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Stomach contents of common dolphin (*Delphinus* sp.) from New Zealand waters

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Abstract This paper provides the first report of stomach contents of common dolphin (*Delphinus* sp.) from New Zealand waters. We examined 53 stomachs from 42 stranded and 11 by-caught common dolphin from the North Island of New Zealand between 1997 and 2006. Although the diet of by-caught and stranded common dolphin comprised a diverse range of fish and cephalopod species, the prevalent prey were arrow squid *Nototodarus* spp., jack mackerel *Trachurus* spp., and anchovy *Engraulis australis*. Stranded dolphins that originated from coastal waters, and dolphins by-caught within neritic waters, fed on both neritic and oceanic prey. Moreover, this mixed prey composition was evident in the diet of common dolphin by-caught in oceanic waters, suggesting inshore/offshore movements of common dolphin on a diel basis.

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INTRODUCTION

Common dolphins of the genus *Delphinus* are found in a diversity of temperate, subtropical and tropical habitats worldwide (Jefferson et al. 1993; Perrin 2002). In New Zealand waters, common dolphin previously assumed to be short-beaked common dolphin (*D. delphis*) occur around much of the New Zealand coastline, especially off the east coast of the North Island (Webb 1973). However, extensive morphological variation (Stockin & Visser 2005) and the absence of any molecular studies prevent the taxonomic clarification of *Delphinus* in New Zealand waters. Thus, more recently, New Zealand common dolphin have been referred to as *Delphinus* sp. (Stockin et al 2007, 2008a,b). Within New Zealand waters, the southern limit of their distribution is considered to be 44°S near Banks Peninsula (South Island east coast), with abundance presumed to increase towards the equator (Gaskin 1968). Generally, the conservation status of common dolphin is considered of "least concern" by the IUCN, owing to the global abundance of this species (IUCN 2007). However, Mediterranean Sea common dolphin have recently been listed as "endangered" in the Red List of Threatened Species, based on criterion A2, which refers to a 50% decline in abundance over three generations (IUCN 2007). Based on the New Zealand threat classification system (Hitchmough 2002), common dolphin are considered "not threatened", but this classification is ambiguous given that no population estimates exist for this species within New Zealand waters.

The entanglement and subsequent drowning of cetaceans in fisheries is of worldwide concern (Reeves et al. 2003). Within New Zealand waters, mortality from fishery interactions occurs for a number of marine mammal species including New Zealand fur seal *Arctocephalus forsteri* (Manly et al. 2002), New Zealand sea lion *Phocarctos hookeri* (Chilvers et al.

2008), Hector's dolphin *Cephalorhynchus hectori* (e.g., Baird & Bradford 2000; Slooten et al. 2006), and common dolphin (Du Fresne et al. 2007). Of all New Zealand fishing practices, mid-water trawling is likely to represent the largest potential threat for common dolphin (Du Fresne et al. 2007; Rowe 2007). This method is primarily used in the jack mackerel *Trachurus* spp. fishery off the west coast of the North Island, where common dolphin have been frequently by-caught (Du Fresne et al. 2007). Although the extent of this by-catch remains unclear, earlier extrapolations by Slooten & Dawson (1995) suggest 80 to 300 common dolphin per annum were by-caught within this fishery. Common dolphin are also reportedly by-caught within set nets (K. A. Stockin unpubl. data) and in the purse seine fishery (C. Loveridge pers. comm.).

Interactions between marine mammals and fisheries typically occur when a marine mammal consumes one or more species targeted by commercial fisheries, or indirectly if the prey serves as food for other species that are commercially exploited. Thus, knowledge on the diet of marine mammals gives a better understanding of the potential interactions with fisheries. Before this study, the only existing insight into the diet of New Zealand common dolphin originated from underwater video footage taken in the Bay of Plenty, North Island, New Zealand during a study of behavioural ecology (Neumann & Orams 2003). The authors identified kahawai (*Arripis trutta*), jack mackerel, yellow-eyed mullet (*Aldrichetta forsteri*), flying fish (*Cypselurus cineatus*), parore (*Girella tricuspidata*), and garfish (*Hyporamphus ihi*) as potential prey items (Neumann & Orams 2003). In other parts of the world, dietary studies showed that common dolphins in neritic areas feed predominantly on small epipelagic shoaling species (e.g., Sekiguchi et al. 1992; González et al. 1994; Young & Cockcroft 1994; Santos et al. 2004; Meynier et al. 2008), whereas in oceanic regions, the small fish and cephalopods from the deep scattering layer (DSL) form most of their diet (e.g., Chou et al. 1995; Ohizumi et al. 1998; Pusineri et al. 2007). Diet also changed accordingly with fluctuations in prey abundance and distribution (Young & Cockcroft 1994; Silva 1999; Santos et al. 2004).

Our knowledge of common dolphin movements within New Zealand waters is limited. Common dolphin observed near the coast during the austral summer are reported, at least in some areas, to move further offshore during the winter months (Neumann 2001). A photo-identification study revealed that some individuals also move along the coast between adjacent geographical locations (Neumann et al. 2002). Thus, we would expect the most recent diet of coastal common dolphin to be composed of neritic species only. Conversely, if common dolphin found in open waters belong to a separate oceanic subpopulation, we would envisage feeding to be on oceanic prey. Herein, we document the first report on the diet of common dolphin in New Zealand waters as revealed by stomach contents of stranded and by-caught animals, and assess any neritic versus oceanic dietary differences between the two groups.

MATERIALS AND METHODS

Sample collection

Common dolphin, which stranded alive or dead around the North Island coastline, were accessed through the New Zealand Department of Conservation. Access to by-caught dolphins from the jack mackerel fishery operating off the west coast, North Island, was facilitated through the Conservation Services Levy Fisheries Observer Programme (New Zealand Ministry of Fisheries). Typically, all carcasses were frozen and transported to Massey University for a systematic necropsy (Duignan et al. 2003, 2004; Duignan & Jones 2005). Pathological examination and sampling was conducted according to a standard protocol adapted from Geraci & Lounsbury (1993). Measurements of each animal were recorded and the gonads examined to determine sexual maturity (visual examination of ovaries and histological examination of testes; details in Duignan et al. 2003, 2004; Duignan & Jones 2005).

Stomach analysis

Stomach contents were thawed and washed through a 0.25 mm mesh sieve. Diagnostic hard parts (otoliths, jaw bones, and cephalopod beaks) were identified to the lowest possible taxonomic level using published guides (Clarke 1986; Smale et al. 1995) and the reference collection held at Massey University. Some uncertainty remained in the identification of cephalopod species because only limited beak material was available in the reference collection. Thus, except for *Nototodarus* spp. and *Sepioteuthis bilineata*, the identification of beaks from stomach contents was based on the descriptions by Clarke (1986) only.

The sieved remains were preserved in 70% ethanol except for bones and otoliths, which were stored dry. Each prey item was scored as belonging to the fresh or the digested fraction (Pusineri et al.

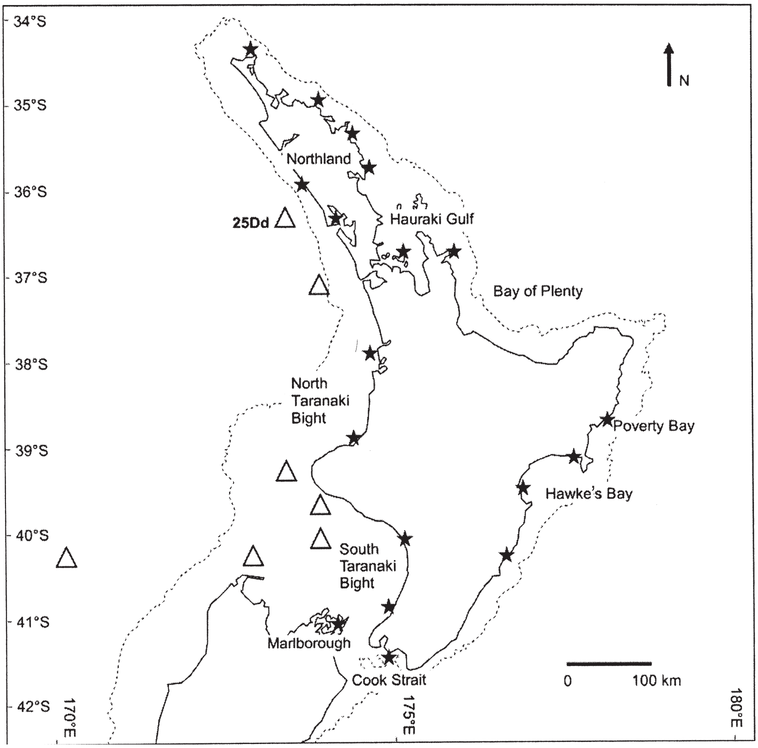

Fig. 1 Location of stranded (stars) and by-caught (triangles) *Delphinus* sp., North Island, New Zealand, from 1997 to 2006. More than one animal may be represented by the same symbol. Dashed line represents 200 m bathymetric contour. Map provided by Research Data Management, Ministry of Fisheries. (25Dd, by-caught dolphin separated from other samples owing to its greatly different diet.)

2007). The fresh fraction included whole prey and hard remains with some flesh attached (e.g., skulls and vertebral columns) that were ingested shortly before the death of the dolphin. The digested fraction consisted of remains without associated flesh (e.g., free otoliths, bones, and beaks), which were part of meals ingested from one to several days before death (gut passage time estimated from feeding experiments for otariids; Bigg & Fawcett 1985; Dellinger & Trillmich 1988; Tollit et al. 2003). The number of fish in each stomach was estimated by the number of otoliths: if less than 10 otoliths per taxon were present, left and right otoliths/dentaries were sorted, and the highest number was taken. If more than 10 otoliths were present, the total number was divided by two. The number of cephalopods was estimated by the number of upper or lower beaks, whichever was higher (Pierce & Boyle 1991).

Prey size and mass were estimated by measuring otolith length (or width when the tip was broken), lower beak rostral length (LRL) for squid, or lower beak hood length (LHL) for octopods and sepiolids at an accuracy of 0.5 mm, and using regression equations from the literature (Smale et al. 1995; Fea et al. 1999; Lu & Ickeringill 2002). When a species was represented by >40 otoliths or beaks in a stomach, 30 were randomly selected and measured. In this instance, a weighing factor (ratio of measured prey to the total of prey) was multiplied to each measurement (Santos et al. 2004). Only otoliths with no sign of erosion were measured, to minimise the underestimation of size and mass.

The relative importance of each prey was estimated as O, occurrence (number of stomachs in which the taxon was observed); %N, percentage of the total prey number in the sample set; and %M, percentage of the total reconstructed mass (product of the number of prey and the average body mass). Stranded and by-caught animals were considered separately. Within the stranded sample set, we separately examined individuals from Hauraki Gulf (Fig. 1), a region where a population of common dolphin have been studied extensively over recent years (Stockin & Visser 2005; Stockin et al. 2007, 2008a,b). Prevalent prey as determined for each category (i.e., by-caught, stranded in Hauraki Gulf, other stranded) was defined as any species present in more than half the examined stomachs.

To assess the distribution of prey types among the categories, we classified each prey species into one of the following groups: neritic = species living over the continental shelf; coastal = neritic species confined to coastal waters; oceanic = species living beyond the edge of the continental shelf, in waters deeper than 200 m; combined = species living in both neritic and oceanic waters. These classifications were based on published distributions and/or fisheries data for New Zealand waters (Paul 2000; Ministry of Fisheries 2007).

RESULTS

A total of 53 stomachs were examined from 42 stranded and 11 by-caught common dolphins from 1997 to 2006. Of these, 37 stomachs (27 stranded; 10 by-caught), contained identifiable prey remains of 13 males and 24 females. Samples from stranded animals were obtained from the coast of North Island. By-caught dolphins from the commercial jack mackerel fishery off the west coast were as follows: four dolphins from the Cook Strait/Taranaki region in neritic waters; four others west of Northland in oceanic waters less than 30 km from the continental slope; and two dolphins caught more than 100 km from the shelf edge (Table 1, Fig. 1). The sample size was too small to allow examination of some factors that can influence diet, e.g., sex, maturity, season, and year.

Among the 37 stomachs analysed, one of the by-caught samples (WB04-25Dd herein referred to as 25Dd) presented a high prey diversity compared with the other examined individuals. Nine different taxa not found in any other stomach content were observed in 25Dd. Therefore, 25Dd was not included with the other by-caught animals and was considered separately (Table 2). In total, at least 31 fish and seven cephalopod species were identified from diagnostic hard parts (Table 2). However, each dolphin consumed between one and six taxa only, except for 25Dd whose stomach contents comprised 13 different taxa. Fish comprised more than 90% by number (%N) of the diet of stranded common dolphins including also 25Dd. Cephalopods were as important as fish for the other by-caught dolphins.

Although individual 25Dd contained a relatively high diversity of fish and cephalopods, lanternfish Myctophidae were the dominant prey in its stomach content, accounting for 80.7% by number (%N) and 93.1% by mass (%M) (Table 2). This prey family was also important by number in the contents of other by-caught animals (28.0%N). Nonetheless, their occurrence was low (two out of nine stomachs), thus lanternfish were not a representative prey item for the by-caught group as a whole. Prevalent prey were jack mackerel, anchovy *Engraulis australis*, and arrow squid *Nototodarus* spp. The latter two taxa were consumed in relatively large numbers, explaining a high contribution by number (41.9%N and 13.3%N for arrow squid and anchovy, respectively), and by mass for arrow squid (50.7%M) owing to a relatively large size (Table 2).

Stranded common dolphin fed frequently on arrow squid (1.0%N and 11.3%M for Hauraki Gulf; 8.1%N and 41.9%M for other regions) and animals stranded outside Hauraki Gulf also on jack mackerel (2.1%N and 12.6%M) (Table 2). Cardinal fish *Epigonus* sp. and grey mullet *Mugil cephalus* combined, comprised 85.4%N and 54.2%M of the total stomach content of Hauraki Gulf individuals, but these species were present in only a third of the stomachs and were not considered representative. Their significant percentages by number and by mass were owing to high numbers of prey in some stomach contents (more than 200 fish for cardinal fish and 70 for grey mullet). A similar scenario was observed for lanternfish in the stomach contents of stranded animals other than from Hauraki Gulf (78.9%N), with more than 700 individual prey found in each of two stomachs.

Approximately 80% of the total prey individuals were <10 cm long (Fig. 2). These small prey comprised pelagic fish such as redbait *Emmelichthys nitidus* and yellow-eyed mullet, dermersal fish such as cardinal fish, scarpee *Helicolenus percoides*, and dwarf cod *Austrophycis marginata*, and mesopelagic fish such as lanternfish (Table 2). The lanternfish predominantly measured between 4 and 6 cm, which fell within the most frequent length of prey targeted by common dolphins (Fig. 2). The prevalent prey, arrow squid and jack mackerel, formed the tail of the length distribution with a mean length of 13.6 ± 5.4 cm and 18.3 ± 7.6 cm, respectively (Table 2). Prey larger than 40 cm such as conger eel Congridae, barracouta *Thyrsites atun*, and flying fish Exocoetidae, represented less than 5% of the total length distribution (Fig. 2).

Each prey species was categorised according to its known New Zealand habitat (oceanic, neritic, coastal, and combined). Among the most important prey, anchovy was considered coastal, lanternfish oceanic, and jack mackerel and arrow squid both neritic and oceanic. Both by-caught and stranded dolphins preyed on fish and cephalopods from both oceanic and neritic (including coastal) waters (Fig. 3). Among the animals stranded in Hauraki Gulf, four stomachs contained remains of oceanic prey (cardinal fish, lanternfish), of which two contained large numbers

Table 1 Locality, date, and biological data of stranded and by-caught *Delphinus* sp., North Island, New Zealand, of which stomachs have been examined. (BC, body condition.)

Code	Date	Sex	Location	Maturity	BC	Comments
Stranded						
WS97-17Dd	Jul 1997	F	Wellington	Adult		
WS00-01Dd	Dec 1999	M	East coast-Northland	Adult		
WS00-33Dd	Sep 2000	F	East coast-Northland	Adult	emaciated	
WS00-34Dd	Oct 2000	F	Hauraki Gulf	Adult		empty stomach
WS00-41Dd	Oct 2000	F	Hauraki Gulf	Adult		empty stomach
WS01-39Dd	Jul 2001	F	unknown	Juvenile		empty stomach
WS01-43Dd	Aug 2001	F	unknown	Adult		
WS02-03Dd	Jan 2002	F	Marlborough Sounds	Adult		
WS02-04Dd	Jan 2002	F	Marlborough Sounds	Adult		
WS02-14Dd	Mar 2002	M	South Taranaki Bight	Juvenile		
WS02-37Dd	Jul 2002	F	East coast-Northland	Juvenile		empty stomach
WS03-20Dd	Jul 2002	M	Poverty Bay	Adult		
WS02-38Dd	Aug 2002	F	Marlborough	Adult	emaciated	
WS02-39Dd	Oct 2002	F	South Taranaki Bight	Adult	emaciated	
WS03-41Dd	Oct 2003	F	West coast-Northland	Juvenile	emaciated	empty stomach
WS03-42Dd	Oct 2003	F	West coast-Northland	Adult	emaciated	
WS03-43Dd	Oct 2003	F	West coast-Northland	Adult	emaciated	
WS04-19Dd	Aug 2004	M	Hauraki Gulf	Adult		
WS04-28Dd	Dec 2004	F	Hauraki Gulf	Adult	emaciated	
WS04-29Dd	Dec 2004	F	Hauraki Gulf	Adult	emaciated	
WS04-30Dd	Dec 2004	M	Hauraki Gulf	Juvenile		empty stomach
WS04-32Dd	Dec 2004	F	Hauraki Gulf	Juvenile		empty stomach
WS04-33Dd	Dec 2004	F	Hauraki Gulf	Adult	emaciated	
WS04-34Dd	Dec 2004	F	Hauraki Gulf	Adult		
WS04-35Dd	Dec 2004	F	Hauraki Gulf	Adult	emaciated	
WS04-36Dd	Dec 2004	F	Hauraki Gulf	Adult		
WS05-06Dd	Jan 2005	M	Hauraki Gulf	Adult		empty stomach
WS05-28Dd	Mar 2005	M	South Taranaki Bight	Juvenile		empty stomach
WS05-16Dd	Mar 2005	F	Hauraki Gulf	Adult	emaciated	empty stomach
WS05-22Dd	May 2005	F	Wellington	Juvenile		empty stomach
WS05-23Dd	May 2005	F	Hawke's Bay	Adult		empty stomach
WS05-24Dd	May 2005	F	Hauraki Gulf	unknown		empty stomach
WS05-26Dd	Jul 2005	M	Hauraki Gulf	Juvenile		
WS05-27Dd	Jul 2005	F	South Taranaki Bight	Juvenile		empty stomach
WS05-25Dd	Jul 2005	F	Hauraki Gulf	Juvenile		
WS05-21Dd	Nov 2005	M	Poverty Bay	Adult		
WS05-37Dd	Nov 2005	F	West coast-Northland	Adult		
WS05-18Dd	Dec 2005	M	Bay of Plenty	Adult		
WS05-19Dd	Dec 2005	M	Bay of Plenty	Adult		
WS05-20Dd	Dec 2005	M	Bay of Plenty	Adult		
WS06-08Dd	Mar 2006	F	South Taranaki Bight	Juvenile		empty stomach
WS06-09Dd	Apr 2006	F	North Taranaki Bight	Adult		
By-caught						
WB00–06Dd	Oct 1999	F	Off South Taranaki Bight	Juvenile		
WB01-13Dd	Dec 2000	F	Off South Taranaki Bight	Juvenile		
WB02-01Dd	Oct 2001	M	Off South Taranaki Bight	Adult		
WB03-02Dd	Oct 2002	F	unknown	Adult		empty stomach
WB03-03Dd	Oct 2002	M	Off South Taranaki Bight	Adult		
WB03-17Dd	Apr 2003	M	Oceanic zone/offshore	Adult		
WB03-18Dd	Apr 2003	M	Oceanic zone/offshore	Adult		
WB04-12Dd	Dec 2003	F	Off West Northland	Adult		
WB04-13Dd	Dec 2003	F	Off West Northland	Juvenile		
WB04-05Dd	Dec 2003	F	Off West Northland	Adult		
WB04-25Dd	Nov 2004	F	Off West Northland	Adult		

Table 2 Composition of stomach contents of stranded and by-caught *Delphinus* sp., North Island, New Zealand. One by-caught dolphin (25Dd) was separated from the other by-caught samples, since its diet was greatly different from the other animals. Stranded samples were divided into two groups: Hauraki for the animals stranded in Hauraki Gulf, and animals stranded in other North Island regions. Numbers in parentheses represent the number of stomachs analysed for each category. (O, occurrence; %N, percentage by number; %M, percentage by reconstructed mass; *n*, number of individual prey used to reconstruct the length over all groups; diversity, average number of taxa per stomach (± SE); *Trachurus* spp. for *T. murphyi*, *T. declivis*, or *T. novaezelandiae*; *Seriolella* spp. for *S. brama*, *S. punctata*, or *S. caerulea*; and *Nototodarus* spp. for *N. gouldi* or *N. sloani*.)

	By-caught					Stranded						Reconstructed length	
	without 25Dd (9)			25Dd		Hauraki (9)			without Hauraki (18)				Length ± SD
	O	%N	%M	%N	%M	O	%N	%M	O	%N	%M	*n*	(cm)
Fish	**9**	**54.8**	**48.4**	**98.6**	**97.6**	**8**	**98.3**	**88.0**	**15**	**91.4**	**57.7**		
Apogonidae													
Epigonus sp (cardinal fish)						3	75.1	12.6	2	0.1	<0.04	80	7.6 ± 2.0
Argentinidae													
Argentina elongata (silverside)	1	1.6	1.8									21	15.6 ± 1.3
Carangidae													
Trachurus spp. (jack mackerel)	5	4.1	8.0			3	1.9	12.0	9	2.1	12.6	124	18.3 ± 7.6
Centrolophidae													
Seriolella spp. (warehou)	2	1.6	13.6									22	19.6 ± 5.6
Chauliodontidae													
Chauliodus sloani (viperfish)				1.3	0.7							19	10.1 ± 0.7
Clupeidae													
Sardinops neopilchardus (pilchard)	3	0.8	1.0			2	3.2	13.0	2	0.3	0.7	36	17.7 ± 4.7
Congridae													
Conger wilsoni (conger eel)	4	3.1	18.1						3	2.4	10.5	87	40.9 ± 13.8
Gnathophis habenatus (silver conger)	1	0.1	<0.04						2	0.7	0.5	27	23.4 ± 5.5
Unid. Congridae									2	2.1	15.6	30	50.4 ± 8.5
Emmelichtidae													
Emmelichthys nitidus (redbait)	1	0.1	<0.04									2	8.5 ± 0.1
Eugraulidae													
Engraulis australis (anchovy)	5	13.3	5.2			2	0.3	0.1	4	0.9	0.1	108	10.6 ± 1.2
Exocoetidae (flying fish)									1	0.0	1.5	2	42.0 ± 1.0
Gempilidae													
Thyrsites atun (barracouta)									1	0.0	0.4	2	40.8 ± 1.8
Hemirhamphidae													
Hyporhamphus ihi (garfish)						2	6.6	7.7				91	21.8 ± 3.7
Moridae													
Austrophycis marginata (dwarf cod)	1	0.5	<0.04						2	0.8	<0.04	31	4.1 ± 2.0
Pseudophycis bachus (red cod)						1	0.1	0.2				2	13.8 ± 0.5
Mugilidae													
Aldrichetta forsteri (yellow-eyed mullet)						1	0.1	<0.04	1	0.3	0.1	12	7.8 ± 1.4
Mugil cephalus (grey mullet)						2	10.3	41.6	5	1.3	9.3	96	23.6 ± 5.9

Mugiloididae													
Parapercis colias (blue cod)						1	0.1	0.7				2	18.0 ± 1.0
Myctophidae (lanternfish)	**2**	**28.0**	**4.5**	**80.7**	**93.1**	**1**	**0.1**	**<0.04**	**2**	**78.9**	**3.0**		
Diaphus brachycephalus/efulgens	1	17.5	0.3									30	2.4 ± 0.1
Diaphus ostenfeldi									1	0.0	<0.04	2	6.5 ± 0.0
Diaphus sp.				23.4	24.1							67	7.1 ± 0.8
Lampanyctodes hectori	1	10.4	0.3						2	78.8	6.3	101	4.7 ± 1.0
Lampanyctus australis				24.7	43.7							80	6.6 ± 1.2
Myctophum/Hygophum									2	0.1	<0.04	3	6.8 ± 0.9
Notoscopelus/Gymnoscopelus				32.6	21.6	1	0.1	<0.04				48	8.3 ± 0.7
Symbolophorus sp.	1	0.1	0.1									1	9.1
Notosudidae													
Scopelosaurus sp. (wary fish)				1.4	1.2							22	11.1 ± 1.6
Percophidae													
Hemerocoetes sp. (opalfish)	1	0.1	<0.04									1	11.3
Scorpionidae													
Helicolenus percoides (scarpee)	1	0.6	<0.04									8	2.7 ± 1.0
Sternoptychidae													
Maurolicus muelleri (pearlside)				8.6	0.5							36	3.6 ± 0.3
Stomiidae													
Stomias sp (scaly dragonfish)				6.6	5.9							54	10.1 ± 0.9
Unid. Fish	4	1.0	-			3	0.5	–	5	1.5	–		
Cephalopods	**6**	**45.2**	**51.6**	**1.4**	**2.4**	**6**	**1.5**	**12.0**	**14**	**8.6**	**42.3**		
Brachioteuthidae													
Brachioteuthis picta?				0.2	<0.04							2	3.8 ± 0.3
Cranchidae													
Teuthowenia sp.				0.2	0.2							2	7.1 ± 0.4
Histioteuthidae (violet squid)													
type A				0.1	0.9				1	0.0	0.1	2	5.8 ± 0.1
type B				0.1	0.2							1	2.2
Loliginidae													
Sepioteuthis bilineata (broad squid)	1	0.3	0.3			3	0.5	0.7	1	0.0	0.3	8	19.6 ± 5.5
Ommastrephidae													
Nototodarus spp. (arrow squid)	6	41.9	50.7	0.2	0.5	5	1.0	11.3	12	8.1	41.9	298	13.6 ± 5.4
Sepiolidae (bobtail squids)	3	3.0	0.6	0.5	0.5				1	0.3	<0.04	23	2.4 ± 0.2
Unid. cephalopod									2	0.2			
Diversity ± SE		5 ± 1		13			3 ± 2			3 ± 2			

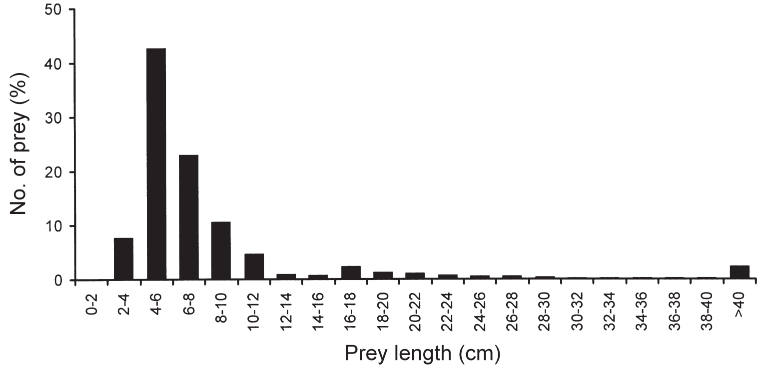

Fig. 2 Overall prey length distribution of the diet of *Delphinus* sp., North Island, New Zealand expressed in % by number. Measurements were combined across all stomach contents.

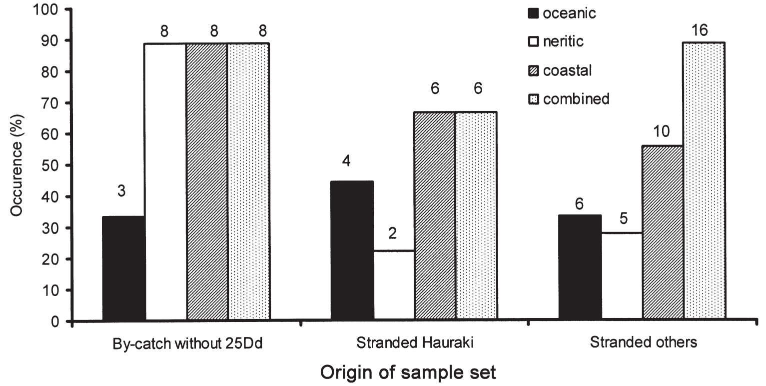

Fig. 3 Occurrence (%) of different prey types (oceanic, neritic, coastal, and combined) of *Delphinus* sp., North Island, New Zealand, by sampling origin of the dolphins: by-caught (9 dolphins without 25Dd), stranded in Hauraki Gulf (9 dolphins), and stranded in other regions (18 dolphins). Number above each bar is absolute occurrence (number of stomachs in which the prey type was present). (25Dd, by-caught dolphin separated from other samples owing to its greatly different diet.)

of cardinal fish (>700 fish). Lanternfish and violet squid Histioteuthidae (oceanic) were present in six other stranded animals in small numbers except in two dolphins from Poverty Bay from which large numbers of lanternfish were retrieved (>700 fish). Within the by-catch group, the two animals caught at more than 100 km from the western continental shelf contained some neritic species (jack mackerel, bobtail squid Sepiolidae) in the fresh fraction of their stomach contents, plus anchovy (coastal) in the digested fraction.

DISCUSSION

This is the first quantitative study of the diet of common dolphin in New Zealand waters. Although the diet of by-caught and stranded dolphins comprised a diverse range of fish and cephalopod species, the prevalent prey were arrow squid, jack mackerel, and anchovy. We expected common dolphin that occur in coastal waters (as evidenced by live strandings or fresh carcasses) to feed primarily on neritic prey, and dolphins that occur in offshore waters to consume mostly oceanic species. However, stranded dolphins that were believed to originate from coastal waters, and dolphins by-caught within neritic waters, fed on both neritic and oceanic prey. Moreover, this mixed prey composition was in the diet of common dolphin by-caught in waters further offshore, suggesting inshore/offshore movements of common dolphin on a diel basis.

Dietary composition

Previous investigations on the diet of common dolphin have revealed a high diversity of prey, with primary prey being small pelagic shoaling fish and cephalopods (e.g., Young & Cockcroft 1994; Ohizumi et al. 1998; Silva 1999; Santos et al. 2004; Pusineri et al. 2007; Meynier et al. 2008). These findings are consistent with the results in the present study, in which prevalent prey of the New Zealand common dolphin were arrow squid, jack mackerel, and anchovy (Table 2). Neumann & Orams (2003) observed the feeding behaviour of common dolphin in the Bay of Plenty from video footage, and of six identified prey species, four (jack mackerel, flying fish, yellow-eyed mullet, and garfish) were found in the stomach contents reported herein.

Each of the stomachs analysed in the present study contained only a few different prey species (from one to six). However, individual variability was high, possibly reflecting the diversity of environments from which the samples originated (i.e., west versus east coast, neritic versus oceanic location, by-caught versus stranded). Also, the range of prey size was wide from 2 cm to >40 cm, though most of the prey were <30 cm. A high number of prey species and a wide range of prey size are usually considered indicative of an opportunistic feeding behaviour: dolphins are expected to eat the most available and easily captured prey in a given area at a particular time (Santos et al. 2004). However, the diet of common dolphin stranded within Hauraki Gulf did not represent the pelagic shoaling community present in this region. Anchovy, pilchard, jack mackerel, and mullet are abundant in this area (Paul 2000; Kendrick & Francis 2002), but were present in less than half the stomachs of individuals stranded in Hauraki Gulf. In contrast, arrow squid are reportedly not abundant in these waters (Morrison & Francis 1999), yet appeared to be a common prey species for common dolphin that stranded in this region. The discrepancy between stomach contents and prey availability probably reflects bias in the diet of emaciated animals examined from this region (four out of nine), but could also result from prey selection.

Prey species such as lanternfish, viperfish *Chauliodus sloani*, wary fish *Scopelosaurus* sp., pearlside *Maurolicus muelleri*, and scaly dragonfish *Stomias* sp. are mesopelagic species from the DSL (Whitehead et al. 1984). These fish migrate to the surface at night, where they become an available resource for the dolphins (e.g., Evans 1994; Ohizumi et al. 1998). Their presence in the diet indicates that common dolphin examined herein fed at night. They also feed during the daytime on epipelagic shoaling species as reported from different locations in New Zealand (Bay of Plenty, Neumann & Orams 2003; Hauraki Gulf, Burgess 2006).

Oceanic versus neritic prey

Some oceanic prey items were found in the stomachs of stranded dolphins (Fig. 3). Stranded dolphins are likely to come from coastal/neritic areas, but the continental shelf of New Zealand is narrow in some regions such as the east coast of the North Island (Fig. 1), thus some dolphins may have died in oceanic waters and have drifted to the coast and stranded. However, the two stranded dolphins at Poverty Bay with large amounts of oceanic prey (lanternfish) in their stomachs were found in fresh condition, therefore it is unlikely that they died far from the coast. Consequently, these animals appear to have moved from oceanic waters towards coastal waters within days. Furthermore, some of the stranded individuals examined from the Hauraki Gulf region had a selection of oceanic prey species evident within their diet, thus suggesting that at least some proportion of common dolphin occurring in Hauraki Gulf waters undertake foraging trips offshore. Lastly, dolphins caught in waters further than 100 km from the continental shelf fed on neritic species, suggesting that these animals foraged further inshore within days before their death. These examples are based on samples where the prey species were found in large numbers in the stomach or as the single prey species, thereby excluding the bias of secondary ingestion (when a prey in the stomach comes from another prey).

In New Zealand waters, seasonal inshore/offshore migrations of common dolphin were reported in the Bay of Plenty, with dolphins shown to move further offshore during winter months (Neumann 2001). However, our data suggest that dolphins travel between neritic and oceanic areas over a much shorter temporal scale. Common dolphin are extremely mobile and have previously been reported to travel up to 270 miles (c. 435 km) within a 10-day period (Evans 1982). Within a narrow continental shelf such as that off northern New Zealand, it is not surprising that dolphins using coastal waters may regularly travel offshore to productive areas such as the slope of the continental shelf, where they can take advantage of DSL prey that move to the surface at night. Common dolphin exploiting both oceanic and neritic zones provide dietary evidence of a foraging plasticity. We suggest that this foraging plasticity enables common dolphin to feed on the epipelagic schooling community in neritic waters during the daytime, and then move further offshore to feed on the DSL prey in oceanic waters at night. It is within these waters and at night that they are at most risk of being incidentally caught in the mid-trawl jack-mackerel fishery (Du Fresne et al. 2007). Moreover, jack mackerel consumed by dolphins had a size range overlapping with the one targeted by the fishery (5.5–38.9 cm in this study versus 20–50 cm harvested in the waters west of New Zealand (Taylor 2002). Other anthropogenic impacts on this species have been observed in coastal waters (e.g., pollution, Stockin et al. 2007; tourism, Stockin et al. 2008a). Thus, New Zealand common dolphin are under pressure from a variety of human activities yet the scale and significance of those impacts remain unknown.

Limitations of the study

Limitations from the study arose both from sampling and stomach analysis. The data set presented herein may be considered opportunistic, since sampling was dependent upon stranding and by-catch events. Biases related to the use of stranded specimens in dietary analysis have been previously discussed in the literature (e.g., Pierce & Boyle 1991). Strandings can be biased towards sick animals, whose diet is not necessarily representative of healthy individuals within the population. Some dolphins reported in this study were emaciated, representing a third of the total number of all stranded animals examined. Of these, over 40% were from Hauraki Gulf ($n = 4$) originating from one mass stranding, thus we question the representativeness of these samples for this region. As stranded animals likely represent dolphins using inshore waters before death, neritic prey is likely to be overestimated in their diet. Likewise, the recent diet of animals incidentally captured in commercial fisheries could be biased towards the targeted species of that fishery, i.e., jack mackerel in this study. However, jack mackerel was not present in every by-caught animal examined during the present study, and its occurrence in stranded dolphins was significant.

Some other limitations of the study are inherent to the method. They include prey species-specific gut transit times and digestion rates and are detailed in the literature (e.g., Bigg & Fawcett 1985; Dellinger & Trillmich 1988; Harvey & Antonelis 1994; Yonezaki et al. 2005). For instance, fish otoliths may be partially or completely digested, affecting the probability that a prey eaten is recovered, and preventing an accurate back-calculation of the original prey size (Dellinger & Trillmich 1988). In an attempt to reduce these biases, bones were used in conjunction with otoliths for identification (Pierce & Boyle 1991; Tollit et al. 2003) and back calculation of prey size was applied to non-eroded otoliths.

CONCLUSION

We acknowledge the constraints and limitations of the presented dietary data. Nonetheless, we consider the present findings to be an important insight into the diet of New Zealand common dolphin. This is particularly important from a conservation perspective, given that this population appears to be subject to both coastal and oceanic anthropogenic impacts as a result of apparent inshore/offshore movements.

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