A photo-ID study of the Risso’s dolphin (*Grampus griseus*) in coastal waters of Anglesey, along with the environmental determinants of their spatial and temporal distribution in the Irish Sea.

(For submission to the Journal of Marine Biological association of the UK)

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science (MSc) in Marine Environmental Protection.

By Diksha Shyam Mandlik

MSc Marine Biology (Pondicherry University, 2019)

Supervisor: Dr Peter GH Evans

Submitted in September 2021

School of Ocean Sciences

Bangor University

Menai Bridge, Isle of Anglesey LL59 5AB

www.bangor.ac.uk

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Author: Diksha S. Mandlik

Address: School of Ocean science (Bangor University), Menai Bridge, Isle of Anglesey LL59 5AB

Email address: dkm20sgy@bangor.ac.uk

Abstract: *Despite of Risso's dolphins being regular visitors in waters around the British Isles, their ecology, distribution, and life processes remain largely unknown. The regularity of their occurrence can be attributed to favourable biotic and abiotic (environmental) cues present in the region. The considerable number of sightings occurring in coastal Anglesey is a subject of significance, as the considerable interest is being shown in the broader area as potential marine renewable energy development site due to the high tidal energy environment. In the light of adverse conditions that are being faced by cetaceans globally due to climate change, designing policies for effective conservation management is quintessential, which requires in depth knowledge about the species' population ecology and distribution.*

The technique of photo identification, being non-invasive and facilitative, has been popularly used to assess cetacean ecology. The present study identified 105 individuals sighted in Anglesey waters by the Sea watch Foundation during 2014 and 2021, with a site fidelity rate of 16.19% and the longest record of Risso's home range observed by the SWF. The sighting data collected by the SWF during 2003-2021 was correlated with environmental parameters such as bathymetry, slope gradient, sediment profile, underlying benthic habitats and energy profile of the region to understand ecological drivers influencing the distribution of species in the area. The studied population was seen to prefer a depth of 10-80 meters, 4.5^o to 6.75^o slope, hard to coarse sediment, comparatively more productive habitats such as reefs and a high energy environment.

Keywords: Risso's dolphin, *Grampus griseus*, photo identification, habitat preference, Wales, abundance.

INTRODUCTION

The Risso's dolphin (*Grampus griseus*) (Cuvier, 1812) is probably the least known of all marine mammal species occurring regularly in British waters (Evans *et al.,* 2003; Evans & Waggitt, 2020). They belong to the family Delphinidae of order Cetacea. Food availability and suitable conditions for breeding tend to influence Spatio-temporal variation in animal distribution. Records from the eastern Atlantic indicate that the species ranges throughout the European waters, and the present northern range limit is at the Faroe Islands (~62°N; Bloch *et al.,* 2012) and central Norway (~64°N; N. Øien, pers. comm. in Jefferson *et al.,* 2014), with one verified record even from northern Norway at ~69°N (D. Zanoni, pers. comm. in Jefferson *et al.,* 2014), the latter record being considerably further north than the others, and thought to be extra-limital by Jefferson *et al.,* (2014).

Despite their global distribution, occurring in every major ocean (viz. Atlantic, Indian, and Pacific) of the world except the Southern Ocean (Kruse *et al.,* 1999; Jefferson *et al.,* 2008; Baird, 2009), information on the distribution and habitat preferences of Risso's dolphins seems inconsistent (Jefferson *et al.,* 2014). At a European level, the species recorded by IUCN as Data Deficient (Hilton-Taylor, 2000). The species is uncommon in UK shelf seas with a very patchy distribution (Reid *et al.,* 2003; Baines & Evans, 2012; Hammond *et al.,* 2017), apparently returning to areas year after year whilst being largely absent elsewhere (De Boer *et al.,* 2013; Stevens, 2014). In the UK, the peak season for sightings of this species has typically been late summer (July to September) – the warmest months of the year (Evans *et al.,* 2003; Evans, 2008). However, recent, more extensive, visual, and acoustic surveys in all seasons indicate that at least some individuals can be found in these waters year-round (Evans & Waggitt, 2020). Peak sightings of Risso's dolphins are seen between April and November in Irish waters, but they are mostly absent from Irish shelf waters otherwise (Wall *et al.,* 2013).

The birthing period of the species varies geographically, but around the UK appears to be mainly between March and July (Evans *et al.,* 2003; Evans, 2008). During these times, social groups are often observed. Risso's dolphins form small to medium-sized pods of 2-50 animals at most European locations where they have been studied (Kruse *et al.,* 1999; Evans, 2008; Bearzi *et al.,* 2011). Group size is typically of 6-12 individuals around the British Isles, although aggregations of fifty or more have also been reported (Evans *et al.,* 2003; Evans, 2008). The pods are potentially associated on the basis of same gender, similar age, similar reproductive status or genetic relatedness (Wells *et al.,* 1987). Kruse (1999) described that female and calf pairs formed intimate social bonds that lasted at least 11 months. The species is often seen cohabiting with other cetacean species in the same area, phenomenon known as 'habitat segregation/partitioning' that possibly results from interspecific competition for food (Azzellino *et al.,* 2008).

The classification of this species, whether tropical or temperate, is still debated. Leatherwood *et al*. (1980) and Davies (1963) regarded the Risso's dolphin as a tropical species and those temperate waters marked the limit of their range, whereas Kruse (1989) characterized it as a temperate species. The difference of opinion relates to the fact that Risso's dolphins, unlike most other small cetaceans that show a marked preference for either cold or warm water, inhabit tropical (e.g., around the Maldives, Sri Lanka, Taiwan) as well as warm temperate waters (around the Azores, Mediterranean Sea and California), and cool temperate seas (e.g., the UK) (Evans 2008; Jefferson *et al.,* 2014).

The other major enigmatic finding is the apparent discontinuous distribution of the species, with no consistent preference for a specific habitat. Several apparent hotspots have been identified around the British Isles coasts; these include the Northern Isles, Hebrides, around the Isle of Man, northern Anglesey, western end of the Llŷn Peninsula, west of Pembrokeshire, and west Cornwall (Evans *et al.,* 1993; Atkinson *et al.,* 1998; Weir *et al.,* 2001; Reid *et al.,* 2003; Baines & Evans, 2012; Dolman & Hodgins, 2013; de Boer *et al.,* 2014; Evans & Waggitt, 2020).

Various abiotic (i.e., climate, physical and chemical environment, morphology, and geological characteristics) and biotic (productivity of the region which influences prey distribution) characteristics of the local marine environment determine the distribution of cetaceans in an area (Borcard *et al.,* 1992; Jaquet, 1996; Lusseau *et al.,* 2004). From a simplistic view, these cues govern the primary production in the area (Takao *et al.,* 2012), which in turn, define the prey abundance (Bearzi *et al.,* 2011).

Risso's dolphins are known to favour areas that are topographically well-defined, predominantly the upper continental slope, and are seen to occupy areas of high seafloor relief. Although Risso's dolphins are seen to aggregate around the continental slope and outer continental shelf waters, there are many records of the species occupying offshore oceanic waters. Continental slopes are considered as areas of high productivity that can support the species in higher densities (Yen *et al.,* 2004; Wells *et al.,* 2009). The species exhibit a strong preference for mesopelagic cephalopods (Hartman *et al.,* 2008); the periodic pattern of concentration of pelagic zooplankton in the waters adjacent to the slopes provides an ample food source for cephalopod predators, which could be the probable reason for the predilection of species towards the upper slope area (Azzellino *et al.,* 2008; Azzellino *et al.,* 2012).

Water masses of different temperature converge to form oceanic fronts (Miller & Christodoulou, 2014), resulting in elevated primary and secondary production, high biodiversity, and localized abundance of pelagic predators (Hyrenbach *et al.,* 2000; Miller, 2012; Miller & Christodoulou, 2014). These oceanic fronts regularly occur in UK shelf seas (Miller & Christodoulou, 2014), and have been found to sustain numerous biodiversity hotspots that support high cetacean abundance. As these fronts occur seasonally in nature, the sightings of Risso's dolphins could be seasonal (Gannier & Praca, 2006).

Along with physiography, water temperature heavily influences the distribution of cetaceans. Risso's dolphins prefer areas with sea-surface temperature (SST) exceeding 10^{o}C, but commonly inhabit waters measuring 15–20^{o}C (Kruse *et al.,* 1999, Baird, 2002). The preferred depth for Risso's dolphins in tropical waters is thought to be around 200-1000 meters (de Boer *et al.,* 2014; Hartman, 2018). By contrast, the species has shown a preference for waters of just 50-100 meters depth around the UK coast (Reid *et al.,* 2003; Evans, 2008, 2020; Wall *et al.,* 2013). They also have been sighted in waters 30–40 m, and occasionally around 7 m deep (de Boer *et al.,* 2013). This can be attributed to the relatively wide continental shelf around the British Isles and Ireland (Evans & Hammond, 2004).

The seafloor gradient is also thought to be an influential factor in determining the local productivity, and a few studies report that Risso's dolphins favor relatively steep bottom gradients (Baumgartner, 1997; Cañadas *et al.,* 2002; Azzelino *et al.,* 2008). Jefferson *et al.* (2014) attributed the past reports of the abundance of these animals to areas around continental or insular margins to possible sighting biases and concluded that the distribution of the species is not constrained to those margins.

The skin pigmentation of Risso's dolphins differs as the animals advance in age (Figure 1). At birth, the calves are greyish brown, and develop into grey-colored adults. White scars are accumulated by adults as a result of intraspecific and interspecific (with other cetaceans) interactions (Figure 1) that can also attributed to parasites and cephalopod prey (McCann, 1974; Lockyer and Morris, 1990; MacLeod, 1998).

Photo-identification (photo-ID) of individuals in a population has been a popular non-invasive technique typically applied to analyze distributions in space and time, and population dynamics of species (Hammond *et al.,* 1990). The most common use for photo-ID studies have been to ascertain area distribution, short-term movement patterns and group fidelity (Norris *et al.,* 1985; Wells *et al.,* 1990).

Identification studies are possible in cetaceans that show the tendency to retain these markings over time. Along with Risso's dolphins, this permanency of body markings is observed in other cetaceans like narwhals, sperm whales, and some beaked whale species (MacLeod, 1998). Photographic assessment of the body markings is one of the most widely and efficiently used non-invasive methods to collect ecological data about the population, age, and social structure of Risso's dolphins and other marine mammals (Fearnbach *et al.,* 2011).

Any changes in marks over time are an important aspect of identifying animals based on scarring. Individuals' scars may change appearance if additional marks are inflicted as a result of social interactions that occur between the year of original identification and resighting. Markings, as well as nicks and cuts defining the outline of the fin/fluke, may change for similar reasons. As was seen while assessing mark-recaptures for this study, marks (and nicks) may shift positions, especially as the animal grows from young/juvenile to adult (Figure 2). It is advised not to depend much upon patterns of colouration as the pigmentation is subject to change over time due to age or might alter upon gathering of scars over it.

The behavioural tendency of animals to return to a previously occupied area is termed as site fidelity (Switzer, 1993). The site fidelity of cetaceans is often assessed through photo-ID studies, as movement patterns on a wider scale can be efficiently established through re-sighting of individuals in the area (Würsig & Jefferson, 1974; Leatherwood *et al.,* 1980). Stronger site fidelity is considered an indicator a resident individual or population (Hartman *et al.,* 2008), although it might simply be reflective of the animal's or population's repeated return to an area, which may have a seasonal component to it. Based upon recaptures, David & DiMéglio (1999) and Casacci & Gannier (2000) have observed long-term (interannual > 3 years) site fidelity in Risso's. The site fidelity differs temporally, with changing seasons.

Mark-recapture methods were initially developed for studies that intended to physically capture individuals and release them after marking (painting, branding, mutilating, tagging), and then recapture (Evans & Hammond, 2004). To overcome the invasiveness of this method, mark recapture method started being used to assess photo-ID data to study movements and population parameters of cetaceans (Hammond, 1986, 1990a). The mark-recapture part is achieved through photos of individuals captured on a minimum of two sampling occasions.

Cetaceans and their habitats are protected in European waters by number of legislations, conventions, treaties, and agreements. the establishment of Marine Protected Areas (MPAs) is progressively being used as a management tool (Villa *et al.,* 2001; Lubchenco *et al.,* 2003; Palumbi, 2004; Evans, 2008). In spite of the notable progress that is being made in allocating areas as MPAs, the processes of site identification, management and monitoring have remained informal, making it much less effective (Evans, 2008).

Despite detailed studies that have been conducted and are being conducted, there are still severe lacunae in our understanding of this species. Understandably so, as data collection for the cetacean species is quite tough (Compton *et al.,* 2007; Kiszka *et al.,* 2007), because most of them are highly mobile, spending most of their time below the surface, making detection, identification, and group size estimation challenging (Redfern *et al.,* 2006). Weather, as well as the state of the sea, also alter the detectability of cetacean species (Hammond *et al.,* 2002). Conservation efforts largely are dependent upon accurate data on species distribution, population size and impacts of global environmental changes, which makes it necessary to continuously monitor populations of various plant and animal species (De Boer *et al.,* 2013; Zemanova, 2020).

The species is known to undertake summer migrations; however, the exact locations to where they travel, and thus the exact distance for which they migrate remains lesser known (Leatherwood *et al.,* 1980; Casacci & Gannier, 2000; Evans *et al.,* 2003; Hartman *et al.,* 2008; de Boer *et al.,* 2013).

Records of Risso's dolphins in particular areas within UK waters (Evans *et al.,* 2003; Reid *et al.,* 2003), around the Mediterranean (Azzellino *et al.,* 2016) and in the Azores (Silva *et al.,* 2003; Hartman *et al.,* 2008), may simply correspond to areas of greater study (Jefferson *et al.,* 2014). Similarly, around the world the patchy recorded abundance of the species could be effort-based and thus may differ from its actual abundance. Attempts to address such potential biases include the use of stranding data in such studies, which found to be useful to detect the presence of this species in Hawaii (Maldini *et al.,* 2005) and the eastern North Pacific (Pyenson, 2010). However, stranded animals are often unhealthy and may have strayed some distance from the actual location where they usually reside (Fraser, 1949; Worthy *et al.,* 1993; Chit *et al.,* 2011).

Jefferson *et al.* (2014) regarded the available range maps in the literature as 'hypothesized ranges', being largely prediction-based. They concluded this as the maps were generally made from interpreted habitat preferences and then further derived potential rather than actual distributions. This inferred indication of species status has been widely propagated through the scientific literature. Where theoretical research is not reinforced by appropriate practical efforts, the risk of inaccurate or misleading information being carried forward, increases. This should be carefully considered, as the identification of conservation measures and thus implementation of mitigation measures is completely dependent upon spatial and temporal patterns of cetacean abundance (Evans & Hammond, 2004).

Globally, the Risso's dolphins' habitats are being afflicted to various anthropogenic disturbances, including material pollution, increased direct and indirect interference; noise pollution is one of the major disturbances (through recreational and commercial vessel traffic, seismic surveys, pile driving, military, and industrial sonar, etc.). Their exact effects upon the species are not known certainly, however, a few cases of negative responses from disruption by recreational activities have been observed in Scotland (P.G.H. Evans, *personal observations*), Italy (Miragliuolo *et al.,* 2004), and the Azores (Visser *et al.,* 2006; Oudejans *et al.,* 2007). Gas embolisms through bubble formation causing mild to severe tissue injury have been linked to exposure to mid-frequency active sonar exposure, which is often used for Naval purposed (Fernandez *et al.,* 2005). This gas embolism was observed in a Risso's dolphin stranded on the North Wales coast in 2009 (Deaville & Jepson, 2011), but the death wasn't definitively attributed to gas embolism.

Several sites around the Welsh coastline are characterized by strong tidal range resource, high tidal current energy, and a spatially limited wave energy resource, which is attributed to narrow channels in and around the headland (such as to the West and North of Anglesey and off the Pembrokeshire coastline) (Roche *et al.,* 2016). These sites are considered potential areas of interest for the development of offshore renewable energy. Off the coast of Anglesey, a tidal stream array (10 MW) project is under construction, a Tidal lagoon extending from Llandudno to Prestatyn is proposed, and the 'Morlais' tidal energy project (240 MW) managing a 35 km^2 of seabed off the Holy Island coast has been approved (Marine Energy Wales). Despite this, in Welsh waters, no protected areas exist but a key hotspot for Risso's dolphin occurs in North Wales between Bardsey Island and the north coast of Anglesey, that overlaps with these sites of special interest.

Because of its conservation status, the Scottish Government has designated a Marine Protected Area for the species in the Outer Hebrides. The reasons for its distinct discontinuous distribution remain unknown. However, this information would enable potential impacts from environmental change and offshore constructions to be better identified. Ultimately, the relative significance of different conservation threats should be evaluated on a regional scale, and implementation of potential marine protected areas for the species should be considered.

The present study hopes to aid conservation of Risso's dolphins through analysing home ranges, site fidelity and Spatio-temporal species distribution which might help in increasing the current understanding of Risso's dolphins and their ecology. The objective of photo-identification, upon completion, will add to the current database from SWF and will be helpful when referred to by potential similar studies.

METHODOLOGY

The focus of this study was the Irish Sea, although coastal waters of the UK encompassing other areas are also considered (Figure 3). The study is divided into three key parts: i) photo-identification of Risso's dolphins, ii) determining site fidelity and home ranges of identified individuals, and iii) ascribing causal environmental factors to the observed distribution of the population.

The method of photo identification was used to assess spatial distribution, short-term movement patterns and site fidelity in Risso's dolphin population around the Isle of Anglesey. The photographs for identification purpose were acquired from the Sea Watch Foundation (SWF). This collection was obtained between 2003-2021 from the Welsh coastal waters. With the objective of producing a catalogue of sighted individuals and examining if any individuals were sighted repeatedly over the years, a total of 2483 images were processed.

The pre-identification processing of the photos was carried out based upon the methodology described by Gowans & Whitehead (2001). For recapture analysis, images were selected only when they were of sufficient quality to ensure that identifiable features could be recognized. The criteria for pre-identification categorization were picture clarity, exposure, and angle at which fins were captured in the image. The photographs were distinguished on a scale of 6 (Q1-Q6, Q1 being of lowest quality and Q6 being of highest quality) (Table 1). The images of quality Q3 and above were processed further; this decision was made in accordance with the photo-ID of white sharks conducted previously by Towner *et al.,* (2013). At times, images of lower quality were also considered, for the lack of a better option, so long as the body marks were distinguishable.

The selected photographs, as required, were edited using photo-editing software GIMP (GNU Image Manipulation Program) 2.10.24. The process of enhancement was carried out on an individual basis, and involved magnifying the images, cropping them, altering brightness/ contrast/ saturation/ hue for better identification prospects, sharpening them as required and removal of background in certain cases where the view of the individual to be identified was obstructed by the others.

The individuals were given catalogue numbers according to the last two digits of the year that they were last seen, followed by the code for the location where they were sighted, followed by the year-wise serial number. For example, the third individual sighted in year 2020 at Point Lynas was denoted as "20PL03". Similarly, the code for Anglesey (generalized) can be found as AN, WF for Wylfa, and BB for Bull Bay. The details of the sighting, including date of observation, marking type (nicks or scars or both), description of the marking, maturity stage (calf, adult or juvenile), and sex were noted as well. Heavily scarred individuals were provisionally identified as adults and males, whereas individuals sighted with calves in proximity, particularly if they were re-sighted over the years with calves, were noted as females. Heavily marked individuals appearing nearly white were noted to be mature, and juveniles were distinguished by darker hues and scant markings. The individuals that were sighted twice or more were termed as 're-sighted'. The rates of re-sighted individuals were used to calculate a measure of 'site fidelity' (de Boer *et al*., 2014; Stevens, 2014), which was expressed as the percentage of individuals sighted between 2003 and 2020.

Upon entering all the identified individuals into the database, the resulting matches were made and compared with previous records of Risso's dolphins around coastal waters of the UK and Ireland. The re-sighting coordinates were plotted in ArcMap 10.7.2 to give a measure of the distance covered by them which helped in determine 'home ranges' for those individuals. The sightings data for Risso's dolphins were obtained from the SWF database covering the years 2007 to 2021 and were assessed for monthly and annual trends in the occurrence of the species.

The best estimates of the group size seen at each of the sightings were plotted in ArcMap and were expressed according to the group size categories as 1-10, 11-20, 21-29 and 30-80. To investigate the determinants that make the study areas favoured by Risso's dolphins, the relationship with the following environmental factors were assessed: (i) bathymetry, (ii) slope gradient, (iii) tidal energy, (iv) sediment type at the seabed, and the underlying (v) benthic habitat type. The bathymetry grid data were obtained from the General Bathymetric Chart of the Oceans (GEBCO), and slope gradient was calculated using the 'Spatial analyst' tool in the ArcMap software. Tidal energy data, seabed sediment and benthic habitat data were obtained as polygon files from the European Marine Observation and Data Network (EMODNET), through the EMODNET EUSeaMap Pilot Portal.

RESULTS

Photo ID

Out of the 2483 total number of photographs taken between 2014 and 2021 in waters around Anglesey, 1874 were identified as Q3 or above and were processed further for identification purposes. In a few cases, when higher quality photographs were unavailable, and the identification marks were clear, lower quality photographs were used. A total of 105 individuals were identified and entered in a catalogue. From the available photographs, individuals were identified based on markings in the form of scars on the body and/or fin, as well as nicks on the fin including their relative positions. As the photographs were of either the left or right profile, the positions of nicks on the fin and the fin outline were manually matched to ascertain if the fins were of the same individuals. Six individuals in the catalogue are photographed from both profiles, but the rest are represented by the photographs of either their left or right side.

Out of the total of 105 individuals, 52 were identified as males or probable males due to the heavy body scarring, based on the fact that males tend to be more aggressive and are prone to rake other males with their teeth (Hartman, 2020); 11 individuals were identified as females or probable females due to the sighting of a calf alongside them. Two females ascertained in this way were sighted more than once, each time with a calf. The maturity stage was determined (whether adult or juvenile) according to the amount of scarring and the relative fin size (as compared to other individuals in the same photograph). Calves were easily identified due to much smaller fin size and grey or browner unmarked body; they were seldom sighted alone, as there was always an adult sighted with them with which to compare the fin size. Out of the catalogued animals, five were identified as juveniles or probable juveniles, four were identified as calves, and 73 as adults or probable adults.

Upon matching the records from 2003-2014 (Stevens 2014) with the current catalogue, 17 individuals were found to have been re-sighted over the span of 20 years, mostly around Anglesey waters, whilst a few were re-sighted as far away as Isle of Man (one individual), Bardsey Island (four individuals), and Cornwall (three individuals) (Table 2). Five individuals were sighted three times, and 12 were sighted twice. This makes the re-sighting rate to be 16.19%. The most re-sightings of 12 individuals were recorded in the year 2020. The geographical range travelled by the catalogued animals was plotted using ArcMap. The individuals sighted in Cornwall showed the longest migration recorded by Sea Watch up to now. The Risso's dolphin individual by catalogue name 21AN22 shows the greatest range recorded in this study, from Cornwall to the Isle of Man. It was also one of the individuals recorded across the longest period of time, with the sighting in the Isle of Man occurring in 2005 and the re-sighting in Cornwall in 2021.

Sighting data:

The sighting data obtained from the SWF provided records of Risso's dolphin sightings around Anglesey from 2003 to 2021; the data for the years 2004-2006 were unavailable. These sightings were obtained between the months of April to November through a combination of dedicated boat surveys, opportunistic sightings, and land-based observations. The total of 428 sighting events over these years recorded approximately 2883 individuals. The estimated number of dolphins recorded at each encounter varied from a single animal to a group of 80 individuals, but most pods, on an average, had a group size of 5-8 individuals (considering statistical modal and medial calculations), although the plotted data showed maximum groups to be of 11-20 individuals; this is in accordance with group sizes found elsewhere around the British Isles, where the most common group sizes were 6-12 individuals (Evans *et al.* 2003; Evans, 2008).

Upon reviewing the annual variations in sightings (Figure 4a), no obvious trend was observed. In 2020, the highest number of sightings (86) was recorded, followed by year 2015 (63), and year 2018 (58). The least number of sightings was recorded in the years 2003 and 2010 (one each). These observations do not follow any particular patterns and may simply reflect variation in sighting effort or spotting conditions in a particular year.

The trends in monthly sightings (Figure 4b) followed the observations of Evans *et al.* (2003) and Evans (2008) who reported the peak season for sightings of this species in the UK to be late summer to autumn (July to September), being the warmest months of the year. The sightings peaked between June and October (on average, 79 sightings and on average 550 individuals), with the highest number of sightings (185) and of individuals (1333 animals) observed in September. The months of September-October had the highest number of sightings (average 150) and animals (average 1084). By comparison, far fewer numbers of sightings and individuals were seen in April-May and in November (on average 12 sightings and 46 individuals respectively); the least number of sightings (6) and individuals (29) occurred in April.

Environmental Relationships

When plotted in ArcMap, the sightings were seen to be distributed around the coast of Anglesey, but a few areas were preferred and frequented more by the Risso's dolphins, than others. To understand the environmental drivers behind their concentration, parameters such as bathymetry, slope gradient, underlying seabed sediment type, Annex I benthic habitats, and tidal energy were assessed.

When the sightings data were plotted over the bathymetric features (Figure 5), it was observed that groups of Risso's dolphins were mostly sighted between areas with depths between 20 and 70 meters. They were seen to occur across depths of $\pm$ 10 meters of the range, since a few sightings were observed in 70-80 meters depth, and some in waters of 10-20 meters depth. The larger groups of 30-80 individuals were exclusively observed in shallow depths of 10-30 meters. No sightings occurred in waters >90 meters deep.

The slope gradient of the area (Figure 6) ranges between 0% and 35%, which relates to a slope of 0^{o} to 15.75^{o}. This indicates a moderate slope, mostly devoid of steep rises and falls. The sightings exclusively coincided with regions of 10% to 15% of slope gradient, translating to 4.5^{o} to 6.75^{o} slope. A few regions in the area have high slopes of 35% (15.75^{o}), although they were avoided altogether with no sightings observed near those.

Comparing the distribution of sightings with sediment type (Figure 7), the majority were observed over hard rocky substrate, followed by coarse substrate. A few were recorded around sandy and mixed sediments, and the lowest number occurred around muddy/sandy substrate.

Annex I lists the specific habitats that have been designated as a Special Area of Conservation (SAC) and are subject to EU-wide legislation. Among these, certain habitats have been further designated as "priority habitat types". The Annex I habitats around Anglesey (Figure 8) include submerged mudflats/sandflats, reefs, and submerged sandbanks. Most sightings were concentrated over reefs, stretching from Holyhead to the Skerries and Middle Mouse. The rest of the sightings were recorded over submerged sandbanks, which extend from Middle Mouse to Red Wharf Bay. No sightings coincided with areas associated with submerged mudflats/sandflats.

The tidal energy at the seabed due to currents ranges from high or moderate to low, in the area (Figure 9). Sightings were recorded around high energy regions such as Holyhead, the Skerries, Cemaes Bay, and Point Lynas. A few sightings were observed in moderate to low energy areas, but most were clearly concentrated around high energy zones.

Salinity and primary productivity are standard parameters to investigate when relating species abundance with environmental drivers, but they were not included in this study as little variation in these factors are known to exist in the area. Primary productivity, in terms of chlorophyll *a* concentration fluctuates within a narrow range around Anglesey, whilst salinity remains very similar as there is little freshwater input in terms of precipitation (year-round rainfall in the area) or river input (no major rivers flow into the sea along the Anglesey coast).

DISCUSSION

Studying cetacean distribution patterns, the determinants of variations in abundance, and understanding habitat preferences is essential for identifying the changes in marine ecosystem processes, and formulating conservation policy (Reid *et al*., 2003). In particular, assessing the spatio-temporal patterns of dispersion has helped in determining whether certain areas are appropriate to be declared as MPAs (Hooker *et al*., 1999; Cañadas *et al*., 2002, 2005; Gomez De Segura *et al*., 2006; Weilgart, 2006), and in developing conservation and management strategies within the MPAs (Hastie *et al*., 2003; Cañadas & Hammond, 2008; Panigada *et al*., 2008). Photo-identification of individuals in a population has been a popular technique applied to analyze spatio-temporal trends in species distributions, and their population dynamics; it is based on the premise that every individual is exclusive, attributable to numerous unique physical characteristics and natural marks appropriate for its clear discrimination (Hammond *et al.,* 1990; Hammond, 2010). The method has advantages over previously popular mark-recapture techniques like branding, tagging, etc., of being a relatively easy (in terms of labour), economical and non-invasive research approach (Evans & Hammond, 2004). Photographs allow for a more objective evaluation of a sighting record, but they may introduce a bias in population demographics because some species are easier to photograph or identify from photos than others (Evans & Hammond, 2004).

Identifying animals has helped to determine descriptions of surfacing-respiration-dive cycles, and their correlation with general behaviour patterns such as resting, socializing, travelling, and feeding (Taylor and Saayman, 1972; Wiirsig, 1978). Mark-recapture techniques also are frequently applied to obtain an estimate of population size (Hansen, 1983, 1990; Hammond, 1986). For these techniques to give reliable and realistic results, natural markings should be detectable over time, they should be unique to the identified animal, and have a reasonable probability of being 'captured' and 'recaptured'. This can be fairly difficult, due to difference in the quality of markings (well-marked or not), and due to the fact that some animals are shyer (Hammond *et al.,* 1990). It is advised by Hammond (1986) to omit consideration of individuals with obscure markings out of population size analysis, but to include them in movement and range studies.

Several other biases are possibly introduced while using photo-ID method for identification and mark recapture purposes. A major factor impeding the process of identifying animals based upon scarring is the change in marks over time. The scars, along with the nicks and cuts on any individual may change their appearance while healing, and if additional scarring occurs due to social interactions taking place between the year of original identification and re-sighting. The outline of the fin/fluke may alter for similar reasons, owing to inflicted nicks and cuts. In some cases, marks may be relatively permanent. The examination of northern bottlenose whales by Gowans and Whitehead (2001) between 1990 and 1997 recorded no losses for notches. However, some difficulties were met during this study while identifying individuals; as individuals heal or grow (from juveniles to adults), some scars may shift positions slightly, and additional scars may be accumulated over the years, making identification uncertain. In case of having to process lower quality images for the want of better options, misidentification of the individuals may follow.

The measure of site fidelity calculated in this study based upon recaptures was low across the sampled population, at 16.2% re-sighting rate. This implies that site fidelity is not very strong around Anglesey but suggests that the population probably shows a large-scale movement pattern (see also de Boer *et al.*, 2013). Whilst the overall site fidelity is considerably lower, some long-term site fidelity was observed in the study. Five individuals were sighted three times in the area, while the interannual site fidelities (gaps between re-sightings) were observed to be between 5 and 14 years. This exceeds the expectation based on previous recapture reports of David and DiMéglio (1999) and Casacci and Gannier (2000) who reported long-term (interannual >3 years) site fidelity in Risso's dolphins. The large sighting gaps, contrary to popular belief, do not translate to absence of the individuals from the area, but that the individual was not captured or identified during the re-sighting period. Site fidelity is potentially correlated with ample foraging opportunities at the site. It varies with respect to season and time. Risso's dolphins are known to undertake summer migrations. However, the exact locations to which they migrate, and thus the distance they travel are less well known (Leatherwood *et al*., 1980; Casacci and Gannier, 2000; Evans *et al*., 2003; Hartman *et al*., 2008; de Boer *et al*., 2013). Two females were re-sighted with calves, which suggests the probable usage of offshore waters on the Irish Sea as a breeding ground by the species. On more than one occasion, two to three female-calf pairs were sighted, which possibly denote nursery groups. The study also reports some of the longest ranges previously found in the UK, with at least three individuals identified in waters around Cornwall that were previously also sighted at the Isle of Man and Bardsey Island.

Habitat selection is a complex process that aims to sustain a population through meeting their nutritional (prey and feeding strategies), reproductive (mating purposes) and ecological (predation/competition avoidance) needs (Schofield, 2003). Evaluating environmental drivers aids in understanding the factors that potentially support the distribution of species in the given area through correlating the causal abiotic parameters with previously mentioned biological processes. The plotted sightings were seen to be aggregated over/around specific abiotic features, which suggest definite trends in the recorded distribution of Risso's dolphins in the area.

The seasonal distribution of Risso's dolphins was reflected through the spread of sightings from April to November, and the progressive increase in sightings numbers towards warmer months possibly indicating the species affinity towards warmer waters, which is supported by the drop in the number of sightings in November. It should be noted that the lower number of sightings in April can be accounted for by the fact that in the waters around British Isles, peak calving period occurs between March and July (Evans *et al*., 2003; Evans, 2008), suggesting that some members of the population could move out of the region, either offshore or possibly to the south, at that time. According to Evans & Hammond (2004), inclusion of casual land-based observations introduces the bias of seasonality into data collection, as people tend to gather outdoors when weather is most favourable. November being a particularly cold month, people prefer staying indoors, which leads to fewer sightings observed and reported; this could be the cause of low sightings during November.

Being primarily teutophagic, Risso's dolphin prominently prey upon squids and octopi (Clarke & Pascoe, 1985; Blanco *et al*., 2006). Stomach contents of stranded Risso's dolphins on the south coast of England and in Scottish waters suggest that the octopus *Eledone cirrhosa* forms the most important prey component of the species followed by the common squid *Loligo* sp. and bobtail squids (family Sepiolidae) (Clarke & Pascoe, 1985; Pierce *et al*., 2007; MacLeod *et al*., 2014). Risso's dolphins stranded on Welsh coasts showed similar stomach contents (Merrett, 1998). Lishchenko *et al*. (2021) report that the cephalopods of North Atlantic exhibit highest abundance in summer months, while the most spawning mothers are sampled in July and August, their spawning period being late summer and autumn (Lin *et al*., 2019). The seasonal abundance in prey probably contributes to the seasonal sighting of the species, among other factors.

Thermal stratification creates zones of primary productivity in the marine environment. Water masses of different temperature converge to form oceanic fronts (Miller and Christodoulou, 2014), and are known to support elevated primary and secondary production resulting in high biodiversity and localized abundance of pelagic predators (Hyrenbach *et al*., 2000; Miller, 2012; Miller and Christodoulou, 2014). Higher primary productivity pertaining to upwelling and downwelling at the fronts may attract species of successive higher trophic levels due to reliable prey concentrations (Gannier and Praca, 2006; Anderwald *et al*., 2011, 2012; Baines and Evans, 2012; Miller and Christodoulou, 2014). These oceanic fronts regularly occur in UK shelf seas (Miller and Christodoulou, 2014), as these fronts occur seasonally in nature, the distribution through sightings of Risso's dolphins could be seasonal (Gannier and Praca, 2006). Possibly, the occurrence of cold-blooded cephalopod prey in relatively warmer waters (and its absence from colder waters) also plays a part in the seasonal occurrence of Risso's dolphins.

Sightings of Risso's dolphins were in depth of 10 meters to 80 meters, showing strong preference for 20-70 meters of depth. No sightings occurred over the depth of >90 m, while deepest regions in the area did not exceed the depth of 150 meters. These findings indicate shallower depths than many other records in British waters which indicate a preference for the outer continental shelf at about 50-100m isobaths (Evans *et al.*, 2003; Evans, 2008). The presence of sightings at those relatively shallow depths indicate that depth alone is not determining the distribution of Risso's dolphins. However, it is not possible to say that the species prefers those depths since the study area generally is in shallow waters and this study analyses presence-only data in which sightings are presented without effort. The sample size of number of sightings was enhanced by inclusion of casual (land-based) records which does not take effort into consideration, which also means that the distribution of sightings is influenced by bathymetry and other sampled environmental parameters. Thus, the lack of sightings at greater depths could simply reflect where effort was greatest (i.e., in shallow waters along the coast). To understand where these biases might have occurred, a map of vessel survey effort in the area was included (Figure 10), although this covers only offshore vessel-based survey effort. Evans & Hammond (2004) suggest that while studying distribution patterns, it should be kept in mind that inshore waters will generally have the best coverage.

Sightings exclusively occurred within a 4.5^o to 6.75^o slope, which indicates a relatively moderate slope gradient. It should be noted that the study area was seen to have a slope ranging from 0^o to 15.75^o which are all fairly gentle slopes, and the (relatively) steepest regions in the area were avoided altogether by the species. This also differs from available records which suggest a preference by Risso's dolphins towards steep upper continental slopes (Azzellino *et al*., 2008; Azzellino *et al*., 2012) as during their vertical nocturnal migration, pelagic prey species such as euphausiids, hyperiids and mysids, are transported landwards by surface currents and get amassed in waters overlying the slopes during their reverse diurnal migration (Macquart-Moulin & Patriti, 1996). This periodic pattern of concentration of pelagic zooplankton in the waters adjacent to the slopes provides an abundant food source for cephalopod predators.

When correlated with the sediment profile, most sightings were seen over hard rocky substrate, followed by coarse substrate, sandy and mixed sediments. The lowest muddy/sandy substrate was least favoured by the local population. Habitat-wise, the greatest number of sightings were observed aggregated over reefs, and the rest over submerged sandbanks. Regions associated with submerged mudflats/sandflats were excluded altogether by the species. Yen *et al.* (2004) state that the species is strongly associated with sediment type, as well as habitat type, which may potentially be attributed to the fact that habitats such as reefs (probably contributing to a hard substratum) support higher biomass and thus, elevated productivity, resulting in higher prey concentrations.

Most sightings were found to be associated with regions characterised by high tidal energy at the seabed. Some occurred in moderate to low tidal energy areas, but the species' preference for high energy zones was apparent. Due to the study area being mainly coastal, higher energy characterised this study area. The dynamics of currents, especially at the seabed result in nutrient mixing, upwelling etc., enhancing productivity in the area, and making prey concentration reliably available (Simard *et al.,* 2002), reflected in the cetacean abundance in the area (Hyrenbach *et al.*, 2000).

Such dynamic tidal environments are present widely along parts of the Welsh coast. Recognizing the importance of this marine renewable energy resource, the Welsh Government has set ambitious goals of acquiring at least 10% of the potential tidal stream and wave energy by 2025 (equivalent to 8 kWh/day/person of the mean consumption of 22 kWh/day/person) and has committed to investigating where tidal range technologies may be adequate along the shoreline (Welsh govt. energy policy statement, 2010).

Coinciding with areas frequented by cetaceans and other marine mammals, these projects threaten their habitats. The primary effects of climate change on marine mammals observed globally have been visible range shifts and habitat loss due to melting polar caps, modifications in the food web, increased sensitivity to algal toxins, and vulnerability to disease (Evans and Waggitt, 2020). This trend is palpable around the British Isles, with subtropical and warm temperate water pelagic species visiting the area in greater frequency, and cold-water pelagic species becoming less regular (Evans and Bjørge, 2013; Evans and Waggitt, 2020). The regime shifts being observed may result in higher competition for food in marine mammals, due to their increased abundance in the area and, at the same time, reduced food availability through influence on their poikilothermic prey resulting in re-distribution of their resident populations (Evans *et al*., 2010; Evans and Waggitt, 2020b).

Risso's dolphins are uncommon and patchily distributed in Europe. Knowledge of the life history and diet of a species is fundamental for conservation management; without the understanding of demography, age at sexual maturity, age at first reproduction, and natural longevity, the dynamics of a population cannot be determined (Myrick *et al*., 1983). Along with predictive habitat modelling, systematic surveys should be carried out to identify hotspots for the species in the field. Rather than relying solely on mark-recapture estimates from photo-ID, traditional line-transect surveys should aim to obtain population estimates in real space and time. Although, costly in terms of time and resources, surveys of genetic variations should be conducted globally, along with acoustic surveys and stable isotope studies. The findings from these genetic studies will prove to be of assistance to create management and mitigation units worldwide. The current and future photo-ID studies should be planned to be carried out over the long term to survey animal movements, home ranges, group and population structure, and study life cycles which will allow drawing robust conclusions. Geographical and seasonal variations in the diet of Risso's dolphins remain largely unknown and should be investigated in depth by assessing stomach contents and analysing fatty acids and stable isotopes.

CONCLUSION

Upon identifying 105 individuals from 1874 photographs taken between 2015 and 2020, the population of Risso's dolphins in the Anglesey waters showed a low resighting rate (16.19 %), but high interannual (long-term) site fidelity. A few individuals also exhibited longer home ranges than observed before. The resighting data suggests presence of nursery groups in the area, and repeated sightings of females with calves implies the offshore waters to harbour breeding grounds.

The 428 sightings that occurred over between 2003 and 2021 mostly complied with the records in present literature, in terms of commonly observed group sizes, seasonality in sighting events of the Risso's dolphins, as well as preference for high energy environments, occurrence over high biomass supporting habitats and predilection towards hard to coarse sediment regions. Although, when correlated with bathymetry and slope gradient, the findings of the study differed from observations in the existing literature. As opposed to records from the UK water, the population assessed in this study was observed in gentler slope regions and shallower depths, which can be possibly attributed to higher sampling efforts made in the nearshore coastal regions. Similarly, the seasonality in the Risso's dolphin sightings could be due to bias in sampling efforts, which could be higher in summer months with more favourable weather conditions.

The tidal energy due to currents at the seabed, along with sediment profile and underlying benthic habitats seem to influence the higher sightings in regions with favourable conditions of those parameters, which individually or in combination, create optimal feeding/breeding/nursing conditions in the area; the conditions known to facilitate habitat selection process for any biological population. Statistical analysis of the same is required to ascertain these findings.

It is recommended to those undertaking the future studies to overcome the mentioned biases as much as possible to obtain more accurate results, which will considerably enrich our understanding of the species and its ecology, enabling better policymaking process and conservation efforts. The ongoing studies rely heavily upon photo-ID and predictive, which should be more and more replaced with systematic surveys and genetic studies to achieve effective management strategies.

ACKNOWLEDGMENT

I would like to express my sincere and heartfelt gratitude towards Dr Peter Evans for his unending patience, continuous support, and guidance throughout the period of this study. I would also like to thank the team at SWF for their relentless work, and for giving a chance to indulge in cetology. Many thanks to ESRI, General Bathymetric Chart of Oceans (GEBCO) and European Marine Observation and Data Network (EMODNET) for supplying the necessary data.

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FIGURE LEGENDS

Figure 1: Adult male Risso's dolphin (top) as compared to the female (bottom left) and calf (bottom right). Photographs taken from the Sea Watch Foundation.

Figure 2: 21AN20 sighted off Anglesey in 2015 (Top) and sighted in Falmouth, Cornwall in 2021 (bottom). Photo curtsey: Dr. PGH Evans, SWF (2015) and AK Wildlife Cruises (2021).

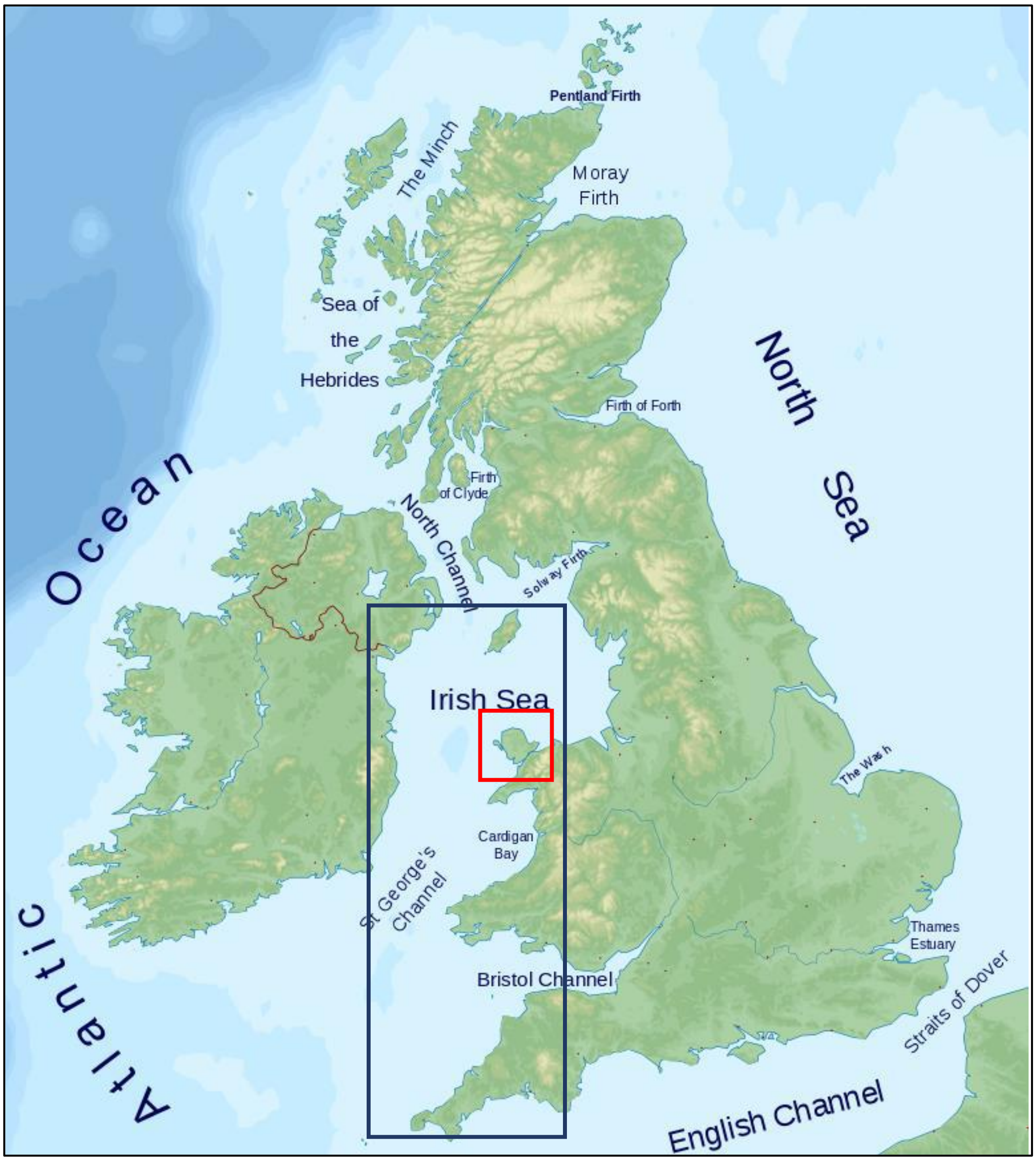

Figure 3: The study areas focused upon for photo-identification and site fidelity (blue rectangle), and environmental variables affecting the Risso's dolphin distribution (orange square).

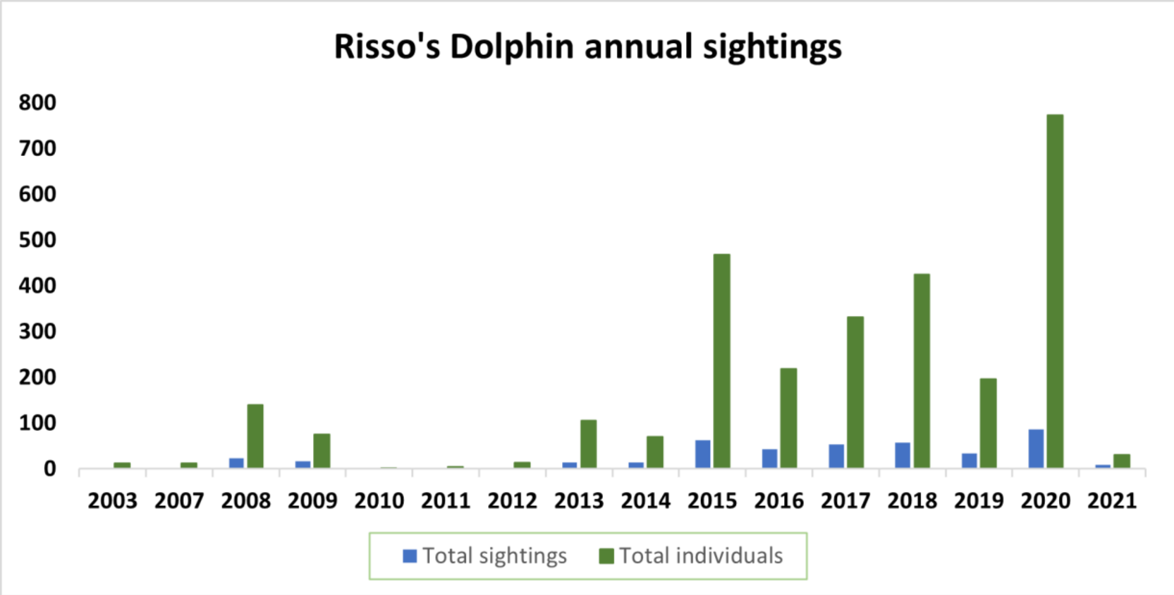

Figure 4a: Annual sightings of Risso's dolphins in Anglesey waters from 2003 to 2007.

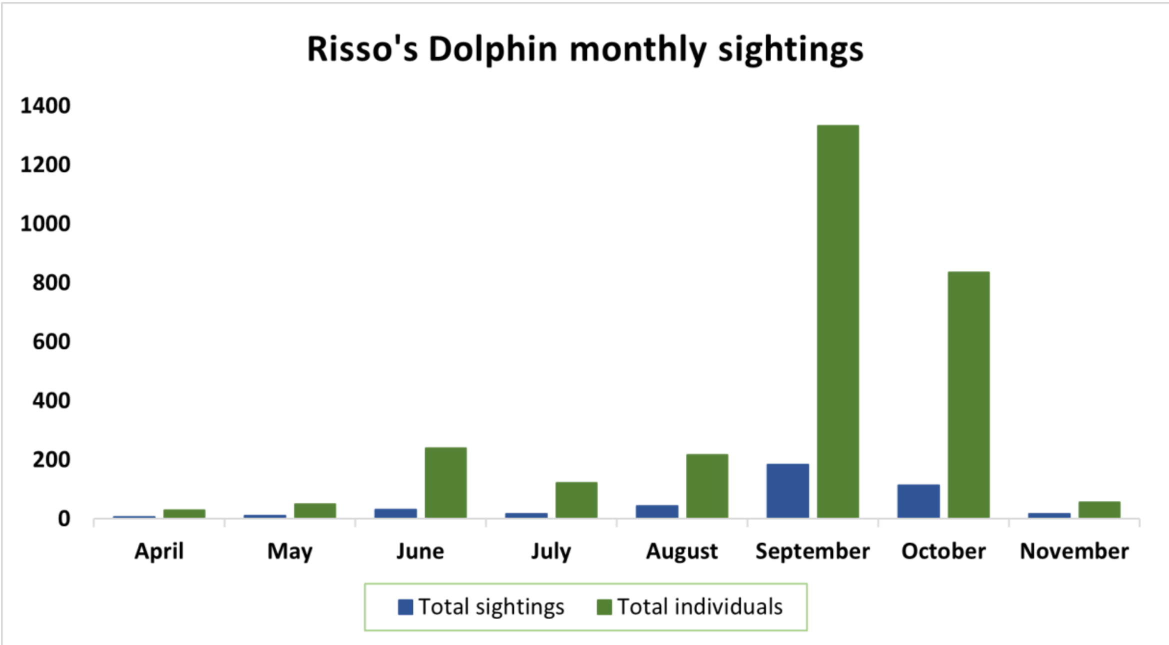

Figure 4b: Monthly sightings of Risso's dolphins in Anglesey waters from 2003 to 2007.

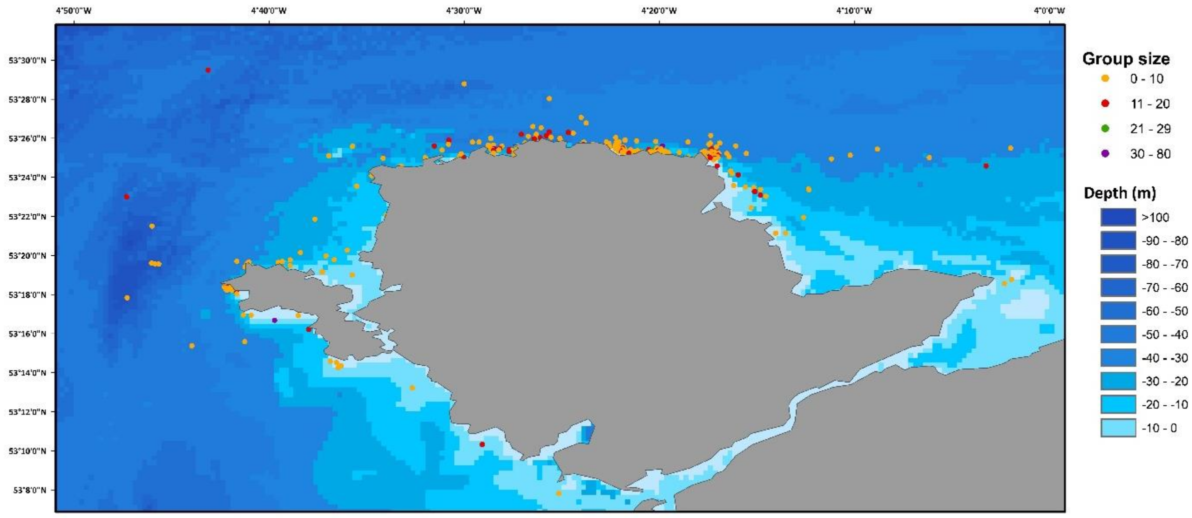

Figure 5: Risso's dolphin sightings from 2007 to 2013 correlated with the bathymetry of the study area.

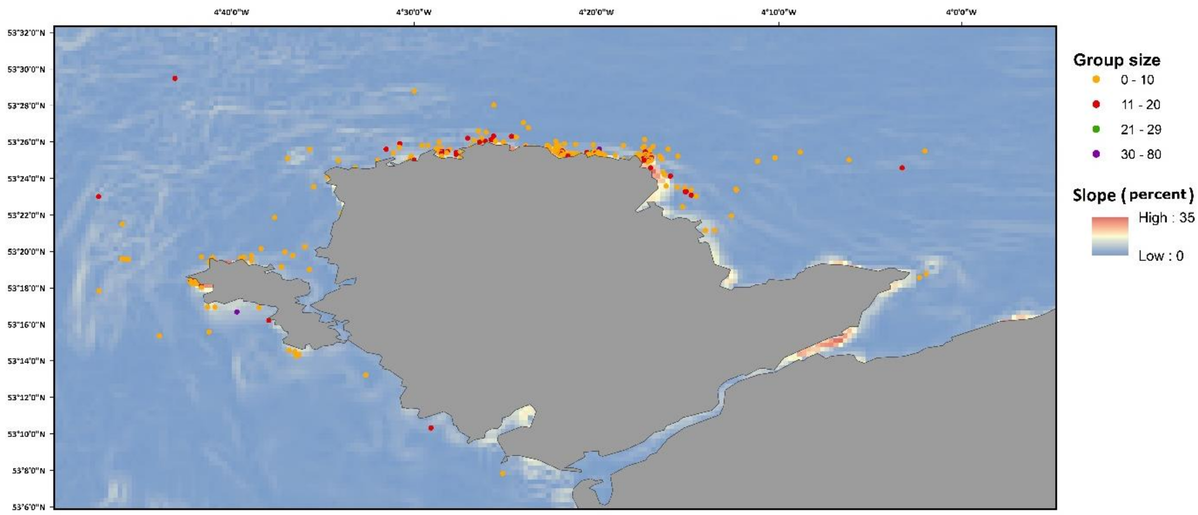

Figure 6: Risso's dolphin sightings from 2007 to 2013 correlated with the slope gradient of the study area.

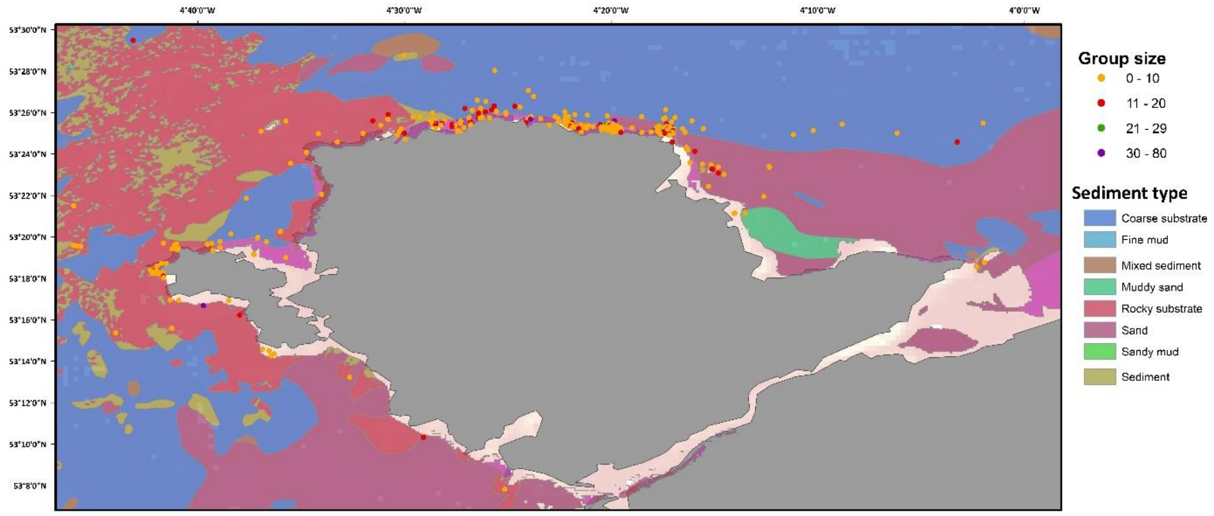

Figure 7: Risso's dolphin sightings from 2007 to 2013 correlated with the sediment profile of the study area.

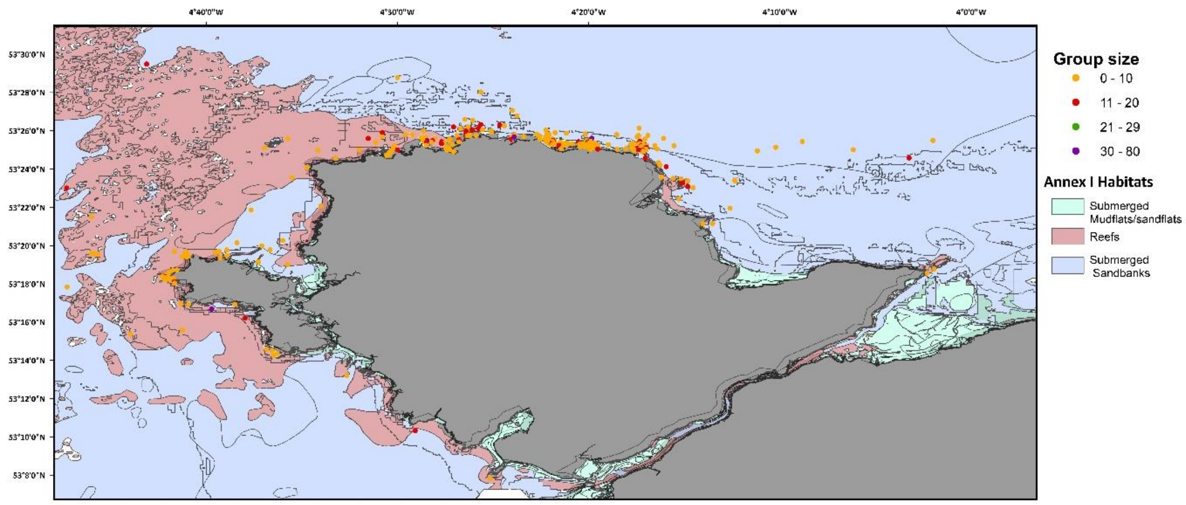

Figure 8: Risso's dolphin sightings from 2007 to 2013 correlated with the Annex I habitats present in the study area.

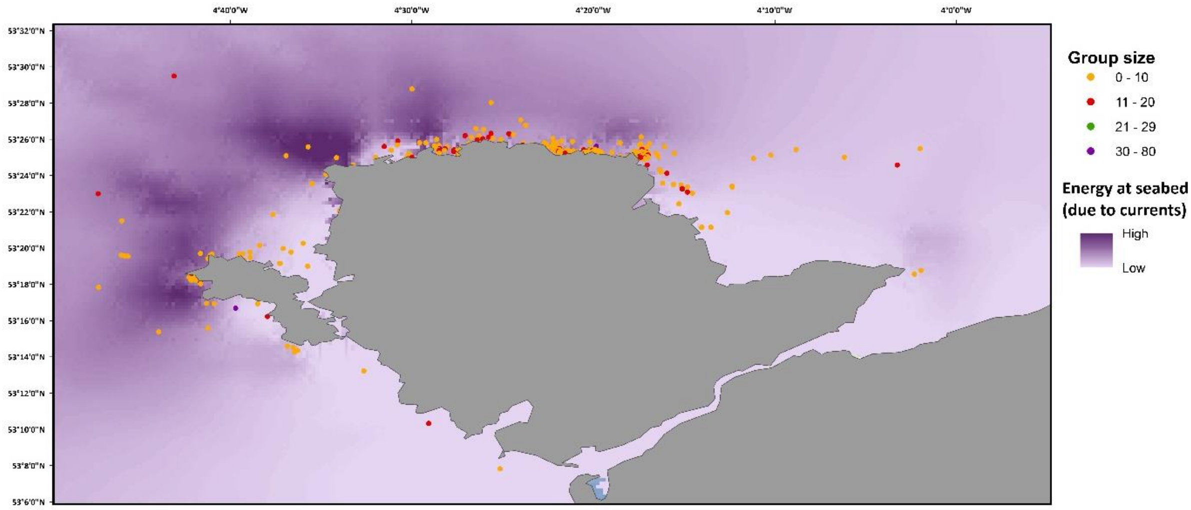

Figure 9: Risso's dolphin sightings from 2007 to 2013 correlated with the tidal energy at the seabed of the study area.

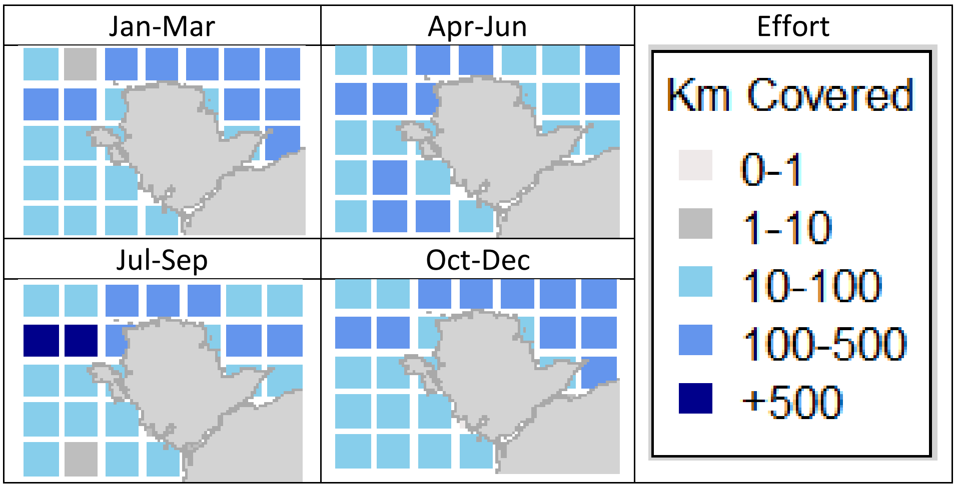

Figure 10: Distribution of offshore effort around Anglesey by season (from NRW Atlas of Cetaceans in Wales, in press)

TABLES

Quality rating	Description
Q1	Very distant, poor focus and very little portion of the fin showing; rather unmarked individual
Q2	Very distant photograph with little fin showing, poorly marked individual
Q3	Distant photograph with little fin showing, adequately marked individual
Q4	Distant photograph with most of the fin showing, fairly marked individual
Q5	Close with good representation of the fin, well-marked individual
Q6	Close photograph with most of the fin showing, well focused and exposed image, very defined marks on the individual

Table 1: The scale used for quality assessment in order to segregate good quality photographs of Risso's dolphins for further processes; based on the methodology of Gowans and Whitehead (2001).

No	Cat.ID	1st sighting	Location	2nd sighting	Location	3rd sighting	Location	Total
17	21AN17	20/04/21	Cornwall	04/10/15	Anglesey	05/09/07	Bardsey	3
20	21AN20	20/04/21	Cornwall	04/10/15	Anglesey			2
22	21AN22	20/04/21	Cornwall	01/07/05	Isle of Man	07/09/07	Anglesey	3
29	21AN28	15/08/21	Anglesey	20/08/21	Amlwch			2
30	20AN01	29/09/20	Anglesey	04/10/15	Anglesey			2
31	20AN02	29/09/20	Anglesey	10/09/20	Point Lynas	04/10/15	Anglesey	3
35	20AN06	29/09/20	Anglesey	09/10/15				2
36	20AN07	29/09/20	Anglesey	22/06/05				2
52	20AN23	29/09/20	Anglesey	06/09/20				2
58	20AN29	06/09/20	Anglesey	06/09/20	Point Lynas			2
61	20AN32	06/09/20	Anglesey	09/10/15	Anglesey			2
67	20PL05	10/09/20	Point Lynas	13/10/13				2
68	20PL06	10/09/20	Point Lynas	05/06/18	Wylfa			2
83	18AN02	04/10/18	Anglesey	13/09/17	Amlwch	04/10/15	Anglesey	3
86	18WF01	06/06/18	Wylfa	05/09/07	Bardsey			2
93	15AN03	04/10/15	Anglesey	12/10/08	Bardsey	05/09/07	Bardsey	3
105	15AN15	09/10/15	Anglesey	28/08/07				2

Table 2: Resighting data of individuals observed over the period of 2003-2007, assessed from photographs provided by the SWF.

APPENDIX (Catalogue)

Catalogue Name	1
Nickname	21AN01
Maturity Category	P. Adult
Gender	P. Male
Profile	Both
Marking category	Well-marked
Marking Type	Large semilunar nick on the posterior fin edge, Two parallel scars near fin apex
First seen	17/04/21
Sighting frequency	

Catalogue Name	2
Nickname	21AN02
Maturity Category	P. Adult
Gender	P. male
Profile	Right
Marking category	Well-marked
Marking Type	Two parallel scars near anterior fin edge, and fin tip; single transverse scar at the middle of the fin
First seen	17/04/21
Sighting frequency	

Catalogue Name	3
Nickname	21AN03
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two scars near posterior fin edge intersected by a single transverse scar, heavily scarred back
First seen	17/04/21
Sighting frequency	

Catalogue Name	4
Nickname	21AN04
Maturity Category	Adult (could be senescent)
Gender	Male
Profile	Both
Marking category	Well-marked
Marking Type	Wing-like four parallel scars on the fin, individual heavily scarred, appears completely white. Patch of grey on the head.
First seen	17/04/21
Sighting frequency	

Catalogue Name	5
Nickname	21AN05
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Series of vertical scars in the middle of the fin
First seen	17/04/21
Sighting frequency	

Catalogue Name	6
Nickname	21AN06
Maturity Category	
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Double semi-circular scar on the upper-half fin
First seen	17/04/21
Sighting frequency	

Catalogue Name	7
Nickname	21AN07
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Fin darker at the ages, small nick at the anterior fin edge, large circular scar above eye, V-shaped scar on the forehead
First seen	17/04/21
Sighting frequency	

Catalogue Name	8
Nickname	21AN08
Maturity Category	
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Small nick at the posterior fin edge, numerous scars on the fin
First seen	17/04/21
Sighting frequency	

Catalogue Name	9
Nickname	21AN09
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Fin darker at the posterior edges, heavily scarred fin, two parallel oblique scars at the fin base
First seen	17/04/21
Sighting frequency	

Catalogue Name	10
Nickname	21AN10
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Heavily scarred fin (anterior half), two parallel horizontal scars at fin base
First seen	17/04/21
Sighting frequency	

Catalogue Name	11
Nickname	21AN11
Maturity Category	
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Criss-cross scars at anterior fin edge, three parallel oblique scars, start mid fin near the base, extend posteriorly
First seen	17/04/21
Sighting frequency	

Catalogue Name	12
Nickname	21AN12
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Nick at dorsal edge, two parallel scars at anterior fin edge
First seen	20/04/21
Sighting frequency	

Catalogue Name	13
Nickname	21AN13
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Heavily scarred, intricate criss-cross scars mostly in the anterior half)
First seen	20/04/21
Sighting frequency	

Catalogue Name	14
Nickname	21AN14
Maturity Category	Adult
Gender	Probable female, seen with a calf
Profile	Right
Marking category	Slightly-marked
Marking Type	Large oblique scar at mid anterior margin, parallel oblique scars near posterior margin
First seen	20/04/21
Sighting frequency	

Catalogue Name	15
Nickname	21AN15
Maturity Category	Calf of 21AN14
Gender	
Profile	Right
Marking category	
Marking Type	Unmarked
First seen	20/04/21
Sighting frequency	

Catalogue Name	16
Nickname	21AN16
Maturity Category	
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Circular spots allover, double semicircular scars (1/3-2/3:1)
First seen	20/04/21
Sighting frequency	

Catalogue Name	17
Nickname	21AN17 (001_3S)
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Faint inverse Z-shaped scars
First seen	20/04/21
Sighting frequency	04/10/15 (Anglesey), 05/09/07 (Bardsey)

Catalogue Name	18
Nickname	21AN18
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Inverse z-shaped scar prominent
First seen	20/04/21
Sighting frequency	

Catalogue Name	19
Nickname	21AN19
Maturity Category	P. juvenile
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Circular scars at the fin base, slight nick at fin apex
First seen	20/04/21
Sighting frequency	

Catalogue Name	20
Nickname	21AN20
Maturity Category	
Gender	Probable female, seen with a calf
Profile	Right
Marking category	Well-marked
Marking Type	Peculiar semilunar scar, accentuated by parallel bottom scar
First seen	20/04/21
Sighting frequency	04/10/15

Catalogue Name	21
Nickname	21AN21
Maturity Category	
Gender	Calf with 21AN20
Profile	Right
Marking category	Unmarked
Marking Type	dual colouration
First seen	20/04/21
Sighting frequency	

Catalogue Name	22
Nickname	21AN22 (001_10S)
Maturity Category	Probable adult
Gender	Probable male
Profile	Left
Marking category	Well-marked
Marking Type	Numerous scars (1/2:1), two sigmoid scars mid fin
First seen	20/04/21
Sighting frequency	07/09/07 (Anglesey) (2009: Isle of Man)

Catalogue Name	23
Nickname	21BB01
Maturity Category	
Gender	
Profile	Left
Marking category	Unmarked
Marking Type	Intact dorsal fin
First seen	9th May 2021
Sighting frequency	

Catalogue Name	24
Nickname	21AN23
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Completely white anterior half fin, three sigmoid scars adjacent to the nick
First seen	15/08/21
Sighting frequency	

Catalogue Name	25
Nickname	21AN24
Maturity Category	
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Two parallel oblique scars starting (2/3:1), two parallel horizontal scars mid fin
First seen	15/08/21
Sighting frequency	

Catalogue Name	26
Nickname	21AN25
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Four oblique parallel scars in the upper half of anterior fin margin
First seen	15/08/21
Sighting frequency	

Catalogue Name	27
Nickname	21AN26
Maturity Category	
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Prominent vertical scar at the mid-bottom, faint scarring at the apex
First seen	15/08/21
Sighting frequency	

Catalogue Name	28
Nickname	21AN27
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Heavily scarred, notch (1/2:2)
First seen	15/08/21
Sighting frequency	

Catalogue Name	29
Nickname	21AN28
Maturity Category	
Gender	
Profile	Both
Marking category	Well-marked
Marking Type	Prominent vertical scar, slight notches (2/3:2)
First seen	15/08/21
Sighting frequency	

Catalogue Name	30
Nickname	20AN01
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Long vertical scar with two horizontal spots near fin tip, Circular spot (2/3:1)
First seen	29/09/20
Sighting frequency	

Catalogue Name	31
Nickname	20AN02
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Three horizontal scars mid fin on anterior fin edge, cross-shaped oblique scars at fin base
First seen	29/09/20
Sighting frequency	09/09/20 (Point Lynas), 04/10/15 (Anglesey)

Catalogue Name	32
Nickname	20AN03
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two oblique scars meeting a tick mark shaped horizontal scars at fin base, almost star-shaped mark
First seen	29/09/20
Sighting frequency	

Catalogue Name	33
Nickname	20AN04
Maturity Category	P. Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Three horizontal scars, meeting a tick mark shaped oblique scar at fin base
First seen	29/09/20
Sighting frequency	

Catalogue Name	34
Nickname	20AN05
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Three circular spots in a straight-line mid fin, two vertical semilunar scars (1/2:2)
First seen	29/09/20
Sighting frequency	04/10/15

Catalogue Name	35
Nickname	20AN06
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two oblique scars extending from base to tip
First seen	29/09/20
Sighting frequency	09/10/15

Catalogue Name	36
Nickname	20AN07 (2005-21S)
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Slightly marked
Marking Type	Crescent-shaped nicks on the posterior fin edge (1/2, 2/3)
First seen	29/09/20
Sighting frequency	22/06/05

Catalogue Name	37
Nickname	20AN08
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Slightly-marked
Marking Type	Vertical dark line mid-fin, parallel horizontal scars along it
First seen	29/09/20
Sighting frequency	

Catalogue Name	38
Nickname	20AN09
Maturity Category	Juvenile
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Tiny crescent-shaped scar near the anterior edge of the fin
First seen	29/09/20
Sighting frequency	

Catalogue Name	39
Nickname	20AN10
Maturity Category	Adult
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Two horizontal scars adjoining the anterior edge of the fin, oblique scar at the fin tip
First seen	29/09/20
Sighting frequency	

Catalogue Name	40
Nickname	20AN11
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Three oblique scars from fin tip to mid fin
First seen	29/09/20
Sighting frequency	

Catalogue Name	41
Nickname	20AN12
Maturity Category	P. juvenile
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Single oblique white scar near fin tip
First seen	29/09/20
Sighting frequency	

Catalogue Name	42
Nickname	20AN13
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Deep oblique scars on anterior fin margin (1/5, 4/5)
First seen	29/09/20
Sighting frequency	

Catalogue Name	43
Nickname	20AN14
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Oblique dorsal scars, series of oblique scars near fin tip
First seen	29/09/20
Sighting frequency	

Catalogue Name	44
Nickname	20AN15
Maturity Category	P. juvenile
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Patches of scars
First seen	29/09/20
Sighting frequency	

Catalogue Name	45
Nickname	20AN16
Maturity Category	P. adult
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Series of parallel horizontal scars near fin-base, three scars at the tip at right angles
First seen	29/09/20
Sighting frequency	

Catalogue Name	46
Nickname	20AN17
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Slightly-marked
Marking Type	Series of oblique scars at the fin tip
First seen	29/09/20
Sighting frequency	

Catalogue Name	47
Nickname	20AN18
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Two parallel semilunar scars extending from the fin tip to base
First seen	29/09/20
Sighting frequency	

Catalogue Name	48
Nickname	20AN19
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Semilunar scar at fin base, parallel oblique scars at fin tip and fin base
First seen	29/09/20
Sighting frequency	

Catalogue Name	49
Nickname	20AN20
Maturity Category	P. adult
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Y-shaped oblique scar
First seen	29/09/20
Sighting frequency	

Catalogue Name	50
Nickname	20AN21
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Sigmoid parallel scars and scar group mid fin, parallel horizontal scars at fin base
First seen	29/09/20
Sighting frequency	

Catalogue Name	51
Nickname	20AN22
Maturity Category	Adult
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Dark three parallel vertical scars on mid anterior edge
First seen	29/09/20
Sighting frequency	

Catalogue Name	52
Nickname	20AN23
Maturity Category	Adult
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Distinct dark vertical line mid fin
First seen	29/09/20, 06/09/20
Sighting frequency	

Catalogue Name	53
Nickname	20AN24
Maturity Category	Adult
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Anterior half fin covered in spots, large scar parallel to anterior fin edge
First seen	29/09/20
Sighting frequency	

Catalogue Name	54
Nickname	20AN25
Maturity Category	Adult
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Nicks at mid and base of posterior fin
First seen	29/09/20
Sighting frequency	

Catalogue Name	55
Nickname	20AN26
Maturity Category	
Gender	P. female, seen with a calf (new-born)
Profile	Left
Marking category	Slightly marked
Marking Type	Oblique parallel scars at fin base
First seen	06/09/20
Sighting frequency	

Catalogue Name	56
Nickname	20AN27
Maturity Category	
Gender	P. female, seen with a calf (new-born) and in group with other p. females
Profile	Left
Marking category	Well-marked
Marking Type	Distinct nick on the posterior fin edge
First seen	06/09/20
Sighting frequency	

Catalogue Name	57
Nickname	20AN28
Maturity Category	Adult
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Series of scars parallel to anterior fin edge
First seen	06/09/20
Sighting frequency	

Catalogue Name	58
Nickname	20AN29
Maturity Category	
Gender	P. Male
Profile	Left
Marking category	Well-marked
Marking Type	Two parallel horizontal scars near fin tip
First seen	06/09/20
Sighting frequency	06/09/20 (point Lynas)

Catalogue Name	59
Nickname	20AN30
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two dark semi-circular scar groups at fin base, parallel scars at mid fin
First seen	06/09/20
Sighting frequency	

Catalogue Name	60
Nickname	20AN31
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two parallel oblique scars extending from tip to base, nick on the posterior fin edge
First seen	06/09/20
Sighting frequency	

Catalogue Name	61
Nickname	20AN32
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Double nicks on the posterior fin edge near bottom
First seen	06/09/20
Sighting frequency	09/10/15 (Anglesey)

Catalogue Name	62
Nickname	20AN33
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Single oblique scar at mid fin
First seen	06/09/20
Sighting frequency	

Catalogue Name	63
Nickname	20PL1
Maturity Category	
Gender	
Profile	Right
Marking category	Well-marked
Marking Type	Horizontal scars along anterior fin edge
First seen	15/09/20
Sighting frequency	

Catalogue Name	64
Nickname	20PL2
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Two parallel oblique scars at fin base, one at mid fin
First seen	15/09/20
Sighting frequency	

Catalogue Name	65
Nickname	20PL3
Maturity Category	P. Juvenile
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Distinct nicks on the posterior fin edge
First seen	27/09/20
Sighting frequency	

Catalogue Name	66
Nickname	20PL4
Maturity Category	Adult
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	White scar near fin tip on the anterior fin edge
First seen	27/09/20
Sighting frequency	

Catalogue Name	67
Nickname	20PL5
Maturity Category	Adult
Gender	Female, seen with a calf both times
Profile	Both
Marking category	Slightly-marked
Marking Type	White scar near fin tip on the anterior margin
First seen	10/09/20
Sighting frequency	13/10/13

Catalogue Name	68
Nickname	20PL6
Maturity Category	Adult
Gender	Female, seen with a calf
Profile	Left
Marking category	Slightly-marked
Marking Type	Parallel oblique scars, nick on the anterior fin edge
First seen	10/09/20
Sighting frequency	05/06/18 Wylfa (also with a calf)

Catalogue Name	69
Nickname	20PL7
Maturity Category	Calf
Gender	
Profile	Left
Marking category	Unmarked
Marking Type	Distinct nicks on the posterior fin edge
First seen	09/09/20
Sighting frequency	

Catalogue Name	70
Nickname	20PL8
Maturity Category	Adult
Gender	P. female, seen with a calf
Profile	Left
Marking category	Slightly-marked
Marking Type	Scars on the anterior fin edge
First seen	09/09/20
Sighting frequency	

Catalogue Name	71
Nickname	20PL9
Maturity Category	Adult
Gender	
Profile	Left
Marking category	Slightly-marked
Marking Type	Single horizontal scar mid fin, large circular scar just below the fin
First seen	09/09/20
Sighting frequency	

Catalogue Name	72
Nickname	20PL10
Maturity Category	Adult
Gender	P. female, seen with a calf
Profile	Right
Marking category	Slightly-marked
Marking Type	Horizontal parallel scars on the anterior fin edge
First seen	09/09/20
Sighting frequency	

Catalogue Name	73
Nickname	20PL11
Maturity Category	Adult
Gender	P. female, seen with a calf
Profile	Left
Marking category	Slightly-marked
Marking Type	Distinct nicks on the posterior fin edge
First seen	09/09/20
Sighting frequency	

Catalogue Name	74
Nickname	20PL12
Maturity Category	Adult
Gender	
Profile	Left
Marking category	Well-marked
Marking Type	Distinct scar pattern
First seen	09/09/20
Sighting frequency	

Catalogue Name	75
Nickname	20PL13
Maturity Category	Adult, senescent
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Distinct nicks on the posterior fin edge, Heavily scarred, completely white body
First seen	09/09/20
Sighting frequency	

Catalogue Name	76
Nickname	20PL14
Maturity Category	Adult
Gender	P. female, seen with a calf
Profile	Left
Marking category	Slightly-marked
Marking Type	Numerous circular spots
First seen	09/09/20
Sighting frequency	

Catalogue Name	77
Nickname	20PL15
Maturity Category	Adult (p. senescent)
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Heavily scarred, completely white
First seen	06/09/20
Sighting frequency	

Catalogue Name	78
Nickname	20PL16
Maturity Category	P. adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Scars lined along the anterior fin margin
First seen	06/09/20
Sighting frequency	

Catalogue Name	79
Nickname	20PL17
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Parallel oblique scars all over the fin
First seen	06/09/20
Sighting frequency	

Catalogue Name	80
Nickname	20PL18
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Large, scarred area near fin tip
First seen	06/09/20
Sighting frequency	

Catalogue Name	81
Nickname	20PL19
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Slightly-marked
Marking Type	Large adjacent scar spots around fin tip
First seen	06/09/20
Sighting frequency	

Catalogue Name	82
Nickname	18AN01
Maturity Category	Adult senescent
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Nick on the posterior margin
First seen	04/10/18
Sighting frequency	

Catalogue Name	83
Nickname	18AN02
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Parallel oblique scars at fin bottom, prominent nick near the bottom of posterior fin margin
First seen	04/10/18
Sighting frequency	13/09/17 Amlwch, 04/10/15 (Anglesey)

Catalogue Name	84
Nickname	18AN03
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Prominent scar area near fin tip, heavily scarred back
First seen	04/10/18
Sighting frequency	

Catalogue Name	85
Nickname	18AN04
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Many horizontal and oblique scars extending from fin tip to mid fin
First seen	04/10/18
Sighting frequency	

Catalogue Name	86
Nickname	18WF01
Maturity Category	Adult
Gender	Male
Profile	Both
Marking category	Well-marked
Marking Type	Prominent nick near the bottom of posterior fin margin
First seen	06/06/18
Sighting frequency	05/09/07 (Bardsey)

Catalogue Name	87
Nickname	17AN01
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly-marked
Marking Type	Oblique scar near the bottom of posterior fin margin
First seen	26/09/17
Sighting frequency	

Catalogue Name	88
Nickname	17AN02
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Many oblique and vertical scars all over the fin
First seen	26/09/17
Sighting frequency	

Catalogue Name	89
Nickname	17AN03
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Many oblique and vertical scars all over the fin, Prominent nick near the bottom of posterior fin margin
First seen	26/09/17
Sighting frequency	

Catalogue Name	90
Nickname	17AN04
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Patches of scarring, many oblique and vertical scars all over the fin
First seen	31/08/17
Sighting frequency	

Catalogue Name	91
Nickname	15AN01
Maturity Category	Adult
Gender	P. female, seen with a calf
Profile	Left
Marking category	Slightly marked
Marking Type	Oblique scar near the bottom of anterior fin margin
First seen	04/10/15
Sighting frequency	

Catalogue Name	92
Nickname	15AN02
Maturity Category	Calf
Gender	
Profile	Left
Marking category	Slightly marked
Marking Type	Distinct pattern of pigmentation
First seen	04/10/15
Sighting frequency	

Catalogue Name	93
Nickname	15AN03 (001_04S)
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Heavily-marked
Marking Type	Distinct squarish pattern of scars at fin tip
First seen	04/10/15
Sighting frequency	05/09/07 (Bardsley), 12/10/08 (Bardsley)

Catalogue Name	94
Nickname	15AN04
Maturity Category	Adult
Gender	Male
Profile	Right
Marking category	Slightly marked
Marking Type	Circular spots near the fin bottom, oblique scars near fin tip
First seen	04/10/15
Sighting frequency	

Catalogue Name	95
Nickname	15AN05
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Slightly marked
Marking Type	Scarred area near fin tip and bottom
First seen	04/10/15
Sighting frequency	

Catalogue Name	96
Nickname	15AN06
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Slightly marked
Marking Type	Nick near the bottom of posterior fin margin, large scar parallel to anterior fin margin, circular mark at fin bottom
First seen	04/10/15
Sighting frequency	

Catalogue Name	97
Nickname	15AN07
Maturity Category	Adult
Gender	P. Male
Profile	Left
Marking category	Well-marked
Marking Type	Double tick-mark shaped scar
First seen	04/10/15
Sighting frequency	

Catalogue Name	98
Nickname	15AN08
Maturity Category	
Gender	
Profile	Left
Marking category	Slightly marked
Marking Type	Thick scar at mid anterior fin edge
First seen	04/10/15
Sighting frequency	

Catalogue Name	99
Nickname	15AN09
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well marked
Marking Type	Prominent nick near the bottom of posterior fin margin, oblique scar at mid-fin
First seen	04/10/15
Sighting frequency	

Catalogue Name	100
Nickname	15AN10
Maturity Category	Adult
Gender	Male
Profile	Left
Marking category	Well-marked
Marking Type	Prominent nick near the bottom of posterior fin margin, peculiar scar exactly opposite of anterior fin margin
First seen	04/10/15
Sighting frequency	

Catalogue Name	101
Nickname	15AN11
Maturity Category	Juvenile
Gender	Male
Profile	Right
Marking category	Well-marked
Marking Type	Huge nick cut out of posterior fin margin, numerous scars on anterior half of the fin
First seen	09/10/15
Sighting frequency	

Catalogue Name	102
Nickname	15AN12
Maturity Category	Adult
Gender	P. Male
Profile	Right
Marking category	Slightly-marked
Marking Type	Prominent oblique scars near the bottom of anterior fin margin
First seen	09/10/15
Sighting frequency	

Catalogue Name	103
Nickname	15AN13
Maturity Category	Adult
Gender	P. Male
Profile	Right
Marking category	Slightly marked
Marking Type	Parallel scars mid-fin
First seen	09/10/15
Sighting frequency	

Catalogue Name	104
Nickname	15AN14
Maturity Category	
Gender	
Profile	Right
Marking category	Slightly marked
Marking Type	Series of scars at the fin tip extending along anterior fin margin
First seen	09/10/15
Sighting frequency	

Catalogue Name	105
Nickname	15AN15 (001_23W)
Maturity Category	Adult
Gender	P. Male
Profile	Both
Marking category	Well-marked
Marking Type	Prominent nick near the top of posterior fin margin, oblique parallel scars at fin tip and mid-fin
First seen	09/10/15
Sighting frequency	28/08/07