SCIENCE & RESEARCH SERIES NO.29

AN ANALYSIS OF THE NEW ZEALAND WHALE STRANDING RECORD

by

Mark W. Brabyn

Published by
Head Office,
Department of Conservation,
P O Box 10-420,
Wellington

ISSN 0113-3713
ISBN 0-478-01275-6

National Library of New Zealand
Cataloguing-in-Publication data

Brabyn, Mark William.
An analysis of the New Zealand whale stranding record / by Mark W. Brabyn. Wellington [N.Z.] : Head Office, Dept. of Conservation, c1991.
1 v. (Science & research series, 0113-3713 ; no. 29)
Includes bibliographical references.
ISBN 0-478-01275-6
1. Whales–New Zealand–Stranding–Data processing. 2. Whales–New Zealand–Behavior–Data processing. I. New Zealand. Dept. of Conservation. II. Title. Series: Science & research series ; no. 29.
599.50285 (639.97950285)

Keywords: strandings, stranding theories, whales, dolphins, cetaceans, weather patterns, geographical distribution, database, cetacean distribution

FOREWORD

Whales and dolphins loom large in the public imagination - and the New Zealand waters contain a high proportion of the world's known species. Although whaling is now almost completely consigned to the dust-bin of history, the conservation of cetaceans still involves bycatches of fishing and stranding rescues. The Department of Conservation has taken a very active interest in the rescue of stranded whales and dolphins, but decisions as to the planning and prediction of effort have been hampered in the past by our lack of scientifically organised data on which to base management decisions.

A coherent and systematic collection of data on the stranding of whales and other delphinids is crucial if any successful action is to be taken to protect these animals. The data presented here will not only call other workers' attention to the fact that it is available but also serve as a part of a basic framework within which further work in the field can be undertaken.

This monograph presents the first collected results of the New Zealand Whale Stranding Data Base, which was set up in 1988 for the Department of Conservation. The author (who set up the data base) describes the objectives catered for in the data base and then summarises the whale stranding record up to early 1989. He examines the effect of weather on whale strandings and provides a general discussion that includes mention of various stranding theories. Stranding trends are discussed, in general as well as by species and geographical area.

R. M. Sadleir
Director of Science and Research

CONTENTS

AN ANALYSIS OF THE NEW ZEALAND WHALE STRANDING RECORD

by

Mark W. Brabyn

Department of Zoology, University of Canterbury, Private Bag, Christchurch

ABSTRACT

The New Zealand Whale Stranding Data Base (NZWSDB) was set up in 1988 with the Department of Conservation. The NZWSDB contains 1140 records of whale strandings, representing a total of 8287 individuals, 35 species, 163 herd strandings, and 304 known live strandings (up to April 1989). The geographical distribution and seasonality of strandings are given for 25 species of whales, dolphins and porpoises. Major centres for strandings occur at Whangarei, Hawke Bay, Farewell Spit, and Chatham Islands (Waitangi and Okawa). Herd stranding is most pronounced for offshore delphinids, in particular the pilot whale; distribution is highly clumped. In contrast, strandings of single, dead animals (indicative of the population distribution) are evenly scattered. There is a summer high and winter low.

Weather conditions at the time of and 24 hours before stranding are studied for 24 pilot whale and four sperm whale herd strandings. A significant relationship with increasing barometric pressure was found. Strandings are divided into nine categories, and theories on the causes of whale strandings are discussed.

1 TRENDS IN THE NEW ZEALAND WHALE STRANDING RECORD

The reason for the occurrence of stranding is based more on opinion than established fact.

Cordes 1982, p. 21

This section identifies stranding records contained in the New Zealand Whale Stranding Record (NZWSR). Comparisons between species, groups of species (offshore/inshore) and types of strandings (single-dead/single-live/herd) were made. Studies of other stranding records have related strandings to geomagnetic topography, whale feeding grounds, oceanographic conditions, coastal configuration, and the medical condition of whales (Goodall 1978, Mead 1979, Sheldrick 1979, Sergeant 1982, McManus *et al.* 1984, Klinowska 1986a, Nicol and Croome 1988). However, none of these studies compared different species and types of strandings in detail.

Details of New Zealand whale strandings up to 1964 were published by Gaskin (1968), and in 1981 a paper summarizing whale stranding events by season and region was presented to a joint New Zealand Wildlife Society/N.Z. Veterinary Association/Greenpeace technical seminar (Baker 1981).

The compilation of whale stranding records into a centralised data base, which was the initial basis of this study, has made the data more accessible and complete.

1.1 Terminology

Whale is used in this report in the broad sense representing all whales, dolphins and porpoises. They are subdivided into five groups based on their habits and taxonomy: offshore delphinids, inshore delphinids, sperm whales, beaked whales, and baleen whales. Sperm whales, beaked whales, and baleen whales are all considered *offshore species*, those species that spend the majority of their time off the continental shelf. *Inshore species* spend most of their time on the continental shelf. This division is not a clear-cut one. There are some species (e.g., bottlenose dolphin) which have both inshore and offshore populations.
Single strandings were strandings of an individual or a mother/calf pair.

Herd strandings were of more than one animal, excluding mother/calf pairs. All herd animals were assumed to be alive at the time of stranding.

Single strandings were recorded as *live* or *dead* when found. Single-dead strandings may have involved whales that died at sea and washed ashore or whales that died on the beach before being discovered.

Clump or *cluster* is used to define a site where two or more herd strandings or three or more single strandings have occurred.

A *hotspot* is the site of a major clump of strandings.

1.2 Objectives

The specific objectives of this study were:

- To determine the geographic distribution of strandings for each species and to identify areas of stranding clusters (or "hotspots").
- To determine whether there are any notable differences in the geographical distribution of strandings between the main whale groups.
- To determine whether single-live stranding events are distributed in a similar pattern to herd strandings (which may imply similar causes).
- To analyse sex ratio and mother/calf data which may indicate calving areas.
- To present information on seasonality, distribution and abundance of whales in New Zealand waters using the stranding record.
- To determine whether or not live strandings occur in relation to the abundance of cetaceans around New Zealand waters (single dead strandings have been used as an indicator of the natural abundance of species).

The last objective requires further explanation, as a fundamental assumption based on this comparison has been made. Little is known about the abundance, distribution and migration of cetaceans in New Zealand waters. However, the distribution of single-dead strandings may be an approximate indicator of distribution and abundance of cetaceans in coastal waters because they invariably involve whales that have died at sea and wash ashore. Most whales sink when they die and later, after buildup of decomposition gases, refloat if the water is not too deep. In deep water the hydrostatic pressure will entrap decomposition gases in the body and prevent refloating of carcasses. The number of single-dead strandings will therefore be representative of the relative number of whales in the area. There is some difficulty in distinguishing between a whale that has been washed ashore dead and one that has died on the beach before being discovered. However, a valid comparison can still be made because the proportion of either "washed ashore dead" or sick animals that have drifted ashore will be high.

A further assumption is that though single-dead whales may have been carried up to 100 km by currents, they will rarely have been carried for greater distances.

1.3 Methods

The New Zealand Whale Stranding Data Base (NZWSDB) was established in January 1988 from records held by the National Museum of New Zealand, Ministry of Agriculture and Fisheries, Department of Conservation, Frank Robson (1984 and private records), Gaskin (1968), International Whaling Commission reports (Cawthorn 1978, 1979, 1982) and newspaper archives. A list of the categories used in the NZWSDB can be found in Appendix A. Copies of the NZWSDB are held at the Zoology Department, University of Canterbury, at Department of Conservation, Head Office, Wellington, and at the National Museum, Wellington.

All stranding records have been verified against original sources. Some misidentification of species and sexes has probably occurred but every attempt has been made to minimise errors. Only events occurring before April 1989 have been used in this study. The localities of all place names mentioned in the text are shown in Figure 1.

Strandings were mapped by species and by group. The accuracy of stranding locations was estimated to be within 5 km. Only species with more than four stranding records were studied. Comparisons were made between species, between groups and between types of stranding (single-herd and live/dead). Strandings were considered to be clustered where three or more single strandings, or two or more herd strandings occurred within 50 km.

Sex and mother/calf data were tabulated to determine whether calving was correlated with stranding. Areas where numerous female and mother/calf strandings occurred may show calving regions around New Zealand. Records for each species and group of species were analyzed monthly, and variation in latitude was compared with time of year strandings occurred.

Fig. 1 New Zealand placenames mentioned in text.

1.4 Results

The NZWSDB (as at April 1989) contains 1140 stranding records, involving a total of 8287 individual whales. These records consist of 163 herd strandings (87 of 10 or more whales) and 977 single strandings. Of these, 304 are recorded as live strandings (or active strandings), 123 are recorded as single-dead strandings and 713 are undetermined.

Animals from 35 species have stranded in New Zealand, representing nearly half of the world's 75-80 cetacean species. Although the data base contains records dating back to 1840, it cannot be considered even nearly complete until 1978, when the Marine Mammals Protection Act was introduced and it became government policy to record all strandings. Since this date the record averages six herd strandings and 44 single strandings per year (Figure 2), one of the highest rates of herd stranding in the world.

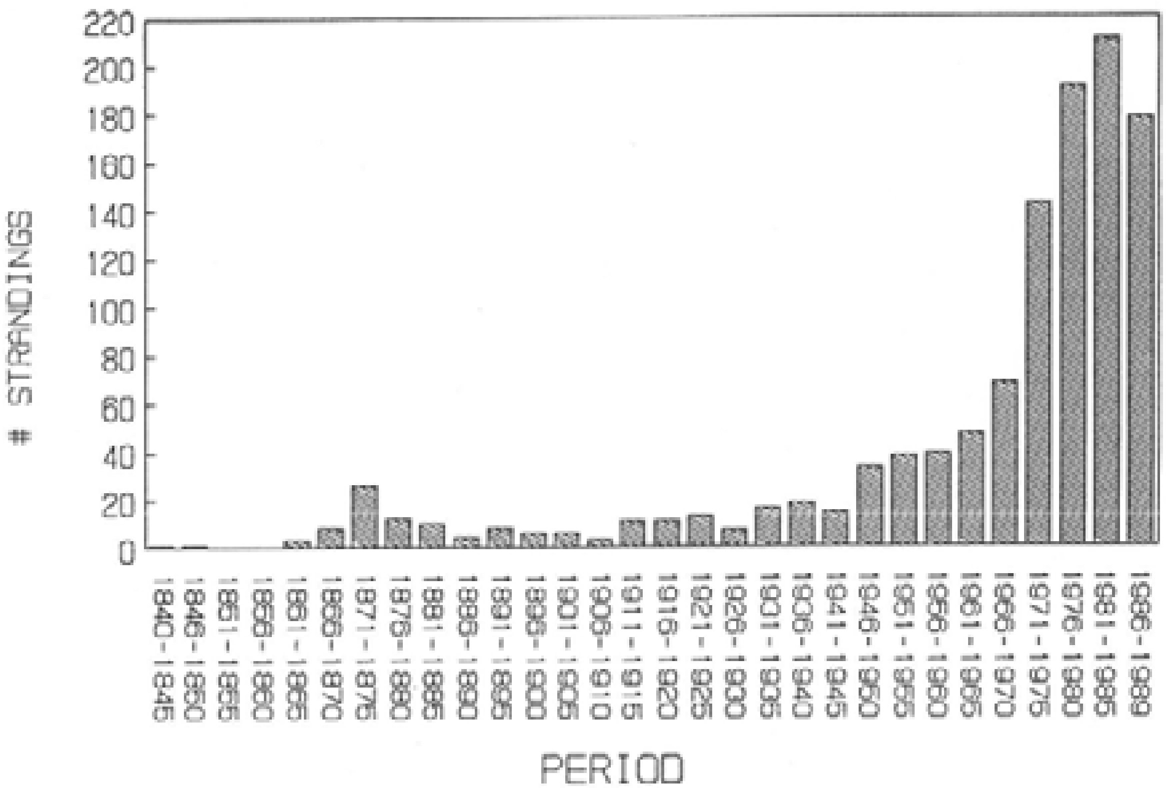

Fig. 2 The New Zealand stranding record from 1840 to April 1989. Note the increase in strandings recorded after the introduction of the Marine Mammal Act in 1978.

A summary of the species composition and number of strandings recorded in the NZWSDB is given in Table 1. All species recorded in New Zealand waters have stranded. Five species account for 48% of all New Zealand's strandings: pygmy sperm whales, pilot whales, sperm whales, common dolphins, and scamperdown whales. A further 34% of strandings are by 10 other species, which have stranded at least 18 times.

Table 1. The New Zealand whale stranding record to April 1990.

TOOTHED WHALES (ODONTOCETI)		**1009**	**148**	**102**	**163**		**8157**
Sperm whales (Physeteridae)		252	37	49	21		526
Sperm whale	*Physeter macrocephalus*	104	17	6	11	(72)	336
Pygmy sperm whale	*Kogia breviceps*	147	20	42	10	(4)	189
Dwarf sperm whale	*K. simus*	1	-	1	-		1
Dolphins (Delphinidae)		**448**	**66**	**33**	**116**		**7229**
Common dolphin	*Delphinus delphis*	95	26	10	8	(20)	146
Bottlenose dolphin	*Tursiops truncatus*	46	7	9	6	(49)	142
Dusky dolphin	*Lagenorhynchus obscurus*	45	5	2	6	(10)	73
Hourglass dolphin	*L. cruciger*	1	1	-	-		1
Hector's dolphin	*Cephalorhynchus hectori*	57	8	1?	-		59
Southern right whale dolphin	*Lissodelphis peronii*	10	-	-	5	(75)	89
Pilot whale	*Globicephala melaena*	118	12	5	71	(450)	5442
Killer whale	*Orcinus orca*	16	3	4	4	(17)	49
False killer whale	*Pseudorca crassidens*	20	2	2	6	(300)	760
Risso's dolphin	*Grampus griseus*	8	1	-	1	(6)	14
Striped dolphin	*Stenella coeruleoalba*	4	1	-	-		4
Spotted dolphin	*S. attenuata*	1	-	-	-		1
Rough-toothed dolphin	*Steno bredanensis*	1	-	-	-		1
Spectacled porpoise	*Phocoena dioptrica*	1	-	-	-		1
Unidentified dolphins		20	-	-	4		34
Blackfish:pilot/false killer		5	-	-	5		413
Beaked whales (Ziphidae)		**309**	**45**	**20**	**26**		**402**
Arnoux's beaked whale	*Berardius arnouxi*	41	7	-	5	(6)	51
Southern bottlenose whale	*Hyperoodon planifrons*	18	3	3	2	(2)	21
Andrew's beaked whale	*Mesoplodon bowdoini*	12	1	-	-	12	
Scamperdown whale	*M. grayi*	82	14	7	14	(25)	147
Hector's beaked whale	*M. hectori*	13	2	-	1	(2)	15
Straptooth whale	*M. layardi*	53	11	4	3	(4)	61
Gingko-toothed whale	*M. gingkodens*	1	-	-	-		1
Shepherd beaked whale	*Tasmacetus shepherdi*	13	-	1	1	(2)	14
Cuvier's beaked whale	*Ziphius cavirostris*	59	7	5	-		62
Unidentified beaked whale		17	-	-	-		18
BALEEN WHALES (MYSTICETI)		**121**	**13**	**12**	-		**121**
Right whales (Balaenidae)		**21**	**7**	-	-		**21**
Southern right whale dolphin	*Balaena glacialis australis*	2	1	-	-		2
Pigmy right whale	*Caperea marginata*	19	6	-	-		19
Rorqual whales (Balaneopteridae)		**84**	**6**	**12**	-		**84**
Blue whale	*Balaenoptera musculus*	13	1	-	-		13
Fin whale	*B. physalus*	13	-	-	-		13
Bryde's whale	*B. edeni*	2	-	-	-		2
Sei whale	*B. borealis*	8	-	-	-		8
Minke whale	*B. acutorostrata*	40	4	12	-		40
Humpback whale	*Megaptera noaveangliae*	8	1	-	-		8

Unidentified baleen whale	6	-	-	-	6
Unidentified species	19	-	-	-	19
TOTAL	**1139**	**161**	**114**	**163**	**8287**

Eighty-four percent of the individuals stranding are in three species: pilot whales, false killer whales, and sperm whales. These herds strand in large numbers (up to 450 whales).

Sites of clusters of single and herd strandings for each species are summarized in Table 2. More detailed accounts of stranding trends for major groups are given below, and trends of stranding clusters for each group are noted at the end of each section.

1.4.1 Species stranding trends.

1.4.2 *Sperm and pygmy sperm whales* account for 22% of all strandings and 13% of herd strandings (Table 1). The distributions for the sperm whale and pygmy sperm whale are shown in Figure 3.

Pygmy sperm whales have, with 147, the highest incidence of stranding in New Zealand. However, only 10 of these have been herd strandings, most of which were pairs (the largest being of four animals). Opoutama is the only hotspot for pygmy sperm whale herd strandings. However, there are hotspots for single strandings at Opoutama, Napier, Wellington, and Canterbury. With the exception of South Westland and Southland, single strandings of pygmy sperm whales have been recorded throughout New Zealand.

The only cluster of herd strandings observed for sperm whales is near Kaipara Harbour, Northland, where five of the 11 recorded herd strandings occurred. Five of the 11 herd strandings of sperm whales have been nursery/harem herds - four at Kaipara and one at Gisborne. The six bachelor herd strandings are widely distributed. The distribution of single strandings is relatively even throughout New Zealand, although female strandings have only been recorded in the North Island. Of single strandings where sex has been recorded 78% have been males. Single strandings of sperm whales are concentrated along Wellington's coast and at Opoutama beach.

There is only one record of a stranding of a dwarf sperm whale, and this was at Waiwera beach, North of Auckland. Dwarf and pygmy sperm whales are morphologically very similar, and only recent records differentiate these species. It is probable that some of the strandings recorded as pygmy sperm whales are in fact dwarf sperm whales, and this must be kept in mind when looking at the pygmy sperm whale stranding distribution map.

Sperm and pygmy sperm whales have no common herd stranding sites. However, of the nine sites where single strandings of sperm whales are concentrated, four (Opoutama, Napier, Wellington, and Canterbury) are also sites where single strandings of pygmy sperm whales are clustered. All sites where single pygmy sperm whale stranding concentrations occur are also common to single sperm whale strandings (Table 2).

The *offshore delphinids* (pilot whales, false killer whales, Risso's dolphin, and southern right whale dolphin) make up only 14% of all strandings but 50% of herd strandings, three times more herd strandings than any other group. The distribution of offshore delphinid strandings is shown in Figure 4.

Table 2. Summary of clumping sites for whale strandings in New Zealand.

Sites of clumping does not necessarily represent distribution. More solitary species (many of the beaked whales and baleen whales) are not expected to have as many herd strandings as the more social species (pilot whales).

	Location of Clumping / Species	North Island										South Island					Islands			
		Ninety Mile Beach	Kaipara Coast	Houhora/Doubtless	Whangarei	Coromandel Peninsula	Tekaha	Opoutama Beach	Napier	New Plymouth	Wellington	Nelson	Golden Bay	Canterbury	Dunedin	Southland	Stewart Island	Chatham Island	Total ○	Total ×
Sperm Whales	Sperm Whale	○	⊗					○	○	○	○			○	○	○		○	10	1
	Pygmy Sperm Whale							⊗	○		○			○					4	1
Inshore Delphinids	Hector's Dolphin									○				○		○			3	0
	Common Dolphin				○	○		○	○	○	○	⊗	○						8	1
	Dusky Dolphin								○		○	×						×	2	2
	Bottlenose Dolphin				○								×		○				2	1
Offshore Delphinids	Pilot Whale	×		×	×	×	×	×	×		○		×				×	⊗	2	10
	Risso's Dolphin										○								1	0
	Sthrn Right Whale Dol.												×						0	1
	False Killer Whale							⊗											1	1
Beaked Whales	Arnoux's Beaked Whale					○			○		⊗								3	1
	Sthrn Bottlenose Whale					○													1	0
	Cuvier's Beaked Whale										○			○				○	3	0
	Scamperdown Whale						○	○	○		○							⊗	5	1
	Straptooth Whale										○			○				○	3	0
	Hector's Beaked Whale								○										1	0
Baleen Whales	Minke Whale					○					○		○	○	○				5	0
	Humpback Whale									○									1	0
	Total ○	1	1	0	2	4	1	5	7	4	11	1	2	6	3	2	0	5	55	
	Total ×	1	1	1	1	1	1	3	1	0	1	2	3	0	0	0	1	3		20

○ Clumping of single strandings (>=3)
× Clumping of herd strandings (>=2)

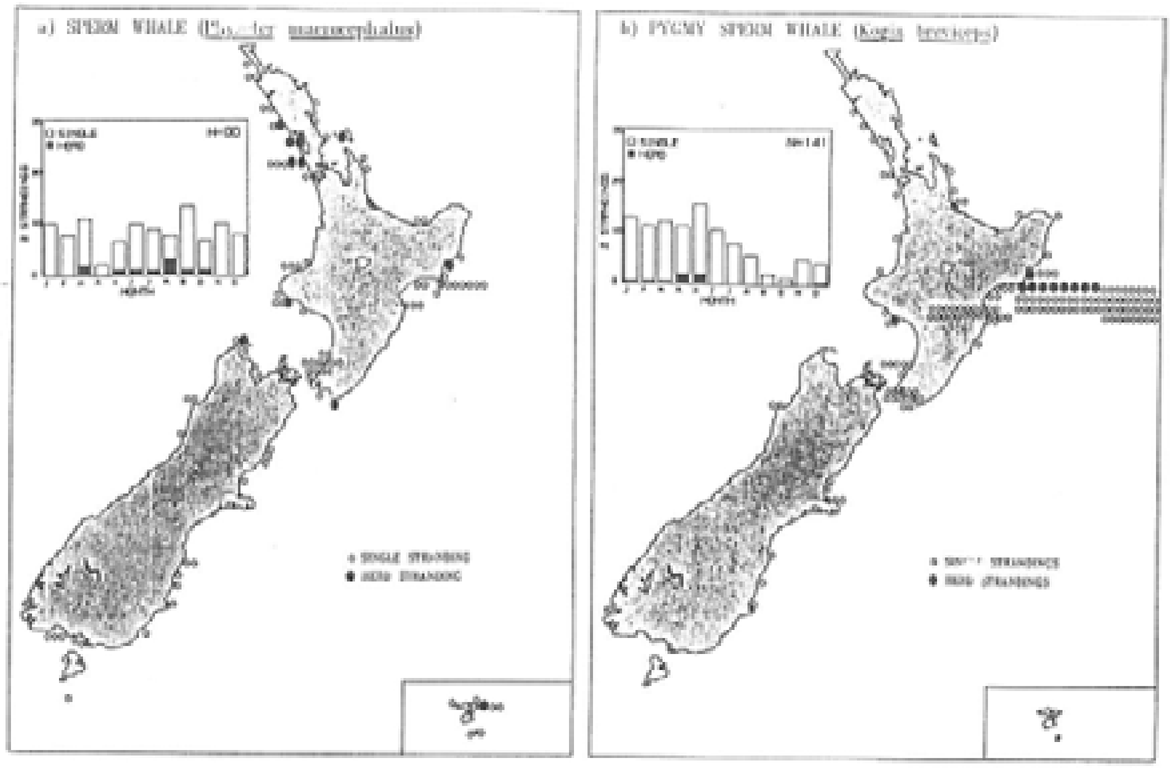

Fig. 3 Distribtuion and seasonality of strandings for sperm whales: (a) sperm whale, and (b) pygmy sperm whale.

Large solid dots = herd strandings; small circles = single strandings. Note the clump of herd strandings of sperm whales in the Kaipara coast and the clump of strandings of pygny sperm whales at either end of Hawke Bay. All dots off Mahia Pennisula are strandings at Opoutama Beach on the inside of the peninsula.

Pilot whales are the most frequent herd standers of all cetaceans, with 71 strandings recorded, whereas only twelve herd strandings are recorded for all other offshore delphinids combined. Pilot whales also have the largest single stranding recorded in New Zealand with some 450 whales at Kawa Bay, Great Barrier Island in 1985. The distribution of pilot whale herd strandings is concentrated with three or more events at: Whangarei Harbour, Mahia Peninsula, Golden Bay, and Chatham Islands, and two events at: Houhora Heads, Doubtless Bay, Kipiro Bay, Great Barrier Island, Mercury Islands, Te Kaha, Clifton, and Stewart Island. Of the 21 herd stranding sites identified for pilot whales, 15 have been multiple herd stranding sites (i.e., have had two or more herd strandings).

The distribution of herd strandings of other offshore delphinids are also clustered. The southern right whale dolphin, has four out of five herd strandings at Farewell Spit, and the false killer whale has three out of seven herd strandings at Opoutama. The number of strandings of Risso's dolphin is too small to identify hotspots however no strandings have been recorded in South Island.

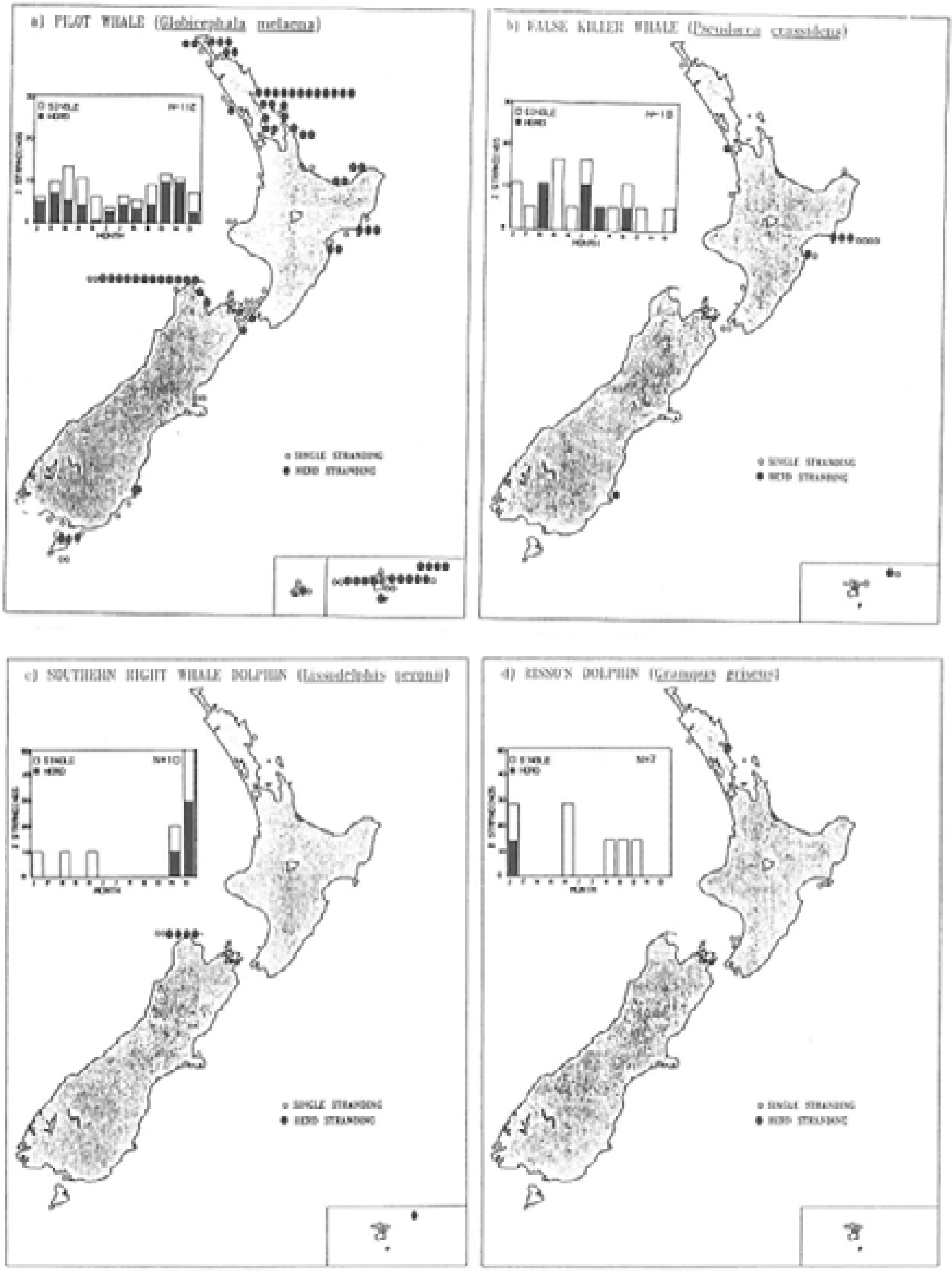

Fig. 4 Distribtuion and seasonality of strandings for offshore delphinids: (a) pilot whale, (b) false killer whale dolphin, (c) southern right whale dolphin, (d) Risso's dolphin.
Dots at Farewell Spit = strandings on the inside of the spit. Note the hotspots for herd strandings of pilot whales at Whangarei, Golden Bay, Hawke Bay and Chatham Islands. Also note that the 13 sites of herd strandings of southern right whale dolphin, Risso's dolphin, and false killer whale, only one has not also has a pilot whale stranding.

Of the total of 13 herd strandings for Risso's dolphin, false killer whale, and the southern right whale dolphin, only one has not had a pilot whale herd stranding in the same location. (This was a false killer whale stranding in Manukau Harbour in 1978.) Thus it appears that the offshore delphinids herd strand at similar locations.

Inshore delphinids (dusky dolphin, Hector's dolphin, common dolphin, bottlenose dolphin, and killer whale) make up 23% of all strandings but only 15% of herd strandings. The distribution of inshore delphinid strandings is shown in Figure 5.

Large solid dots = herd strandings; small circles = single strandings. Note the clump of herd strandingsd of sperm whales on the Kaipara coast and the clump of strandings of pygmy sperm whales at either end of Hawke Bay. All dots off Mahia Peninsula are strandings at Opoutama Beach on the inside of the peninsula.

The distribution of strandings of the inshore delphinids is clearly indicative of the known distribution of these species. The common dolphin, with 95 strandings, has had almost twice as many strandings as any other inshore species, presumably reflecting its abundance in New Zealand inshore waters.

The number of herd strandings for any one species of inshore delphinid is too small to indicate obvious hotspots. Of the 57 Hector's dolphin strandings recorded, there were no herd strandings and only one live stranding. Nelson Haven is the only site which has a concentration of herd strandings for two species - dusky dolphins and common dolphins. (There are four sites where there is clumping of single strandings common to two species - Whangarei, Napier, New Plymouth, and Wellington.) Nine of the 23 herd strandings for inshore delphinids have occurred in estuaries (e.g., four in Nelson Haven).

The *beaked whales* (scamperdown whale, straptooth whale, Andrews' beaked whale, Hector's beaked whale, Shepherd's beaked whale, Cuvier's beaked whale, southern bottlenose whale, and Arnoux's beaked whale) make up 27% of all strandings and 16% of herd strandings. The distribution of strandings for the beaked whales is shown in Figure 6.

With the exception of the scamperdown whale, herd strandings are not very common and consist of only a few animals (usually two, but up to six). Fourteen herd strandings have been recorded for scamperdown whales (second commonest herd strander after the pilot whale), the largest of which involved 25 whales. A concentration of herd strandings has been noted on the Chatham Islands. Concentrations of single strandings also occur at Chatham Islands, Hawke Bay, Te Kaha, and Wellington.

There are no sites where clumping of herd strandings occurs for more than one species of beaked whale. The sites of herd stranding concentrations at Wellington for Arnoux's beaked whale and at Chatham Islands for the scamperdown whale are also sites for clusters of single strandings of three and two other species of beaked whale (respectively). The other site at which scamperdown herd strandings commonly occur is Nelson which has no clumping for any other species (single or herd).

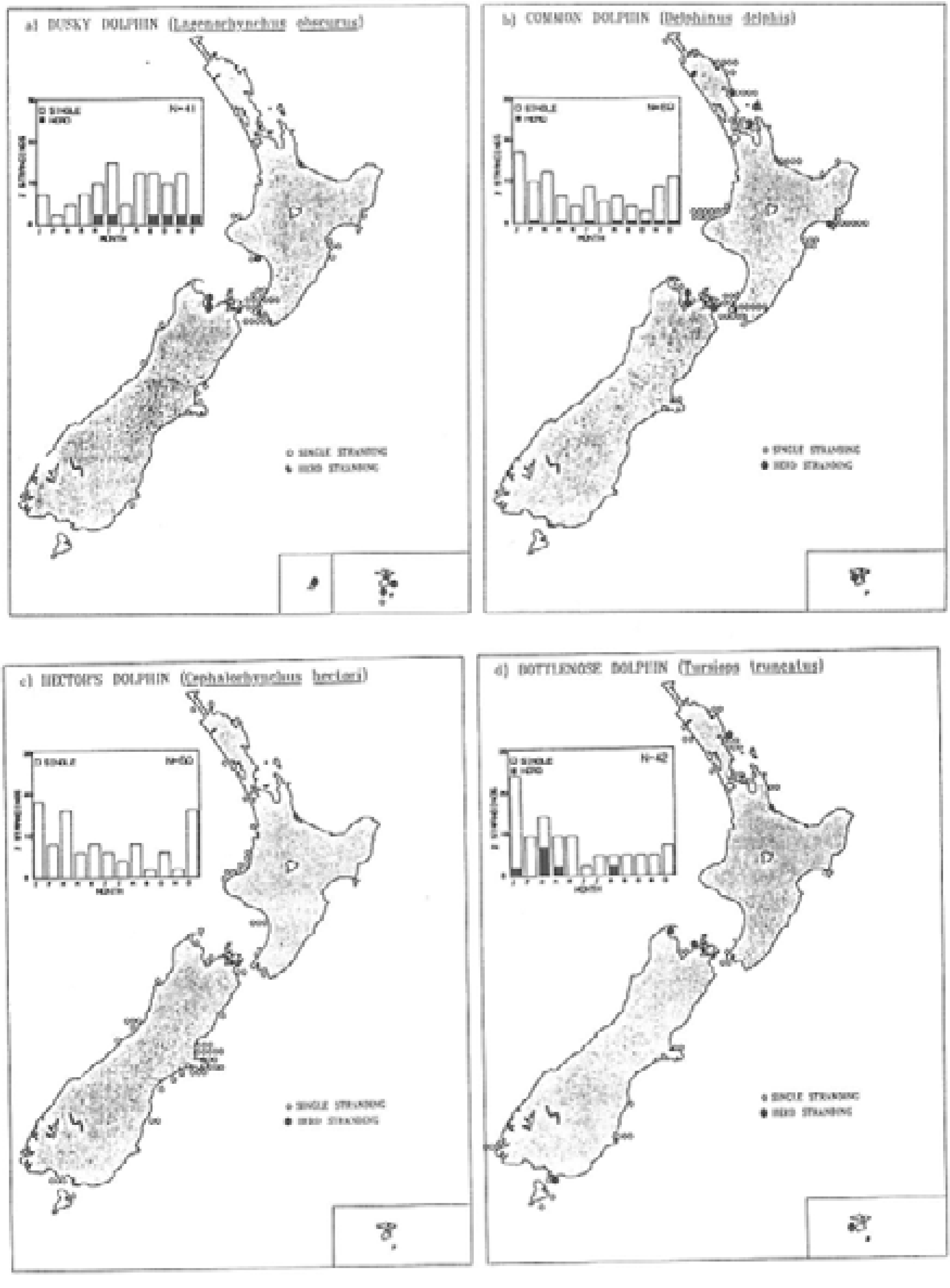

Fig. 5 Distribution and seasonality of strandings for inshore delphinids: (a) dusky dolphin, (b) common dolphin, (c) Hector's dolphin, (d) bottlenose dolphin (continued on next page)
These distribution reflect known natural distribtuions. Note that no outstanding hotspots occur.

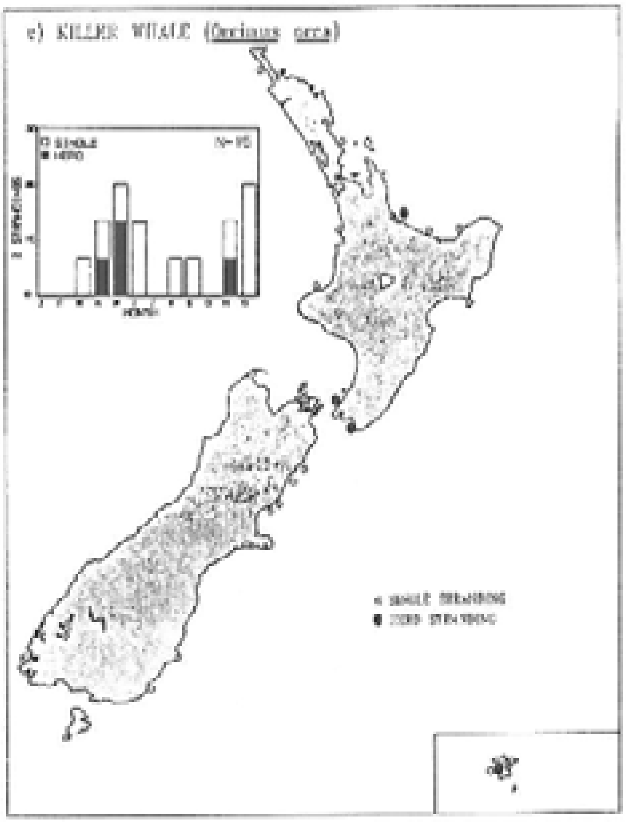

Fig. 5 continued: (e) killer whale.

At Wellington, clusters of single strandings occurs for four species (Arnoux's beaked whale, Cuvier's beaked whale, scamperdown whale, and straptooth whale). While at Napier and Chatham Islands, single stranding clumps occur for three species, and at another two sites, Coromandel and Canterbury, single stranding clumps occur for two species (Table 2).

Baleen whales (right whale, pygmy right whale, humpback whale, blue whale, fin whale, sei whale, Bryde's whale, and minke whale) make up only 10% of all strandings. The distribution of strandings for the baleen whales is shown in Figure 7.

Of this group the minke whale has the highest number of strandings (40), which are spread evenly throughout both islands. A clump of four minke whale strandings was recorded in Golden Bay, and another clump of four strandings of humpback whales has occurred at New Plymouth. Five strandings of pygmy right whales at Stewart Island also occurred in a similar location. Too few other baleen whales have stranded to comment on any distributional patterns. No herd or mother/calf strandings have been documented for baleen whales in New Zealand.

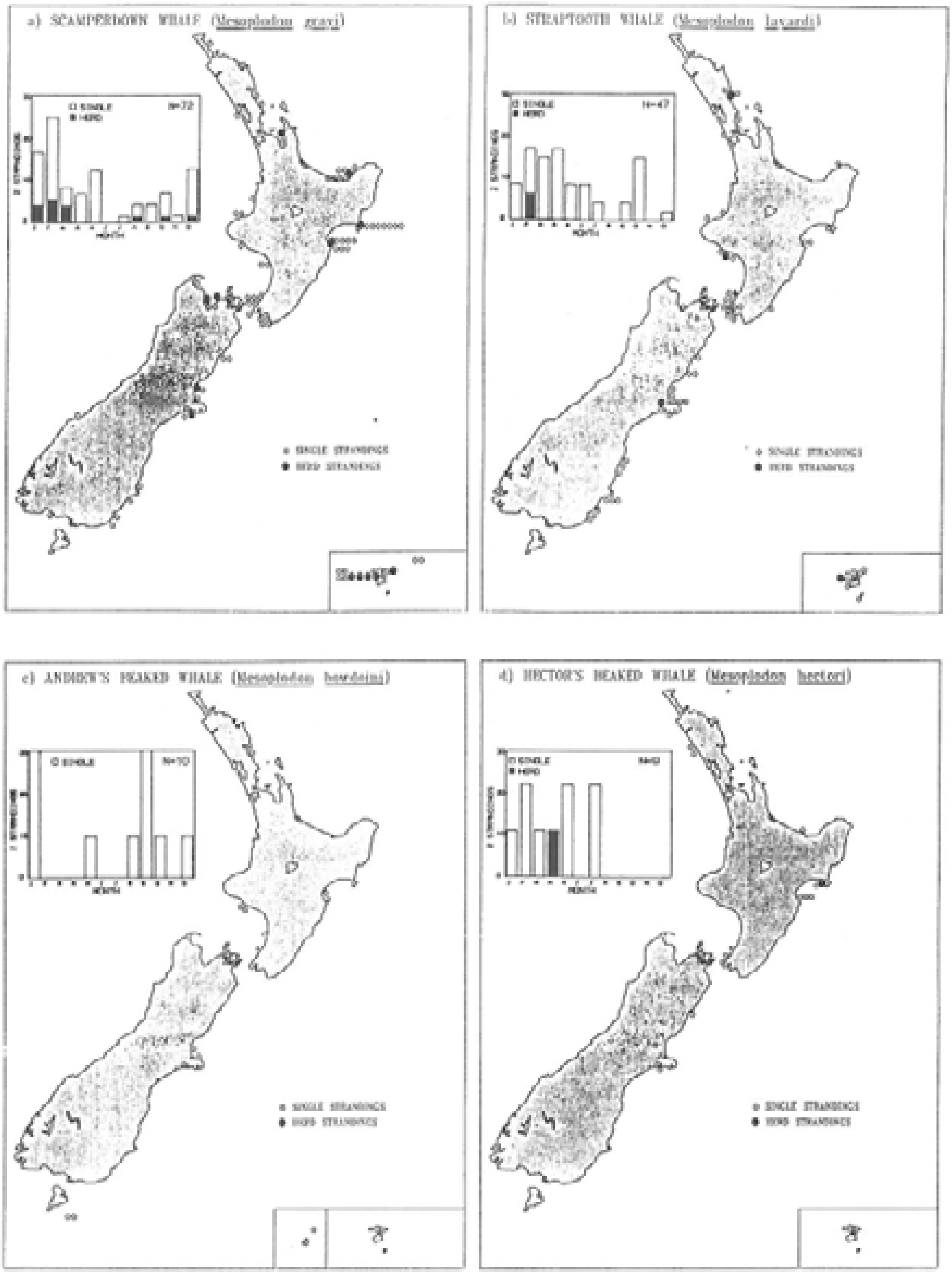

Fig. 6 Distribution and sesonality of strandings for beaked whales: (a) scamperdown whale, (b) straptooth whale, (c) Andrew's beaked whale, (d) Hector's beaked whale. (Continurd on next page)

A hotspot for herd strandings of scamperdown whales occurs at Chatham Islands, but no hotspots for other beaked whales were noted.

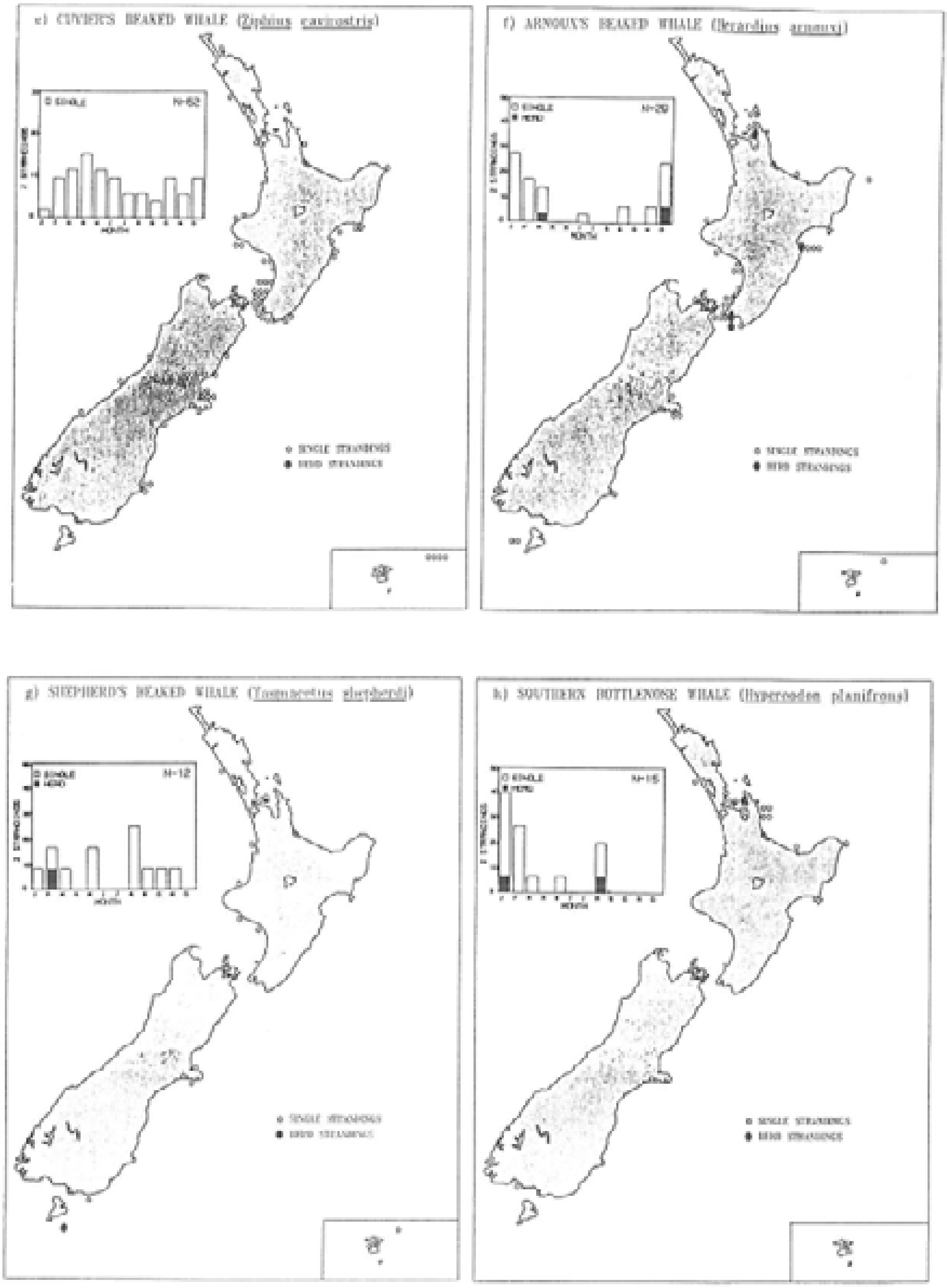

Fig. 6 continued: (e) Cuvier's beaked whale, (f) Arnoux's beaked whale, (g) Shepherd's beaked whale, (h) southern bottlenose whale.

Note hotspots for the southern whale and Arnoux's beaked whale in the Firth of Thames.

Fig. 7 Distribution and seasonality of strandings for baleen whale: (a) minke whale, (b) sei whale, (c) blue whale, (d) fin whale. (Continued on next page.)

Note hotspot for minke whale at Golden Bay. There have been no herd or mother-calf strandings of baleen whales in New Zealan

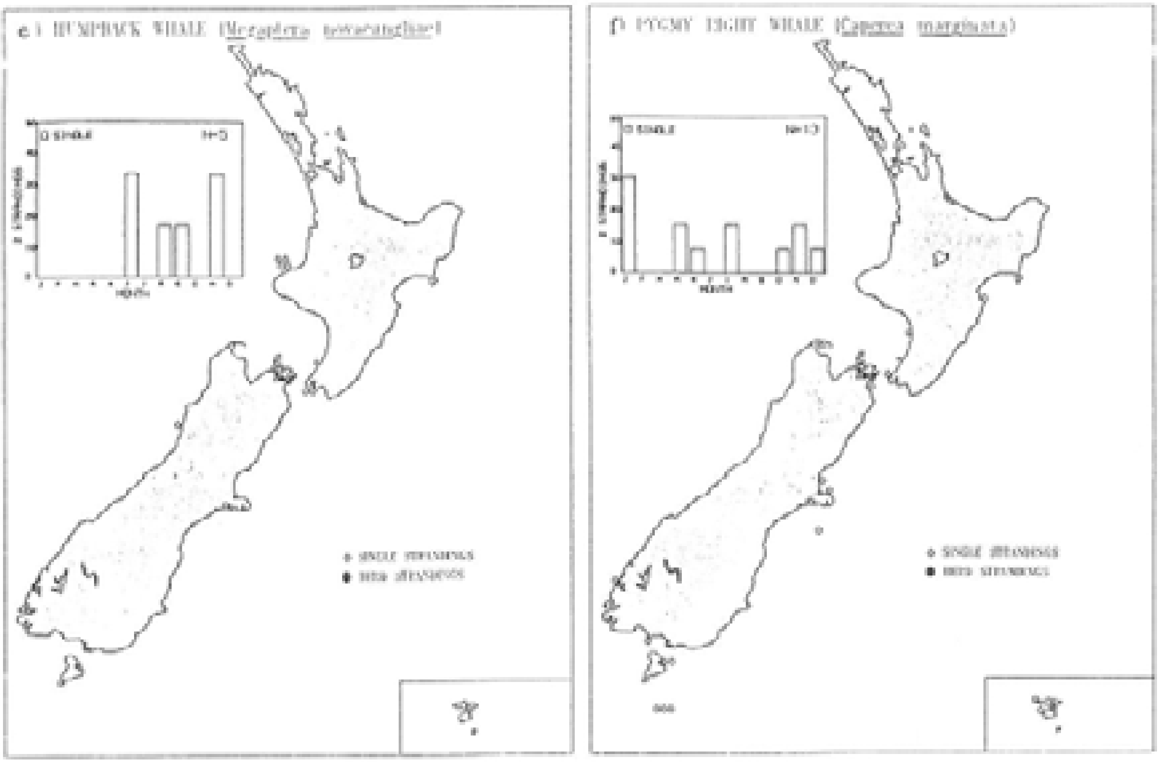

Fig. 7 continued: (e) humpback whale, (f) pygmy right whale.
Note hotspot for humpback whales at New Plymouth.

1.4.2 Overall Geographic Trends. The most common herd stranding hotspots across all species are Opoutama, Golden Bay, and Chatham Islands. Each of these sites is a hotspot for three different species (Table 2). The most common single stranding hotspot is Wellington, with 11 species, followed by Napier (7 species), Canterbury (6 species), Opoutama and Chathams (5 species) (Table 2).

1.4.3 Comparison of Live Strandings Between Groups. The geographic distribution of live strandings was compared between groups to determine whether or not similar stranding patterns are found across all groups. Live strandings for each group are shown in Figure 8a, 9a, 10a, 11a, and a summary of group clumping data is given in Table 3

Major points that arise from this comparison are:

- Kaipara is a unique hotspot for sperm whale strandings. No other species has a cluster of strandings there.
- All four live-stranding hotspots for beaked whales and four out of six live-stranding hotspots for inshore delphinids are also live-stranding hotspots for offshore delphinids.
- Opoutama is a hotspot for live strandings for four groups (pygmy sperm whales, inshore delphinids, offshore delphinids, and beaked whales); Napier, Coromandel, and the Chatham Islands are hotspots for live strandings for three other groups.

•Houhora Harbour/Doubtless Bay, Ninety Mile Beach, and Stewart Island are live-stranding hotspots for offshore delphinids (pilot whales) but for no other groups.
•Offshore delphinids have more live-stranding hotspots than any other group (nine sites compared with six for inshore delphinids, and four for beaked whales).

Table 3. Summary of clumpings sites for single-dead versus live strandings in New Zealand. Offshore species have fewer single strandings than inshore species because animals that die in very deep water will not refloat and wash ashore.

Location of Clumping / Group	North Island										South Island					Islands			
	Ninety Mile Beach	Kaipara Coast	Houhora/Doubtless	Whangarei	Coromandel Peninsula	Tekaha	Opoutama Beach	Napier	New Plymouth	Wellington	Nelson	Golden Bay	Canterbury	Dunedin	Southland	Stewart Island	Chatham Island	Total O	Total X
Sperm Whales		⊗					⊗	X							O			3	3
Inshore Delphinids	O			X			X	O	O	X	⊗	⊗	O				X	6	5
Offshore Delphinids	X		X	X	X		X	X				X				X	⊗	1	9
Beaked Whales					X		X	⊗									⊗	2	4
Baleen Whales					X							O	O					2	1
Total O	1	1	0	0	0	0	1	2	1	0	1	2	2	0	1	0	2	14	
Total X	1	1	1	2	3	0	4	3	0	1	1	2	0	0	0	1	3		23

X Clumping of Live Strandings (>=3)   O Clumping of Single-dead Strandings (>=3)

Note different definitions of symbols from table 2

1.4.4 Comparison of Single-Dead/Live Strandings. Comparison between single-dead and live strandings indicates that live strandings do not occur directly in relation to cetaceans distribution and abundance. In Figures 8-11, live strandings are mapped alongside single-dead strandings to enable comparison of their geographic distributions.

A summary of clumping for each of these groups is given in Table 3. The important points from this comparison are:
•Both Kaipara and Opoutama have been sites of clusters of single-dead and live strandings for sperm whales and pygmy sperm whales respectively.
•Of the nine sites at which offshore herd strandings concentrations occur, only the Chatham Islands is also a site for concentrations of single dead strandings.
•Of the three sites at which clusters of inshore delphinid herd strandings occur, only Chatham Islands does not have a concentration of single-dead strandings. The other two sites, Nelson and Golden Bay, are also sites for single-dead strandings, and therefore these locations may have high densities of semi-resident dolphins.
•Of the six sites at which clumping of beaked whale live strandings occur, two sites (Coromandel and Opoutama) do not have concentrations of single-dead strandings.
•The live strandings of baleen whales at Coromandel does not occur in conjunction with any single-dead stranding concentrations. However, the number of strandings of baleen whales is small.

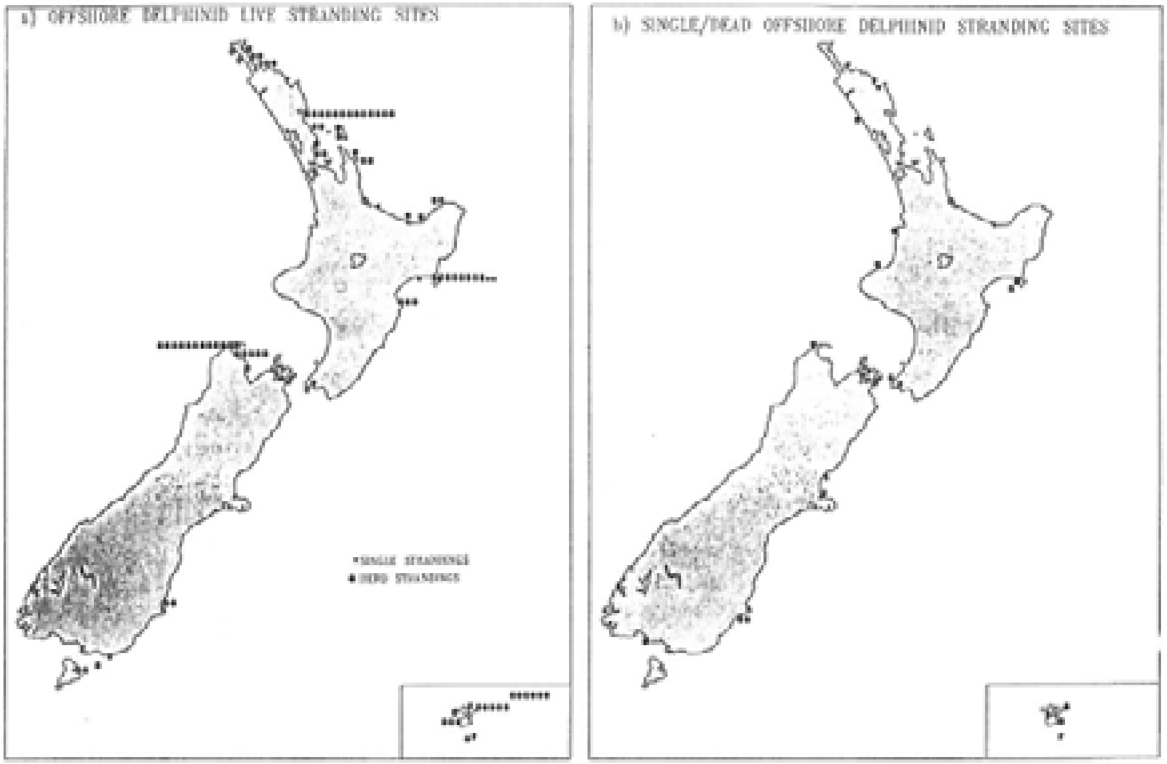

Fig. 8 Distribution of (a) live strandings and (b) single-dead strandings for the offshore delphinids.
Note clumping of live strandigns at Whangarei, Hawke Bay, Golden Bay, and the Chatham Islands, but no clumpings at all single-dead strandings.

Fig. 9 Distribution of (a) live strandings and (b) single-dead strandings for the inshore dephinids.
Note no definite clumping of either live or single-dead strandings.

Fig. 10 Distribtuion of (a) live strandings and (b) single-dead strandings for the beaked whales.
Note clumping of live strandings in the Firth of Thames, Hawke Bay, and the Chatham Islands, but no clumping of single-dead strandings.

Fig. 11 Distribtuion of (a) live strandings and (b) single-dead strandings for the baleen whales.
Note no definite clumping of either live or single-dead strandings. All live strandings have been minke whales.

•From the comparison of the distribution of single-live and herd strandings (Figs 8-11) it appears that single-live stranding sites generally reinforce the patterns of herd stranding concentrations.

1.4.5 Seasonality of Strandings. Stranding records show high numbers of strandings in summer and low numbers in winter (Fig. 12). The extent of this seasonality varies between species (Figs 3-7) and between groups (Fig. 13a-d). Herd strandings appear to have a bimodal seasonality with peaks in both February and October (Fig. 14a). Bimodal seasonality is not seen in single-live, single-dead, or single-toothed whale strandings (Fig. 14b-d).

The seasonality of strandings for the various regions is shown in Figure 15. No obvious latitudinal variation is apparent. The seasonality of strandings for pilot whales is given (Fig. 16) for four regions where hotspots exist: North Auckland, Gisborne/Hawke Bay, Nelson, and Chatham Islands. Herd strandings of pilot whales occur at different times of the year in North Auckland (September, October, and November), than in Nelson (January, February, and March). No obvious seasonality emerges in the other regions.

Sex ratio and mother/calf data are presented in Table 4. Twice as many female pygmy sperm whales strand as male pygmy sperm whales and approximately half of the females are with a calf. Twice as many male as opposed to female sperm whales have singly stranded. For straptooth whales, the trend is reversed; more than twice as many females have stranded than males. More beaked whale calves have stranded singly than any other group.

1.5 Discussion

1.5.1 Sources of Variation in Results. The similarity in appearance between the pygmy sperm whale and the dwarf sperm whale makes it likely that some of the strandings recorded as pygmy sperm whales were in fact dwarf sperm whales. Pilot whales recently stranded at Farewell Spit were identified as the short-finned species (*Globicephala macrorhynchus*) by Baker (MAF report 1977). Prior to this all pilot whale strandings have been recorded as long-finned species (*G. melaena*).

Sperm whales have three distinct social groupings - nursery and harem herds, bachelor herds, and solitary males (Gaskin 1982). Nursery and harem herds do not usually migrate farther south than Cook Strait (Gaskin and Cawthorn 1967). The effect of social structure on stranding in other whale species is not known.

The National Museum has been recording strandings in Wellington since 1865, and Robson has been recording strandings in the Hawke Bay area since 1966. Therefore, these regions may show an exaggerated number of strandings as a consequence of this. Clusters may occur elsewhere but recordings have not been made consistently.

Many strandings of the three smaller species of dolphin (Hector's, dusky, and common dolphin), may be a result of incidental catch from set nets. This will elevate stranding records of a species in regions where set netting occurs and may alter any trend in the natural distribution of stranding hotspots.

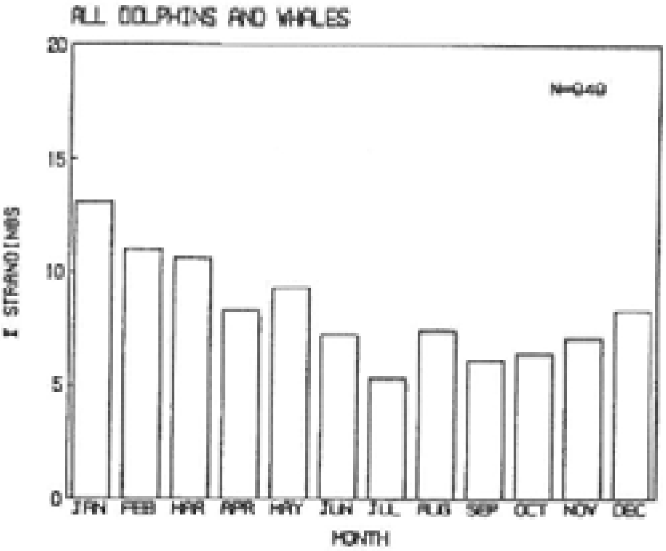

Fig. 12 Seasonality of all whale strandings in New Zealand.

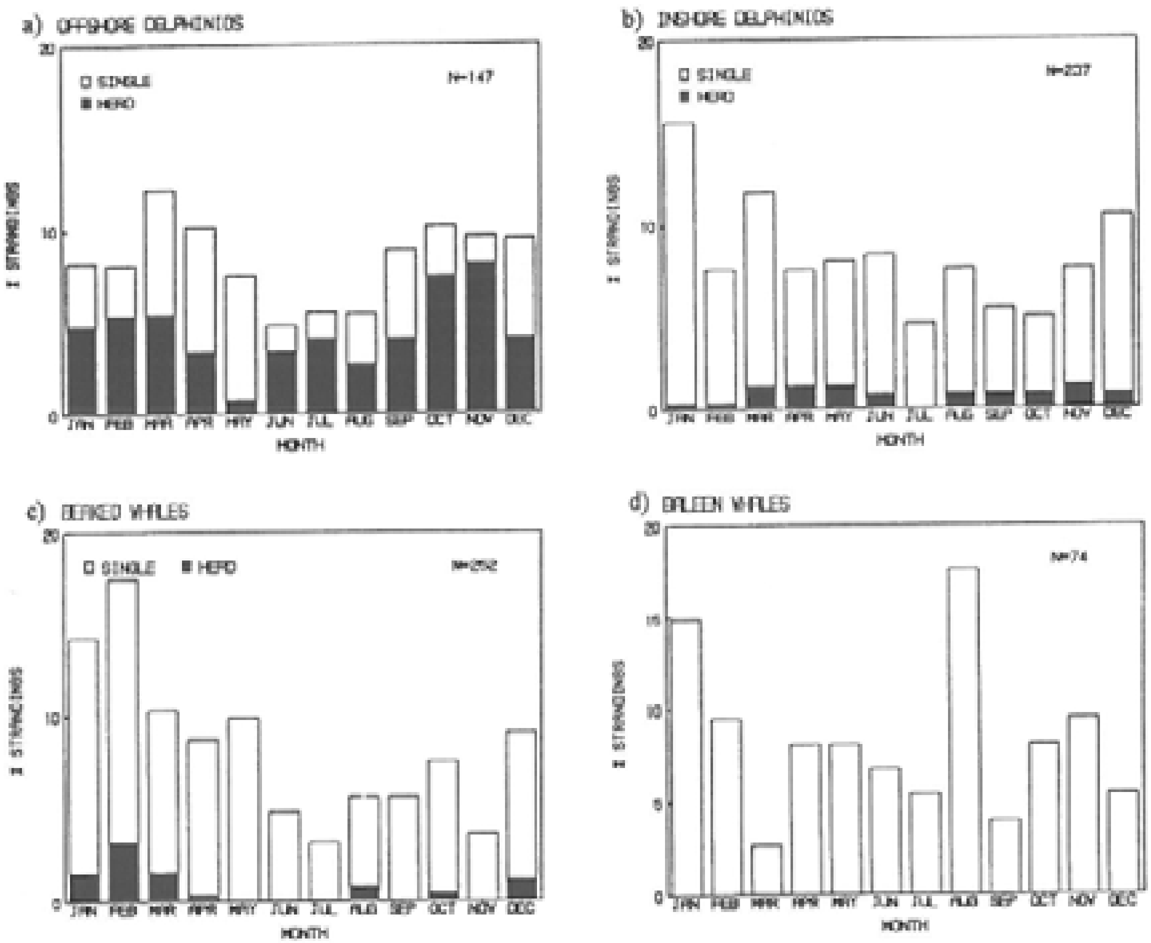

Fig. 13 Seasonality of strandings for (a) offshore delphinids, (b) inshore delphinids, (c) beaked whales, (d) baleen whales.

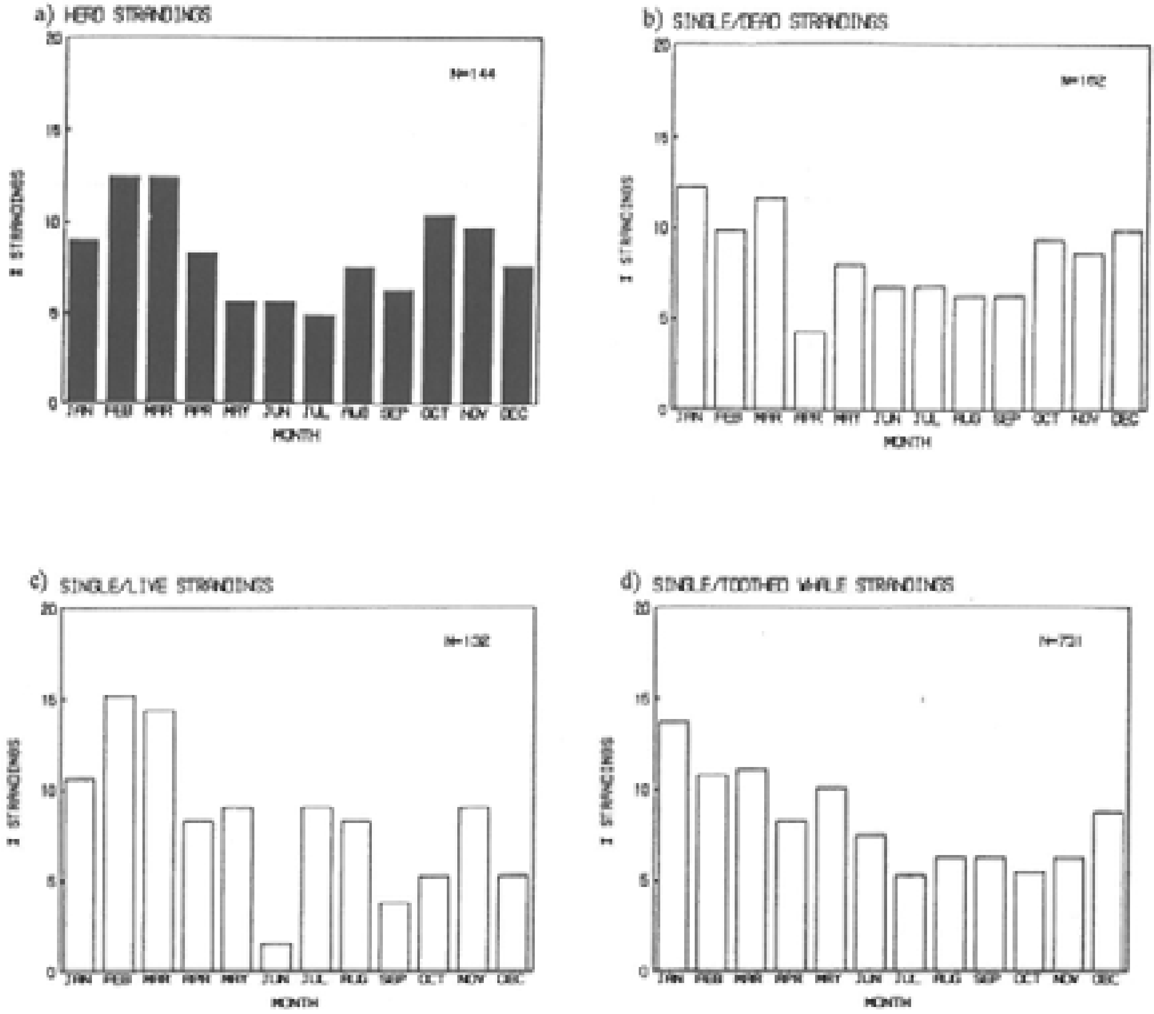

Fig. 14 Seasonality of all herd strandings and three catergories of single stranding.
Note highs in the frequency of herd strandings in February and October.

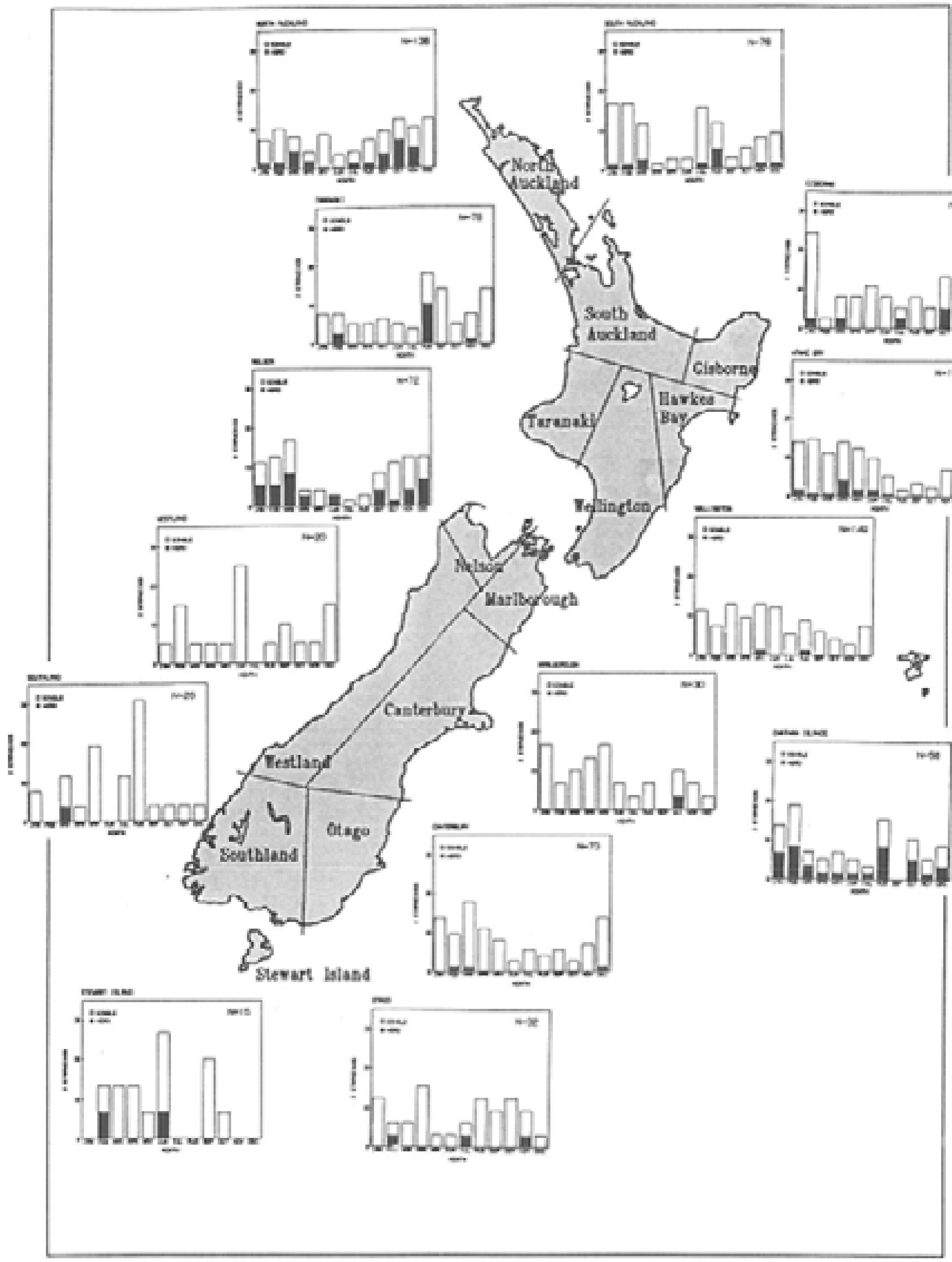

Fig. 15 Seasonality of strandings in various parts in New Zealand. There is ano obvious variation by latitude.

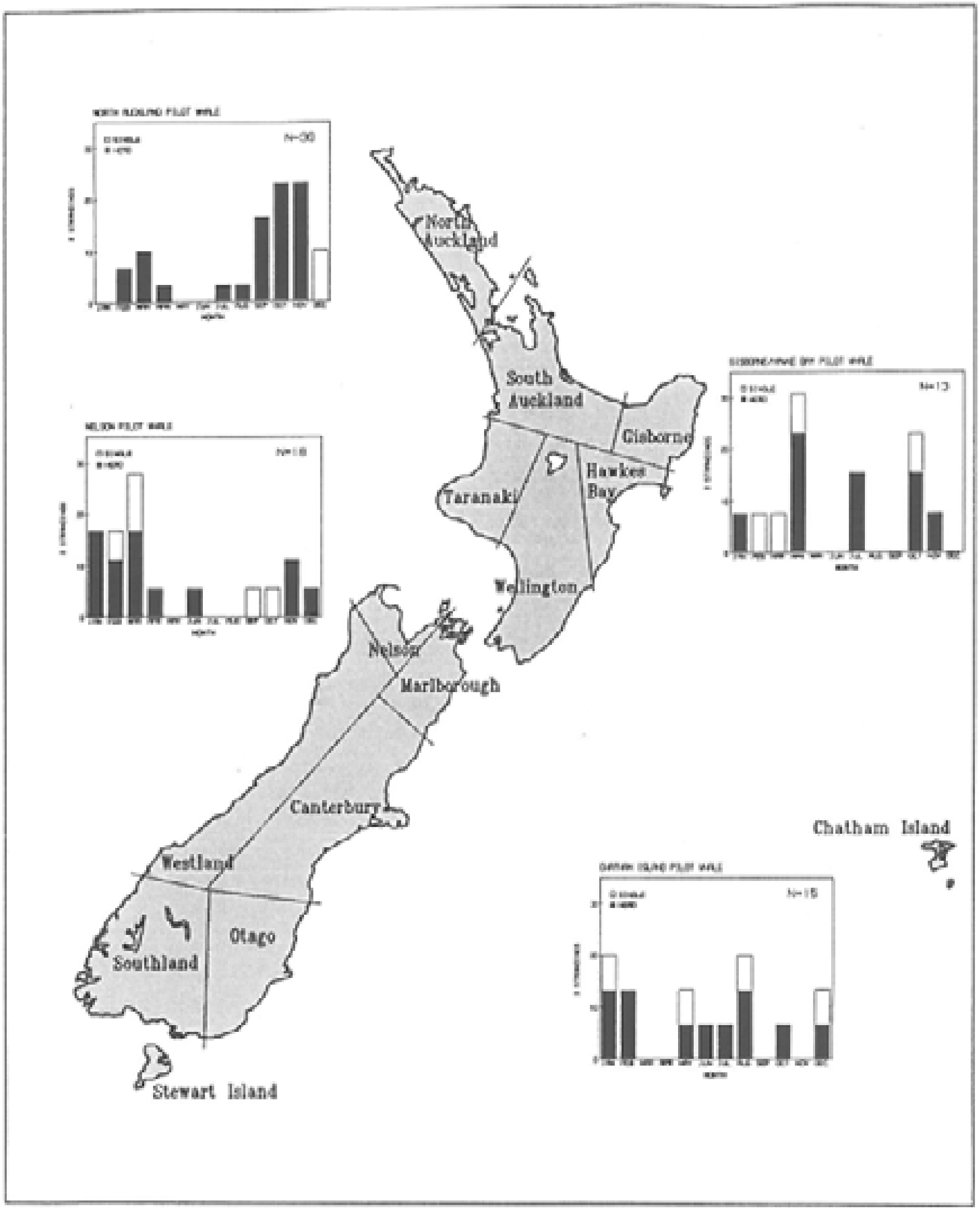

Fig. 16 Seasonality of pilot whale strandings for the four major stranding regions.
Note that herd strandings are at different times of year in North Auckland (September-November) and Nelson (January-March).

Table 4. Sex and calf data from the New Zealand whale stranding record. Note the high proportion of female pygmy sperm whales with calf and the high number of beaked whale calves/juveniles

Species	Single strandings				Herd strandings			
	Male	Female	Fc*	c/j**	Mixed	FF	MM	
Sperm whale	38	14	-	4	1	4	-	
Pygmy Sperm	25	54	20	2	3	-	-	
Hector's dol.	5	4	1	-	-	-	-	
Common dol.	16	6	1	-	-	2	1	
Dusky dol.	6	9	1	1	-	-	-	
Bottlenose dol.	2	-	-	-	-	-	-	
Killer whale	1	2	1	-	-	-	-	
Pilot whale	8	4	-	3	4#	-	-	
Risso's dol.	-	2	1	-	-	-	1	
S.Right W.Dol.	1	-	-	1	-	-	-	
False Killer	1	2	1	-	-	-	-	
Arnoux's		6	8	3	-	3	-	-
S.Bottlenose	3	4	1	1	-	-	-	
Andrew's		3	4	-	-	-	-	-
Scamperdown	14	13	1	7	4	1	-	
Straptooth	9	22	1	2	-	-	-	
Shepherd's	4	1	-	1	-	-	1	
Cuvier's		16	15	2	-	-	1	-
Minke whale	7	11	-	-	-	-	-	
Sei whale		1	3	-	-	-	-	-
Blue whale	1	2	-	-	-	-	-	
Fin whale		1	3	-	-	-	-	-
Pygmy Right	1	1	-	-	-	-	-	
Humpback whale	-	1	-	-	-	-	-	
Total	169	185	34	22	15	8	3	

Fc* - subset of females that stranded with a calf
c/j** - single strandings of either a calf or a juvenile
- most herd strandings of pilot whales are of mixed groups, however this has been recorded only 4 times.

1.5.2 Major Stranding Trends. Stranding patterns for any given species may be explained by differences in distribution of prey species, feeding patterns, migration, and social organisation. However, for many species, much of this behaviour is either poorly documented or unknown and therefore any discussion is necessarily tentative. However there are several questions worthy of discussion:

What can be learnt from the differences in distribution of single-dead and live strandings?

Single-dead strandings, which I suggest indicate the natural distribution of any species, are scattered evenly around the coast, as opposed to live strandings, which are highly clumped. This comparison indicates that concentrations of live strandings are not merely a result of high cetacean numbers in the region of stranding hotspots. It is possible to reject at least five herd stranding theories because they do not explain this highly concentrated nature of live strandings. These are (1) instinctive land-seeking drive (Wood 1979), (2) key whale (Robson 1984), (3) breathing reflex (A.G. Tomilin, pers. comm.), (4) parasites, and (5) harassment/predation (Geraci and St Aubin 1979).

Why don't baleen whales herd strand?

No herd or mother-calf baleen whale strandings have been recorded in New Zealand waters. In Tasmania there has been only one reported mother/calf stranding (a pygmy right whale, Nicol 1987). There have been no reports of baleen whales herd stranding anywhere in the world, with the possible exception of an apparently dubious, century-old record from Norway (Geraci 1978). It has been suggested that baleen whales do not herd strand because they do not echolocate, although this has not been verified. It now appears that echolocation is used by toothed whales for short ranges and not for navigation (Geraci 1978, Gaskin 1982). Baleen whales do not form the large, cohesive social groups characteristic of some toothed whales. Nevertheless they do form small loose groups (Frazer 1976), and therefore these groups could, in theory, strand together. Why this does not occur is unclear.

Why don't Hector's dolphins herd strand?

Hector's dolphins are one of the world's most coastal cetacean species (Dawson and Slooton, in press). There have been no herd strandings recorded for other species in the genus *Cephalorhynchus*, all of which are coastal (Sergeant 1982). For example, the Commerson's dolphin (*Cephalorhynchus commersonii*), which has very similar habits to the Hector's dolphin (Mermoz 1980) and also has considerable mortality from incidental catch (Goodall 1978), has had no recorded herd strandings.

The white-beaked dolphin (*Lagenorhynchus albirostris*), also an inshore dweller, similarly does not herd strand, however the closely related but oceanic Atlantic white-sided dolphin (*L. acutus*) has been reported to herd strand (Dudok van Heel 1962). There are no records of herd strandings among the freshwater dolphins (Sergeant 1982). The absence of inshore species herd stranding is clearly related to their familiarity with coastal waters.

Why is there a concentration of sperm whale herd strandings on the Kaipara coast?

Stephenson (1975) comments that the oceanic conditions around Kaipara Harbour mouth may be responsible for the re-occurrence of sperm whale herd strandings in that area. He states "A treacherous shifting sand bar extending 3-7 km seaward of Kaipara Harbour entrance, and strong surf assisted by prevailing westerly winds are the probable local factors likely to disrupt near-shore migration" (p. 303). However, he noted that these conditions also occur off most other west coast harbours where no strandings have occurred, and the Kaipara stranding situation remains unsolved.

It may be that the Kaipara coast is a feeding ground for sperm whales, and that the concentration of single-dead sperm whales in this area (see Table 3) indicates that sperm whales are often present. In contrast, Kaikoura, a well-documented feeding ground for bachelor males, has had very few strandings recorded. The Kaikoura shoreline may not have the appropriate physical characteristics for strandings.

Interestingly, the Kaipara Harbour mouth has had a number of wrecks (Churchouse 1982), of ships which have attempted to go through the treacherous Kaipara bar into the Kaipara Harbour. Similarly Cape Hatteras (North Carolina USA), also a site of numerous ship wrecks, has had a number of sperm whale strandings (James Mead, Smithsonian Institution, pers. comm.).

Why is the clustering of offshore delphinid live strandings so pronounced compared with that for other groups of whales?

The clumping of offshore delphinid live strandings may be influenced by local coastal topography. Some coastlines may entrap offshore delphinids because the animals have little if any experience of coastal waters and topography. After a study of strandings on the French coast Duguy (1978) noted that species not adapted to low water were very vulnerable when they found themselves in the shallows. Similarly, Sheldrick (1979) noted (p. 51), "pilot whales, false killer whales and sperm whales seem prone to strandings, perhaps because their behaviour is adapted to deep water life and not survival in coastal waters."

The fact that offshore species make up the greatest proportion of herd strandings also implies that other factors besides local abundance are involved in the frequency of strandings (Mead 1979, Sheldrick 1979, Baker 1981, Cordes 1982, Klinowska 1986a).

Are the high percentages of mother/calf strandings of pygmy sperm whales at Mahia, and beaked whales in the Firth of Thames, indicators of calving areas?

McCann (1964, p. 124) noted "The New Zealand archipelago appears to be the rendezvous for many cetacean species, particularly some of the Ziphidae, some of which are known to calve in the area during spring and early summer". The western side of the Firth of Thames has had six strandings of Arnoux's beaked whale, and southern bottlenose whales (Fig. 6f, h), some of which were with a calf. Both of these species are subantarctic deep-diving squid feeders (Gaskin 1982), while the Firth of Thames is shallow and temperate. A possible explanation for this stranding pattern is that the Firth of Thames is a breeding/calving area for these beaked whales.

James Mead (interviewed in Hoyt 1987) commented that live strandings of pygmy sperm whales from the Smithsonian record were often a mother/calf pair. In New Zealand a similar situation occurs. Twice as many female pygmy sperm whale strandings occur as male strandings, and half of the female strandings are with a calf. This seems to indicate a pygmy sperm whale calving area in the region of Mahia Peninsula, the site where most of these strandings occur.

Why do killer whales strand at different sites from pilot whales?

There have been 20 herd strandings of pilot whales on the Chatham Islands, and most of these occurred on two beaches (Okawa and Waitangi). In contrast, only one herd stranding of killer whales has been recorded on Chatham Island, and this was at a different site from the pilot whale strandings (Radio Station Beach). In total there have been four killer whale herd strandings in New Zealand, none at the same localities as pilot whale strandings. Why then do killer whales, which seldom strand, strand in different localities than pilot whales which commonly strand? We don't know yet.

In conclusion, there are clear trends in the distribution of strandings that can not be readily explained by high local population densities. The tendency to herd strand is less for inshore species than for offshore species, and unfamiliarity with coastal waters may therefore be a key factor in strandings.

1.6 Key Points

- Herd strandings of offshore delphinids are highly concentrated.
- Offshore delphinids herd strand more often than inshore delphinids.
- Hotspots for offshore delphinid herd strandings occur at different locations from sites where inshore delphinids (including killer whales) herd strand.
- Single-live strandings show similar stranding patterns to herd strandings, suggesting a similar cause.
- No herd or mother/calf strandings of baleen whales have been recorded in New Zealand.
- Hector's dolphins do not herd strand, and only one live stranding has been recorded.

2. THE EFFECT OF WEATHER ON HERD STRANDINGS

It has been suggested that weather conditions immediately prior to strandings may be a contributory factor of the stranding (Dudok van Heel 1962, Robson and van Bree 1971, Duguy 1978). According to Dudok van Heel, gently sloping beaches cause distortion of the echo signal crucial to cetacean navigation. He further noted that the echo signals might be distorted during storm conditions when air is mixed with water and sand is swept up from the bottom into suspension.

Robson and van Bree reported that the three most recent strandings on the Hawke Bay - Poverty Bay coast of New Zealand were all preceded by violent electric storms and/or very sudden meteorological changes. They concluded (p. 59) that "...electric storms may have a disruptive influence on the nervous system in general and on the sonar system in particular with as a result of panic and due to strong social cohesion - mass stranding." In a study of strandings on the French coast, Duguy was able to demonstrate a clear correlation between strandings and high winds.

The aim of this chapter is to test 29 of the most recent herd strandings from the New Zealand stranding record for any relationship with weather, particularly barometric pressure, wind speed, wind direction, and electrical activity.

Meteorological Service records from Kelburn, Wellington, were used to obtain data on the local weather conditions on the day of strandings for the 25 most recent herd strandings of pilot whales and four most recent herd strandings of sperm whales. Weather maps are produced every three hours, but as most recordings of strandings do not give times of stranding, the mid-day map was taken to be representative of the weather for that particular day. Weather conditions for the day prior to the stranding were also examined to determine if there was any relationship between strandings and the weather preceding the stranding date.

Data on weather conditions were taken from the weather office nearest to the stranding sites. Weather factors considered were barometric pressure, change in barometric pressure, wind speed, change in wind speeds, wind direction, and electrical activity. Meteorological measurements were taken directly from the weather maps. Measurements of electrical activity were only taken for the 15 most recent pilot whale strandings. Peter Wood, Kaikoura Meteorological Office, estimated the probability of electrical activity at the time and place of a stranding by studying the weather situation (note this was done as a very rough estimate).

2.1 Results

A summary of data on weather conditions 24 hours prior to and at the time of the 25 pilot whale and four sperm whale herd strandings is given in Table 5. The number of strandings in each analysis varied according to the availability data.

Barometric pressure. The mean annual barometric pressure in New Zealand varies between 1010 hPa and 1015 hPa (P. Wood, pers. comm.). Mean barometric pressure of pilot whale (prior = 1011.67 hPa and during = 1015.4 hPa) and sperm whale (prior = 1017.5 hPa and during = 1019.9 hPa) herd strandings were close to this range.

Table 5. Summary of weather conditions 24 hours before and on day of stranding. Most pilot whale strandings occurred during increasing barometric pressure; all sperm whale strandings occurred during an onshore wind.

	barometric pressure (+1000hPa)							
	24hrs prior to stranding				day of stranding			
	<05	05-14	15-24	>24	<05	05-14	15-24	>24
pilot	4	11	8	-	4	7	10	4
sperm	-	1	3	-	-	1	2	-
total	4	12	11	-	4	8	12	4

	change in barometric pressure (hPa)									
	decreasing					increasing				
	total	≥9	6-9	3-6	0-3	0-3	3-6	6-9	≥9	total
pilot	5	1	1	-	3	6	8	3	1	18
sperm	0	-	-	-	-	1	1	1	-	3
total	5	1	1	0	3	7	9	4	1	21

	wind speed (knots)									
	24 hrs prior to stranding					day of stranding				
	<5	5-9	10-14	15-19	≥20	<5	5-9	10-14	15-19	≥20
pilot	3	1	7	5	7	3	2	9	3	3
sperm	1	1	-	-	2	2	-	-	1	1
total	4	2	7	5	9	5	2	9	4	4

	difference in wind speed (knots)										
	decreasing						increasing				
	total	>15	15-10	10-5	5-0	0	0-5	5-10	10-15	>15	total
pilot	10	2	6	2	-	3	-	3	3	1	7
sperm	3	-	1	1	1	1	-	-	-	-	0
total	13	2	7	3	1	4	0	3	3	1	7

	wind direction					
	24hrs prior to stranding			day of stranding		
	onshore	offshore	alongside	onshore	offshore	alongside
pilot	8	11	5	10	6	6
sperm	4	-	-	4	-	-
total	12	11	5	14	6	6

	prob. of electrical activity on date					
	<10%	10-19%	20-29%	30-39%	40-49%	>50%
pilot	5	3	2	3	-	2

Change in barometric pressure. Significantly more strandings occurred when barometric pressure was increasing (21 strandings) than when it was decreasing (five strandings) ($\chi^2 = 4.16$, $p < 0.05$). Mean increase in barometric pressure prior to stranding was 4 hPa for pilot whales and 2.8 hPa for sperm whales.

Wind speed. Herd strandings occurred in a range of wind speeds from less than five knots to 25 knots.

Change in wind speed. More strandings occurred when wind speed was decreasing (10 pilot whale strandings, three sperm whale strandings) than when it was increasing (seven pilot whale stranding, nil sperm whale strandings), but the difference was not significant ($\chi^2 = 1.39$, $p = 0.24$).

Wind direction. Wind directions during sperm whale herd strandings were all onshore both prior to and during strandings. Pilot whale strandings have occurred during onshore, offshore and alongshore winds.

Electrical activity. The probability of electrical activity occurring was greater than 50% for only two strandings. Both these strandings occurred in Northland, which has more electrical activity than any other region. Otherwise strandings do not appear to occur during periods of electrical activity.

2.2 Discussion

Strandings occurred in all weather conditions. However, it is possible that aspects of the weather are contributory causes of strandings. The majority of strandings tested (21 out of 26) occurred when the barometric pressure was increasing. Increasing barometric pressure may indicate that the weather has been worse in the days prior to the strandings.

Onshore winds were prevalent during all sperm whale herd strandings that were analyzed (four strandings). The predominant wind direction for the location of strandings must be taken into account - Pihama and Muriwai have predominantly westerly winds; Okawa (Chatham Island) has a predominant south-westerly wind. For these three stranding sites onshore winds are to be expected.

In Golden Bay, a site of 17 pilot whale herd strandings, strandings coincide with the time of the year (November-March) when there is a wind-induced current into the head of the bay (Heath 1985). At Cape Verde, Senegal, strandings also occur when there is a wind-induced current (May/June) (Maigret 1979, cited in Sergeant 1982). The relationship between wind-induced currents and time of stranding could be coincidental with whale migration past these areas, although both factors may be important. Further research on the migration of pilot whales around New Zealand and Senegal could confirm this hypothesis.

These preliminary results suggest some relationship between strandings and weather conditions. Further analysis would be valuable.

2.3 Key Point

Most herd strandings tested (21 out of 26) occurred when the barometric pressure was increasing. This may indicate that the weather has been bad on the days prior to the stranding.

3. GENERAL DISCUSSION OF STRANDINGS

> If indeed, the unsubstantiated stories of dolphins pushing humans ashore are true, they must be viewed in the same context as humans pushing stranded dolphins back to sea.
>
> Conner and Norris (1982, p. 371)

As part of this study, the author and D. McLean of Canterbury University tried to determine if there were any similar physical aspects found across herd stranding sites. Physical aspects of herd strandings sites and non-stranding sites were compared. Factors analysed were slope of beach, indentation of bay, sediment type, depth of bay and beach type. Slope and bay indentation of stranding sites were significantly different from non-stranding sites. Herd strandings appeared to occur on gently sloping beaches with protruding coastline. It was also found that the coastal configuration of major New Zealand stranding sites were very similar to the configuration of overseas stranding sites. A second study tested the theory proposed by Klinowska (1986b) that strandings occur as a result of mistakes made when following geomagnetic anomaly contours. She noted that all of the 70 live strandings in the Britain stranding record occurred where geomagnetic anomaly contour lines ran perpendicular to the coast. The author and R. Frew (Geophysics Division, DSIR) repeated this study with the New Zealand stranding record and found no such relationship. Where the geomagnetic contour lines ran perpendicular to the coast, the number of strandings was similar to that occurring where the contour lines ran parallel to the coast. Since the sample number of New Zealand herd strandings was considerably larger than that of Klinowska, there seems no evidence for geomagnetic anomalies as a guide to possible strandings.

3.1 Categorisation of Strandings

In an attempt to identify stranding circumstances, strandings have been divided into nine categories based on findings from this study. This may help to organize world-wide data on strandings. A flow chart showing this scheme is given in Figure 17.

Single-dead strandings. This category covers all strandings where dead whales have washed ashore and where whales that are sick have washed up on the beach to die. Disease, pollution, incidental catch, old age, or injury due to shark attack are factors responsible for these strandings. Most Hector's dolphin and baleen whale strandings fall into this category. These strandings occur on all beach types.

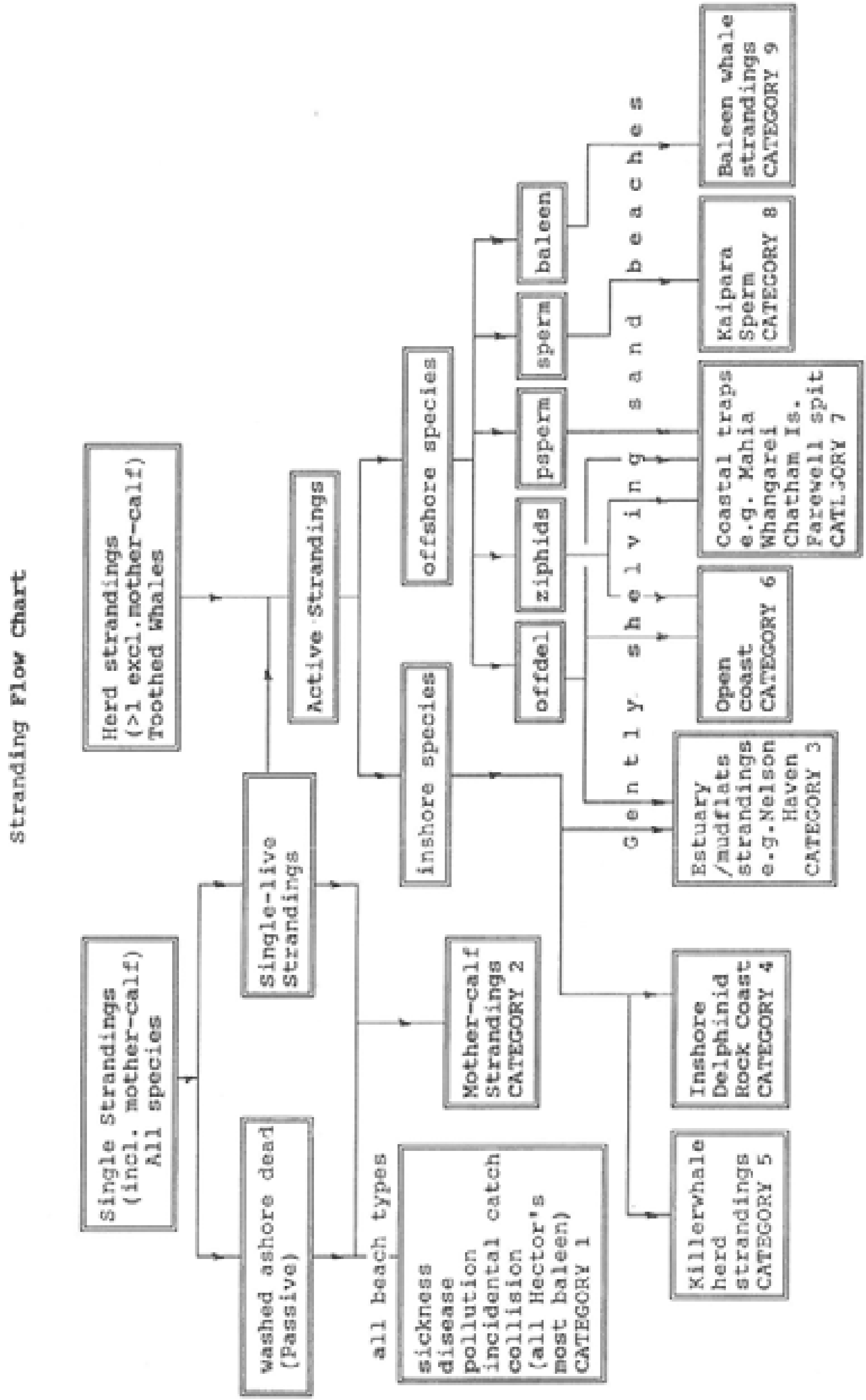

Fig. 17 Summary of trends in the New Zealand Stranding Record.

Mother/calf strandings. This category includes beaked whale strandings around Coromandel Peninsula and pygmy sperm whale strandings in Hawke Bay. These sites may correspond to calving areas. Whales moving into unfamiliar coastal waters or birth related sicknesses probably explain these strandings.

Inshore delphinid estuary strandings. This category covers strandings of inshore delphinids that move into estuaries, probably to feed, and are caught by the receding tide.

Inshore delphinid herd strandings on rocky coasts. This minor category covers the two common dolphin herd strandings and one dusky dolphin herd stranding on rocky coasts. As in category 3, chasing prey may have contributed to these strandings.

Killer whale herd strandings. These strandings occurred at completely different sites from both inshore delphinids and offshore delphinids. As killer whales can move onto, and off the beach to catch seals (Lopez and Lopez 1985), these strandings are very hard to explain. One killer whale herd stranding occurred on the steepest beach measured in this study.

Open coast strandings. This category involves live strandings of most groups and occurs on open sandy stretches of the coast where there are no trap-like configurations. They invariably involve gently sloping beaches.

Coastal traps. This category includes most live strandings of offshore delphinids, and some strandings of beaked whales and pygmy sperm whales. In general these strandings occur because whales appear to be unfamiliar with the coast and its currents. Strandings in this category occur mostly at eastern Northland, Whangarei, Hawke Bay, Golden Bay and Chatham Islands. These stranding sites have gently sloping beaches and protruding peninsulas or sand spits with tidal flats.

Sperm whale herd strandings. This category includes herd strandings of sperm whales, mostly off the Kaipara Coast. This category differs from category 7 because no concentration of herd strandings of other offshore species occurs at Kaipara.

Baleen whale live strandings. This category covers all baleen whale strandings. Live strandings have been recorded only for minke whales.

Other observations on stranding. Before further discussion of whale strandings, it is worth mentioning some observations reported by Department of Conservation, and Ministry of Agriculture and Fishery officers at whale strandings.

A group of pilot whales was observed milling around in Golden Bay. Small groups were observed to break away from the herd, "explore" channels, and then return to the herd. An eyewitness reported that when one of these groups found a channel that led out into deep water, the herd followed. This is not an isolated observation; there are other reports of whales milling around, sometimes up to two days before stranding. Milling behaviour may indicate that whales are confused and disoriented.

There are six records of mixed species strandings (three pilot/bottlenose dolphin, one pilot/false killer, one pygmy sperm/false killer, one pygmy sperm/beaked). Pilot whales seen off Kaikoura during summer have always been with bottlenose dolphins (B. Todd, pers. comm.). Dolphins have been observed to aid in the rescue of pilot whales by apparently guiding them out to sea. This has been reported on two separate occasions.

With the findings of this study on New Zealand strandings it is possible to discuss theories on why whales strand with new light. Stranding theories are supported or rejected on the basis of how well they fit the New Zealand stranding data. A summary of theories rejected and supported is given in Table 6.

Table 6. List of stranding theories rejected or supported from this study of the New Zealand whale stranding record.

Theory	Reject/Support	Reason
Physical Factors		
1. Geomagnetic topography	reject	no relationship in NZ
2. Echo distortion	some support	strandings on shelving beaches
3. Whale traps-coastal configuration	support	similar coastal configurations
4. Oceanic currents	some support	tidal currents
5. Weather-electric storms	maybe	increasing barometric pressure?
Behavioural Factors		
6. Instinctive land seeking drive	reject	does not explain clumping
7. Ancient migratory route	reject	some sites never sea passages
8. Key whale	reject	does not explain clumping
9. Suicide	reject	does not explain clumping
10. Breathing reflex	reject	does not explain clumping
11. Inshore feeding	reject	does not explain clumping
12. Parasites/disease	reject	does not explain clumping
13. Lunatic effect	unlikely	no strong relationship in NZ
14. Whale graveyards	reject	healthy and young strand
15. Harassment/Predation	reject	does not explain clumping
16. Pollution	reject	stranding occurring for years

The theories can be discussed in two groups - those that involve physical factors and those that involve behaviourial/biological factors.

3.2 Physical Factors Related to Stranding

3.2.1 Geomagnetic Topography. Margaret Klinowska's theory relating live strandings to geomagnetic topography and geomagnetic disturbances has currently been the most popular explanation on why whales strand. A similar analysis of the NZWSR does not show any significant relationship (see above). Since the NZWSR contains four times as many herd strandings as the British record used by Klinowska (1986a), there must now be considerable doubt as to whether live strandings are related to the geomagnetic field.

3.2.2 Echo-Distortion. Dudok van Heel's echo-distortion theory explains why New Zealand strandings occur on gently sloping beaches and not on steep shingle boulder beaches or rocky coasts. No other theory explains this characteristic of stranding sites. Using a navy echo-sounder, Dudok van Heel (1962) showed that gently sloping beaches gave weak echoes. He suggested that whales may also receive poor signals from such beaches. However, Geraci (1978) claims that whales have the ability to detect these gently sloping beaches. Further work on the echolocation ability of whales may give insight into this theory.

3.2.3 Whale Traps. The theory that certain beaches are "whale traps" has been put forward by many authors (A.G. Tomilin, pers. comm., Gilmore 1957, Dudok van Heel 1962, Warneke 1987). The New Zealand stranding data strongly support this idea. Multiple herd stranding sites all appear to have similar protruding coastlines and long gently sloping beaches. Offshore species are presumably unfamiliar with the coast and its tides and currents. Inshore species, on the other hand, can be expected to be familiar with these conditions. The whale trap theory can therefore explain why offshore species appear to be more prone to stranding than inshore species.

3.2.4 Oceanic Conditions. The present study also found that in two areas of New Zealand (Golden Bay and Hawke Bay) local currents appear to explain the distribution of strandings within the area. Wind-derived currents occur in Golden Bay and at another multiple herd stranding site Cape Verde (Senegal), coincident with the time of year when strandings occur. Details of the local currents within other major stranding areas of New Zealand are not clear. Further research is required in this area.

3.2.5 Weather Conditions. A relationship between strandings and increasing barometric pressure has been found, suggesting that poor weather preceded strandings. However, the sample of only 21 strandings is too small to make any definite conclusions and more work is needed.

3.3 Behaviourial/Biological Factors

The following theories are treated together, as I consider them unlikely to be to sole cause of herd strandings: instinctive land seeking drive, key whale, breathing reflex, parasites, and harassment/predation. They cannot explain herd strandings completely because they do not explain the concentrated nature of strandings and predict that strandings should occur in relation to the local distribution and abundance of the species involved. As shown earlier, after making a comparison of single-dead strandings (indicator of natural distribution) with live strandings, this was not the case. Single-dead strandings were evenly scattered around New Zealand as opposed to herd strandings which are highly clustered.

3.3.1 Ancient Migratory Routes. The theory that whales follow ancient migration routes which have since become closed off by land can be rejected on the grounds that strandings are clustered at sites that have never in geological history been major sea passages (e.g., Whangarei, Clifton, and Warrington).

3.3.2 Suicide. It could be argued that just as humans tend to commit suicide at particular spots, whales also have what could be called suicide beaches. The primary factor that has led many to believe that stranding is suicide is that whales pushed out to sea consistently turn around and strand again. This behaviour is not unusual when the animals' social structure is considered.

One of the likely reasons for the success of whales at sea is their tight social groups. This cohesion probably developed in response to predatory pressures incurred when their ancestors moved back into the marine environment. Living in cohesive schools and developing supporting behaviour (social whales actively support sick members of their herd) enabled whales to overcome predatory pressures (Conner and Norris 1982).

Examples of the social cohesion that cause whales to remain with distressed herd members on a beach can be seen elsewhere. Whalers would often harpoon a calf first because they knew that other members of the herd would respond to its distress calls. They were then able to catch most of a herd (Nishiwaki 1962, cited in Conner and Norris 1982). Similarly, during pilot whale drives, individuals that get outside of the ring of driving boats return to the herd and are slaughtered, instead of escaping, presumably because they are responding to distress calls. That whales pushed out to sea return to distressed whales still on the beach is likely to be a result of social cohesion, not suicide.

Another reason rejecting the suicide theory is that whales are successfully rescued, although it is rare for an entire herd to be rescued. New Zealand Department of Conservation officers are usually able to rescue at least 70% of the whales from herd strandings.

3.3.3 Inshore Feeding. Inshore feeding may explain some strandings by inshore dolphins in estuaries. However, in some parts of the world dolphins follow fish onto mudflats and manoeuvre back into the water. Killer whales use a similar technique to capture seals on the coast of Argentina (Lopez and Lopez 1985). Why stranded whales can not similarly manoeuvre off a beach is not clear.

Most herd strandings involve offshore species. It is unlikely that they are feeding inshore because their prey do not occur there. In areas where the continental shelf is close to shore (e.g., Kaikoura) there have been no herd strandings. Stomach analysis of stranded whales shows that many have empty stomachs, although this may be a result of regurgitation when under stress. This theory can be rejected.

3.3.4 Parasitic Disease. Parasitic disease is likely to be the cause of some single strandings. Autopsies of singly stranded whales usually indicate a high parasite load (Geraci and St Aubin 1986, Hall and Schimff 1979, Odell 1987). However, as the normal parasite load of whales is not known (it is probably high), one must be cautious in blaming parasites for single strandings.

To date, no evidence of major neurological disease has been found in herd stranded cetaceans (Hall and Schimff 1979). Disease, furthermore, does not explain the clustered distribution of herd strandings. Sick whales should strand anywhere.

Although parasites commonly occur in the middle ear of whales, there is no evidence of parasite-induced damage disrupting the echolocation ability (Geraci 1979), as is suggested by Fraser (1966). Parasitic disease can thus be rejected as a cause of herd strandings.

3.3.5 Lunar Effect. The results of a preliminary study made by the author indicate that if there is a lunar effect, it is weak. In no case was there an obvious relationship with any phase of the moon. Resources and time were insufficient to directly test for a relationship between strandings and spring tides in this study. Further statistical analysis if being carried out by Frank Lad, Mathematics Department, University of Canterbury.

3.3.6 Whale Graveyards. An analogy has been made between whale strandings and elephant graveyards (Cousteau and Paccalet 1988). Whales summon their last ounce of strength to cross thousands of miles to breathe their last breath on ancestral burial grounds. This theory explains the clumping nature of strandings but does not take into account that whales of various age and health are stranding. This theory is rejected outright.

3.3.7 Pollution. High levels of heavy metals, pesticides or PCBs may have been involved in bottlenose dolphin strandings off the east coast of North America and grey whale strandings in Puget Sound, off the west coast (Vancouver *Herald*, 14 April 1990). However, pollution alone cannot be the factor that explains herd strandings because strandings have been recorded for thousands of years. Aristotle recorded whale strandings more than 2000 years ago. This theory is rejected.

4 CONCLUSION

Major theories on stranding have been reviewed with regard to the New Zealand stranding record. It must be emphasised that this record contains 164 herd strandings - probably more herd strandings than any other record.

My findings show that strandings of offshore species are highly concentrated in relation to their natural distribution. This indicates that strandings are not related to a species abundance factor. Offshore species are more prone to herd strand than inshore species and also herd strand at different sites to inshore species. This suggests that coastal unfamiliarity is an important factor in strandings.

Distribution patterns of single-live strandings support the patterns of herd strandings, suggesting that they have similar cause.

All offshore species herd strand at sites with gently sloping beaches and in almost all cases they are where there is a protruding peninsula or sandbar. This suggests that the configuration of these sites and their associated tidal and oceanic currents are in some way traps to offshore species.

The tight cohesion within the group of the social whales explains why it is almost impossible to return whales to deep water while other, live whales call in distress from the beach.

5 FURTHER RESEARCH

Many of the present theories on why whales strand appear to be based on fanciful notions rather than the established evidence. Future study of whale strandings should concentrate on geography and site characteristics. The following is a list of areas where future research could be fruitful.

Continuation of analysis of trends. Are similar stranding patterns seen in overseas records? Do they fall into similar stranding categories as shown in Figure 17?

Tagging of all stranded whales successfully rescued. Tagging of stranded whales that are successfully rescued would enable us to determine whether these individuals strand again months or years later. Cattle ear tags would be appropriate for this.

Radio tagging of a whale in a herd would enable tracking of whales in the weeks following strandings to determine whether whales remain in the area.

Satellite tracking of a rescued whale in a herd would help determine migration routes and seasonal movement of whales. It would then be known whether whales are getting trapped, when migrating past a frequent stranding site.

Stranding warning beacon - "killer whale sounds". It appears that whales are caught by natural whale traps which are related to the coastal configuration. It may be possible to develop a beacon, such as a buoy giving out "killer whale sounds", to scare whales from these "hazardous" areas.

Extensive autopsy of dead whales. Are single-live strandings occurring for the same reason as herd strandings, or are they sick animals? Because the distribution of single-live strandings is similar to the distribution of herd strandings, whales may be stranding for the similar reasons. Research on the health of whales involved in single-live strandings would help to evaluate this relationship.

Reproductive state of whales. A high proportion of mother/calf strandings of beaked whales in the Firth of Thames, and pygmy sperm whales at Opoutama may indicate calving grounds in the area. More research on the reproductive state of stranded whales at these sites may confirm this.

Weather conditions and lunar cycle. This study has indicated a possible relationship between herd strandings and increasing barometric pressure. There is also a weak lunatic effect for herd strandings. Both these areas warrant further research.

Commencement and standardization of an international stranding data base. This study has revealed some interesting geographical and site trends from New Zealand whale strandings. These trends need to be explored more on a worldwide scale. The establishment of an international whale stranding data base would enable a more comprehensive analysis of strandings.

6 ACKNOWLEDGEMENTS

I would like to thank my thesis supervisor, Ian McLean, and my associate supervisor, Colin McLay. For the set-up and maintenance of the New Zealand Whale Stranding Data Base, thanks to Mike Donoghue (DoC), Alan Baker (National Museum), Martin Cawthorn (DoC), Ross Pickard (DoC).

Further assistance was provided by Wade Doak, Frank Robson, Ewan Fordyce, Steve Dawson, Liz Slooten, Tony Seymour (DoC Gisborne), Dave Houston (DoC Dunedin), Rob Chappell (DoC Chatham Island), Andy Brown (DoC Great Barrier Island), and Bill McLeod (DoC North Cape). In the Chatham Islands, Steve Locke, Brenda Meek, Barry Lanauze (MAF), and Joe Wills. Thanks are also due to Barbara Todd, Roger Sutherland, Steve Cook, Lars Brabyn, Peter Wood and Ian Smith (Meterological Service), and Bob Kirk (Canterbury University, Geography Department).

Financial support came from the World Wildlife Fund New Zealand, Cetacean Society International, and Royal Forest and Bird Protection Society. Laboratory work was done at the Leigh Marine Laboratory (University of Auckland) and the George Knox Research Laboratory (Canterbury University); technical and secretarial help was provided by the Canterbury University Zoology Department. Jon Hardin, Karen Phillips, and Lindsay Chadderton provided valued discussion and help.

7. REFERENCES

Baker, A.N. 1981. Strandings of cetaceans on the New Zealand coast 1862 - 1981. The Management of stranded Marine Mammals - proceedings of the Wildlife Society NZVA/Greenpeace conjoint Technical Seminar. Wildlife Society NZVA Publication 1: 1-12.

Cawthorn, M. 1978. Whale research in New Zealand. *Reports of the International Whaling Commission* 28: 109-113.

Cawthorn, M. 1979. New Zealand progress report on cetacean research, June 1977-may 1978. *Reports of the International Whaling Commission* 29: 123-125

Cawthorn, M. 1982. New Zealand progress report on cetacean research. *Reports of the International Whaling Commission* 32: 189-195.

Churchouse, J. 1982. *Leonard Robertson: the `Whangaroa' and `La Bella'*. Millwood Press, Wellington, New Zealand. 162 pp.

Conner, R.C., and K.S. Norris. 1982. Are dolphins reciprocal altruists? *American Naturalist* 119: 358-347.

Cordes, D.O. 1982. The causes of whale strandings. *New Zealand Veterinary Journal* 30: 21-24.

Cousteau, J., and Y. Paccalet. 1988. Accident or suicide? Pp. 238-241 in Cousteau and Paccalet (eds), *Whales*. Harry N. Abrams, Inc., Publishers, New York.

Dawson, S.M., Slooton, E. in press. Hector's dolphin *Cephalorhynchus hectori*: distribution and abundance. *Reports of the International Whaling Commission* [is this in print yet? please supply page numbers if you can]

Dudok van Heel, W.H. 1962. Sound and Cetacea. *Netherlands Journal of Sea Research* 1(4): 407-507.

Duguy, R. 1978. Researches on the mortality factors of cetaceans on the coasts of France. *Aquatic Mammals* 6(1): 9-13.

Evans, P.G.H. 1987. *The natural history of whales and dolphins*. Christopher Helm, London.

Fraser, 1966. Comments on the Delphinoidea. In Norris, K.S. (ed.), *Whales, dolphins, and porpoises*. University of California Press, Berkeley, Calif. 602 pp.

Frazer, J.F.D. 1976. Herd structure and behaviour in cetaceans. *Mammal Review* 6(1): 55-59.

Gaskin, D.E. 1968. *The New Zealand Cetacea*. Fisheries Research Bulletin No. 1, Fisheries Research Division, New Zealand Marine Department, Wellington.

Gaskin, D.E. 1982. *The ecology of whales and dolphins*. Heinemann, London and Exeter, New Hampshire. 459 pp.

Gaskin, D.E., and M.W. Cawthorn. 1967. Diet and feeding habits of the sperm whale (*Physeter catodon* L.) in the Cook Strait region of New Zealand. *New Zealand Journal of Marine and Freshwater Research* 2: 156-179.

Geraci, J.R. 1978. The enigma of marine mammal strandings. *Oceanus* 21: 38-47.

Geraci, J.R. 1979. The role of parasites in marine mammal strandings. Pp. 85-92 in Geraci, J.R., and Aubin, D.J., *Insights*.

Geraci, J.R., and St Aubin, D.J. 1979. Stranding workshop summary report. Pp. 1-33 in Geraci, J.R., and Aubin, D.J. (eds), *Biology of marine mammals: Insights through strandings*. Marine Mammal Commission, Washington, U.S. Department of Commerce, National Technical Information Service, PB-293 890.

Geraci, J.R., and St Aubin, D.J. 1986. Effects of parasites on marine mammals. Pp. 407-414 in *Proceedings of the 6th International Congress of Parasitology, Brisbane*. Brisbane.

Gilmore, R.M. 1959. On the mass strandings of sperm whales. *Pacific Naturalist* 1(9): 9-16.

Goodall, R.N.P. 1978. Report on the small cetaceans stranded on the coasts of Tierra Del Fuego. *Scientific Report–Whales Research Institute, Tokyo* 30: 197-230.

Hall, N.R., and Schimff, R.D. 1979. Neuropathology in relation to strandings - mass stranded whales. Pp. 236-246 in Geraci, J.R., and St Aubin, D.J., *Insights*.

Heath, R.A. 1985. A review of the physical oceanography of the seas around New Zealand 1982. *New Zealand Journal of Marine and Freshwater Research* 19(1): 79-124.

Hoyt, E. 1987. The Smithsonian's James Mead. *Cetus* (fall 1987): 20-30.

Klinowska, M. 1986. The cetacean magnetic sense - evidence from strandings. Pp. 401-432 in Bryden, M.M., and Harrison, R.J. (eds), *Research on dolphins*. Oxford University,

Lopez, J.C., and Lopez, D. 1985. Killer whales (*Orcinus orca*) of Patagonia, and their behaviour of intentional stranding while hunting inshore. *Journal of Mammalogy* 66(1): 181-183.

McCann, C. 1964. A coincidental distribution pattern of some large marine animals. *Tuatara* 12: 119-124.

McManus, T.J., Wapstra, J.E., Guiler, E.R., Munday, B.L., Obendorf, D.L. 1984. Cetacean strandings in Tasmania from February 1978 to May 1983. *Papers and Proceedings of the Royal Society of Tasmania* 18: 117-135.

Maigret, J. 1979. Les échouges massifs de cetacès dans la region du Cap-Vert (Senegal). Université de Dakar, Institute fondamental d'Afrique noire. Publication trimestrielle 161: 23-28.

Mead, J.G., 1979. An analysis of cetacean strandings along the eastern coast of the United States. Pp. 54-68 in Geraci, J.R., and St Aubin, D.J., *Insights*.

Mermoz, J.F. 1980. A brief report on the behaviour of Commerson's dolphin, *Cephalorhynchus commersonii*, in the Patagonian shores. *Scientific Reports Whales Research Institute–Tokyo* 30: 149-153.

Nicol, D.J., and R.L. Croome. 1988. Trends in the Tasmanian cetacean stranding record. Pp. 59-70 in Augee, M. (ed.), *Marine mammals of Australasia*. Royal Zoological Society of New South Wales special publication, [publisher? place? Sydney, I guess, but pls check]

Nicol, D.J. 1987. A review and update of the Tasmanian Cetacean Stranding Record. Environmental Studies Work Paper 21. University of Tasmania, Hobart.

Nishiwaki, M. 1962. Aerial photographs show sperm whales' interesting habits. *Norsk Hvalfangst-Tidende* 51: 395-398.

Odell, D.K. 1987. The mystery of marine mammal strandings. *Cetus* (fall, 1987): 2-6.

Robson, F.D. 1984. *Strandings: Ways to save whales*. Angus and Robertson Publishers, Sydney. 199 pp.

Robson, F.D., and van Bree, P.J.H. 1971. Some remarks on a mass stranding of sperm whales, *Physeter macrocephalus* Linnaeus, 1758, near Gisborne, New Zealand, on March 18, 1970. *Zeitschrift für Saugetierkunde* 36: 55-60.

Sergeant, D.E. 1982. Mass strandings of toothed whales (Odontoceti) as a population phenomenon. *Scientific Reports–Whales Research Institute, Tokyo* 34: 1-47.

Sheldrick, M.C. 1979. Cetacean strandings along the coasts of the British Isles 1913-1977. Pp. 35-54 in Geraci, J.R., and St Aubin, D.J., *Insights*.

Stephenson, A.B. 1975. Sperm whales stranded at Muriwai beach, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 9(3): 299-304.

1Warneke, R. 1983. Whale stranding - accident or design? *Australian Natural History* 21(2): 43-47.

Wood, F.G. 1979. The cetacean stranding phenomena: An hypothesis. Pp. 129-189 in Geraci, J.R., and St Aubin, D.J., *Insights*.

APPENDIX A

FIELDS IN THE NEW ZEALAND WHALE STRANDING DATA BASE

Date of Stranding: Time of Stranding:

Species:

Location:

Latitude: Longitude:

Metric Grid Reference:

Number stranded: Type of stranding (1=single, 2=herd):

Condition of animals (1=live,2=sick,3=freshly dead,4=decomposed):

Contributing factor (1=stranding,2=entanglement,3=accident):

Behaviour prior to stranding:

Number refloated: Date: Time:

Number restranded: Date: Time:

Location:
Refloating technique (1=pontoon,2=towed,3=helicopter,4=manpower,
5=self refloated,6=other):

Disposal method(1=natural decay,2=burial,3=burning,
4=at sea,5=other):

Location:

Photo's taken? (1=black&white,2=colour):(1=print,2=slide):

Stranding supervisor:

Contact address and phone number:

Observers name:

Contact address and phone number:

Source:

Remarks:

Topographical Features of Stranding Site

Shore type	U/W topography	Current type	Current direction
mudflat=1	sandbars=1	ocean=1	N=1
sandbeach=2	reefs=2	tidal=2	E=2
gravelbeach=3	promontories=3	winddrift=3	E=3
boulder=4	nothing=4	wave induced=4	SE=4
rocky coast=5		river=5	S=5
			SW=6
			W=7
			NW=8

Gradient of shore: Current velocity:
Aspect of shore:
Distance to 30 metre isobath:

24hr Prior Conditions

Sea condition	Swell	Swell direction	Wind speed	Weather
glassy=1	short=1	N=1	calm=0	fine=1
rippled=2	average=2	NE=2	light air=1	cloudy=2
wavelets=3	long=3	E=3	light breeze=2	gloomy=3
slight=4	low=4	SE=4	gentle breeze=3	fog=4
moderate=5	moderate=5	S=5	moderate breeze=4	drizzle=5
rough=6	heavy=6	SW=6	fresh breeze=5	showers=7
very rough=7		W=7	strong breeze=6	rain=6
high=8		NW=8	neargale=7	Th.storm=8
very high=9			gale=8	
phenomenal=10		B:	strong gale=9	
		onshore=1	storm=10	
		offshore=2	violent storm=11	
		alongshore=3	hurricane=12	

Conditons at time of stranding

Sea condition	Swell	Swell direction	Wind speed	Weather
glassy=1	short=1	N=1	calm=0	fine=1
rippled=2	average=2	NE=2	light air=1	cloudy=2
wavelets=3	long=3	E=3	light breeze=2	gloomy=3
slight=4	low=4	SE=4	gentle breeze=3	fog=4
moderate=5	moderate=5	S=5	moderate breeze=4	drizzle=5
rough=6	heavy=6	SW=6	fresh breeze=5	showers=7
very rough=7		W=7	strong breeze=6	rain=6
high=8		NW=8	neargale=7	Th.storm=8
very high=9			gale=8	
phenomenal=10		B:	strong gale=9	
		onshore=1	storm=10	
		offshore=2	violent storm=11	
		alongshore=3	hurricane=12	

Barometric pressure: Temperature: Magnetic intensity:
Phase of Moon (1=new,2=1st quarter,3=2nd quarter,4=full):
Tide (1=full, 2=receding, 3=ebb, 4=rising):

Measurements

	Autopsy done (t/f)
Tag number:	Samples taken of:(t/f)
sex (m/f):	teeth:
pregnant?	earplugs:
age:	blubber:
length(u.jaw-fluke notch):	testes:
u.jaw-tip dorsal fin:	ovaries:
snout length:	stomach contents:
u.jaw-genital aperture:	parasites:
u.jaw-anus:	others (state)
u.faw-flipper(forward insertion):	
flipper length:	
fluke width:	
Concentrations of: (t/f)	Parasite load:(1=nil,2=light
heavy metals:	3=moderate,4=heavy)
PCBS:	stomach:
pesticides:	lungs:
	blubber:
	liver:
	nasal passages:
	external parasites:

Remarks:

Computer package for NZWSDB: DBase III plus (Aston Tate)