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5. THE FINE-SCALE HABITAT USE OF RISSO'S DOLPHINS (*GRAMPUS GRISEUS*) OFF BARDSEY ISLAND, CARDIGAN BAY (UK).

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INTRODUCTION

Information about the habitat use of small cetaceans is essential in order to assess their conservation status. A recent review regarding Risso's dolphins *Grampus griseus* (Bearzi *et al.*, 2010) reported that only limited information exist, and for the majority, these are all for waters outside NW Europe (Bearzi *et al.*, 2010). Large-scale studies within European waters did not yield many sightings and suggest a relatively low abundance for Risso's dolphins, especially in coastal habitats (e.g. Weir *et al.*, 2001; Cañadas *et al.*, 2002; SCANS-II 2008; Panigada *et al.*, 2009).

Risso's dolphins have an apparent preference for deep offshore waters and continental slopes, but may inhabit coastal areas around oceanic islands and narrow continental shelves (e.g. Baird 2009; Bearzi *et al.*, 2010). In UK waters, Risso's dolphins are recorded year-round and are most common off the Western Isles. They are also present around Orkney and Shetland (close to the species' known northern limit of distribution), in the Irish Sea, western and southern Ireland and western English Channel, but they are rare in the North Sea (Weir *et al.*, 2001, Reid *et al.*, 2003; Evans *et al.*, 2003; O'Cadhla *et al.*, 2004, Baines and Evans 2009). Based on both opportunistic and dedicated studies, it appears that they are most abundant between May and October, preferring slopes of 50 – 100m depth (Weir *et al.*, 2001; Evans *et al.*, 2003; Reid *et al.*, 2003; Baines and Evans 2009). Risso's dolphins have been reported in Welsh waters (Baines and Evans 2009) and previous preliminary studies showed the occurrence of this species off Bardsey Island (de Boer *et al.*, 2002). Based on incidental sightings records from Bardsey Island (1976 – 2005), this species occurs here primarily during the months of July to October with additional sightings recorded in April (de Boer 2005). Apart from an area off the West coast of Scotland (1992–1997; Atkinson *et al.*, 1997; Dolman and Hodgins, *this issue*), hardly any studies have taken place in UK waters and current information on the population size and habitat-use is therefore very limited.

The main objectives of this study were (1) to estimate the population size of Risso's dolphins off Bardsey Island using mark-recapture techniques (De Boer *et al.*, 2013); and (2) to study habitat-use in relation to fine-scale oceanographic features. This work provides preliminary information on the habitat-use of Risso's dolphins and will benefit future studies, along with the development of effective conservation measures for this species throughout the region.

MATERIALS AND METHODS

Study Location

Cardigan Bay is a large shallow embayment on the east side of the St. George's Channel entrance to the semi-enclosed Irish Sea Basin. The Llyn peninsula in Wales is orientated northeast/southwest and is some 40 km in length, ending in a headland adjacent to deeper water. Bardsey Island (with dimensions of 2.6 km by 1 km) is situated off the tip of the Llyn Peninsula in the northern part of Cardigan Bay at 52°45.36'N and 004°47.17'W and is separated by Bardsey Sound (approximately 3 km wide; Figure 1). There are strong tidal eddies that exist in the waters surrounding Bardsey Island which have currents of order 3 m s⁻¹ (Elliott *et al.*, 1995).

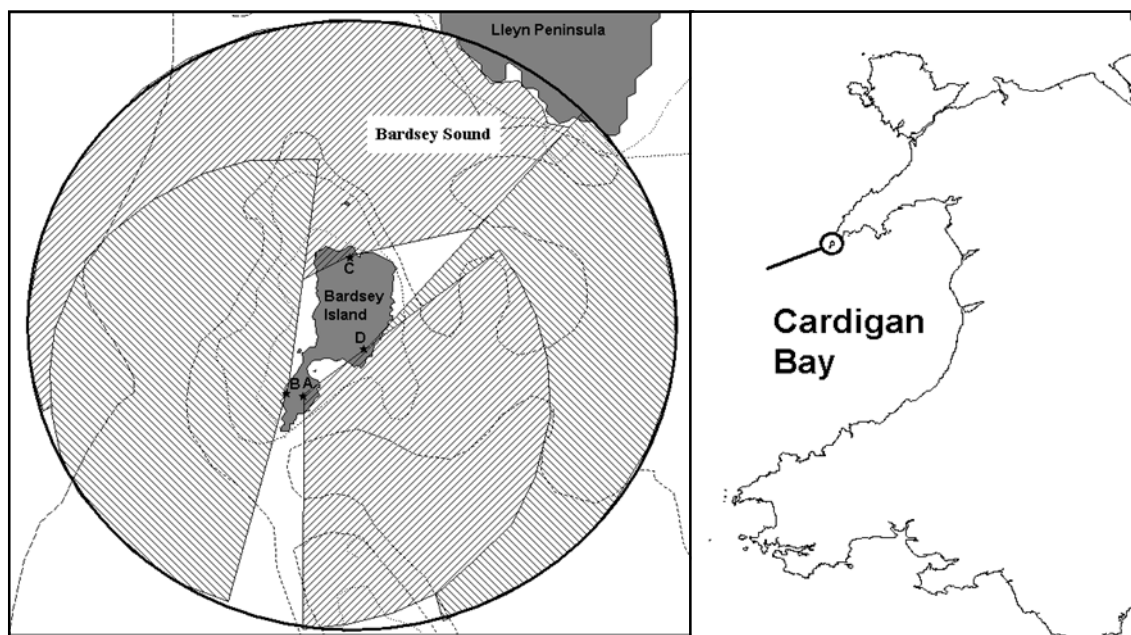


Figure 1. Cardigan Bay and Bardsey Island located off the Llyn Peninsula. The observation points (A-D) and ranges are shaded and overlap in places. Drawn isobaths include 10m, 20m, 30m and 50m.

Land-Based Survey Design

A standardised scan sampling system was used, designed to study harbour porpoise (*Phocoena phocoena*) during the summer months between 2001 and 2006. A study area (85° to 120°) was slowly scanned using 7 x 50 Nikon binoculars for a period of 10 minutes (de Boer and Simmonds 2002; Pierpoint 2008). Whenever possible, simultaneous observations were carried out from four observation points which varied in height and survey area (Figure 1). A series of 10-minute 'snapshots' were produced for each sampling segment, detailing the location of dolphins sighted. Points A and B (both at 17 m height; -5.0 m during spring tide) were situated at the southern tip of the Island, with point B overlooking waters with exposure to prevailing wind and wave action and containing complex bathymetric features, whereas point A overlooked a leeward habitat. The higher points (C–D) were situated at heights of 38m and 60m respectively (-5.0 m during spring tide) and were located on the northern part of the Island. Point C overlooked the waters in Bardsey Sound with strong tidal streams and

partly overlapped with the area covered from point B. Point D overlooked the eastern part of the Sound but also partly overlapped with the area covered from point A. The survey area covered from points B and C included two areas of each approximately 90° in size, totaling 170° – 200°.

Observers switched scanning every 10 minutes and also changed platforms every 3 – 4 hours to create a more spread out observer effort. The following information was collected with each sighting: radial distance (using reticule binoculars), bearing (using the built-in compass in the binoculars – these were frequently checked and calibrated), surfacing direction, group-size, presence of calves and juveniles. Distinctive behaviours were noted separately. For each 10-minute scan the Beaufort sea state (0 – 4) and tidal state were recorded. Optolyth telescopes (x30) were used to aid group-size estimation and to distinguish juveniles and calves. All dolphin encounters (whether they were a new sighting for any one day or were re-sightings from previous scans) made during each 10-minute scan were referenced as Scan Sightings (SS).

Data Analysis

We mapped the positions of all sightings (SS) using bearing, radial distance and observation height. The observation ranges were determined for each platform. This was used to estimate the actual survey area with an observation range of <2400 m for the lower platforms and <3600 m for the higher platforms. Land areas and those sea areas not covered were excluded. Because the chance for sighting cetaceans decreases with distance, we estimated that the optimum distance (the area up to which sightings were most reliably seen) for the lower platforms was 2000 m (75% of all sightings occurred up to this distance) and for the higher platforms this was 3000 m (88% of all sightings).

A grid with a resolution of 300 x 300 m was prepared. The chosen grid-size was checked on the accuracy of the distance and angle data in order to ensure that the grid-size (300m) was larger than distance/angle error. It was found that bias in distance estimations or bearing readings became profound (>300m) for the higher platforms when the distance was > 2500 m and for the lower platforms this was 1800 m. Only few sightings occurred at such distances (27 of 297 scan sightings) and when plotting these sighting positions they appeared to be outliers. Nevertheless, the bias in estimated sighting positions is expected to be profound even at shorter distances (especially when errors were made in both distance and bearing measurements). In some cases, this could therefore cause estimated sighting positions to fall into a neighbouring grid cell. However, due to the preliminary character of these analyses, and bearing in mind the low number of grid cells used, it was decided to not make the grid-size larger or increasing the grid-size dependent on distance from the observer. For the total of 607 grid cells (54.61 km²), the amount of survey effort was calculated (including areas that overlapped). We interpolated mean depth from Acoustic Doppler Current Profiler (ADCP) surveys provided by the University of Bangor (Elliott *et al.*, 1995). Four tidal phases were defined: The High Water (HW) phase was defined as one hour before and after HW and Low Water (LW) was similarly defined. Ebb was defined as 1.5 hours after High Water until 5 hrs after HW; and flood as 5 hrs before HW until 1.5 hrs before HW.

The slope for each grid cell was calculated as $(D_{max} - D_{min})/DI$ where D_{max} is the maximum depth in a quadrant, D_{min} is the minimum depth in a quadrant and DI the distance in meters between the points of maximum and minimum depth of the quadrant, and expressed in units of meters per km (Cañadas *et al.*, 2002).

Sightings (SS) were entered into a Geographic Information System (GIS) and the abundance (number of dolphins per scan per km²), for each grid cell within the survey area was calculated. From this, the total abundance for different areas or tidal phases was calculated by adding up the abundance indices for the different grid cells. Using positive scans (those scans during which dolphins were sighted), we studied the relation with oceanographic features: water depth (m), slope (m km⁻¹), tidal state (relative to High Water, HW), current speed (m s⁻¹) and direction. Chi-squared tests were used to investigate whether the observed number of sightings and abundance index differed from expected according to depth and slope. For depth and slope the following classes were defined: depth 0 – 10, 11 – 20, 21 – 30, 31 – 40, 41 – 50, 51 – 60, 61 – 70; and 71 – 80; slope 0 – 10, 11 – 20, 21 – 30, 31 – 40, 41 – 50, 51 – 60. These classes were defined in order to have sufficient sample size in each of the classes, given the restriction in chi-square tests that requires all expected frequencies to exceed 5. A comparison was made between the depth and seabed slopes recorded during flood and ebb tides using Mann-Whitney-U tests.

RESULTS

Abundance and Group-Size

A total of 155 scans (25.83 hrs) were made during which Risso's dolphins were sighted 297 occasions involving 555 animals (Table 1). The highest number of individual dolphins seen within one scan was 38 but the average was 3.65 (SD 4.84, $n = 155$). Dolphins were sighted at an average distance of 1849.7m (SD 831.3; range 332.0 - 4649.7m).

Table 1. Summary of effort (scans and hours) and information on Risso's dolphin Scan Sightings (SS), number of individuals (Ind) during the land-based surveys.

Year	Month	Effort	SS
		Number of scans (hrs)	(Ind)
2001	Aug – Sept	1378 (229.7)	70 (117)
2002	Aug – Sept	943 (157.2)	47 (62)
2003	July – Sept	1479 (264.5)	0 (0)
2004	July – Sept	1537 (359.0)	2 (4)
2005	July – Sept	2641 (440.2)	158 (328)
2006	Sept	775 (129.2)	20 (44)
Total	July – Sept	9291 (1548.5)	297 (555)

The abundance was calculated as the number of dolphins (per scan/km²) sighted in each of the grid cells. Figure 2 shows the core areas where dolphin abundance exceeded 0.25 dolphins (per scan/km²). There are two main ‘core areas’ with relatively high dolphin abundance (>0.25): Box 1 (to the west and northwest of the Island) and Box 2 (to the north of the Island within Bardsey Sound). In addition, two smaller areas to the east of the island also showed high dolphin abundance. The total abundance in Box 1 was 35.39 dolphins and in Box 2 this was 15.86 dolphins.

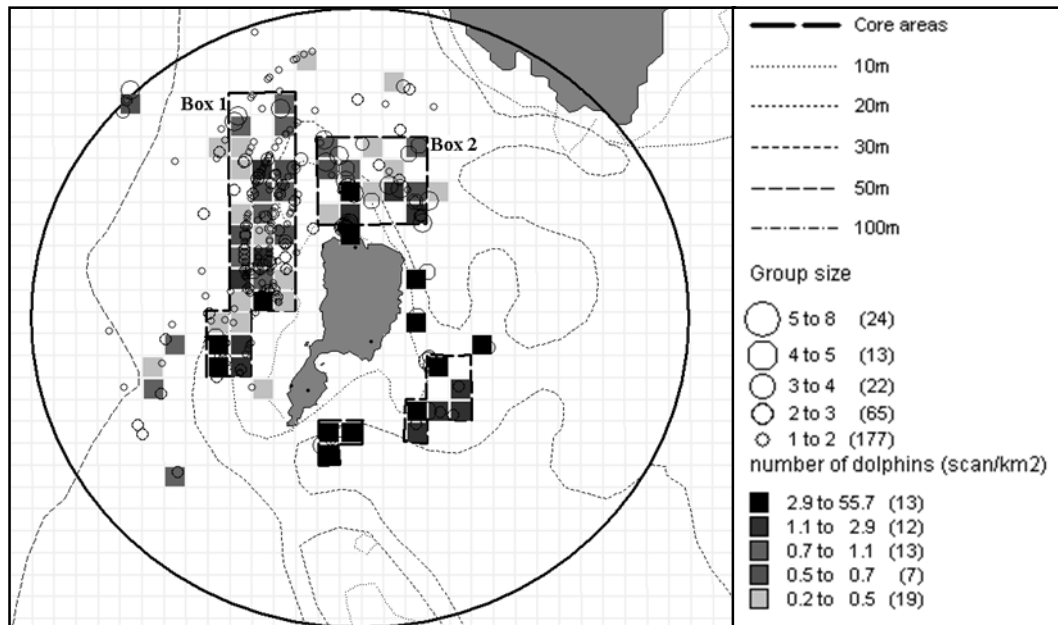


Figure 2. Abundance of Risso's dolphins (dolphins per scan km⁻²) for each grid cell. The position of scan sightings are shown as circles with the size of each circle indicating the number of individuals.

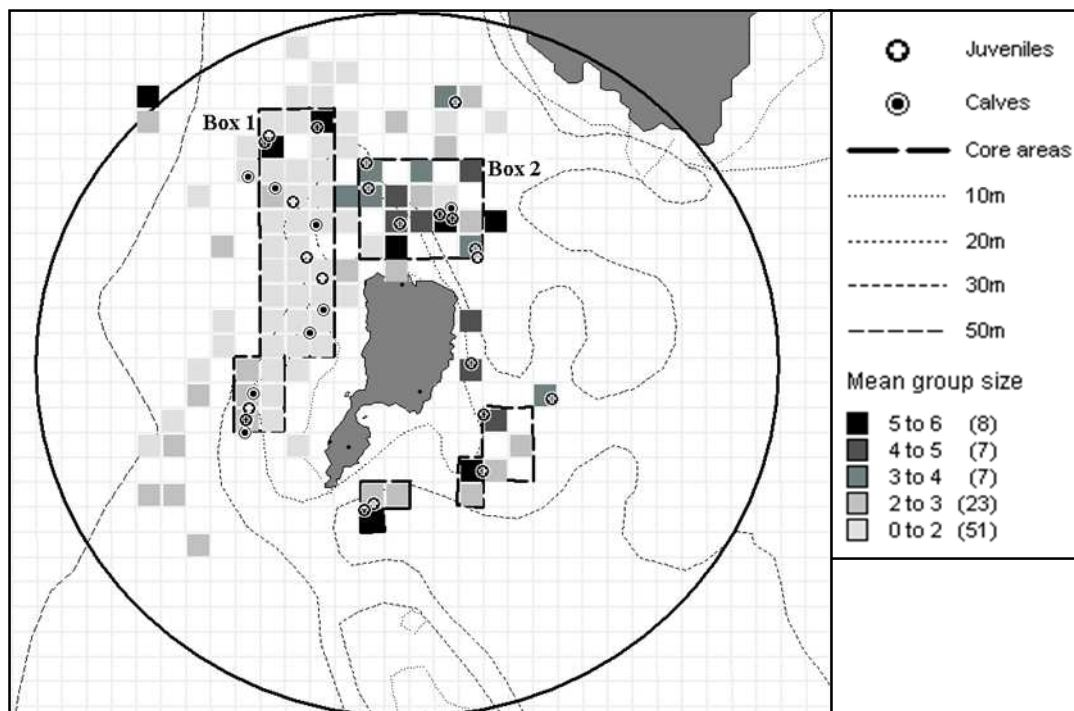


Figure 3. Grid cells with mean group-size for Risso's dolphins. The positions of calves (dotted dots) and juveniles (crossed dots) are also shown.

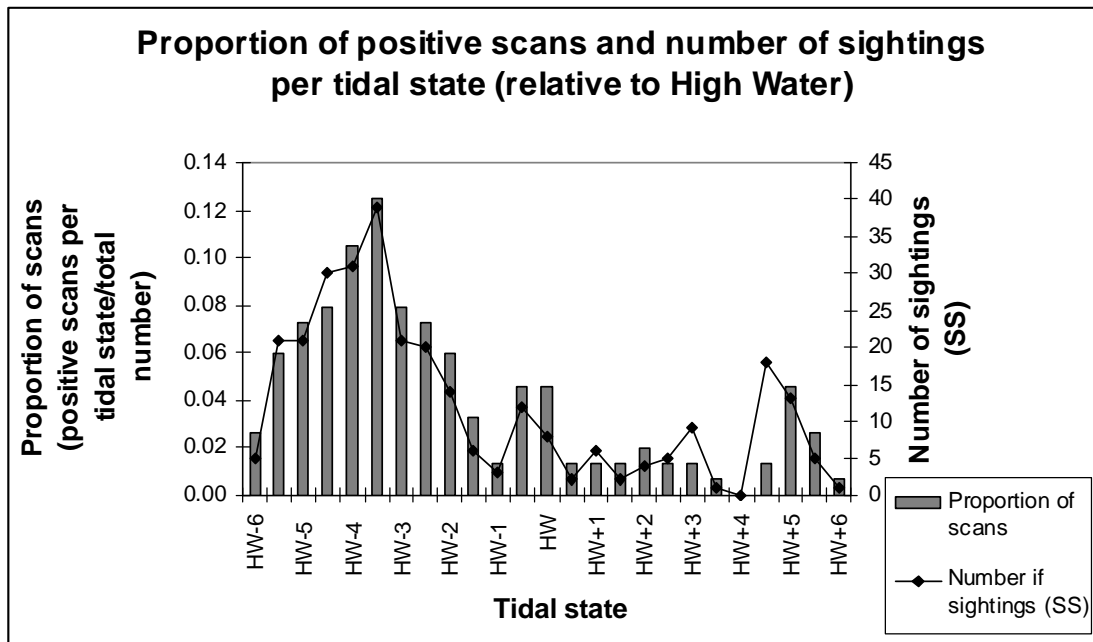


Figure 4. Proportion of positive scans (positive scans per tidal state/total number of positive scans) and proportion of scan sightings (SS per tidal state/total SS). Tidal state is presented as the number of hours +/- High Water (HW).

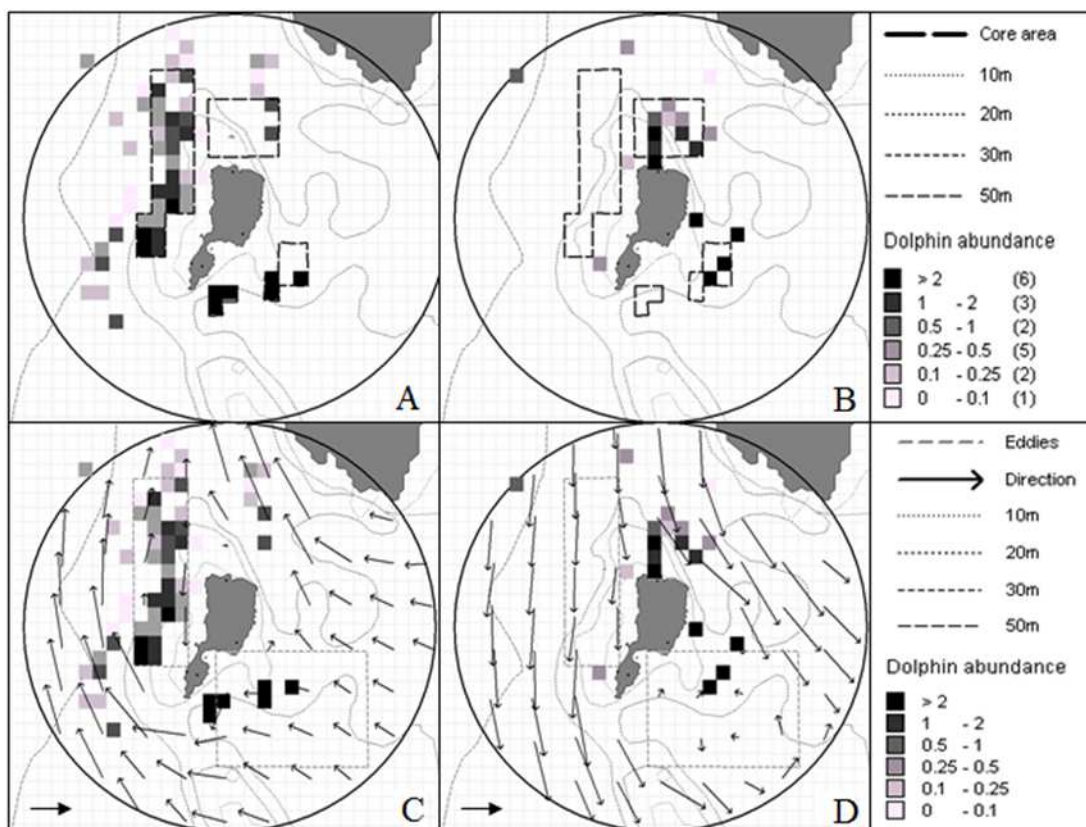


Figure 5. Risso's dolphin abundance (dolphins per scan km^{-2}) during flood (A) and ebb (B) in the core areas (black dotted Boxes) and in relation to tidal eddies (grey dotted Boxes) during flood (C) and ebb (D). Arrows indicate the direction and strength of the currents where the size of the arrow (left bottom corner) corresponds to 1m s^{-1} . Information regarding currents and eddies were derived from Neil (2008).

The mean group size per scan for Risso’s dolphins averaged 2.11 (SD 1.34, $n = 96$, range 1-6) with the highest group size measured in Bardsey Sound (Figure 5). All calves (except for one) were found to the west of the Island (Box 1), whereas juveniles were observed all around the island (Figure 3).

Tidal Cycle

Risso’s dolphins sightings appeared to be correlated with the tidal state with significantly more sightings made during flood ($\chi^2 = 112.27$, $df = 3$, $p < 0.001$). The highest proportion of positive scans was made during HW-3.5 hrs, at the peak of the flood phase, during which also the majority of sightings were made (Figure 4). During ebb the highest proportion of positive scans was made at HW+5 hrs, with the majority of sightings made at HW+4.5 hrs (Figure 4).

During flood, the dolphins were particularly abundant to the west/northwest of the Island (Box 1) and sightings were also made to the southeast and in Bardsey Sound. During ebb they were mostly abundant to the north of the Island (Box 2) with additional sightings to the East (Figure 5a and b). The total abundance in Box 1 during flood was 32.26 dolphins and during ebb this was 11.89 dolphins.

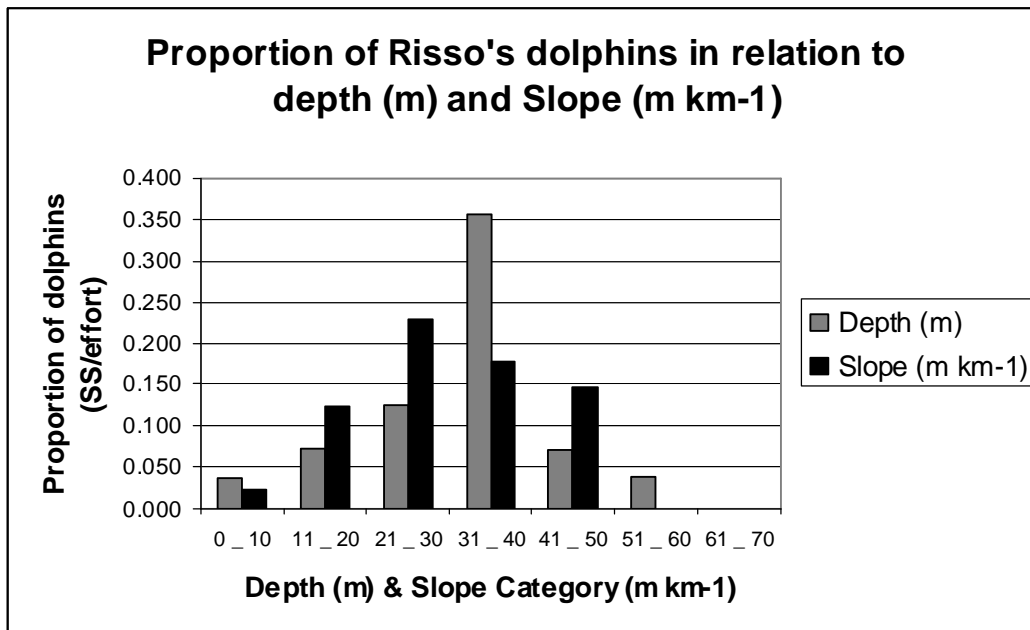


Figure 6. Proportion of Risso’s dolphins (scan sightings per unit effort) in relation to depth (m) and slope (m km⁻¹).

Depth and Slope

The majority of dolphins were sighted in waters between 30–40 m (59%) with a mean water depth of 32.72 m (SD 8.73, $n = 280$, range 13.60–57.40 m) and a mean slope of 23.79 m km⁻¹ (SD 9.68, $n = 291$, range 4.72–42.45 m km⁻¹; Figure 6). Dolphin abundance was not distributed uniformly through all classes of depth ($\chi^2 = 35.43$, $df = 5$, $p < 0.001$) and slope ($\chi^2 = 17.57$, $df = 4$, $p = 0.001$). The mean depth for those grid cells where dolphins occurred was 32.22 m during flood (SD 8.38, $n = 176$) and 30.47 m during ebb (SD 12.47, $n = 39$). The mean slope for those grid cells where dolphins

occurred during flood was 22.29m km⁻¹ (SD 9.03, $n = 175$) and during ebb this was 28.40 m km⁻¹ (SD 9.31, $n = 51$). There was no significant difference to preferred depth class 30–40 m during ebb or flood. However, there was a significant preference for steeper slopes during ebb ($U = 2819.5$, $n = 226$, $p < 0.0001$).

DISCUSSION

Risso's dolphins were mainly sighted in waters with a mean depth class of 30–40 m. However, this was expected as most of the available habitat is 30–40 m depth. The dolphins were also observed in waters as shallow as 7 m. Similar observations with Risso's occurring in shallow waters were reported off NW Scotland (<30 m; Gill *et al.*, 1997) and off the Canary Islands (<20 m; Ruiz *et al.*, 2011). Risso's dolphins are usually found in deeper waters. Across the Mediterranean Sea, they are sighted in waters around 1000m depth (Cañadas *et al.*, 2002; Gannier 2005; Bearzi *et al.*, 2010) and in less deep waters of the continental slope (mean depth 638m; Praca and Gannier 2007). Risso's dolphins off the Azores are more frequently sighted in waters of 600 m (Pereira 2008), whilst most dolphin sightings off Scotland occurred in <200 m depth (Weir *et al.*, 2001). In this study, the dolphins preferred those areas with slopes of 20 – 30m km⁻¹ and this is less-steep than reported for deeper waters. For example, Baumgartner (1997) defined the slope class of 41.6 to 402.5 m 1.1 km⁻¹ as highly preferred in offshore waters (Gulf of Mexico). In deep waters of the Mediterranean Sea, Cañadas *et al.* (2002) reported a preference for slopes exceeding 40 m km⁻¹. Other studies (Mediterranean and Azores) also confirm the preference for steep slopes (Gannier 2005; Praca and Gannier 2007; Azzellino *et al.*, 2008; van Geel *et al.*, 2008; Moulins *et al.*, 2008; Airoidi *et al.*, 2010, Bearzi *et al.*, 2010).

Our observations indicate that relatively shallow coastal waters (up to 50 m) with consequently less-steep slopes may also offer suitable foraging habitats for Risso's dolphins. The majority of calves were recorded in Box 1 where lower current speeds may offer a preferred habitat for nursery groups compared to areas with fast flowing waters (Bardsey Sound) where the risk for mother and calves to become separated is greater. Similar findings have been documented for porpoise calves in Welsh waters (Pierpoint 2008). There have been few studies of cetaceans foraging in island/headland wakes. Johnston *et al.* (2005a) reported on fin whales (*Balaenoptera physalus*) and minke whales (*B. acutorostrata*) that exploited a tidally driven island system in the Bay of Fundy. Pierpoint (2008) reported on foraging porpoises in a headland/island system in Wales. Similarly, porpoise densities were found to be significantly greater during flood in an island wake system (Johnston *et al.*, 2005b). In the Moray Firth (Scotland), bottlenose dolphins showed fine-scale foraging movements within a narrow channel (Bailey and Thompson 2010). In Alaska the abundance of humpback whales (*Megaptera novaeangliae*) appeared to be related to tidal influences near headland wake systems (Chenoweth *et al.*, 2011). Like any other headland/island system, Bardsey has residual eddies that are formed on either side of the island (northwest and southeast eddies) during flood and ebb (Elliott *et al.*, 1995; Neil *et al.*, 2007). At fine spatial scales, small-scale eddies and fronts appear to enhance the primary productivity and it is recognised that these features may concentrate prey (e.g. Simard *et al.*, 2002; Zamon 2003). It seems therefore likely that the areas of upwelling and eddies in Bardsey waters can influence the availability of nutrients, retention of plankton and aggregation of fish that may attract prey (Baumgartner 1997; Kruse *et al.*, 1999; Yen *et al.*, 2004).

The diet of Risso's dolphins consists primarily of cephalopods (Würtz *et al.*, 1992; Clarke 1996; Kruse *et al.*, 1999). Risso's have been observed preying on octopus (*Octopus vulgaris*) off the Canary Islands in shallow waters (<20 m; Ruiz *et al.*, 2011) and off Scotland they predominantly take lesser octopus (*Eledone cirrhosa*; Atkinson and Gill 1996; Santos *et al.*, 1994). The lesser octopus was also found in the stomachs of Risso's stranded in Wales (Merrett 1998) and southern England (Clarke and Pasco 1985). The lesser octopus is especially common inshore in the summer (July – September) during the peak spawning period and further offshore in October – December (Boyle 1986). It is therefore likely that the dolphins in Bardsey waters were also targeting lesser octopus. It is worth noting that the presence of local beds of horse mussel (*Modiolus modiolus*) close to Bardsey may attract squid and octopus (Wharam and Simmonds 2008).

The area where dolphins were most abundant during the flood phase (Box 1) corresponded to a western eddy formed during flood (Figure 5c, d). The high current speeds in Bardsey waters indicate that large volumes of water are transported along and into the eddy during flood and then slow down and circulate, effectively concentrating prey into the eddy region and forming a suitable foraging location for dolphins during flood. The ebb-eddy, which is approximately positioned over a shallow sand bank to the Southeast (Neill 2008), probably does not offer suitable foraging conditions for Risso's dolphins. The dolphins favoured the Sound during ebb and where large upwellings (slick domes of water on the surface) were consistently seen. In addition, the narrowness of Bardsey Sound may concentrate prey. Marine predators can then focus their foraging efforts on such locations to improve efficiency and reduce energetic costs (Bailey and Thompson 2010).

Many large marine predators use vast areas of the ocean, but typically concentrate their activities in smaller, localised biological hotspots for periods of time (Johnston *et al.*, 2005b). The tidal eddies in Bardsey waters enhance the foraging efficiency for Risso's dolphins by aggregating their prey in a predictable manner during different tidal phases in localised areas. Such static bathymetric features may form the initial basis for identifying potentially critical habitats for Risso's dolphins within relatively shallow coastal systems.

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