

Life History of Risso's Dolphin (*Grampus griseus*) (G. Cuvier, 1812) in the Faroe Islands

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Abstract

Risso's dolphins (*Grampus griseus*) were taken for the first time by the opportunistic drive fishery in the Faroe Islands in two separate incidents: three in September 2009 and 21 in April 2010, with in total 16 females and eight males. Their sizes ranged from 193 to 308 cm in length and 60 to 395 kg in weight for females, and 186 to 323 cm in length and 70 to 505 kg in weight for males; the maximum weights are heavier than previously documented for this species. The smallest mature female was 277 cm long, while the youngest and also lightest mature female was 8 y old and weighed 280 kg. Sperm competition and a promiscuous mating system were suggested for the species based on large testicular masses. The diet was composed of cephalopods from both the water column (*Todarodes* and *Loligo*) and the ocean floor (*Eledona* and *Todaropsis*). Although both schools landed showed a mixed diet, the September school diet centred on a pelagic squid (*Todarodes sagittatus*), while the April school diet centred upon a benthic octopod (*Eledona cirrhosa*). Since August 2009, Risso's dolphins have been observed on five occasions in waters around the Faroese north of 61° 34' N, the northernmost observation situated at a latitude of 62° 23' N. Sightings of the species off Shetland occur mostly between April and September, with a peak in August and September, the observations in Faroese waters (2 in April, 1 in August, and 2 in September) falling within this period. While the species had not previously been observed in this area north of the Shetland-Faroe Channel, these observations in Faroese territorial waters indicate a likely northward extension of the known range of the species.

Key Words: Faroe Islands, Shetland, life history, Risso's dolphin, *Grampus griseus*, distribution, diet

Introduction

The Risso's dolphin (*Grampus griseus*) has a worldwide distribution in tropical and temperate waters, ranging from 4.5 to 28° C, with an apparent preference for steep shelf-edge habitats between 400 and 1,000 m deep (Baird & Stacey, 1991; Würtz et al., 1992; Jefferson et al., 1993; Casinos & Filella, 1994; Baumgartner, 1997; Kruse et al., 1999; Reid et al., 2003; Baird, 2009; Culik, 2010). Risso's dolphin may appear in deeper waters in the North Pacific, however (Miyashita, 1993).

In the Northeast Atlantic, the northern range of this species' distribution was believed to lie north of Scotland, with the northernmost observations made northeast off Unst (60° 45' N), the northernmost of the Shetland Islands (Pollock et al., 2000; Weir et al., 2001; Reid et al., 2003). In this area, Risso's dolphins occur over the shelf break but not in deeper water, with a cluster of observations centred on the Outer Hebrides (Reid et al., 2003; Evans, 2008). There are few observations in the North Sea (Reid et al., 2003), some as far north as Bergen (60° 16' N) (Casinos & Filella, 1994; Kruse et al., 1999), as well as one record off Drøbak (59° 39' N) in the Oslo Fjord in 1986 (Øen, 1987). The species has never been observed around Iceland (G. Víkingsson, pers. comm.); and during the five summer surveys of the North Atlantic Sightings Surveys (NASS-TNASS) series (North Atlantic Marine Mammal Commission [NAMMCO], 2009; Víkingsson et al., 2009), the species has only been observed once in 1995 off Galway (53° 16' N), Ireland (Desportes, pers. comm.). During the Cetacean Offshore Distribution and Abundance in the

European Atlantic survey in 2007 (CODA, 2009), only a few observations of Risso's dolphins were made, all well south of 60° N.

Despite their wide distribution in temperate waters, the life history of the Risso's dolphin is poorly known. The species is not prone to mass strandings and has only been taken in whaling operations in significant numbers in a few places, mostly off Sri Lanka and Japan (Kasuya & Izumizawa, 1981; Kasuya, 1985, 2007; Amano & Miyazaki, 2004; Taylor et al., 2008). Relatively few specimens have been available for examination, and life history and diet information are sparse, often based on only a few specimens, except off Japan (Kasuya & Izumizawa, 1981; Kasuya, 1985; Kishiro, 1998, 2001; Amano & Miyazaki, 2004). More information is available on distribution and behaviour, although mostly for the North Pacific, the Gulf of Mexico, and the Mediterranean (Leatherwood et al., 1976; Baird & Stacey, 1991; Würtz et al., 1992; Baumgartner, 1997; Forney & Barlow, 1998; Kruse et al., 1999; Öztürk et al., 2007; Taylor et al., 2008; Bearzi et al., 2011). In the Northeast Atlantic, information is limited to a few articles referring mostly to single strandings or a few opportunistic sightings

(Eggleton, 1905; Taylor, 1913; Hussenot, 1984; Clarke & Pascoe, 1985; Øen, 1987; Sundnes, 1988; Zonfrillo et al., 1988; Evans, 1993; Santos et al., 1994, 1995, 1996; Beaulieu, 1996; Kiszka et al., 2004). The specimens landed in the Faroe Islands in 2009 and 2010 represent a unique opportunity to improve our understanding of this delphinid species in the North Atlantic, especially because the school landed in 2010 was believed to be complete, although the school size was small.

Materials and Methods

Animals and Samples

Three Risso's dolphins (School 1) from a larger school observed on 16 September 2009 in the NW of the island of Kalsoy (Observation 3; Figure 1) were landed in Klaksvík (Figure 1) after a drive lasting about 2 h. On 13 April 2010, an entire school (School 2), made up of 21 Risso's dolphins, was observed some miles east of Hvalba (Observation 4; Figure 1) and landed there after a drive lasting about 15 min. All 24 Risso's dolphins were examined and sampled for life history parameters (e.g., sex, length, weight, teeth, gonads, and mammary glands), diet (stomach content), and

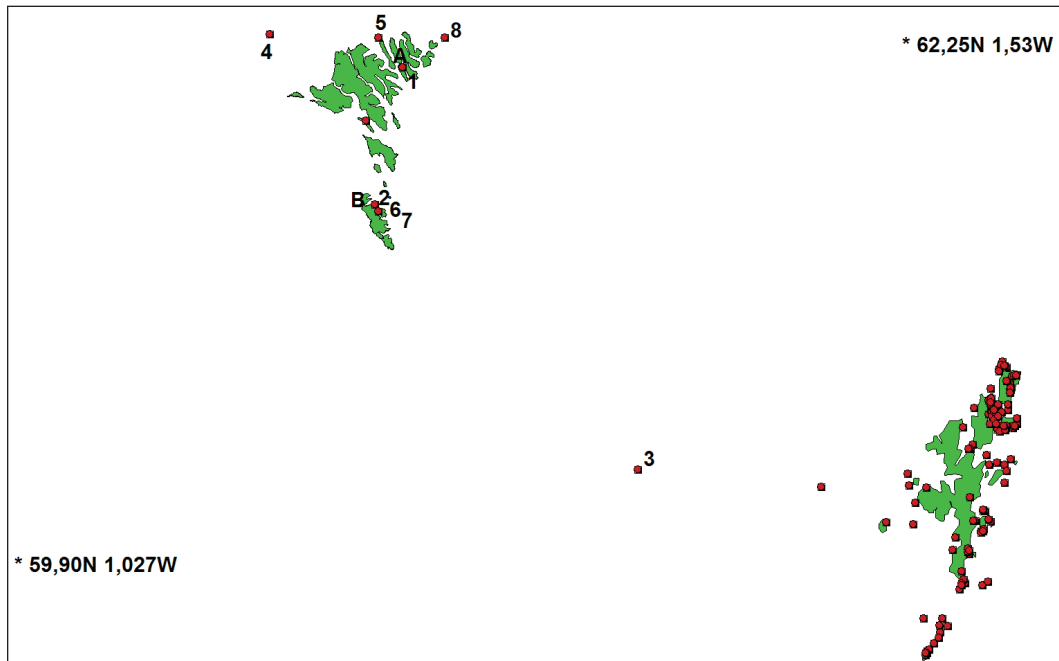


Figure 1. Sightings of Risso's dolphins in Faroese (1998-2011) and Shetlandic waters (2000-2010); the marked * denotes the actual positions of latitude and longitude. School A: Klaksvík, 62° 14' N, 06° 35' W, 16 September 2009; School B: Hvalba, 61° 36' N, 06° 56' W, 13 April 2010; Observation 1: 60° 23' N, 04° 21' W, December 1998; Observation 2: 62° 23' N, 07° 51' W, 28 August 2009; Observation 3: 62° 22' N, 06° 49' W, 16 September 2009; Observation 4: 61° 36' N, 06° 51' W, 13 April 2010, Hvalbiarfjørður; Observation 5: 61° 34' N, 06° 49' W, 30 April 2011, Hvannhagi; Observation 6: 62° 22' N, 06° 11' W, 22 September 2011.

contaminants and chemical composition (e.g., skin, meat, blubber, heart, and liver samples). The total length was measured in a straight line from tip of the upper jaw to the fluke notch. The total weight was measured to the nearest kg by a Dynafor Type LLX 12.5 tons scale (lifted by a truck). External measurements were taken, and the bodies were examined for the presence of external parasites. The Faroese Museum of Natural History kept the three skeletons and the heads, two of them with intact melons (frozen), from School 1. The meat and blubber of the dolphins that landed in Hvalba (School 2) were divided among the local community for human consumption after the museum had taken measurements and samples.

All the teeth of the 24 dolphins were extracted from the jaws after maceration, and then they were cleaned and stored in 70% ethanol. The teeth were prepared following Lockyer (1993), and the thin stained sections were examined under low-power magnification ($\times 10$ to $\times 20$). The dentinal Growth Layer Groups (GLGs) were read at least twice on different occasions by one reader (Lockyer). When there was doubt over the count, the cementum was also examined. By default and in the absence of any age validation, one GLG was taken as equivalent to an annual increment (Figure 2) as has been done previously for Risso's dolphins (Kruse et al., 1999; Amano & Miyazaki, 2004).

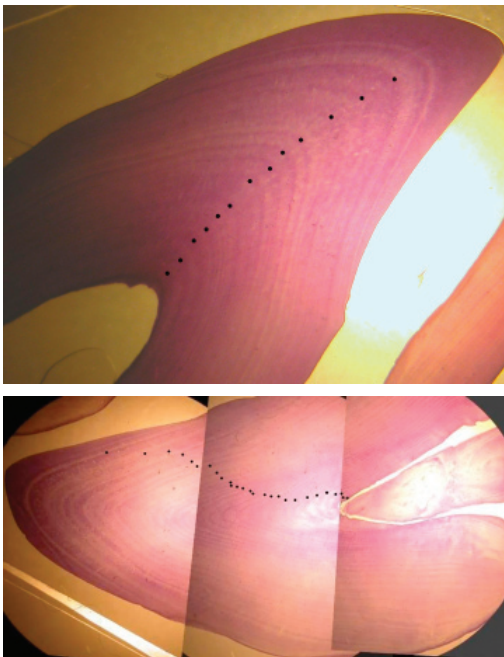


Figure 2. Sectioned teeth of a 13-y-old lactating female (top) and a 27-y-old male (bottom) Risso's dolphin

The ovaries of all the females were hand-sectioned in slices of 1 to 2 mm thickness, and the corpora were counted. Mammary glands were transected and examined by eye for presence of milk. The uterus of the two females exhibiting a *corpus luteum* on an ovary was carefully checked with naked eyes for the presence of a foetus. A slide was taken from the centre of all the testes for histological examination. The histological slides were prepared and stained with haematoxylin and eosin at the State Hospital of Tórshavn. The remaining testis samples were stored in 10% formalin.

The 24 stomachs were removed, and the contents were collected and flushed through a sieve with 1 mm meshsize. All remains were kept in 70% ethanol. Stomach contents were sorted, and lower cephalopod beaks were counted and identified following the guidelines of Clarke (1986a) and the reference collection kept at the Faroese Museum of Natural History. A sample of beaks from the stomachs was sent to M. R. Clarke (Whale Museum, Pico Azores) for confirming species' identification. Lower rostral lengths for squid beaks and hood lengths for octopod beaks were measured using digital callipers according to Clarke (1986a). When the number of beaks of a species exceeded 100 in a stomach, a random subsample of over 100 lower beaks was measured. Body lengths and weights of the prey were estimated from the measurements using regressions from Clarke (1986a).

Historical and Recent Sightings of Risso's Dolphins Around the Faroes

Sightings of cetaceans around the Faroes, usually by local fishermen, are reported to the Faroese Museum of Natural History, and reports are kept in the archive of the museum. The description of size, shape, colour, and behaviour usually allows the museum to identify the species. Observations of Risso's dolphin were searched for in the archive of the museum, and their seasonal timing was compared to the seasonal variation in abundance of Risso's dolphin off Shetland, which represents the geographically closest aggregation of the species.

Records of sightings of Risso's dolphins off Shetland for the period 2000 to 2010 were obtained from The Shetland Amenity Trust. These observations are only indicative of presence as there is no effort data associated to them. The literature was also explored in search of Risso's dolphin sightings in the higher Northeast Atlantic.

Results

External Examination

The external appearance of the 24 landed Risso's dolphins are summarised below. External parasites were not observed on any of the individuals.

All whales had a pale grey to white colour over the back and sides; and on the adult dolphins, the skin was covered with whitish scars and lines criss-crossing the bodies. The immature dolphins (0 to 2 y) were of a more equal pale grey colour without scars, but some had whitish spots at the sides (Figure 3). The whitish anchor-shape coloration patch at the chest between the flippers was more distinct than in long-finned pilot whales. The dorsal fin was large, tall, and very falcate. The blunt head showed a characteristic cleft in the melon (see Figure 3b). The melon itself was soft, like a football lacking air, with a gelatinous mass inside the melon. The consistency of the melons appeared quite different from the melons of other odontocete species sampled by the museum: pilot (*Globicephala melas*), northern bottlenose (*Hyperoodon ampullatus*), and Sowerby's beaked (*Mesoplodon bidens*) whales; white-sided (*Lagenorhynchus acutus*), bottlenose (*Tursiops truncatus*), and striped (*Stenella coeruleoalba*) dolphins; and harbour porpoise (*Phocoena phocoena*). In these species, the melon feels hard with hand pressure on the external surface. Two of the Risso's dolphins' heads were kept intact for further anatomical study, especially regarding sound production.

Morphometrics and Life History Parameters

Length and Weight—Total body lengths ranged from 193 to 308 cm for females and from 186 to 323 cm for males. Body weights ranged from 60 to 395 kg for females and from 70 to 505 kg for males (Table 1). The weight-length relationship calculated from the data (by fitting an exponential function in *Excel*) was

$$W = 7.389 \times L^{3.556}$$

where W is weight in kg and L is total length in m (Figure 4). SE (exponent) = 0.135 corresponds to the formula marked with a red arrow in the screenshot from Wikipedia (RegressionWikipedia.jpg); and SD (regression) = 0.119 corresponds to the square root of the expression marked with a blue arrow in the screenshot from Wikipedia (RegressionWikipedia.jpg).

Age Distribution—The age range of all animals sampled was 0 to 27 y for males and 0 to 31 y for females. The 21 whales of School 2 included six males and 15 females. There were no males aged between 4 to 25 y, and only one female (aged 8)



Figure 3a. Risso's dolphins landed on 16 September 2000 at Klaksvík, Faroe Islands



Figure 3b. Risso's dolphins landed on 16 September 2000 at Klaksvík, Faroe Islands; the blunt head showed a characteristic cleft in the melon.



Figure 3c. Risso's dolphins landed on 13 April 2010 at Hvalba, Faroe Islands

between 3 to 10 y. The pattern of growth is illustrated by the length and weight at age (Figures 5 & 6).

Sexual Maturity—Females—The largest immature female was 2 y old (268 cm, 235 kg), while the youngest and smallest mature females were 8 y old (285 cm, 280 kg) and 11 y old (277 cm,

Table 1. Data on Risso's dolphins landed in the Faroe Islands: School 1 on 16 September 2009, and School 2 on 13 April 2010

Whalekey	Sex	Length (cm)	Weight (kg)	Age	Sexual status	Ov 1, no. CL+CA	Ov 2, no. CL+CA	Left testis weight (g)	Right testis weight (g)	Stomach (empty = 0, full = 1)
20090916-02	F	277	295	11	Mat	0	2			1
20090916-03	M	231	160	>2	Imm			9	9	1
20090916-01	M	323	460	26	Mat (sperm)			6,700	6,900	1
20100413-04	F	193	60	0+	Imm	0	0			0
20100413-05	F	200	75	<1	Imm	0	0			1
20100413-15	F	210	110	1	Imm	0	0			1
20100413-14	F	232	130	1	Imm	0	0			1
20100413-06	F	268	235	2	Imm	0	0			1
20100413-11	F	285	280	8	Lactating	0	2			0
20100413-08	F	308	350	13	Lactating	0	2			1
20100413-10	F	302	340	14	Lactating	1	2			0
20100413-21	F	297	375	14	Lactating	0	1			0
20100413-19	F	293	350	15	Resting	1	4			1
20100413-20	F	283	345	17	Lactating	0	4			0
20100413-07	F	284	300	19	Resting	3	4			0
20100413-18	F	294	380	19	Resting	0	2			0
20100413-13	F	299	305	31	Lactating	0	6			0
20100413-09	F	306	395	31	Lactating	2	7			1
20100413-01	M	186	70	0+	Imm			8.7	8.9	0
20100413-03	M	191	90	0+	Imm			10.1	9.9	0
20100413-02	M	207	110	0+	Imm			7.7	49.7	1
20100413-12	M	259	200	3	Imm			32.8	35.5	1
20100413-16	M	320	505	26	Mat (sperm)			866	--	1
20100413-17	M	304	445	27	Mat			537	--	1

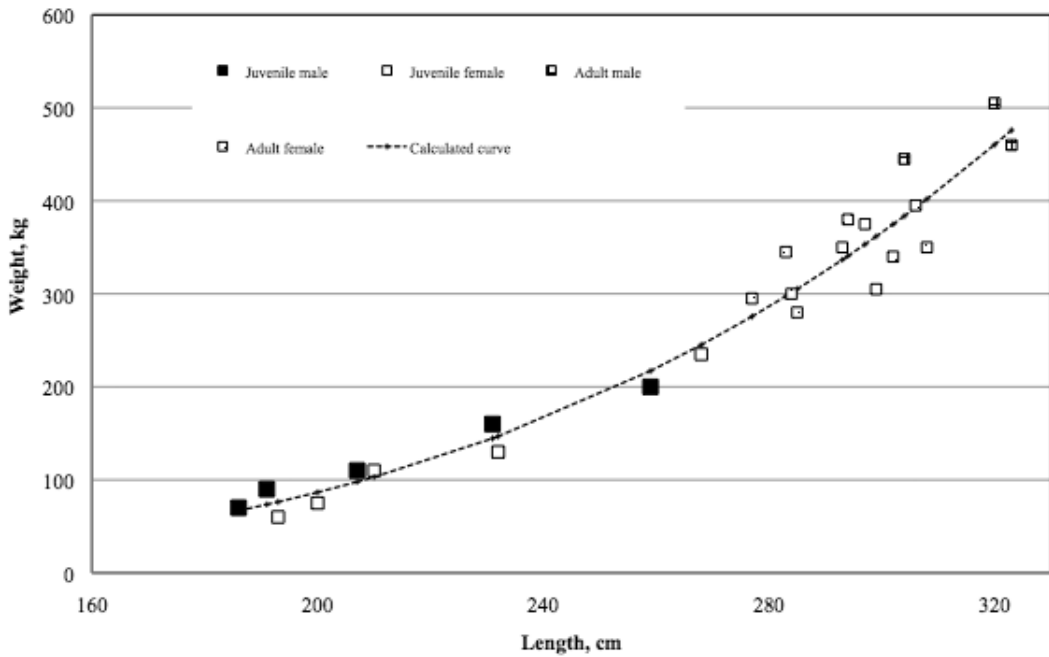


Figure 4. Weight-length relationship of 24 Risso's dolphins captured in 2009-2010 in the Faroe Islands, showing the regression line fitted to the data; data from the sources discussed in the paper are included (+).

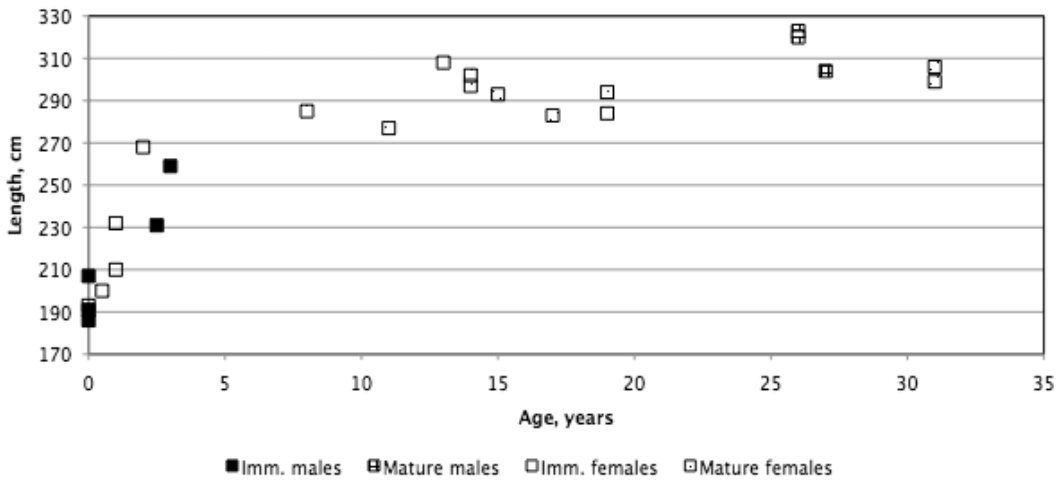


Figure 5. Length at age for 24 Risso's dolphins off the Faroe Islands

295 kg), respectively. There were in total five immature and 11 mature females. Two of the mature females each had one *corpus luteum*, although no foetus could be detected. The 11 mature females had between 1 to 9 *corpora (lutea and/or albicantia)* spread between both ovaries (Table 1 & Figure 7).

Nursing Period—There were seven lactating females in School 2. There were five calves

under 1 y, two 1-y-old calves, and one 2- and one 3-y-old calf (Table 1). Assuming that the whole school had been landed (i.e., in particular, that all the mother-calf pairs were captured), then all calves less than 2 y old were probably nursing, while the 2- and 3-y-old calves were not, thus indicating that calves are probably weaned before 2 y of age.

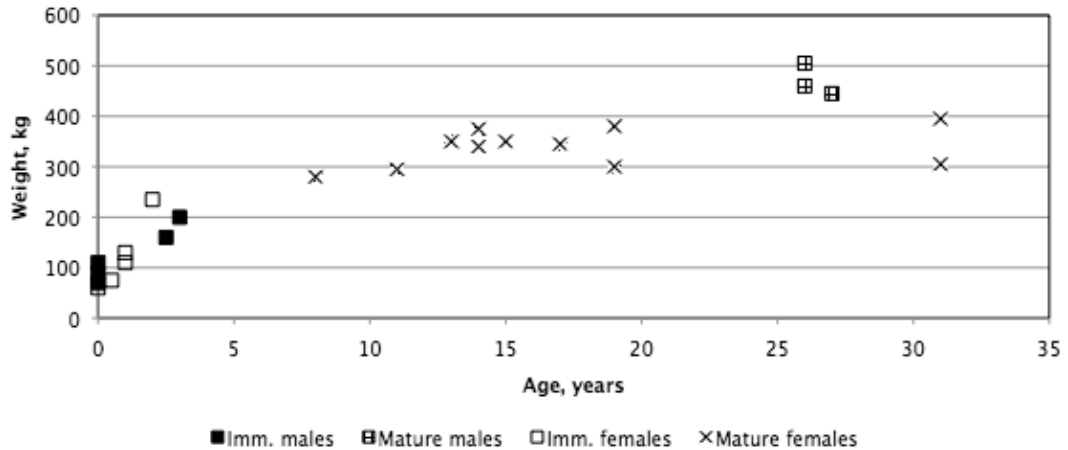


Figure 6. Weight at age for 24 Risso's dolphins in the Faroe Islands

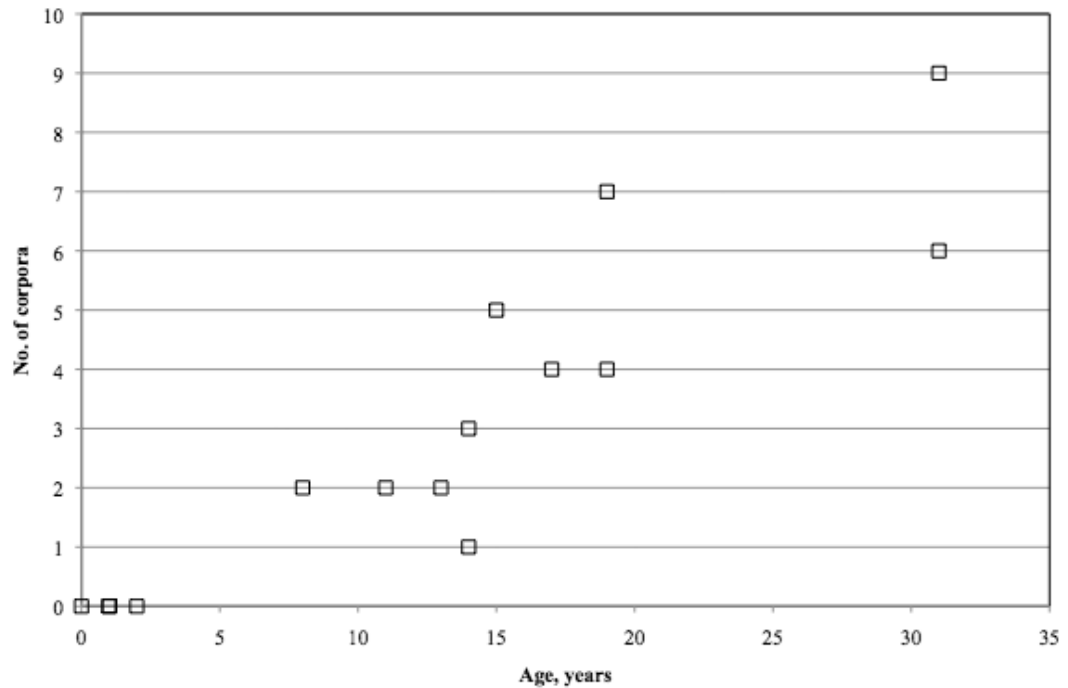


Figure 7. Total number of *corpora albicantia* and *c. lutea* related to age (y) of 16 female Risso's dolphins in the Faroe Islands

Sexual Maturity—Males—The five males that were 3 y old or younger were immature, while the three males aged 26 and 27 y were fully mature, corresponding to total lengths of 304 cm or longer and weights of 445 kg or heavier (Table 1). The longest male, caught in September (total body length of 323 cm), had an impressive total testicular weight of 13.6 kg for a total body weight of 460 kg, the testicular mass thus representing 3% of its total weight.

Group Composition—The overall sex ratio of School 2 was biased towards females (71.4%), with 83.3% of females among mature animals and 55.6% among immature animals. The proportion of sexually mature animals was 66.7% in females and 33.3% in males, and resting (i.e., not pregnant, not lactating) females made up for 30% of the mature females (Table 1). There were no pregnant females, although two had a well-developed *corpus luteum*, which could indicate a

very early pregnancy even if no foetus could be detected with the naked eye.

Diet

All three dolphins from School 1 in September 2009 and 11 of the 21 (52%) from School 2 in April 2010 had food remains in their stomachs (Table 2). Cephalopod beaks from both squid and octopus, and some buccal masses with beaks and squid bodies partially digested, were present in both schools which therefore had been eating shortly before the drive. Single animals contained a crab carapace, a bivalve mollusc, and a gastropod mollusc. No fish remains were identified.

Both schools had consumed the same three species, the flying squid (*Todarodes sagittatus*), the veined squid (*Loligo forbesi*), and the benthic octopus (*Eledona cirrhosa*), but in different proportions. In April (School 2), one dolphin also consumed a fourth species, the demersal lesser flying squid (*Todaropsis eblanae*). Stomachs of three dolphins which had remains of *Eledona* also contained one other benthic invertebrate, although these may have been prey items of the squid. The diet includes both mid-water (*Todarodes* and *Loligo*) and bottom dwelling (*Eledona*, *Todaropsis*) species (Table 3). Previous to this study, the stomach content of only 17 Risso's dolphins had been reported for the Northeast Atlantic, showing a diet centred upon cephalopods (Table 4).

Todarodes sagittatus was present in the stomachs of all three animals killed in September (School 1) and contributed 95% of the total number of beaks and 94% of the corresponding weight of prey (Table 2). School 2 from April had a more diverse diet (Table 2). The main prey, *E. cirrhosa*, was present in all stomachs but only contributed 89 and 72% of the beaks and prey weight, respectively; the diet was supplemented with *L. forbesi*, which accounted for 10 and 24% of the beaks and prey weight, respectively. One single *Todaropsis eblanae* was also present. *Todarodes sagittatus* was present in only one stomach from School 2, but the 12 individuals eaten, which represented only 1% of the prey in numbers, were so large that they accounted for 4.5% of the total prey weight. Several beaks belonged to individuals weighing over 1 kg and over 34 cm in mantle length, while the largest squid weighed 2.8 kg and measured 51 cm in mantle length.

Dolphin Distribution

Until April 2009, the northernmost record of Risso's dolphins in the middle Eastern Atlantic was an observation (Observation 1; Figure 1) made in December 1998 at 60° 23' N, 04° 21' W about 100 nmi south from the closest Faroese coast (Archive of Faroese Museum of Natural

History; Bloch, 1998; Bloch et al., 2001). Since April 2009, there have been five observations of Risso's dolphins in Faroese territorial waters (within 12 nmi from the coast; Figure 1):

1. 28 August 2009 – A fisherman observed four Risso's dolphins 100 m from his boat at 62° 23' N, 07° 51' W, less than 16 nmi NNW off the islands of Mikines (Observation 2; Figure 1).
2. 16 September 2009 – A school of about 300 dolphins was observed in the northern part of the Faroes at 62° 22' N, 06° 49' W (Observation 3; Figure 1). They were first believed to be pilot whales, and the school was driven to Klaksvík (62° 14' N, 06° 35' W; Figure 1) following the normal procedure for a pilot whale drive (Bloch, 2007). Three whales were killed, while the remaining animals were driven back to sea again. The three carcasses were delivered to the museum and identified as Risso's dolphins (School 1).
3. 13 April 2010 – A school of 21 Risso's dolphins was observed at Hvalbiarfjørður (61° 36' N, 06° 51' W) in the southernmost part of the Faroe Islands, Suðuroy (Observation 4; Figure 1). The whole school (School 2) was driven to and landed in Hvalba (61° 36' N, 06° 56' W). The Faroese Museum of Natural History was contacted, and all the individuals were thoroughly examined and sampled by museum staff.
4. 30 April 2011 – One year later, a school of about 15 Risso's dolphins was observed off Suðuroy swimming out of Hvannhagi (61° 34' N, 06° 49' W), just south of Hvalba (Observation 5; Figure 1).
5. 22 September 2011 – A school of about 20 Risso's dolphins was observed about 1 nmi east of Viðareiði at 62° 22' N, 06° 11' W in the northern part of the Faroes (Observation 6; Figure 1).

The number of Risso's dolphins observed in near-shore waters around Shetland in the period 2000 to 2010 varied annually between two to over 100, with 70 and 100 individuals in 2009 and 2010, respectively (Figure 8). Most sightings occurred between April and September, with a marked annual peak in August-September (Figure 9), although this increase may partly represent the likely increase effort in this period. Risso's dolphins were especially abundant around the Hebrides, where the existence of a resident population has been suggested (Evans, 1993; Pollock et al., 2000; Weir et al., 2001; Reid et al., 2003). The species also occurred offshore but was not observed north of the Shetland-Faroe Channel (Figure 1). During an investigation of seabird

Table 2. Contribution in frequency (number of stomachs where present), count, and estimated total wet weight, individual lengths, and individual weights of the prey found in the stomachs of the Risso's dolphins

	Frequency		Prey count		Prey weight (g)		Prey length (mm)		Prey weight (g)	
	Frequency	%	Beak count	%	Weight	%	Range	Average	Range	Average
Pooled data										
Total	14		1,540		400.562					
<i>Loligo forbesi</i>	8	57.1	121	7.9	78.206	19.5	143-440	322	108-1,234	646
<i>Todarodes sagittatus</i>	4	28.6	371	24.1	94.269	23.5	113-507	204	49-2,800	254
<i>Todaropsis eblanae</i>	1	7.1	3	0.2	350.000	0.1	115-128	120	104-142	117
<i>Eledona cirrhosa</i>	13	92.9	1,045	67.9	227.737	56.9	52-182	98	30-1,224	218
Crab	1	7.1								
<i>Littorina</i>	1	7.1								
<i>Arcopagia crassa</i>	1	7.1								
16 Sept 2009										
School 1										
Total	3		377		88.734					
<i>Loligo forbesi</i>	2	66.7	8	2.1	3.148	3.5	143-313	249	126-596	394
<i>Todarodes sagittatus</i>	3	100.0	359	95.2	83.619	94.2	113-274	201	49-515	233
<i>Todaropsis eblanae</i>	0	--	--	--	--	--	--	--	--	--
<i>Eledona cirrhosa</i>	2	66.7	10	2.7	1.967	2.2	70-120	96	73-365	197
Crab	0	--								
<i>Littorina</i>	0	--								
<i>Arcopagia crassa</i>	0	--								
13 April 2010										
School 2										
Total	11		1,163		315.278					
<i>Loligo forbesi</i>	6	54.5	113	9.7	75.058	23.8	170-440	327	108-1,239	664
<i>Todarodes sagittatus</i>	1	9.1	12	1.0	14.060	4.5	237-507	352	350-2,800	1,172
<i>Todaropsis eblanae</i>	1	9.1	3	0.3	350.000	0.1	115-128	120	103-141	117
<i>Eledona cirrhosa</i>	11	100.0	1,035	89.0	225.811	71.6	52-182	98	30-1,223	218
Crab	1	9.1								
<i>Littorina</i>	1	9.1								
<i>Arcopagia crassa</i>	1	9.1								

and cetacean distribution from 1997 to 2000 on the Scottish side of the Faroe-Shetland Channel, three animals were recorded over the shelf in November 1997, and one was observed over the slope in December 1998 (Skov et al., 2002). The timing of the Faroese observations falls within the period of the year when most sightings are made off the Shetland (April to September), with three observations out of five corresponding to the peak period of sightings (August-September; Figure 9).

Enquiries to local scientists and a literature search revealed a short note in the journal of the Norwegian Zoological Society (Sundnes, 1988), which has been overlooked by later reviewers of the distribution of the species in the Northeast Atlantic such as Casinos & Filella (1994) and Kruse et al. (1999). The note reports on several

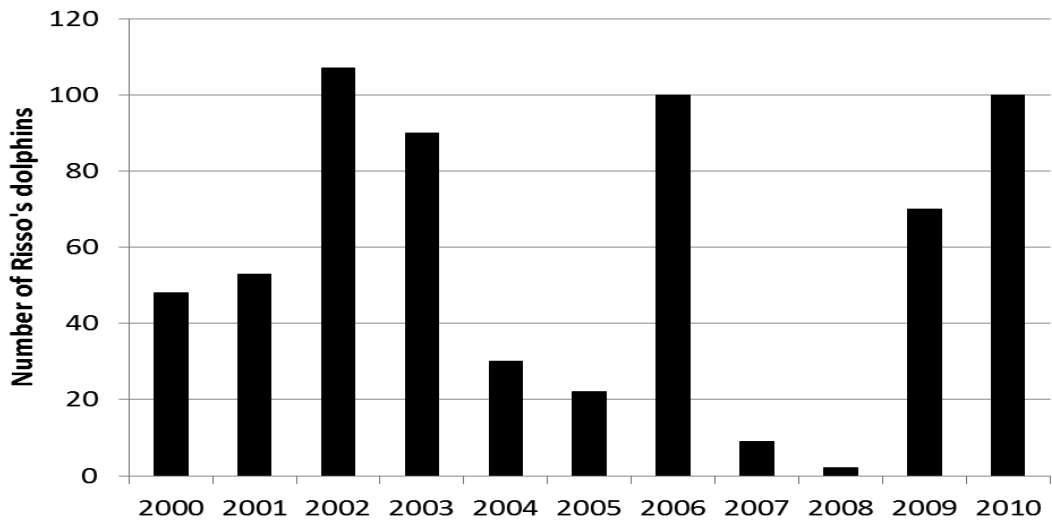
observations made in the Trondeheimsfjord in the period 1982 to 1987, including an observation in 1982 in the northern end of the fjord, Beitstadfjorden (i.e., at a latitude just under 64° N). The species was given a Norwegian name in the updated national species list, *arrdelfin* (scarred dolphin), and is still considered a rare visitor (Syvertsen et al., 2010).

Discussion

The life history of Risso's dolphin has never been described in the Northeastern part of the Atlantic Ocean, and the species was not observed in the Faroe Islands before 2009. Therefore, the catch of 24 Risso's dolphins from two schools provided a unique opportunity for examining the life history of this dolphin species in this area.

Table 3. Ecological characteristics of the prey found in the stomachs of the Risso's dolphins landed in the Faroes

Decapods		Distribution	Depth	Behaviour
Loliginidae	<i>Loligo forbesi</i>	Temperate and subtropical waters, avoiding temperature below 8.5° C	On the shelf in temperate water; depth range 100 to 400 m	Aggregate near the bottom in daytime, dispersing through water column at night
Ommastrephidae	<i>Todarodes sagittatus</i>	Temperate and cold waters	Offshore; deep water > 200 m	Epi-mesopelagic
	<i>Todaropsis eblanae</i>	Disjunct around British Isles and in 2009 Faroes; Temperature range from 9° to 18° C	Depth range 20 to 700 m	Demersal on sandy to muddy bottoms
Benthic octopods				
Octopodidae	<i>Eledona cirrhosa</i>	Northeast Atlantic, Iceland to 67° N	From coastline to 500 m (mostly 60 to 150 m)	Benthic
Diverse invertebrates				
	Crab			Mostly benthic
	<i>Littorina</i>			Benthic
	<i>Arcopagia crassa</i>			Benthic

**Figure 8.** Number of Risso's dolphins observed off Shetland annually in the period 2000 to 2010

Life History

The range of total body length in the Faroese sample lies within the range reported in other localities (Kruse et al., 1999), with a lack of very small and very large individuals, possibly caused by the small sample size. The Faroese animals appeared much heavier, however, than previously reported. The weight of the heaviest male from the Faroese sample was 505 kg for 320 cm, while the heaviest male reported by Harrison et al. (1972,

from California) weighed 386 kg for 307 cm. The Faroese female animals weighed up to 395 kg for 306 cm, while the heaviest female reported by Kruse et al. (1999, from Portuguese waters) was weighing 291 kg for 308 cm. Unfortunately, Amano & Miyazaki (2004) do not report body weight for the fresh individuals they examined. These differences in maximum weight could support the hypothesis of morphological differences between populations suggested by some

Table 4. Contribution in wet weight (%; bold font) of the preys found in stomachs of Risso's dolphins stranded or caught in the Northeast Atlantic (0 indicates a value <0.5); when the information is missing, either the presence (“+”) or the contribution in numbers (%) is indicated in parenthesis (regular font).

Authors	Eggleton (1905)	Taylor (1913)	Clarke & Pascoe (1985)	Desportes (1985)	Zonfrillo et al. (1988)	Santos et al. (1994)	Santos et al. (1995)	Santos et al. (1996)	Bloch et al. (this study)	
Event year	1904	1912	1983	1985	1986	1990-1993	1992-1993	1994-1995	2009 School 1	2010 School 2
# of stomachs	1	1	1	1	1	3	1	3	3	14
Location	SE Scotland (North Sea)	NE Scotland (North Sea)	SW England (Western Channel)	SW France (Bay of Biscay)	Western Scotland (NE Atlantic)	Galician Coast (NE Atlantic)	Scottish coast Atlantic	Galician coast (NE Atlantic)	N Faroes (North Atlantic)	S Faroes (North Atlantic)
<i>Eledone cirrhosa</i>			55		(20)	(14)	98	6	2	72
<i>Octopus vulgaris</i>						(22)	(+)	79		
<i>Sepia officinalis</i>			13		(6)		0	1		
<i>Rossia macrosoma</i>					(27)					
<i>Septietta oweniana</i>				100				14	4	24
<i>Loligo</i> sp.			8		(+)		2			
<i>Loligo forbesi</i>						(17)				
<i>Loligo vulgaris</i>			19							0
<i>Todaropsis eblanae</i>			5		(27)			0	94	4
<i>Todarodes sagittatus</i>						(22)				
<i>Illex coindetii</i>								1		
Ommastrephidae					(20)					
<i>Gonatus ? steenstrupii</i>			(1 pen)							
Oceanic squid										
Cuttlefish	(1)									
Fish remains	(Bones from codfish)	(Bones)			(1 otolith)	(3)				
Other invertebrates		(Shells of crabs and urchins)				(22)			(Shells of a crabs and sea shells)	
					Crustaceans					

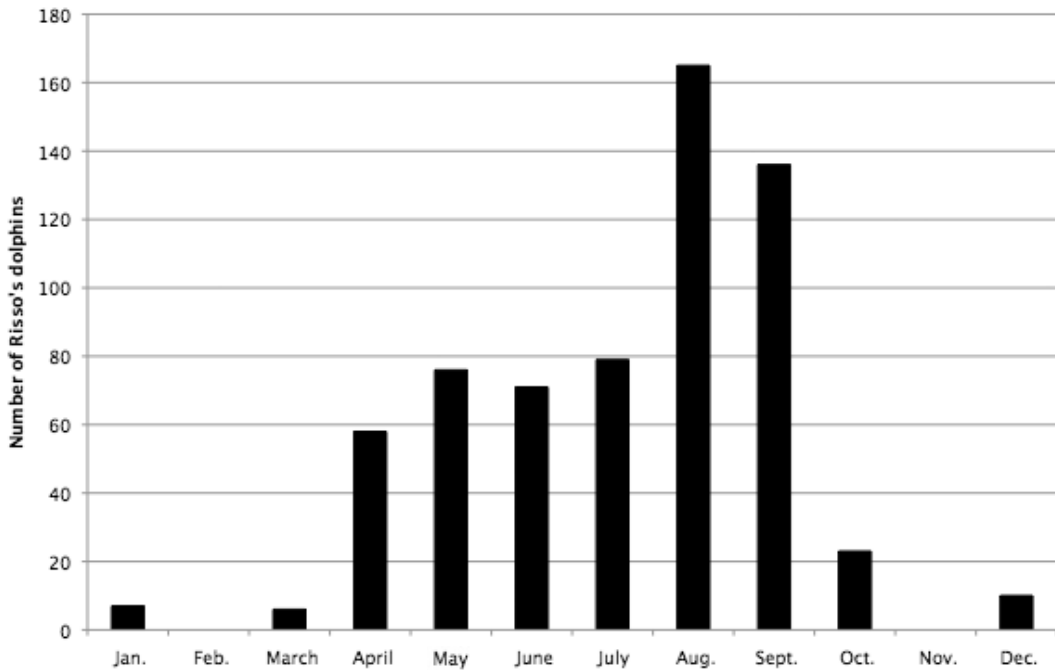


Figure 9. Monthly distribution of numbers of Risso's dolphins observed off Shetland in the period 2000 to 2010

authors (for an overview, see Kruse et al., 1999; Amano & Miyazaki, 2004). Differences in weight could, however, also reflect a seasonal body weight variation as observed in harbour porpoises (Lockyer et al., 2003), although it is not possible to examine from our data nor the data reported by Kruse et al. (1999). Several reports were based on strandings rather than fresh carcasses like the present and the Japanese studies, which may affect the results and in particular the weight of the animals. The Faroese sample also presents large individual variations in weight at size with, for example, both 505 kg for 320 cm and 460 kg for 323 cm in males. This could explain part of the apparent variation between the studies.

A lack of sexual dimorphism has generally been reported for Risso's dolphins (Kruse et al., 1999), although studies in Japan indicate a slight but significant sexual dimorphism in body length, relative size of appendages, and the accumulation of body scars (Kishiro, 2001), with males possibly growing longer than females (Amano & Miyazaki, 2004). Although the small number of specimens in the present study combined with a lack of older males cannot confirm or disprove sexual dimorphism for this species in this region, males seem to grow larger and become heavier than females.

The length at sexual maturity reported here for females, with the largest immature female being 268 cm long and the smallest mature female

277 cm long, lies in the higher end of the 260 to 264 cm range for smallest mature females listed by Perrin & Reilly (1984) and Kishiro (1998).

Testicular masses representing 3% of the body mass, as observed in one mature male of this study, have also been observed by Toshiya Kishiro off Japan (pers. comm., May 2011). In males ranging in length between 271 to 309 cm, he observed single testis weight of over 5 kg with the maximum testicular mass of 13.1 kg observed in June in a 291-cm-long male. Testis weights over 5 kg have also been reported by Orr (1966, 6,360 g) and Kasuya & Izumizawa (1981, 5,250 g). As a comparison, the same testicular mass is found in pilot whales weighing over 2 tons and measuring over 560 cm in length (Desportes et al., 1993). Such large testes suggest sperm competition and a promiscuous mating system in Risso's dolphins, with females mating with multiple males in a single oestrus period.

School Composition and Social Structure

Risso's dolphin groups ranging from one to 4,000 individuals have been reported (for a review, see Baird & Stacey, 1991; Bearzi et al., 2011), averaging perhaps 30 animals and showing a high group fluidity (Kruse et al., 1999). Few studies have focused on the social structure of Risso's dolphins, and only Amano & Miyazaki (2004) report the detailed age, sex, and reproductive

composition of a school of 79 Risso's dolphins captured in Japan.

The size of School 2 is small, and observations on school structure have to be interpreted with caution. As in Amano & Miyazaki (2004), the sex ratio of School 2 was highly biased towards females (71%) with a high maturity rate in females (66.7%), but the proportion of mature males is much higher in the Faroese School 2 (33.3 compared to 3.3%). Resting females made up 30% of the mature females, and there was no pregnant female—although the presence of a *corpus luteum* in two females could indicate either a very early pregnancy or an ovulation—even though the gestation period for the species is assumed to be 13 to 14 mo (Amano & Miyazaki, 2004).

School 2 lacks old males, with the oldest being 27 y old, while Kruse et al. (1999) report a 30+-y-old male. Some females are older (up to 35 y old) in the Amano & Miyazaki (2004) sample than in the Faroese sample (31 y old). Males in the age group 4 to 25 y and females in the age group 3 to 12 y were lacking, except for a single 8-y-old female. Weaned immature individuals are missing in School 2, supporting the hypothesis of young individuals of both sexes leaving the natal school after weaning (Amano & Miyazaki, 2004). While the sex ratio of immatures is not different from 1:1, the sex ratio of mature animals is significantly different from parity, with only 16.7% of males. Since, the longevity appears to be similar between the sexes, this suggests the segregation of adult males from mature females.

Diet

Risso's dolphins are thought to feed mostly on cephalopods, with a mix of neritic, oceanic, and occasionally bottom dwelling species (Clarke, 1966, 1986b; Kruse et al., 1999), although the information on the diet is scarce for European waters, only available for a few specimens—mainly from the Mediterranean (Eggleton, 1905; Taylor, 1913; Clarke & Pascoe, 1985; Desportes, 1985; Zonfrillo et al., 1988; Bello, 1992; Carlini et al., 1992; Würtz et al., 1992; Santos et al., 1994, 1995, 1996; Blanco et al., 2006; Öztürk et al., 2007; Bearzi et al., 2011). Limited behavioural research suggests that Risso's dolphins feed primarily at night (Baird, 2009). In the North Atlantic, the analysis of 15 stomach contents during the period 1983 to 1995 also pointed to a teuthophagous diet, with a mix of squid, cuttlefish, and octopuses (Clarke & Pascoe, 1985; Desportes, 1985; Zonfrillo et al., 1988; Santos et al., 1994, 1995, 1996). Remains of fish and other invertebrates were found only in two of these studies (Zonfrillo et al., 1988; Santos et al., 1994) and an older one (Eggleton, 1905). Fish constituted the

only remains in one specimen from an older study (Taylor, 1913).

The present analysis of stomach contents of 14 individuals from the two different schools showed a mixed diet, with both mid-water (*Todarodes* and *Loligo*) and bottom dwelling (*Eledona* and *Todaropsis*) species (Roper et al., 1984), suggesting that these dolphins fed on prey from both the water column and the ocean floor. Most prey species are typically neritic, and some individual prey were in a relatively fresh state, probably indicating that the dolphins had eaten on the Faroe Plateau. Although School 1 in September had a diet centred upon *Todarodes*, which is typically pelagic, this species moves on to the shelf from deeper oceanic water for a limited part of the year (Clarke, 1966). At that time, they can be very common on the Faroese Plateau (e.g., Hátún & Gaard, 2010). The individual squid eaten by this school have an average mantle length of 20 cm (range 11 to 27 cm) that corresponds to the size of the flying squid caught on the Faroe Plateau at that time of the year (e.g., Hátún & Gaard, 2010). Notably, the squid eaten by the only dolphin from School 2 in April 2010 which preyed on *Todarodes* are much larger, with an average mantle length of 35 cm (range 24 to 51 cm). Although both dolphin schools showed a mixed diet, School 1 in September had a diet centred upon a pelagic squid (*Todarodes sagittatus*), which at that time of year is present on the Faroe Plateau; while School 2 in April had a diet centred upon a benthic octopod (*Eledona cirrhosa*).

Distribution

Until August 2009, the most northerly record of Risso's dolphins in the middle Northeast Atlantic was at 60° 23' N. Five observations of Risso's dolphins in Faroese territorial waters in the period 2009 to 2011, in two different periods of the year, both spring and late summer, at latitudes between 61° 34' N and 62° 23' N, could indicate a northward extension of the known range of this species. This would fit well with the fact that in recent years more southern species of cetaceans have been occasionally observed around the Faroes, Shetland, and northwestern Scotland, such as striped dolphin, pygmy sperm whale (*Kogia breviceps*), dwarf sperm whale (*K. sima*), common dolphin (*Delphinus delphis*), and Sowerby's and Cuvier's beaked whale (*Ziphius cavirostris*) (Archive of Faroese Museum of Natural History; Bloch et al., 1996, 2000, 2010; Bloch & Olsen, 1998; MacLeod et al., 2005; Bloch & Mikkelsen, 2009; Harvey et al., 2011; Mikkelsen et al., 2011). It also fits well with the fact that the number of observations of exotic small cetaceans in Norwegian coastal waters seems to have increased

in recent years (Sundnes, 1988; Syvertsen et al., 2010).

The Risso's dolphin seems to have been scarcer in Shetland waters until about the 1980s (Buckley & Evans, 1899; Venables & Venables, 1955; Berry & Johnston, 1980). There were only a handful of records during the 1980s and very few between 1955 and 1980 (P. Harvey, pers. comm., 2012). MacLeod et al. (2005) studied changes in occurrence and abundance of different whale species off western Scotland in relation to climate changes. Species with a more southern distribution (common dolphin) have increased in numbers, while those with a northerly distribution (white-beaked dolphin [*Lagenorhynchus albirostris*]) have decreased (MacLeod et al., 2005). Hátún et al. (2009) and Hátún & Gaard (2010) showed an increasing temperature in North Atlantic waters of 1° C since 1995. The occurrence of Risso's dolphins off the Faroes in 2009, 2010, and 2011 fits well with the general tendency of more southerly species observed off Shetland, possibly as a consequence of the increasing North Atlantic temperature.

The general tendency described and the recent observations of Risso's dolphins in Faroese territorial waters strongly suggest that the northern border of the species range has moved northward since the distribution pattern described by Casinos & Filella (1994), Kruse et al. (1999), and Evans (2008). More observations are necessary to confirm this hypothesis.

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