

# Photo-Identification Methods Reveal Seasonal and Long-Term Site-Fidelity of Risso's Dolphins (*Grampus griseus*) in Shallow Waters (Cardigan Bay, Wales)

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## ABSTRACT

A photo-identification study on Risso's dolphins was carried out off Bardsey Island in Wales (July to September, 1997-2007). Their local abundance was estimated using two different analytical techniques: 1) mark-recapture of well-marked dolphins using a "closed-population" model; and 2) a census technique based on the total number of identified individual dolphins sighted over the study period. The mark-recapture estimates of 121 (left sides; 64 - 178, 95% CI; CV 0.24) and 145 dolphins (right sides; 78 - 213, 95% CI; CV 0.24) closely matched the census technique estimates (population size of 90 - 151). It was found that the dolphins showed a degree of long-term and seasonal site-fidelity. A first long-distance match was made for Risso's dolphins (319 km) between Bardsey Island and Cornwall, confirming they can be wide-ranging animals. This study demonstrates that the combination of systematic and opportunistic photo-ID studies has complementary value as a population assessment tool in generating the first local abundance estimate for Risso's dolphins in UK waters. From the conservation perspective, these studies confirm the regular presence of Risso's dolphins in these waters and the presence of calves shows breeding. Bardsey Island may be part of a network of localities that are important habitats to this species where it may take advantage of prey abundance in shallow waters. As such, results of this study may provide assistance to include the Risso's dolphin in future regional conservation strategies including the envisaged marine protected areas.

**Keywords:** Risso's Dolphin; *Grampus griseus*; Abundance; Mark-Recapture; Photo-Identification; Conservation

## 1. Introduction

The present status of Risso's dolphins *Grampus griseus* in European waters is largely unknown [1]. For NW Europe, sightings data concerning this species mainly consist of opportunistic records although some effort-related data are also available (e.g. [2,3]). The only abundance estimates available for other European waters (based on line-transect methods) are for the Mediterranean Sea [4-6]. The picture is not different on a global scale, and only a few abundance estimates exist for waters outside Europe (e.g. [4]). Some large-scale studies in the eastern Atlantic such as the NASS (North Atlantic Sightings Survey), SCANS (Small Cetacean Abundance in the European Atlantic and North Sea), CODA (Cetacean Offshore Distribution and Abundance in the Euro-

pean Atlantic) have been carried out and provided some additional information regarding Risso's dolphin distribution within Europe [e.g. 4,7]. However, the yield of sightings data was not enough to allow the calculation of abundance estimates, suggesting a relatively low density for this species (e.g. [7,8]).

Mark-recapture techniques are widely used to estimate population-size where animals can be identified individually through photographs (e.g. [9]). Risso's dolphins typically exhibit long-lasting identifiable natural marks, which include distinctive nicks in their dorsal fins, patterns of scarring and variations in dorsal fin shape. Therefore, photo-identification (photo-ID) techniques can be used to study association patterns and social structure for this species [10]. Mark-recapture techniques have yielded one preliminary abundance estimate for

Risso's dolphins in the Mediterranean Sea [11].

Risso's dolphins have an apparent preference for deep offshore waters and continental slopes but also inhabit coastal areas around oceanic islands and narrow continental shelves (e.g. [4]). In UK waters, they are recorded most frequently, and year-round, 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 [2,3,8]. Both opportunistic and dedicated studies reported most sightings between May and October [3,4,12]. Risso's dolphins have been regularly seen in Welsh waters (e.g. [12]) and incidental sightings made from Bardsey Island (1976-2005) indicate that this species occurs here primarily during the months of July to October with additional sightings recorded in April [13]. Apart from studies off the West coast of Scotland (1992-1997; [14]), hardly any dedicated research has been reported from UK waters on this species.

The study was conducted off Bardsey Island between 1997 and 2007 and the main objective was to estimate the local summer population size of Risso's dolphins. Secondly, site fidelity and ranging patterns were examined. Thirdly, an evaluation was made of the utility of small-scale, opportunistic and relatively low-cost studies for studying a relatively scarce species.

## 2. Material and Methods

Boat-based surveys were carried out in July (1997), August (2001, 2002, 2004, 2007) and September (2000, 2005-2006). Risso's dolphins were approached and photographed under license from the Countryside Council for Wales (CCW) adhering to local guidelines to minimise disturbance. The different boats used had an eye-level height of 2 - 3 m and included both outboard powered vessels (sailing vessel under motor, rigid-hulled inflatable boat) and 5 - 8 m inboard powered vessels such as the Bardsey ferry, a dory (small fishing boat) and a local wildlife-watching boat. Whenever conditions allowed, the boat surveys were carried out following line-transect survey protocols [12].

### 2.1. Study Location

Bardsey Island is situated in the northern parts of Cardigan Bay, Wales, a large shallow embayment on the east side of the St. George's Channel entrance to the semi-enclosed Irish Sea Basin. The northern shores of the Bay are formed by the Lley Peninsula, which is orientated NE/SW and extends 40 km, ending in a headland adjacent to deeper water. Bardsey Island (with approximate dimensions of 3 km by 1 km) is situated off the tip of Lley Peninsula at 52°45'36"N and 004°47'17"W and

is separated by Bardsey Sound (approximately 3 km wide) from the mainland (**Figure 1**).

### 2.2. Photographic Survey Design

Photographs of Risso's dolphins were collected both during systematic line-transect surveys to the east and west off Bardsey (**Figure 2**) and opportunistic boat surveys. Opportunistic boat-surveys were launched when the dolphins were seen during dedicated land-based observations which were carried out from one to four look-out points on the Island [15]. In addition, Risso's dolphins were also photographed on four occasions from land when they came close to the shore (September 2005 and 2006).

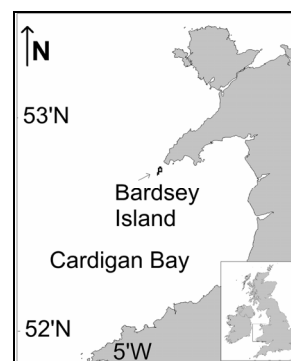
During line-transect surveys, dedicated watches were conducted during calm seas (Beaufort Sea states 0 - 3) and good visibility (>1 nmile). Two experienced observers were on watch covering a combined arch of 180°. Scanning was done with the naked eye and with occasional scans using 7 × 50 reticule binoculars (NIKON 7 × 50).

When a sighting was made, the survey went "off-effort" in order to approach the animals and obtain photographs. Photographs were taken using 35-mm slide film (1997-2004) or digital SLRs (2005-2007).

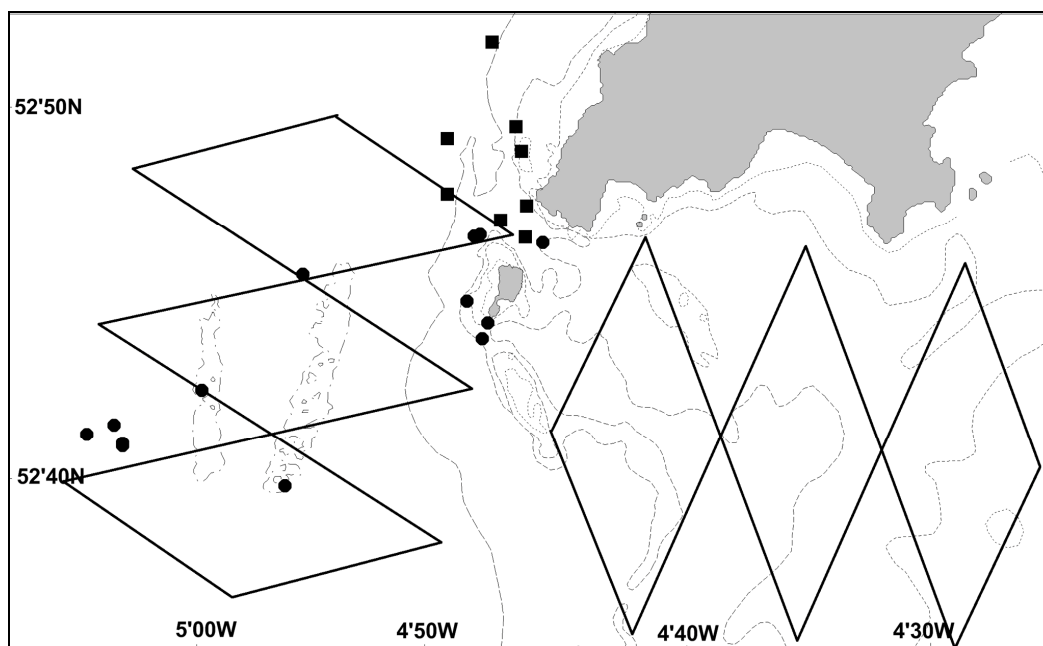
Upon completing the Photo-ID work, the line-transect survey was then re-started from the point where "off-effort had commenced". If a dolphin group was spotted from land, it was either observed from there or subsequently approached by boat for opportunistic studies. Dolphins were followed for 30 minutes to up to 2 hours, to allow time for all individuals to be photographed. Group-size was assessed in the field and later confirmed through the examination of photographs.

### 2.3. Individual Recognition

Dorsal fin photographs from both sides were taken of individuals irrespective of their natural marks to enable an unbiased estimation of the proportion of well-marked



**Figure 1.** Cardigan Bay and Bardsey Island located off the Lley Peninsula (inset: UK).



**Figure 2.** Estimated sighting positions of Risso's dolphins from both systematic (line-transect; dots) and opportunistic photo-ID boat-surveys (blocks) together with the dedicated line-transect survey design.

animals (those with distinctive and permanent marks on the dorsal fins). For each sighting, the group size and presence of adults, sub-adults and calves were noted. Adults were defined as individuals with moderate to high scarification or white body coloration and mature body size [10]. Sub-adults were defined as dark brown individuals with limited scarification. Calves were identified when being less than 75% of the size of adults and accompanied by adults [10], newborn calves were identified by the presence of fetal folds and by their erratic surfacing behavior.

## 2.4. Photo Processing

The photographs were analysed by three independent assessors who studied markings such as scars, nicks and shape of dorsal fin. In addition, scars or wounds found elsewhere on the body were also noted. Images were graded as good, moderate and poor based on the angle of the dorsal fin, contrast and focus. Poor photographs were excluded from analysis. Individuals were classed into well-marked, subtle-marked or unmarked dolphins. The selected photographs were used—as described in the following two sections—in two different techniques to estimate dolphin abundance.

## 2.5. Mark-Recapture Application and Model Selection

To comply with the assumptions for mark-loss, only those dolphins with well-marked dorsal fins were used in the mark-recapture analysis. Subtle marks were included

in the mark-recapture analysis as long as these were distinctive and the scarification grade (based on the ratio of dark skin to white scars on the dorsal fin) of animals showing these subtle marks exceeded 10% [10]. Calves were excluded from the mark-capture analyses because their probability of capture was not exclusive from that of their mothers.

Photo-identification data from eight summers (1997–2007) were then pooled per field season and considered as sampling units and recaptures in different survey years were taken into account. The program CAPTURE [16] was used on capture histories of well-marked animals.

To prevent errors arising from mismatching left and right sides, we estimated abundance using the left and right sides independently [17]. Mark-recapture methods rely on a number of fundamental assumptions (e.g. [9]), including 1) that a marked animal will be recognized with certainty if recaptured and failure to do so will bias estimates upward; 2) that marks do not change to the extent that they affect subsequent recognition; 3) that marked animals do not demonstrate behavioural responses that affect the probability of their recapture, and 4) that all individuals have the same probability of capture within a sampling session. Furthermore, a population may be regarded as a “closed” or “open” population. A closed population model assumes that the population is closed to births, deaths, immigration and emigration, *i.e.* it does not change over the period of study (e.g. [9]). Even though births and possibly deaths occurred during the study periods, the population may be considered

geographically closed if the same population units recurrently visited the Bardsey Island waters over time. We applied mark-recapture closed-models [18] to estimate the total abundance of well-marked dolphins. The model selection procedure (based on goodness-of-fit tests and discriminant function analysis) was performed to indicate the relative fit of competing models. A score of 1.00 indicates a high probability that the model chosen is more appropriate for the data set than any of the other models [19].

The models for mark-recapture analysis for a closed population include, amongst others:  $M_0$  (assumes that all individuals have an equal chance of being captured and that capture probabilities do not change over time);  $M_t$  (allows capture probabilities to vary by time),  $M_h$  (accounting for heterogeneity of probability of capture) and  $M_{th}$  (allows capture probabilities to vary by time and by individual animal). To calculate the proportion of unmarked individuals (including calves) in the population for each season, the total number of unmarked individuals was divided by the total number of individual dolphins identified. The estimate of well-marked animals in the population that was derived from CAPTURE was then expanded to incorporate the proportion of unmarked individuals to give a total population estimate ( $\hat{N}_{Tot}$ ; [20]). The variance and confidence intervals for  $\hat{N}_{Tot}$  were calculated as by Wilson *et al.* [17].

## 2.6. Census Based Technique

The census method was used to calculate the minimum local population size as the number of recognisable (marked) individuals recorded. For this analysis, all recognizable dolphins were included in the analysis (*i.e.* dolphins with dorsal fins that were subtle-marked or well-marked, and dolphins with distinct recognizable

marks elsewhere on body), comprising adults, sub-adults and calves. We also included both moderate-quality images showing highly distinctive animals and high-quality images showing relatively poorly-marked animals for this type of analysis. This enabled us to calculate the minimum number of identified respectively recognizable dolphins, bearing features either on the left- or the right-side or both, in Bardsey waters each summer.

## 2.7. Data analysis

The local summer population size of Risso's dolphins was estimated using the above mentioned two different analyses techniques. Furthermore, sighting rates and group-size of dolphins encountered during systematic line-transect boat surveys were calculated. The term population here describes the local population of Rissos dolphins frequenting the Bardsey study area in summer rather than having genetic or absolute abundance implications.

## 3. Results

### 3.1. Photographic Survey

Risso's dolphins were photographed during 24 encounters (**Table 1**) mostly in shallow waters (<50 m; **Figure 2**). The group-size encountered during photo-ID surveys ranged from 1 to 12, but generally was between 1 and 6 dolphins (mean 5.43; SD 4.25,  $n$  12); hence, photographing all dolphins in a group was usually readily achievable although not always on both sides of all dolphins. A wide variety of natural markings were observed including 1) white and dark teeth rake scars; 2) epidermal lesions; 3) linear, parallel and/or crossed marks; 4) circular, irregular well-shaped, or smoothed depigmentation patterns; 5) nicks; and 6) healed wounds (**Figure 3**).

**Table 1. Information on Photo-ID encounters, Sightings (S), Individuals (IND) and dedicated (line-transect) boat days.**

Year	Month	Photo-ID encounter	Boat-based survey	
			Number of Survey days	S (IND)
1997	July	1 (20 July)	1	1 (10)
1999	Aug	0	3 (11 - 18 Aug)	0 (0)
2000	Sept	5 (3 - 9 Sept)	5 (3 - 9 Sept)	5 (16)
2001	Aug-Sept	1 (29 Aug)	2 (2, 11 Sept)	1 (15)
2002	Aug	1 (19 Aug)	3 (15 - 16, 28 Aug)	1 (15)
2003	July	0	2 (16 - 17 July)	1 (1)
2004	Aug-Sept	3 (31 Aug)	2 (31 Aug, 5 Sept)	3 (22)
2005	Sept	3 (1 - 12 Sept)	2 (12, 14 Sept)	3 (28)
2006	Sept	7 (11 - 17 Sept)	1 (16 Sept)	7 (67)
2007	Aug-Sept	3 (24 Aug)	2 (24 Aug/22 Sept)	3 (16)
Total	July-Sept	24	23	25 (190)



**Figure 3.** Natural markings of Risso's dolphins, including nicks; different shapes of dorsal fins; healed scars from wounds; and teeth rake scars. A photograph of a new-born calf (with foetal folds) is also shown (photographs © WDC).

### 3.2. Mark-Recapture Based Abundance Estimate

Forty-six dolphins had distinct permanent scars (well-marked) on their dorsal fins (27 left sides and 29 right sides). We adopted a “closed” population model using data for the whole survey period (1997-2007). The best model was the closed jackknife estimator  $M(h)$ . Other models that tolerate behavioural and innate differences in capture probabilities were also explored but did not yield high criteria values.

Using CAPTURE and taking into account the proportion of well-marked vs unmarked dolphins in the population, we produced abundance estimates for left and right sides separately. We estimate that a total of 121 dolphins

(left sides; 64 - 178, 95% CI; CV 0.24) and 145 dolphins (right sides; 78 - 213, 95% CI; CV 0.24) occur in these waters in late summer (Table 2). The estimate for left sides had a criteria value equal to one and was therefore regarded as the best estimate (Table 2). The rate at which new (well-marked) dolphins were identified throughout the study period is shown as the discovery curve which has a steady increase over time (Figure 4). The dolphin sightings were expressed by field-season (summer) and 25% of the total dolphins had been identified after the third year and 86% had been identified by the end of the seventh year (Figure 4).

### 3.3. Census Technique Based Abundance Estimate

A total of 59 well-marked and 124 subtle-marked dolphins were identified. Some duplication may have occurred because during the long study-period some of the subtle-marked animals may have changed in appearance. The minimum annual total numbers of individuals seen in Bardsey waters based on marked individuals alone ranged from 4 to 28 animals (Table 3). In 2005 and 2006 these numbers were the highest (Table 3). There was no positive correlation between the number of photo-ID surveys carried out and the minimum number of animals identified in each year (Spearman's rank order correlation:  $r_s = 0.586$ ,  $n = 8$ ,  $p = 0.127$ ). In total, 103 recognizable individuals were photographed of which 24 were photographed on both sides, 66 on left and 61 on right sides (Table 3). This means that an estimated minimum of 90 (assuming all 61 right sides correspond to the 66 left sides) and a maximum of 151 (supposing that all left and right sides are from different animals) dolphins occur off Bardsey in the late-summer months. A total of 11 different calves were photographed representing 10.7% of photographed individuals.

### 3.4. Site Fidelity and Associations

Throughout the study, 11 individuals were re-sighted at least once and thus the re-sighting rate represented 18.6% of the total number of well-marked animals. Intervals of time between sighting and re-sighting ranged from 347 to 3345 days (9.16 yrs), and the distance separating the

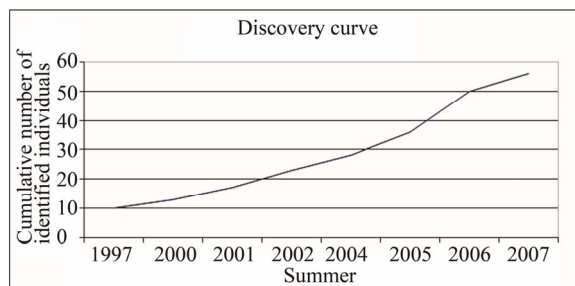
**Table 2.** Mark-recapture estimates of Risso's dolphin abundance during the summer months off Bardsey Island based on dorsal fin photographs showing left sides (LSD) and right sides (RSD).

	Animal captures	$p$	Criteria value for $M_h$	$\hat{N}(WM)$	CV	95% CI	$\theta(WM)$	$\hat{N}_{Tot}$	95% CI $\hat{N}_{Tot}$	Se $\hat{N}_{Tot}$	CV $\hat{N}_{Tot}$
LSD	33	0.07	1	58	0.21	43 - 91	0.48	121	64 - 178	29.01	0.24
RSD	34	0.06	0.81	76	0.21	54 - 117	0.52	145	78 - 213	34.33	0.24

$\hat{N}_{Tot}$ , total abundance; WM, well-marked individuals;  $p$ , probability of capture;  $\theta$ , proportion well-marked individuals; CV, coefficient of variation; se, standard error; CI, upper and lower bounds of the 95% confidence interval;  $M_h$ -model type.

**Table 3. Total population size using the number of marked dolphins for each survey year. The total minimum is calculated as the highest number of either left or right sides (under-lined) together with the total number of dolphins photographed on both sides. The total maximum is estimated supposing that all left and right sides are from different animals.**

Survey year	Left sides	Right sides	Both sides	Total minimum	Total maximum
1997	3	<u>7</u>	0	7	10
2000	<u>4</u>	3	0	4	7
2001	2	<u>4</u>	0	4	6
2002	4	<u>4</u>	2	6	10
2004	5	<u>9</u>	2	11	16
2005	14	<u>15</u>	13	28	42
2006	<u>25</u>	11	3	28	39
2007	<u>9</u>	8	4	13	21
Total	<u>66</u>	61	24	90	151



**Figure 4. Discovery curve of the cumulative number of well-marked Risso's dolphins per summer (1997-2007) in the waters around Bardsey Island.**

sightings ranged from 2.39 - 17.24 km. Two adult dolphins seen together in 1997 were again seen together in 2006. A mother and calf identified in 2005 were subsequently seen in 2006. Two adults within a group seen in 2001 were again seen in 2006, although not as part of the same group.

### 3.5. Range

Photographs were received from colleagues working elsewhere within Cardigan Bay. These images were matched against the Bardsey Island photo-catalogue and a total of eight matches were made. One dolphin was photographed in 2004 (by J. Baxter), then in 2005 (this study) and finally again in 2009 (by R. Crossen). The distances between the re-sighting locations were 124.6 and 132.23 km respectively from Bardsey Island. The time periods between re-sightings were 454 to 1,476 days. Another dolphin photographed off Bardsey Island in 2006 and 2007 was subsequently photographed (by H. Jones) 319 km further south (off Cornwall, SW England), 995 days later in 2009.

### 3.6. Boat-Based Survey-Sighting Rate and Group-Size

Line-transect boat effort was carried out over 630.5 km (49.13 hrs) during which the waters around Bardsey Island were systematically covered every year between 1999-2007, except for 2006 (**Figure 2**).

A total of 12 Risso's dolphin sightings were made, totaling 51 dolphins. The estimated sighting positions were plotted using the radial sightings distance and bearing (**Figure 2**). The abundance using standard line-transect (distance) techniques could not be estimated due to low sample size. The sighting rate was  $0.081 \text{ dolphins km}^{-1}$  and the group size averaged 5.42 individuals (SD 4.25,  $n = 12$ , range 1 - 12).

## 4. Discussion

Due to inclement weather conditions most photo-ID surveys were opportunistic, *i.e.* not conducted whilst doing line-transect surveys, and were carried out to complement the dedicated surveys by enhancing our chances of photo-identifying the dolphins when they were close to the island. The opportunistic photo-ID surveys were typically launched when Risso's dolphins were spotted from one of the four look-out points on the Island. It also proved useful to leave a small group of observers behind on the island who would continue to scan the waters around the island when the opportunistic boat surveys were carried out. Those land-based observers were then able to give directions as to where other pods of dolphins were present within the area. In that way we could ensure that all (sub) pods of dolphins were approached for photo-ID purposes.

#### 4.1. Abundance Estimates

Dolphin abundance was estimated using two different analytical methods. The census based technique indicated that the minimum population size of the dolphins occurring in these waters was 90 - 151 individuals.

Using the mark-recapture based technique, we estimated that during the late summer months at least 121 dolphins occur in these waters. The relatively close agreement between the left (121) and right side (145; both with a CV of 0.24) estimates supports the reliability of this estimate. This estimate matches the estimate calculated with the census based technique. We are of the view that the census based estimate provides the least biased estimate. This is based on the uncertainty about the extent to which the assumptions for an appropriate application of the mark-recapture technique were met as will be elaborated upon in the following section.

We aimed to ensure that our mark-recapture techniques met the appropriate assumptions for the estimates generated to be valid. Most of our boat surveys were opportunistic bringing along an irregular photo-ID survey effort. There was no correlation between the number of surveys conducted and the number of individuals identified and this indicates that the likelihood of recapture was not affected by irregular survey effort. The assumption that all individuals have the same probability of capture within a sampling session was difficult to assess as dolphins may have different preferences for particular areas which varies between individuals. Such differences in capture probabilities can negatively bias the estimates. However, the jackknife model used takes this into account as it assumes that each individual has its own probability of capture and that over time these probabilities do not change [18]. This model accounts for variations of heterogeneity such as age or sex of an individual as well as the preferences of particular animals for certain areas and/or individual boat attraction or avoidance. The jackknife estimation procedure [21] is most commonly used for estimating animal abundance and is regarded as fairly robust [18,22]. However, negative bias will still occur if some members of the population are uncatchable [18]. A violation in the assumption that well-marked animals do not demonstrate behavioural responses affecting the probability of their recapture can lead to under- or overestimates. Such violations seemed unlikely in this relatively non-invasive photo-identification study where no physical interaction occurred (avoiding “trap-shy” scenarios). We aimed to photograph all individuals within groups in order to avoid over-estimating capture probability and as a consequence under-estimating abundance [23]. We used photographs of dolphins with distinct marks on the dorsal fin only, so we could assume that the well-marked animal was recog-

nised with certainty during “recapture” and avoid missing matches which leads to over estimations [19]. The assumption that marks do not change to the extent that they affect subsequent recognition was likely not to be violated because photo-ID techniques have been shown to be a good tool for individual identification of Risso’s dolphins [10]. We aimed to meet the assumption that population changes through births, deaths and movements were minimal. “Closure” is therefore only a reasonable assumption when studies are of relatively short duration. In the present study, sufficient data were only available to allow the use of “closed-population” models. The fact that the two different analytical techniques using different data sets produced similar population estimates, corroborates our use of the closed-population model.

Adults have heavier body scarring and may therefore be overrepresented in the group of well-marked individuals. Calves and sub-adults with little scarring were also encountered and the apparent increase in the discovery curve (**Figure 4**) can be explained by recruitment of (scarring) sub-adults into the well-marked population. The discovery curve (**Figure 4**) should be interpreted with care as the curve was still on an incline with seven new individuals added to the catalogue in the final season (2007) and indicates that more effort is required. Despite the limitations discussed above, the research successfully added new insights to the status of Risso’s dolphin in UK waters.

Whilst large-scale line-transect cetacean studies in the western Atlantic have resulted in Risso’s dolphins abundance estimations, this has not been hitherto possible for eastern Atlantic waters due to low sighting numbers. A preliminary mark-recapture abundance estimate was calculated for Risso’s dolphins in the Ligurian Sea (Mediterranean) of 242 dolphins (right-sides) and 267 dolphins (left-sides) for a large study area (24,000 km<sup>2</sup>; [11]). The only abundance estimates in European waters based on aerial line-transect methods refers to the waters east of Spain (32,270 km<sup>2</sup>; 493 dolphins; CV 0.61) with a minimum density of 0.015 dolphins km<sup>-2</sup> [6]. Another survey reports a line-transect abundance estimate for Risso’s dolphins in the northwestern Mediterranean (143,000 km<sup>2</sup>) of 2360 dolphins with a minimum density estimate of 0.018 dolphins/km<sup>2</sup> [5]. In the present study, Risso’s dolphins were encountered within a relatively small area (795 km<sup>2</sup>; **Figure 2**). With the present abundance estimate of 121 dolphins, the density of the present study is 0.15 dolphins/km<sup>2</sup>. This is ten-fold higher when comparing this to the line-transect survey estimates of [5,6] but it should be noted that the area used in the present study was relatively small. Nevertheless, compared to these studies, the estimated numbers of dolphins in our study area indicate that this area can be considered an important habitat for Risso’s dolphins.



The line-transect boat-surveys alone did not achieve high enough sample size to allow for dolphin abundance to be estimated using distance-sampling techniques. The dolphins were seen foraging in localised shallow hotspots [15] and this may have impacted the chances of detection during the line-transect surveys.

#### 4.2. Site Fidelity and Associations

Site-fidelity of Risso's dolphins, expressed in re-sighting rates, was measured in our study at 18.6%. This is comparable to studies in the northwestern Mediterranean where 9.2% - 15.7% has been found [24]. In other areas higher re-sighting rates were observed: 63% in the Azores [10] and in the Ligurian Sea [25], and 37% off Scotland [14]. Individuals have been re-sighted up to 5 years in the Mediterranean (e.g. [24,26]). In the present study, one pair of dolphins was re-sighted nine years later. Preliminary studies in the Mediterranean and off the Canaries report strong associations of Risso's dolphins over a period of 3 - 4 years (e.g. [26]) and similar findings were reported off the Azores [10].

#### 4.3. Long-Distance Match

One long-distance re-sighting was made in the present study (319 km). In the Mediterranean Sea, Risso's have also been re-sighted over quite long distances (164 km; [24]). One Risso's dolphin which stranded in the Gulf of Mexico was subsequently released and satellite-tagged and traveled over 3300 km in 23 days [27]. Considering their seasonal occurrence and comparatively low re-sighting rates around Bardsey, it is to be expected that "Welsh" Risso's dolphins travel over large distances.

### 5. Conclusions

The Risso's dolphin is a relatively difficult species to study: difficult to approach and, in our experience, are relatively shy and as deep divers often disappear underwater for long periods of time. In addition, the number of days that could be spent in the field was limited because of the local conditions. The Welsh name for Bardsey translates as "island of the tides" and the waters around the island are notorious for fast water movements that make even transport to and from the island difficult. Difficult working conditions in the field, an elusive focal species and sometimes a limited budget will not be unique to this study area, so the question is opportune as to whether data gained in this study are still of value as a demonstration of its applicability to obtain information on marine mammals in other remote areas or less well studied species.

As pointed out by [23], opportunistic photo-ID data sets need to be viewed with caution in order to produce

data appropriate for robust population assessment. The main limitations identified in the present dataset were 1) the discovery curve indicating that the population had not yet been sufficiently sampled after 11 years of study; whilst 2) the longevity of the study period (1997-2007) did not fully justify the application of mark-recapture methods based on a "closed population" model. An "open population" model may be more appropriate to the study of these animals, given the apparently transient nature of the Risso's dolphins that appear annually in the study area and the obvious births and presumed deaths occurring during the study years. However, that approach would also require a great deal more data from each year, as it would effectively require a "closed population" estimate to be generated from each summer and we strongly recommend this for future studies with a similar set-up. On the other hand, continuing the photo-ID work on Risso's dolphins will increase sample size and allow studying estimates of survival, recruitment and population trends using "open" population models. Comparisons of photo-ID catalogues from other hotspots may add valuable information and allow us to work out where these Risso's dolphins reside in other seasons. This would also add to our understanding of the wide-scale movements of Risso's dolphins throughout the region and possible connections between different parts of the meta-population. Furthermore, comparisons to other such catalogues may add valuable information, for example, by providing information on individuals that have disappeared from other study sites, on animals that have changed appearance, or on new calves.

This study emphasizes the benefits of (small-scale) opportunistic photo-ID studies in yielding important information for conservation management purposes (*i.e.* assessments of population status and trends). The study also highlights the practical difficulties of studying such irregular but seasonal aggregations of a relatively scarce species and explores alternative methods of analysing sparse opportunistic data.

We conclude that this dataset provided new information regarding the minimum number of dolphins that frequent these coastal waters during the summer months, and that the opportunistic boat surveys complemented the dedicated line-transect surveys by increasing the sample-size of the number of identified dolphins. In addition, the outcome of the mark-recapture based technique could be further improved by focusing on 1) a shorter temporal periodicity; 2) a higher sample effort per year; and 3) applying subsequently a "closed-population" analysis.

From the conservation perspective, these studies confirm the presence of Risso's dolphins in these waters on a regular basis. The indications so far are that the population is relatively small, but the regular presence of calves shows breeding. There is a variety of conservation initia-



tives being progressed in Cardigan Bay and the North Wales area, particularly regarding the designation of various marine protected areas. However, none at this point specifically take the Risso's dolphins into account. Our study shows the Bay to be important for the elusive and little known Risso's dolphin, which should provide additional incentive for regional conservation strategies.

We estimated that during the late summer months at least 121 dolphins occur in these waters. The relatively close agreement between the left (121) and right side estimates (145; both with a CV of 0.24) supports the reliability of this estimate and closely matched the census technique estimates (population size of 90 - 151). The study furthermore revealed that Risso's dolphins show regular seasonal occupancy in these waters with some dolphins showing site-fidelity comparable to but also differing with results measured in other studies on this species. Movement to and from the study area is evident and at least part of the population of dolphins returns to these waters. The long distance match of 319 km shows that Risso's dolphins can range widely. The waters around Bardsey Island may be part of a network of localities that are important to this species where it may take advantage of prey abundance in shallow waters. The existence of such localities has important implications in the design of conservation actions [28] and requires a more dynamic species conservation approach.

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