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Strandings of striped dolphin *Stenella coeruleoalba* in Scottish waters (1992–2003) with notes on the diet of this species

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During 1992–2003, 52 striped dolphin strandings were recorded in Scotland (UK). Although strandings were recorded in every month of the year, highest numbers were found in January–March and August. Striped dolphins were stranded all around the Scottish coast, but the majority were recovered from the west coast. Necropsies were carried out on 33 of these animals: 29 had live-stranded and cause of death was not established for four animals. Stomach contents were analysed for 20 animals: whiting and Trisopterus *were the main prey species in the diet (both by number and by reconstructed biomass). Females had a higher average number of* Trisopterus *in their stomachs than did males.* Trisopterus *eaten in winter were larger than* Trisopterus *eaten in summer and both* Trisopterus *and whiting eaten on the east coast were bigger than those eaten on the west coast. The reproductive status was determined for six females and six males during 2001–2003, with the majority being immature but the sample included one pregnant female and one sexually active mature male. We calculated the length–weight relationship for this species in Scottish waters. In addition, age data were collected from samples obtained during necropsies on six striped dolphins: the oldest dolphin sampled was around 14 y old but the majority were 2–7 y old. Although the numbers are low, the regular occurrence of stranded striped dolphins in recent years around Scotland, suggests that this warm water species may now be considered resident in Scottish waters.*

Keywords: striped dolphin; strandings; distribution; diet

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INTRODUCTION

Striped dolphins (*Stenella coeruleoalba* Meyen, 1833) are widely distributed in temperate, subtropical and tropical seas. The species is found worldwide and, in the Atlantic, it ranges north to Newfoundland, southern Greenland, Iceland, the Faroes and Denmark (Rice, 1998), with the northern limit on the eastern seaboard of North America changing as a function of the Gulf Stream (Archer, 2002). There have been occasional sightings in Norwegian waters (Isaksen & Syvertsen, 2002), and strandings of this species have been recorded as far north as Iceland and the Faroe Islands (Bloch *et al.*, 1996). Striped dolphins are typically found outside the continental shelf, usually over the continental slope and over oceanic waters (Archer, 2002). It tends to occur in sea depths of 1000 m or deeper, but has been recorded in waters of 60 m or less (Forcada *et al.*, 1990); when found close to land it is usually seen in deep water.

In UK waters, the species is classed as rare (Reid *et al.*, 2003). Its normal distribution appears to reach its northern limits at 50°N, with most records coming from the Western Approaches (off the south-west of England) and off Southern Ireland, although it has been recorded as far north as Shetland and in deep waters off the continental shelf north to 62°N (Evans, 1992; Reid *et al.*, 2003). It was not recorded among the 15 cetacean species sighted off the north and west of Scotland between 1979 and 1998 by Weir *et al.* (2001) or among nine cetacean species identified off north-west Scotland in July/August 1998 (Macleod *et al.*, 2003), or the eight species encountered off the west coast of Ireland between May and September 2004 (Wall *et al.*, 2006). During the 1994 Small Cetacean Abundance in the North Sea and Adjacent Waters (SCANS) survey, which included the North Sea (including waters north to 62°N), Skagerrak, Kattegat, western Baltic Sea, Channel and Celtic Shelf, striped dolphins were encountered only in the Celtic Sea, in relatively deep waters over the continental shelf off France (Hammond *et al.*, 1995). Striped dolphins have been identified during observations from seismic surveys in UK waters; these sightings include a group of about 18 individuals north of Shetland in 1996, a group of approximately 13 individuals on the edge of the continental shelf to the west of Ireland in 1998, a group of 18 dolphins in the southern North Sea in 1999 and, during seismic surveys in 2000, 'possible' striped dolphins occurred in deep waters in the Faroe–Shetland Channel and in shelf waters to the west and east of Shetland (Stone, 1997, 2000, 2001, 2003).

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The striped dolphin appears to be a relatively recent addition to the Scottish cetacean community, with the first stranding recorded on the Isle of Lewis, Western Isles in 1988 (Reid *et al.*, 1993; Sheldrick *et al.*, 1994). The first evidence of striped dolphins (euphrosyne dolphin) stranding on the British coast was in 1923 at Criccieth on the Lleyn Peninsula, Wales (Fraser, 1974). In Ireland, the first published record of a striped dolphin was in 1985, although they may have been present as early as 1912 (Berrow & Rogan, 1997).

García-Martínez *et al.* (1999), in a genetic study using mtDNA restriction analysis to determine the status of the species in European waters, found evidence for the existence of two distinct populations, one in the Mediterranean and one in the Atlantic Ocean, with very low gene flow between them. In the early 1990s, striped dolphins were a significant component of the cetacean by-catch in the Atlantic French tuna-drift-net fishery (Goujon *et al.*, 1993). In the Mediterranean, between 1990 and 1992, more than 1100 striped dolphin carcasses were recorded on beaches extending from the Spanish Mediterranean coast to the Tyrrhenian and Aegean Seas (Aguilar & Raga, 1993). This massive die-off affected only the striped dolphin and it has been linked to an infection by a morbillivirus similar to the one that causes distemper in carnivores (van Bressem *et al.*, 2001).

Studies throughout the range of striped dolphins indicate that mating is seasonal, with gestation lasting from 12 to 13 months and lactation between 12 and 18 months. The interbirth interval is 3–4 y. Body length at birth has been estimated to be between 93 and 100 cm, with adults reaching body lengths of 2.0–2.4 m. In general, males appear to reach sexual maturity between 7 and 15 y of age, possibly around 9 y, and estimates for the age of sexual maturity for females are between 5 and 14 y (Archer, 2002; Evans & Stirling, 2002). The maximum estimated age for both males and females is 30–35 y, but may be as old as 57.5 y (Archer & Perrin, 1999; Evans & Stirling, 2002). In the western Pacific, a complex schooling system has been documented, in which adult and mixed (juvenile and adults) schools are separated into breeding and non-breeding schools (Miyazaki & Nishiwaki, 1978; Archer, 2002).

Striped dolphins feed on a variety of pelagic and benthopelagic fish and squid. Regional variations in the diet have been reported, with myctophid fish dominating the diet off the coasts of Japan and South Africa while in the Mediterranean the species tend to feed primarily on squid (Archer & Perrin, 1999). In the eastern North Atlantic the diet consists of a variety of mesopelgaic and benthic fish, squid and crustaceans (Desportes, 1985; Berrow & Rogan, 1995).

The present study summarizes information on life history and diet of the species at the northern limit of its distribution, as derived from strandings along the Scottish coast during 1992–2003. We analysed geographical, seasonal, sex- and size-related variation in diet.

MATERIALS AND METHODS

During 1992–2003, 52 striped dolphin strandings were recorded in Scotland, species identity being positively confirmed in 42 cases. Strandings locations were mapped using ARCVIEW.

Necropsies were carried out on 33 animals and samples of stomach contents were obtained from 20 of these (Table 1). Teeth and gonad samples were also available for some animals (6 dolphins and 12 dolphins respectively, Table 2). Necropsy procedures, sampling and data collection, as conducted by the Scottish Agricultural College (SAC), followed the recommendations of the European Cetacean Society (Kuiken & Hartmann, 1991) and the UK Marine Mammal Project (Law, 1994). Cause of death was determined when possible.

Teeth were removed from the middle of the lower jaw and preserved in 10% neutral buffered formalin. Tooth preparation methods were adapted from Hohn & Lockyer (1995) and Lockyer (1995) and age was estimated by counting

Table 1. Striped dolphins (*Stenella coeruleoalba*) stranded around the Scottish coast (1992–2003) for which stomach samples were obtained.

Code	Date found	Location stranded	Sex	Length (cm)	Weight (kg)	Cause of death
M1775/92	08 August 1992	Islay, Strathclyde	Male	205	71.4	By-catch suspected
M1620/93	15 July 1993	Bixta Boe, Shetland	Male	229	104	Live stranding
M1908/92	23 August 1992	North Uist, Western Isles	Male	182	64.6	Live stranding, pulmonary disease
M0006/95	01 January 1995	Roesound, Muckle Roe, Shetland	Male	180		No diagnosis
M0040/95	09 January 1995	Culla Bay, Benbecula, Western Isles	Female	146	38	Live stranding
M2194/94	17 October 1994	Golspie, Highland	Male	179	66.8	Live stranding
M0696/92	03 April 1992	Findhorn, Grampian	Male	211.5	106	Live stranding, pulmonary emphysema
M2004/92	29 August 1992	Carbost, Isle of Skye	Male	185	61.8	By-catch
M0474/98	03 March 1998	Whale Firth, Yell, Shetland	Male	208	97.5	Live stranding
M1799/98	21 August 1998	Traigh Bhan, Islay				No diagnosis
M0656/99	14 December 1999	Duartaig, Highland	Female	167	56	Live stranding, *Brucella* meningitis
M0524/99	08 May 1999	Dunnet Beach, Caithness, Highland	Male	223	102	Live stranding
M0094/98	14 January 1998	Crinan, Argyll, Strathclyde	Male	207		Live stranding
M0133/01	10 September 2001	Dunnet Bay, Caithness	Female	189	72	Live stranding, Meningoencephalitis
M0054/00	16 March 2000	Tayvallich, Strathclyde	Male	164		Not established
M0009/02A	17 January 2002	Glenelg Beach, Highland	Female	152	39	Live stranding, *Brucella* meningitis
M0022/02	26 February 2002	Yell, Shetland	Female	194	72	Live stranding, *Brucella* meningitis
M0009/02B	17 January 2002	Glenelg Beach, Highland	Female	160	40.5	Live stranding
M0609/02	16 December 2002	Scalloway, Shetland	Female	160	44	Live stranding
M0119/03	10 March 2003	Glenelg Bay, Highland	Male	186	59	Live stranding

Table 2. Striped dolphins (*Stenella coeruleoalba*) stranded around the Scottish coast (1992–2003) for which teeth and gonad samples were available.

Code	Date found	Location stranded	Sex	Length (cm)	Weight (kg)	Estimated age (years)	Reproductive status	Cause of death
M1804/97	06 August 1997	Staffin, Isle of Skye	Male	182	60.0		pubescent	Live stranding (maternal separation)
M0094/98	14 January 1998	Crinan, Argyll, Strathclyde	Male	207	–	–	pubescent	Live stranding
M0474/98	03 March 1998	Whale Firth, Yell, Shetland	Male	208	97.5	–	pubescent	Live stranding
M0949/98	28 April 1998	Talmine, Sutherland, Highland	Female	159	37.0	–	–	Not established
M0524/99	08 May 1999	Dunnet Beach, Caithness, Highland	Male	223	102.0	–	mature (sexually active)	Live stranding (old animal in poor condition)
M0642/99	16 November 1999	Scousburgh, Shetland	Female	188	71.0	–	–	Live stranding, *Brucella* meningitis
M0654/99	10 December 1999	Machir Bay, Islay, Strathclyde	Male	185	58.0	–	immature	Live stranding, *Brucella* meningitis
M0656/99	14 December 1999	Rubh'an Dobhrain, Duartai, Highland	Female	167	56.0	–	–	Live stranding, *Brucella* meningitis
M0131/01	09 September 2001	Ornsay, Isle of Skye	Female	206	102.0	14	pregnant (foetus: 90 cm)	Live stranding, Meningoencephalitis
M0133/01	10 September 2001	Dunnet Bay, Caithness, Highland	Female	189	72.0	7	immature	Live stranding, Meningoencephalitis
M0009/02A	17 January 2001	Glenelg Beach, Highland	Female	152	39.0	2	immature	Live stranding, *Brucella* meningitis
M0009/02B	17 January 2002	Glenelg Beach, Highland	Female	160	40.5	2	immature	Live stranding
M0022/02	26 February 2002	Yell, Shetland	Female	194	72.0	7	immature	Live stranding, *Brucella* meningitis
M0609/02	16 December 2002	Scalloway Beach, Shetland	Female	160	44.0	–	immature	Live stranding
M0119/03	10 March 2002	Glenelg Bay, Highland	Male	186	59.0	6	immature	Live stranding
M0280/03	30 September 2003	Balavanich, Benbecula, Western Isles	Male	178	67.0	–	–	Live stranding

growth layer groups (GLG), which are thought to be laid down annually in odontocetes (Perrin & Myrick, 1980).

The ovaries were removed and preserved in 10% neutral buffered formalin during the post-mortem examination of females, and any evidence of lactation or presence of a foetus was recorded. Both ovaries were examined externally and internally to record the presence and number of *corpora lutea* (CL) and *corpora albicantia* (CA). Females were classed as sexually immature if there were no *corpora* present. Females were considered sexually mature if the ovaries contained at least one *corpus luteum* or *albicans*. Pregnancy was established by the presence of a foetus. The assessment of female reproductive status was based on the procedures and terminology recommended by the International Whaling Commission (Perrin *et al.*, 1984).

The testes were removed and preserved in 10% neutral buffered formalin during the post-mortem examination of males. Sections, approximately $2 \times 2 \times 0.5$ cm, were dissected from the middle of each testis with its associated epididydmis, and stored in 70% ethanol before histological processing. The tissue sections were dehydrated, embedded, and cut into 7 μm sections. The mounted sections were then stained with haematoxylin and eosin. The reproductive status was classified as: (i) immature; (ii) pubescent; (iii) active mature; or (iv) resting mature; based on the mean diameter of the seminiferous tubules and the relative proportion (low, medium and high) of Sertoli cells, interstitial tissue, and germinal cells such as spermatogonia, spermatocytes, spermatids and spermatozoa, as described by Collet & Saint-Girons (1984) for common dolphins.

Stomach contents were removed during necropsy and stored frozen or in 70% alcohol prior to analysis. Prey remains comprised mainly fish and cephalopods, also some crustaceans and polychaetes. Otoliths and bones of fish and mandibles (beaks) of cephalopods were identified using reference material and published guides (Clarke, 1986; Härkönen, 1986; Watt *et al.*, 1997). Fish were enumerated by counting otoliths and other paired bones, notably jaw bones, using the structure that yielded the higher number. Cephalopods were enumerated based on the number of upper or lower beaks, whichever was higher. Crustacean material (found in three stomachs only) was usually well-digested and could not be further identified.

Prey lengths and weights were estimated by applying standard regressions: regressions for fish were based on various sources as summarized by Brown & Pierce (1998), while those for cephalopods derived mainly from Clarke (1986). It was not possible to estimate weights for crustaceans or polychaetes and their contribution is assumed to be minimal. Some bobtail squid (Sepiolidae) were identified to family from upper beaks, for which no general regression was available. It is assumed for the purpose of weight estimation that the animals had the same average weight as sepiolids for which lower beaks were found. Where large numbers of otoliths were present, a random sub-sample of at least 30 was measured (length or width). Length distributions of the main prey were calculated.

Dietary importance of each prey category was expressed as frequency (F, the number of stomachs in which it occurred), number of individuals summed across all stomachs (N), and the estimated weight of all individuals from otolith measurements summed across all stomachs (W). These indices were also expressed as percentages, %F expressing the percentage

of stomachs in which a prey category occurs while %N and %W are based on sums of prey importance across all categories.

Statistical analysis (to relate diet to sex, season and body length) was based on data for numerical importance together with data on the median size of the two main prey species (whiting and *Trisopterus*) eaten by dolphins and used Kruskal–Wallis tests and Spearman's correlations. For comparison of seasons, the year was divided into two periods, 'summer' (April–September) and 'winter' (October–March). Body lengths were arbitrarily divided into three classes: ≤175 cm, 176–200 cm and >200 cm. Stranding locations were divided into 'east coast' (east of 4°W) and 'west coast' (west of 4°W). A length–weight relationship was derived for the stranded animals.

RESULTS

Between 1992 and 2003 the total number of stranded and by-caught cetaceans in Scotland was 1575 of which 1549 were identified to species. Of these, 52 animals were identified as *Stenella coeruleoalba* (3.4% of the total identified cetaceans). Strandings of striped dolphins occurred all around the Scottish coast (Figure 1) but with the majority of strandings recovered from the west coast. Strandings were recorded in every month of the year, with highest numbers being recorded in January–March and August. Twenty of the 52 strandings occurred between 1992 and 1997, with 32 between 1998 and 2003. Sex was determined for 41 dolphins, 17 females and 24 males. There was no difference in the seasonal pattern of strandings of males and females (Figure 2).

Of the 33 striped dolphins examined, at least 29 had live-stranded. Pathologies recorded in some of the animals stranded included meningoencephalitis and *Brucella* meningitis. Seventeen of the 29 live-stranded dolphins were male, 11 were female and the sex was not determined for one animal. There was one 'group' stranding involving two females that stranded together at Glenelg Beach, Highland on 17 January 2002. Both females were immature, with body lengths of 152 cm and 160 cm and aged two years old. One of these animals was diagnosed with *Brucella* meningitis.

The length distribution of stranded striped dolphins is illustrated in Figure 3. The stranded animals ranged between 143 cm and 242 cm in length. The seven largest animals were all males, contributing to males having significantly greater average length than females (Student's *t*-test, $t = 2.41$, $P = 0.021$). The relationship between body weight and length (based on 26 individuals for which both length and weight were available) was:

$$\text{Wt (Kg)} = 0.000078 \times \text{Length(cm)}^{2.613} \quad (R^2 = 0.92)$$

Age was determined for six animals: five females and one male. Ages ranged from 2 to 14 y (Table 2). The reproductive status was determined for six females and six males (Table 2). Five females were immature and one female was pregnant with a 90 cm male foetus. The immature females had body lengths between 152 and 194 cm, were aged 2–7 y, and were recovered from the North Sea and west coasts in the 1st, 3rd and 4th quarters. The pregnant female was aged 14 y, had a body length of 206 cm and was recovered from Skye on

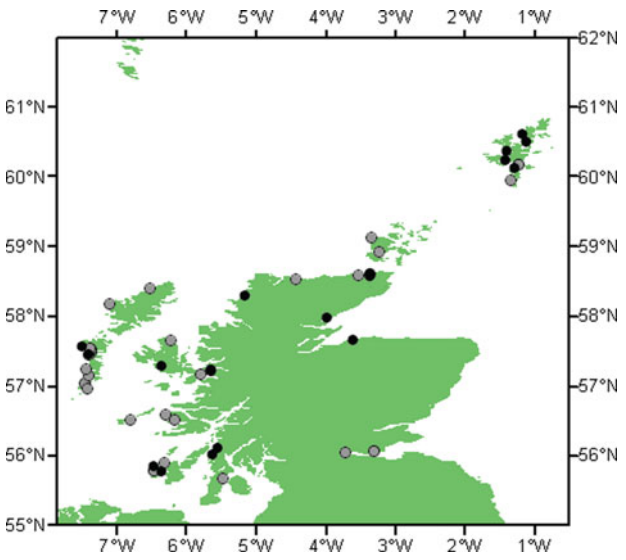

Fig. 1. Locations of striped dolphin strandings (*Stenella coeruleoalba*) around the Scottish coast (1992–2003). Dark circles indicate animals for which stomach contents were obtained.

the west coast of Scotland in September 2001. Of the six males for which reproductive status was analysed: two were classed as immature, three were pubescent and one was mature and sexually active. The two immature males had body lengths of 185 cm and 186 cm and age was determined for one immature male, which was 6 y old. Both immature males were recovered from the west coast, one in the 1st quarter and one in the 4th quarter. The three pubescent males had body lengths between 183 cm and 208 cm; they were recovered during the 1st, 2nd and 3rd quarters on Shetland, the west and Irish Sea coasts. The mature and sexually active male had a body length of 223 cm and was recovered from the North Sea coast in May.

Numbers of prey recorded in the stomach samples ranged from 1 to over 600, with up to 11 different taxa identified in individual stomachs. At least 21 different taxa were identified overall, of which fish of the family Gadidae were the most important numerically and in terms of biomass (Table 3). Whiting (*Merlangius merlangus*) comprised 32% of the diet by number and 58% of the diet by weight while *Trisopterus* spp. accounted for 36% of prey numbers and 13% of prey biomass. The most important cephalopods, numerically, were sepiolids (2.1%). In terms of biomass, *Gonatus* sp. (probably *G. steenstrupii*) were the most important cephalopods (10%), although they were found in only one stomach—an animal stranded in Shetland.

There was no difference between summer and winter, east or west coasts, or between dolphin length-classes, in the average numerical importance of whiting, *Trisopterus* or sepiolids. The numerical importance of these species in the diet was not correlated with dolphin body length. The number of *Trisopterus* present in stomachs was significantly higher in females than in males (Kruskal–Wallis test, $H = 5.99$, $P = 0.014$), although no such difference was observed for whiting or sepiolids. None of the other prey taxa occurred sufficiently frequently to allow such comparisons to be made.

Similar analysis was carried out on the median size of whiting and *Trisopterus* eaten by dolphins. *Trisopterus* eaten in winter were larger than *Trisopterus* eaten in summer

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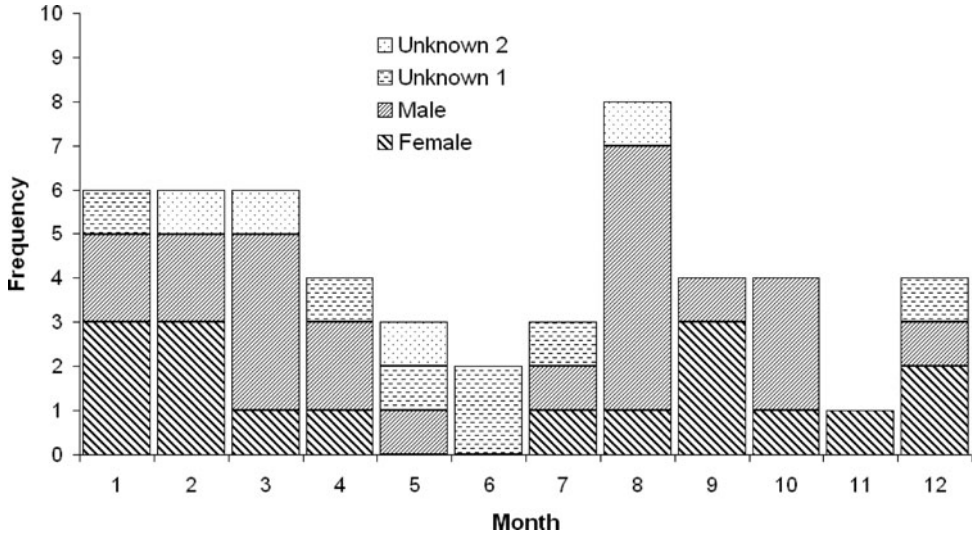

Fig. 2. Seasonal distribution of striped dolphin (*Stenella coeruleoalba*) strandings around the Scottish coast (1992–2003).

(Kruskal–Wallis test, H = 4.41, $P = 0.036$). Both *Trisopterus* and whiting eaten on the east coast were bigger than those eaten on the west coast (Kruskal–Wallis test, H = 5.40, $P = 0.020$; H = 5.81, $P = 0.016$, respectively).

The estimated size of whiting eaten ranged from 2.5 cm to 18.5 cm (Figure 4), with evidence of as many as four size modes. The majority of *Trisopterus* eaten were under 12 cm in length, with modes around 6–7 cm (Figure 4). Note that these sizes are based on uncorrected otolith measurements.

DISCUSSION

Striped dolphins were not reported in Scottish waters until 1988 (Reid *et al.*, 1993; Sheldrick *et al.*, 1994). It has been suggested that *Stenella coeruleoalba*, a warm water species, could have recently expanded its distribution northwards. MacLeod *et al.* (2005), in their analysis of changes in the cetacean community on the north-west Scottish coast, noted that it was highly unlikely that the species would have been simply unrecorded prior to 1988 if it was present in Scottish waters. The authors also comment on the current frequency of the strandings of striped dolphins in the area (double the number of those of white beaked dolphins, *Lagenorhynchus albirostris*) and note that the species is also occasionally sighted at sea. Macleod *et al.* (2005) proposed that increased sea temperatures caused by climate change could explain this shift in distribution. Forcada *et al.* (1990) analysed the water temperature at which a total of 69 sightings of striped dolphins had taken place in the north-eastern Atlantic and the authors found that it ranged from 10° to 21°C with a mode at 19°C.

The majority of strandings occurred on the west coast (60%) and most animals stranded during the 1st and 3rd quarters. The month in which most strandings were recorded was August (15.4% of all records). This pattern of strandings could be explained if water temperature was playing a role in determining the distribution of the species in Scottish waters (i.e. highest numbers are recorded in summer and on the west coast where the warming effect of the Gulf Stream

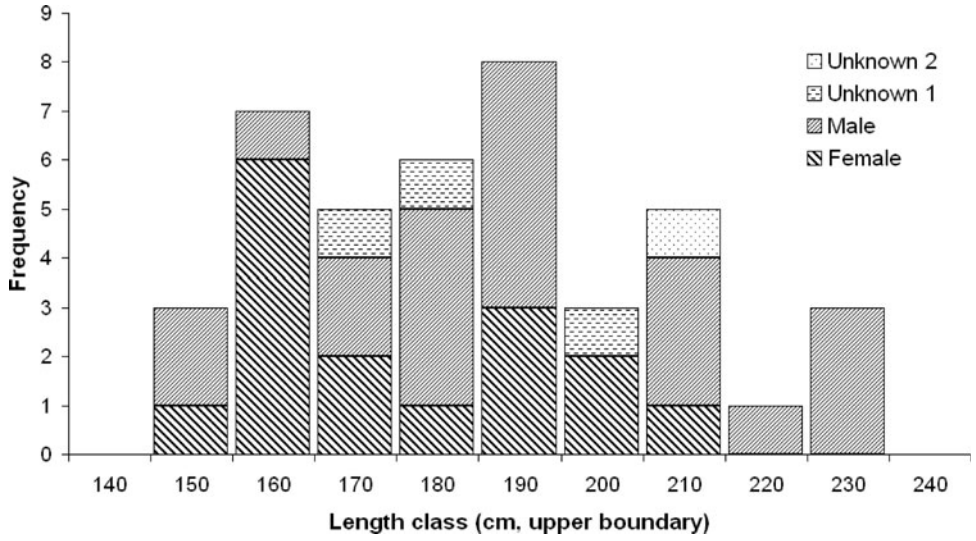

Fig. 3. Length distribution of stranded striped dolphin (*Stenella coeruleoalba*) around the Scottish coast (1992–2003).

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Table 3. Summary of diet composition. Indices of importance for each prey taxon are as follows: F, frequency of occurrence; N, minimum number of individual prey recovered from the set of stomachs; and W, reconstructed weight based on otoliths and beaks only. The indices are also expressed as percentages.

Prey taxon	Frequency	%F	Number	%N	Weight (g)	%W
Crustacea	5	25	71	2.5	–	–
Polychaete	5	25	5	0.2	–	–
Unid Cephalopoda	1	5	2	0.1	–	–
Eledone	3	15	9	0.3	496.2	2.7
Alloteuthis	1	5	1	0.0	6.6	0.0
Loligo	2	10	2	0.1	423.5	2.3
Gonatus	1	5	27	1.0	1796.1	9.7
Ommastrephid	4	20	10	0.4	160.4	0.9
Rossia	1	5	1	0.0	24.2	0.1
Sepietta	2	10	7	0.2	52.8	0.3
Sepiola atlantica	4	20	37	1.3	58.2	0.3
Unidentified Sepiolid	4	20	23	0.8	87.2	0.5
Unidentified fish	4	20	26	0.9	–	–
Unidentified Gadidae	8	40	154	5.5	692.6	3.7
5-bearded rockling	1	5	3	0.1	41.9	0.2
Gadiculus	2	10	17	0.6	36.9	0.2
Haddock/Sai/Pol	3	15	18	0.6	450.5	2.4
Rockling	3	15	6	0.2	181.4	1.0
Trisopterus	9	45	997	35.4	2399.2	12.9
Whiting	11	55	917	32.6	10803.5	58.1
Unid flatfish	1	5	5	0.2	20.1	0.1
Plaice	1	5	2	0.1	40.0	0.2
Gobiidae	4	20	301	10.7	97.0	0.5
Labridae	3	15	3	0.1	48.1	0.3
Mackerel	1	5	4	0.1	0.0	0.0
Sandeel	4	20	145	5.1	492.2	2.6
Scad	1	5	1	0.0	40.2	0.2
Sea bream	2	10	12	0.4	128.5	0.7
Sprat	2	10	11	0.4	7.6	0.0
Total			2817	100	18584.8	100.0

current is at its peak). Nevertheless, live strandings of striped dolphins have been recorded in all months of the year and not only on the west coast but also on the east coast and the northern islands, which would seem to indicate that at least some animals are present all year round. High numbers of strandings in the first quarter (winter) could have originated due to bad weather conditions affecting juvenile and/or weakened animals, a possibility already suggested by Isaksen & Syvertsen (2002) who found the highest number of stranded striped dolphins in January in Norway. Winter was also the period when most strandings of striped dolphins were recorded in Ireland (47% of all records from 1901–1995, Berrow & Rogan 1997). Historic stranding records (1933–1992) from the British coast indicate that the majority of striped dolphins have stranded on the west coast and strandings were recorded throughout the year, except in March, May and June (Fraser, 1946, 1953, 1974; Sheldrick, 1989; Sheldrick *et al.*, 1994). In Ireland striped dolphin strandings have also been reported in all months except May and June (Rogan *et al.*, 1997). Most nearshore sightings of striped dolphins in the UK have been recorded between July and December (Evans, 1992; Reid *et al.*, 2003).

There were a high number of live standings, at least some of which could have been partly caused by infectious diseases such as meningoencephalitis and *Brucella* meningitis, the latter condition having been recorded in one of the two female dolphins that live- stranded together in January 2002.

Striped dolphins can occur in large groups consisting of hundreds of individuals, although in European waters group sizes of 6–60 are most common. In British and Irish waters, however, most sightings are of single animals or small groups of fewer than 20 individuals (Stone, 1997, 2000, 2001, 2003; Reid *et al.*, 2003). The majority of striped dolphin strandings in this study and historic stranding records involved individual dolphins, with the exception of

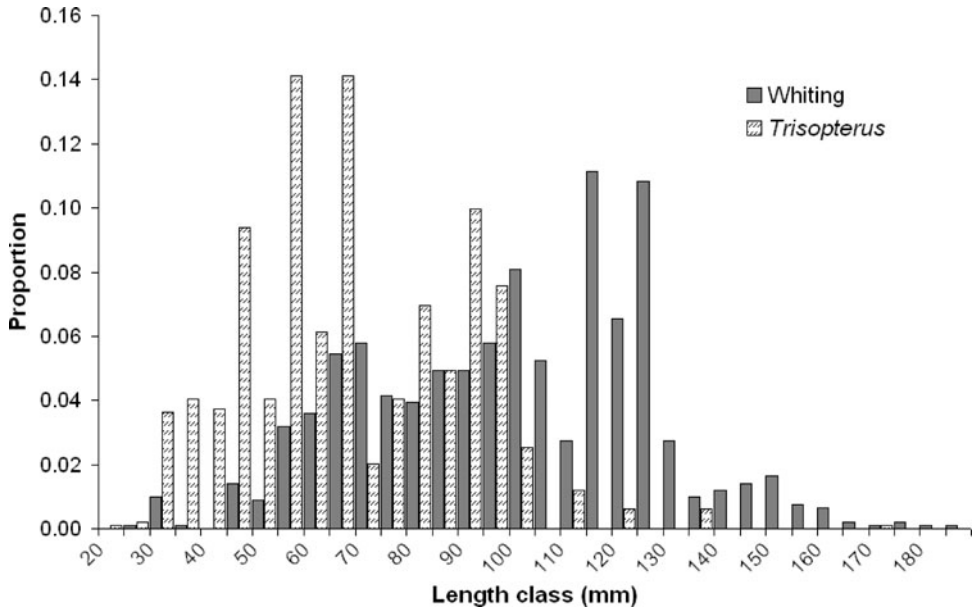

Fig. 4. Reconstructed length distributions for the main prey taxa in the stomach contents of striped dolphins (*Stenella coeruleoalba*) stranded around the Scottish coast (1992–2003).

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two females that stranded together at Glenelg Beach, Highland in January 2002 (Fraser, 1946, 1953, 1974; Sheldrick, 1989; Sheldrick *et al.*, 1994).

Several authors have found evidence of sexual dimorphism in this species, with males attaining bigger sizes than females. The recorded difference between the sexes varies with the area/population studied. Thus, males have been found to measure 11–15 cm more in length than females in the western Pacific but only 2 cm longer in the Mediterranean according to Miyazaki (1984). Calzada *et al.* (1997) estimated a 6 cm difference in length between males and females in the western Mediterranean and the author explained this sexual dimorphism as the result of males displaying continuous growth for several years after female growth has stopped. In the present study, males were also found to have significantly greater average length than females (the seven largest animals were all males) although the number of animals sampled was small. Similarly, in striped dolphins stranded and by-caught around Ireland males were larger than females, with a maximum length of 214 cm for females and 228 cm (Rogan *et al.*, 1997).

Reproductive samples were analysed from six female and six male striped dolphins stranded around Scotland. Based on this limited dataset, it appears that female striped dolphins could attain sexual maturity at body lengths between 194 to 206 cm and ages of 7–14 y, while male striped dolphins could attain sexual maturity at body lengths of about 208–223 cm. This is consistent with data from striped dolphins in Irish waters, which suggest that the onset of sexual maturation in males occurs after 11 y of age and total body lengths greater than 201 cm, and where the youngest sexually mature female was 14 y old with a body length of 201 cm (Rogan *et al.*, 1997). López (2003) recorded ten mature females from strandings in Galicia, Spain during 1990–1999 and estimated that matuity occurs at a length of around 200 cm and between the ages of 3 and 10 y. The single mature male recorded was 219 cm in length. In a subsequent study (2001–2003), four mature females were recorded from Galicia, with body lengths of at least 197 cm and aged 15 y or older, also three mature males with body lengths of 211 cm and over, aged 18 y or older (Learmonth *et al.*, 2004).

The reproductive season for striped dolphins in Scottish waters is difficult to determine due to the small sample size, however, the period of conception appears to be in May, based on the mature and sexually active male that stranded at this time and the calving period may occur around September–October, based on pregnant female with near-term 90 cm foetus found in September. Rogan *et al.* (1997) suggested that calving in Irish waters may occur from July to November, which is consistent with the findings of this study and the recovery of a lactating female in November 2002 on the Irish coast (Learmonth *et al.*, 2004). Mature and sexually active male striped dolphins have been recovered from the coasts of Galicia and France between January and April and in June (Learmonth *et al.*, 2004). This could indicate that the male reproductive period for striped dolphins in the north-eastern Atlantic extends up to six months or there could be regional variations in reproductive season, unfortunately sample sizes in all studies are too small to examine this further.

In the present study from the Scottish coast, whiting was the most important prey species of striped dolphins (by reconstructed weight). The diet of striped dolphins has been studied in several parts of the world, including Japan (Miyazaki *et al.*, 1973), the Mediterranean (e.g. Desportes, 1985; Bello, 1992; Würtz & Marrale, 1993; Blanco *et al.*, 1995), South Africa (Sekiguchi *et al.*, 1992) and the north-eastern Atlantic (Desportes, 1985; Spitz *et al.*, 2006). In general, the diet of the species includes oceanic fish, cephalopods and crustaceans, with the relative abundance of each major taxon in the diet changing with location. For example, Desportes (1985) analysed the stomach contents of striped dolphins stranded on the French Atlantic ($N = 25$) and Mediterranean ($N = 20$) coasts. Desportes found fish to be the most frequent prey in the Atlantic samples but cephalopods were more frequent in the Mediterranean samples, with some seasonal variation. The most frequently recorded fish species was blue whiting (*Micromesistius poutassou*). In a sample of 60 striped dolphins by-caught in the French albacore fishery (1992–1993) squid dominated the diet, mainly *Teuthowenia megalops* and *Histioteuthis* spp. Fish made up around 40% of the diet, mainly mesopelagic species such as lanternfish (mainly *Notoscopelus kroeyeri* and *Lobianchia gemellarii*). Crustaceans, mainly mesopelagic shrimps Sergestidae and Pasiphaeidae, were also important (Ringelstein *et al.*, 2006).

Fourteen fish, ten cephalopod and two crustacean taxa were found in the stomachs of striped dolphins collected along the coasts of the Bay of Biscay ($N = 23$) (Spitz *et al.*, 2006). Fish comprised 91% of the diet by number, with blue whiting and *Atherina presbyter* being the main fish species eaten and *Gonatus steenstrupi* and an unidentified Ommastrephidae as the main cephalopods taken.

Very little is known of the life history of the striped dolphin in Scottish waters. The population size is unknown and the present analysis, although based on a small sample size, arises from the study of stranded specimens over a 12 y period, and represents the first attempt to gather all the available information.

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