily squid, were the next most important prey group. About a quarter of the prey items were in the 'other' prey group, and a large proportion of these were plastic. Crustaceans and salps were a minor component of the diet.

Dealfish (*Trachipterus trachypterus*)
A small sample of stomachs (*n* = 56) indicated a diet comprising about one-third fish, which, when identified, was mainly small mesopelagic teleosts (Table 3, Table A11). Salps and squid each comprised about a quarter of the diet, and there was a small crustacean prey component.

Ribbonfish (*Agrostichthys parkeri*)
A small sample of stomachs (*n* = 22) indicated a diet dominated by crustaceans, with fish being a strong secondary prey group (Table 3, Table A12). Small components of squid and salps were also recorded.

Dolphinfish (*Coryphaena hippurus*)
A small sample of stomachs (*n* = 10) suggested a diet dominated by fish, but also with records of salps and squid (Table 3, Table A13).

Ray's bream (*Brama* sp.)
A large sample of stomachs (*n* = 1560) indicated a diet comprising over half fish, with myctophids and lighthouse fish making up virtually all of the identified fish component (Table 3, Table A14). There was one record of cannibalism. Salps, squid and crustaceans each made up just over 10% volume of the remaining diet.

Big-scale pomfret (*Taractichthys longipinnis*)
A moderate sample of stomachs (*n* = 113) indicated a diet comprising about half fish, which, when identified, was dominated by small mesopelagic teleosts (Table 3, Table A15). Cephalopods (primarily squid, but also octopus) accounted for about one-third of the contents. Salp and crustacean prey were also recorded.

Flathead pomfret (*Taractes asper*)
A small sample of stomachs (*n* = 21) indicated a diet comprising about one-third fish, which, when identified, was dominated by small mesopelagic teleosts (Table 3, Table A16). Salps and squid each made up about a quarter of the contents.

Escolar (*Lepidocybium flavobrunneum*)
A small sample of stomachs (*n* = 22) indicated a diet strongly dominated by unidentified fish, with squid also of importance (Table 3, Table A17).

Oilfish (*Ruvettus pretiosus*)
A small sample of stomachs (*n* = 11) indicated a diet comprising fish, crustaceans, and squid (Table 3, Table A18).

Slender tuna (*Allothunnus fallai*)
A small sample of stomachs (*n* = 10) indicated a diet dominated by crustaceans, but also with components of fish, squid, and salps (Table 4, Table A19).

Butterfly tuna (*Gasterochisma melampus*)
A large sample of stomachs (*n* = 949) indicated a diet comprising about half squid (Table 4, Table A20). About one-third of the diet was fish, with the identified component of this prey group comprising mainly small mesopelagic species (e.g., myctophids) and medium pelagic species (e.g., hoki and Ray's bream), but also including demersal species (e.g., flatfish). One instance of cannibalism was recorded. Salps were a minor component of the diet.

Albacore (*Thunnus alalunga*)
A moderate sample of stomachs (*n* = 694) indicated a diet where fish and squid each comprised about one-third of the prey volume (Table 4, Table A21). Identified fish were mainly small mesopelagic species. Salps and crustaceans each comprised a small dietary component. There was evidence of some feeding on or near the sea bottom (i.e., records of crab and scampi).

Yellowfin tuna (*Thunnus albacares*)
A large sample of stomachs (*n* = 967) indicated a diet comprising about two-thirds fish (Table 4, Table A22). Most of the identified fish prey species were medium sized pelagic species, with skipjack tuna, saury, flying fish, pufferfish, and lancetfish being the most common. Cephalopods (primarily squid, but also significant number of nautilus) made up about a fifth of the diet. Salps were a minor dietary component.

Southern bluefin tuna (*Thunnus maccoyii*)
A very large sample of stomachs (*n* = 9 966) indicated a diet comprising just over 60% fish (Table 4, Table A23). The identified fish comprised 46 different species or species groups, virtually all pelagic teleosts, covering a wide range of potential prey sizes. However, two groups strongly dominated the fish prey: Ray's bream, and mesopelagics with light organs (i.e., myctophids and lighthouse fish). Salps and cephalopods (primarily squid) accounted for most of the remaining diet. Plastic items were recorded in 63 stomachs, equal to about 1% of the non-empty stomachs.

Pacific bluefin tuna (*Thunnus orientalis*)
A small sample of stomachs (*n* = 47) indicated a diet strongly dominated by fish, with a secondary component of squid (Table 4, Table A24). Most of the identified fish were Ray's bream and other medium-sized pelagic teleosts.

Bigeye tuna (*Thunnus obesus*)
A large sample of stomachs (*n* = 1 169) indicated a diet comprising just over 60% fish (Table 4, Table A25). The identified fish were dominated by medium sized pelagic teleosts (i.e., lancetfish, skipjack tuna, and Ray's bream). Most of the remainder was cephalopods, primarily squid, but with a number of nautilus. There was evidence of some feeding on or near the sea bottom (i.e., records of crab and crayfish).

Swordfish (*Xiphias gladius*)
A very large sample of stomachs (*n* = 3 494) indicated a diet comprising about three-quarters fish prey (Table 4, Table A26). The identified fish comprised 39 different species or species groups, most being medium sized pelagic teleosts, but with some elasmobranchs and small

mesopelagic teleosts. The identified fish were dominated by Ray's bream, with a secondary group including hoki, hake, saury, jack mackerel, and lancetfish. Most of the non-fish dietary component comprised squid. There was evidence of some feeding on or near the sea bottom (i.e., records of scampi).

Striped marlin (*Tetrapturus audax*)

A small sample of stomachs (*n* = 20) indicated a diet dominated by fish, with a secondary component of squid (Table 4, Table A27). One instance of cannibalism was recorded.

Rudderfish (*Centrolophus niger*)

A moderate sample of stomachs (*n* = 177) indicated a diet dominated by salps, with a minor component of squid (Table 3, Table A28).

Sunfish (*Mola mola*)

A small sample of stomachs (*n* = 21) indicated that the most frequent dietary item was seaweed, with smaller components of salps and squid (Table 3, Table A29).

Table 2: Summary of diet data in five broad prey groups for elasmobranch species. No., number of non-empty stomachs; %V, mean percentage volume by prey group in non-empty stomachs; F, frequency of prey group records; %F, percentage of non-empty stomachs containing the prey group; % identified, percentages of 'fish', 'crustacean', and 'other' prey groups that were identified in more detail; Plastic, number of stomachs containing plastic items.

Predator	No.	Prey group	%V	F	%F	% identified	Plastic
Smooth skin dogfish	76	Fish	21.8	18	23.7	5.6	
		Crustacean	4.7	5	6.6	60.0	
		Squid	68.2	53	69.7	–	
		Salp	0.0	0	0.0	–	
		Other	5.3	4	5.3	100.0	0
Thresher shark	102	Fish	92.7	95	93.1	42.1	
		Crustacean	0.0	0	0.0	–	
		Squid	2.4	5	4.9	–	
		Salp	1.0	1	1.0	–	
		Other	3.9	4	3.9	0.0	0
Mako shark	993	Fish	87.2	888	89.4	37.3	
		Crustacean	0.2	2	0.2	0.0	
		Squid	10.1	136	13.7	–	
		Salp	0.6	12	1.2	–	
		Other	1.9	35	3.5	48.6	4
Porbeagle shark	1489	Fish	63.9	1013	68.0	40.0	
		Crustacean	0.4	11	0.7	72.7	
		Squid	29.7	524	35.2	–	
		Salp	2.2	43	2.9	–	
		Other	3.7	72	4.8	59.7	3
School shark	423	Fish	49.8	233	55.1	7.7	
		Crustacean	0.9	6	1.4	83.3	
		Squid	40.7	197	46.6	–	
		Salp	0.6	6	1.4	–	
		Other	8.0	47	11.1	21.3	0
Blue shark	8584	Fish	42.7	4057	47.3	44.4	
		Crustacean	0.8	115	1.3	55.7	
		Squid	47.5	4710	54.9	–	
		Salp	1.9	259	3.0	–	
		Other	7.1	784	9.1	63.4	25

Table 3: Summary of diet data in five broad prey groups for non-tuna and billfish teleost species. No., number of non-empty stomachs; %V, mean percentage volume by prey group in non-empty stomachs; F, frequency of prey group records; %F, percentage of non-empty stomachs containing the prey group; % identified, percentages of 'fish', 'crustacean', and 'other' prey groups that were identified in more detail; Plastic, number of stomachs containing plastic items.

Predator	No.	Prey group	%V	F	%F	% identified	Plastic
Shortsnouted lancetfish	381	Fish	16.4	144	37.8	8.3	
		Crustacean	60.5	285	74.8	78.9	
		Squid	4.4	39	10.2	–	
		Salp	7.7	50	13.1	–	
		Other	10.9	67	17.6	25.4	1
Longsnouted lancetfish	849	Fish	31.5	441	51.9	30.2	
		Crustacean	3.1	58	6.8	41.4	
		Squid	8.6	136	16.0	–	
		Salp	20.8	268	31.6	–	
		Other	36.0	426	50.2	58.7	10
Hoki	102	Fish	77.9	84	82.4	34.5	
		Crustacean	11.7	15	14.7	80.0	
		Squid	5.6	8	7.8	–	
		Salp	0.0	0	0.0	–	
		Other	4.9	5	4.9	0.0	0
Moonfish	1565	Fish	38.8	749	47.9	25.1	
		Crustacean	2.7	70	4.5	55.7	
		Squid	28.6	592	37.8	–	
		Salp	2.8	65	4.2	–	
		Other	27.1	532	34.0	75.6	288
Dealfish	56	Fish	35.2	22	39.3	18.2	
		Crustacean	5.1	4	7.1	25.0	
		Squid	24.6	17	30.4	–	
		Salp	28.0	19	33.9	–	
		Other	7.1	4	7.1	50.0	0
Ribbonfish	22	Fish	24.9	10	45.5	10.0	
		Crustacean	55.6	15	68.2	73.3	
		Squid	4.5	1	4.5	–	
		Salp	8.7	3	13.6	–	
		Other	6.3	3	13.6	33.3	0
Dolphinfish	10	Fish	83.0	9	90.0	44.4	
		Crustacean	0.0	0	0.0	–	
		Squid	7.0	1	10.0	–	
		Salp	10.0	1	10.0	–	
		Other	0.0	0	0.0	–	0
Ray's bream	1560	Fish	57.1	952	61.0	53.3	
		Crustacean	10.2	212	13.6	65.1	
		Squid	11.2	220	14.1	–	
		Salp	12.0	218	14.0	–	
		Other	9.5	175	11.2	28.0	4
Big-scale pomfret	113	Fish	47.3	62	54.9	14.5	
		Crustacean	2.3	7	6.2	28.6	
		Squid	27.9	39	34.5	–	
		Salp	3.0	4	3.5	–	
		Other	19.6	26	23.0	19.2	0
Flathead pomfret	21	Fish	32.4	8	38.1	25.0	
		Crustacean	4.8	1	4.8	100.0	
		Squid	21.4	5	23.8	–	

Predator	No.	Prey group	%V	F	%F	% identified	Plastic
		Salp	26.2	6	28.6	–	
		Other	15.2	4	19.0	0.0	0
Escolar	22	Fish	65.9	15	68.2	0.0	
		Crustacean	0.0	0	0.0	–	
		Squid	15.9	4	18.2	–	
		Salp	0.0	0	0.0	–	
		Other	18.2	4	18.2	0.0	0
Oilfish	11	Fish	43.6	5	45.5	0.0	
		Crustacean	14.5	3	27.3	33.3	
		Squid	27.3	3	27.3	–	
		Salp	9.1	1	9.1	–	
		Other	5.5	1	9.1	0.0	0
Rudderfish	177	Fish	2.9	6	3.4	0.0	
		Crustacean	0.0	0	0.0	–	
		Squid	4.5	9	5.1	–	
		Salp	73.8	133	75.1	–	
		Other	18.8	34	19.2	0.0	0
Sunfish	21	Fish	4.8	1	4.8	0.0	
		Crustacean	0.0	0	0.0	–	
		Squid	14.3	3	14.3	–	
		Salp	23.8	5	23.8	–	
		Other	57.1	12	57.1	75.0	0

Table 4: Summary of diet data in five broad prey groups for tuna and billfish species. No., number of non-empty stomachs; %V, mean percentage volume by prey group in non-empty stomachs; F, frequency of prey group records; %F, percentage of non-empty stomachs containing the prey group; % identified, percentages of 'fish', 'crustacean', and 'other' prey groups that were identified in more detail; Plastic, number of stomachs containing plastic items.

Predator	No.	Prey group	%V	F	%F	% identified	Plastic
Slender tuna	10	Fish	15.0	2	20.0	50.0	
		Crustacean	60.0	7	70.0	42.9	
		Squid	10.0	1	10.0	–	
		Salp	10.0	1	10.0	–	
		Other	5.0	1	10.0	0.0	0
Butterfly tuna	949	Fish	33.1	383	40.4	16.4	
		Crustacean	1.2	19	2.0	47.4	
		Squid	52.5	592	62.4	–	
		Salp	4.8	67	7.1	–	
		Other	8.4	115	12.1	27.0	5
Albacore	694	Fish	34.4	312	45.0	18.6	
		Crustacean	7.4	91	13.1	61.5	
		Squid	33.3	306	44.1	–	
		Salp	6.2	54	7.8	–	
		Other	18.7	166	23.9	7.8	1
Yellowfin tuna	967	Fish	67.5	713	73.7	18.9	
		Crustacean	0.8	25	2.6	24.0	
		Squid	18.7	261	27.0	–	
		Salp	4.7	55	5.7	–	
		Other	8.3	112	11.6	34.8	3
Southern bluefin tuna	9966	Fish	61.5	6513	65.4	41.9	
		Crustacean	3.3	468	4.7	41.9	
		Squid	12.5	1616	16.2	–	
		Salp	18.0	2127	21.3	–	
		Other	4.7	635	6.4	40.9	63
Pacific bluefin tuna	47	Fish	73.9	37	78.7	32.4	
		Crustacean	0.0	0	0.0	–	
		Squid	15.1	10	21.3	–	
		Salp	4.1	2	4.3	–	
		Other	6.8	4	8.5	50.0	1
Bigeye tuna	1169	Fish	60.8	795	68.0	18.9	
		Crustacean	1.4	32	2.7	59.4	
		Squid	30.0	444	38.0	–	
		Salp	0.5	13	1.1	–	
		Other	7.2	114	9.8	69.3	2
Swordfish	3494	Fish	75.4	2924	83.7	12.0	
		Crustacean	1.1	78	2.2	52.6	
		Squid	21.9	1152	33.0	–	
		Salp	0.2	13	0.4	–	
		Other	1.5	91	2.6	20.9	3
Striped marlin	20	Fish	70.5	16	80.0	25.0	
		Crustacean	0.0	0	0.0	–	
		Squid	19.5	6	30.0	–	
		Salp	0.0	0	0.0	–	
		Other	10.0	2	10.0	50.0	1

3.2 Detailed diet descriptions

3.2.1 Mako shark

Mako shark (*Isurus oxyrinchus*) have been caught and sampled over virtually the entire range of the surface longline fishery in New Zealand waters, but particularly off the southwest coast of South Island and adjacent to East Cape (Figure 3). The distributions of mako shark with and without stomach contents were visually very similar (Figure 3). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 4). The number of observations per year was low before 1997, relatively high from 1997 to about 2003, but declined again in most years since then (Figures 4 and 5).

An examination of data correlations (Figure 5) indicates some trends. Mako shark were caught more commonly in southern latitudes and western longitudes in the first half of the calendar year, and in northern latitudes and eastern longitudes later in the year. Mako sharks were generally taken in cooler waters (12–14 °C) in May–June, and warmer waters (14–20 °C) at other times. Females appeared to prefer warmer or more northern waters than males. They were commonly caught over a broad hook depth range (40–140 m), but samples since 2004 were taken mainly from relatively shallow sets (less than 80 m). The length-frequency distribution of sampled fish was unimodal, with a mode at about 200 cm FL; 75% of mako were in the length range of 110–225 cm FL. On average, northern fish were smaller than southern ones. Sex was determined for most fish, and about two-thirds of these were male.

There were ontogenetic changes in diet (Table 5). Small mesopelagic prey species were found only in mako sharks shorter than 150 cm FL, and shark prey were found only in larger (longer than 150 cm) mako. Large mesopelagic species (primarily Ray's bream, but also albacore, other tunas, and other mesopelagic species) increased in abundance as mako size increased. Overall, however, there was a relatively small change in the total percentage volume of fish as mako grew. It appears likely that larger prey species were easier to identify than smaller ones, as the percentage of unidentified fish prey decreased markedly as mako size increased. As mako grew, the slight increase in percentage fish prey was balanced by a decline in cephalopod prey, all identified only as squid. There was a consistent trend in the proportion of empty stomachs relative to mako size, with over half the smallest individuals having empty stomachs, reducing to less than one-third empty in the largest size class.

The between-area differences in prey may, to a slight extent, be related to differences in mean size of mako sharks (Table 5). Mako from Southwest and Kermadec were large, and had diets of about 90% fish, with Ray's bream being the most important species group in the south, and tunas being the most important prey in the north. Northeast mako were smaller, and although their diet was strongly fish-dominated (84%) with the components primarily albacore and other large mesopelagic species, they also had a relatively high cephalopod component. Salps were also more important in Kermadec than in the two other areas. The Kermadec sample size was relatively small, however.

The seasonal differences in diet (i.e., Ray's bream dominating the identified fish component from January–June, with cephalopods most abundant during the rest of the year) were correlated with changes in area, and to a lesser extent predator size (Table 6). Most mako from January–June were from the Southwest area (and relatively large), while 93% of fish sampled from July to December were from the Northeast (and were smaller on average). There were no obvious consistent dietary trends across years.

In conclusion, a broad size range of mako shark was sampled, and all had a diet strongly dominated by fish, particularly Ray's bream in the south and albacore and other potentially large mesopelagic species in the north. Squid were the only other significant dietary component, and it was apparent that these were consumed slightly more frequently by smaller mako. Mako caught in the Northeast were, on average, smaller than those sampled in the Southwest.

Table 5: Mako shark — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area		
Prey category			62–105	106–150	151–190	191–225	226–350	Kermadec	Northeast	Southwest
Fish	Sharks	2.1	–	–	0.7	3.5	7.4	–	0.9	3.7
	Small mesopelagics	0.8	5.7	1.0	–	–	–	2.3	1.3	–
	Ray's bream	12.1	0.9	5.4	15.3	18.4	12.3	–	2.0	25.6
	Albacore	6.9	2.8	6.9	5.8	7.7	11.5	11.6	9.5	3.2
	Other tunas	2.4	0.9	–	2.2	2.1	8.2	4.6	2.8	1.6
	Large mesopelagics	8.1	5.7	3.5	8.0	11.1	12.3	18.5	8.0	7.1
	Other teleosts	0.3	–	–	–	1.0	–	–	0.2	0.5
	Unidentified fish	54.7	66.5	66.3	53.8	47.6	38.7	53.3	59.3	49.1
	Total fish	87.2	82.6	83.1	85.8	91.5	90.6	90.3	84.0	90.7
Cephalopods		10.1	14.1	14.8	10.4	6.9	6.1	2.8	13.8	6.3
Salps		0.6	–	0.6	0.8	0.6	1.3	4.3	0.0	1.0
Crustacea		0.2	–	–	0.4	–	–	–	0.4	–
Other		1.9	3.3	1.5	2.6	1.0	2.1	2.6	1.8	1.9
Mean FL (cm)		172.8	85.8	128.8	171.3	206.7	247.1	190.7	152.5	195.4
Mean SST (°C)		15.9	18.1	16.6	15.4	14.9	15.6	18.7	17.6	13.5
Sample size		993	104	198	269	278	118	42	523	428
% empty		47.4	54.4	53.7	46.1	35.3	31.8	48.8	54.5	35.0

Table 6: Mako shark — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year				
Prey category		Jan-Apr	May	Jun	Jul-Dec	94–97	98–00	01–03	04–07	08–12
Fish	Sharks	1.1	2.3	3.4	1.3	1.7	4.7	0.9	1.3	1.3
	Small mesopelagics	2.8	0.8	0.4	–	0.6	1.3	0.9	0.4	0.7
	Ray's bream	11.2	22.2	12.4	3.6	7.5	6.8	15.9	17.2	11.8
	Albacore	5.1	6.0	6.4	9.1	5.2	9.0	11.5	4.7	2.0
	Other tunas	7.9	1.5	1.1	1.0	–	2.6	7.5	–	0.7
	Large mesopelagics	9.5	8.3	5.3	9.4	4.0	11.1	8.9	8.2	6.6
	Other teleosts	1.1	0.4	–	–	–	1.3	–	–	–
	Unidentified fish	52.8	49.2	56.5	59.0	71.2	50.3	42.1	50.8	67.1
	Total fish	91.5	90.5	85.4	83.3	90.1	87.0	87.7	82.6	90.1
Cephalopods		5.1	7.1	11.4	14.5	7.1	9.6	8.5	16.3	7.5
Salps		0.3	0.6	0.9	0.7	0.7	1.5	0.8	–	–
Crustacea		0.6	–	–	0.3	–	–	0.5	–	0.7
Other		2.6	1.7	2.3	1.2	2.1	1.9	2.5	1.1	1.7
Mean FL (cm)		168.8	186.5	177.8	158.8	161.7	190.4	189.9	158.2	155.7
Mean SST (°C)		17.5	14.7	15.1	16.6	15.7	15.5	17.0	15.4	15.8
Sample size		174	257	261	301	171	230	216	225	151
% empty		47.9	40.4	48.1	51.5	56.8	41.3	43.5	44.6	51.8

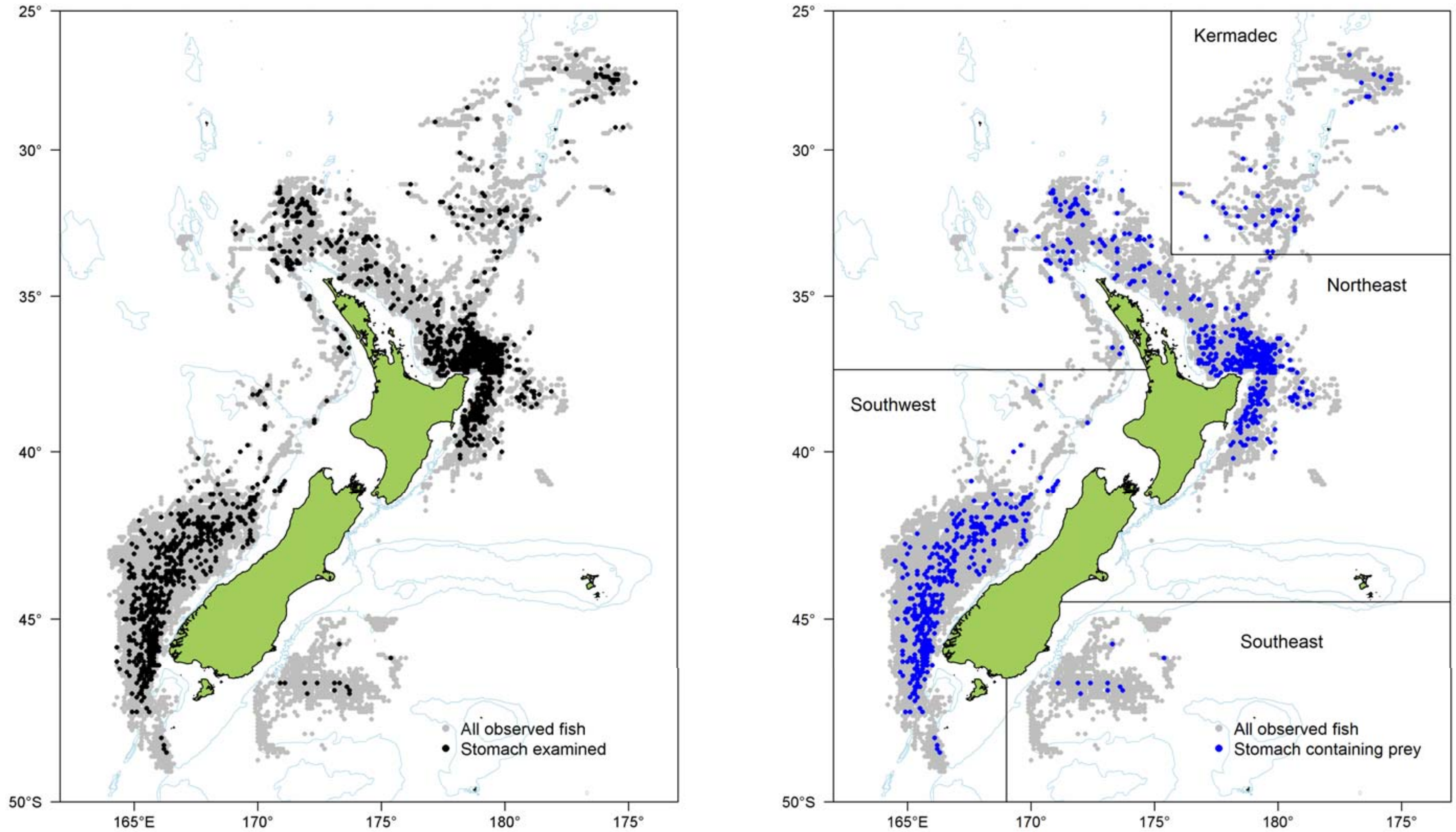


Figure 3: Distributions of all mako shark examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

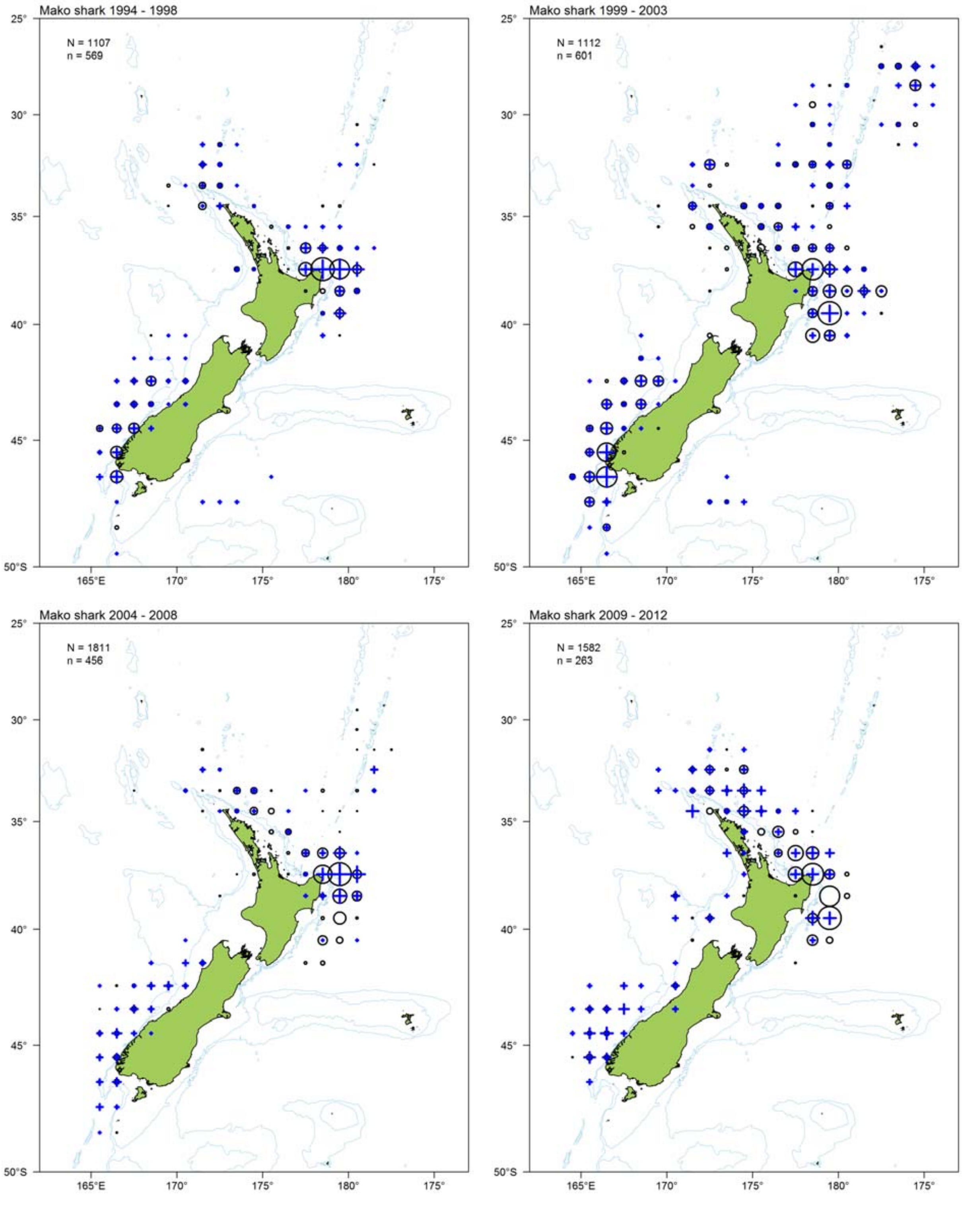


Figure 4: Mako shark — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

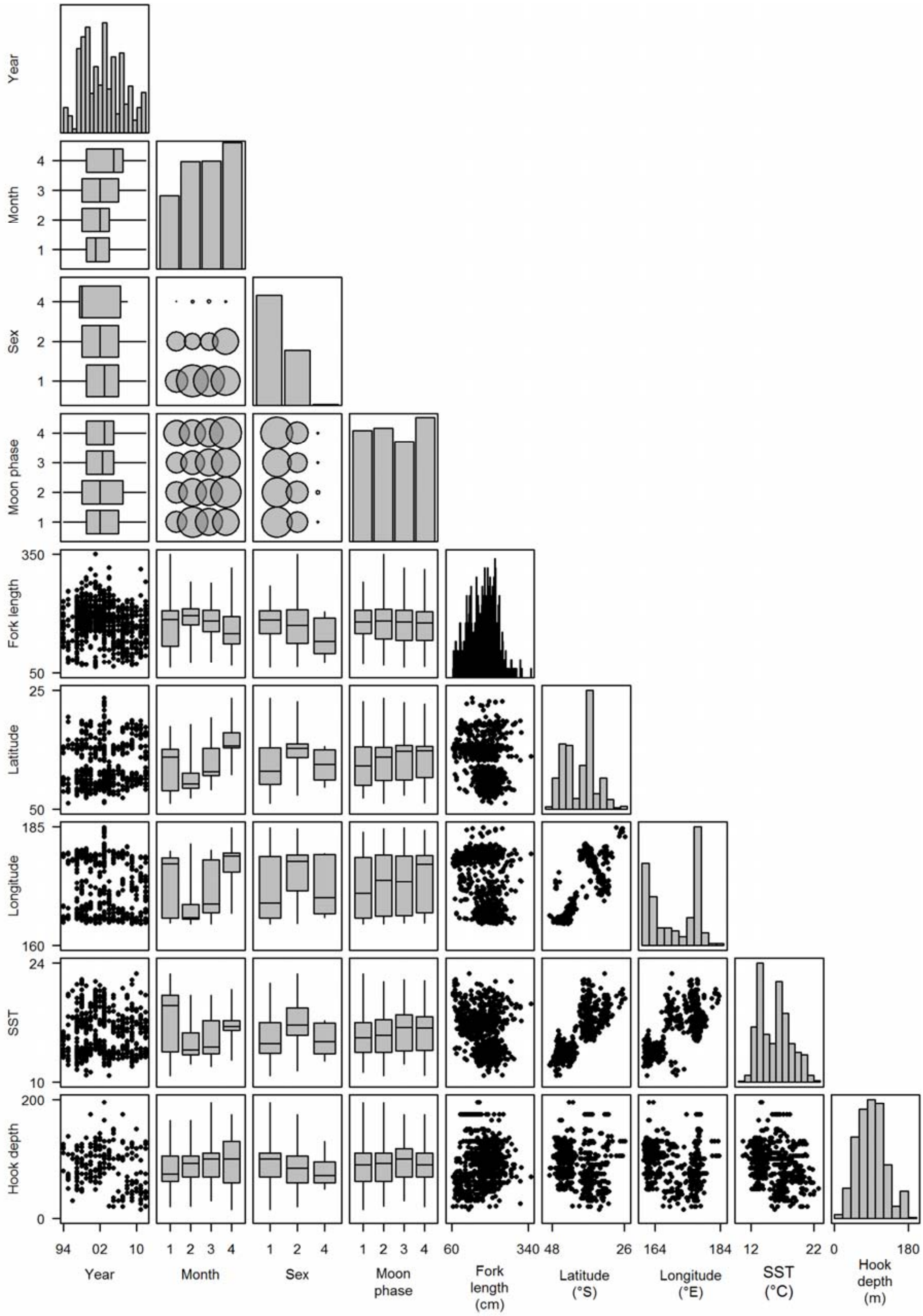


Figure 5: Mako shark — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–April; 2, May; 3, June; 4, July–December. Sex: 1, male; 2, female; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.2 Porbeagle shark

Porbeagle shark (*Lamna nasus*) have been caught and sampled over virtually the entire range of the surface longline fishery in New Zealand waters, but particularly off the southwest coast of South Island and East Cape, and to a lesser extent off southeast South Island (Figure 6). The distributions of porbeagle shark with and without stomach contents were visually very similar (Figure 6). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 7). Samples were sparse before 1997, most abundant from 1997 to 2001, and moderate since then (Figures 7 and 8).

An examination of data correlations (Figure 8) indicated some trends. Porbeagles were caught more commonly in southern latitudes early in the calendar year, and in northern latitudes and eastern longitudes later in the year. They were caught primarily in a relatively narrow SST range of 12.0 to 15.0 °C. Porbeagle were taken commonly over a broad hook depth range (40–140 m), but samples since 2004 were taken mainly from shallow sets (less than 80 m). The length-frequency distribution of sampled fish was bimodal, with modes at 86 cm and 130 cm FL; 75% of fish were in the length range of 85–155 cm FL. Sex was determined for most fish, with similar numbers of males and females. Porbeagle sharks were caught most frequently around full moon, and least frequently around new moon.

The porbeagle diet was dominated by fish, with an increasing percentage as predator size increased (Table 7). There was an increase in large mesopelagic fish prey (primarily dealfish and Ray's bream) as porbeagles grew. Small mesopelagic species were a minor dietary component, and only for smaller porbeagle sharks (i.e., shorter than 140 cm FL). Cephalopods (mostly identified as squid, but with 3.5% of the cephalopod volume identified as octopus) made up most of the remaining diet, but they declined in importance as porbeagles increased in size. Stomachs were more likely to be found empty in the north than in the southern areas, but there was no apparent correlation between porbeagle size and proportions of empty stomachs.

The diets of porbeagle sharks from the Northeast and Southeast areas were similar, comprising approximately equal proportions of cephalopods and fish, primarily unidentified species (Table 7). Sample sizes in both these areas were small. The diet in the Southwest area was dominated by fish (with large components of dealfish and Ray's bream), with cephalopods comprising only about a quarter of the prey volume.

Fish were more prevalent in the porbeagle diet from January–May, relative to the rest of the year (Table 8), but there is no obvious reason for this. There were no obvious consistent dietary trends across years. Stomachs were more likely to be empty in May, and less likely to be empty in the latter half of the year.

In conclusion, a broad size range of porbeagle shark were sampled, and all had a diet dominated by fish, particularly dealfish and Ray's bream in the south and other large mesopelagic species in the north. Cephalopods (probably mainly squid) comprised almost one-third of the diet, although these were consumed more frequently by smaller predators. Porbeagles caught in the Northeast were, on average, smaller than those sampled in the Southwest, and they in turn were shorter than Southeast fish.

Table 7: Porbeagle shark — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area		
Prey category			61–90	91–115	116–140	141–170	171–246	Northeast	Southwest	Southeast
Fish	Small mesopelagics	0.6	0.7	1.6	0.4	–	–	0.5	0.7	–
	Dealfish	13.4	3.0	9.9	20.4	15.8	12.0	–	17.1	1.2
	Ray's bream	6.7	3.7	3.5	8.8	7.1	17.5	–	8.0	5.3
	Large mesopelagics	4.4	3.3	3.5	3.2	5.9	4.6	8.8	3.7	4.7
	Other teleosts	0.4	0.4	–	0.6	0.6	0.9	0.5	0.2	1.8
	Unidentified fish	38.4	40.7	46.1	33.9	34.1	35.9	38.8	38.5	35.7
	Total fish	63.9	51.8	64.5	67.4	63.6	70.8	48.7	68.3	48.5
Cephalopods		31.2	43.0	31.8	27.6	30.3	21.8	44.2	26.7	50.2
Salps		2.2	0.7	1.7	3.0	3.5	2.5	0.3	2.8	–
Crustacea		0.4	0.8	0.2	0.0	0.2	3.0	2.0	0.2	–
Other		2.3	3.8	1.9	2.0	2.4	1.9	4.9	2.0	1.3
Mean FL (cm)		123.7	85.8	128.8	171.3	206.7	247.1	106.0	124.6	139.9
Mean SST (°C)		18.1	18.1	16.6	15.4	14.9	15.6	17.6	13.3	11.2
Sample size		1489	251	297	449	299	101	182	1157	150
% empty		66.6	63.7	60.5	66.9	64.6	64.6	77.3	64.9	58.3

Table 8: Porbeagle shark — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year				
Prey category		Jan-Apr	May	Jun	Jul-Dec	94–96	97–98	99–00	01–05	06–12
Fish	Small mesopelagics	0.2	0.5	0.9	0.9	–	–	0.4	0.7	2.1
	Dealfish	7.8	19.5	13.2	2.6	2.2	18.0	18.0	14.0	3.7
	Ray's bream	6.7	9.4	4.6	0.9	1.1	7.3	9.0	5.5	6.2
	Large mesopelagics	5.3	3.0	5.1	6.0	6.1	5.2	4.6	4.1	2.1
	Other teleosts	0.7	0.3	0.5	–	–	0.6	0.4	0.7	0.4
	Unidentified fish	44.2	39.5	29.8	40.9	51.7	28.4	35.7	39.9	46.3
	Total fish	65.0	72.3	54.1	51.1	61.1	59.6	68.1	65.0	60.8
Cephalopods		31.2	23.4	39.0	44.1	33.9	36.7	26.6	28.1	36.0
Salps		2.1	2.3	2.8	–	0.7	1.8	3.5	2.6	0.5
Crustacea		0.3	0.3	0.5	0.9	1.0	0.5	–	0.6	0.6
Other		1.4	1.7	3.5	4.0	3.3	1.5	1.9	3.7	2.1
Mean FL (cm)		168.8	186.5	177.8	158.8	161.7	190.4	189.9	158.2	155.7
Mean SST (°C)		17.5	14.7	15.1	16.6	15.7	15.5	17.0	15.4	15.8
Sample size		402	580	396	111	162	306	533	257	231
% empty		57.3	65.5	70.7	77.0	67.3	65.5	66.1	66.8	68.2

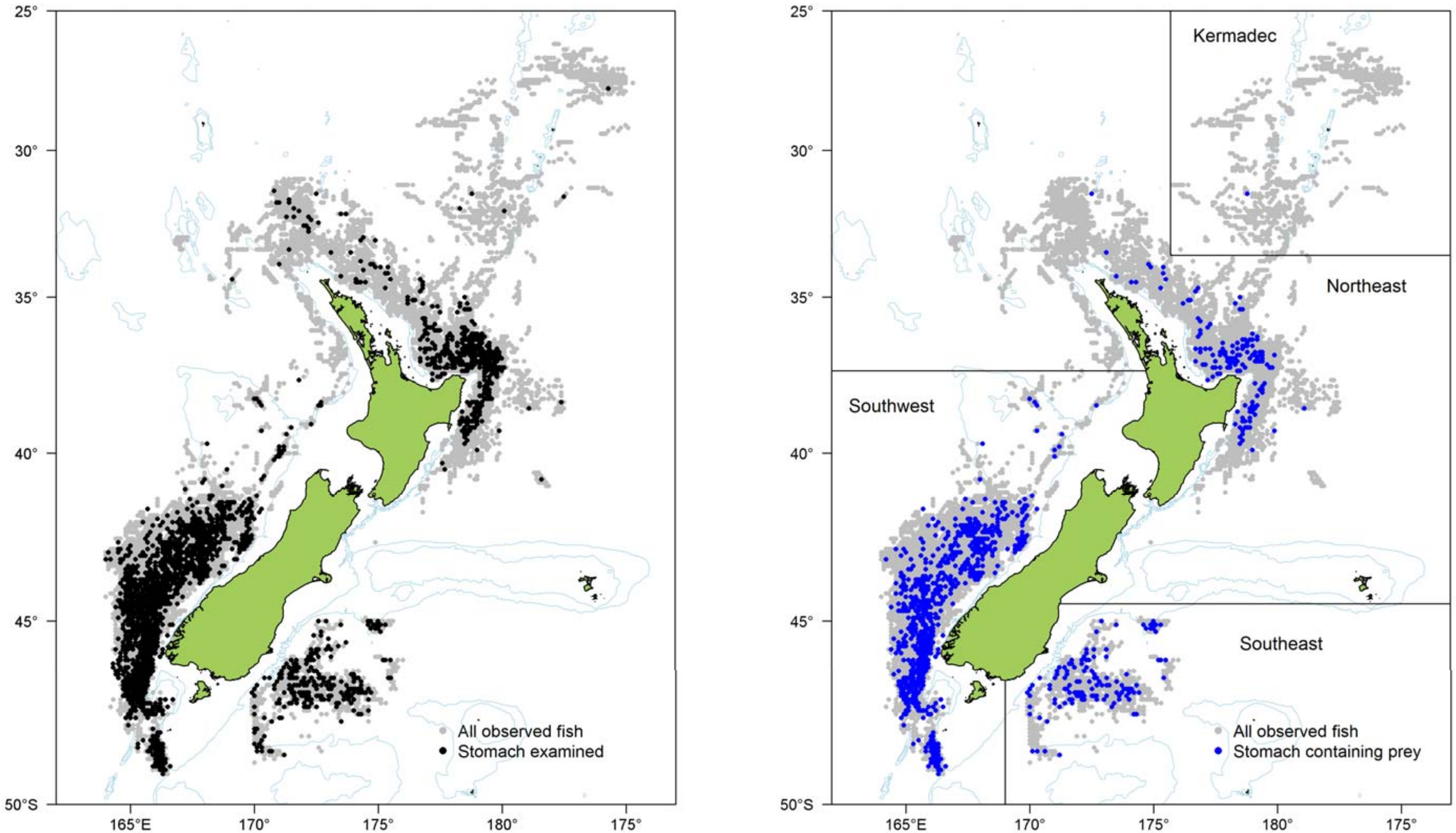


Figure 6: Distributions of all porbeagle shark examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

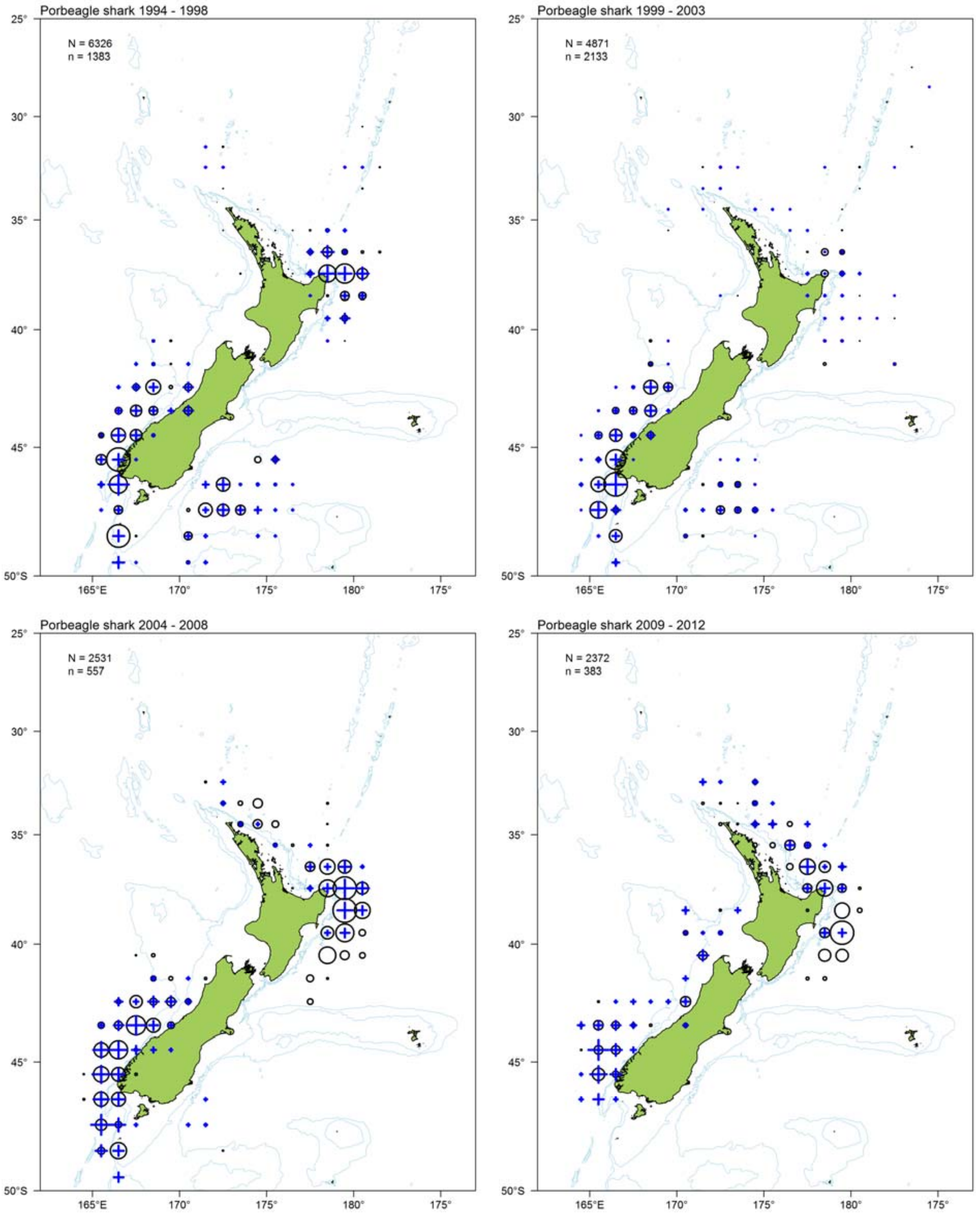


Figure 7: Porbeagle shark — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

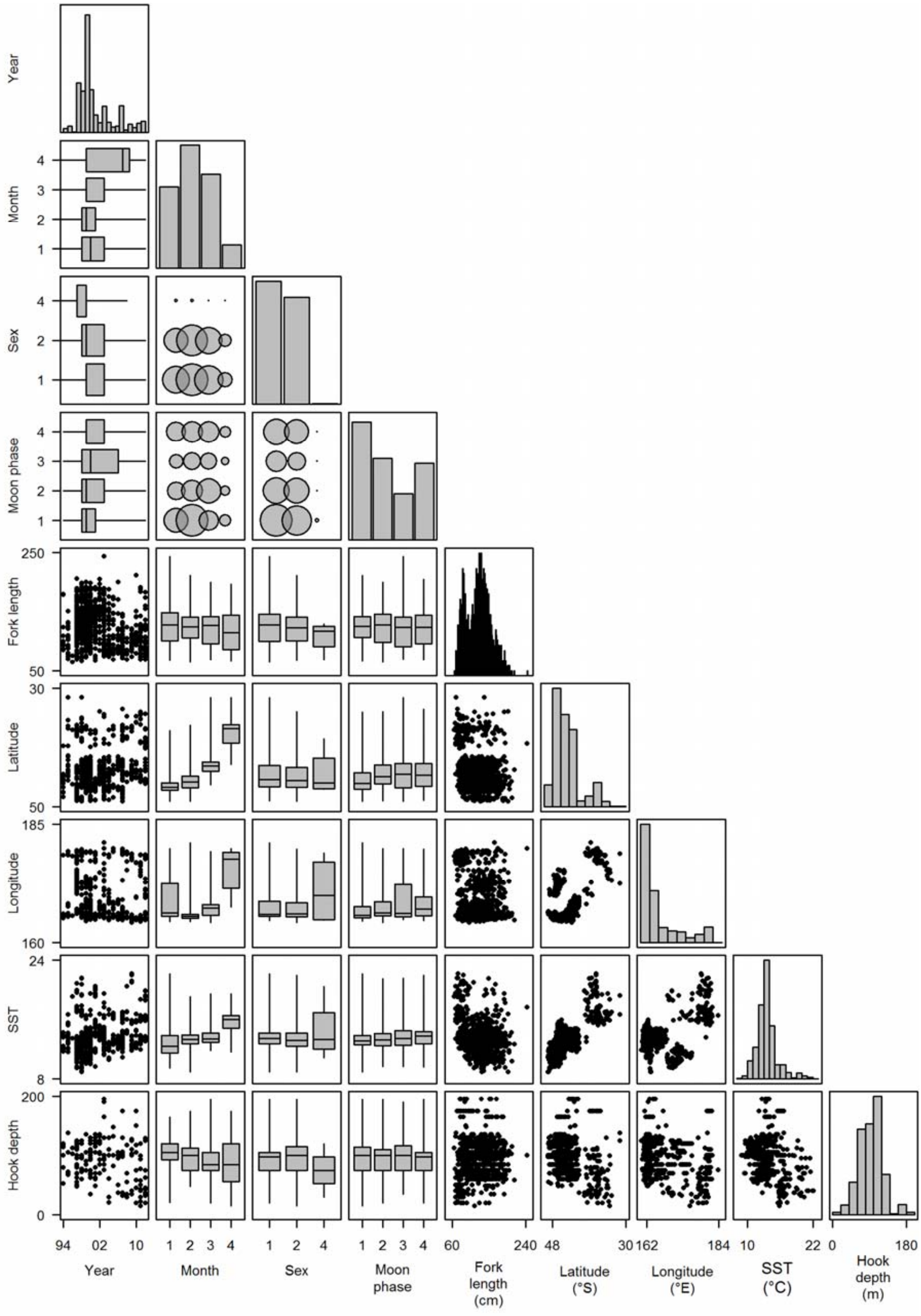


Figure 8: Porbeagle shark — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–April; 2, May; 3, June; 4, July–December. Sex: 1, male; 2, female; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.3 Blue shark

Blue shark (*Prionace glauca*) have been caught and sampled over virtually the entire range of the surface longline fishery in New Zealand waters, but particularly off the southwest coast of South Island and around East Cape (Figure 9). The distributions of blue shark with and without stomach contents were visually very similar (Figure 9). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 10). The number of observations per year was sparse before 1997, but has generally been increasing since then (Figures 10 and 11).

An examination of data correlations (Figure 11) indicated some trends. Male blue shark appeared to be more abundant that females at northern latitudes. There was also a trend of blue sharks being taken at more northerly latitudes as the calendar year progressed. Sample sizes were smaller around full and new moon than around the quarter moon phases. Blue sharks were generally taken in cool waters (12.5–15.0 °C) in April-June. They were most commonly caught over a moderate hook depth range (70–130 m), but samples since 2004 were taken mainly from shallow sets (less than 80 m). The length-frequency distribution of sampled fish was bimodal, with the main mode at about 162 cm FL, and a second mode at about 94 cm FL. Sex was determined for most fish, and about 70% of these were female.

There was a steady ontogenetic trend, with the diet of small blue shark dominated by cephalopods, changing to predominantly fish as blue shark grew (Table 9). Most of the cephalopods were simply identified as ‘squid’, but about 7% of the cephalopod prey volume was identified as octopus, and smaller components were identified as nautilus and cuttlefish. Small mesopelagic prey species were most commonly taken by sharks shorter than 90 cm FL, Ray’s bream and dealfish were most commonly taken by sharks 130–210 cm FL, and tunas and other larger mesopelagic species were most abundant in the stomachs of the largest predator size class (over 210 cm FL). Salps and crustaceans were minor dietary components, and were consumed more by smaller blue sharks. The proportion of empty stomachs decreased slightly as blue sharks grew.

There was a trend of decreasing mean size of blue sharks with increasing latitude, and associated with this, sharks caught in the north had a greater proportion of fish and a lesser proportion of cephalopods in their stomachs than southern fish (Table 9).

There was no obvious reason for the seasonal differences in diet, where fish (primarily Ray’s bream and dealfish) dominated the diet from January to May, and cephopods were dominant for the rest of the year (Table 10). The increase in mean size of blue sharks and mean SST in July–December was associated with the majority of the Kermadec fish being sampled during this month stratum. There was some variation in the ratio of cephalopod to fish prey across years, possibly related to blue shark size, as the three year groups where cephalopods were dominant correlated with smaller mean shark sizes. Interestingly, there was a change in the relative abundance of dealfish and Ray’s bream; the former was most abundant from 1998 to 2003, and the latter from 2004 to 2012. Both these prey species were virtually exclusive to the southern areas.

In conclusion, a broad size range of blue shark was sampled, with smaller sharks clearly preferring a range of cephalopods, and larger sharks preferring fish (primarily large mesopelagic species) but still having a substantial cephalopod component. There was a clear north-south split in the preferred or available fish prey; Ray’s bream and dealfish were taken almost exclusively in the two southern areas, while tunas and other large mesopelagic species were taken primarily in the northern areas. Blue sharks caught in the Northeast and, particularly, Kermadec areas were, on average, larger than those sampled in the two southern areas.

Table 9: Blue shark — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area			
Prey category			50–90	91–130	131–170	171–210	211–310	Kermadec	Northeast	Southwest	Southeast
Fish	Elasmobranchs	0.7	0.2	0.2	0.8	0.8	1.6	–	0.9	0.6	–
	Small mesopelagics	0.9	1.4	1.1	0.9	0.9	–	–	0.3	1.0	1.1
	Ray's bream	8.4	0.4	3.1	12.3	16.5	1.2	–	0.5	9.6	3.3
	Dealfish	4.9	0.7	1.7	6.5	6.9	0.8	–	–	5.7	–
	Tunas	0.8	–	0.0	0.3	1.3	12.0	14.7	4.1	0.1	–
	Large mesopelagics	3.2	0.5	1.0	2.5	4.2	16.1	18.1	5.7	2.6	4.4
	Other teleosts	0.1	0.2	0.2	0.2	0.1	0.0	0.0	0.1	0.2	0.0
	Unidentified fish	23.8	14.0	21.0	26.6	27.8	22.7	20.1	29.0	23.2	25.6
	Total fish	42.7	17.3	28.5	50.2	58.5	54.4	52.8	40.6	42.9	34.5
Cephalopods	Octopus	3.1	5.5	4.6	3.0	2.4	2.2	1.4	1.5	3.3	4.9
	Other cephalopods	47.5	68.0	59.2	40.3	33.7	37.7	40.9	49.0	47.3	58.8
Salps		1.9	2.8	2.3	2.3	1.5	0.0	–	1.1	2.1	0.6
Crustacea		0.8	2.6	0.9	0.6	0.2	0.5	–	1.3	0.8	0.7
Other	Birds	0.6	0.2	0.5	0.8	0.3	0.4	0.7	0.5	0.6	–
	Other items	3.4	3.5	4.0	2.8	3.4	4.8	4.2	6.1	3.1	0.5
Mean FL (cm)		145.4	80.9	110.7	152.9	181.6	236.3	209.7	154.1	142.9	147.6
Mean SST (°C)		13.9	14.1	13.7	13.6	14.0	18.0	18.9	17.3	13.4	11.5
Sample size		8584	485	1809	3054	1370	228	144	938	7426	76
% empty		63.0	64.4	66.8	61.8	61.2	57.7	68.3	75.2	60.3	69.4

Table 10: Blue shark — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year					
Prey category		Jan-Apr	May	Jun	Jul-Dec	94–97	98–00	01–03	04–06	07–09	10–12
Fish	Elasmobranchs	0.7	0.8	0.4	0.7	0.6	0.9	0.7	1.1	1.1	0.3
	Small mesopelagics	1.3	0.8	1.1	0.3	0.1	0.2	0.7	1.7	1.7	0.3
	Ray's bream	11.8	11.1	5.0	1.2	1.9	5.2	4.1	11.2	11.2	12.9
	Dealfish	4.2	7.2	3.6	0.6	1.6	11.8	9.1	2.8	2.8	3.5
	Tunas	1.0	0.3	0.6	2.5	0.5	1.0	3.3	0.7	0.7	0.1
	Large mesopelagics	4.1	1.7	3.4	6.7	4.6	8.1	4.5	2.2	2.2	0.3
	Other teleosts	0.3	0.1	0.1	0.1	0.0	0.1	0.3	0.2	0.2	0.1
	Unidentified fish	24.8	26.8	17.5	24.3	29.0	18.3	23.1	18.0	18.0	40.2
	Total fish	48.1	48.7	31.7	36.3	38.3	45.6	45.8	30.7	37.8	57.7
Cephalopods	Octopus	1.8	2.7	5.1	2.0	0.6	4.1	5.4	5.7	1.5	0.8
	Other cephalopods	43.9	42.0	56.3	54.1	54.0	42.3	37.6	58.7	56.3	34.8
Salps		1.6	2.1	2.4	0.7	0.8	4.4	5.5	0.5	0.6	1.2
Crustacea		0.9	0.8	0.6	0.9	1.3	0.8	0.8	0.8	0.8	0.5
Other	Birds	1.3	0.6	0.3	0.2	0.9	0.5	0.9	0.6	1.0	0.1
	Other items	2.4	3.1	3.5	5.7	4.1	2.3	4.1	3.1	1.9	4.8
Mean FL (cm)		145.5	143.3	143.5	160.5	145.7	151.3	154.4	139.5	140.5	146.6
Mean SST (°C)		13.9	13.7	13.6	15.5	14.0	14.0	15.1	13.2	14.1	13.7
Sample size		1394	3925	2236	1029	1077	1290	1090	1948	1341	1838
% empty		60.6	64.4	59.5	67.2	64.6	64.8	64.5	49.3	61.1	70.1

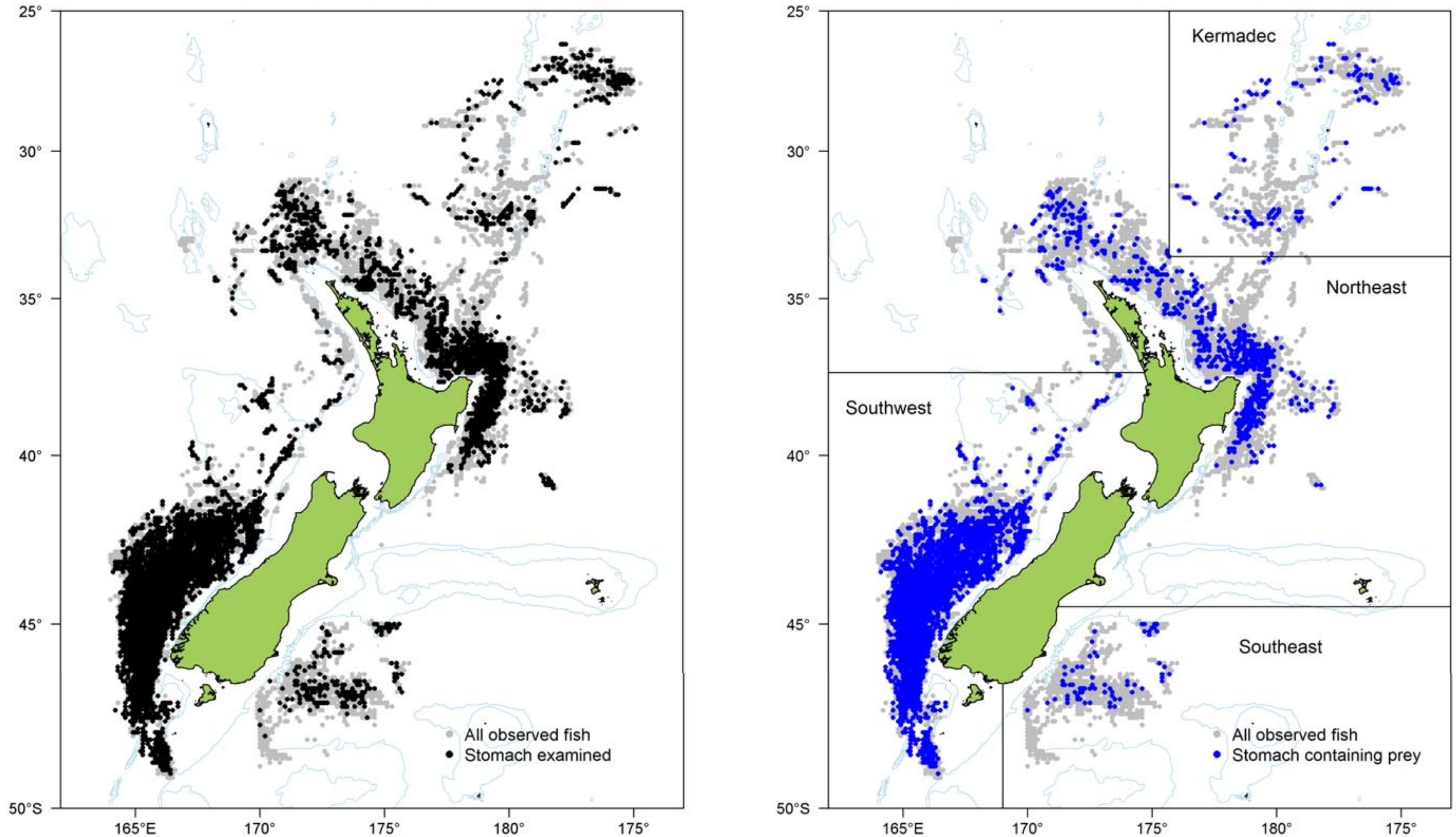


Figure 9: Distributions of all blue shark examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four areas are shown on the right panel.

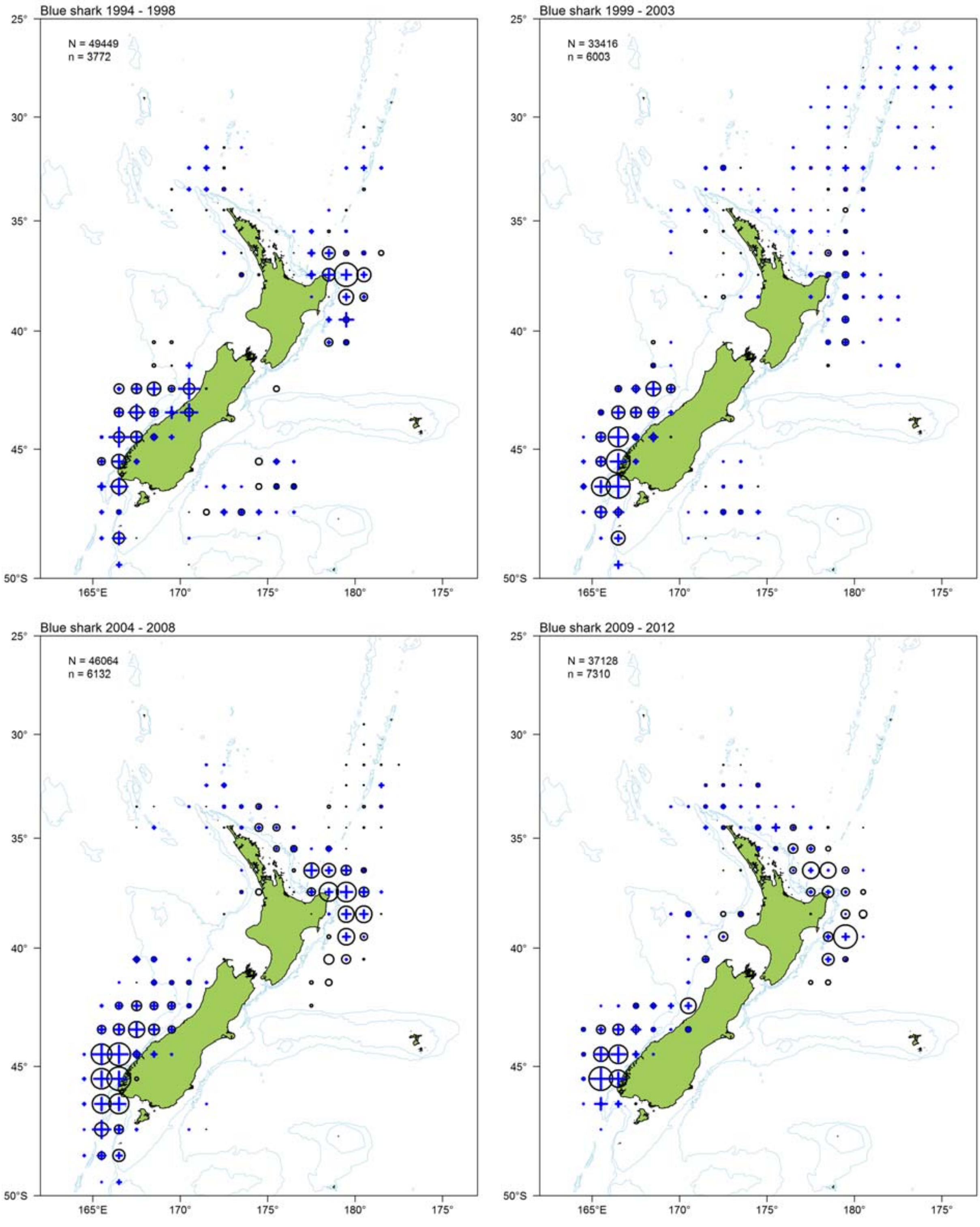


Figure 10: Blue shark — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

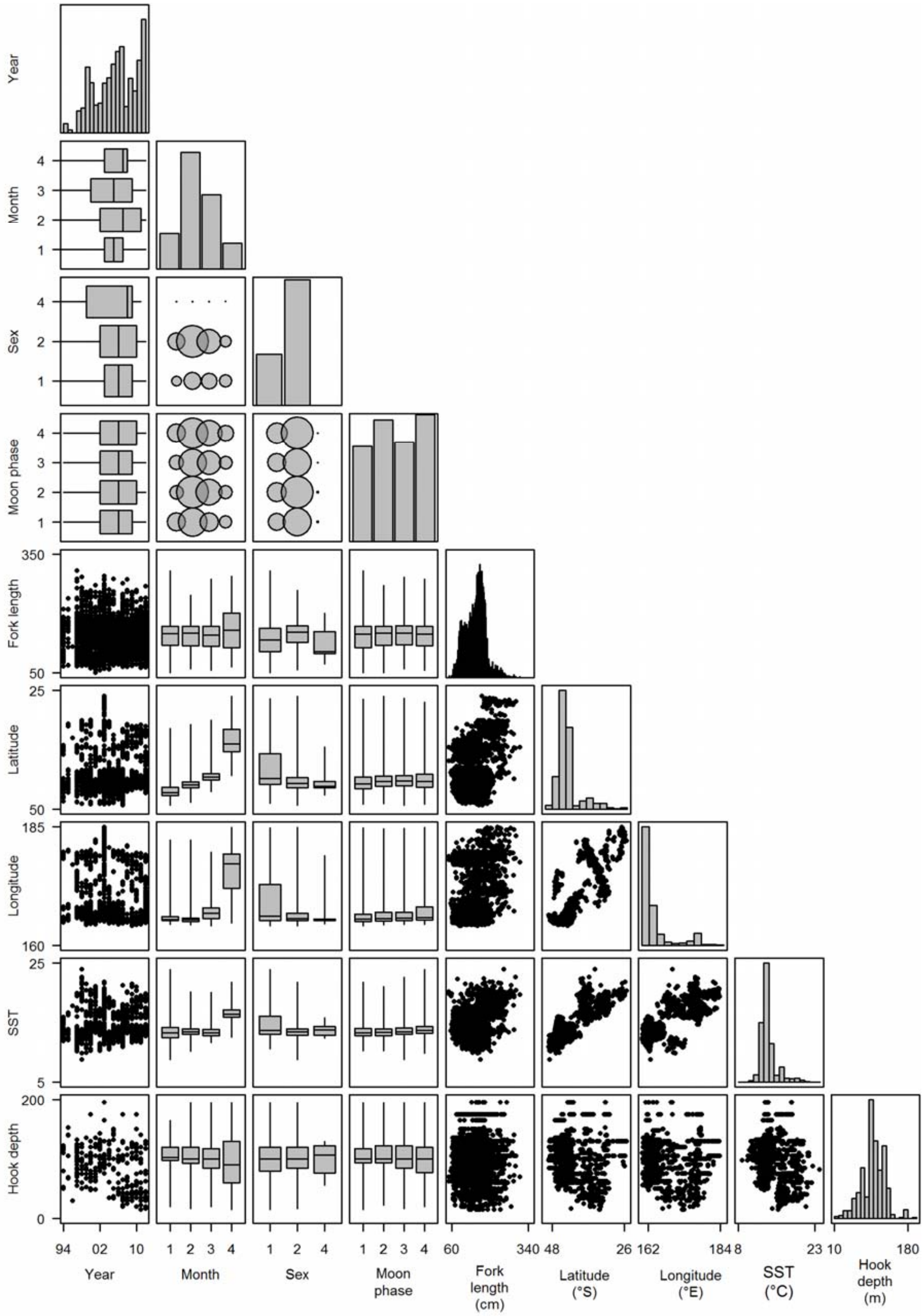


Figure 11: Blue shark — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–April; 2, May; 3, June; 4, July–December. Sex: 1, male; 2, female; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.4 Shortsnouted lancetfish

Shortsnouted lancetfish (*Alepisaurus brevirostris*) have been caught and sampled almost exclusively in the Northeast area north of latitude 40° S, mainly in the Bay of Plenty and east of East Cape (Figure 12). The distributions of lancetfish with and without stomach contents were visually very similar (Figure 12). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 13). About two-thirds of the sampled fish were caught in 2001, with 1998 being the only other year with a reasonable sample (Figures 13 and 14). Shortsnouted lancetfish may have been sampled before 1998, but the two lancetfish species were not distinguished before then, so any *A. brevirostris* stomachs would have been recorded as being from *A. ferox*.

An examination of data correlations (Figure 14) indicated no clear trends. Shortsnouted lancetfish were caught over a relatively narrow SST range of 19.0 to 22.5 °C. Most fish were caught over a relatively narrow hook depth range (40–90 m). Sampling frequency was much greater around the first quarter moon phase than at other times of the lunar cycle. The length-frequency distribution of sampled fish was bimodal, with modes at 61 cm and 78 cm FL; 75% of fish were in the relatively narrow length range of 58–80 cm FL. Shortsnouted lancetfish are likely to be simultaneous hermaphrodites (i.e., fish have both testes and ovaries functional at the same time, Smith & Atz 1973), and most fish were not sexed.

Diet across all sampled size classes was dominated by crustaceans, but with a clear decreasing trend in crustaceans as lancetfish grew (Table 11). The reduction in crustaceans was balanced primarily by an increase in fish and, to a lesser extent, cephalopods. Salps were a small prey category for lancetfish of all sampled sizes. About a quarter of the cephalopod records, and one-third of the volume, comprised nautilus.

Crustaceans occurred more frequently in stomachs in January than at other times of the year, while the ‘other’ diet component was low in January relative to the rest of the year (Table 11). Only two year groups were examined, and crustaceans were found to be much more dominant in 2001 than in 1998. Conversely, the ‘other’ component and, to a lesser extent, fish, were more dominant in 1998. There were no obvious reasons for any of these temporal differences.

Shortsnouted lancetfish of all sizes were crustacean specialists, with fish prey being the next most important dietary component. Most crustacean prey were unidentified, but items with additional information were described as ‘shrimp’ or ‘krill’ and imply an epipelagic or mesopelagic feeding habitat. Fish prey were likely to be dominated by small epipelagic or mesopelagic species, with some cannibalism and consumption of the con-specific *A. ferox* apparent.

Table 11: Shortsnouted lancetfish — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, by month, and by year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)			Month		Year	
Prey category			43–63	64–74	75–125	Jan	Feb-Dec	98–00	01–10
Fish	Small mesopelagics	0.5	0.4	0.3	–	0.2	0.7	0.9	0.3
	Lancetfish	0.6	–	1.0	0.8	0.7	0.4	0.9	0.5
	Other teleosts	0.3	–	0.3	0.4	0.2	0.4	0.9	0.2
	Unidentified fish	15.0	11.4	13.6	19.0	11.9	18.6	23.7	12.0
	Total fish	16.4	11.8	15.4	20.2	13.1	20.2	26.4	13.0
Cephalopods		6.7	3.1	4.8	7.4	6.7	6.8	7.0	6.6
Salps		7.7	3.5	13.3	7.7	7.8	7.6	9.3	7.2
Crustacea		60.5	76.8	57.6	53.2	71.3	48.2	28.1	71.7
Other		8.7	4.9	8.9	11.4	1.1	17.3	29.3	1.5
Mean FL (cm)		69.2	57.2	69.4	80.2	67.7	70.9	71.7	68.3
Mean SST (°C)		20.5	20.4	20.6	20.3	20.2	20.8	21.6	20.1
Sample size		381	108	116	114	203	178	98	283
% empty		29.7	27.5	28.0	34.9	33.4	24.9	18.3	32.9

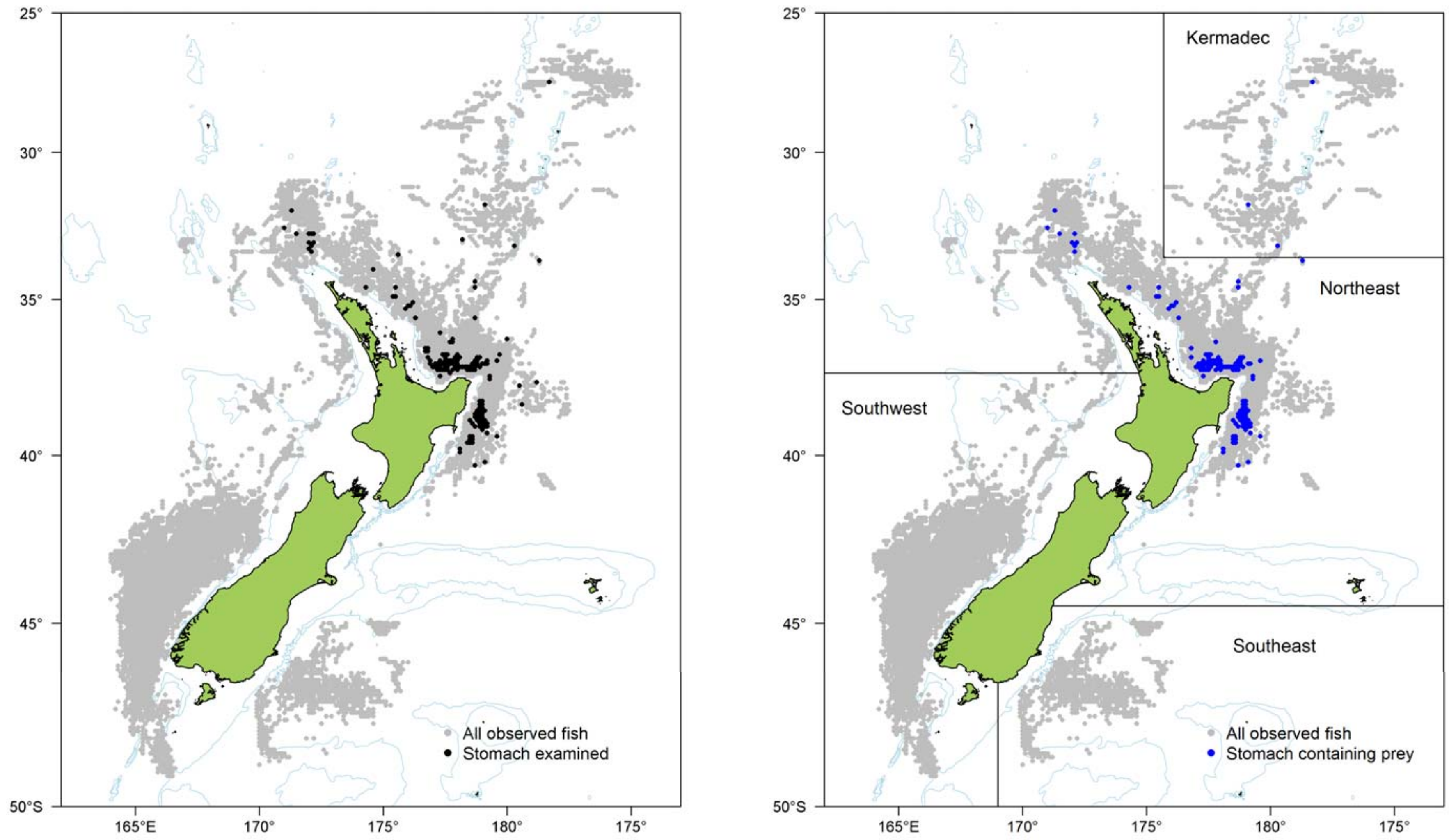


Figure 12: Distributions of all shortsnouted lancetfish examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

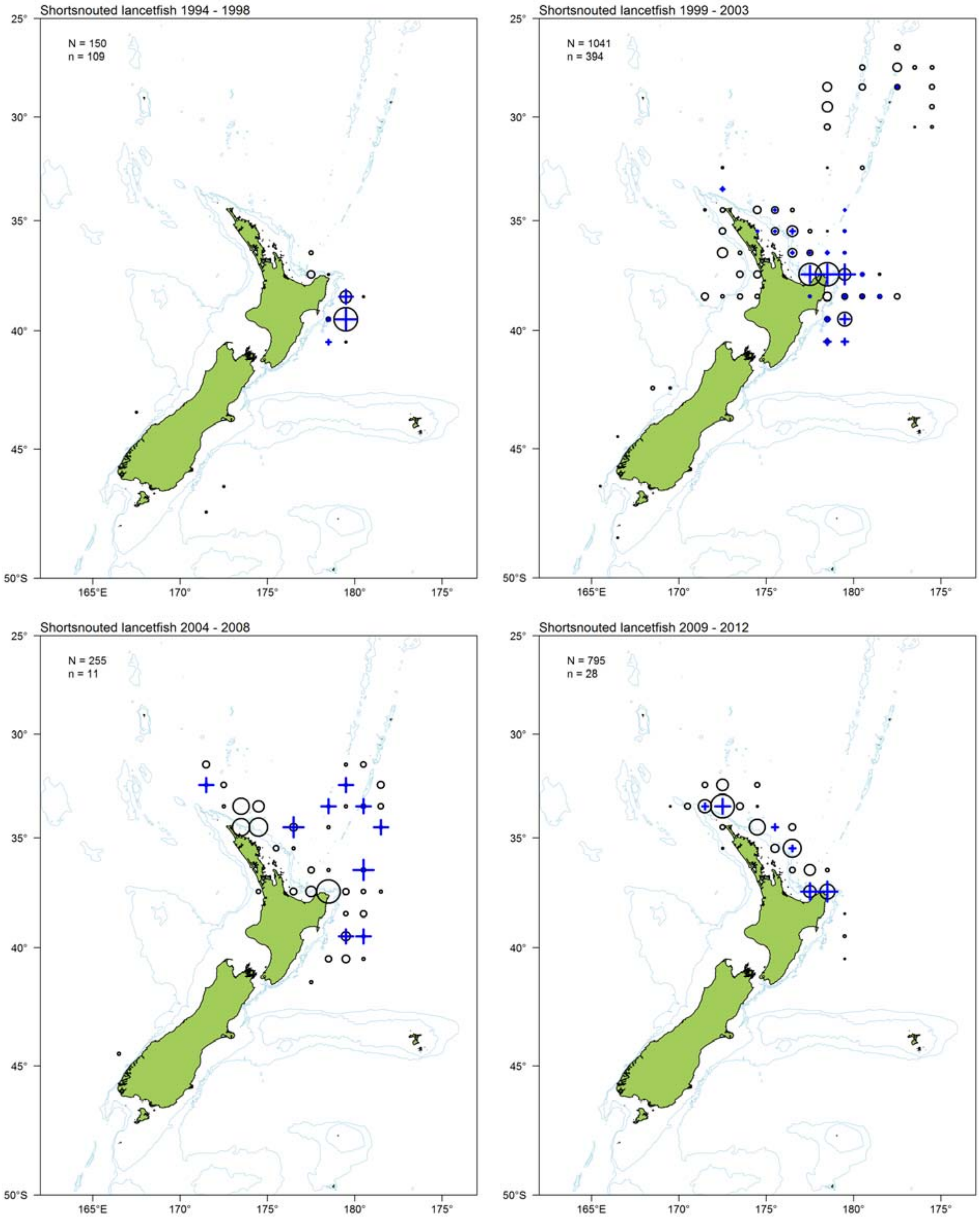


Figure 13: Shortsnouted lancetfish — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

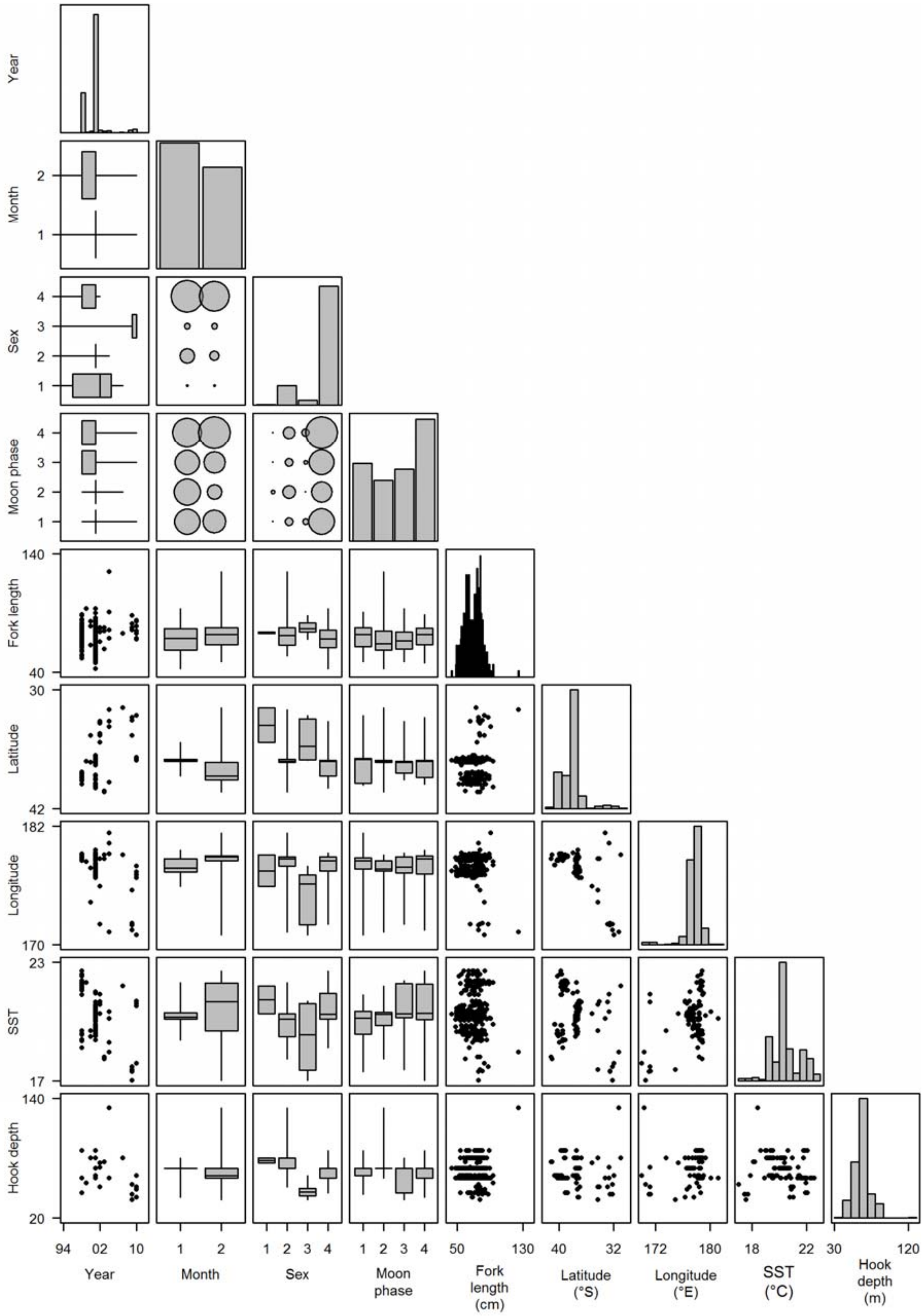


Figure 14: Shortsnouted lancetfish — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January; 2, February–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.5 Longsnouted lancetfish

Longsnouted lancetfish (*Alepisaurus ferox*) have been caught and sampled primarily in the Northeast area north of latitude 40° S, with greatest concentrations in the Bay of Plenty (Figure 15). A few fish were also sampled from the Kermadec and Southwest areas. The distributions of lancetfish with and without stomach contents were visually very similar (Figure 15). The distribution of sampled lancetfish was visually similar to the catch distribution for the species (Figure 16). About 40% of the sampled fish were caught in 1997, with 2001 and 2009 being the only other years with reasonable samples (Figures 16 and 17). The two lancetfish species were not distinguished before 1998, so some of the stomach samples before then were probably from *A. brevirostris*.

An examination of data correlations (Figure 17) indicated few clear trends. Longsnouted lancetfish were caught more frequently in the north later in the calendar year. They were caught over a relatively narrow SST range of 17.0 to 21.0 °C. Most fish were caught over a relatively narrow hook depth range (40–70 m). Sampling frequency was much lower around the third quarter moon phase than at other times of the lunar cycle. The length-frequency distribution of sampled fish was bimodal, with modes at 74 cm and 124 cm FL; 75% of fish were in the range 70–132 cm FL. Longsnouted lancetfish are simultaneous hermaphrodites (i.e., fish have both testes and ovaries functional at the same time, Smith & Atz 1973), and most fish were not sexed.

Small longsnouted lancetfish (50–90 cm FL) had a diet dominated by salps, but this dietary component declined steadily as lancetfish grew (Table 12). Conversely, large lancetfish (over 130 cm FL) had a diet dominated by cephalopods; this prey category was only a minor component for the smallest lancetfish. About 60% of the cephalopod volume was further identified as nautilus, and about 3% were octopus. Fish prey were moderately important for lancetfish of all sizes, but particularly for medium-large longsnouted lancetfish (over 80 cm FL). The most frequently identified fish prey were lancetfish (both *A. ferox* and *A. brevirostris*). A large component of the diet of small (less than 80 cm FL) lancetfish fell in the ‘other’ category; no additional information was available to better describe this component. Crustaceans were a minor prey category, taken more frequently by smaller lancetfish.

Most longsnouted lancetfish were sampled from the Northeast area, with only a few from Kermadec and Southwest (Table 12). There were marked between-area differences in diets, with a large reduction in the fish prey component and increase in the ‘other’ component when moving from north to south. Salps were less abundant in the Kermadec diet, and crustaceans were taken more often in the south. The Southwest lancetfish were generally large, but unlike large Northeast fish, their stomachs contained few fish prey, but relatively high proportions of salps, crustaceans, and ‘other’ categories.

Some marked dietary differences were apparent between months, primarily relating to the cephalopod, salp, and ‘other’ categories; fish prey proportions were relatively constant across months (Table 13). The differences were, in part, associated with differences in mean size of longsnouted lancetfish. In February, the sampled lancetfish were smaller and contained a high volume of salps and a low volume of cephalopods. In contrast, the largest fish were caught in August–December, with high volumes of cephalopods and few salps.

Differences between year groups were also likely to be related to differences in mean size of longsnouted lancetfish. Smaller fish predominated early in the sampled period, and there were higher proportions of the salp and 'other' categories. Since 1998, larger lancetfish were more abundant and diets were dominated by cephalopods and fish prey. Note also that all lancetfish since 1998 would have been *A. ferox*, while some from the first year group (1996–97) were probably *A. brevirostris*.

A comparison of diets of all sampled fish (probably including some *A. brevirostris*) with those from 1998–2012 (*A. ferox* only) is presented in Table 12. There is little difference in the importance and composition of the fish prey, but the exclusion of the earlier years results in cephalopods increasing in importance and salps decreasing.

The longnouted lancetfish had a relatively broad diet with the major components being fish, cephalopods (dominated by nautilus), and salps. There were marked ontogenetic changes, with salps dominant for small lancetfish, and fish and cephalopods dominant for larger ones. Fish prey, when identified, were dominated by small epipelagic or mesopelagic species, with some cannibalism and consumption of the con-specific *A. brevirostris* apparent, particularly as longsnouted lancetfish grew.

Table 12: Longsnouted lancetfish — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, all fish from 1998 to 2012, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish		Predator length (cm FL)				Area		
Prey category		All years	1998–2012	50–79	80–109	110–129	130–180	Kermadec	Northeast	Southwest
Fish	Small mesopelagics	3.2	2.6	2.3	4.6	3.1	2.7	3.0	3.1	2.4
	Lancetfish	5.4	8.4	1.0	5.6	8.7	7.6	15.1	5.3	–
	Large mesopelacics	0.4	0.6	–	–	0.5	1.1	–	0.3	1.2
	Other teleosts	0.5	0.3	–	0.7	1.0	0.5	–	0.5	–
	Unidentified fish	22.0	22.8	13.9	23.7	24.7	28.1	33.3	22.1	–
	Total fish	31.5	34.8	17.2	34.6	38.0	40.0	51.4	31.4	3.6
Cephalopods		31.4	49.9	6.6	38.3	35.5	51.2	26.6	31.5	30.7
Salps		20.8	6.9	42.2	16.5	15.7	4.5	10.5	21.1	19.2
Crustacea		3.1	3.5	3.4	2.9	2.4	1.4	6.4	2.9	10.3
Other		13.2	4.8	30.6	7.8	8.4	2.8	5.1	13.1	36.2
Mean FL (cm)		103.4	118.2	68.5	97.5	120.3	137.2	116.7	102.7	127.1
Mean SST (°C)		19.3	19.1	19.5	19.3	19.0	19.1	20.2	19.3	13.4
Sample size		849	464	220	186	256	131	21	815	13
% empty		36.3	40.2	39.1	43.1	36.6	40.2	36.4	36.4	27.8

Table 13: Longsnouted lancetfish — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year		
Prey category		Jan	Feb	Mar-Jul	Aug-Dec	1996–97	1998–2003	2004–10
Fish	Small mesopelagics	2.1	2.9	7.5	0.3	3.6	1.2	4.1
	Lancetfish	6.2	5.3	4.0	6.0	3.9	12.7	2.0
	Large mesopelacics	0.6	–	0.6	0.3	–	0.9	0.5
	Other teleosts	0.3	–	1.7	0.0	0.7	0.3	0.3
	Unidentified fish	26.0	21.1	18.4	22.0	19.3	19.5	28.1
	Total fish	35.1	29.4	32.2	28.5	27.4	34.6	35.0
Cephalopods		37.0	8.1	17.8	64.1	9.0	47.7	52.2
Salps		17.4	42.1	20.4	2.4	37.5	7.2	6.7
Crustacea		3.6	2.1	5.7	0.8	2.6	5.5	1.5
Other		6.8	18.2	23.9	4.2	23.4	5.0	4.6
Mean FL (cm)		107.2	89.3	100.0	119.1	86.8	115.7	120.4
Mean SST (°C)		20.1	20.1	18.4	18.2	19.4	20.0	18.2
Sample size		235	212	206	196	385	233	231
% empty		42.4	31.8	36.0	32.9	30.8	36.9	43.4

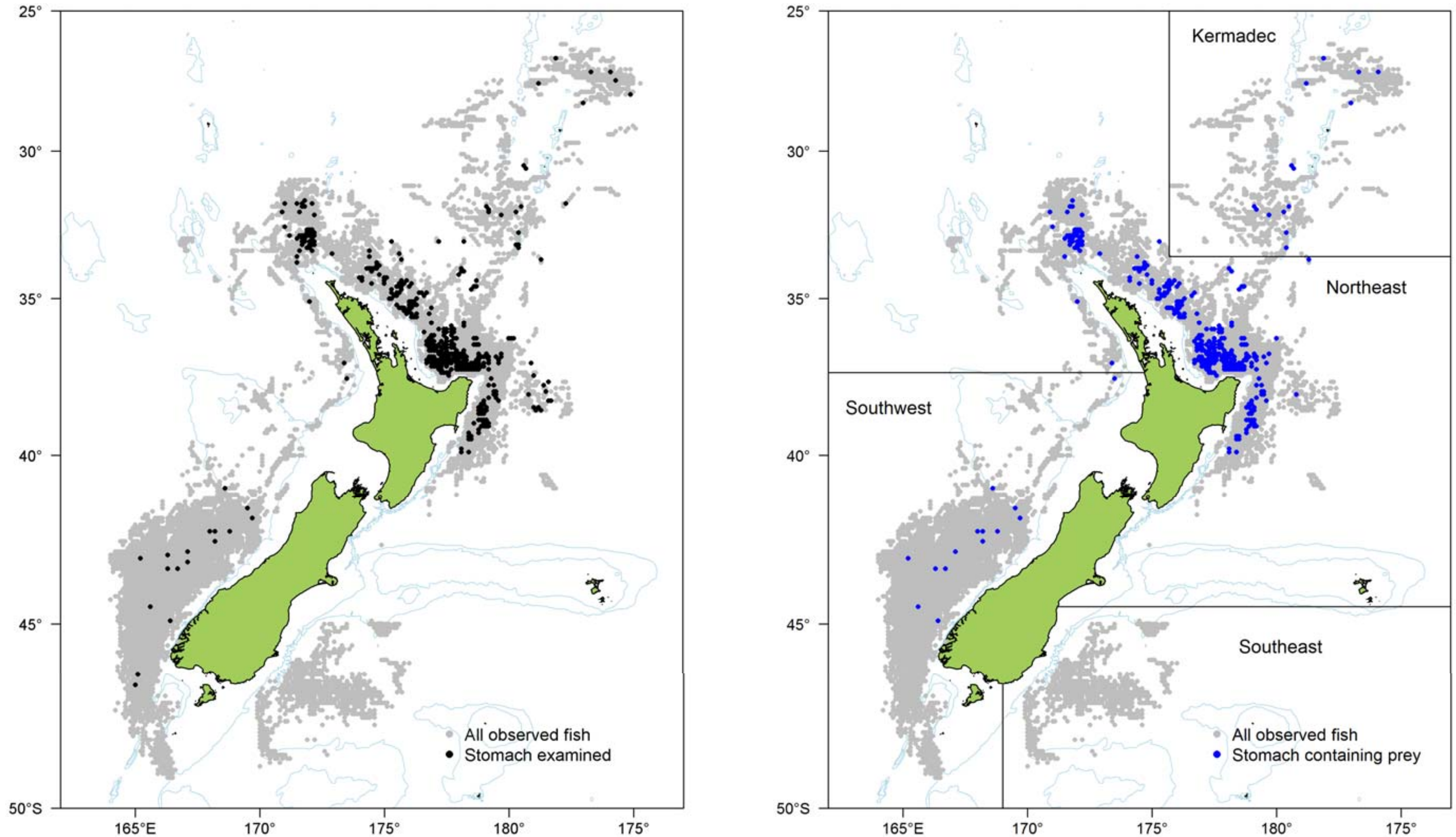


Figure 15: Distributions of all longsnouted lancetfish examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

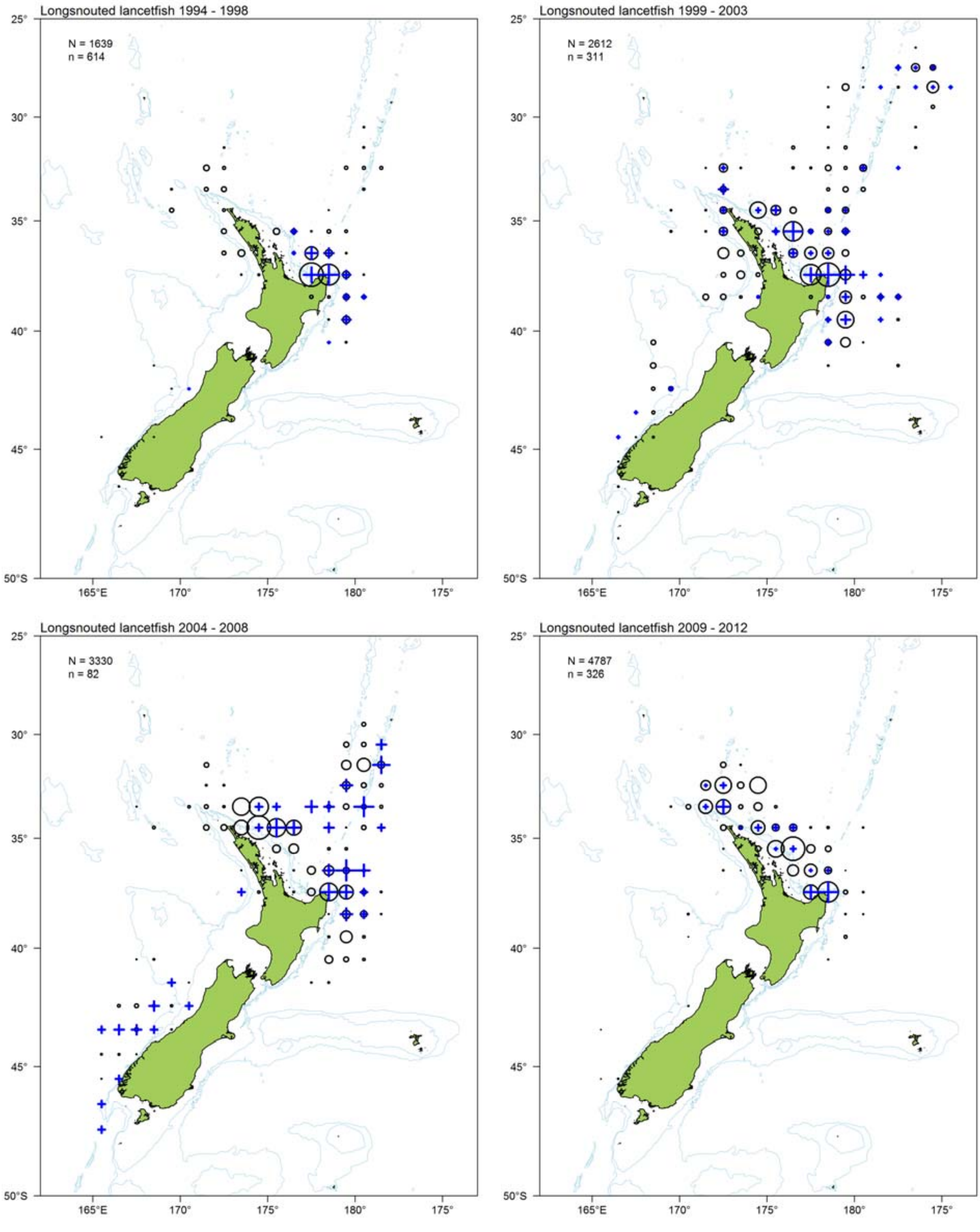


Figure 16: Longsnouted lancetfish — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

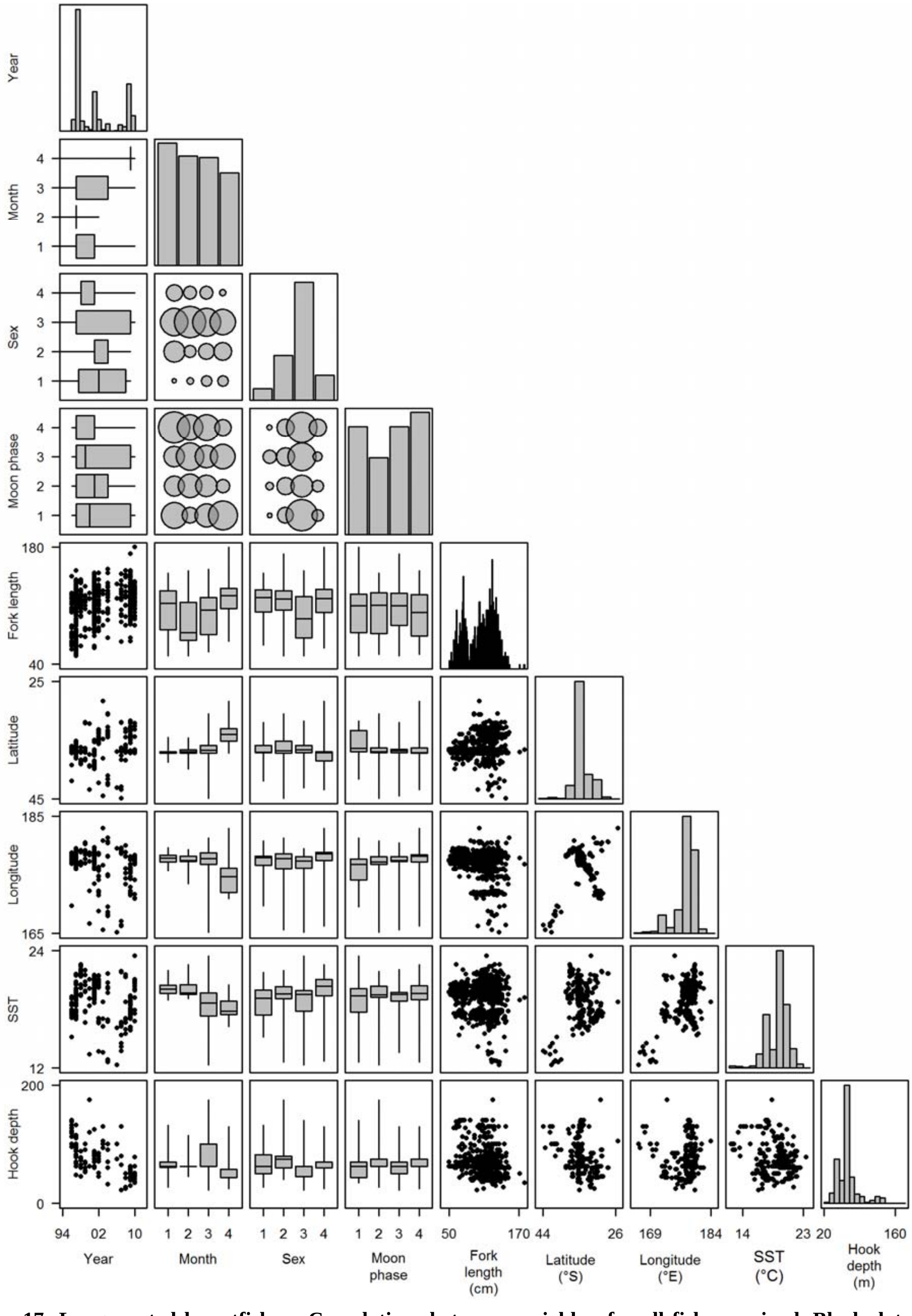


Figure 17: Longsnouted lancetfish — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January; 2, February; 3, March–July; 4, August–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.6 Moonfish

There are two *Lampris* species in New Zealand waters. The moonfish (*L. guttatus*) is found around much of mainland New Zealand, while the opah (*L. immaculatus*) occurs predominantly off the southeast of South Island (McMillan et al. 2011). Based on the distribution of the stomachs sampled by observers (Figure 18) it is likely that almost all were from *L. guttatus*. Moonfish have been caught and sampled over virtually the entire range of the surface longline fishery in New Zealand waters, but they were most abundant off East Cape, North Cape, and the southwest coast of South Island (Figure 18). The distributions of moonfish with and without stomach contents were visually very similar (Figure 18). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 19). Sampling levels were low before 1998, relatively high from 1998 to 2007, and low again since then (Figures 19 and 20).

An examination of data correlations (Figure 20) indicated some trends. Moonfish were caught more commonly in southern latitudes early in the calendar year, and northern latitudes and western longitudes later in the year. They were caught mainly where SST ranged between 14.0 and 18.0 °C, and where hook depth ranged between 40 and 140 m. The average size of sampled moonfish tended to decrease with increasing latitude. The length-frequency distribution of sampled fish was unimodal with the mode at 98 cm FL; 75% of fish were in the relatively narrow length range of 75–107 cm FL. Sex was determined for most fish, and 55% of sexed fish were female.

The percentage of fish (about 40%) and cephalopods (about 30%) in the diet remained relatively constant over the five size classes of moonfish examined (Table 14). However, a decrease in small mesopelagics (particularly lanternfish) and an increase in lancetfish was apparent as moonfish grew. Most of the remaining dietary components were in the ‘other’ category (about 25%), but more than half of this was anthropogenic litter, primarily plastic, but also netting, fabric and foil (see Table A10). The component of anthropogenic litter increased in abundance as moonfish size increased. Nautilus and octopus each comprised about 4% of the cephalopod prey volume. Salps and crustaceans were minor components of the diet, but both were clearly more important for smaller moonfish (i.e., shorter than 83 cm FL). Plant material (both marine and terrestrial) was another minor component. Fish were more prevalent in the diet in the Kermadec area than around northeastern or southwestern New Zealand. Anthropogenic litter was recorded more frequently in the stomachs of northern fish than those off southwest South Island.

There were no marked differences in proportions of fish and cephalopods in the diet of moonfish across the seasonal or year groups (Table 15). A seasonal trend in the proportion of anthropogenic litter (i.e., increasing across the calendar year) was likely to be associated with fish being more frequently caught in the north as the year progressed, where northern fish consumed a greater proportion of this dietary component. Because northern moonfish tended to be larger on average, there was also a trend of increasing fish size across the year. There were no clear trends across year groups for any dietary components.

In conclusion, most of the moonfish sampled occurred in a relatively narrow size range, and all had diets dominated by fish (primarily lancetfish and small mesopelagic species) and cephalopods (probably squid). Ontogenetic differences were apparent only for some of the less important dietary components: salps and crustaceans declined in importance, and anthropogenic litter increased in importance, as moonfish size increased.

Table 14: Moonfish — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area		
Prey category			54–70	71–82	83–94	95–105	106–158	Kermadec	Northeast	Southwest
Fish	Lanternfish	2.2	5.7	3.2	0.9	1.5	1.4	1.2	1.9	3.1
	Small mesopelagics	1.0	0.8	0.7	1.5	0.8	1.4	1.2	0.8	1.5
	Lancetfish	5.1	–	2.7	5.7	8.1	7.2	10.9	7.5	–
	Large mesopelagics	1.1	0.4	1.7	1.3	1.0	0.5	1.2	1.2	0.9
	Other teleosts	0.2	0.4	0.5	–	0.2	–	–	0.3	0.2
	Unidentified fish	29.1	25.7	36.2	30.6	25.0	26.0	32.7	27.7	31.4
	Total fish	38.8	33.1	45.1	40.1	36.6	36.5	47.2	39.3	37.0
Cephalopods		31.1	32.4	26.1	30.4	35.0	30.1	28.0	29.9	33.3
Salps		2.8	4.9	2.8	3.1	1.7	2.3	4.1	1.5	5.3
Crustacea		2.7	10.2	3.3	1.9	0.7	0.6	0.0	1.4	5.6
Other	Plant	2.3	1.0	2.8	1.5	3.2	2.0	–	2.4	2.6
	Anthropogenic rubbish	14.8	7.2	12.3	15.8	17.4	19.7	14.9	19.6	5.5
	Other	7.5	11.2	7.6	7.1	5.3	8.7	5.7	5.9	10.6
Mean length		88.4	64.4	77.0	88.8	99.8	109.7	97.7	92.4	79.7
Mean SST		16.1	13.9	15.8	16.5	16.6	17.0	17.6	17.3	13.7
Sample size		1565	188	341	434	409	172	70	977	514
% empty		52.7	48.9	57.5	53.0	50.3	45.0	53.3	55.7	45.6

Table 15: Moonfish — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year			
Prey category		Jan-May	Jun	Jul	Aug-Dec	94–98	99–01	02–05	06–12
Fish	Lanternfish	1.6	1.7	4.2	–	1.0	1.0	2.7	5.9
	Small mesopelagics	0.9	1.7	0.7	0.4	0.8	1.4	1.0	0.9
	Lancetfish	2.4	8.0	3.8	7.4	7.0	7.4	2.9	1.2
	Large mesopelagics	0.9	0.5	1.9	0.9	1.2	1.0	1.6	0.3
	Other teleosts	–	0.2	0.3	0.4	0.3	0.2	0.2	–
	Unidentified fish	32.3	25.2	30.5	28.0	26.0	27.9	29.6	36.4
	Total fish	38.1	37.4	41.4	37.2	36.3	38.9	38.0	44.8
Cephalopods		32.9	32.9	28.9	27.8	26.1	34.7	34.3	29.7
Salps		4.2	2.8	1.5	3.2	3.4	3.9	2.4	0.7
Crustacea		5.3	3.1	0.6	1.4	2.4	2.8	3.4	2.2
Other	Plant	3.6	0.7	3.5	0.8	2.8	1.6	2.1	3.1
	Anthropogenic rubbish	6.2	14.3	18.9	23.8	20.6	10.7	11.8	14.9
	Other	9.5	8.8	5.2	5.8	8.5	7.6	8.0	4.5
Mean length		82.7	88.9	91.7	91.5	88.0	88.4	91.9	84.0
Mean SST		15.7	15.9	16.5	16.6	16.9	15.6	16.4	15.3
Sample size		418	476	475	196	493	419	398	255
% empty		48.5	51.7	56.0	54.2	58.8	45.7	49.2	53.9

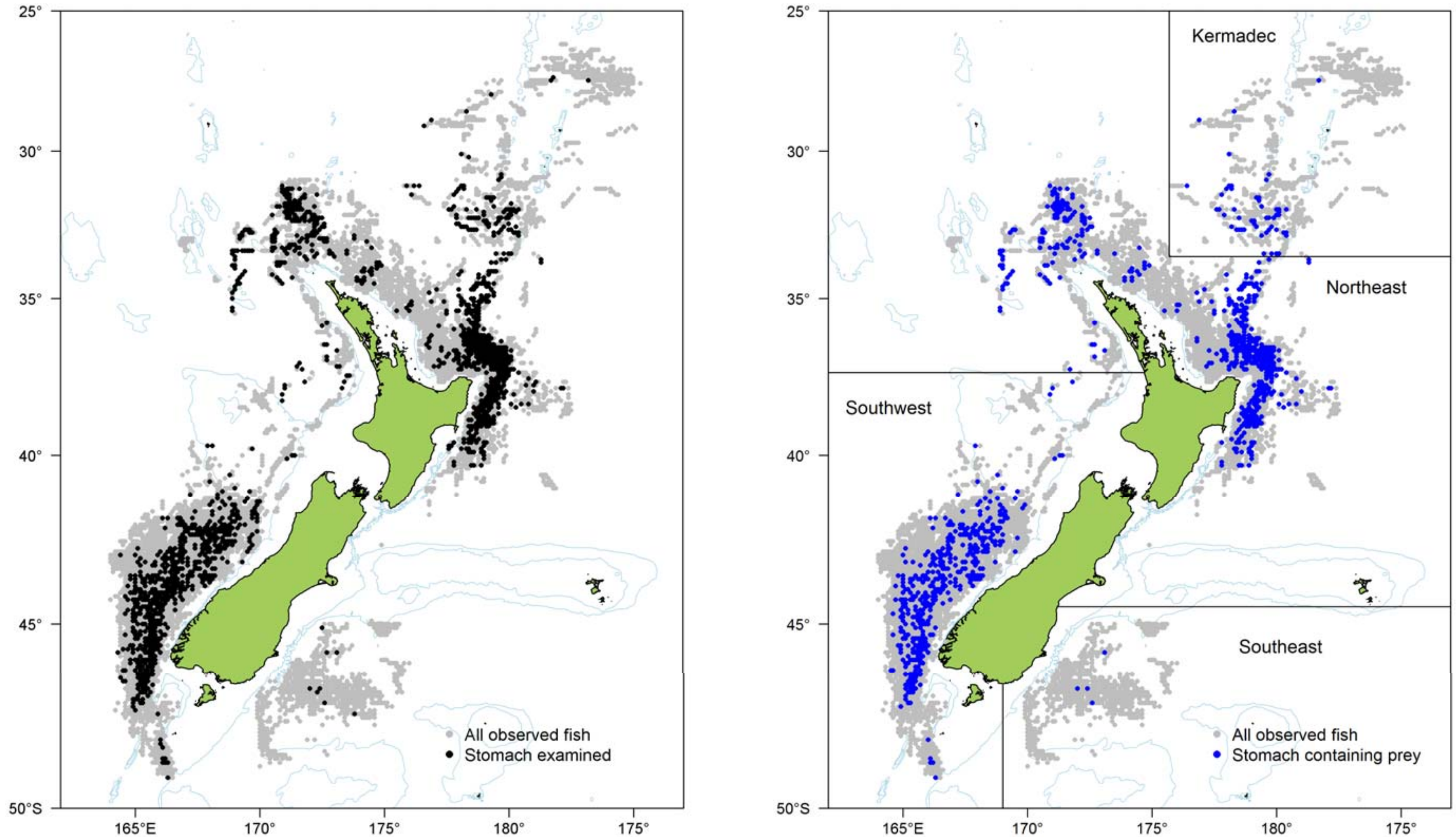


Figure 18: Distributions of all moonfish examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

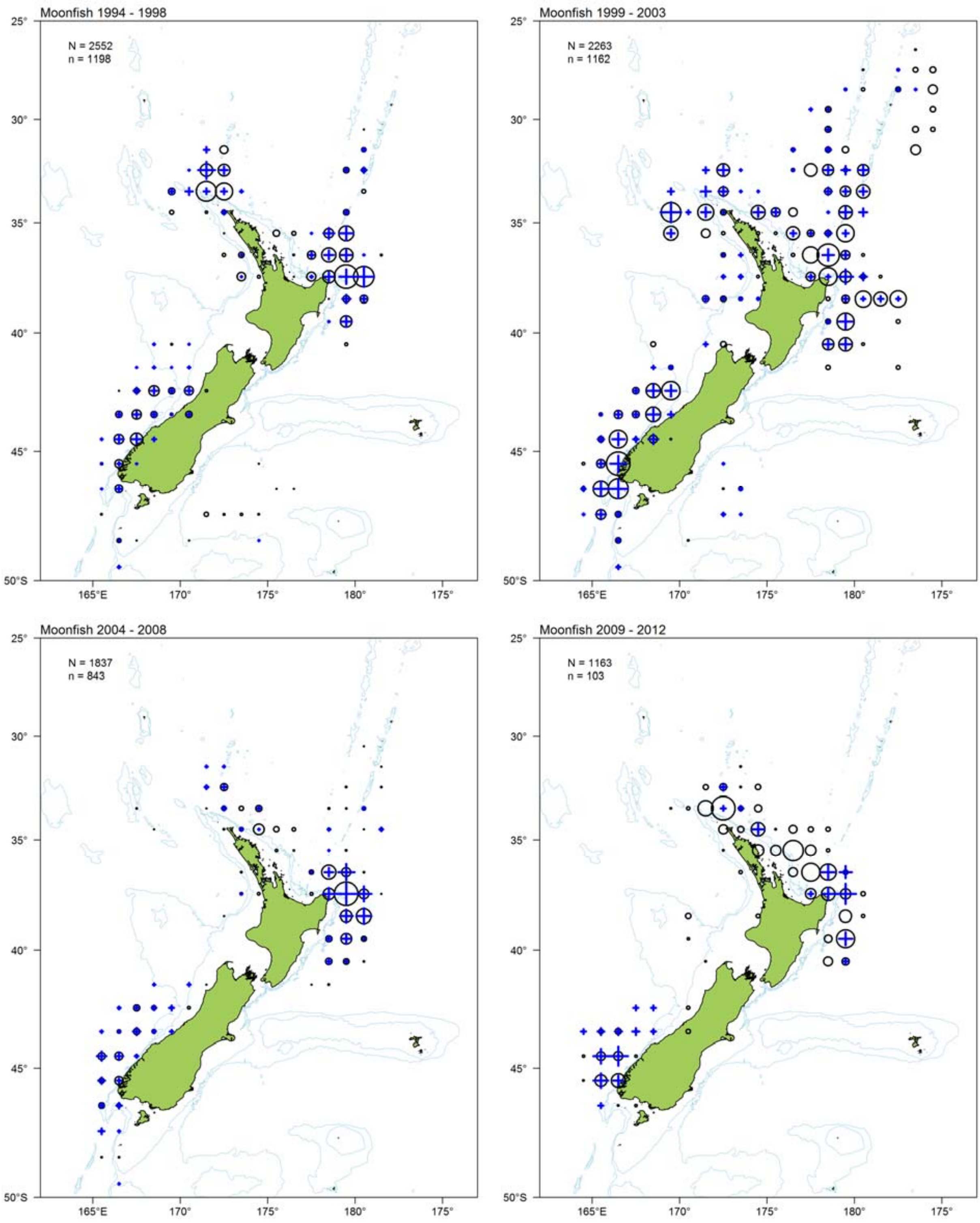


Figure 19: Moonfish — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

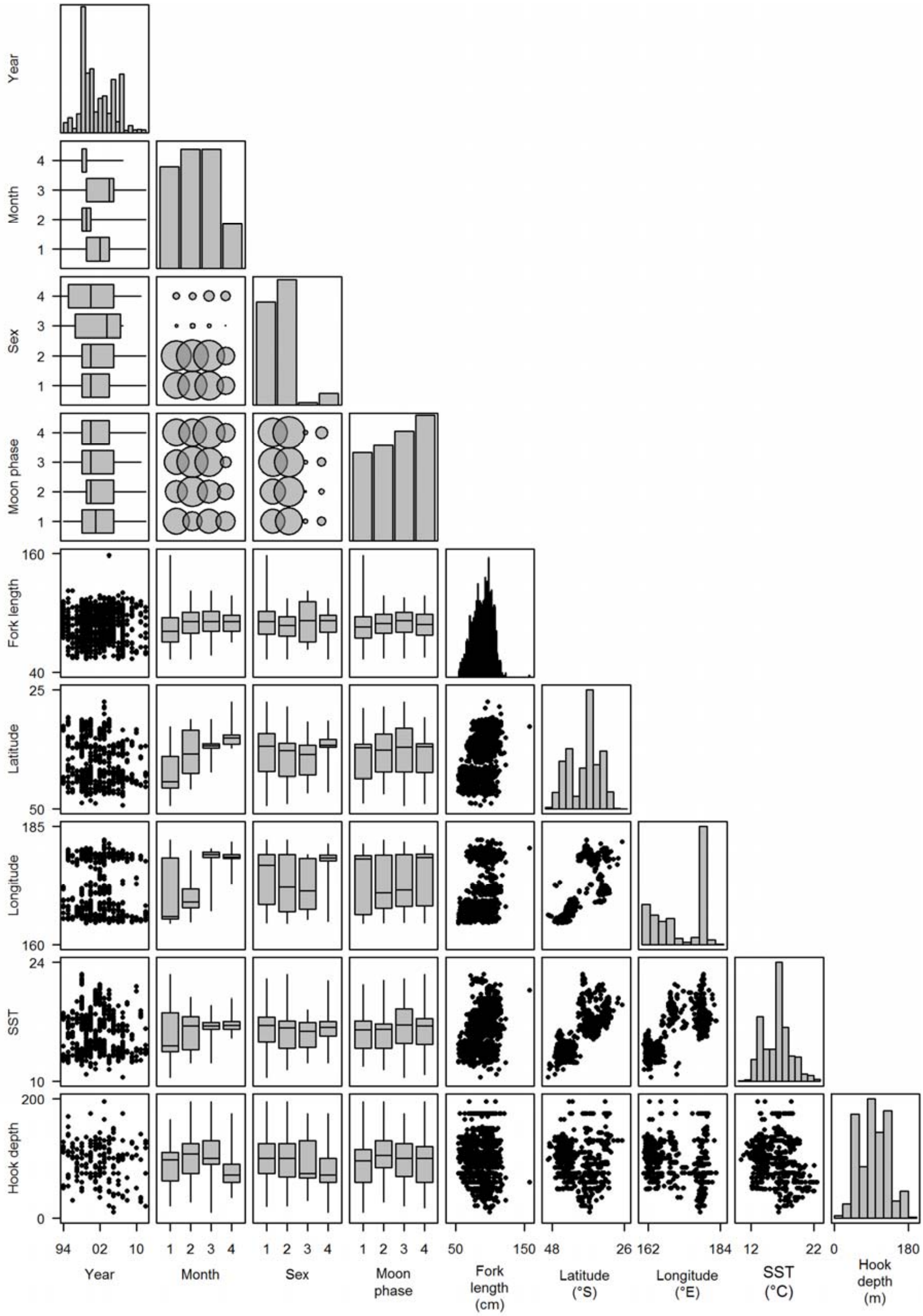


Figure 20: Moonfish — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–May; 2, June; 3, July; 4, August–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.7 Ray's bream

There are known to be at least three species of Ray's bream (*Brama* sp.) in New Zealand waters (Stewart 2001). Most Ray's bream caught and sampled were from the southwest coast of South Island, although a few were also sampled off East Cape and southeast South Island (Figure 21). It is likely that most of the southern individuals were the southern Ray's bream (*B. australis*), while most northern individuals were *B. brama*, but the distributions of the two main species do overlap (McMillan et al. 2011). The distributions of Ray's bream with and without stomach contents were visually very similar (Figure 21). The distribution of sampled fish was visually similar to the catch distribution for the species up to about 2008, but some relative under-sampling of northern fish has occurred since then (Figure 22). Sampling did not occur, or was sparse, in all years except 2003 and 2005–2007 (Figures 22 and 23).

An examination of data correlations (Figure 23) indicated few trends. Ray's bream were caught more commonly in northern latitudes early in the calendar year, and southern latitudes later in the year, and mainly where SST ranged from 13.0 to 18.0 °C. They were caught predominantly over a narrow hook depth range (80–110 m). The length-frequency distribution of sampled fish with was unimodal, with a mode at 45 cm FL, and with 75% of fish being in the narrow length range of 42–48 cm FL. Sex was determined for most fish, and there were similar numbers of males and females.

Diets of all sampled size classes were dominated by fish prey, almost exclusively lanternfish when the components were identified (Table 16). Cephalopods, salps and crustaceans were also relatively important for all size classes of Ray's bream. Most of the cephalopod prey was identified simply as 'squid', but about 6% of the volume was attributed to octopus. Where additional information was provided on the crustacean component, 'krill' was dominant, and was indicative of an epipelagic or mesopelagic feeding strategy. Salps were relatively more abundant in stomachs of the largest Ray's bream, with a concurrent reduction in fish prey.

Virtually all Ray's bream were sampled in the Southwest area. The few fish from Northeast had diets of almost exclusively fish, with minor components of cephalopods and salps, and no crustaceans (Table 16).

All sampled Ray's bream were collected from five consecutive months (March–July). There were no marked dietary differences over months, although a slight reduction in the proportion of crustaceans was apparent as the year progressed (Table 17). Some marked differences between year groups were apparent, primarily an increasing trend in fish prey importance, concurrent with a declining trend in salps. The mean size of Ray's bream was relatively large in the earliest sampling period (1996–2000), and because salps were relatively more common in the stomachs of larger bream (see Table 16), the earliest sample had a higher proportion of salps. There were no trends in the mean size of sampled Ray's bream over month.

In conclusion, most of the Ray's bream sampled were in a relatively narrow size range, and no consistent ontogenetic trends in diet were apparent. All Ray's bream had diets dominated by fish prey, but with components of cephalopods (probably squid), salps, and crustaceans.

Table 16: Ray's bream — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)				Area	
Prey category			34–40	41–45	46–49	50–65	Northeast	Southwest
Fish	Lanternfish	30.1	18.4	30.6	34.0	16.4	22.5	30.3
	Large mesopelagics	0.1	–	0.3	–	–	–	0.1
	Other teleosts	0.2	–	0.1	0.2	0.7	–	0.2
	Unidentified fish	26.7	33.8	25.8	26.8	26.8	58.4	26.3
	Total fish	57.1	52.2	56.7	61.0	44.0	80.9	56.9
Cephalopods		12.1	16.6	11.6	11.6	11.6	10.0	12.1
Salps		12.0	12.3	11.9	9.9	23.9	4.5	12.1
Crustacea		10.2	11.2	11.2	8.7	10.2	–	10.2
Other		8.6	7.6	8.5	8.8	10.3	4.5	8.7
Mean FL (cm)		45.2	39.1	43.6	47.2	51.1	41.4	45.3
Mean SST (°C)		13.4	13.8	13.4	13.4	13.5	16.3	13.4
Sample size		1561	94	751	577	120	22	1534
% empty		77.9	75.6	77.2	78.7	78.9	86.3	77.7

Table 17: Ray's bream — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

				Month			Year
Prey category		Mar-Apr	May	Jun-Jul	96–00	01–04	05–07
Fish	Lanternfish	23.5	38.5	23.4	2.5	0.5	42.3
	Large mesopelagics	0.2	0.1	–	–	0.3	0.1
	Other teleosts	0.2	0.1	0.2	–	0.3	0.2
	Unidentified fish	31.1	21.9	29.6	9.3	29.8	27.2
	Total fish	55.0	60.7	53.2	11.7	30.9	69.8
Cephalopods		9.4	12.2	15.3	9.1	4.6	14.4
Salps		11.4	10.4	15.6	48.0	29.8	2.7
Crustacea		17.9	8.1	4.2	12.4	7.8	10.6
Other		6.3	8.6	11.7	18.7	27.0	2.5
Mean FL (cm)		45.5	45.1	45.3	47.7	44.8	45.0
Mean SST (°C)		13.1	13.7	13.3	13.2	13.6	13.4
Sample size		485	704	371	143	295	1121
% empty		78.4	76.6	79.3	82.2	71.1	78.5

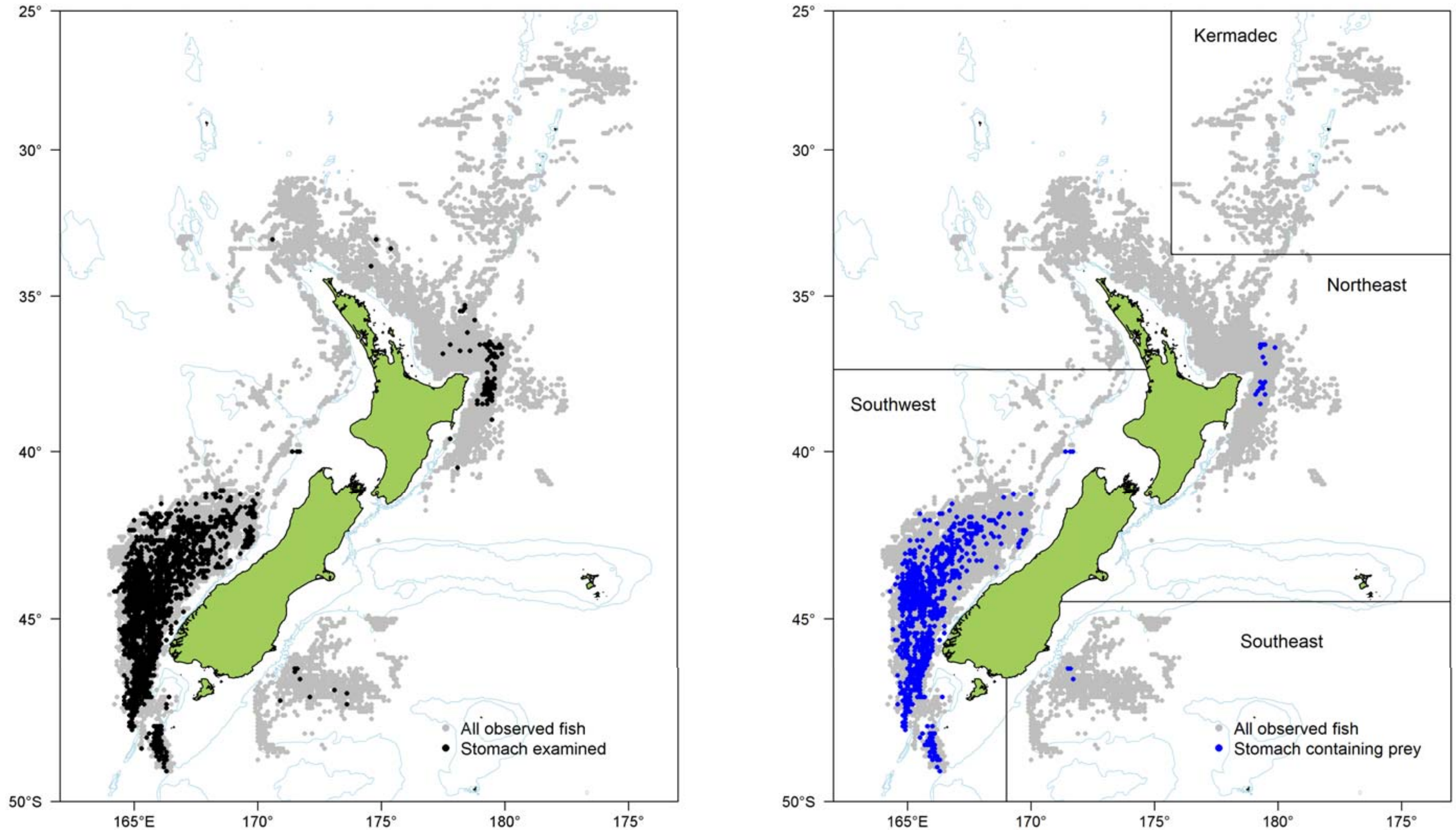


Figure 21: Distributions of all Ray's bream examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

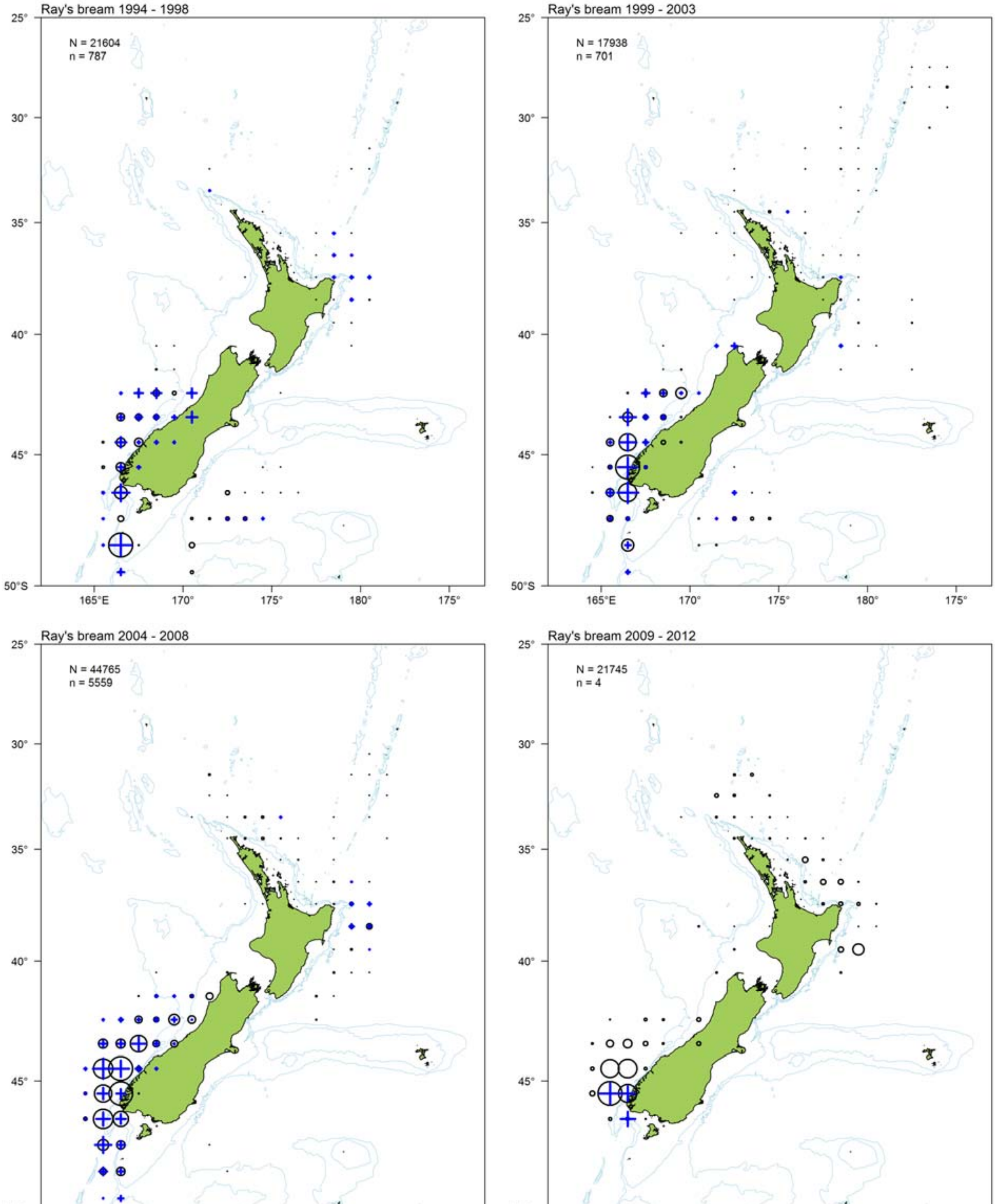


Figure 22: Ray's bream — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

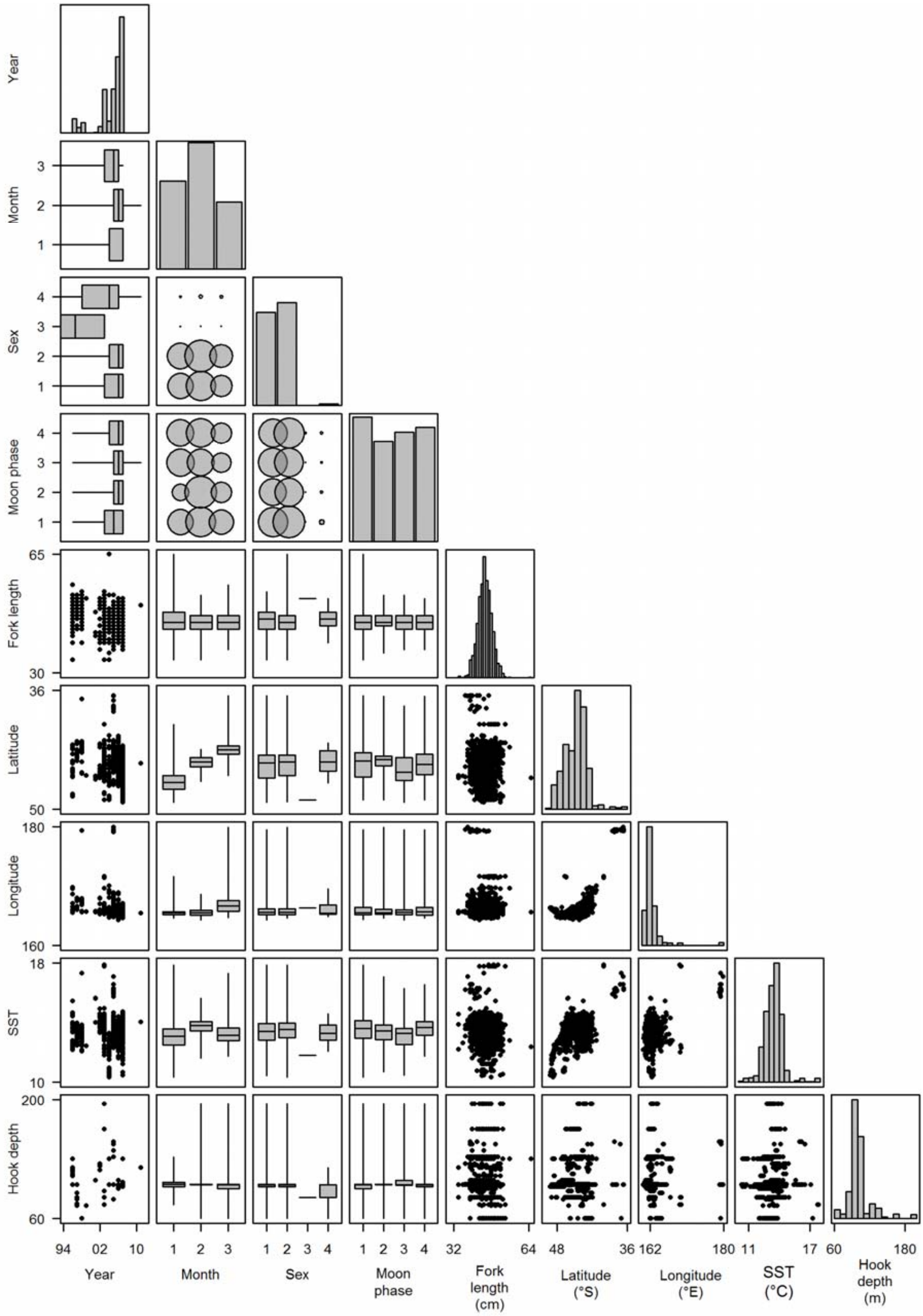


Figure 23: Ray's bream — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, March–April; 2, May; 3, June–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.8 Butterfly tuna

Most butterfly tuna (*Gasterochisma melampus*) caught and sampled were from the southwest and southeast coasts of South Island, although some were also sampled off East Cape (Figure 24). The distributions of butterfly tuna with and without stomach contents were visually very similar (Figure 24). The distribution of sampled fish was visually similar to the catch distribution for the species up to about 2008, but some relative under-sampling of East Cape fish has occurred since then (Figure 25). The sampling intensity was low before 1997, relatively high from 1997 to 2001, and low again since then (Figures 25 and 26).

An examination of data correlations (Figure 26) indicated some trends. Butterfly tuna were caught more commonly in southern latitudes early in the calendar year, and northern latitudes later in the year, and mainly where SST ranged between 10.0 and 14.0 °C. They were caught primarily over a hook depth range of 80–130 m. Peak sampling appears to have occurred later in the year as the years have progressed. Sample sizes were smaller around full and new moon than around the quarter moon phases. The length-frequency distribution of sampled fish was unimodal, with a mode at about 146 cm FL, and with 75% of fish being in the length range of 120–160 cm FL. Sex was determined for most fish, and only about 12% of sampled fish were male.

The dietary composition of all sizes of butterfly tuna was relatively constant, being about half cephalopods (virtually all identified simply as ‘squid’) and one-third fish (Table 18). Salps comprised a minor component, and crustaceans were less important. Seaweed accounted for 1.4% of the butterfly tuna dietary volume. There was some indication of a shift from small mesopelagic species to larger mesopelagic species as butterfly tuna grew, but most of the fish prey were unidentified. Butterfly tuna sampled in the Northeast area had relatively greater proportions of fish and crustacean in their stomachs than predators from the two southern areas. However, the northern sample size was small. There was a consistent trend in the proportion of empty stomachs relative to the size of butterfly tuna, with over 70% of the smallest tuna having empty stomachs, reducing to half that value in the largest tuna size class. Southeast fish were less likely to have empty stomachs than Southwest fish.

Dietary composition from March to May was relatively constant and strongly dominated by cephalopods and, particularly, fish (Table 19). The recorded diet from June to August was more varied, with larger components of salps, crustaceans, and other non-fish items than in the other sampled months. There were dietary variations across year groups, primarily in the relative proportions of fish and cephalopods, although cephalopods dominated in all years.

In conclusion, butterfly tuna of all size classes sampled had a preference for squid, but with a significant component of mesopelagic fish species. The composition of the fish prey items may have changed from smaller to larger species as butterfly tuna grew.

Table 18: Butterfly tuna — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)				Area		
Prey category			32–120	121–140	141–160	161–191	Northeast	Southeast	Southwest
Fish	Small mesopelagics	1.4	3.0	1.5	1.3	–	1.5	1.4	1.3
	Large mesopelagics	3.5	–	2.8	4.4	5.9	1.5	4.4	2.3
	Other identified fish	0.5	0.8	0.3	0.6	0.7	–	0.9	–
	Unidentified fish	27.7	29.4	25.8	26.8	33.2	40.2	25.2	29.8
	Total fish	33.1	33.2	30.4	33.2	39.9	43.2	31.9	33.3
Cephalopods		52.9	53.7	57.4	50.9	47.0	30.4	58.5	47.4
Salps		4.8	3.9	3.6	6.0	3.9	3.4	3.5	7.1
Crustacea		1.2	1.1	0.8	1.7	1.0	10.1	–	1.7
Other		8.0	8.1	7.8	8.2	8.3	12.9	6.0	10.5
Mean FL (cm)		140.3	109.1	131.8	149.5	168.0	132.7	141.0	140.3
Mean SST (°C)		12.1	12.3	12.0	12.2	11.9	16.2	11.0	13.3
Sample size		949	123	322	374	113	58	561	330
% empty		53.1	72.0	56.6	40.0	35.1	72.4	41.3	61.6

Table 19: Butterfly tuna — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year			
Prey category		Mar	Apr	May	Jun-Aug	94–97	98–00	01–03	04–12
Fish	Small mesopelagics	3.0	1.0	–	2.0	1.3	1.0	2.8	0.9
	Large mesopelagics	7.5	3.4	4.8	1.4	5.9	2.8	1.7	1.7
	Other identified fish	0.8	0.8	–	–	0.8	0.6	–	–
	Unidentified fish	32.4	24.5	22.7	33.9	18.1	34.4	24.0	33.0
	Total fish	43.7	29.7	27.5	37.3	26.1	38.9	28.5	35.6
Cephalopods		53.4	58.0	58.8	40.1	65.1	42.4	58.5	54.3
Salps		1.4	4.8	3.5	7.0	2.5	6.5	6.2	1.9
Crustacea		–	–	1.3	4.1	1.5	0.6	1.7	2.3
Other		1.6	7.4	8.9	11.6	4.8	11.7	5.1	5.9
Mean FL (cm)		142.2	140.3	140.5	139.2	139.7	143.1	139.2	131.1
Mean SST (°C)		11.5	11.0	13.2	14.0	11.6	12.0	12.7	13.5
Sample size		114	469	120	246	288	422	142	97
% empty		46.7	41.2	68.9	60.8	52.4	50.6	50.3	65.4

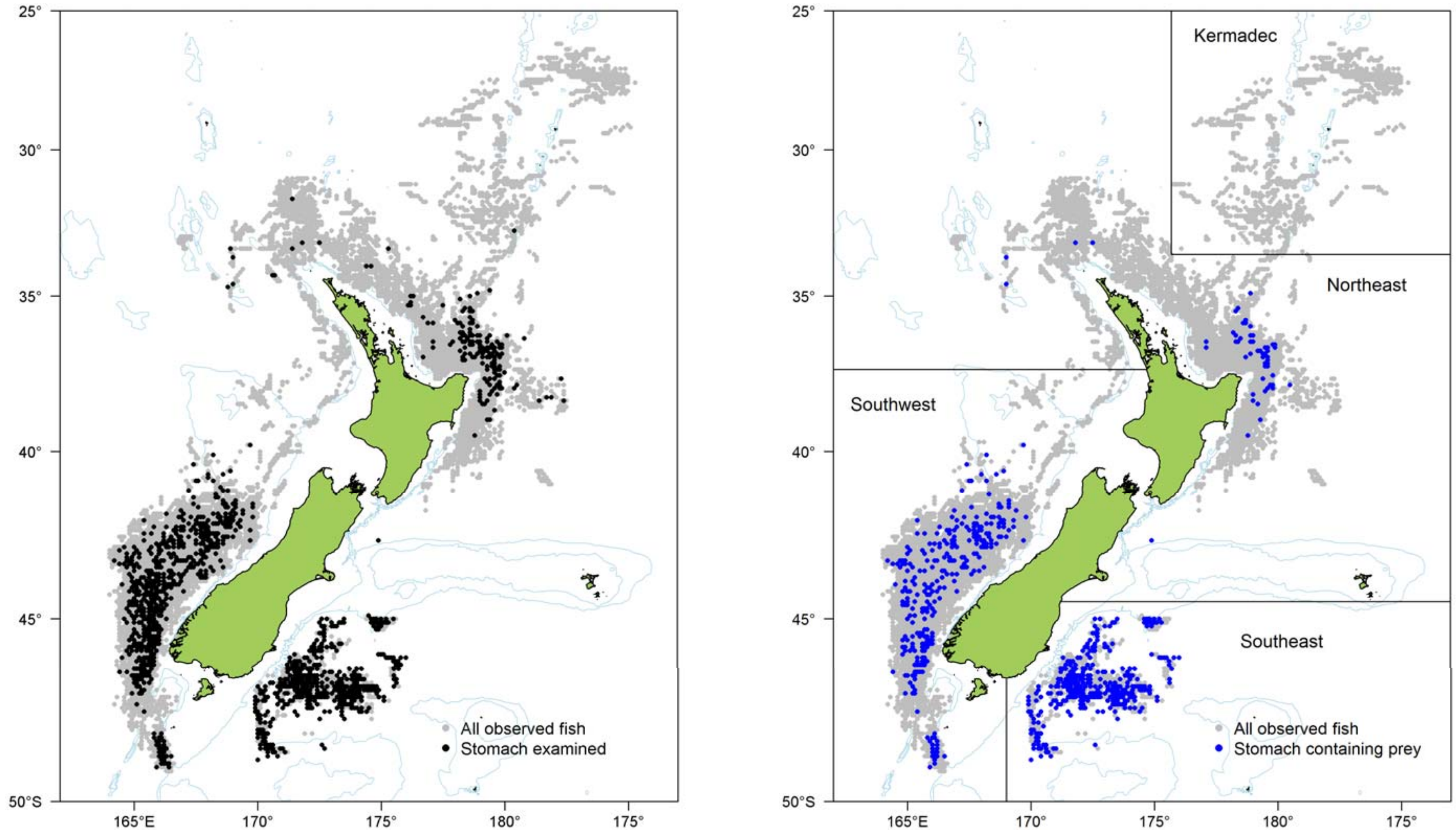


Figure 24: Distributions of all butterfly tuna examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

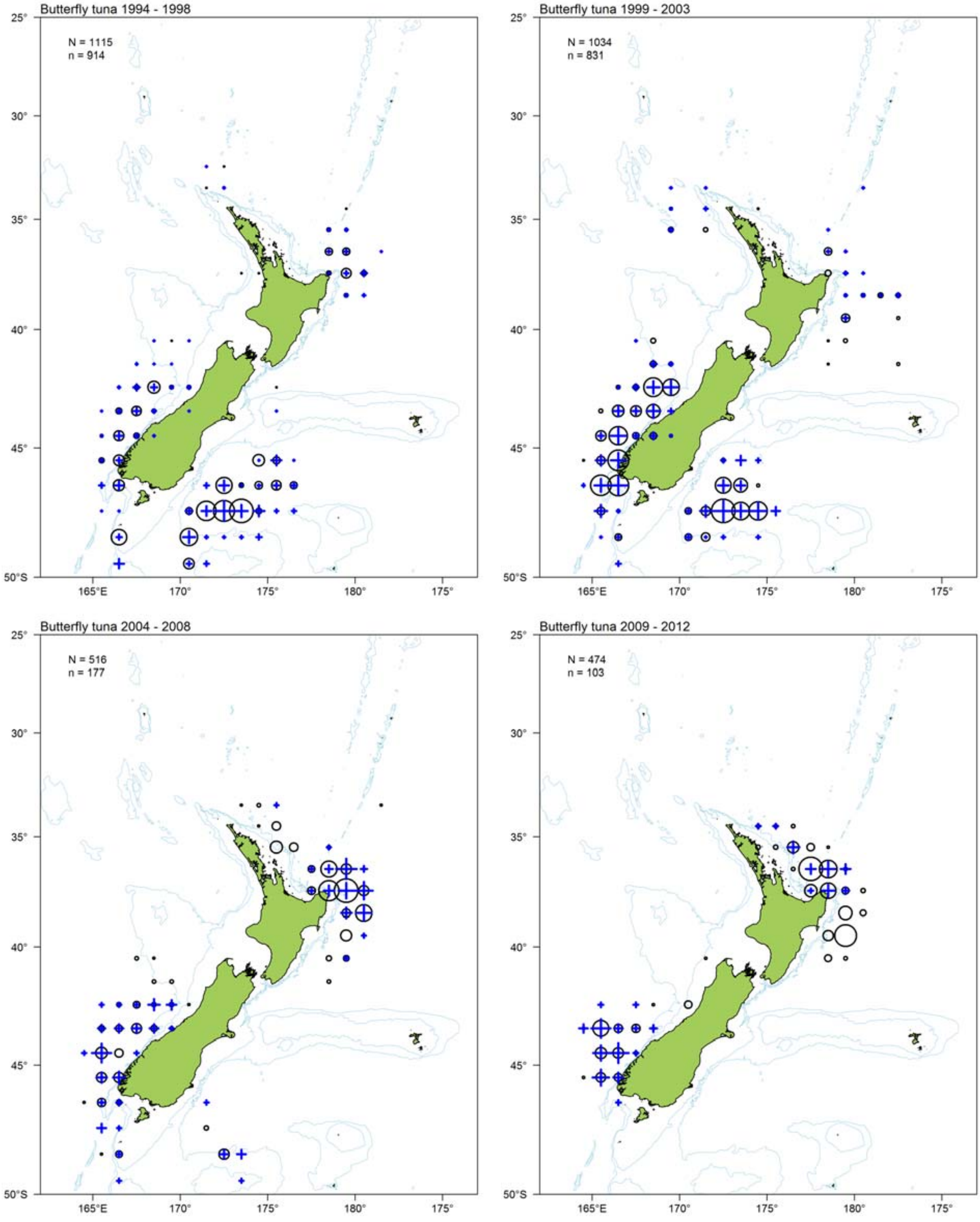


Figure 25: Butterfly tuna — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

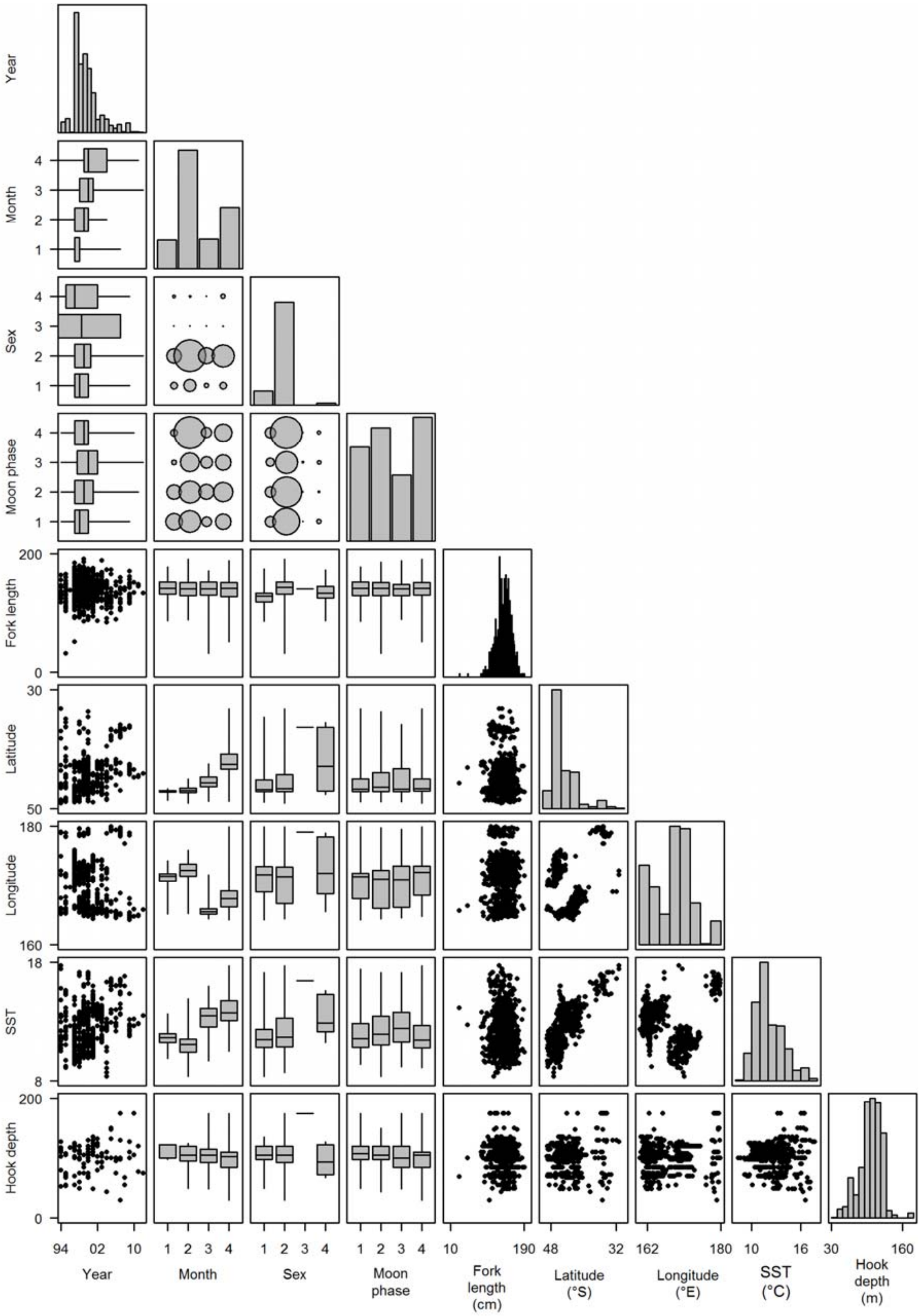


Figure 26: Butterfly tuna — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, March; 2, April; 3, May; 4, June–August. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.9 Albacore

Albacore (*Thunus alalunga*) have been caught and sampled over virtually the entire range of the surface longline fishery in New Zealand waters, but most particularly off the southwest coast of South Island, around East Cape, and north of North Cape (Figure 27). The distributions of albacore with and without stomach contents were visually very similar (Figure 27). The distribution of sampled fish was visually similar to the catch distribution for the species, although there has been some under-sampling of albacore in the Northeast area since 2009 (Figure 28). The numbers of observations per year were high in 1996 and 1998, but low in all other years (Figures 28 and 29). Albacore are known to be abundant, and available to the trolling fleet, down the entire western coast of New Zealand (Murray et al. 1999), so the samples examined here do not cover its full distribution.

An examination of data correlations (Figure 29) indicated some trends. Albacore were caught more commonly in southern latitudes and western longitudes early in the calendar year, and northern latitudes and eastern longitudes later in the year. They were relatively abundant at two SST modes: 12.0–15.0 °C (primarily southwestern fish) and 17.0–18.0 °C (primarily northeastern fish). Most fish were caught in a very narrow hook depth range (90–110 m). Albacore were more frequently sampled around the third quarter moon phase, relative to other times of the lunar cycle. The length-frequency distribution of sampled fish was bimodal, with modes at about 78 cm and 94 cm FL; 75% of sampled fish were in the length range of 72–97 cm FL. Sex was determined for most fish, and there were similar numbers of males and females.

Albacore exhibited an increasing proportion of fish in their diets as they grew; most of the identified fish prey were small mesopelagic species (Table 20). The increase in fish prey was balanced by a decrease in prey classified as ‘other’; no information was available to better define the likely composition of this category. On average, fish comprised about one-third of the prey volume. Cephalopods (virtually all identified simply as ‘squid’, but with a small component of octopus) comprised another third of the diet, and this was consistent across all sizes of albacore. ‘Other’ prey was the next most important component. Salps and crustaceans were minor components, and it appeared likely that salps declined in importance as albacore grew. Mean size of albacore was negatively correlated with mean SST (Table 20). Cephalopods dominated the diet of albacore in the Southwest area; albacore in the Northeast consumed fewer cephalopods, but a much greater proportion of ‘other’ prey. Fish were dominant in the diet in the Kermadec area, but the sample size was very small.

Most (85%) albacore were sampled in May–June of 1996 and 1998. Some temporal variations in diet were apparent, but reasons for these trends were not obvious (Table 21). The proportion of fish prey in diets was greatest in the latter half of the year, and lowest in June. In contrast, cephalopods were more prevalent in the first half of the year. The ‘other’ dietary category was dominant in June, and in 1996, but seldom recorded in other months or years. Crustaceans were most commonly recorded in the latter half of the year, and in years since 2000. Albacore were sampled from water with decreasing SST over time.

A relatively broad length range of albacore was sampled, and the diet was diverse and variable over space and time, although generally dominated by fish and squid. The importance of fish prey increased from about 20% of stomach volume for the smallest albacore, to about half the diet for the largest fish. Unfortunately, the likely composition of a relatively abundant ‘other’ prey category (particularly important for smaller albacore) could not be defined.

Table 20: Albacore — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)				Area		
Prey category			54–72	73–84	85–96	97–108	Kermadec	Northeast	Southwest
Fish	Small mesopelagics	4.1	0.6	5.3	2.7	9.0	7.4	0.9	7.4
	Large mesopelagics	1.5	–	1.3	2.1	1.0	–	2.8	0.2
	Other teleosts	0.8	–	0.7	0.9	1.0	–	1.3	0.2
	Unidentified fish	28.0	18.6	26.6	29.6	37.1	51.8	26.1	29.3
	Total fish	34.4	19.3	33.8	35.3	48.2	59.2	31.2	37.2
Cephalopods		33.9	27.0	38.4	34.2	34.0	12.5	25.5	44.6
Salps		6.2	9.0	6.5	5.1	5.3	10.0	5.2	7.2
Crustacea		7.4	8.8	6.0	7.3	8.0	10.0	6.4	8.6
Other		18.1	36.1	15.3	18.0	4.4	8.3	31.8	2.5
Mean FL (cm)		84.7	68.4	78.4	91.6	101.4	74.5	84.5	85.2
Mean SST (°C)		15.7	16.6	15.3	15.9	14.9	17.4	17.5	13.5
Sample size		694	104	232	233	103	12	368	314
% empty		56.9	61.3	54.1	57.2	56.4	62.5	61.3	50.2

Table 21: Albacore — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month			Year		
Prey category		Feb-May	Jun	Jul-Sep	94–96	97–99	00–12
Fish	Small mesopelagics	9.1	2.0	1.4	–	4.0	11.0
	Large mesopelagics	0.7	1.8	2.9	2.3	0.7	1.3
	Other teleosts	0.4	1.1	0.0	1.5	–	0.4
	Unidentified fish	28.7	25.2	47.1	25.8	26.9	34.0
	Total fish	38.9	30.0	51.4	29.6	31.6	46.7
Cephalopods		37.4	34.3	18.6	23.9	49.1	31.3
Salps		8.8	4.7	7.6	4.2	9.6	5.0
Crustacea		10.3	4.5	19.6	5.9	4.3	14.6
Other		4.6	26.5	2.8	36.4	5.3	2.3
Mean FL (cm)		83.6	84.6	89.3	83.9	84.6	86.4
Mean SST (°C)		14.3	16.2	16.6	16.8	15.3	14.2
Sample size		204	433	57	301	227	166
% empty		51.4	58.8	59.9	58.0	59.7	50.0

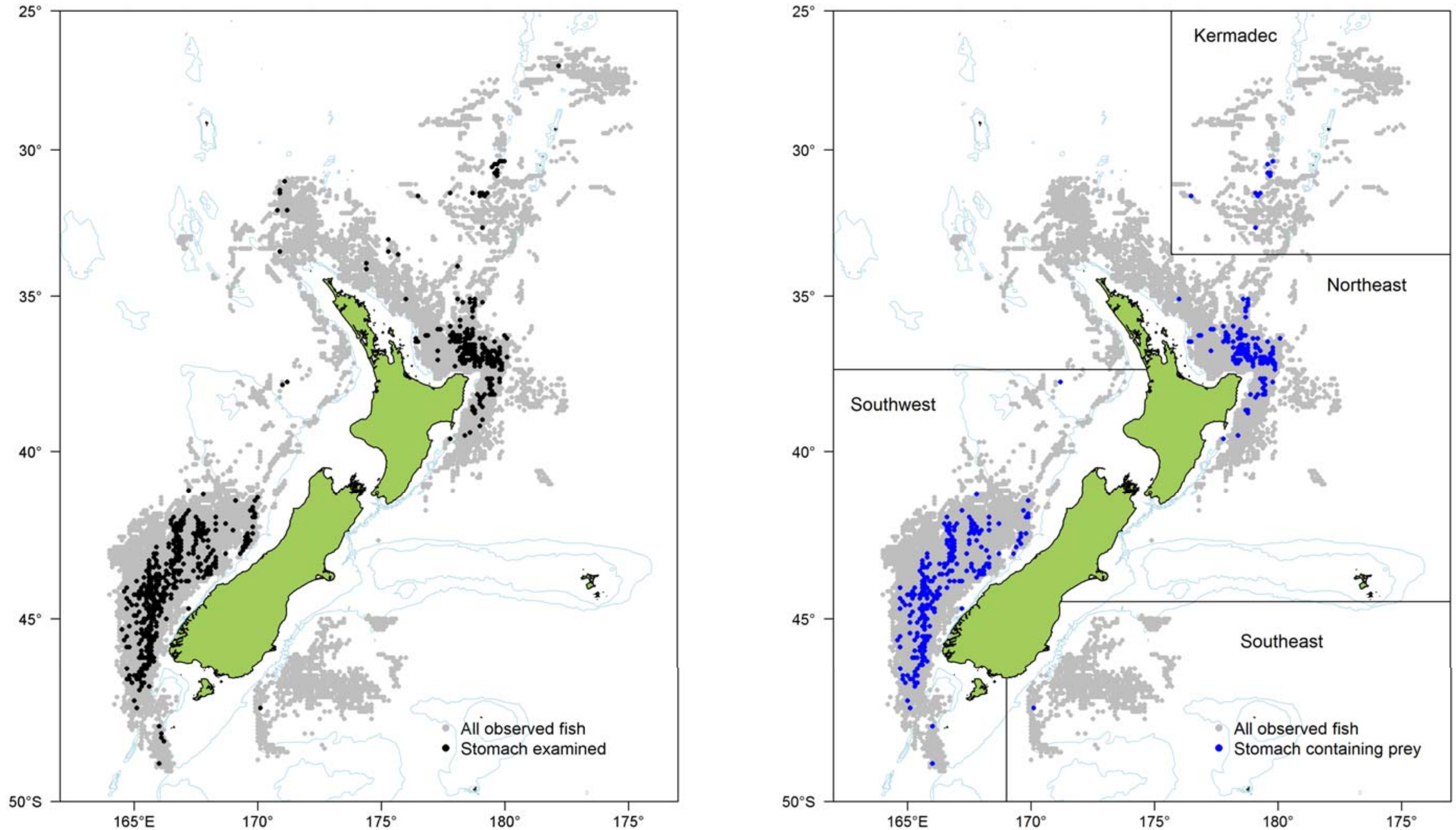


Figure 27: Distributions of all albacore examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

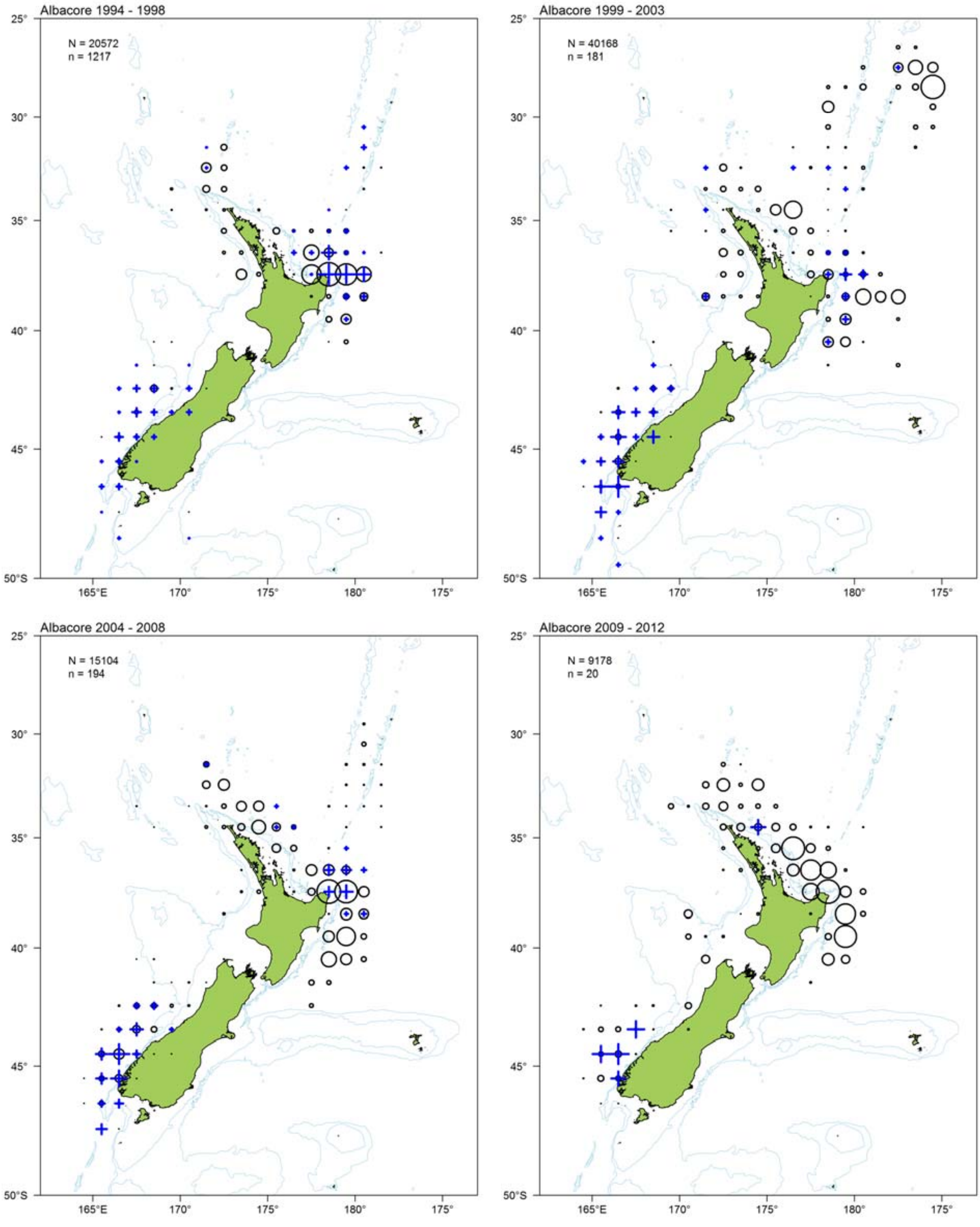


Figure 28: Albacore — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

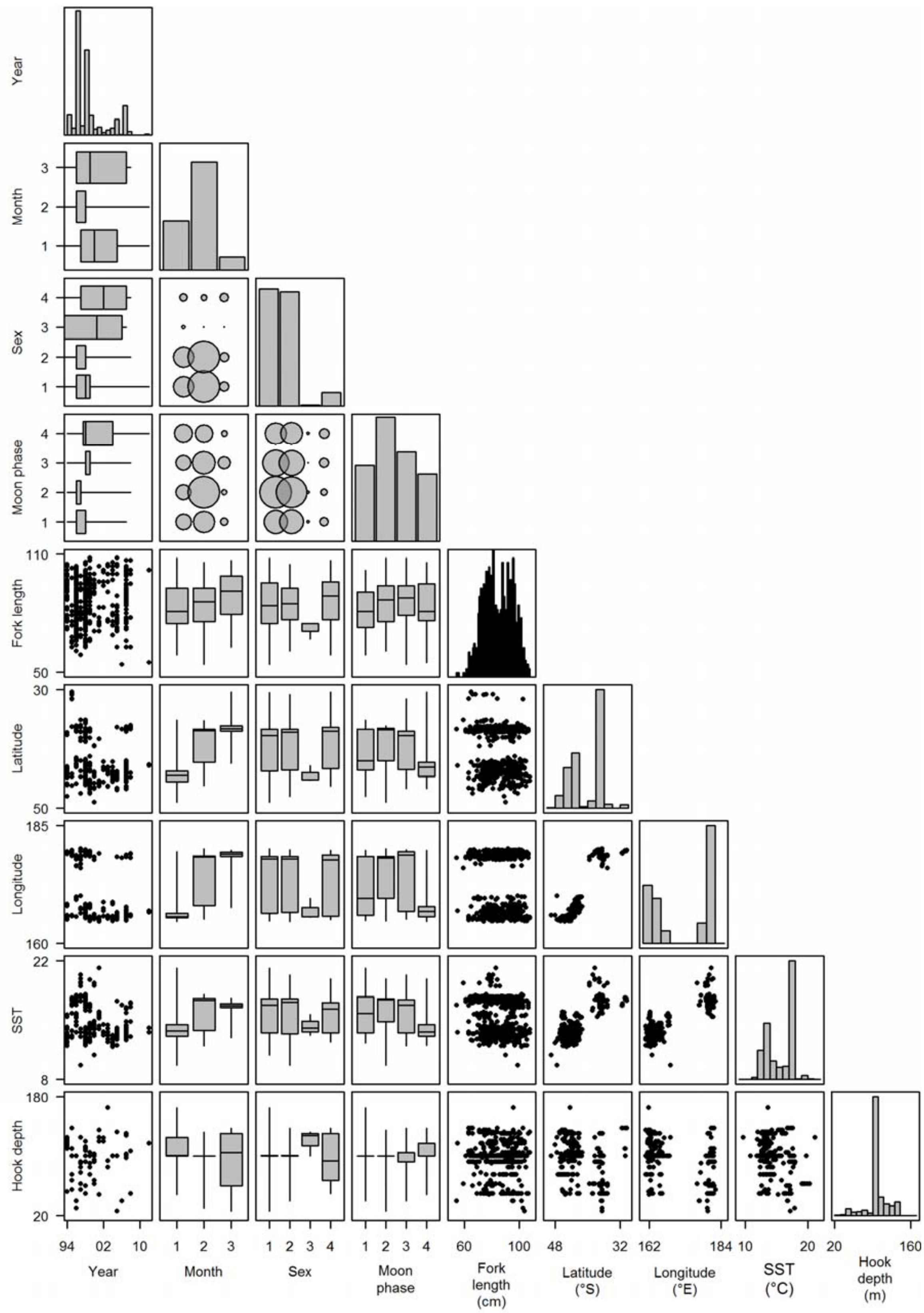


Figure 29: Albacore — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, February–May; 2, June; 3, July–September. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.10 Yellowfin tuna

Yellowfin tuna (*Thunnus albacares*) have been caught and sampled almost exclusively north of latitude 40° S, mainly in the Bay of Plenty and on the northern Kermadec Ridge (Figure 30). The distributions of yellowfin tuna with and without stomach contents were visually very similar (Figure 30). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 31). The number of observations peaked in 2003, but declined steadily after then (Figures 31 and 32).

An examination of data correlations (Figure 32) indicated some trends. Yellowfin tuna were caught more commonly in southern latitudes early in the calendar year, and northern latitudes later in the year, and mainly where SST ranged between 19.0 and 21.0 °C. They were caught over a broad hook depth range (40–140 m), but samples since 2004 were taken from relatively shallow sets (less than 70 m), and hook depth was generally shallow during the first three months of the year. The length-frequency distribution of sampled fish was unimodal, with a mode at about 112 cm FL; 75% of fish were in the relatively narrow length range of 103–126 cm FL. Sex was determined for most fish, and about 55% of sampled fish were female.

The percentage of fish in the diet remained relatively constant over the four size classes examined (Table 22). However, an increase in larger mesopelagic species (large mesopelagics, skipjack tuna, and flying fish) with increasing yellowfin size was apparent, while unidentified fish declined. Nautilus became more important in the diet as yellowfin grew, and total cephalopods (including nautilus) showed a slight increasing trend. The minor dietary components of salps and crustaceans declined in abundance as yellowfin size increased. Fish were more dominant in the diet in the Kermadec area (79%) than around northeast New Zealand (58%), with cephalopods exhibiting the reverse trend. Stomachs from the Kermadec area were more likely to be empty than those from Northeast fish.

The seasonal differences in diet (i.e., fish less prevalent in the diet from January–March, relative to the rest of the year) were associated with changes in area and predator size (Table 23). All fish from January–March were from the Northeast area (and relatively large), while 86% of fish sampled from April to December were from the Kermadec Ridge (and were smaller on average). The trend of an increasing proportion of fish in diets over time may well also have been influenced by sampled area: from 1994 to 2002, more than 99% of samples were from the Northeast area, but all 2003 samples were from Kermadec, and 72% of samples from 2004 to 2010 were again from Northeast. For the Northeast samples alone, there was an increasing trend in yellowfin size, with a corresponding increase in the fish dietary component, in line with the ontogenetic changes described above.

In conclusion, although most of the yellowfin tuna sampled occurred in a relatively narrow size range (i.e., there are few fish smaller than 100 cm FL), a diet dominated by fish, but with an increase in larger mesopelagic fish and cephalopods (particularly nautilus) as yellowfin grew, was apparent. Smaller yellowfin tuna may have a greater reliance on prey categories like small mesopelagic teleosts, salps and crustaceans.

Table 22: Yellowfin tuna — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)				Area	
Prey category			58–104	105–117	118–130	131–164	Northeast	Kermadec
Fish	Saury	3.9	0.8	2.4	8.6	4.4	6.9	–
	Small mesopelagics	1.3	1.6	1.4	0.7	2.7	1.2	1.5
	Skipjack tuna	3.5	0.8	4.0	3.7	3.5	2.2	5.1
	Flying fish	1.3	–	1.6	1.1	2.7	1.9	0.6
	Pufferfish	1.3	1.6	2.0	–	1.8	0.8	1.9
	Large mesopelagics	1.1	–	0.8	1.9	2.7	1.9	0.2
	Other teleosts	0.3	–	0.4	0.4	–	0.5	–
	Unidentified fish	54.7	58.4	56.4	48.4	49.7	42.5	69.9
	Total fish	67.5	63.1	69.0	64.8	67.4	57.9	79.3
Cephalopods	Nautilus	4.0	1.1	3.2	7.0	11.4	9.0	0.3
	Other cephalopods	20.1	22.3	19.2	20.1	17.2	22.2	15.0
Salps		4.5	7.5	5.3	4.2	1.2	7.2	1.6
Crustacea		0.8	2.1	0.4	0.9	–	0.6	1.1
Other		3.1	3.9	2.9	3.0	2.8	3.1	2.7
Mean FL (cm)		115.7	94.3	111.3	122.8	141.4	119.4	110.7
Mean SST (°C)		20.2	19.9	20.1	20.5	20.3	20.4	19.9
Sample size		961	112	459	248	103	533	434
% empty		55.2	58.7	55.6	55.0	52.8	53.8	56.4

Table 23: Yellowfin tuna — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year					
Prey category		Jan	Feb-Mar	Apr-Jul	Aug-Dec	94–96	1997	98–00	01–02	2003	04–10
Fish	Saury	3.8	9.3	3.1	–	0.7	5.1	14.0	10.9	–	–
	Small mesopelagics	0.8	0.8	1.6	2.0	0.7	1.7	2.5	0.6	1.4	1.3
	Skipjack tuna	3.4	1.6	4.7	4.3	0.7	–	0.8	6.4	5.4	1.3
	Flying fish	2.5	0.8	0.4	1.6	2.1	0.8	4.1	0.6	0.5	2.6
	Pufferfish	–	0.4	1.2	3.3	0.7	–	1.6	0.6	1.8	2.6
	Large mesopelagics	1.7	1.9	0.4	0.7	0.7	2.5	2.5	1.3	0.2	2.6
	Other teleosts	–	–	0.8	0.3	0.7	–	–	–	–	2.6
	Unidentified fish	46.4	42.3	63.3	64.4	41.5	39.0	37.0	44.3	70.0	63.1
	Total fish	58.6	57.0	75.3	76.5	47.7	49.1	62.5	64.9	79.3	76.0
Cephalopods	Nautilus	9.6	5.5	0.5	3.8	6.6	0.8	16.0	13.9	0.3	1.7
	Other cephalopods	17.4	29.8	20.6	11.1	18.4	39.8	19.6	15.6	15.0	19.5
Salps		10.3	3.7	1.4	4.0	18.3	9.0	0.5	2.1	1.7	1.4
Crustacea		0.8	0.2	0.8	1.4	0.1	–	1.2	1.3	0.9	1.1
Other		3.3	3.8	1.4	3.2	9.0	1.2	0.2	2.2	2.8	0.3
Mean FL (cm)		118.9	120.6	110.1	113.4	114.8	111.0	124.8	123.0	110.3	123.9
Mean SST (°C)		20.4	20.9	20.1	19.5	20.6	19.7	21.0	20.2	19.9	20.2
Sample size		214	235	241	277	133	105	106	142	403	72
% empty		55.2	53.0	62.9	47.0	56.3	50.5	39.8	57.7	57.4	57.9

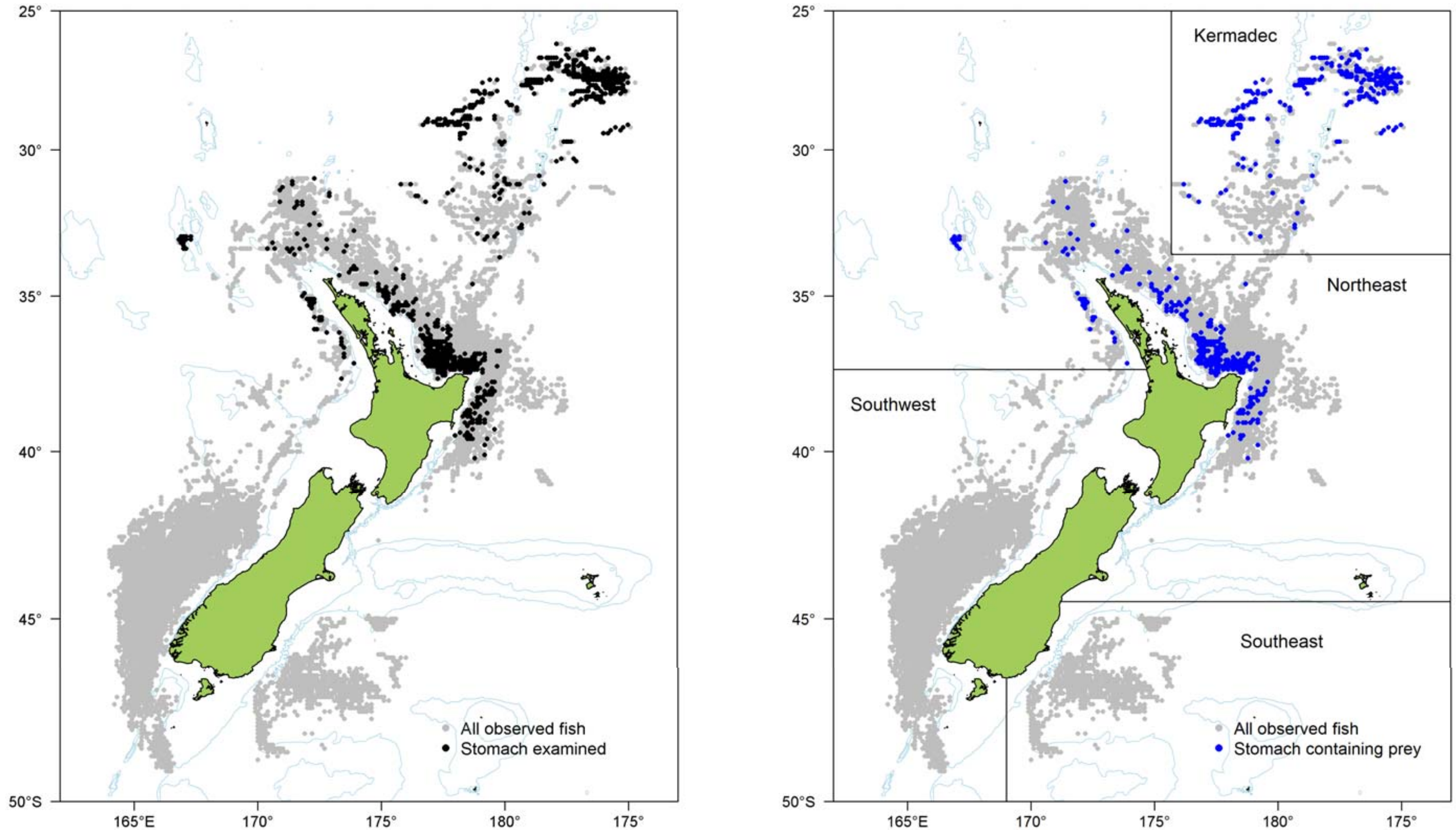


Figure 30: Distributions of all yellowfin tuna examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

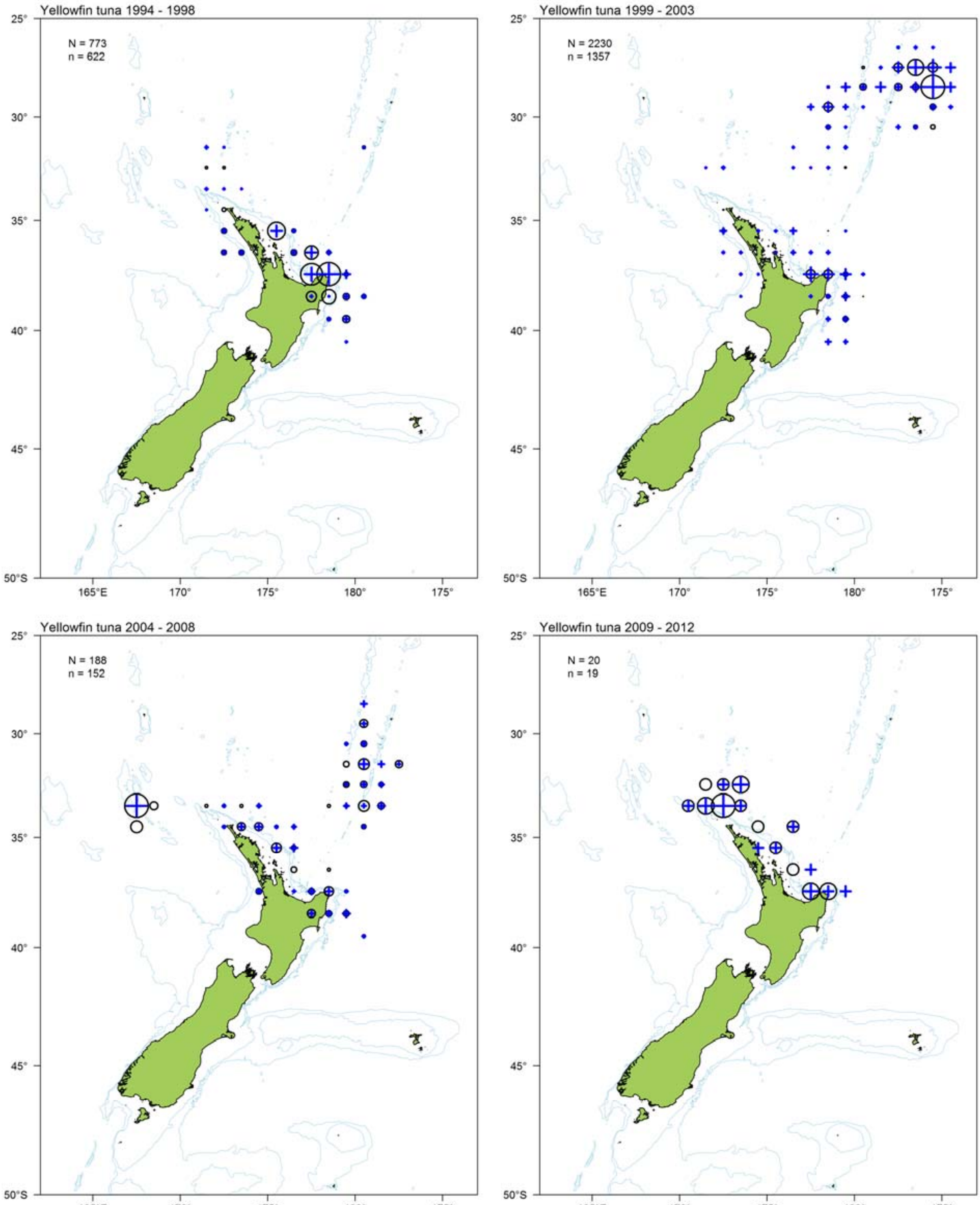


Figure 31: Yellowfin tuna — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

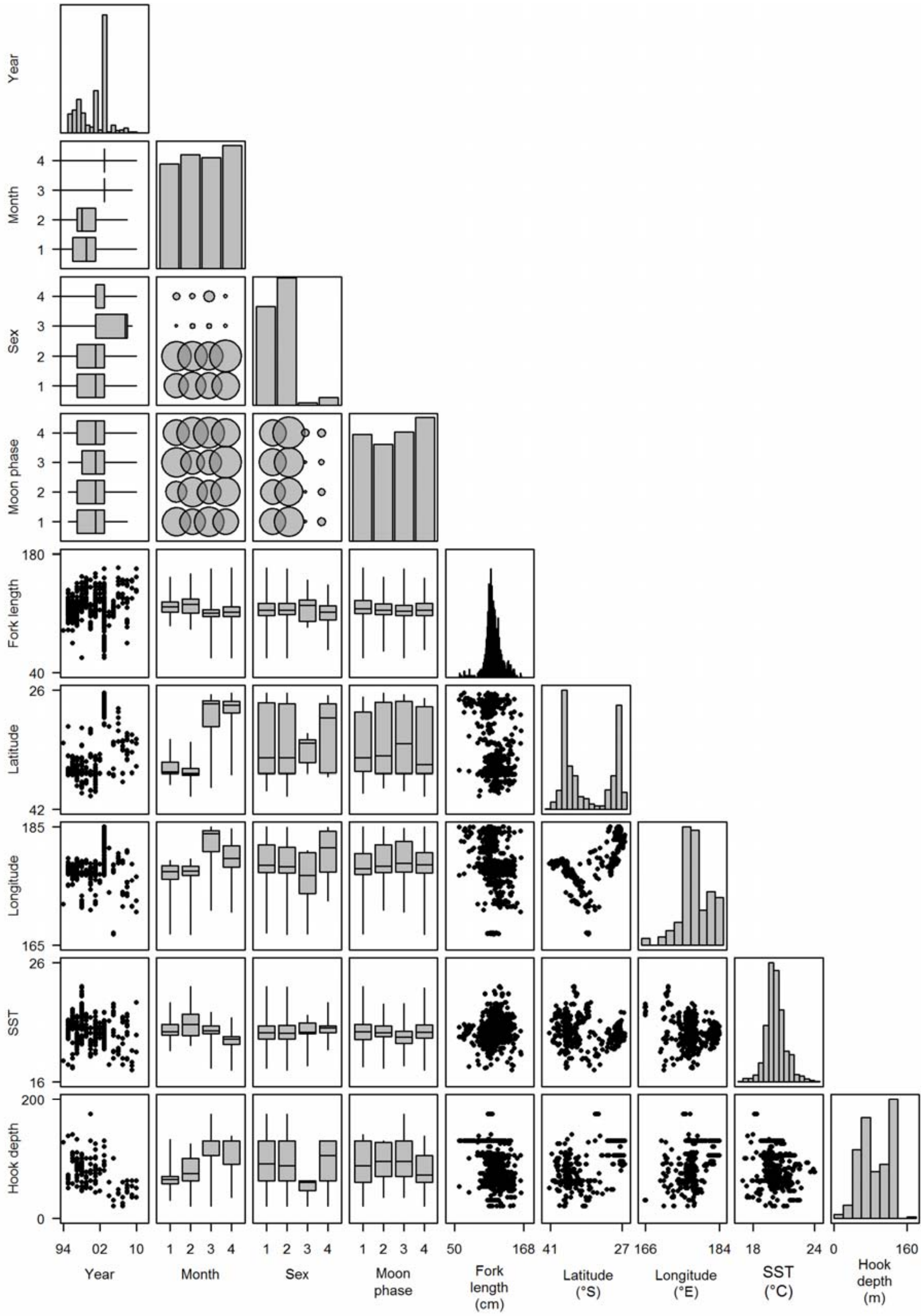


Figure 32: Yellowfin tuna — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January; 2, February–March; 3, April–July; 4, August–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.11 Southern bluefin tuna

Southern bluefin tuna (*Thunnus maccoyii*) have been caught and sampled primarily off the south coast of South Island, and to a lesser extent off Bay of Plenty and East Cape, and off the Otago coast (Figure 33). The distributions of southern bluefin tuna with and without stomach contents were visually very similar (Figure 33). The distribution of sampled fish was visually very similar to the catch distribution for the species (Figure 34). The number of fish sampled per year was relatively constant over the entire period, with the exception of low sampling in 1996 (Figures 34 and 35).

An examination of data correlations (Figure 35) indicated some trends. Fish were caught mainly where SST ranged between 12.5 and 14.5 °C, and where estimated hook depth ranged between 90 and 120 m. The length-frequency distribution of sampled fish was unimodal, with 75% of fish being in the relatively narrow length range of 135–185 cm FL. Fish caught in the peak season (i.e., May and June) were slightly smaller on average than those caught at other times of the year. Sex was determined for most fish, and males were slightly more abundant than females (i.e., they comprised 55% of sexed fish).

The percentage of fish in the diet steadily increased as southern bluefin grew (Table 24). This trend was largely attributable to a marked increase in predation on Ray's bream by southern bluefin tuna larger than about 161 cm FL. Small mesopelagic species (primarily lanternfish) were relatively abundant in the diets of all size classes, but were less abundant in the diet of tuna larger than 187 cm FL. As fish grew a reduction in cephalopods, salps, and crustaceans was evident. Most of the cephalopod prey was identified simply as 'squid', but there were small components of both nautilus and octopus. There was a consistent trend in the proportion of empty stomachs as size changed, with about three-quarters of the small to medium sized fish having empty stomachs, reducing to about half in the largest fish. There was some indication of differences in diets between areas (Table 24). The Northeast and Southwest areas had similar sized southern bluefin, but in the Northeast the diet had larger components of fish and cephalopods, while salps were a major component only in the Southwest. The Southeast diet was dominated by cephalopods rather than fish, but the sample size from this area was relatively small.

There were no clear within-year trends in diet. This was not surprising, however, as 92% of fish were sampled during April–June (Table 25). A shift in diet was apparent between 2003 and 2004; salps dropped markedly in importance, while fish increased in importance. The increased fish component comprised both Ray's bream and small mesopelagic fish with light organs. There was no concurrent trend in mean predator size that might otherwise help explain this dietary shift.

In conclusion, the southern bluefin tuna diet was generally dominated by fish, primarily small mesopelagic species and Ray's bream, but squid and salps also made up a notable contribution to the diet. An ontogenetic change was apparent, where salps and squid were replaced by fish as the southern bluefin grew. There was no apparent reason for a marked dietary shift about 2004, when salps were largely replaced by fish. Some between-area differences in diet were apparent, but most of the sampled fish were derived from only one area.

Table 24: Southern bluefin tuna — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area		
Prey category			81–112	113–137	138–161	162–186	187–225	Northeast	Southwest	Southeast
Fish	Lanternfish	13.0	9.5	10.6	14.0	16.3	6.0	9.8	13.1	14.5
	Small mesopelagics	0.8	1.3	1.9	0.6	0.6	0.2	4.0	0.6	1.0
	Ray's bream	11.1	0.4	1.5	3.5	24.2	32.2	5.0	11.7	3.3
	Large mesopelagics	0.7	0.6	0.5	0.6	0.9	2.5	0.9	0.7	1.0
	Other teleosts	0.2	0.2	0.3	0.1	0.1	0.2	0.3	0.1	0.7
	Unidentified fish	35.7	35.0	37.7	35.9	39.0	39.8	52.2	35.1	16.2
	Total fish	61.5	47.1	52.5	54.7	71.0	81.1	72.2	61.4	36.7
Cephalopods		13.1	19.1	14.4	14.4	11.2	8.2	16.9	11.6	57.8
Salps		18.0	23.6	23.7	22.3	12.4	5.5	4.1	19.4	3.1
Crustacea		3.3	6.8	4.6	3.6	2.2	1.7	1.3	3.5	–
Other		4.1	3.3	4.7	4.9	3.2	3.6	5.5	4.0	2.4
Mean FL (cm)		154.5	104.9	126.1	151.0	172.3	191.5	160.3	160.3	154.0
Mean SST (°C)		13.5	13.5	13.6	13.5	13.5	13.3	16.6	11.1	13.3
Sample size		9966	420	1811	3370	3888	415	629	9089	248
% empty		71.9	76.9	77.6	74.5	65.2	54.9	83.0	70.6	68.0

Table 25: Southern bluefin tuna — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year								
Prey category		Mar-Apr	May	Jun	Jul-Aug	94–95	96–97	98–99	00–01	02–03	04–05	06–07	08–09	10–12
Fish	Lanternfish	8.4	13.0	15.4	10.7	–	9.4	8.0	18.0	11.4	22.4	42.5	20.5	4.6
	Small mesopelagics	0.8	0.3	1.2	3.1	–	0.6	1.1	0.4	0.6	1.6	1.6	1.3	0.8
	Ray's bream	13.5	14.0	6.7	4.4	–	10.1	5.4	5.7	8.1	18.8	22.6	27.4	13.7
	Large mesopelagics	0.6	0.8	0.6	1.0	–	2.1	1.3	1.8	0.4	0.4	0.3	0.3	0.6
	Other teleosts	0.5	0.1	–	0.3	–	0.2	0.2	0.3	0.3	0.2	0.1	0.2	–
	Unidentified fish	38.5	35.5	32.2	47.8	47.2	23.5	32.9	23.4	26.7	33.3	19.1	28.5	62.9
	Total fish	62.3	63.7	56.2	67.2	47.2	45.9	48.9	49.5	47.4	76.6	86.2	78.3	82.6
Cephalopods		21.1	8.9	14.8	19.7	9.3	17.1	17.1	19.1	11.1	16.4	10.3	15.9	7.4
Salps		12.2	19.1	21.6	6.1	26.7	32.3	26.8	20.1	31.6	3.7	1.0	4.7	5.4
Crustacea		0.8	4.0	3.7	1.6	10.0	1.2	2.0	9.6	3.8	0.7	0.7	0.1	0.5
Other		3.6	4.3	3.6	5.4	6.8	3.4	5.2	1.8	6.0	2.6	1.8	0.9	4.0
Mean FL (cm)		160.7	154.8	150.8	157.5	154.1	156.7	153.2	149.1	150.2	166.2	164.8	153.2	149.5
Mean SST (°C)		12.6	13.5	13.4	15.5	13.0	13.1	13.6	13.8	13.8	13.4	13.8	13.4	13.5
Sample size		1316	4921	3042	687	1483	753	1538	714	1393	906	862	883	1434
% empty		62.9	71.4	72.5	80.9	60.1	69.4	68.6	69.7	64.0	67.9	66.6	78.3	83.4

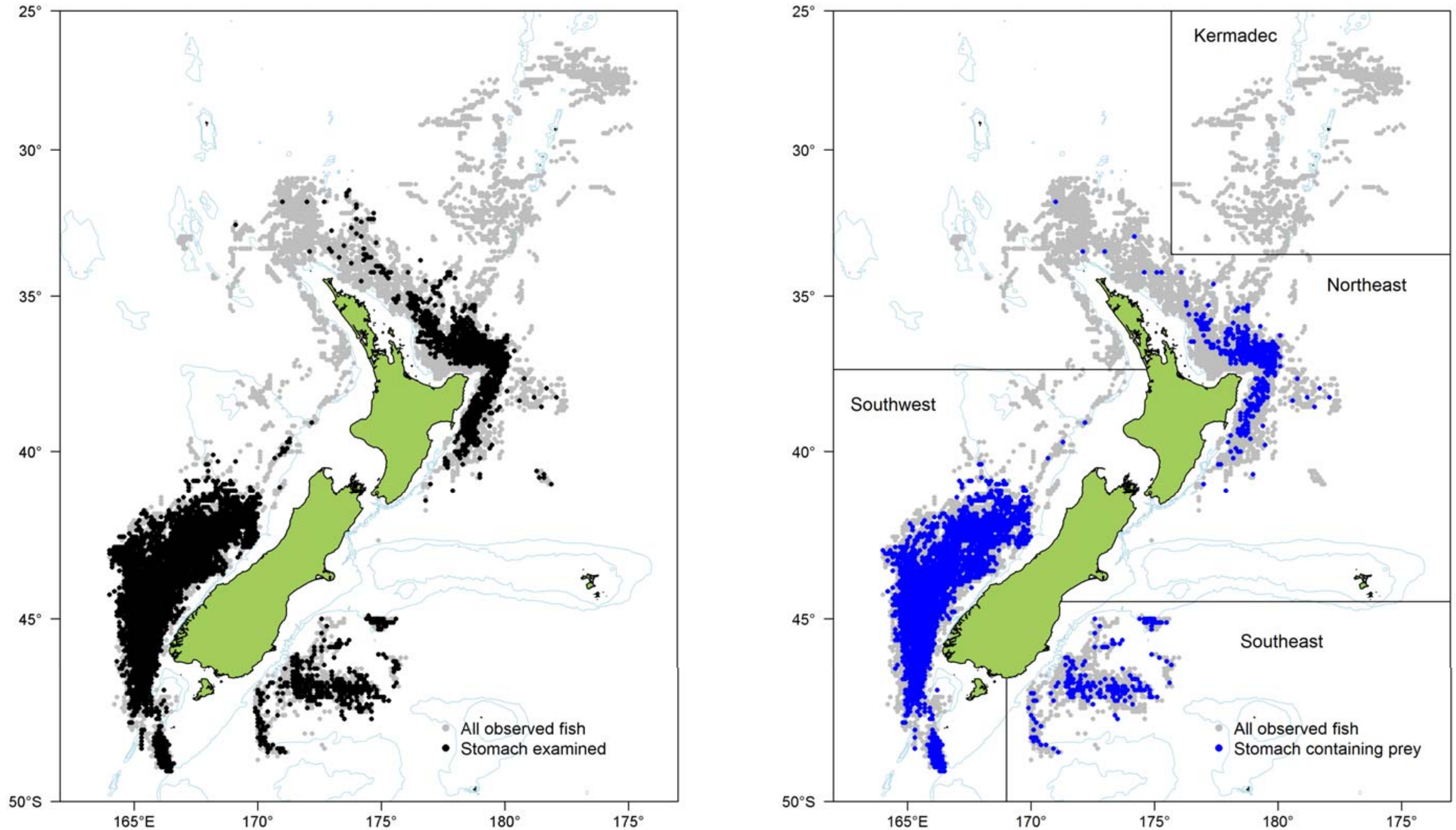


Figure 33: Distributions of all southern bluefin tuna examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

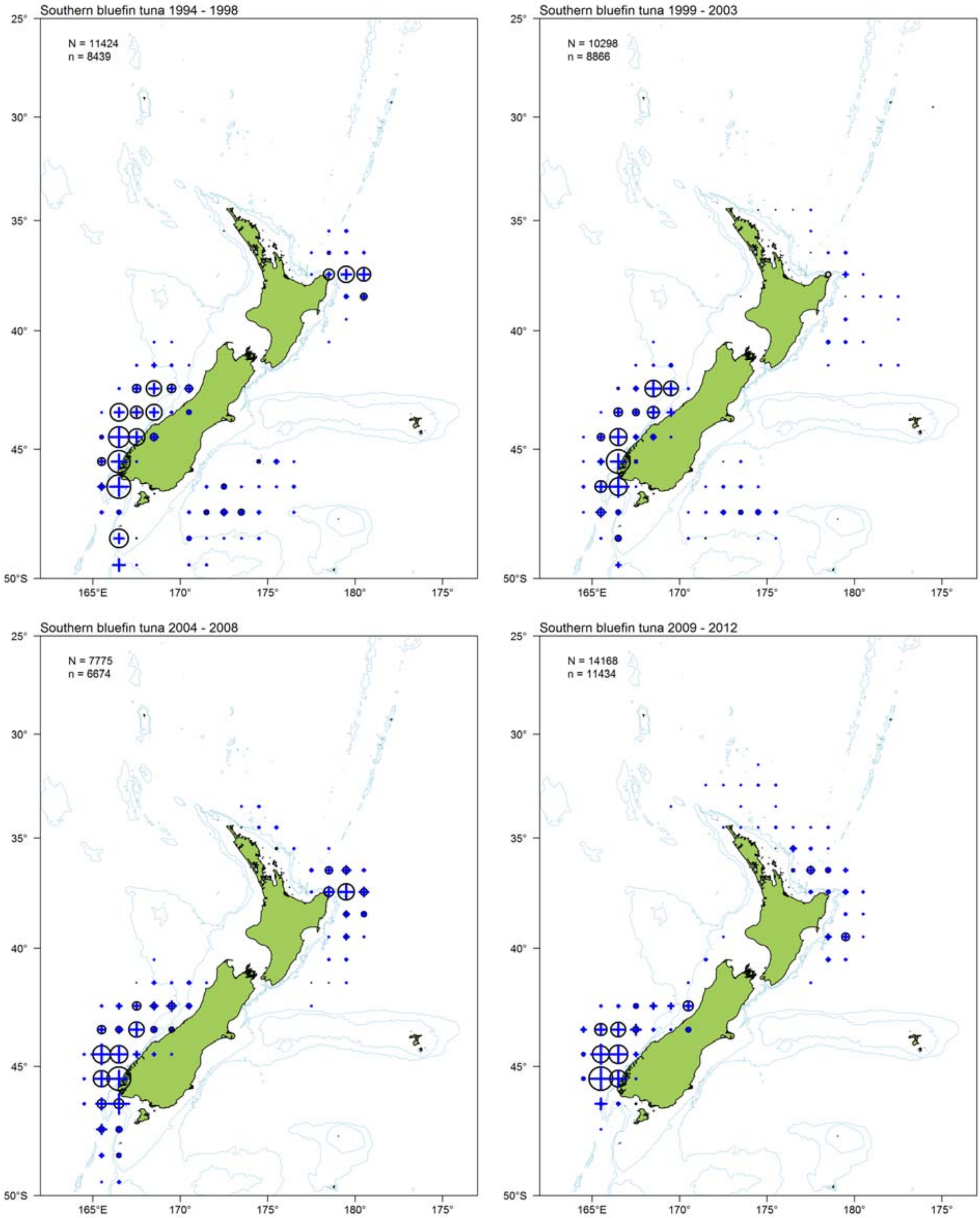


Figure 34: Southern bluefin tuna — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

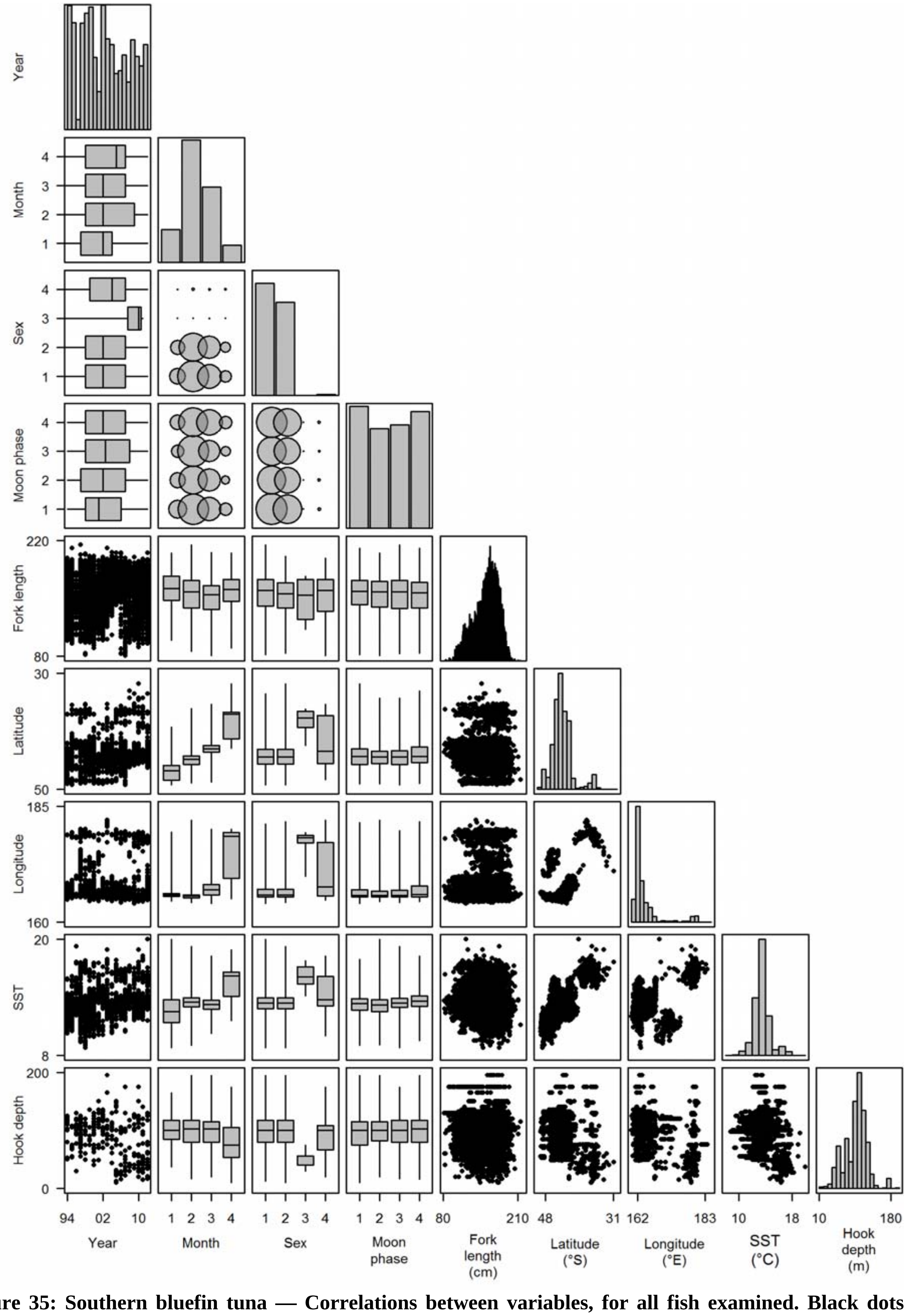


Figure 35: Southern bluefin tuna — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, March–April; 2, May; 3, June; 4, July–August. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.12 Bigeye tuna

Bigeye tuna (*Thunnus obesus*) were caught and sampled almost exclusively north of latitude 40° S, mainly from East Cape to north of North Cape, and on the northern Kermadec Ridge (Figure 36). The distributions of bigeye tuna with and without stomach contents were visually very similar (Figure 36). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 37). Sampling occurred reasonably consistently in most years since 1994, but with strong peaks in 1998 and 2003, and sparse samples in 1996, 2002, and 2012 (Figures 37 and 38).

An examination of data correlations (Figure 38) indicated some trends. Bigeye tuna were caught more commonly in southern latitudes early in the calendar year, and northern latitudes later in the year. They were caught generally where SST ranged between 16.0 and 21.0 °C, mainly at the warmer end of this range from January to May. Bigeye were caught commonly over a broad hook depth range (30–130 m), but samples since 2004 were taken primarily from relatively shallow sets (less than 70 m), and they were generally deeper in June and July than at other times of the year. Catches of bigeye were lower around the third lunar quarter than at other times of the lunar cycle. The length-frequency distribution of sampled fish was unimodal, with a peak at about 142 cm FL; 75% of fish were in the length range of 110–155 cm FL. Sampled fish were smaller in July than at other times of the year, and in Kermadec relative to Northeast. Sex was determined for most fish, and there were similar numbers of males and females.

The diets of all size classes of bigeye tuna were dominated by fish prey (average 60% of volume), and this component increased slightly in importance as the tuna grew (Table 26). The proportions of large mesopelagic species (particularly lancetfish, Ray's bream, and skipjack tuna) were greatest for the larger bigeye size classes. Cephalopods were an important secondary prey category, comprising about one-third of the prey volume, and this proportion was relatively constant over all tuna size classes. Most cephalopods were identified simply as 'squid', but nautilus accounted for 15% of the cephalopod volume (or about 5% of the total bigeye tuna diet). The minor dietary components of crustaceans and 'other' items declined in abundance as bigeye grew. There was a declining trend in the proportion of empty stomachs as tuna size increased. Fish were less dominant in the diet in the Kermadec area (56%) than around northeast New Zealand (62%), possibly attributable to the slightly smaller mean size of Kermadec tuna. Stomachs were less likely to be empty in June-July than at other times of the year.

Seasonal differences in diet manifested as greater proportions of fish prey, and concurrent lower proportions of cephalopods, in June and July relative to other times of the year (Table 27). The reason for this was not apparent. There were no consistent differences in diets across year groups.

In conclusion, although a relatively broad size range of bigeye tuna was sampled, the diet appeared to be quite consistent across tuna size classes, being strongly dominated by fish (mainly large mesopelagic species), with a significant cephalopod (squid and nautilus) secondary component. Prey from other categories was negligible. Slight ontogenetic changes in the fish component of diet was apparent: fish prey increased as bigeye tuna grew.

Table 26: Bigeye tuna — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)				Area	
Prey category			65–104	105–130	131–159	160–191	Kermadec	Northeast
Fish	Small mesopelagics	1.6	–	1.3	2.1	1.9	1.5	1.6
	Lancetfish	3.7	1.6	3.9	2.6	12.1	5.7	3.2
	Ray's bream	1.6	–	–	1.9	8.4	–	2.0
	Skipjack	3.3	–	2.8	4.8	0.9	0.4	4.0
	Large mesopelagics	1.3	0.8	0.9	1.4	1.9	1.5	1.2
	Unidentified fish	49.4	50.8	49.3	50.9	40.1	46.8	50.0
	Total fish	60.8	53.2	58.2	63.6	65.3	55.9	62.0
Cephalopods		34.9	36.8	38.0	32.4	32.3	36.9	34.4
Salps		0.5	–	0.2	0.9	0.8	0.3	0.6
Crustacea		1.4	2.1	1.4	1.4	0.7	1.8	1.3
Other		2.4	8.0	2.1	1.7	1.0	5.1	1.7
Mean FL (cm)		131.4	95.0	118.6	142.7	168.2	115.7	135.1
Mean SST (°C)		18.6	19.4	18.5	18.5	18.7	18.9	18.6
Sample size		1169	110	418	511	101	227	942
% empty		62.7	68.7	66.0	60.1	51.9	65.0	62.0

Table 27: Bigeye tuna — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year			
Prey category		Jan-May	Jun	Jul	Aug-Dec	94–98	99–03	04–07	08–12
Fish	Small mesopelagics	1.5	2.1	2.6	0.8	2.1	2.4	1.1	0.6
	Lancetfish	3.3	2.1	3.3	4.8	1.7	5.0	4.3	3.2
	Ray's bream	0.4	–	0.3	3.8	–	0.2	1.4	5.1
	Skipjack	0.4	13.7	1.6	1.0	11.0	1.0	1.1	1.3
	Large mesopelagics	1.5	0.4	1.0	1.8	0.7	1.4	1.1	1.9
	Unidentified fish	44.9	49.7	55.5	47.7	47.9	46.9	50.8	52.6
	Total fish	51.9	68.2	64.4	59.9	63.3	56.9	59.7	64.7
Cephalopods		43.9	28.6	32.3	34.7	32.4	37.9	33.8	34.2
Salps		0.9	1.1	0.4	0.2	0.6	1.1	0.2	–
Crustacea		2.1	1.2	1.6	0.9	1.5	2.0	1.5	0.2
Other		1.1	1.0	1.3	4.3	2.2	2.0	4.7	0.9
Mean FL (cm)		139.3	137.3	123.8	129.2	134.3	124.4	129.4	139.4
Mean SST (°C)		20.4	18.5	18.5	17.9	19.1	18.9	18.2	18.3
Sample size		235	208	279	447	267	368	253	281
% empty		62.8	45.7	57.9	70.0	51.8	56.7	70.4	51.0

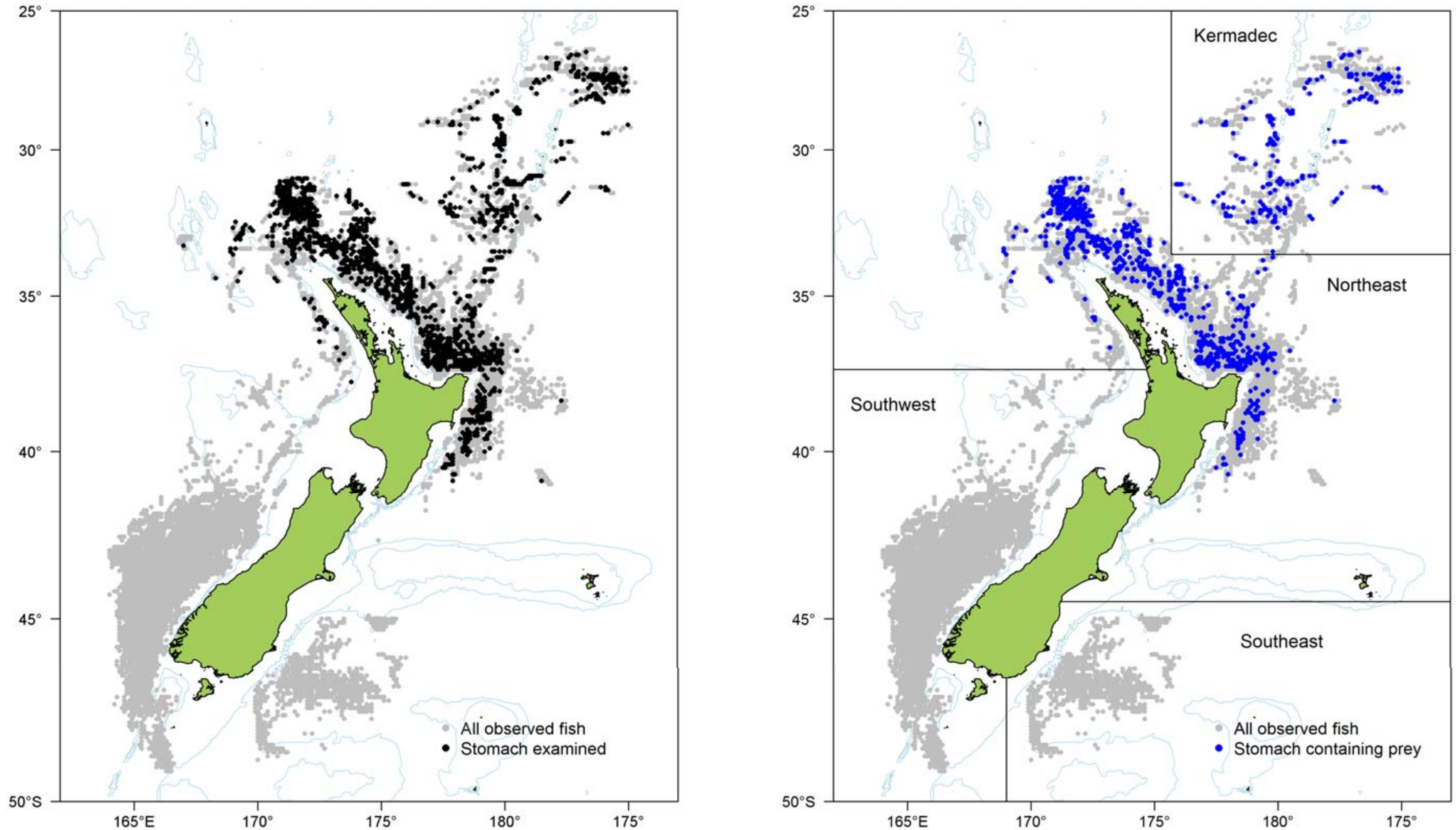


Figure 36: Distributions of all bigeye tuna examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

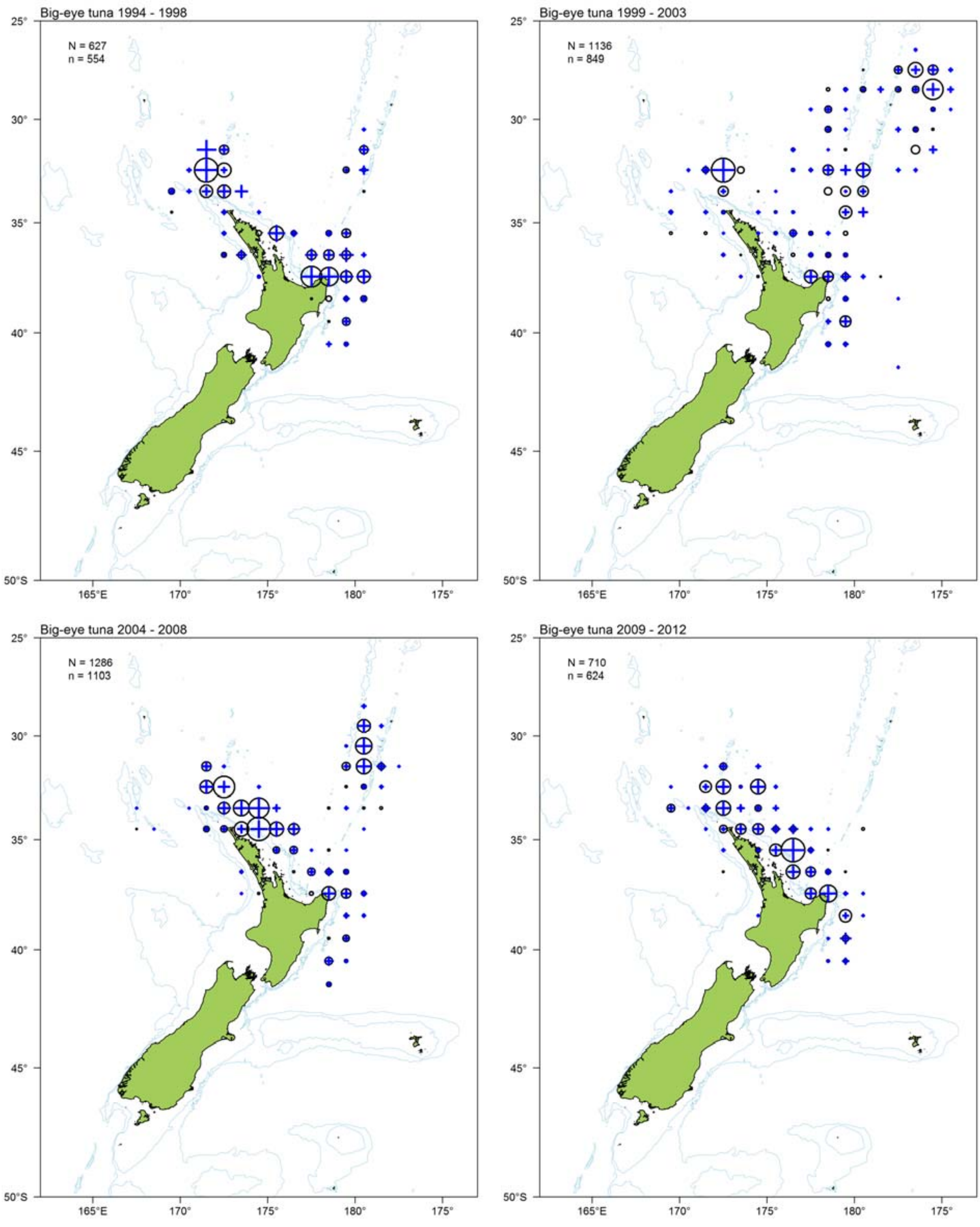


Figure 37: Bigeye tuna — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

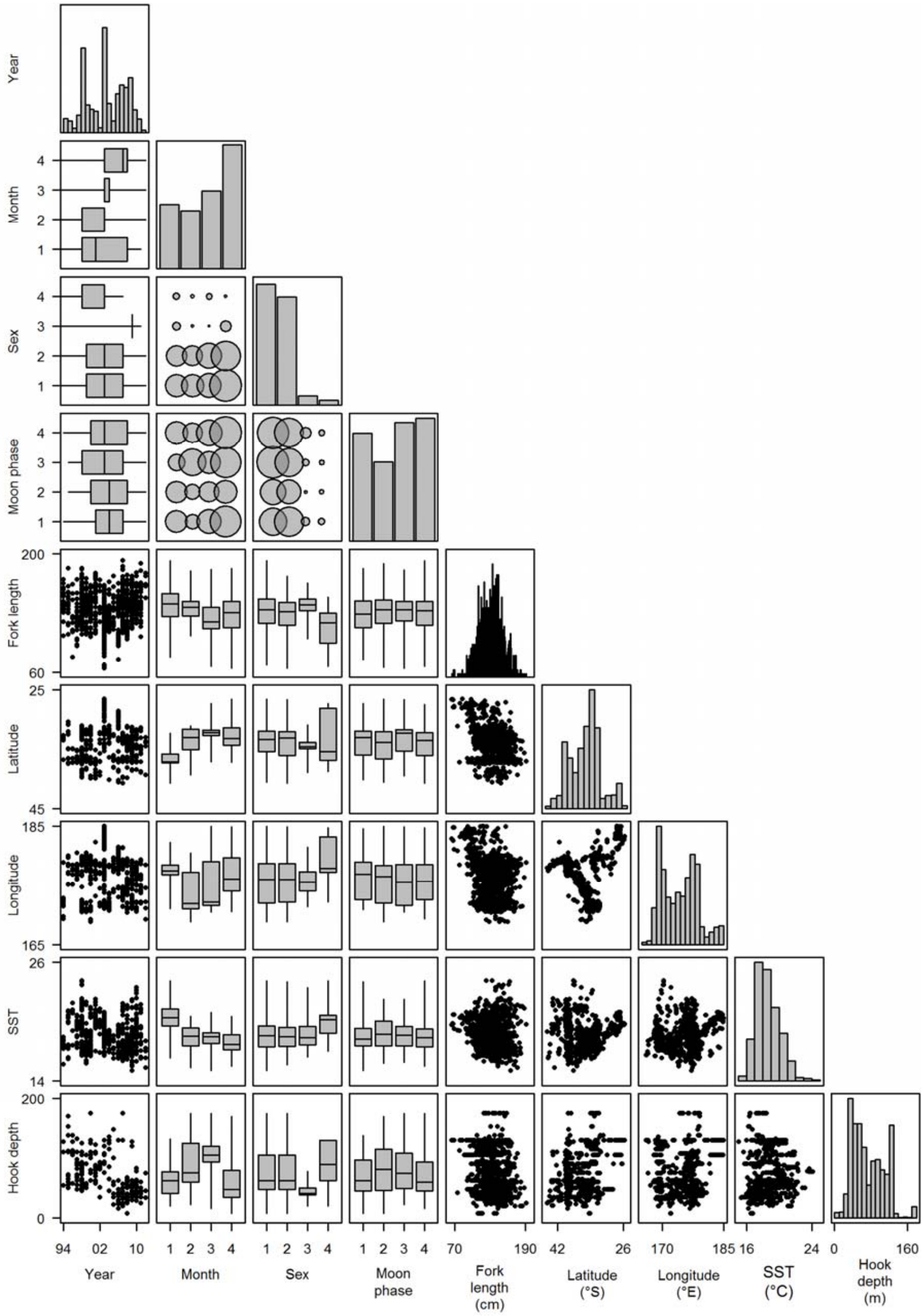


Figure 38: Bigeye tuna — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–May; 2, June; 3, July; 4, August–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.2.13 Swordfish

Swordfish (*Xiphias gladius*) have been caught and sampled in all areas covered by the New Zealand surface longline fishery, except the Southeast area (Figure 39). The main concentration of samples of this species was in the Northeast area, from Hawke Bay to the northern Bay of Plenty. The distributions of swordfish with and without stomach contents were visually very similar (Figure 39). The distribution of sampled fish was visually similar to the catch distribution for the species (Figure 40). The number of observations was sparse before 1997, but has been more widespread, and generally increasing, since then (Figures 40 and 41). Swordfish is probably the most widespread of all the species examined in detail here.

An examination of data correlations (Figure 41) indicated some trends. Swordfish were caught more commonly in southern latitudes (and consequently in cooler waters) during May and June, relative to other times of the year. Fish length was correlated with latitude, longitude, and SST; larger fish tended to be southern, western, and in cooler waters. Consequently, the fish caught during May-June were, on average, larger than those caught at other times. Swordfish were commonly caught over a broad range of SSTs (13.0–22.0 °C). They were commonly caught over a broad hook depth range (20–120 m), but most samples since 2004 were taken from relatively shallow sets (less than 70 m). Catches of swordfish were lower around full moon than at other times of the lunar cycle. The length-frequency distribution of sampled fish with was broadly unimodal, with a relatively flat distribution from about 130 to 200 cm FL; 75% of fish were in the length range of 118–224 cm FL. Sex was determined for most fish, and there was a dominance of females (73%) in the samples.

All sizes of swordfish had diets dominated by fish (Table 28). While most of the fish prey was unidentified, the small amounts that were identified indicated that as swordisfh grew, the occurrence of small mesopelagic prey species declined, and the occurrence of Ray’s bream, hoki, sharks, and other large mesopelagic prey species increased. Almost all of the non-fish component of swordfish diet was cephalopods. There were only nine records of octopus or nautilus, so most of the cephalopods were likely to be squid. The ratio of fish to cephalopod volume was relatively constant across the four smaller swordfish size classes, but with more fish in the largest size class (i.e., greater than 250 cm FL). There was a consistent trend in the proportion of empty stomachs relative to fish size, with over half the stomachs of the smallest swordfish being empty, reducing to less than one-third empty in the largest size class.

There was a spatial trend in swordfish diets, with increasing proportions of fish and decreasing proportions of cephalopods with southward movement (Table 28). The larger fish in the Southwest area were much less likely to have empty stomachs than the smaller fish from the northern areas.

Swordfish stomachs sampled in January-April had relatively low volumes of fish prey (and high volumes of cephalopods), whereas stomachs in June had relatively high volumes of fish (Table 29). Samples from 2002 to 2009 differed from those in other year groups by having lower proportions of fish and higher proportions of cephalopods. There was no consistent association between the temporal changes described here and mean predator size.

In conclusion, swordfish of all sizes have a diet about three-quarters fish, primarily large mesopelagic species, with the remainder comprising squid.

Table 28: Swordfish — Summary of the dietary components classified as mean percentage volume per stomach, for all fish, by fish size class, and by sampling area. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		All fish	Predator length (cm FL)					Area		
Prey category			52–120	121–160	161–200	201–250	251–330	Kermadec	Northeast	Southwest
Fish	Sharks	0.2	–	0.1	0.2	0.2	0.6	1.3	0.0	0.1
	Small mesopelagics	0.7	1.5	1.3	0.2	0.6	–	0.6	0.8	0.5
	Hoki	1.1	–	0.2	1.1	2.1	2.8	–	0.7	2.7
	Ray's bream	4.5	0.2	0.7	3.4	10.1	15.3	1.3	1.4	17.2
	Large mesopelagics	2.6	0.5	1.6	1.2	5.4	6.2	1.6	1.6	6.2
	Unidentified teleosts	66.3	74.3	72.1	65.6	58.4	58.8	53.4	69.7	59.0
	Total fish	75.4	76.5	75.9	71.8	76.8	83.6	58.1	74.3	85.8
Cephalopods		22.1	19.8	21.0	25.9	21.3	14.6	39.2	22.9	12.8
Salps		0.2	0.3	0.1	0.2	0.1	0.1	0.2	0.2	0.1
Crustacea		1.1	2.7	1.4	0.8	0.4	0.1	1.1	1.3	0.1
Other		1.3	0.6	1.5	1.3	1.4	1.5	1.5	1.3	1.2
Mean FL (cm)		175.8	109.2	140.5	180.9	222.7	263.7	167.9	163.4	222.1
Mean SST (°C)		17.5	18.3	18.1	18.0	16.4	15.2	19.6	18.1	14.8
Sample size		3494	382	1001	1007	883	164	273	2509	712
% empty		43.9	53.4	49.6	42.7	32.4	31.4	47.4	47.9	19.7

Table 29: Swordfish — Summary of the dietary components classified as mean percentage volume per stomach, by month and year group. In each column, the values for total fish plus other non-fish prey categories sum to 100%. –, no prey of that category was recorded.

		Month				Year				
Prey category		Jan-Apr	May	Jun	Jul-Dec	94–98	99–01	02–05	06–09	10–12
Fish	Sharks	–	0.1	0.1	0.3	0.2	–	0.1	0.4	–
	Small mesopelagics	1.0	0.6	0.8	0.5	1.2	1.1	0.9	0.6	0.2
	Hoki	0.7	1.5	2.2	0.2	3.9	2.3	0.6	–	–
	Ray's bream	0.7	7.8	8.5	2.9	4.6	9.5	4.4	4.2	1.4
	Large mesopelagics	1.0	3.1	4.8	1.8	2.5	6.1	3.5	1.6	0.6
	Unidentified teleosts	62.0	62.0	67.2	71.8	66.1	60.3	61.0	62.8	78.7
	Total fish	65.4	75.2	83.6	77.5	78.4	79.3	70.5	69.6	80.9
Cephalopods		30.8	21.9	15.3	20.1	19.4	17.0	27.1	28.5	16.4
Salps		–	0.2	–	0.3	–	0.4	0.2	0.2	–
Crustacea		2.4	0.6	0.4	0.6	1.1	2.1	0.9	0.9	0.5
Other		1.4	2.0	0.6	1.4	1.1	1.2	1.3	0.8	2.2
Mean FL (cm)		167.6	188.0	187.1	166.6	184.6	192.6	183.4	164.6	165.9
Mean SST (°C)		20.3	16.9	15.8	16.9	17.5	16.6	17.4	18.1	17.6
Sample size		950	607	888	1049	520	589	585	969	831
% empty		51.4	42.9	35.0	43.0	40.8	41.5	38.5	45.4	48.5

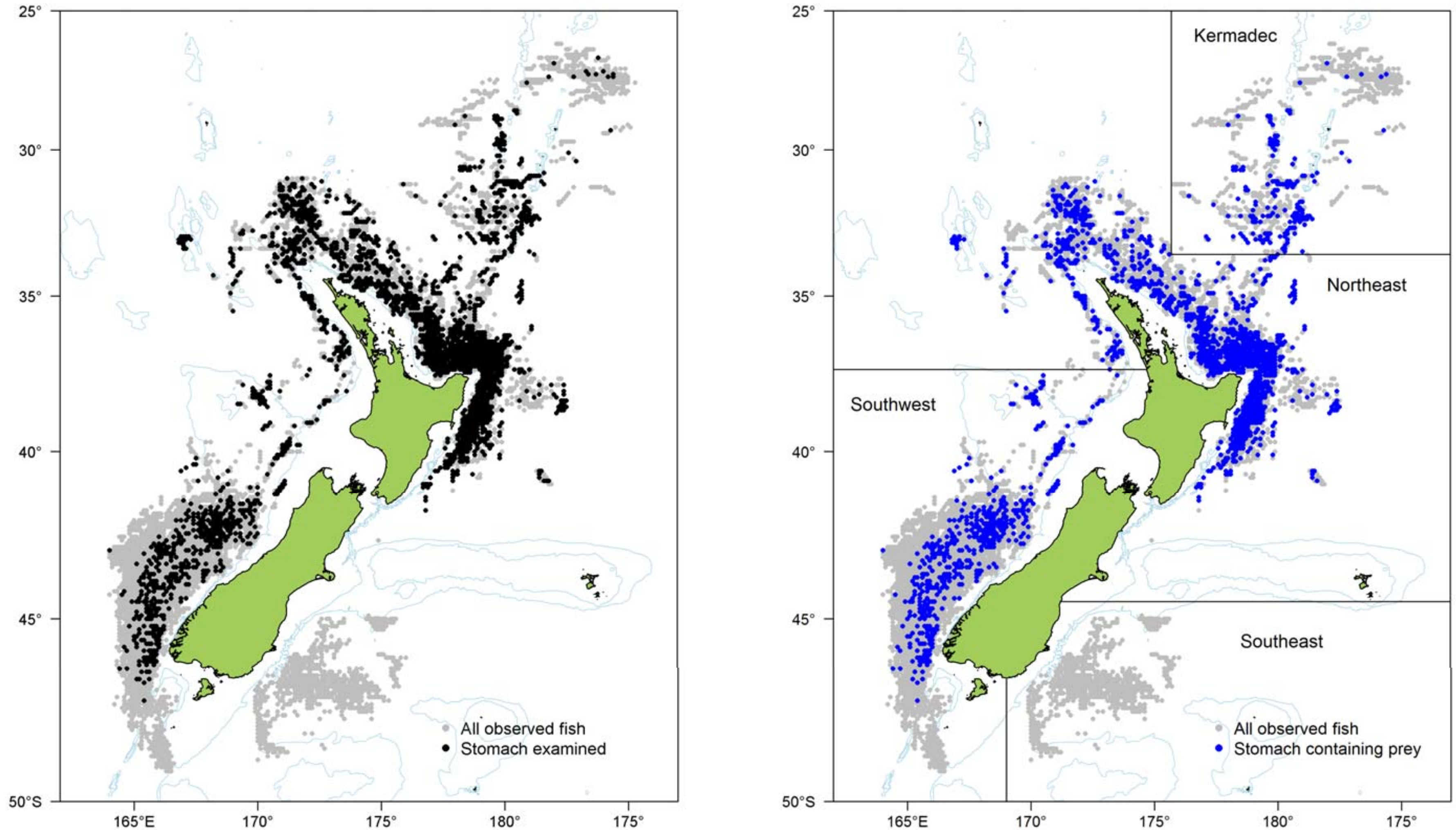


Figure 39: Distributions of all swordfish examined for stomach contents (black dots), and those with stomachs containing prey (blue dots), relative to the distribution of all species examined for stomach contents (grey dots). The boundaries for the four sample areas are shown on the right panel.

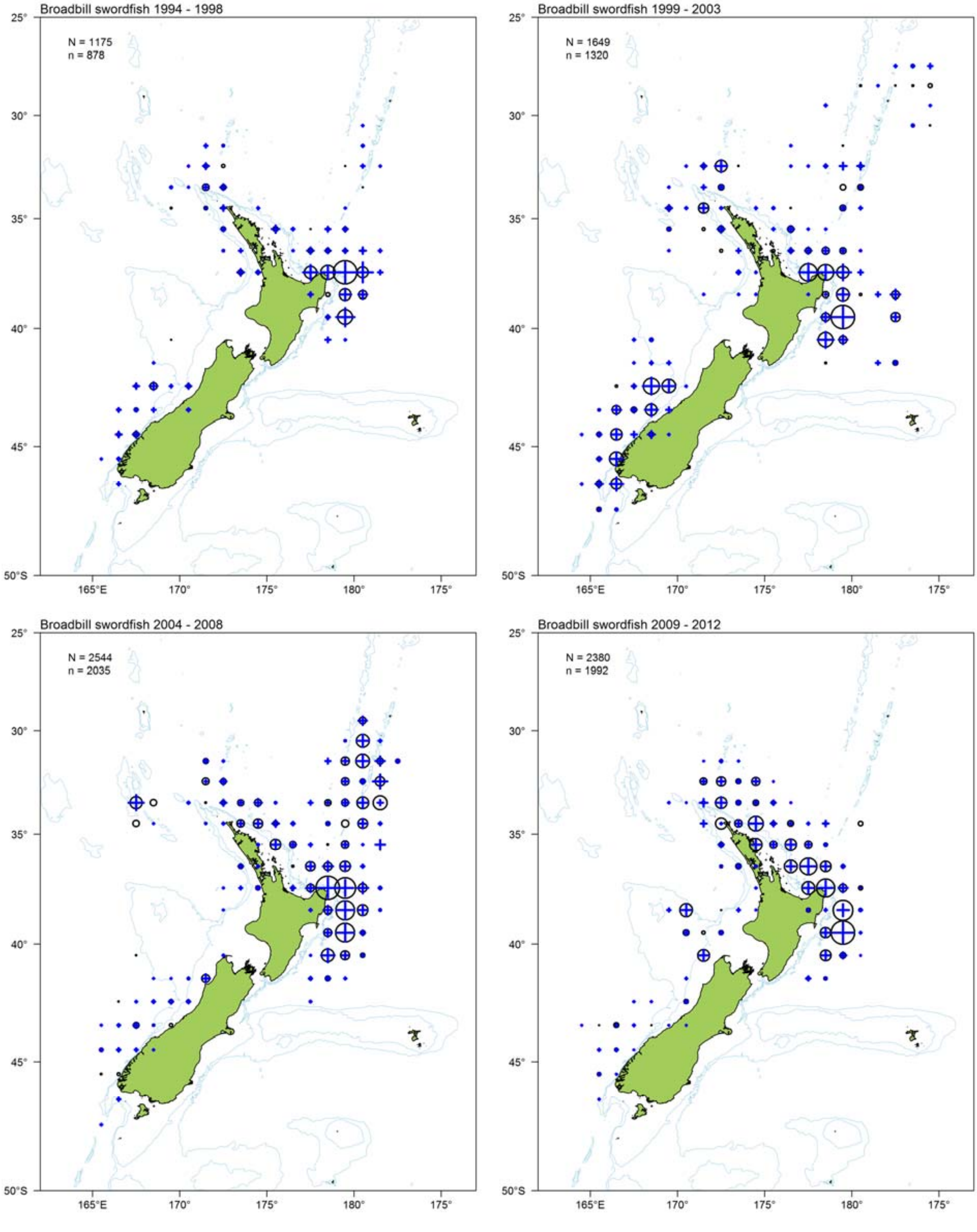


Figure 40: Swordfish — Comparisons of the observed catch (*N*, circles) and catch sampled for stomach contents (*n*, crosses), by 1 degree latitude-longitude rectangles, over four sampling periods. Symbol size is proportional to the number of fish caught or sampled.

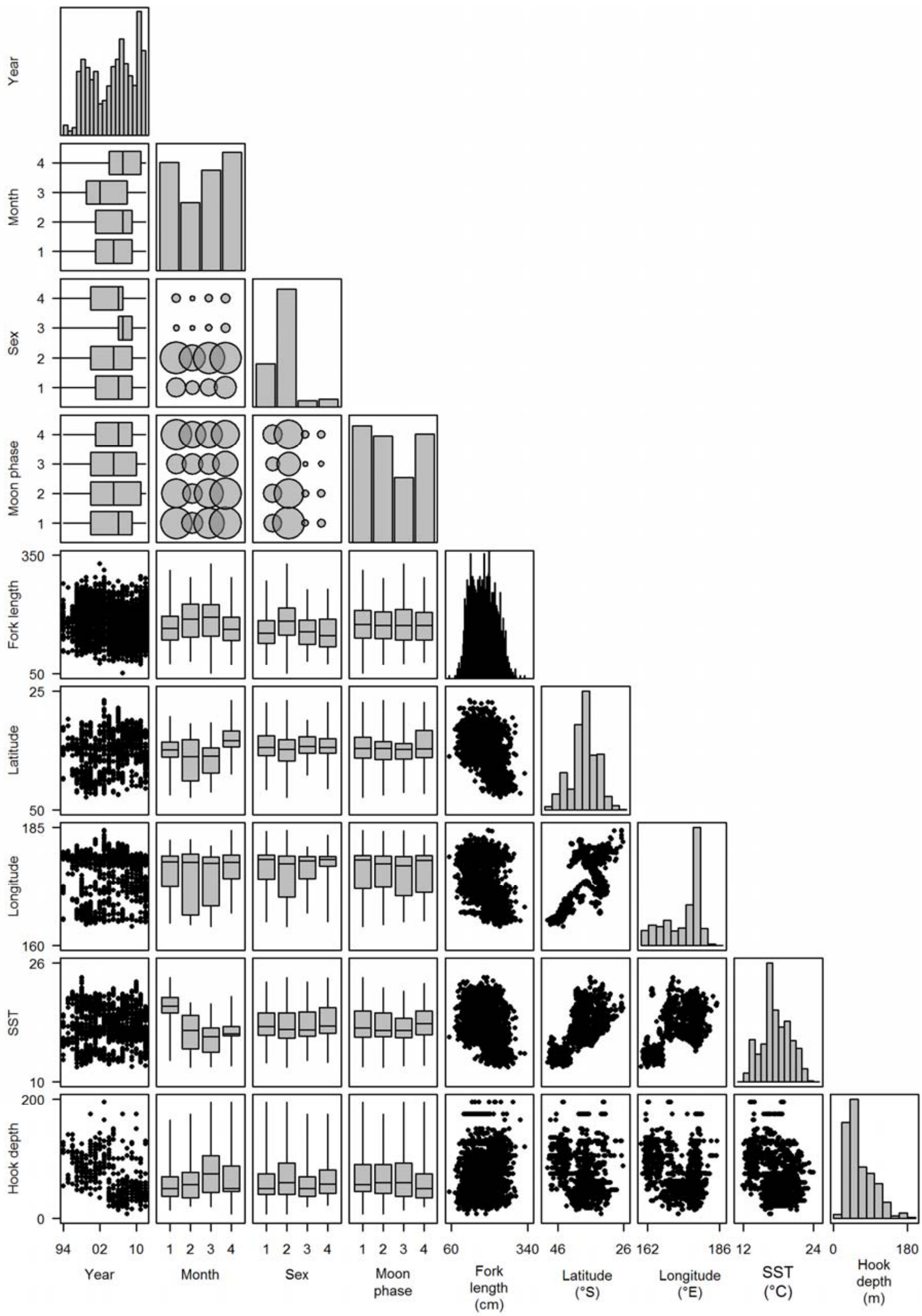


Figure 41: Swordfish — Correlations between variables, for all fish examined. Black dots show data for individual fish. Box and whisker plots show the median, upper and lower quartiles, and upper and lower extremes. Circle area is proportional to sample size. The plot at the top of each column is a frequency histogram. Month: 1, January–April; 2, May; 3, June; 4, July–December. Sex: 1, male; 2, female; 3, undistinguishable; 4, not examined. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

3.3 Anthropogenic material in stomachs

Anthropogenic litter was found in the stomachs of 16 species (Table 30). No records of plastic or other litter on the outside of fish were made. Most internal items were plastic (i.e., bags, wrap, or strapping), but the records also included foil wrapping, cardboard, fabric, netting, string, and galley waste (see Appendix A). Fish hooks are not included here. For 12 of the species, the frequency of occurrence of litter was very low, comprising less than 1.2% by number of all the items recorded in stomachs. The percentages were higher for kingfish, Pacific bluefin tuna and striped marlin, but these three species returned only one rubbish record each in a relatively small sample size of stomachs examined. Moonfish was the only species that consistently consumed litter; 19% of its recorded prey items were in this category. Most of the recorded items were plastic. Moonfish was much more likely to ingest litter in the Kermadec and Northeast areas than off the southwest coast of South Island (see Table 14).

Table 30: Summary of records of anthropogenic material in predator stomachs, showing numbers of items recorded, and the frequency of occurrence (%FO) as a percentage of the number of all prey items recorded in stomachs.

Species	Stomachs examined	Non-empty stomachs	Rubbish (*n*)	%FO
Mako shark	1 889	993	6	0.60
Porbeagle shark	4 456	1 489	3	0.20
Blue shark	23 217	8 584	32	0.36
Shortsnouted lancetfish	542	381	2	0.52
Longsnouted lancetfish	1 333	849	10	1.18
Moonfish	3 306	1 565	295	18.85
Kingfish	7	5	1	14.29
Ray's bream	7 051	1 560	4	0.26
Butterfly tuna	2 025	949	6	0.64
Albacore	1 612	694	2	0.28
Yellowfin tuna	2 150	967	3	0.31
Southern bluefin tuna	35 413	9 966	72	0.72
Pacific bluefin tuna	150	47	1	2.10
Bigeye tuna	3 130	1 169	2	0.17
Swordfish	6 225	3 494	4	0.12
Striped marlin	33	20	1	5.00

3.4 Influence of moon phase on feeding

Instances where absolute numbers of sampled fish have varied across the lunar cycle were noted under the species descriptions in Section 3.2. To examine whether feeding intensity varied across the lunar cycle, percentages of each predator recorded with prey in their stomachs, by moon phase category, were plotted (Figure 42). Although the percentages of stomachs containing prey varied markedly between predators, there was little within-predator variation across the lunar cycle. Only longsnouted lancetfish, butterfly tuna, and yellowfin tuna varied by more than 10 percentage points. Longsnouted lancet fish stomachs were most likely to be empty around new moon, whereas yellowfin tuna were most likely to contain prey at this time. Butterfly tuna were more likely to contain food items at first quarter than at any other time in the lunar cycle.

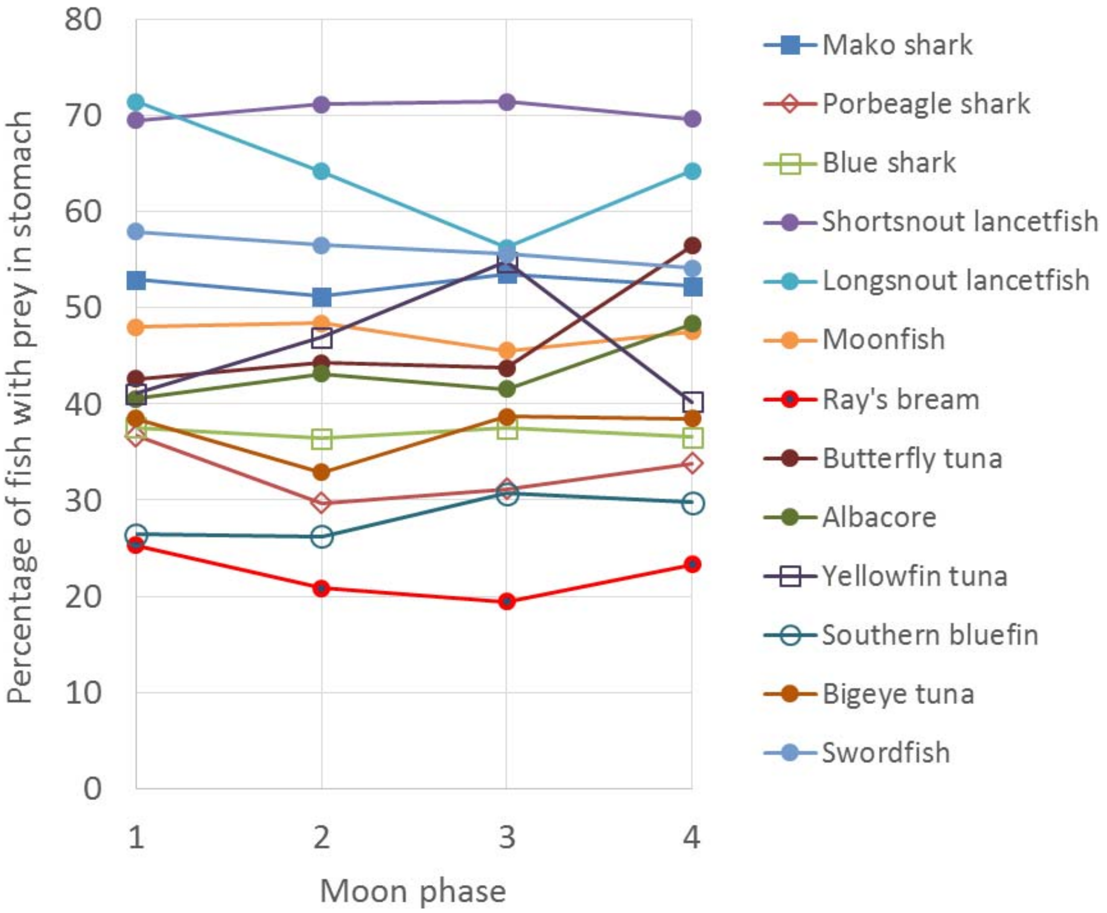


Figure 42: Percentages of stomachs of all predators examined that contained prey items, by predator species and moon phase category. Moon phase: 1, full moon; 2, third quarter; 3, new moon; 4, first quarter.

The influence of moon phase on diet was examined by plotting the mean percentages of diet attributed to each of the five broad prey categories (i.e., fish, cephalopods, crustaceans, salps, and other) for the 13 predators analysed in detail. A visual examination of the diets indicated no differences for the mako, porbeagle, and blue sharks, or for Ray's bream, moonfish, and longsnouted lancetfish (Figure 43). Shortsnouted lancetfish appeared to consume relatively more crustaceans (primarily at the expense of the fish and other prey categories) around full moon and third quarter (Figure 43). Southern bluefin, yellowfin, and butterfly tunas, and swordfish exhibited no variation in dietary composition across moon phase (Figure 44). A slight trend was apparent for bigeye tuna, with the ratio of fish to cephalopods being greatest at new moon and least at full moon. Albacore exhibited some quite marked changes, primarily in the percentage of the 'other' prey category. Unfortunately, there was no additional information that enabled a better definition of the contents of this category.

Figure 43: Mean percentage stomach contents by prey category (fish, cephalopod, crustacean, salp, other) in each of four moon phases, for the sharks, lancetfish, moonfish, and Ray's bream. Moon phase: Ph 1, full moon; Ph 2, third quarter; Ph 3, new moon; Ph 4, first quarter.

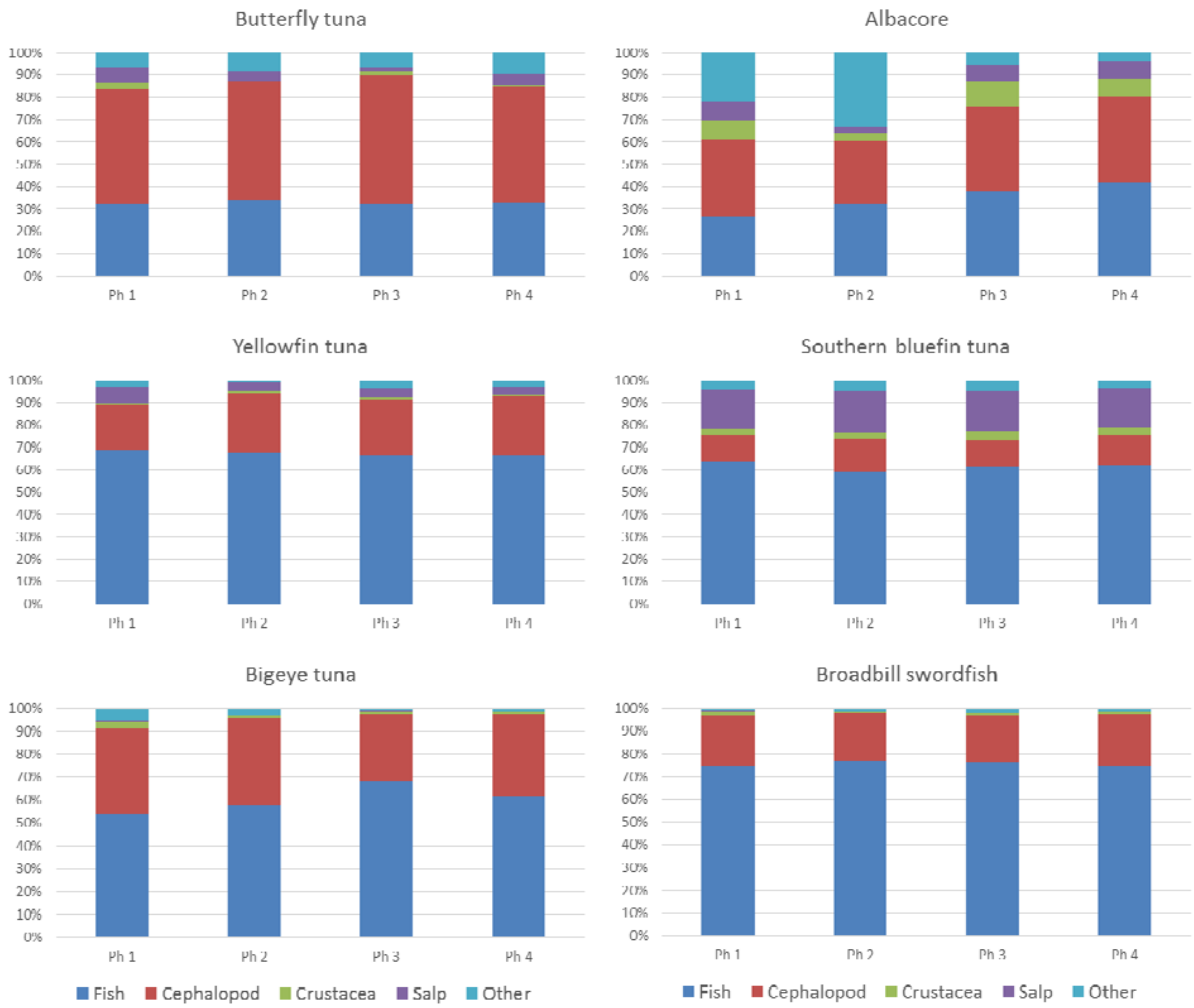


Figure 44: Mean percentage stomach contents by prey category (fish, cephalopod, crustacean, salp, other) in each of four moon phases, for the tunas, and swordfish. Moon phase: Ph 1, full moon; Ph 2, third quarter; Ph 3, new moon; Ph 4, first quarter.

4. DISCUSSION

4.1 Data quality

Information was presented on the diets of an extensive group of species caught during commercial surface longline fishing in and adjacent to the New Zealand EEZ. The species sampled were likely to comprise a reasonable representation of the large carnivorous species (i.e., species willing and able to take a hook baited with fish or squid) occurring in near-surface waters (i.e., the top 300 m of the water column). Clearly, small individuals or species with a mouth gape too small to take a hook would not be sampled even if they occurred in the fished environment. Similarly, species that feed exclusively or predominantly on salps, crustaceans, or plant material were unlikely to be caught, and would certainly not be caught in numbers proportional to their abundance. Shortsnouted lancetfish, a crustacean specialist, probably falls into this category.

The sampling of fish from the longline catch was intended to be roughly random, but because it occurred during targeted commercial fishing it is unlikely that the abundance of an individual species in the samples is an unbiased index of its relative abundance in the fished environment. Target fishing is conducted in a way that aims to maximise the catch of the target species, so the location, timing, hook and bait type, and depth fished will all be tailored to achieve that aim. Target species were likely to be relatively over-represented in the catch, and hence in the samples, while bycatch species were probably under-represented. Also, comments from observers indicated that stomach sampling had a lower priority than some other tasks, so fewer samples might be taken at busy times, leading to a density-dependent bias in sampling effort. It is clear that the sampling of some species was not random in some years, e.g., southern bluefin tuna were heavily sampled in 1994 and 1995, but few other species were.

The diets of 13 species were analysed in detail, but the analyses were limited to summary tables showing the influence of size, sample area, month, and year on diet. The use of a statistical multivariate analysis, such as the DistLM available in PRIMER software (Clarke & Gorley 2006), to identify which biophysical predictors explained most of the variability in diet response (e.g., Dunn et al. 2010a, Horn et al. 2013) would have been ideal, but was not practical here owing to the lack of resolution of the prey data (i.e., ‘fish’, ‘crustacean’, and ‘squid’ were seldom identified in any more detail). The analysis would have been driven by the generally dominant, but uninformative ‘unidentified fish’ component. Ignoring the ‘unidentified fish’ component would strongly bias the diets towards non-fish components, and the unidentified fish prey components could not logically be scaled up to the relatively sparse identified components without a serious risk of obscuring any real ontogenetic, spatial, or temporal effects. Also, because the identified items were unlikely to represent a random sample of the prey consumed by a predator, up-scaling of these items would produce a biased estimate of overall diet.

Based on a knowledge of how the database administrator interprets comments written by observers and enters them in the ‘office codes’ attributes of the database table, and on the answers given by observers to questions presented in Appendix C, it is clear that there were some shortfalls and inaccuracies in the available data, and they are listed here.

- Where additional information was recorded for some prey items there will have been some misidentifications. For example, some lighthouse fish (PHO) were likely to have been lanternfish (LAN), and vice versa. Consequently, these two species were grouped in all our analyses. Crustaceans identified as krill were probably euphausiids, but could have been amphipods, squat lobsters (*Munida* sp.), or small decapod prawns.

- There is often no knowledge on what the ‘other’ prey component comprised. This is very uninformative, particularly for species where ‘other’ comprised a significant component of the diet, e.g., lancetfish, moonfish, albacore.

- Some additional information provided by observers in the comments field of the data form was lost because there was no facility for it in the database. For example, if a stomach was recorded to contain 100% fish, with a comment that the fish was 80% RBM and 20% LAN, then at best the contents would have been recorded on the database as RBM, because there is space for only one fish prey code. Similarly, there is only one space to enter specific codes for each of the crustacean and ‘other’ prey categories.

- There is no facility in the database to record any additional information for prey items in the squid or salp categories. Sometimes, octopus and nautilus were recorded as components of the ‘other’ category, with a comment noting this, resulting in this information being included in the database. It is likely, however, that octopus and nautilus prey were sometimes simply recorded as a percentage in the squid category, with no additional comment.

- In some instances, stomachs containing only cephalopod beaks were recorded as being empty.

- Sometimes, data ‘created’ by the database administrator will be incorrect. For example, if a stomach contained 90% unidentified digested fish and 10% lanternfish, and the observer noted only the identified portion (lanternfish) in the comments, then the information recorded on the database would imply a stomach containing 100% lanternfish.

- There is no facility on the form or in the database to record any information on stomach fullness. The data recorded were the percentages of total prey volume made up by a particular prey category. This could lead to the importance of generally small prey items being overstated (e.g. a stomach containing one prawn would have the same data weighting as a stomach containing one Ray’s bream, despite the Ray’s bream contributing much more to the diet than the prawn).

- There is no facility in the database to record any information on the digestive state of the prey items although sometimes the comments recorded by observers provide some information on this (e.g., fresh lanternfish, squid beaks only).

- Bait items were generally identifiable in stomachs. There could be some difficulty, however, when small whole fish were used as bait, or when bait had been digesting in the stomach for some time.

Most of the data shortfalls and misinterpretations could be easily solved by redesigning the Stomach Sampling Form (see Figure 2). An alternative form design is shown in Appendix D. The amount of data proposed to be collected is little different to the current sampling regime. Codes to identify the degrees of prey digestion and stomach fullness can be added. Up to five categories of prey, and the percentage of the total prey volume they comprise, would be recorded by the observer. Any comments noted by the observers would be recorded on the database.

It would be useful to have information on the time and depth of capture of individual fish. Time of capture would allow an analysis of diel trends in feeding activity, by species. Depth of capture would provide information on preferred feeding depths by species, and, when combined with time of capture, would enable an investigation of trends in vertical migration with time. Neither time nor depth of capture can be reliably inferred from the available data. The time between the setting of the first hook and and the hauling of the last hook in a set is usually in the order of about 20 hours (Murray et al. 1999), and a captured fish can take the hook any time between setting and hauling. Capture depth in the current analysis is assumed to be the average of the maximum and minimum hook depths of each set, with these two metrics estimated by the vessel skipper. The average difference between minimum and maximum depths for the sets used here is 85 m, with the range between maximum and minimum of 3 to 240 m. Consequently, actual capture depth is often likely to be markedly different to the estimated average depth. It is of note, also, that since about 2004 there have been many more sets closer to the surface (i.e., less than 60 m deep) than occurred before this date.

4.2 Diet summaries

Information on dietary composition was derived from large sample sizes, and despite the data quality problems, the diets of the most abundant species were described. In this section, these diets are compared with published information for the same species elsewhere.

Mako shark

Diet of mako sharks from a sample of 17 stomachs off eastern Australia was exclusively teleosts, with 90% of the prey weight being tuna (Young et al. 2010). Off southern Australia, teleosts dominated the prey weight, with barracouta being the most abundant species, but with cephalopods (primarily arrow squid) contributing significantly to the diet (Rogers et al. 2012). The Australian mako diets were similar to that derived in the current study, with large mesopelagic teleosts being dominant (tunas and barracouta off Australia, tunas and Ray's bream off New Zealand), and squid being of secondary importance. Sharks can switch to different prey in different habitats, however, and this was demonstrated for mako by Stillwell & Kohler (1982).

Porbeagle shark

Joyce et al. (2002) reviewed the relatively sparse data on porbeagle diet and noted that prey comprised numerous species of epibenthic and pelagic teleosts (frequently mackerel and herring) and squids. The same authors examined 1022 porbeagle stomachs from the northwest Atlantic and found that the diet was diverse, comprising about 43% (by weight) groundfish, 26% pelagic teleosts, 5% squid, and 4% spiny dogfish, with most of the remainder being unidentified teleosts. The New Zealand porbeagle diet was similarly diverse, but with a greater abundance of squid than in the diet reported by Joyce et al. (2002). An ontogenetic shift from cephalopods and small pelagic fish to large teleosts as fish size increased was apparent for both New Zealand and northwest Atlantic porbeagles. A change in the northwest Atlantic diet, where pelagic fish and cephalopods were dominant in spring while groundfish dominated the autumn diet, was attributed to a seasonal migration of the sharks from deep to shallow waters (Joyce et al. 2002). In New Zealand, cephalopods were relatively less abundant in the January-May (essentially autumn) diet.

School shark

School shark were the thirteenth most abundant species sampled from the surface longline catch, but their diets were not analysed in detail here. However, a comprehensive dietary analysis for the species on the Chatham Rise, New Zealand, was available (Dunn et al. 2010b) and it showed a diet consisting largely of fish (benthic, demersal, and mesopelagic), with some crustaceans (benthic and mesopelagic), cephalopods (mainly squid, but also octopus) and salps. The prey species composition reported by Dunn et al. (2010b) matched closely with this study (see Table A5).

Blue shark

A review of blue shark diet indicated that offshore individuals fed on mesopelagic cephalopods with a smaller component of teleosts, whereas inshore (waters less than 500 m deep) diets were dominated by teleosts (particularly gadoids, scombrids, and clupeoids) with a secondary component of neritic cephalopods (Markaida & Sosa-Nishizaki 2010). A sample of 108 stomachs from blue shark off eastern Australia showed that they fed approximately equally on cephalopods (mainly arrow squid, but with an octopus component) (55% by weight) and teleosts (primarily Ray's bream and jack mackerel) (Young et al. 2010). The sharks fed day and night. The Australian diet was very similar to that derived in the current study, with both analyses also showing a strong ontogenetic shift from cephalopods to teleosts as blue shark size increased.

Lancetfish

The diets of two species of lancetfish (shortsnouted, *Alepisaurus brevirostris,* and longsnouted, *A. ferox*) were examined in the current study, and it was clear that they differed markedly. Shortsnouted lancetfish fed on mesopelagic crustaceans, with fish as an important secondary component. Longsnouted lancetfish fed on equal proportions of fish and cephalopods, but with salps as an important secondary component (although salps decreased in importance if data before 1998 were excluded, i.e., when lancetfish species were not distinguished). No published accounts of the diet of *A. brevirostris* were found, however diets of *A. ferox* in the Pacific, Indian, and Atlantic Oceans have been described (e.g., Haedrich & Nielsen 1966, Fujita & Hattori 1976, Kubota 1977, Matthews et al. 1977, Moteki et al. 2001, Satoh 2004, Potier et al. 2007a, 2007b, Romanov & Zamorov 2007). Diet at a particular location could be strongly dominated by a particular prey species or taxonomic group e.g., hatchetfish in the eastern tropical Pacific Ocean (Moteki et al. 2001), crustaceans in the western Indian Ocean (Potier et al. 2007a, b). But when examined across areas, or across seasons within areas, a wide variety of prey items were recorded (Kubota 1977). Common prey items included pelagic crustaceans (amphipods, shrimps, swimming crabs and crab larvae), pelagic polychaetes, cephalopods (squid and octopus), other pelagic molluscs (heteropods and pteropods), tunicates, and small fishes (primarily epipelagic and mesopelagic species like hatchetfish, barracudinas, pufferfish, and young lancetfish). In summary, *A. ferox* worldwide are opportunistic predators feeding on slow-swimming epipelagic and mesopelagic crustaceans, cephalopods and fish. Feeding was likely to be concentrated in daylight hours (Haedrich & Nielsen 1966, Matthews et al. 1977, Satoh 2004, Potier et al. 2007a)

The current study found that both *Alepisaurus* species exhibited ontogenetic shifts away from small non-fish prey towards fish and cephalopods as they grew. Ontogenetic dietary changes have been seldom commented on by other authors; Matthews et al. (1977) noted that polychaetes were found mainly in stomachs of small *A. ferox,* and Romanov & Zamorov (2007) showed that large *A. ferox* (FL over 100 cm) exhibited higher rates of cannibalism and contained greater proportions of large evasive prey species than small lancetfish. Cannibalism has been noted regularly for *A. ferox,* with conspecifics sometimes being the most abundant prey (Haedrich & Nielsen 1966, Matthews et al. 1977, Moteki et al. 2001, Satoh 2004, Potier et al. 2007a, 2007b, Romanov & Zamorov 2007). Haedrich & Nielsen (1966) and Fujita & Hattori (1976) noted both *A. ferox* and *A. brevirostris* as prey for *A. ferox* in the southern Pacific Ocean. This observation was in agreement with the current findings that both *Alepisaurus* species prey on their conspecific and congeneric, and that *Alepisaurus* prey was a major dietary component for *A. ferox* in New Zealand waters.

Marked differences in the diets of both lancetfish species can occur between locations and times. In the current study, both species were sampled predominantly in the same area (from the Bay of Plenty to the east of East Cape). Sampling levels varied markedly between years, with little overlap, but in 2001 substantial samples were collected for both species, primarily in January. The stomach contents from the 2001 samples were compared. The diet for *A. brevirostris* from these samples (*n* = 251 non-empty stomachs) was dominated by crustaceans (78% average volume), with fish (13%) being the secondary component. The *A. ferox* diet (*n* = 150) was dominated by cephalopods (60%), with fish (28%) also being the secondary component. Both species had similar levels of salps (4%). This analysis indicated that although the lancetfish diet might vary over time and space, when the two species were at the same location they differ in their prey selection. There may be a subtle between-species difference in preferred water temperature, as *A. brevirostris* was sampled most frequently where SST range from 19 to 22.5 °C and *A. ferox* was most abundant where SST was 17–21 °C.

Moonfish

Information on the diet of *Lampris* species is scarce. Anecdotal information from Hawaii-based commercial longline fishers suggested a dominance of squid in the diet of *Lampris* spp. (Polovina et al. 2008). Choy et al. (2009) noted the prey of *Lampris* spp. off Hawaii to be strongly dominated by upper mesopelagic species (i.e., species with median daytime depths of 200–600 m, as opposed to epipelagic or lower mesopelagic), but provided no list of actual prey items. Choy et al. (2013) reported that the diet of *Lampris* spp. consisted of large numbers and frequent occurrences of the onychoteuthid squid *Walvisteuthis youngorum*, as well as a diverse range of micronekton species from the animal groups fishes, cephalopods, crustaceans (particularly hyperiid amphipods (Choy & Drazen 2013)), and gelatinous animals. This broad diet range contrasts with a relatively narrow range reported for southern opah (*Lampris immaculatus*) along the Patagonia Shelf by Jackson et al. (2000). The most common prey for the southern species was the deepwater onychoteuthid squid (*Moroteuthis ingens*), but with other squid, myctophids and anthropogenic litter also being moderately abundant. Choy & Drazen (2013) also found *Lampris* spp. in the central North Pacific Ocean to be a frequent consumer of plastic. The *L. immaculatus* diet reported by Jackson et al. (2000) was very similar to that derived here for *L. guttatus* with squid numerically dominant and small mesopelagic fish species and anthropogenic waste important.

Moonfish was the only species examined here that was found to ingest significant quantities of anthropogenic litter, mainly plastic, and it is logical to assume that moonfish mistake these items for gelatinous animals. Because most plastics float (Choy & Drazen 2013), it was indicative of significant epipelagic feeding. However, Polovina et al. (2008) found that moonfish seldom ascended to depths shallower than 50 m, and were generally in depths of 100–400 m during the day and 50–150 m during the night. A preponderance of feeding in the mesopelagic layers, rather than the epipelagic, was also concluded by Choy et al. (2009). The frequent occurrence of species like hatchetfish, lanternfish and lighthouse fish in stomachs of New Zealand moonfish was also indicative of feeding below the epipelagic zone.

Ray’s bream

Virtually all of the Ray’s bream examined in this study were likely to have been the southern Ray’s bream (*B. australis*), with the few individuals around East Cape more likely to have been *B. brama*. Some information was available on the preferred prey of *B. australis* off Chile; it included euphausiids, small pelagic fishes and squid (Muñoz et al. 1995; Garcia & Chong 2002). A comprehensive dietary study, however, was completed for trawl-caught *B. australis* on the Chatham Rise, New Zealand (Horn et al. 2013), showing a diet dominated by myctophids, pearlside (*Maurolicus australis*), hyperiid amphipods, and euphausiids. Salps and *Sergestes* species shrimps were also relatively abundant. There was a clear ontogenetic shift in diet with bream larger than about 44 cm FL feeding on fish, and with most of the amphipods and salps taken by smaller bream. Variations in diet were also related to moon phase, bottom depth, and location on the Chatham Rise (Horn et al. 2013). The diets for Ray's bream caught by longline primarily off southwest South Island and trawl on Chatham Rise were quite similar, with myctophids dominant in both areas and the main differences being relatively more crustaceans and fewer cephalopods on Chatham Rise.

Butterfly tuna

The only published information on the diet of butterfly tuna was a description of cephalopods removed from 16 stomachs collected in the eastern South Pacific, most of which were mesopelagic species (Tsuchiya & Sawadaishi 1997), and notes on the stomach contents of a specimen from north of Hawaii which included onychoteuthid and ommastrephid squids, vertebrae and fin rays from an unidentified fish, and bird feathers (Ito et al. 1994). A diet dominated by squid, but with fish and other items present, matched the findings from the current study.

Albacore

The diet of albacore off eastern Australia was strongly dominated by squid, primarily ommastrephids, with the residual diet being mainly lancetfish and myctophids (Young et al. 2010). Albacore examined under the current study fed on almost equal proportions of fish and squid, but the suite of teleost prey was very similar to that recorded off Australia. Off Australia, most feeding occurred during daylight hours at depths around 200 m (Young et al. 2010), although studies of albacore in other areas showed variations in the time and depth of feeding, and in overall diet composition, with season and location (e.g., Matthews et al. 1977, Glaser 2010, Goñi et al. 2011). These studies found that albacore fed mainly on fishes (primarily small mesopelagic species like myctophids, barracudinas, and hatchetfish, and epipelagic species like saury and anchovy), and cephalopods, with crustaceans (primarily pelagic species and larvae) making up a small portion of the diet. Crustaceans were found to be the dominant prey at some locations (Goñi et al. 2011). Ontogenetic changes in diet were shown in some studies (Young et al. 2010, current study), but not in others (Consoli et al. 2008).

Yellowfin tuna

The diet of yellowfin tuna has been extensively investigated in the Indian (Rohit et al. 2010), Atlantic (Matthews et al. 1977, Vaske & Castello 1998, Vaske et al. 2003, Rudershausen et al. 2010), and Pacific (Ortega-García et al. 1992, Kim et al. 1997, Ménard et al. 2006, Graham et al. 2007, Choy et al. 2009) Oceans, and in the Tasman Sea (Young et al. 2010). These studies showed that yellowfin feed on a wide variety of items, primarily teleosts and squids, but also crustaceans. In most areas the diet was dominated by a few families of prey, often epipelagic teleosts, ommastrophid squid, or hyperiid amphipods, suggesting near-surface feeding. However, feeding on some deeper species of teleosts in some areas and times has been noted (Rohit et al. 2010, Young et al. 2010). This study found that in New Zealand mesopelagic teleosts make up the bulk of the diet, but with a significant contribution by cephalopods. Interestingly, of the 13 New Zealand species investigated in detail, only yellowfin tuna had a significant flying fish (Exocetidae) component in its diet. This prey group has been recorded frequently from yellowfin in other areas (e.g., Matthews et al. 1977, Rudershausen et al. 2010, Young et al. 2010), and was the dominant dietary component in one area (Vaske et al. 2003).

Seasonal (Vaske & Castello 1998) and ontogenetic changes (Graham et al. 2007) in diet were observed. Feeding by yellowfin off eastern Australia occurred predominantly between midday and midnight (Young et al. 2010); off Mexico Ortega-García et al. (1992) recorded greatest stomach fullness in late morning and early evening. Yellowfin tuna are opportunistic predators with a very broad forage base.

Southern bluefin tuna

Studies of the southern bluefin diet have examined fish off the coasts of Australia (Serventy 1956, Young et al. 1997, Kemps et al. 1998, Ward et al. 2006, Young et al. 2010, Itoh et al. 2011) and New Zealand (Robins 1963, Webb 1972). Diets were generally dominated by fish, primarily epipelagic teleosts like pilchard, blue mackerel and jack mackerel. Squid, most commonly *Nototodarus*, were sometimes a significant secondary component, and actually dominated the diet of offshore southern bluefin tuna east of Tasmania (Young et al. 1997). Small pelagic crustaceans, often the amphipod *Phronima sedentaria* (Talbot & Penrith 1963), and tunicates were usually recorded, but not usually in significant quantities (i.e., less than 2% of prey weight). Nine southern bluefin tuna, caught on longlines off southwest New Zealand, contained Ray's bream and salps (Webb 1972). Ray's bream was also a significant component of the fish prey of large southern bluefin off eastern Australia (Young et al. 2010) and New Zealand, but this study is the only one to identify salps as significant contribution to the diet. The reported diets are characteristic of feeding primarily in the epipelagic zone, but with some deeper feeding excursions. Peaks in feeding activity were likely to occur just after sunrise and again in the evening (Talbot & Penrith 1963, Young et al. 1997). Ontogenetic changes in diet were noted in the current study and by Young et al. (1997), with a reduction in squid prey and an increase in large mesopelagic teleosts as fish grew.

Bigeye tuna

Reported diets of bigeye tuna have generally been dominated by fish (Matthews et al. 1977, Grundinin 1989, Kim et al. 1997, Bertrand et al. 2002, Ménard et al. 2006, Vaske et al. 2012), but occasionally by squid (Xu et al. 2008), and all studies also noted an important crustacean component. Results from the current study support this. In the Atlantic fish prey of bigeye were predominantly from the families Bramidae, Alepisauridae, Omasudidae and Paralepididae, all mesopelagic species (Matthews et al. 1977, Vaske et al. 2012). In the Indian Ocean, however, Xu et al. (2008) recorded the squid *Loligo* as the most abundant prey, followed by an epipelagic mackerel *Scomber*, a *Penaeus* prawn, and the demersal crab *Portunus trituberculatus*. The diet off Hawaii was strongly dominated by epipelagic prey (Choy et al. 2009), while in the western tropical Pacific, mesopelagic species (primarily Myctophidae and Alepisauridae) were dominant (Kim et al. 1997). Bertrand et al. (2002) found that bigeye tuna in the central Pacific preyed on myctophid aggregations as well as piscivorous fishes and mesopelagic squids. The reported diets are consistent with the vertical behaviour of bigeye, occurring most commonly in depths ranging from 150 to 600 m (Grundinin 1989, Dagorn et al. 2000, Vaske et al. 2012). Grundinin (1989) concluded that bigeye tuna probably fed predominantly during daylight hours, and although Young et al (2010) concluded that feeding occurred both day and night, most of their timed captures were from late afternoon to early morning. Ontogenetic changes in diet were noted in the current study and also by Kim et al. (1997) and Ménard et al. (2006) with a shift towards larger mesopelagic fish as size increased.

Swordfish

Diets of swordfish from a sample of 638 stomachs off eastern Australia were dominated by ommastrophid squid, followed by the teleost *Cubiceps* (Young et al. 2006, 2010). In the

Pacific and Atlantic Oceans cephalopods are frequently reported as the main diet (e.g., Velasco & Quintans 2000, Ibáñez et al. 2004, Markaida & Hochberg 2005, Chancollon et al. 2006). In New Zealand (current study) and the central Indian Ocean (Clarke et al. 1995, Ribeiro Simões & Andrade 2000, Potier et al. 2007a) fish dominated the diet. Off eastern Australia, however, Young et al (2006) found differences inshore and offshore where cephalopods dominated the prey offshore and fish were the main prey in inshore waters. Crustaceans were usually reported to be a minor or negligible food item, however it was clear that copepods and shrimps are important for juvenile swordfish (Velasco & Quintans 2000, Govoni et al. 2003). Swordfish was the only species in the current study to prey on significant amounts of hoki (*Macruronus novaezelandiae*), although the major teleost prey of swordfish was Ray's bream. It appears that swordfish are opportunistic predators with a broad forage base that varies between area and season. Ontogenetic changes in prey have been noted and usually involved a shift from smaller to larger teleosts, and a shift away from crustaceans, as swordfish grew (Velasco & Quintans 2000, Chancollon et al. 2006, current study). Swordfish probably fed predominantly at night (Markaida & Hochberg 2005, Young et al. 2010), and probably more intensively around full moon (Draganik & Cholyst 1988). They were rarely caught below 150 m depth off eastern Australia (Young et al. 2010).

4.3 Inter-specific resource partitioning

If resources are limited, competition for those resources will arise. Potential inter-specific competition for prey can be reduced through various mechanisms such as for species to segregate themselves in time and/or space within the habitat, or to have different diets. There are difficulties, however, in evaluating when competition between marine fishes is actually occurring (Link & Auster 2013), as the exploitation of the same resource by two species occurring in the same time and place does not necessarily indicate true competition. Competition only occurs when resources are limited and has not been shown to occur between any of the species evaluated here. Nevertheless, the spatial and dietary differences between the 13 species analysed in detail are discussed below, giving consideration as to how the differences may reduce potential conflicts in resource use.

The three large highly migratory shark species (mako, porbeagle, and blue shark) occurred in all four areas (Kermadec, Northeast, Southwest and Southeast), although mako were uncommon in Southeast, and porbeagle were scarce in Kermadec. Mako appeared to be particularly abundant off East Cape; porbeagle were most commonly caught off the southwest of South Island; and blue shark were abundant in all areas where the longline fishery occurred. So although all species overlap spatially, there were differences between the main areas of abundance between mako and porbeagle sharks that could reduce conflicts in resource use. The diets of these two species were relatively similar, both dominated by fish prey, although more so for mako (87% fish) than porbeagle (64%). Both had cephalopods (mainly squid) as their important secondary dietary component.

Ontogenetic changes were similar for mako and porbeagle; small mesopelagic fish and cephalopods are important for small sharks while large mesopelagic teleosts make up the bulk of the diet of large sharks. In the Southwest, where both species overlapped considerably, Ray's bream was a significant component of the large mesopelagic species prey for mako and porbeagle, but it did appear that mako also consumed other sharks and tunas, while porbeagles targeted dealfish. Latitudinal differences in the large mesopelagic prey were also apparent. Mako predominantly ate Ray's bream is the south, and albacore and other tunas in the north; porbeagle targeted Ray's bream and dealfish in the south and other (non-tuna) large mesopelagics in the north. Mako reached a larger maximum size than porbeagles and were able to feed on large prey like tunas and swordfish that were seldom found in the stomachs of porbeagles. In conclusion, differences in distribution, the ratio of fish to squid prey, and dietary preferences for particular teleosts may act to reduce competition between mako and porbeagle sharks.

Blue sharks had a diet consisting of cephalopods (about 50%) and fish (40%), with minor crustacean and salp components. Their diet changes as they grow with small mesopelagic fish and cephalopods (as well as crustaceans and salps) for small blue sharks and large mesopelagic teleosts for large individuals. Blue shark targeted the larger mesopelagic species such as Ray's bream and dealfish in the south, and tunas and other species in the north. Blue shark and mako were the largest predators examined in this study, and both regularly exploited large prey species such as tuna and billfishes that were not found in the diets of other species examined. Blue shark was the only species examined here that had frequent occurrences of birds and marine mammals in its stomach, which may be indicative of some surface foraging. So while blue sharks occur in the same areas as mako and porbeagle they feed mostly on cephalopods and other non-fish prey, which may act to reduce any competition with the other large sharks.

The two lancetfish (shortsnouted, *Alepisaurus brevirostris*, and longsnouted, *A. ferox*) had strongly overlapping distributions in the Northeast. The longsnouted species was not uncommon off the southwest of South Island. Shortsnouted lancetfish had a diet dominated by mesopelagic crustaceans, with fish prey as an important secondary component. They were the only species examined in detail in this study that had a crustacean-dominated diet. Longsnouted lancetfish had cephalopods and fish as the most dominant item in their stomachs, with salps as an important secondary component. Both lancetfish species exhibited ontogenetic shifts away from crustaceans (shortsnouted) or salps (longsnouted), and towards fish and cephalopods, as they grew. Clearly, although the lancetfish species overlapped geographically, the marked differences in their preferred diets might reduce resource use conflicts between them. Both species preyed on their conspecifics.

Moonfish occurred in all areas, although they were relatively scarce in Southeast. They had a diet dominated by fish and cephalopods, but with a relatively diverse selection of other components similar to longsnouted lancetfish. An ontogenetic shift was apparent away from smaller prey items (small mesopelagic fish, salps, and crustaceans) towards larger mesopelagic fish species. There was also an increase in anthropogenic waste in stomachs of large moonfish (15% of stomach contents volume; with less than 1% for all other species), possibly because larger fish consumed more waste, or because the matter is not digested or ejected from the stomachs, and so accumulated as the fish aged and grew.

Ray's bream, probably southern Ray's bream, *Brama australis*, were caught frequently off southwest South Island, with small numbers of southeast South Island (*B. australis*) and East Cape (probably *B. brama*). Their diet was dominated by fish, with important secondary components of cephalopods, salps, and crustaceans. The fish prey was almost exclusively 'lanternfish' (i.e., Myctophidae and *Photichthys argenteus*). This is markedly different from all other species examined, probably because Ray's bream is the smallest species under study. Ray's bream were preyed on by several of the larger fish examined here (mako, porbeagle, and blue sharks; southern bluefin and bigeye tuna; and swordfish).

Seven tuna species were examined, two (slender and Pacific bluefin) were relatively uncommon and did not warrant detailed analysis. Of the species that were analysed, four were large (butterfly, yellowfin, southern bluefin, and bigeye) and one (albacore) was relatively small. Albacore overlapped the distributions of the four large tuna species in Northeast, and butterfly and southern bluefin tunas in Southwest. The albacore diet was relatively diverse, with approximately equal proportions of fish, squid, and other prey categories, and individual items were generally small (e.g., small mesopelagic fish and crustaceans, and salps). Albacore diet was markedly different to yellowfin, southern bluefin, and bigeye tuna, which have diets consisting of fish (about 60%) dominated by large mesopelagic species. There could be some competition between albacore and butterfly tuna if food was limited where their distributions overlap; butterfly tuna had a diet about half squid and one-third fish (including both small and large mesopelagics). Butterfly tuna appeared to be most abundant off southeast South Island where albacore were essentially absent.

The distributions of yellowfin and bigeye tuna were the same, although bigeye appeared to be sampled relatively more often in Northeast and yellowfin in the Kermadecs. No temporal differences in the distributions of these two species were apparent. Their diets also showed some similarities, about two-thirds fish followed by cephalopods (both squid and nautilus). Both species fed on smaller prey items (e.g., crustaceans) as young fish and larger mesopelagic fish as their size increased. However some differences were apparent. Salps were a minor but notable prey item for yellowfin, but a negligible component for bigeye tuna. Small mesopelagic species were taken more frequently by yellowfin tuna; Ménard et al. (2006) also found that bigeye tuna selected larger prey than yellowfin when such prey were available. Both species targeted skipjack tuna, but flying fish and pufferfish were taken more frequently by yellowfin tuna, and Ray's bream and lancetfish were taken more frequently by bigeye tuna. This suggests that yellowfin foraged nearer the surface, whereas bigeye were more likely to forage in deeper water. The physiological difference in eye size (i.e., the bigeye tuna has a bigger eye) also indicated that that species may feed in a darker (and deeper) habitat than the yellowfin. Bigeye are more abundant in cooler, deeper waters below the thermocline, and yellowfin occur in warmer, shallower surface waters (Grundinin 1989). While there may be considerable overlap in diet, differences have been shown (Kim et al. 1997). Small-scale spatial differences relating to preferred depth probably result in different diets of yellowfin and bigeye tuna.

The distribution of southern bluefin tuna overlapped those of all the other tuna species, but particularly albacore and butterfly tuna. Like most of the other large tuna species, southern bluefin diet was dominated by fish, but the species they feed on were quite different to the other tunas. 'Lanternfish' (i.e., Myctophidae and *Photichthys argenteus*) were taken by all sizes of southern bluefin, while Ray's bream are taken predominantly by larger individuals. Salps were of secondary importance (comprising 18% by volume), particularly in the Southwest area. Albacore and yellowfin also feed on small quantities of salps. Cephalopods, mainly squid, were also relatively important in the southern bluefin diet. Southern bluefin tuna have a similar diet to butterfly tuna and albacore, where all three species feed on lanternfish and their distributions overlapped comprehensively. Southern bluefin and bigeye tuna both feed on Ray's bream in the Northeast where their distributions overlap.

Swordfish were caught regularly in all areas except Southeast, and were particularly abundant in Northeast. Their diet was quite similar to the tuna, with fish dominant and squid as a secondary component of the diet. Relatively few fish prey were identified, but similar to larger southern bluefin and bigeye tuna, Ray's bream were an important prey for larger swordfish. Unlike tuna, however, items of prey other than fish or cephalopods were negligible in their diet. Swordfish was the only predator examined in this study that regularly consumed the merluccids hoki and hake. Potier (2007a) found that where the distributions of swordfish and yellowfin tuna overlapped, competition for prey was probably limited as swordfish feed in deeper water and on larger prey than yellowfin.

In conclusion, although most of the prey items in the dataset were identified to only a coarse level (fish, cephalopod, crustacean, or salp), there was often sufficient information available to enable conclusions to be drawn on diet. This, in turn, allowed postulation on resource partitioning. Although some prey species (e.g., Ray's bream) were found to be targeted by several of the predators, other species that are abundant (e.g., hoki) were only found in the stomachs of a single species. Unfortunately, squid prey were virtually never identified to species level, so it is not known what squid species were preferred by the various predators.

Cephalopods are frequently fed on by all species examined. However, there are probably numerous species in this group and it is likely that different predators would feed on different cephalopod prey which would create a division of available resources (Young et al. 2010). The data available for this analysis provided no fine-scale information on preferred depths and feeding times of predators, or preferred prey sizes. Characteristics such as these have been shown to explain niche segregation of oceanic top predators occurring off eastern Australia (Young et al. 2010). For example, resource use conflicts between yellowfin and bigeye tuna may be reduced by different feeding times and preferred depth distributions. Young et al. (2010) concluded that feeding habits were influenced by prey size, preferred predator depth distributions and feeding times. When factored together these could differentiate predators caught by the longline fishery off eastern Australia.

4.4 Other trends

Some trends were apparent from this study that probably have little influence on the partitioning of resources between species, but are interesting from a dietary perspective nevertheless.

For all three shark species, fish was most dominant in all diets from January to May–June, and less important at other times of the year. For blue shark, fish was superceded by cephalopods as the most dominant group from June to December. These trends may be indicative of a greater relative availability of cephalopods in the latter half of the calendar year.

As would be expected, some prey species were clearly abundant in only part of the area under investigation, e.g., Ray's bream was consumed primarily in Southwest. It is possible that salps are more abundant in Southwest relative to the other three areas as they are more frequently encountered in the stomachs examined in that area.

For most of the large species examined, small individuals are more likely to have empty stomachs than larger individuals.

5. IMPLICATIONS FOR ECOSYSTEM APPROACHES TO FISHERIES MANAGEMENT

A goal of the National Fisheries Plan for Highly Migratory Species (Ministry of Fisheries 2010) is to implement an ecosystem approach to fisheries management, and to maintain food chain relationships and conserve trophic linkages. The first step towards this goal is to determine what the trophic linkages are. The research reported here examined the stomach contents data collected by observers from an extensive selection of species caught by surface longline around New Zealand. Although large volumes of data were available, its quality, in terms of the precision of prey species identification, was not adequate to allow any useful multivariate analyses. Recommendations for a modified Stomach Samples Log are presented in Appendix D. Subsequent analyses using the data collected as recommended are likely to allow more statistically rigorous results to be produced.

The information derived from the current analysis is descriptive, informative, and useful. It may allow the production of at least a qualitative or semi-quantitative ecosystem model for the pelagic environment in New Zealand waters, including descriptions of trophic linkages and information on the trophic status of the main species caught in the surface longline fishery.

6. ACKNOWLEDGMENTS

We thank the many Ministry for Primary Industries observers who were involved in the collection of data at sea, the observers who provided answers to the questions in Appendix C, Steve Brouwer (MPI) for creating the draft Stomach samples Log in Appendix D and for a review of the document, and the members of the HMS and AEBR Working Groups for providing useful comments and suggestions on the development of these analyses. Matthew Dunn (VUW) is thanked for ongoing discussions and guidance throughout the duration of this project, and for providing a valuable review of this document. The work was funded by the Ministry for Primary Industries under project ZBD2011-01.

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APPENDIX A: Frequency of prey items by predator species

Details of all the stomach contents identified for each species for which ten or more stomachs containing food were recorded. Species are listed in taxonomic order. *N*, number of stomachs containing food; Count, the number each prey identified in all stomachs; %F, percentage frequency of non-empty stomachs containing the identified prey item.

Table A1: Smooth skin dogfish, *Centroscymnus owstoni*, (*N* = 76).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Macruronus novaezelandiae*	Hoki	1	1.32
	Fish unidentified	Fish unidentified	17	22.37
Mollusca	Teuthoidea	Squid undetermined	53	69.74
	Octopoda	Octopus undetermined	4	5.26
Crustacea	Prawn unspecified	Prawn unspecified	3	3.95
	Crustacea unspecified	Crustacea unspecified	2	2.63

Table A2: Thresher shark, *Alopias vulpinus*, (*N* = 102).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Photichthys argenteus*	Lighthouse fish	3	2.94
	Myctophidae	Laternfish	7	6.86
	Macruronus novaezelandiae	Hoki	1	0.98
	Trachipterus trachypterus	Dealfish	1	0.98
	Brama sp.	Ray's bream	24	23.53
	Katsuwonus pelamis	Skipjack tuna	1	0.98
	Thunnus alalunga	Albacore	3	2.94
	Fish unidentified	Fish unidentified	55	53.92
Tunicata	Tunicata	Salp	1	0.98
Mollusca	Teuthoidea	Squid undetermined	5	4.90
Other	Other unidentified	Other unidentified	4	3.92

Table A3: Mako shark, *Isurus oxyrinchus*, (*N* = 993).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Isurus oxyrinchus*	Mako shark	1	0.10
	Lamna nasus	Porbeagle shark	1	0.10
	Galaeorhinus galeus	School shark	1	0.10
	Prionace glauca	Blue shark	15	1.51
	Sphyrna zygaena	Hammerhead shark	1	0.10
	Shark unspecified	Shark unspecified	2	0.20
	Conger sp.	Conger eel	1	0.10
	Anguilliformes	Marine eel unspecified	1	0.10
	Stomias sp.	Stomiatidae	1	0.10
	Alepisaurus ferox	Longsnouted lancetfish	6	0.60
	Macruronus novaezelandiae	Hoki	5	0.50
	Merluccius australis	Hake	1	0.10
	Hyporhamphus ihi	Garfish	2	0.20
	Scomberesox saurus	Saury	6	0.60
	Lampris guttatus	Moonfish	1	0.10
	Trachipterus trachypterus	Dealfish	13	1.31
	Trachurus sp.	Jack mackerel	6	0.60
	Brama sp.	Ray's bream	123	12.39
	Taractichthys longipinnis	Big-scale pomfret	5	0.50
	Lepidocybium flavobrunneum	Escolar	19	1.91
	Nesiarchus nasutus	Black barracouta	1	0.10
	Ruvettus pretiosus	Oilfish	16	1.61
	Lepidopus caudatus	Frostfish	2	0.20
	Allothunnus fallai	Slender tuna	1	0.10

	Katsuwonus pelamis	Skipjack tuna	12	1.21
	Thunnus alalunga	Albacore	70	7.05
	Thunnus maccoyii	Southern bluefin tuna	6	0.60
	Thunnus obesus	Bigeye tuna	1	0.10
	Xiphias gladius	Swordfish	4	0.40
	Centrolophus niger	Rudderfish	6	0.60
	Tetragonurus cuvieri	Squaretail	1	0.10
	Mola mola	Sunfish	1	0.10
	Fish unidentified	Fish unidentified	557	56.09
Tunicata	Tunicata	Salp	12	1.21
Cnidaria	Scyphozoa	Jellyfish	2	0.20
Mollusca	Teuthoidea	Squid undetermined	136	13.70
Crustacea	Crustacea unspecified	Crustacea unspecified	2	0.20
Other	Bird (or part of)	Bird (or part of)	1	0.10
	Marine mammal (or part of)	Marine mammal (or part of)	2	0.20
	Terrestrial plant material	Terrestrial plant material	3	0.30
	Plastic	Plastic	4	0.40
	Fish hook	Fish hook	4	0.40
	Paper/cardboard	Paper/cardboard	2	0.20
	Other unidentified	Other unidentified	17	1.71

Table A4: Porbeagle shark, *Lamna nasus*, (*N* = 1489).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Squalus acanthias*	Southern spiny dogfish	1	0.07
	Isurus oxyrinchus	Mako shark	1	0.07
	Hydrolagus novaezelandiae	Dark ghost shark	1	0.07
	Derichthys serpentinus	Longnecked eel	1	0.07
	Photichthys argenteus	Lighthouse fish	2	0.13
	Magnisudus prionosa	Barracudina	1	0.07
	Alepisaurus ferox	Longsnouted lancetfish	12	0.81
	Alepisaurus brevirostris	Shortsnouted lancetfish	2	0.13
	Myctophidae	Laternfish	4	0.27
	Macruronus novaezelandiae	Hoki	24	1.61
	Scomberesox saurus	Saury	1	0.07
	Trachipterus trachypterus	Dealfish	212	14.24
	Trachurus sp.	Jack mackerel	4	0.27
	Brama sp.	Ray's bream	107	7.19
	Ptercalis velifera	Wingfish	1	0.07
	Pterycombus petersii	Fanfish	1	0.07
	Taractes asper	Flathead pomfret	1	0.07
	Taractichthys longipinnis	Big-scale pomfret	1	0.07
	Emmelichthys nitidus	Redbait	1	0.07
	Nesiarchus nasutus	Black barracouta	1	0.07
	Ruvettus pretiosus	Oilfish	1	0.07
	Thyrsites atun	Barracouta	4	0.27
	Benthodesmus sp.	Scabbardfish	1	0.07
	Scomber australasicus	Blue mackerel	1	0.07
	Thunnus alalunga	Albacore	3	0.20
	Centrolophus niger	Rudderfish	12	0.81
	Tetragonurus cuvieri	Squaretail	1	0.07
	Pleuronectiformes	Flatfish unspecified	2	0.13
	Sphoeroides pachygaster	Pufferfish	1	0.07
	Fish unidentified	Fish unidentified	608	40.83
Tunicata	Tunicata	Salp	43	2.89
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	2	0.13
	Nautilidae	Nautilus	6	0.40
	Teuthoidea	Squid undetermined	524	35.19
	Octopoda	Octopus undetermined	1	0.07
Crustacea	Prawn unspecified	Prawn unspecified	1	0.07

	Shrimp unspecified	Shrimp unspecified	1	0.07
	Krill unspecified	Krill unspecified	1	0.07
	Crustacea unspecified	Crustacea unspecified	8	0.54
Other	Terrestrial plant material	Terrestrial plant material	2	0.13
	Plastic	Plastic	2	0.13
	Fish hook	Fish hook	11	0.74
	Foil wrapper	Foil wrapper	1	0.07
	Other unidentified	Other unidentified	29	1.95

Table A5: School shark, *Galaeorhinus galeus*, (*N* = 423).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Photichthys argenteus*	Lighthouse fish	2	0.47
	Myctophidae	Laternfish	1	0.24
	Macruronus novaezelandiae	Hoki	2	0.47
	Merluccius australis	Hake	1	0.24
	Trachipterus trachypterus	Dealfish	1	0.24
	Trachurus sp.	Jack mackerel	5	1.18
	Brama sp.	Ray's bream	3	0.71
	Thyrsites atun	Barracouta	2	0.47
	Cubiceps sp.	Cubehead	1	0.24
	Fish unidentified	Fish unidentified	215	50.83
Tunicata	Tunicata	Salp	6	1.42
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	1	0.24
	Teuthoidea	Squid undetermined	197	46.57
	Octopoda	Octopus undetermined	6	1.42
Crustacea	Amphipoda	Amphipod	1	0.24
	Prawn unspecified	Prawn unspecified	3	0.71
	Crab unspecified	Crab unspecified	1	0.24
	Crustacea unspecified	Crustacea unspecified	1	0.24
Other	Seaweed	Seaweed	2	0.47
	Fish hook	Fish hook	1	0.24
	Other unidentified	Other unidentified	37	8.75

Table A6: Blue shark, *Prionace glauca*, (*N* = 8584).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Centroscymnus owstoni*	Smooth skin dogfish	15	0.17
	Etmopterus baxteri	Baxter's lantern dogfish	1	0.01
	Squalus acanthias	Southern spiny dogfish	2	0.02
	Dogfish unspecified	Dogfish unspecified	3	0.03
	Lamna nasus	Porbeagle shark	6	0.07
	Prionace glauca	Blue shark	24	0.28
	Rajiformes	Skate unspecified	1	0.01
	Shark unspecified	Shark unspecified	10	0.12
	Notacanthus chemnitzi	Giant spineback	1	0.01
	Conger sp.	Conger eel	2	0.02
	Anguilliformes	Marine eel unspecified	5	0.06
	Engraulis australis	Anchovy	2	0.02
	Photichthys argenteus	Lighthouse fish	9	0.10
	Stomias sp.	Stomiatidae	1	0.01
	Magnisudus prionosa	Barracudina	2	0.02
	Alepisaurus ferox	Longsnouted lancetfish	29	0.34
	Myctophidae	Laternfish	30	0.35
	Macruronus novaezelandiae	Hoki	22	0.26
	Genypterus blacodes	Ling	1	0.01
	Ceratias sp.	Seadevil	1	0.01
	Himantolophus appelii	Prickly anglerfish	8	0.09
	Melanocetus johnsonii	Humpback anglerfish	2	0.02
	Ceratioidei	Anglerfish unspecified	9	0.10

	Scomberesox saurus	Saury	1	0.01
	Lampris guttatus	Moonfish	8	0.09
	Trachipterus trachypterus	Dealfish	470	5.48
	Monocentris japonicus	Pineapplefish	1	0.01
	Beryx splendens	Alfonsino	1	0.01
	Allocyttus niger	Black oreo	1	0.01
	Hippocampus abdominalis	Seahorse	1	0.01
	Polyprion oxygeneios	Hapuku	1	0.01
	Trachurus sp.	Jack mackerel	44	0.51
	Brama sp.	Ray's bream	796	9.27
	Taractes asper	Flathead pomfret	2	0.02
	Taractichthys longipinnis	Big-scale pomfret	29	0.34
	Pseudopentaceros richardsoni	Southern boarfish	1	0.01
	Uranoscopidae	Stargazer unspecified	1	0.01
	Lepidocybium flavobrunneum	Escolar	31	0.36
	Nesiarchus nasutus	Black barracouta	2	0.02
	Ruvettus pretiosus	Oilfish	13	0.15
	Thyrsites atun	Barracouta	5	0.06
	Lepidopus caudatus	Frostfish	2	0.02
	Katsuwonus pelamis	Skipjack tuna	2	0.02
	Thunnus alalunga	Albacore	63	0.73
	Thunnus albacares	Yellowfin tuna	1	0.01
	Thunnus maccoyii	Southern bluefin tuna	3	0.03
	Scombridae	Tuna unspecified	2	0.02
	Xiphias gladius	Swordfish	3	0.03
	Centrolophus niger	Rudderfish	44	0.51
	Cubiceps baxteri	Cubehead	2	0.02
	Cubiceps caeruleus	Cubehead	2	0.02
	Cubiceps sp.	Cubehead	14	0.16
	Tetragonurus cuvieri	Squaretail	63	0.73
	Allomycterus jaculiferus	Porcupine fish	2	0.02
	Mola mola	Sunfish	3	0.03
	Eggs - fish/other	Eggs - fish/other	13	0.15
	Fish unidentified	Fish unidentified	2257	26.29
	Fish (commercial discards)	Fish (commercial discards)	5	0.06
Tunicata	Tunicata	Salp	259	3.02
Porifera	Porifera	Sponge	1	0.01
Cnidaria	Scyphozoa	Jellyfish	5	0.06
Mollusca	Nautilidae	Nautilus	29	0.34
	Sepiida	Cuttlefish	5	0.06
	Teuthoidea	Squid undetermined	4710	54.87
	Opisthoteuthis sp.	Umbrella octopus	1	0.01
	Octopoda	Octopus undetermined	292	3.40
Echinodermata	Holothuroidea	Sea cucumber	2	0.02
Crustacea	Amphipoda	Amphipod	3	0.03
	Euphasiacea	Euphausiid	3	0.03
	Acanthephyra sp.	Subantarctic ruby prawn	1	0.01
	Prawn unspecified	Prawn unspecified	36	0.42
	Shrimp unspecified	Shrimp unspecified	4	0.05
	Krill unspecified	Krill unspecified	13	0.15
	Metanephrops challengeri	Scampi	1	0.01
	Crayfish unspecified	Crayfish unspecified	1	0.01
	Crab unspecified	Crab unspecified	3	0.03
	Crustacea unspecified	Crustacea unspecified	51	0.59
Other	Seabird	Seabird	4	0.05
	Bird (or part of)	Bird (or part of)	50	0.58
	Feathers	Feathers	22	0.26
	Marine mammal (or part of)	Marine mammal (or part of)	15	0.17
	Seaweed	Seaweed	2	0.02
	Terrestrial plant material	Terrestrial plant material	4	0.05

Plastic	Plastic	25	0.29
Fish hook	Fish hook	16	0.19
Paper/cardboard	Paper/cardboard	3	0.03
Foil wrapper	Foil wrapper	1	0.01
Food (galley waste)	Food (galley waste)	3	0.03
Other unidentified	Other unidentified	287	3.34

Table A7: Shortsnouted lancetfish, *Alepisaurus brevirostris*, (*N* = 381).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Sternoptychidae	Hatchetfish	2	0.52
	Alepisaurus ferox	Longsnouted lancetfish	2	0.52
	Alepisaurus brevirostris	Shortsnouted lancetfish	3	0.79
	Myctophidae	Laternfish	2	0.52
	Oreosomatidae	Oreo unspecified	1	0.26
	Ptercalis velifera	Wingfish	1	0.26
	Meuschenia scaber	Leatherjacket	1	0.26
	Fish unidentified	Fish unidentified	132	34.65
Tunicata	Tunicata	Salp	50	13.12
Mollusca	Nautilidae	Nautilus	12	3.15
	Teuthoidea	Squid undetermined	39	10.24
Crustacea	Copepoda	Copepod	1	0.26
	Shrimp unspecified	Shrimp unspecified	204	53.54
	Krill unspecified	Krill unspecified	18	4.72
	Crab unspecified	Crab unspecified	2	0.52
	Crustacea unspecified	Crustacea unspecified	60	15.75
Other	Feathers	Feathers	1	0.26
	Seaweed	Seaweed	1	0.26
	Wood	Wood	1	0.26
	Plastic	Plastic	1	0.26
	Foil wrapper	Foil wrapper	1	0.26
	Other unidentified	Other unidentified	50	13.12

Table A8: Longsnouted lancetfish, *Alepisaurus ferox*, (*N* = 849).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Sternoptychidae	Hatchetfish	21	2.47
	Photichthys argenteus	Lighthouse fish	1	0.12
	Alepisaurus ferox	Longsnouted lancetfish	46	5.42
	Alepisaurus brevirostris	Shortsnouted lancetfish	30	3.53
	Myctophidae	Laternfish	16	1.88
	Scomberesox saurus	Saury	7	0.82
	Trachipterus trachypterus	Dealfish	1	0.12
	Zenopis nebulosa	Mirror dory	1	0.12
	Allocyttus verrucosus	Warty oreo	1	0.12
	Oreosomatidae	Oreo unspecified	3	0.35
	Hippocampus abdominalis	Seahorse	1	0.12
	Ptercalis velifera	Wingfish	1	0.12
	Centrolophus niger	Rudderfish	1	0.12
	Hyperoglyphe antarctica	Bluenose	1	0.12
	Meuschenia scaber	Leatherjacket	1	0.12
	Sphoeroides pachygaster	Pufferfish	1	0.12
	Fish unidentified	Fish unidentified	308	36.28
Tunicata	Tunicata	Salp	268	31.57
Cnidaria	Scyphozoa	Jellyfish	3	0.35
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	3	0.35
	Nautilidae	Nautilus	217	25.56
	Teuthoidea	Squid undetermined	136	16.02
	Octopoda	Octopus undetermined	11	1.30

Crustacea	Amphipoda	Amphipod	2	0.24
	Prawn unspecified	Prawn unspecified	1	0.12
	Shrimp unspecified	Shrimp unspecified	11	1.30
	Krill unspecified	Krill unspecified	9	1.06
	Crab unspecified	Crab unspecified	1	0.12
	Crustacea unspecified	Crustacea unspecified	34	4.00
Other	Feathers	Feathers	2	0.24
	Seaweed	Seaweed	2	0.24
	Terrestrial plant material	Terrestrial plant material	2	0.24
	Wood	Wood	1	0.12
	Plastic	Plastic	10	1.18
	Other unidentified	Other unidentified	178	20.97

Table A9: Hoki, *Macruronus novaezelandiae*, (*N* = 102).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Photichthys argenteus*	Lighthouse fish	2	1.96
	Myctophidae	Laternfish	23	22.55
	Macruronus novaezelandiae	Hoki	1	0.98
	Cubiceps sp.	Cubehead	3	2.94
	Fish unidentified	Fish unidentified	55	53.92
Mollusca	Teuthoidea	Squid undetermined	8	7.84
Crustacea	Prawn unspecified	Prawn unspecified	9	8.82
	Krill unspecified	Krill unspecified	3	2.94
	Crustacea unspecified	Crustacea unspecified	3	2.94
Other	Other unidentified	Other unidentified	5	4.90

Table A10: Moonfish, *Lampris guttatus*, (*N* = 1565).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Nemichthyidae	Snipe eels	5	0.3
	Opisthoproctus grimaldii	Mirrorbelly	2	0.1
	Sternoptychidae	Hatchetfish	10	0.6
	Photichthys argenteus	Lighthouse fish	9	0.6
	Magnisudus prionosa	Barracudina	2	0.1
	Alepisaurus ferox	Longsnouted lancetfish	84	5.4
	Alepisaurus brevirostris	Shortsnouted lancetfish	13	0.8
	Myctophidae	Laternfish	34	2.2
	Scomberesox saurus	Saury	2	0.1
	Lophotus capellei	Unicornfish	1	0.1
	Trachipterus trachypterus	Dealfish	4	0.3
	Agrostichthys parkeri	Ribbonfish	1	0.1
	Monocentris japonicus	Pineapplefish	2	0.1
	Cyttus novaezealandiae	Silver dory	1	0.1
	Cyttus traversi	Lookdown dory	3	0.2
	Macroramphosus scolopax	Snipefish	2	0.1
	Trachurus sp.	Jack mackerel	2	0.1
	Brama sp.	Ray's bream	6	0.4
	Nesiarchus nasutus	Black barracouta	1	0.1
	Benthodesmus sp.	Scabbardfish	1	0.1
	Lepidopus caudatus	Frostfish	2	0.1
	Scomber australasicus	Blue mackerel	1	0.1
	Cubiceps sp.	Cubehead	1	0.1
	Sphoeroides pachygaster	Pufferfish	1	0.1
	Fish unidentified	Fish unidentified	561	35.8
Tunicata	Tunicata	Salp	65	4.2
Cnidaria	Scyphozoa	Jellyfish	4	0.3
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	1	0.1
	Nautilidae	Nautilus	25	1.6
	Teuthoidea	Squid undetermined	592	37.8

	Octopoda	Octopus undetermined	25	1.6
Polychaeta	Polychaeta	Polychaete worm	4	0.3
Crustacea	Amphipoda	Amphipod	5	0.3
	Prawn unspecified	Prawn unspecified	13	0.8
	Shrimp unspecified	Shrimp unspecified	8	0.5
	Krill unspecified	Krill unspecified	11	0.7
	Crayfish unspecified	Crayfish unspecified	1	0.1
	Crab unspecified	Crab unspecified	1	0.1
	Crustacea unspecified	Crustacea unspecified	31	2.0
Other	Bird (or part of)	Bird (or part of)	1	0.1
	Feathers	Feathers	7	0.4
	Twig and feather	Twig and feather	1	0.1
	Seaweed	Seaweed	30	1.9
	Terrestrial plant material	Terrestrial plant material	19	1.2
	Wood	Wood	2	0.1
	Twig and plastic	Twig and plastic	1	0.1
	Plastic	Plastic	258	16.5
	Rubber	Rubber	2	0.1
	Rope	Rope	24	1.5
	Netting	Netting	2	0.1
	Fish hook	Fish hook	1	0.1
	Fabric (glove/strapping)	Fabric (glove/strapping)	2	0.1
	Foil wrapper	Foil wrapper	4	0.3
	Paper/cardboard	Paper/cardboard	2	0.1
	Other unidentified	Other unidentified	130	8.3

Table A11: Dealfish, *Trachipterus trachypterus*, (*N* = 56).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Nemichthyidae	Snipe eels	1	1.79
	Stomias sp.	Stomiatidae	1	1.79
	Myctophidae	Laternfish	1	1.79
	Macroramphosus scolopax	Snipefish	1	1.79
	Fish unidentified	Fish unidentified	18	32.14
Tunicata	Tunicata	Salp	19	33.93
Mollusca	Teuthoidea	Squid undetermined	17	30.36
Crustacea	Prawn unspecified	Prawn unspecified	1	1.79
	Crustacea unspecified	Crustacea unspecified	3	5.36
Other	Terrestrial plant material	Terrestrial plant material	1	1.79
	Wood	Wood	1	1.79
	Other unidentified	Other unidentified	2	3.57

Table A12: Ribbonfish, *Agrostichthys parkeri*, (*N* = 22).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Scomberesox saurus*	Saury	1	4.5
	Fish unidentified	Fish unidentified	9	40.9
Tunicata	Tunicata	Salp	3	13.6
Mollusca	Nautilidae	Nautilus	1	4.5
	Teuthoidea	Squid undetermined	1	4.5
Crustacea	Shrimp unspecified	Shrimp unspecified	11	50.0
	Crustacea unspecified	Crustacea unspecified	4	18.2
Other	Other unidentified	Other unidentified	2	9.1

Table A13: Dolphinfish, *Coryphaena hippurus*, (*N* = 10).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Exocoetidae	Flying fish	3	30.0
	Ostracion cubicus	Boxfish	1	10.0

	Fish unidentified	Fish unidentified	5	50.0
Tunicata	Tunicata	Salp	1	10.0
Mollusca	Teuthoidea	Squid undetermined	1	10.0

Table A14: Ray's bream, *Brama* sp., (*N* = 1560).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Nemichthyidae	Snipe eels	1	0.06
	Serrivomer sp.	Sawtooth eel	1	0.06
	Photichthys argenteus	Lighthouse fish	34	2.18
	Myctophidae	Laternfish	468	30.00
	Diretmus argenteus	Discfish	1	0.06
	Brama sp.	Ray's bream	1	0.06
	Rexea solandri	Gemfish	1	0.06
	Eggs - fish/other	Eggs - fish/other	5	0.32
	Fish unidentified	Fish unidentified	445	28.53
	Fish (commercial discards)	Fish (commercial discards)	2	0.13
Tunicata	Tunicata	Salp	218	13.97
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	12	0.77
	Nautilidae	Nautilus	1	0.06
	Teuthoidea	Squid undetermined	220	14.10
	Octopoda	Octopus undetermined	22	1.41
Crustacea	Amphipoda	Amphipod	5	0.32
	Euphasiacea	Euphausiid	3	0.19
	Prawn unspecified	Prawn unspecified	4	0.26
	Shrimp unspecified	Shrimp unspecified	8	0.51
	Krill unspecified	Krill unspecified	116	7.44
	Crab unspecified	Crab unspecified	2	0.13
	Crustacea unspecified	Crustacea unspecified	74	4.74
Other	Seaweed	Seaweed	1	0.06
	Terrestrial plant material	Terrestrial plant material	2	0.13
	Plastic	Plastic	4	0.26
	Other unidentified	Other unidentified	126	8.08

Table A15: Big-scale pomfret, *Taractichthys longipinnis*, (*N* = 113).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Magnisudus prionosa*	Barracudina	1	0.88
	Myctophidae	Laternfish	7	6.19
	Rexea solandri	Gemfish	1	0.88
	Fish unidentified	Fish unidentified	53	46.90
Tunicata	Tunicata	Salp	4	3.54
Mollusca	Teuthoidea	Squid undetermined	39	34.51
	Octopoda	Octopus undetermined	5	4.42
Crustacea	Krill unspecified	Krill unspecified	2	1.77
	Crustacea unspecified	Crustacea unspecified	5	4.42
Other	Other unidentified	Other unidentified	21	18.58

Table A16: Flathead pomfret, *Taractes asper*, (*N* = 21).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Photichthys argenteus*	Lighthouse fish	1	4.8
	Myctophidae	Laternfish	1	4.8
	Fish unidentified	Fish unidentified	4	19.0
Tunicata	Tunicata	Salp	6	28.6
Mollusca	Teuthoidea	Squid undetermined	5	23.8
Crustacea	Krill unspecified	Krill unspecified	1	4.8
Other	Other unidentified	Other unidentified	4	19.0

Table A17: Escolar, *Lepidocybium flavobrunneum*, (*N* = 22).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Fish unidentified	Fish unidentified	15	68.2
Mollusca	Teuthoidea	Squid undetermined	4	18.2
Other	Other unidentified	Other unidentified	4	18.2

Table A18: Oilfish, *Ruvettus pretiosus*, (*N* = 11).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Fish unidentified	Fish unidentified	5	45.5
Tunicata	Tunicata	Salp	1	9.1
Mollusca	Teuthoidea	Squid undetermined	3	27.3
Crustacea	Prawn unspecified	Prawn unspecified	1	9.1
	Crustacea unspecified	Crustacea unspecified	2	18.2
Other	Other unidentified	Other unidentified	1	9.1

Table A19: Slender tuna, *Allothunnus fallai*, (*N* = 10).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Myctophidae	Laternfish	1	10.0
	Fish unidentified	Fish unidentified	1	10.0
Tunicata	Tunicata	Salp	1	10.0
Mollusca	Teuthoidea	Squid undetermined	1	10.0
Crustacea	Prawn unspecified	Prawn unspecified	1	10.0
	Shrimp unspecified	Shrimp unspecified	2	20.0
	Crustacea unspecified	Crustacea unspecified	4	40.0
Other	Other unidentified	Other unidentified	1	10.0

Table A20: Butterfly tuna, *Gasterochisma melampus*, (*N* = 949).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Photichthys argenteus*	Lighthouse fish	3	0.32
	Alepisaurus ferox	Longsnouted lancetfish	4	0.42
	Alepisaurus brevirostris	Shortsnouted lancetfish	2	0.21
	Myctophidae	Laternfish	12	1.26
	Macruronus novaezelandiae	Hoki	15	1.58
	Scomberesox saurus	Saury	1	0.11
	Trachipterus trachypterus	Dealfish	3	0.32
	Congiopodus leucopaecilus	Pigfish	1	0.11
	Trachurus sp.	Jack mackerel	4	0.42
	Brama sp.	Ray's bream	7	0.74
	Pseudopentaceros richardsoni	Southern boarfish	1	0.11
	Thyrsites atun	Barracouta	3	0.32
	Allothunnus fallai	Slender tuna	1	0.11
	Gasterochisma melampus	Butterfly tuna	1	0.11
	Arnoglossus scapha	Witch	4	0.42
	Bothidae	Lefteyed flounders	1	0.11
	Fish unidentified	Fish unidentified	320	33.72
Tunicata	Tunicata	Salp	67	7.06
Cnidaria	Scyphozoa	Jellyfish	1	0.11
Mollusca	Nautilidae	Nautilus	2	0.21
	Teuthoidea	Squid undetermined	592	62.38
	Octopoda	Octopus undetermined	2	0.21
Crustacea	Amphipoda	Amphipod	2	0.21
	Prawn unspecified	Prawn unspecified	2	0.21
	Shrimp unspecified	Shrimp unspecified	3	0.32
	Krill unspecified	Krill unspecified	2	0.21
	Crustacea unspecified	Crustacea unspecified	10	1.05

Other	Seaweed	Seaweed	18	1.90
	Terrestrial plant material	Terrestrial plant material	2	0.21
	Plastic	Plastic	5	0.53
	Paper/cardboard	Paper/cardboard	1	0.11
	Other unidentified	Other unidentified	84	8.85

Table A21: Albacore, *Thunnus alalunga*, (*N* = 694).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Anguilliformes	Marine eel unspecified	1	0.14
	Sternoptychidae	Hatchetfish	5	0.72
	Alepisaurus ferox	Longsnouted lancetfish	10	1.44
	Myctophidae	Laternfish	27	3.89
	Scomberesox saurus	Saury	2	0.29
	Centriscops humerosus	Banded bellowsfish	1	0.14
	Macroramphosus scolopax	Snipefish	1	0.14
	Hippocampus abdominalis	Seahorse	1	0.14
	Syngnathidae	Pipefish	1	0.14
	Ptercalis velifera	Wingfish	1	0.14
	Gasterochisma melampus	Butterfly tuna	1	0.14
	Centrolophus niger	Rudderfish	1	0.14
	Cubiceps sp.	Cubehead	1	0.14
	Sphoeroides pachygaster	Pufferfish	5	0.72
	Fish unidentified	Fish unidentified	254	36.60
Tunicata	Tunicata	Salp	54	7.78
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	1	0.14
	Teuthoidea	Squid undetermined	306	44.09
	Octopoda	Octopus undetermined	9	1.30
Crustacea	Copepoda	Copepod	1	0.14
	Amphipoda	Amphipod	6	0.86
	Euphasiacea	Euphausiid	1	0.14
	Prawn unspecified	Prawn unspecified	7	1.01
	Shrimp unspecified	Shrimp unspecified	17	2.45
	Krill unspecified	Krill unspecified	22	3.17
	Metanephrops challengeri	Scampi	1	0.14
	Crab unspecified	Crab unspecified	1	0.14
	Crustacea unspecified	Crustacea unspecified	35	5.04
Other	Seaweed	Seaweed	1	0.14
	Plastic	Plastic	1	0.14
	Foil wrapper	Foil wrapper	1	0.14
	Other unidentified	Other unidentified	153	22.05

Table A22: Yellowfin tuna, *Thunnus albacares*, (*N* = 967).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Sardinops sagax*	Pilchard	1	0.10
	Alepisaurus ferox	Longsnouted lancetfish	11	1.14
	Myctophidae	Laternfish	1	0.10
	Exocoetidae	Flying fish	14	1.45
	Hyporhamphus ihi	Garfish	2	0.21
	Scomberesox saurus	Saury	41	4.24
	Oreosomatidae	Oreo unspecified	2	0.21
	Hippocampus abdominalis	Seahorse	1	0.10
	Seriola lalandi	Kingfish	1	0.10
	Trachurus sp.	Jack mackerel	3	0.31
	Brama sp.	Ray's bream	1	0.10
	Pseudopentaceros richardsoni	Southern boarfish	1	0.10
	Mugil cephalus	Grey mullet	1	0.10
	Katsuwonus pelamis	Skipjack tuna	37	3.83
	Scomber australasicus	Blue mackerel	1	0.10

	Thunnus alalunga	Albacore	1	0.10
	Sphoeroides pachygaster	Pufferfish	14	1.45
	Allomycterus jaculiferus	Porcupine fish	1	0.10
	Mola mola	Sunfish	1	0.10
	Fish unidentified	Fish unidentified	578	59.77
Tunicata	Tunicata	Salp	55	5.69
Cnidaria	Scyphozoa	Jellyfish	2	0.21
Mollusca	Nautilidae	Nautilus	61	6.31
	Teuthoidea	Squid undetermined	255	26.37
	Octopoda	Octopus undetermined	5	0.52
Crustacea	Prawn unspecified	Prawn unspecified	1	0.10
	Shrimp unspecified	Shrimp unspecified	5	0.52
	Crustacea unspecified	Crustacea unspecified	19	1.96
Other	Feathers	Feathers	1	0.10
	Terrestrial plant material	Terrestrial plant material	1	0.10
	Plastic	Plastic	3	0.31
	Other unidentified	Other unidentified	39	4.03

Table A23: Southern bluefin tuna, *Thunnus maccoyii*, (*N* = 9966).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Centroscymnus owstoni*	Smooth skin dogfish	1	0.01
	Squalus acanthias	Southern spiny dogfish	1	0.01
	Nemichthyidae	Snipe eels	3	0.03
	Engraulis australis	Anchovy	6	0.06
	Opisthoproctus grimaldii	Mirrorbelly	1	0.01
	Sternoptychidae	Hatchetfish	4	0.04
	Photichthys argenteus	Lighthouse fish	229	2.30
	Melanostomias sp.	Scaleless black dragonfish	1	0.01
	Magnisudus prionosa	Barracudina	3	0.03
	Alepisaurus ferox	Longsnouted lancetfish	3	0.03
	Alepisaurus brevirostris	Shortsnouted lancetfish	1	0.01
	Myctophidae	Laternfish	1146	11.50
	Macruronus novaezelandiae	Hoki	12	0.12
	Merluccius australis	Hake	3	0.03
	Lepidorhynchus denticulatus	Javelin fish	1	0.01
	Macrouridae	Rattails	1	0.01
	Hyporhamphus ihi	Garfish	4	0.04
	Scomberesox saurus	Saury	35	0.35
	Trachipterus trachypterus	Dealfish	13	0.13
	Centriscops humerosus	Banded bellowsfish	3	0.03
	Macroramphosus scolopax	Snipefish	1	0.01
	Hippocampus abdominalis	Seahorse	9	0.09
	Syngnathidae	Pipefish	3	0.03
	Polyprion oxygeneios	Hapuku	1	0.01
	Epigonidae	Cardinalfish	1	0.01
	Echeneididae	Remoras	3	0.03
	Trachurus sp.	Jack mackerel	16	0.16
	Brama sp.	Ray's bream	1171	11.75
	Ptercalis velifera	Wingfish	1	0.01
	Taractes asper	Flathead pomfret	1	0.01
	Taractichthys longipinnis	Big-scale pomfret	1	0.01
	Emmelichthys nitidus	Redbait	1	0.01
	Pseudopentaceros richardsoni	Southern boarfish	2	0.02
	Uranoscopidae	Stargazer unspecified	1	0.01
	Nesiarchus nasutus	Black barracouta	1	0.01
	Ruvettus pretiosus	Oilfish	2	0.02
	Thyrsites atun	Barracouta	2	0.02
	Lepidopus caudatus	Frostfish	3	0.03
	Allothunnus fallai	Slender tuna	1	0.01

	Katsuwonus pelamis	Skipjack tuna	1	0.01
	Centrolophus niger	Rudderfish	6	0.06
	Seriolella caerulea	White warehou	1	0.01
	Cubiceps sp.	Cubehead	26	0.26
	Psenes pellucidus	Scissortail	1	0.01
	Ariomma lurida	Ariommid	1	0.01
	Tetragonurus cuvieri	Squaretail	1	0.01
	Fish unidentified	Fish unidentified	3785	37.98
	Fish (commercial discards)	Fish (commercial discards)	2	0.02
Tunicata	Tunicata	Salp	2127	21.34
Porifera	Porifera	Sponge	1	0.01
Cnidaria	Scyphozoa	Jellyfish	4	0.04
Mollusca	Mollusc shell unspecified	Mollusc shell unspecified	11	0.11
	Nautilidae	Nautilus	38	0.38
	Teuthoidea	Squid undetermined	1616	16.22
	Octopoda	Octopus undetermined	47	0.47
Echinodermata	Holothuroidea	Sea cucumber	1	0.01
Crustacea	Amphipoda	Amphipod	67	0.67
	Euphasiacea	Euphausiid	1	0.01
	Prawn unspecified	Prawn unspecified	42	0.42
	Shrimp unspecified	Shrimp unspecified	72	0.72
	Krill unspecified	Krill unspecified	12	0.12
	Crab unspecified	Crab unspecified	2	0.02
	Crustacea unspecified	Crustacea unspecified	272	2.73
Other	Zoo/phytoplankton unspecified	Zoo/phytoplankton unspecified	6	0.06
	Bird (or part of)	Bird (or part of)	6	0.06
	Feathers	Feathers	10	0.10
	Bone unspecified	Bone unspecified	1	0.01
	Seaweed	Seaweed	18	0.18
	Terrestrial plant material	Terrestrial plant material	33	0.33
	Wood	Wood	3	0.03
	Plastic	Plastic	65	0.65
	Rubber	Rubber	2	0.02
	Fish hook	Fish hook	6	0.06
	Glass	Glass	1	0.01
	Foil wrapper	Foil wrapper	2	0.02
	Food (galley waste)	Food (galley waste)	2	0.02

Table A24: Pacific bluefin tuna, *Thunnus orientalis*, (*N* = 47).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Alepisaurus ferox*	Longsnouted lancetfish	1	2.1
	Brama sp.	Ray's bream	8	17.0
	Thunnus alalunga	Albacore	2	4.3
	Sphoeroides pachygaster	Pufferfish	1	2.1
	Fish unidentified	Fish unidentified	25	53.2
Tunicata	Tunicata	Salp	2	4.3
Mollusca	Nautilidae	Nautilus	1	2.1
	Teuthoidea	Squid undetermined	10	21.3
Other	Plastic	Plastic	1	2.1
	Other unidentified	Other unidentified	2	4.3

Table A25: Bigeye tuna, *Thunnus obesus*, (*N* = 1169).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Sternoptychidae	Hatchetfish	4	0.34
	Photichthys argenteus	Lighthouse fish	1	0.09
	Alepisaurus ferox	Longsnouted lancetfish	40	3.42
	Alepisaurus brevirostris	Shortsnouted lancetfish	8	0.68

	Macruronus novaezelandiae	Hoki	1	0.09
	Exocoetidae	Flying fish	1	0.09
	Hyporhamphus ihi	Garfish	1	0.09
	Scomberesox saurus	Saury	8	0.68
	Epigonidae	Cardinalfish	1	0.09
	Trachurus sp.	Jack mackerel	2	0.17
	Brama sp.	Ray's bream	21	1.80
	Mugilidae	Mullet unspecified	1	0.09
	Lepidocybium flavobrunneum	Escolar	1	0.09
	Katsuwonus pelamis	Skipjack tuna	43	3.68
	Scomber australasicus	Blue mackerel	5	0.43
	Thunnus alalunga	Albacore	5	0.43
	Cubiceps baxteri	Cubehead	1	0.09
	Cubiceps sp.	Cubehead	1	0.09
	Sphoeroides pachygaster	Pufferfish	5	0.43
	Fish unidentified	Fish unidentified	645	55.18
Tunicata	Tunicata	Salp	13	1.11
Mollucsa	Nautilidae	Nautilus	68	5.82
	Teuthoidea	Squid undetermined	444	37.98
	Octopoda	Octopus undetermined	3	0.26
Crustacea	Prawn unspecified	Prawn unspecified	4	0.34
	Shrimp unspecified	Shrimp unspecified	4	0.34
	Krill unspecified	Krill unspecified	1	0.09
	Crayfish unspecified	Crayfish unspecified	3	0.26
	Crab unspecified	Crab unspecified	1	0.09
	Crustacea unspecified	Crustacea unspecified	19	1.63
Other	Feathers	Feathers	2	0.17
	Seaweed	Seaweed	4	0.34
	Plastic	Plastic	2	0.17
	Other unidentified	Other unidentified	35	2.99

Table A26: Swordfish, *Xiphias gladius*, (*N* = 3494).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Centroscymnus owstoni*	Smooth skin dogfish	1	0.03
	Isistius brasiliensis	Cookicutter shark	1	0.03
	Dogfish unspecified	Dogfish unspecified	2	0.06
	Lamna nasus	Porbeagle shark	1	0.03
	Apristurus sp.	Catshark	1	0.03
	Sardinops sagax	Pilchard	1	0.03
	Argentina elongata	Silverside	1	0.03
	Photichthys argenteus	Lighthouse fish	3	0.09
	Alepisaurus ferox	Longsnouted lancetfish	10	0.29
	Alepisaurus brevirostris	Shortsnouted lancetfish	1	0.03
	Myctophidae	Laternfish	3	0.09
	Macruronus novaezelandiae	Hoki	41	1.17
	Merluccius australis	Hake	20	0.57
	Hyporhamphus ihi	Garfish	1	0.03
	Scomberesox saurus	Saury	12	0.34
	Trachipterus trachypterus	Dealfish	4	0.11
	Helicolenus sp.	Seaperch	1	0.03
	Epigonidae	Cardinalfish	1	0.03
	Seriola lalandi	Kingfish	2	0.06
	Trachurus declivis	Jack mackerel	1	0.03
	Trachurus sp.	Jack mackerel	11	0.31
	Brama sp.	Ray's bream	176	5.04
	Taractes asper	Flathead pomfret	1	0.03
	Taractichthys longipinnis	Big-scale pomfret	2	0.06
	Bramidae	Pomfrets	1	0.03

	Mugilidae	Mullet unspecified	1	0.03
	Lepidocybium flavobrunneum	Escolar	5	0.14
	Nesiarchus nasutus	Black barracouta	2	0.06
	Ruvettus pretiosus	Oilfish	4	0.11
	Thyrsites atun	Barracouta	4	0.11
	Lepidopus caudatus	Frostfish	5	0.14
	Allothunnus fallai	Slender tuna	2	0.06
	Katsuwonus pelamis	Skipjack tuna	5	0.14
	Thunnus alalunga	Albacore	3	0.09
	Centrolophus niger	Rudderfish	7	0.20
	Cubiceps baxteri	Cubehead	1	0.03
	Cubiceps sp.	Cubehead	7	0.20
	Ariomma lurida	Ariommid	2	0.06
	Tetragonurus cuvieri	Squaretail	4	0.11
	Fish unidentified	Fish unidentified	2573	73.64
Tunicata	Tunicata	Salp	13	0.37
Mollusca	Nautilidae	Nautilus	5	0.14
	Teuthoidea	Squid undetermined	1152	32.97
	Octopoda	Octopus undetermined	4	0.11
Annelida	Polychaeta	Polychaete worm	2	0.06
Crustacea	Prawn unspecified	Prawn unspecified	28	0.80
	Shrimp unspecified	Shrimp unspecified	6	0.17
	Metanephrops challengeri	Scampi	7	0.20
	Crustacea unspecified	Crustacea unspecified	37	1.06
Other	Bone unspecified	Bone unspecified	1	0.03
	Seaweed	Seaweed	1	0.03
	Terrestrial plant material	Terrestrial plant material	1	0.03
	Plastic	Plastic	3	0.09
	String	String	1	0.03
	Fish hook	Fish hook	1	0.03
	Other unidentified	Other unidentified	72	2.06

Table A27: Striped marlin, *Tetrapturus audax*, (*N* = 20).

Group	Scientific name	Common name	Count	%F
Osteichthyes	*Scomberesox saurus*	Saury	2	10.0
	Thunnus alalunga	Albacore	1	5.0
	Xiphidae	Marlin unspecified	1	5.0
	Fish unidentified	Fish unidentified	12	60.0
Mollusca	Teuthoidea	Squid undetermined	6	30.0
Other	Plastic	Plastic	1	5.0
	Other unidentified	Other unidentified	1	5.0

Table A28: Rudderfish, *Centrolophus niger*, (*N* = 177).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Fish unidentified	Fish unidentified	6	3.39
Tunicata	Tunicata	Salp	133	75.14
Mollusca	Teuthoidea	Squid undetermined	9	5.08
Other	Other unidentified	Other unidentified	34	19.21

Table A29: Sunfish, *Mola mola*, (*N* = 21).

Group	Scientific name	Common name	Count	%F
Osteichthyes	Fish unidentified	Fish unidentified	1	4.8
Tunicata	Tunicata	Salp	5	23.8
Mollusca	Teuthoidea	Squid undetermined	3	14.3
Other	Seaweed	Seaweed	9	42.9
	Other unidentified	Other unidentified	3	14.3

APPENDIX B: Group classification of fish prey items

A list of all recorded fish prey items, in taxonomic order, showing how they were grouped in analyses of individual diets. Some prey species were placed in either a generalist (Group 1) or specialist (Group 2) group depending on the dietary composition of the individual predators. Note that some species classified as 'mesopelagic' probably spend most of their time in epipelagic (i.e., less than 200 m depth) waters (e.g., saury, garfish, flying fish).

Scientific name	**Common name**	**Group 1**	**Group 2**
Centroscymnus owstoni	Smooth skin dogfish	Other fish	Sharks
Etmopterus baxteri	Baxter's lantern dogfish	Other fish	Sharks
Isistius brasiliensis	Cookicutter shark	Other fish	Sharks
Squalus acanthias	Southern spiny dogfish	Other fish	Sharks
Dogfish unspecified	Dogfish unspecified	Other fish	Sharks
Isurus oxyrinchus	Mako shark	Other fish	Sharks
Lamna nasus	Porbeagle shark	Other fish	Sharks
Apristurus sp.	Catshark	Other fish	Sharks
Galaeorhinus galeus	School shark	Other fish	Sharks
Prionace glauca	Blue shark	Other fish	Sharks
Sphyrna zygaena	Hammerhead shark	Other fish	Sharks
Rajiformes	Skate unspecified	Other fish	Sharks
Hydrolagus novaezelandiae	Dark ghost shark	Other fish	Sharks
Shark unspecified	Shark unspecified	Other fish	Sharks
Nemichthyidae	Snipe eels	Small mesopelagics	
Notacanthus chemnitzi	Giant spineback	Other fish	
Conger sp.	Conger eel	Other fish	
Derichthys serpentinus	Longnecked eel	Other fish	
Serrivomer sp.	Sawtooth eel	Other fish	
Anguilliformes	Marine eel unspecified	Other fish	
Sardinops sagax	Pilchard	Small mesopelagics	
Engraulis australis	Anchovy	Small mesopelagics	
Argentina elongata	Silverside	Small mesopelagics	
Opisthoproctus grimaldii	Mirrorbelly	Other fish	
Sternoptychidae	Hatchetfish	Small mesopelagics	
Photichthys argenteus	Lighthouse fish	Small mesopelagics	Lanternfish
Stomias sp.	Stomiatidae	Small mesopelagics	
Melanostomias sp.	Scaleless black dragonfish	Small mesopelagics	
Magnisudus prionosa	Barracudina	Small mesopelagics	
Alepisaurus ferox	Longsnouted lancetfish	Large mesopelagics	Lancetfish
Alepisaurus brevirostris	Shortsnouted lancetfish	Large mesopelagics	Lancetfish
Myctophidae	Laternfish	Small mesopelagics	Lanternfish
Macruronus novaezelandiae	Hoki	Large mesopelagics	
Merluccius australis	Hake	Large mesopelagics	
Lepidorhynchus denticulatus	Javelin fish	Other fish	
Macrouridae	Rattails	Other fish	
Genypterus blacodes	Ling	Other fish	
Ceratias sp.	Seadevil	Small mesopelagics	
Himantolophus appelii	Prickly anglerfish	Small mesopelagics	
Melanocetus johnsonii	Humpback anglerfish	Small mesopelagics	
Ceratioidei	Anglerfish unspecified	Small mesopelagics	
Exocoetidae	Flying fish	Large mesopelagics	
Hyporhamphus ihi	Garfish	Small mesopelagics	
Scomberesox saurus	Saury	Small mesopelagics	
Lampris guttatus	Moonfish	Large mesopelagics	
Lophotus capellei	Unicornfish	Other fish	
Trachipterus trachypterus	Dealfish	Large mesopelagics	
Agrostichthys parkeri	Ribbonfish	Large mesopelagics	
Monocentris japonicus	Pineapplefish	Other fish	

Diretmus argenteus	Discfish	Other fish	
Beryx splendens	Alfonsino	Large mesopelagics	
Cyttus novaezealandiae	Silver dory	Large mesopelagics	
Cyttus traversi	Lookdown dory	Large mesopelagics	
Zenopis nebulosa	Mirror dory	Large mesopelagics	
Allocyttus niger	Black oreo	Other fish	
Allocyttus verrucosus	Warty oreo	Other fish	
Oreosomatidae	Oreo unspecified	Other fish	
Centriscops humerosus	Banded bellowsfish	Large mesopelagics	
Macroramphosus scolopax	Snipefish	Small mesopelagics	
Hippocampus abdominalis	Seahorse	Other fish	
Syngnathidae	Pipefish	Small mesopelagics	
Helicolenus sp.	Seaperch	Other fish	
Congiopodus leucopaecilus	Pigfish	Other fish	
Polyprion oxygeneios	Hapuku	Large mesopelagics	
Epigonidae	Cardinalfish	Large mesopelagics	
Echeneididae	Remoras	Large mesopelagics	
Seriola lalandi	Kingfish	Large mesopelagics	
Trachurus declivis	Jack mackerel	Large mesopelagics	
Trachurus sp.	Jack mackerel	Large mesopelagics	
Brama 'brama'	Ray's bream	Large mesopelagics	
Ptercalis velifera	Wingfish	Large mesopelagics	
Pterycombus petersii	Fanfish	Large mesopelagics	
Taractes asper	Flathead pomfret	Large mesopelagics	
Taractichthys longipinnis	Big-scale pomfret	Large mesopelagics	
Bramidae	Pomfrets	Large mesopelagics	
Emmelichthys nitidus	Redbait	Small mesopelagics	
Pseudopentaceros richardsoni	Southern boarfish	Large mesopelagics	
Mugil cephalus	Grey mullet	Large mesopelagics	
Mugilidae	Mullet unspecified	Large mesopelagics	
Uranoscopidae	Stargazer unspecified	Other fish	
Lepidocybium flavobrunneum	Escolar	Large mesopelagics	
Nesiarchus nasutus	Black barracouta	Large mesopelagics	
Rexea solandri	Gemfish	Large mesopelagics	
Ruvettus pretiosus	Oilfish	Large mesopelagics	
Thyrsites atun	Barracouta	Large mesopelagics	
Benthodesmus sp.	Scabbardfish	Large mesopelagics	
Lepidopus caudatus	Frostfish	Large mesopelagics	
Allothunnus fallai	Slender tuna	Large mesopelagics	Tunas
Gasterochisma melampus	Butterfly tuna	Large mesopelagics	Tunas
Katsuwonus pelamis	Skipjack tuna	Large mesopelagics	Tunas
Scomber australasicus	Blue mackerel	Large mesopelagics	Tunas
Thunnus alalunga	Albacore	Large mesopelagics	Tunas
Thunnus albacares	Yellowfin tuna	Large mesopelagics	Tunas
Thunnus maccoyii	Southern bluefin tuna	Large mesopelagics	Tunas
Thunnus obesus	Bigeye tuna	Large mesopelagics	Tunas
Scombridae	Tuna unspecified	Large mesopelagics	Tunas
Xiphias gladius	Swordfish	Large mesopelagics	Tunas
Xiphidae	Marlin unspecified	Large mesopelagics	
Centrolophus niger	Rudderfish	Large mesopelagics	
Hyperoglyphe antarctica	Bluenose	Large mesopelagics	
Seriolella caerulea	White warehou	Large mesopelagics	
Cubiceps baxteri	Cubehead	Small mesopelagics	
Cubiceps caeruleus	Cubehead	Small mesopelagics	
Cubiceps sp.	Cubehead	Small mesopelagics	
Psenes pellucidus	Scissortail	Large mesopelagics	
Ariomma lurida	Ariommid	Large mesopelagics	
Tetragonurus cuvieri	Squaretail	Large mesopelagics	
Arnoglossus scapha	Witch	Other fish	
Bothidae	Lefteyed flounders	Other fish	

Pleuronectiformes	Flatfish unspecified	Other fish
Meuschenia scaber	Leatherjacket	Other fish
Ostracion cubicus	Boxfish	Other fish
Sphoeroides pachygaster	Pufferfish	Other fish
Allomycterus jaculiferus	Porcupine fish	Other fish
Mola mola	Sunfish	Large mesopelagics
Fish unidentified	Fish unidentified	Unidentified fish
Fish (commercial discards)	Fish (commercial discards)	Other fish

APPENDIX C: Questions to Observers regarding data collection

The following set of seven questions was asked of five observers who had all been on surface longline trips where stomach content data were collected. Summarised answers are provided after each question.

1. In the "Comments" column, crustacean prey items in stomachs have sometimes been further defined using the codes "PRA" (prawn), "SHR" (shrimp), and "KRL" (krill). Have you used all these codes? If yes, what characteristics do you use to distinguish between them?
   The instructions to observers state that prey species identification is not expected, so crustaceans are seldom identified further. Also, observers have limited exposure to crustaceans during field work. When used, 'prawn' is likely referring to items some centimetres in length, whereas 'krill' is more likely to be used to describe much smaller prawn-shaped crustaceans (and these will often be euphausiids or amphipods).

2. In the "Comments" column, fish prey items in stomachs include the codes "PHO" (*Photichthys* or lighthouse fish) and "LAN" (Myctophid or lanternfish). Have you used both these codes? If yes, what characteristics do you use to distinguish between them?
   There is seldom sufficient time for observers to use species identification guides to key out stomach contents in detail. When partially digested, these two species groups look similar and are difficult to differentiate. Small fish prey species with photophores are most likely to be recorded as lanternfish.

3. If (for example) there are two species of fish in a single stomach, and both species are clearly identifiable (say, as RBM and JMA), what would you be most likely to write in the "Comments" column? (e.g., one species; both species; the most abundant species?)
   Both species, sometimes with a percentage of total prey volume estimated for each.

4. If a stomach contains a large volume of well-digested fish that cannot be identified to species, plus one small fresh lanternfish, what would you be most likely to write in the "Comments" column relating to the fish contents?
   Sometimes only 'digested fish' (or no comment, which infers unidentified fish), sometimes only 'LAN', and sometimes a more complete comment like 'LAN 10%, unidentified fish 90%'. Some observers have used 10% as their minimum recorded prey quantity, others have used 5% or 1%.

5. Percentage volumes are recorded for the stomach contents in the categories 'fish', 'crustacean', 'squid', 'salp', 'bait', and 'other'. There is also an opportunity to provide further information in the "Comments" column. How do you usually decide what additional information you will record?

If the prey species can be identified ‘on sight’ then this information is likely to be recorded. If there are multiple species in the stomach then sometimes estimates of the percentage by volume of each species would also be noted. The amount of information that is recorded will be influenced by things like weather and what else is happening at the time, e.g., are other fish for which information must be recorded being landed or processed at the time. Plastic and other anthropogenic litter is usually allocated a percentage value in the ‘other’ column, with an associated comment.

6. There is no facility to record any information on the digestion state of stomach contents. Do different digestion states influence what data you record and how you record it?

   A severely digested item will often be recorded only in the percentage columns (e.g., as fish 100%) with no additional comment made. If a fish is digested to an unrecognisable state it could be confused with digested squid or bait, and so a best guess of which category it falls into would be made. Sometimes it is difficult to distinguish between small whole fish used as bait and small fish taken as true prey.

   A stomach containing only squid beaks might be recorded as ‘100% squid’ or ‘empty’, sometimes with ‘beaks’ as a comment.

7. Information on stomach contents of surface longline species has been recorded since 1994. Over the time you have been an observer on SLL trips, what has changed in the way you record information and comments?

   As observers have become more familiar with the different items found in stomachs they have been able to provide more information. A consistent system for recording extra information would be desirable, and more reference photos would be useful.

APPENDIX D: Recommendations for future data collection

This appendix contains details (and a draft proposed Stomach Sample Log) outlining what dietary data could be usefully collected by observers on surface longline trips. The record sheet is based on the dietary section of the 'fish biological' form currently used on all research trawl surveys. It contains space for five prey categories, and the percentage volume (estimated by eye) that each category contributed to the total prey volume. Five prey categories are believed to be sufficient; of the over 100 000 stomachs sampled during trawl surveys, only 0.1% of these recorded four prey categories and 0.001% recorded five. Stomach fullness is usefully categorised using a 4-stage scale ('empty', 'trace', 'part full', 'full'), with a separate category for any everted stomachs. An overall measure of state of prey digestion for all contents combined (called 'stomach condition' on the research survey 'fish biological' form) is of little use if there are items in the stomach with different digestion states. Consequently, it is suggested that recording a digestion state (on a subjective scale like 'fresh', 'part digested', 'heavily digested') for individual prey categories would be useful.

It is acknowledged that dietary data collected during trawl surveys has not been anywhere near as comprehensive and useful as lab investigation of stomach contents, primarily because they still contain too many 'uninformative' codes like 'fish', 'squid', or 'prawn'. Clearly, however, 'at-sea' sampling in any situation will never provide the detail possible from laboratory analysis. However, the adoption of a record sheet similar to that presented below would vastly improve the usefulness of dietary data collected by observers on surface longline vessels.

The other means to substantially increase data quality would be the training of observers in prey species identification, and ensuring that observers are provided with easy-to-use guides describing likely common prey species.

If a new Stomach Sample Log is adopted then it is recommended that within a year of its implementation the new data be examined to determine that its quality is suitable for future multivariate analyses. This examination would also help determine if instructions to observers need to be modified, or if additional resources to aid prey identification need to be provided.

Stomach Sample Log

Ministry for Primary Industries
Manatū Ahu Matua

Trip No. ____

Set No. ____

Observer ____

Page _____ of ____

Vessel ____

Sample Number	Species code	Stomach descriptions																Comments
		State	Prey 1	Condition	% V	Prey 2	Condition	% V	Prey 3	Condition	% V	Prey 4	Condition	% V	Prey 5	Condition	% V	

Stomach State: 0 - Empty; 1 - Trace; 2 - Part full (¼ – ¾); 3 - Full; 9 - Everted.

Prey Condition: 1 - Fresh; 2 - Part digested; 3 - Heavily digested.