Risso's dolphins (*Grampus griseus*) in Isle of Man waters: spatial and temporal distribution with links to cephalopod prey availability

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Risso's dolphins (*Grampus griseus*) in Isle of Man waters: Spatial and temporal distribution with links to cephalopod prey availability

Running head: Risso's dolphins in Isle of Man waters

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Abstract

This study presents an overview of the spatial and temporal distribution of Risso's dolphins (*Grampus griseus*) in the Isle of Man's territorial waters, assessing the potential factors driving their distribution. Cetacean sightings data has been collected from 2006-2022 by Manx Whale and Dolphin Watch, through boat and land-based surveys as well as sightings submitted by the public. Sightings predominantly occurred from March to September, beginning on the eastern side of the island (March-June) then shifting mainly to the southern part (July-Sep). As well as a shift in distribution, the summer months saw increased group sizes and higher individuals per unit of effort (IPUE) rates. Groups containing juveniles/calves were involved in resting behaviours significantly more than adult only groups. Maxent habitat suitability models and fishers' questionnaire responses for potential prey species, the long-finned squid (*Loligo forbesii*) and the curled octopus (*Eledone cirrhosa*), showed that better overlap existed between *E. cirrhosa* and Risso's dolphin feeding behaviours. Furthermore, preliminary identification from stomach content analyses on stranded individuals found in IoM waters confirmed octopus to be the predominant food source. Both cephalopod distribution knowledge and Risso's dolphin dietary information acquired suggests octopus, rather than squid, to be a contributing driving factor behind Risso's dolphin distribution in IoM waters. The additional examination of marine nature reserves provides up-to-date information on how the species are using protected areas, indicating key zones. The results shown on both Risso's dolphin feeding and nursery groups support the hypothesis that Isle of Man waters are critical habitat for the species.

Keywords: Grampus griseus, Risso's dolphin, habitat modelling, cetaceans, distribution, cephalopods, diet, Isle of Man, marine reserves

1 | INTRODUCTION

Understanding the temporal and spatial patterns of highly mobile animals, such as cetaceans, is vital for conservation and management of populations. Cetaceans lead long lives, with complex behaviour, social structure, and ecology that combined with environmental variables (e.g. Cañadas & Hammond, 2008; Gómez de Segura *et al.*, 2008) and intrinsic factors, such as reproductive status or foraging strategies (e.g. Hamilton & Cooper, 2010; Filatova *et al.*, 2019), impact their distribution. Determining key areas of cetacean range and spatiotemporal behaviours can be achieved through long-term monitoring of cetacean populations and their habitat use, helping to establish the areas of critical habitat that are crucial to specific demographic processes, such as breeding, raising calves or feeding. Identifying critical habitat is not only an opportunity to further understand cetacean ecology but also key in providing evidence to ensure their protection by the establishment or better management of marine protected areas (Hoyt, 2011).

Habitat modelling is a useful tool in predicting species distributions, especially for wide-ranging species such as cetaceans that may move between preferred locations, and can determine which physical and biological variables are driving these movements (Pearce & Ferrier, 2000; Guisan & Thuiller, 2005; MacLeod *et al.*, 2008). For example, sea-surface temperature (SST) changes have been linked to cetacean distribution and abundance, resulting in seasonal shifts that may follow inshore/offshore movements (e.g. Neumann, 2001; Cañadas & Hammond, 2008). However, seasonal shifts such as these can often be correlated with changes in prey abundance and so understanding the distribution of a species' preferred prey may better illuminate cetacean distribution patterns (Macleod *et al.*, 2004; MacLeod *et al.*, 2014).

Prey availability is frequently considered the prime factor influencing cetacean distribution and site fidelity (Lambert *et al.*, 2014). Discerning cetacean prey predominantly depends on opportunistic examination from stranded animals or tissue sample collection in the field. Methods may involve stomach content analysis, stable isotopes, molecular identification or fatty acids (e.g. Symondson, 2002; Iverson *et al.*, 2004; Newsome *et al.*, 2010). Habitat modelling therefore, can be a more accessible approach to determining cetacean spatial and temporal patterns that are correlated with potential prey species (Lambert *et al.*, 2014). The use of these models can highlight relationships between cetacean densities, environmental variables and simulated distributions of potential prey to understand habitat selection (Pearce & Ferrier, 2000).

Risso’s dolphins (*Grampus griseus*) occur worldwide between latitudes of at least 64^{o} N and 46^{o} S (Jefferson *et al.*, 2014). Preference in both hemispheres for mid-temperate continental shelf/slope waters at latitudes of between 30^{o} and 45^{o} has been demonstrated. Areas of concentration also exist outside this range such as North-east Atlantic shelf (<200 m depth) waters around the UK and Ireland (50–61^{o} N) that are warmed by the Gulf Stream (Jefferson *et al.*, 2014). In UK waters the species occur primarily around the Hebridean region, off north-east Scotland, the Celtic and Irish Seas as well as the western English Channel (Evans *et al.*, 2003; Reid *et al.*, 2003; Weir *et al.*, 2019; Evans & Waggitt, 2020). Across their distribution, Risso's dolphins are considered a teuthophagic species, feeding primarily on cephalopods (Clarke & Pascoe, 1985; Cockroft *et al.*, 1993; Blanco *et al.*, 2006; Kim *et al.*, 2019), with some populations exhibiting seasonal variation in their diets (Bloch, 2012). Although they are present year-round in UK waters seasonal patterns of occurrence have been observed that may coincide with prey availability, with summer sightings peaks being attributed to seasonal abundance peaks of cephalopods in the North Atlantic (Evans, 2008; Lishchenko *et al.*, 2021). The species’ preference for shallower waters of 50-100 metres in UK waters, contrasting to other areas of their distribution, is also thought to be linked to prey distribution (Evans *et al.*, 2003).

The Irish Sea is considered an important region for Risso’s dolphins, containing multiple hotspots including areas along the Welsh coast (Anglesey, Bardsey Island, and west Pembrokeshire) and around the Isle of Man (Evans *et al.*, 1993; Baines & Evans, 2012; de Boer *et al.*, 2013). Manx Whale and Dolphin Watch (MWDW), a registered charity based on the Isle of Man (IoM), have been conducting research and raising public awareness of the cetaceans inhabiting the area, including Risso’s dolphins, since 2006. In IoM territorial waters, cetaceans are protected under schedule 5 of the Wildlife Act 1990. In 2018 a network of Marine Nature Reserves (MNRs) in IoM waters were re-designated by the IoM Government to provide greater protection, with general restrictions in MNRs prohibiting mobile fishing gear (dredge or trawl), seabed extraction or deposition of materials, damage to protected habitats or species and anchoring in eelgrass areas. Risso’s dolphins are considered an important species within four of these MNRs (Calf of Man &Wart Bank MNR, Baie ny Carrickey MNR, Langness MNR, Little Ness MNR - see https://www.gov.im/MNR).

Documented consistent and prolonged seasonal residency of Risso’s dolphins around the IoM, as well as the frequency of calves observed here, indicates that IoM territorial seas may be critical habitat for the species (Howe, 2018), highlighting the need for further investigation into the driving factors behind this exhibited residency. Both the curled octopus

(*Eledone cirrhosa*) and the long-finned squid (*Loligo forbesii*) inhabit IoM waters and have been identified in stomach content analysis of Risso's dolphins stranded in British waters (Clarke & Pascoe, 1985; Santos *et al.*, 1994; MacLeod *et al.*, 2014). Linking the distribution of these cephalopod species around the IoM, especially migrating *L. forbesii* (Collins *et al.*, 1995), with the spatial patterns of the Risso's dolphins could help uncover the importance of prey as a driving factor.

The aim of this study is to investigate the spatial and temporal distribution of Risso's dolphins in IoM territorial waters and help shed light on the potential overlap with prey availability that could be influencing the consistent and prolonged seasonal residency observed. Furthermore, the study aims to develop a further understanding of Risso's dolphin behaviour and group composition within the current MNRs to determine whether these zones encompass areas of importance for the species regarding feeding and raising their calves.

2 | MATERIALS AND METHODS

Study area

This study focuses on Risso's dolphins observed in the Isle of Man's territorial waters (within 12 nautical miles (nm) of the island), an area that totals approximately 4,000 km^2. On the west and southwest of the island water depths reach >100m, with the east side shallower at depths of 50m (Kennington & Hiscott, 2018). The network of 10 Marine Nature Reserves around the island encompass 10.8% (430.75km^2) of the whole territorial sea, covering 51.8% of inshore (0-3 nm) waters (**Figure 1**).

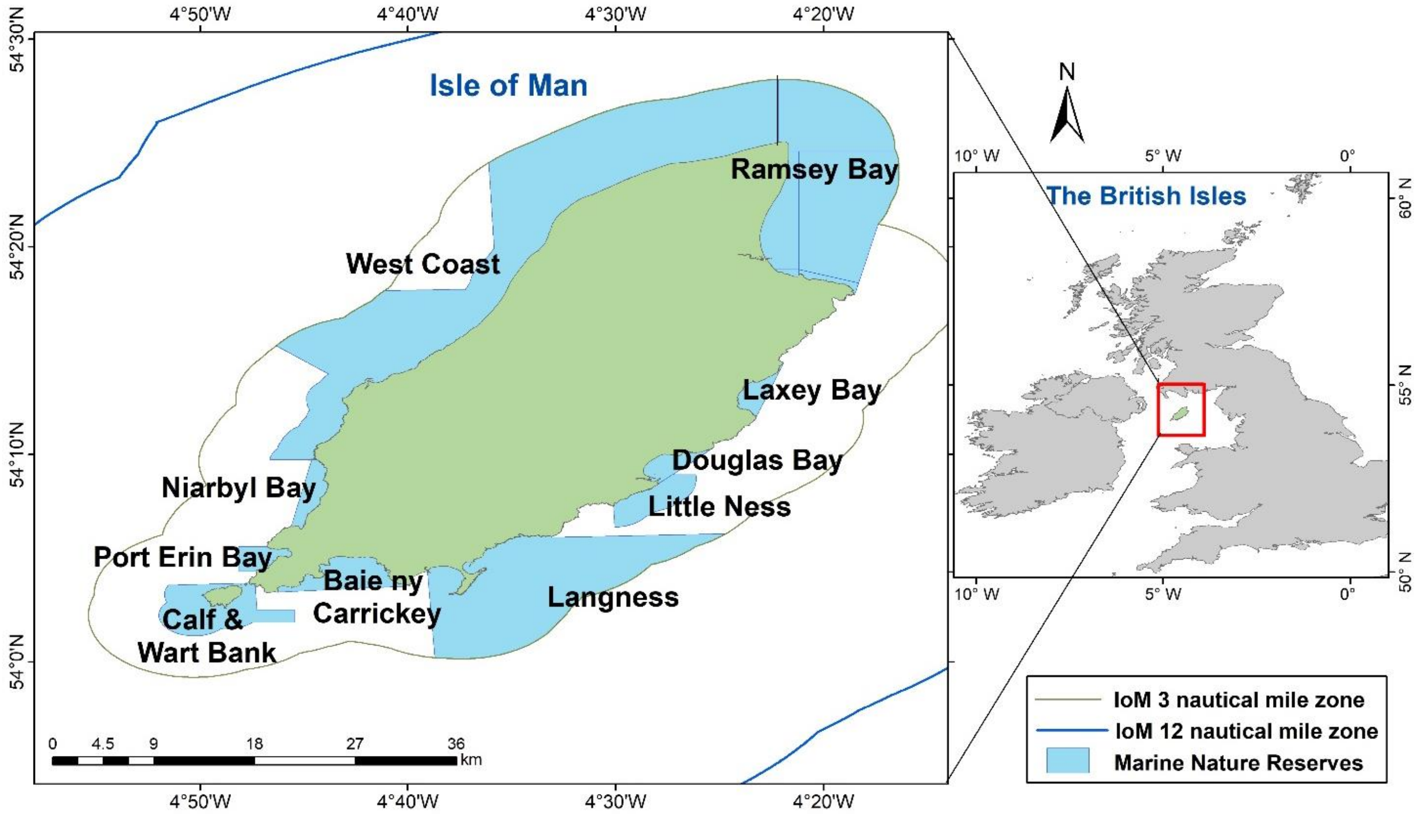


Figure 1. Map of the study area Isle of Man (IoM), shown within the British Isles. The ten Marine Nature Reserves (MNRs), managed by the Department of Environment, Food and Agriculture (DEFA), are highlighted (light blue) within the 3 (green line) and 12 (blue line) nautical mile zones around the island.

Risso's dolphin distribution

Risso's dolphin data

Data on Risso's dolphins in IoM territorial waters was collected by Manx Whale and Dolphin Watch (MWDW). Research began in 2006 and is carried out throughout the year via boat and land-based surveys as well as through sightings records submitted by the public.

Dedicated boat-based surveys following an ad hoc method and opportunistic surveys utilising a range of vessels from tourist boats to ferries were conducted when possible from 2007 to 2022 depending on weather conditions. Both types recorded effort intervals noting latitude and longitude, speed, heading, as well as environmental conditions including Beaufort sea state, visibility (<1km, 1-10km, >10km) and swell height (<0.5m, 0.5-1m, >1m) every 15 minutes or following any changes. Observers continually watching with binoculars and using the naked eye would document the time, GPS position, species, and group size whenever a cetacean sighting was made. Group composition, referring to number of adults, juveniles and calves determined by an individual's size and in the case of calves their proximity to and position in relation to an adult (Airoldi *et al.*, 2015), was also recorded.

Land-based surveys provide a non-invasive method to observe cetaceans without disturbance from boats, using specified survey locations on land to compile sightings information for the same areas. These surveys were conducted in 15-minute intervals and a total land-based survey lasted up to 3 hours, depending on weather. Effort data was recorded every 15 minutes, noting wind direction, sea state and visibility. When a cetacean was spotted coordinates were recorded, noting species and total individuals – including any juveniles, and distance to the sighting was measured using mm below the horizon. This was then matched with the appropriate effort data interval. If the sighting was a definite repeat of a previous one, including the same individuals previously observed, this was noted as a 'repeat sighting'.

Sightings submitted by the public came from opportunistic observations made both on boats or on land. Mandatory information collected from public sightings included date/time, cetacean species, total number of individuals, location and duration of sightings, with an option to identify the presence of juveniles. Behaviour was recorded for all survey types, although some public sightings submitted did not (see Table 2).

In addition to cetacean sightings, DEFA conducted stomach content analysis on a 3m Risso's dolphin of unknown sex in order to gain evidence concerning their diet in IoM waters and contribute valuable feeding information to this project. The individual had been found stranded on Niarbyl Beach, west coast IoM, in November 2011. During the undertaking of this project, a further two strandings occurred and stomach content analyses were carried out.

Firstly, a 2.3m male Risso's dolphin was found on Kirk Michael beach, on the western side of the island in June 2023, followed by a 2.5m female found August 2023 on Jurby beach, along the north-west coast.

Risso's dolphin data analysis

The three different MWDW datasets were first cleaned and standardised into one that comprised all sighting's locations, total individuals, date/time and group type, noting survey type. As only boat-based survey data distinguished between juveniles and calves, dolphin groups were divided into adults only and mixed groups (groups containing adults with juveniles and/or calves). When analysing sightings information, repeat sightings from the land data were removed to give a more accurate depiction of the number of sightings and total individuals. Group composition analysis was conducted in RStudio (version 4.3.0) (R Core Team, 2023) and excluded sightings that did not record age class. Using the GIS (Geographic Information System) software ArcMap (version 10.8.1), effort data was spatially joined to the sightings data and a grid, created using the fishnet tool, so as to map areas around the island standardised by hour of total effort. Sightings per unit of effort (SPUE) and individuals per unit of effort (IPUE) were calculated by dividing the number of sightings/individuals by duration of effort per month and year to give occurrence and abundance values in relation to the effort made. Duration was not always noted for public sightings and so the average of the total recorded durations was used for unrecorded entries to get an approximate total effort for public data.

When looking at spatial and behavioural patterns repeat sightings from the land data were included and referred to as 'observations' so as to understand how dolphin groups move and behave within an area. Observations were plotted using the recorded coordinates in ArcMap and spatially joined with MNR shapefiles to assess behaviour and group differences within the reserves, as well as identify any key areas. The MWDW dataset recorded a multitude of behavioural types and so behaviour for this analysis was standardised to fit four categories: 'Feeding', 'Travelling' 'Resting' and 'Socialising' (Table 1). 'Blowing', referring to when a dolphin surfaces, was incorporated with any accompanying behaviours or when recorded by itself was included in the travelling category. Behavioural analysis was conducted in RStudio, removing observations that did not record any behaviour. A Chi-Square Test of Independence was also conducted in MS Excel to determine if there was a significant relationship between group composition and behaviour.

Table 1. Description of the Risso's dolphin (*Grampus griseus*) behaviours analysed along with the MWDW recorded behaviours that fit into that category. Descriptions are based on those from the MWDW website (www.mwdw.net)

Behaviour	MWDW recorded behaviour	Description
Feeding	Feeding (Suspected foraging)	Prey may or may not be observed at the surface or with a dolphin in pursuit. Dolphins will surface rapidly with frequent direction change. A foraging group may remain in the same area for long periods of time.
Travelling	Normal swimming Fast swim or porpoising	When normal swimming, individuals move at constant speed in persistent directional movement. When fast swimming or porpoising individuals may leap to propel directional movement and white water can be observed.
Resting	Logging	Dolphins rest just beneath the surface with their back and dorsal fin visible. Stationary or slow movement. May be observed in between feeding bouts to conserve energy.
Socialising	Tail slapping Head slapping Breaching Bow-riding (& other boat interactions) Spy hopping	An individual slapping their tail, head or whole body (when breaching) against the surface can be used during social play, as a communication signal or in reaction to boat disturbance. During bow-riding, individuals swim at pace at the bow of a vessel. A form of play with hydrodynamic benefits that may strengthen pair bonds. Spy hopping involves rising vertically out of the water to visually assess surrounding conditions, threats and group members.

Cephalopod distribution

Cephalopod data

In order to investigate the potential prey species of Risso's dolphin, *L. forbesii* and *E. cirrhosa* presence data around the IoM was collected from various sources to be used with environmental variables to produce cephalopod habitat suitability models (Table 2). Another squid species found in IoM territorial waters, *Alloteuthesis sublata*, was also considered and occurrence records collected, however data was not sufficient enough to be included in the models. Maximum entropy modelling (Maxent) is best employed when absence data is not available and presence-only data is utilised. By extracting a sample of background locations and contrasting against the presence points, Maxent generates an estimated probability of habitat suitability/species presence with values that vary from 0, demonstrating the lowest probability of presence, to 1 (highest probability) (Phillips *et al.*, 2006). Due to elements of bias in the datasets that derive from using bycatch data rather than targeted cephalopod surveys, data collection was expanded out of IoM territorial waters to a wider area of the Irish Sea to enhance the robustness of the habitat suitability models. Furthermore, additional questionnaires were designed and circulated among commercial vessels around the IoM to acquire local spatial and temporal information and supplement the data already gathered on *L. forbesii* and *E. cirrhosa* distribution (Supplementary Figure S1).

Table 2. Cephalopod presence records acquired for the Maxent habitat suitability models. Key: QSC = Queen scallop (*Aequipecten opercularis*)

Data	Source	Species	Description
Bycatch data	Bangor University	*L. forbesii, E. cirrhosa, A. subulata*	QSC trawl survey 2012
Bycatch data	Bangor University	*L. forbesii, E. cirrhosa*	QSC trawl survey 2014
Bycatch data	Bangor University	*L. forbesii, E. cirrhosa*	QSC trawl survey 2017 for MSc project on bycatch avoidance with lights
Bycatch data	Bangor University	*L. forbesii, E. cirrhosa*	RV Prince Madog IoM QSC dredge survey (1992-2022)
Occurrence records	National Biodiversity Network (NBN) Atlas	*L. forbesii, E. cirrhosa, A. subulata*	*L.forbesii* (1999-2019), *E.cirrhosa* (1991-2019), *A.subulata* (1997-2019) records from the Irish Sea
Occurrence records	Ocean Biodiversity Information System (OBIS)	*L. forbesii, E. cirrhosa*	Collection of *L.forbesii* datasets (1951-2013) and *E.cirrhosa* (1778-2021)
Vessel monitoring (VMS) data	IFISH	*L. forbesii, E. cirrhosa*	*Nephrops* targeted (2010-2022). Merged to spatial data

Bycatch data	Bangor University	*E. cirrhosa*	RV Prince Madog Wales scallop dredge survey (2012-2014, 2022)
Bycatch data	Agri-Food and Biosciences Institute (AFBI)	*E. cirrhosa*	Northern Ireland scallop dredge survey (1994-2022)

Environmental data

Environmental variables selected for the cephalopod habitat suitability models were chosen with an understanding of cephalopod ecology. *L. forbesii* are a migratory species, moving inshore seeking suitable areas in which to spawn and die, and so water temperature, salinity, and sediment type are particularly important in identifying their distribution (Collins *et al.*, 1995). As *E. cirrhosa* are much more dependent on food requirements, it was also important to include chlorophyll α data (Boyle, 1986; MacLeod *et al.*, 2014). Maximum salinity data was sourced from Bio-ORACLE (Tyberghein *et al.*, 2012; Assis *et al.*, 2018). Diffuse attenuation coefficient at 490 nm (Kd490) indicates the turbidity of the water column, with higher Kd490 values showing lower water clarity (Mueller, 2000). Monthly Kd490, chlorophyll α, and sea surface temperature data for the study area were taken from NASA Earthdata (NASA Ocean Biology Processing Group, 2023). Each variable was then summarised by season into December - March, March - June, June - September and September – December, taking the average across all years of data (2002-2023) for each aggregated layer. Sediment data was obtained from a 2008 systematic survey of benthic habitats around the Isle of Man by Bangor University, with variables ranging from very coarse to coarse sand, very fine to medium sand, gravel and mud (Hinz *et al.*, 2009). Two further environmental factors that are important for understanding the relationship between cephalopod distribution and benthic habitats are bathymetry and bed shear stress, on which data was acquired from EDINA Digimap (EDINA Digimap, 2020) and DEFA, respectively.

Cephalopod data analysis

The cephalopod datasets were integrated and standardised, noting species, latitude and longitude towline points or cephalopod occurrence points and date. Some vessel towlines from the bycatch data were not in a straight-line and so the point which best represented the data first needed to be identified. For this, the start, mid and end points of the tow were plotted to better locate where the cephalopod catch may have occurred. Start points were then chosen as the standardised point for all tows, except the Prince Madog survey in which the midpoint was the only coordinates recorded on the straight-line tows. For the VMS data, mean coordinates were used. Cephalopod points included in the habitat suitability models were visualised in ArcMap.

Answers from the questionnaires for fishers were digitised and plotted in ArcMap to compare spatial information with the habitat suitability models as well as with Risso's dolphin data.

Habitat modelling

Environmental layers were first modified in ArcMap to all be in the same spatial resolution and extent then converted to ASCII format as required by Maxent software. A bias file was also created for each species and included in the running of the models to account for sampling bias within the cephalopod data. Including highly correlated environmental variables can impact the effectiveness of the models and so this was investigated by first stacking the ASCII files into a raster list using the 'raster' package in RStudio (Hijmans & van Etten, 2012) with Pearson rank correlations then run to determine the inclusion of variables within the models. High correlation was presented between chlorophyll α and Kd490, with values ranging from r = 0.71 - 0.99. As chlorophyll α is a more crucial predictor of cephalopod distribution, Kd490 was not included in the habitat suitability models. Prepared environmental layers, standardised dataset and bias file for both *L. forbesii* and *E. cirrhosa* were run in the Java software package Maxent programme (version 3.4.3.).

The output format of the habitat suitability models were set to cloglog. The models were cross-validated with 15 replicates to evaluate the reliability of their predictive performance. Outputs were assessed using the area under the curve (AUC) of the receiver operating characteristics (ROC) curve, with AUC values of 0.5 indicating no difference in the model to a random distribution and increasing AUC values towards the maximum of 1 denoting higher accuracy of the model (Phillips *et al.*, 2006). Response curves were also generated to show changes in predicted probability of presence with variation in environmental variables. Jackknife analysis was also run to demonstrate the effects of including or excluding each variable.

3 | RESULTS

Risso's dolphins

Sightings and number of individuals

The MWDW dataset totalled 1,238 Risso's dolphin sightings from 2006 – 2022, of which a total of 6,361 individuals were recorded (Table 3). The average number of yearly sightings was 72.8, though effort spent searching for cetaceans from both land and sea ranged from 89-372 hours a year, totalling approximately 5,438 hours. Accumulated effort made from 2006-2022 spanned each month of the year (excluding December for the boat surveys) but varied considerably year to year with 84.5% of total effort being made between March and September. Despite more effort made conducting land-based surveys, 82.8% of the total sightings came from sightings that were submitted by the public compared to 12% from land-based surveys and 5.2% from boat-based surveys (Table 3, Figure 2).

Table 3. Number of Risso's dolphin (*Grampus griseus*) sightings, hours of effort (rounded to the nearest hour) for dedicated surveys and number of total individuals per year from the Manx Whale and Dolphin Watch (MWDW) boat and land-based surveys as well as sightings submitted by the public.

	Boat			**Land**			**Public**		
Year	Sightings	Effort (Hrs)	Total Individuals	Sightings	Effort (Hrs)	Total Individuals	Sightings	Effort (Hrs)	Total Individuals
2006	0	0	0	4	92	14	28	157	120
2007	12	120	38	4	59	8	124	152	419
2008	2	40	16	4	65	14	86	76	208
2009	11	52	23	4	55	12	64	83	248
2010	0	16	0	9	356	53	37	116	203
2011	1	24	11	10	282	40	27	78	204
2012	2	63	4	5	157	27	31	93	234
2013	15	136	119	2	69	14	54	97	344
2014	5	43	31	11	216	56	46	126	320
2015	3	51	12	5	77	15	81	88	412
2016	2	28	26	17	253	50	87	87	473
2017	1	25	20	4	150	31	40	174	312
2018	4	17	24	18	148	69	145	227	819
2019	3	47	16	8	138	41	58	164	359
2020	0	16	0	6	88	26	32	194	243
2021	3	26	13	32	63	91	52	252	286
2022	0	5	0	6	112	28	33	185	215
Total:	**64**	**709**	**353**	**149**	**2,380**	**589**	**1,025**	**2,349**	**5,419**

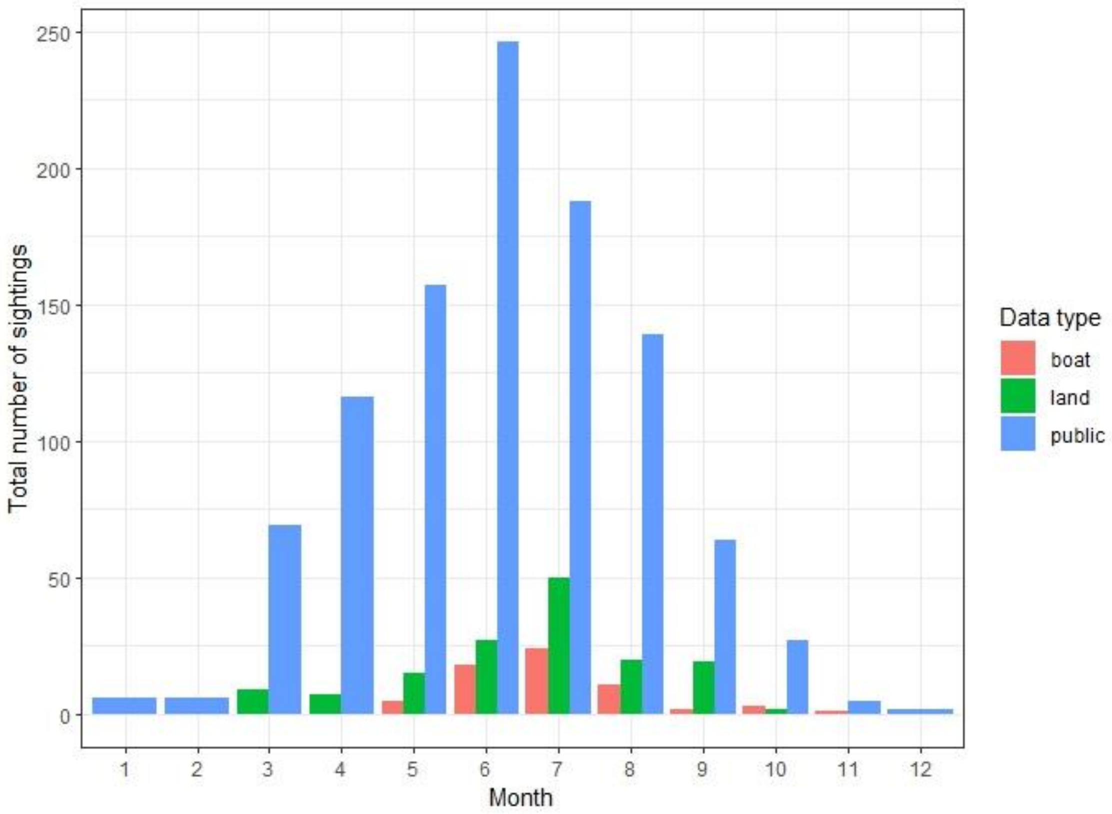


Figure 2. Total number of Risso's dolphin (*Grampus griseus*) sightings from 2006-2022 by month. Columns represent sightings recorded from boat-based surveys (red), land-based surveys (green) and opportunistic sightings reported by the public that may come from either land or boat settings (blue).

The majority (96%) of sightings occurred between March and September with peaks in June and July (n = 291, 262 respectively) (Figure 2). Although the month of June totalled the most sightings, effort was also highest during summer (955 hrs in June, 951 hrs in July), most likely due to favourable weather conditions during summer. Although adult groups were observed every month of the year only a small number of sightings were made during the winter months, with December totalling only 2 sightings over the years, although with much less effort made (118hrs). Calves and juveniles were only present from March to November, with the highest total sightings in June (n=75) and July (n=78), accounting for 29% of all June sightings that recorded age class and 31% in July. A temporal shift in the distribution of sightings could be seen with the majority beginning in Little Ness MNR on the east coast in March (n=45 adult, 13 mixed groups) and moving to Calf & Wart Bank at the southern tip of the island in July (n=85 adult, 23 mixed groups).

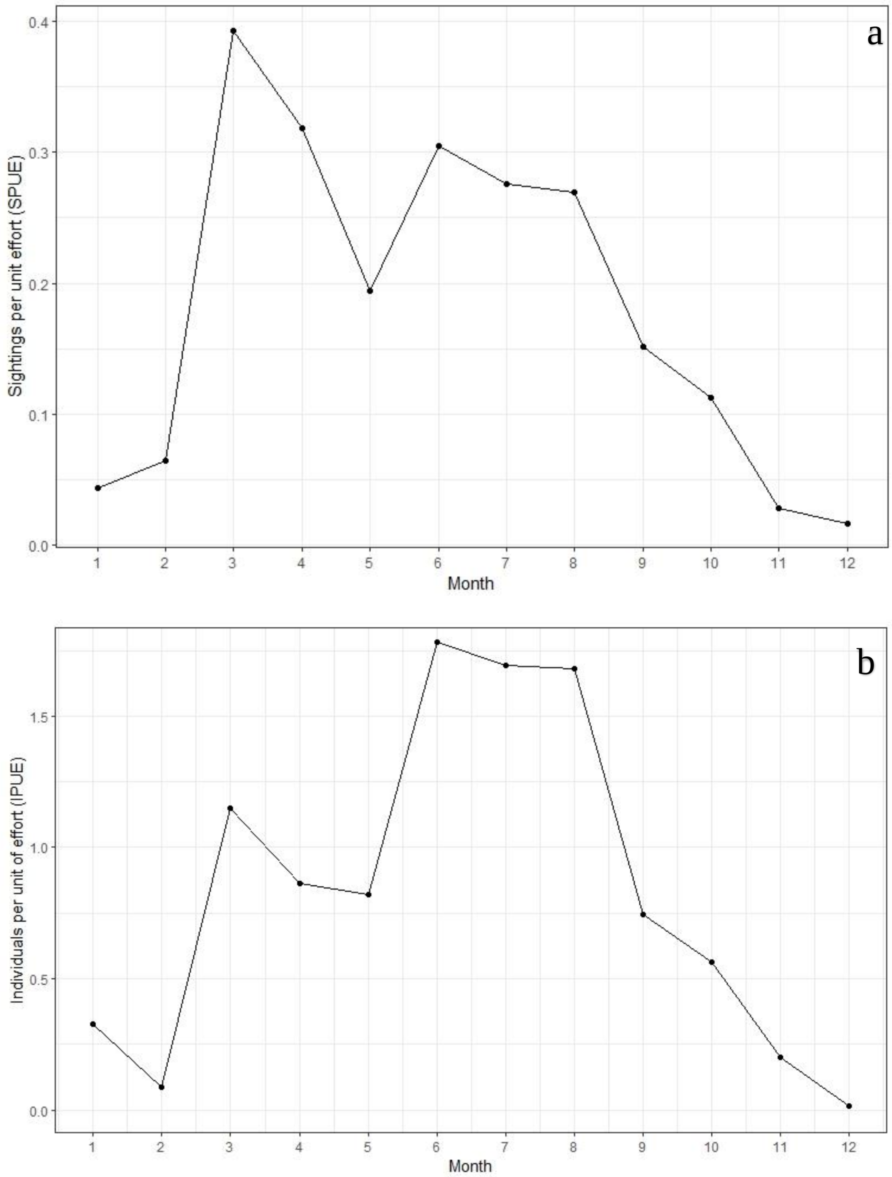


Figure 3. Line charts showing monthly changes in **(a)** Sightings per unit of effort (SPUE) and **(b)** Individuals per unit of effort (IPUE).

When considering sightings and number of individuals in relation to effort, March recorded the highest sightings per unit of effort (SPUE), but the highest number of individuals per unit of effort (IPUE) was in June, after a steep increase from May (Figure 3). Both SPUE and IPUE remained relatively stable during summer followed by a steep decrease after August. Some outliers in the data account for the higher than expected IPUE in January (IPUE = 0.33), where although there was a total of 6 January sightings across the years half of these were of large groups containing 9-15 individuals. Large groups such as these were not observed in other winter months.

SPUE and IPUE fluctuated throughout the years. SPUE peaked in 2008 (SPUE = 0.51), whereas IPUE was highest in 2018 (IPUE = 2.33) (Figure 4). A total of 912 individuals were observed during the 392 hrs of effort in 2018, differing greatly to 2010, which saw the most effort made (488hrs) and 256 individuals spotted. The most sightings of any year were reported in 2018 (n=167) which were predominantly reported from the public (n=145). However, 2007 recorded the second highest number of sightings in a year (n=140) yet had a lower IPUE than 2018 (IPUE = 1.41). Both SPUE and IPUE followed a dip between 2010-2012.

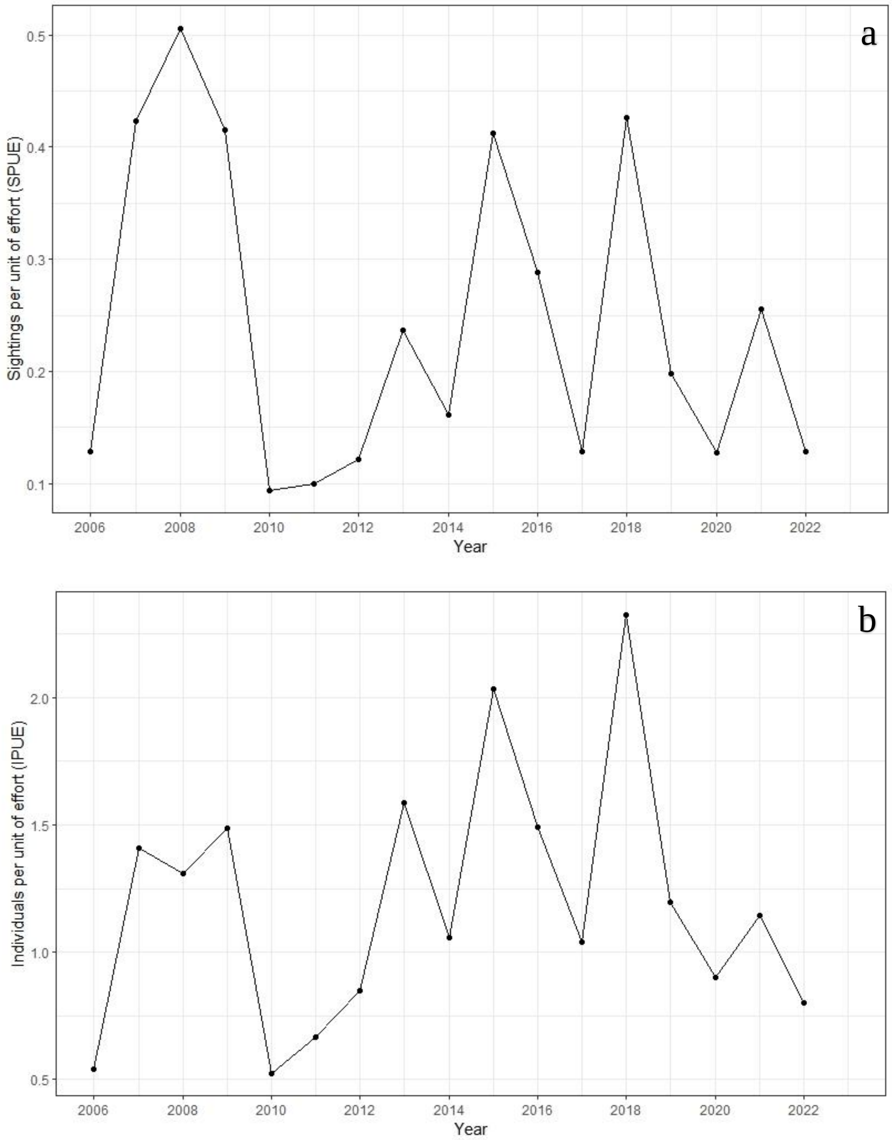


Figure 4. Line charts showing yearly changes in **(a)** Sightings per unit of effort (SPUE) and **(b)** Individuals per unit of effort (IPUE).

Risso's dolphin spatial distribution was also assessed in relation to effort made. There was an uneven distribution of effort made around the island, with greater effort predominantly in the south (Figure 5). Total effort was far less on the northern coasts, especially within Ramsey Bay MNR and the northern section of West Coast MNR ranging from 6-134 hours. SPUE (standardised by hour of total effort) in the two areas with the highest effort (>1,000 hours) differed, with the highest at the south-west tip of the island (1,290 hours, SPUE = 0.25), indicating this area, which encompasses portions of the Calf & Wart Bank, Port Erin Bay and Niarbyl Bay MNRs, could be of importance for Risso's dolphins. Effort extended outside of the IoM territorial seas with SPUE highest around the north-east 12 nm zone line (SPUE = 1.3). However, effort made within that grid totalled approximately 2 hours with only 3 sightings made suggesting more effort is needed here. IPUE for mixed groups displayed a more southerly range than for adults, with high IPUE rates around the southern tip (Figure 6).

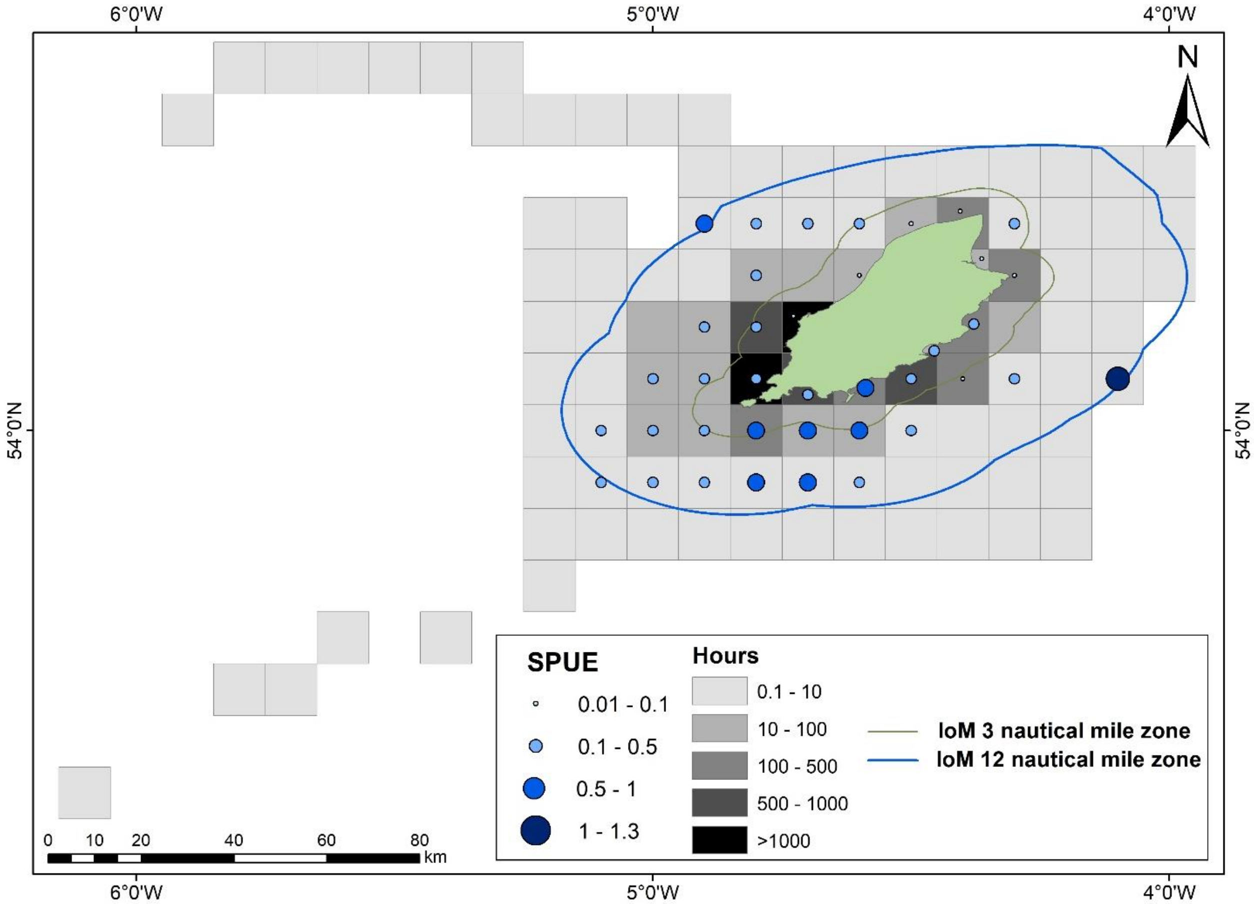


Figure 5. Map showing total effort (hours) from all boat, land and public data with sightings standardised by hour of total effort (SPUE) around the Isle of Man.

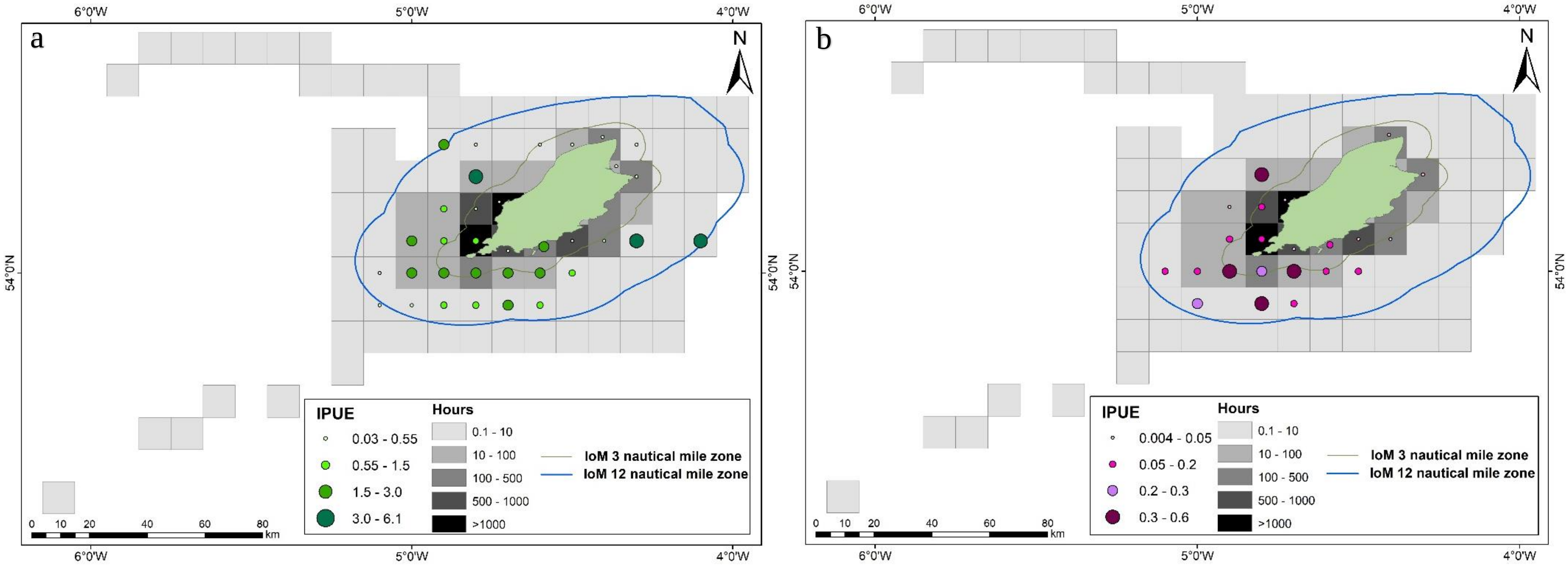


Figure 6. Map showing total effort (hours) from all boat, land and public data with **(a)** total adults standardised by hour of total effort (IPUE) and **(b)** total mixed group individuals standardised by hour of total effort (IPUE) around the Isle of Man.

Marine Nature Reserves

66% of observations occurred within an MNR (n=990), whilst 34% occurred outside the MNRs (n=521). 645 adult group observations were within MNRs, with 336 outside MNRs, and 255 mixed group observations within MNRs, whilst 152 occurred outside MNRs. Little Ness and Calf & Wart Bank were the MNRs that contained the most observations (n=257, 252, respectively) (Table 4). The few observations made in Ramsey and Laxey Bay MNRs highlight the lack of sightings to the north-east of the island.

Table 4. Number of total observations of Risso's dolphins and behavioural events occurring in each Marine Nature Reserve (MNR) around the Isle of Man. Observations and events occurring outside of the MNRs also included.

MNR	Total observations	Feeding	Travelling	Resting	Socialising
Baie ny Carrickey	141	34	98	9	29
Calf & Wart Bank	252	68	153	11	73
Douglas Bay	50	8	28	1	3
Langness	134	22	73	1	37
Laxey Bay	5	1	2	0	2
Little Ness	257	71	161	4	28
Niarbyl Bay	5	3	2	0	2
Port Erin Bay	27	3	21	0	3
Ramsey Bay	4	0	3	0	0
West Coast	115	21	82	7	25
Totals:					
All MNRs	990	231	623	33	202
Outside of MNRs	521	112	343	46	122

Behaviour

Behavioural data was recorded for 87% of Risso's dolphin observations. The most frequently recorded category of behaviour was travelling (n=966), followed by feeding (n=343) then socialising (n=324). Feeding accounted for the highest percentage observed within the MNRs (67.3% of feeding events), followed by travelling (64.5%) and socialising (62.3%). Resting was recorded in the fewest observations (n=79), of which 41.8%, totalling the lowest percentage of any behaviour to occur within the MNRs. Adult only groups were observed feeding in 26.8% (n=230) of observations that recorded both behaviour and age class, socialising in 24.5% (n=210) and travelling 73.4% (n=629). 29.7% of mixed group behavioural events engaged in feeding (n=105), 25.4% in socialising (n=90), and 73.2% in travelling (n=259). There was a significant relationship between group composition and the number of observations that included resting behaviour ($\chi^2(1) = 12.7$, p = < 0.001), with resting occurring in 10.5% (n=37) of mixed group observations and 4.9% (n= 42) of adult only group observations. Travelling was predominantly the most frequently recorded behaviour throughout the months for both groups. However, the month of May differed in that 59.4% (n= 19) of total mixed group behaviours involved feeding which was significantly different to the 22.7% of adult group behaviours that included feeding in May ($\chi^2(1) = 16.0$, p = <0.001) (Figure 7).

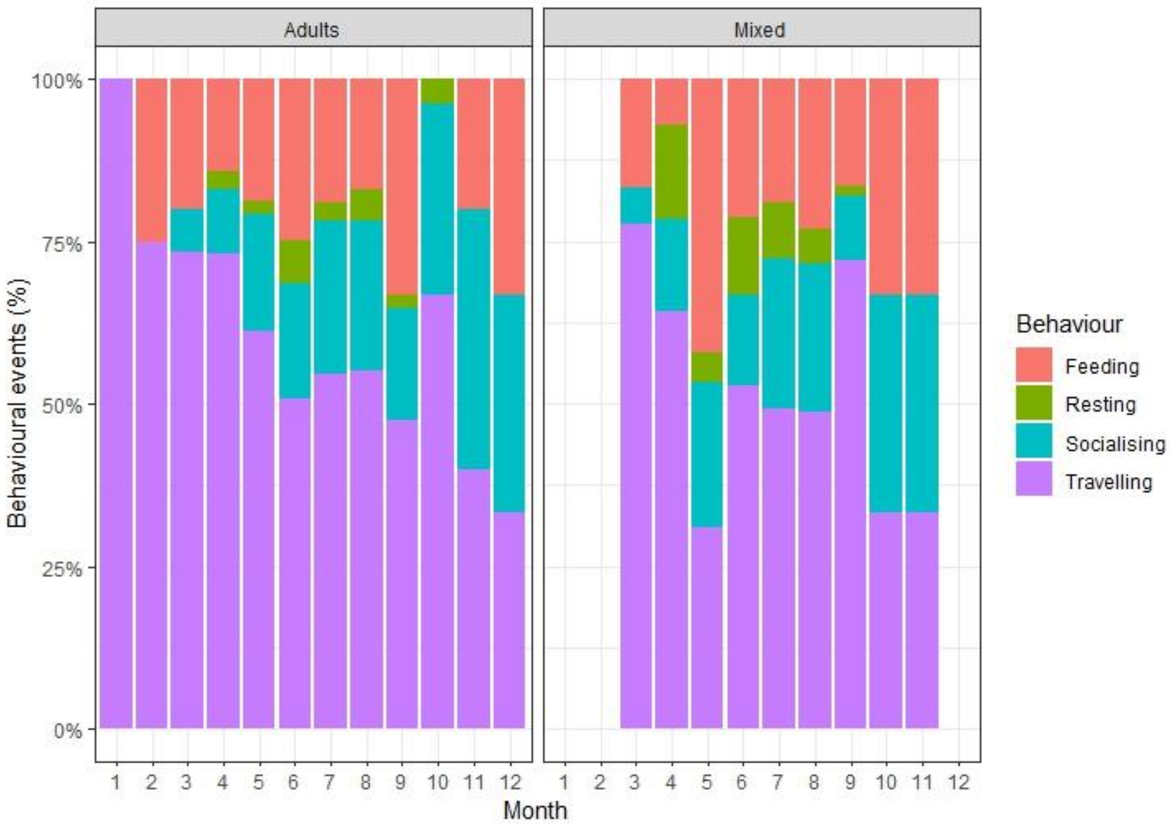


Figure 7. Stacked bar chart showing total percentages (%) of the four different behaviours by month for both adult only groups and mixed groups of Risso's dolphins (*Grampus griseus*).

Group composition

Of the 1,115 sightings that recorded age class, 306 sightings included juveniles or calves, accounting for 27.4%. Excluding the winter months when calves and juveniles were not observed (or only observed once as in November), the average group size per month was consistently larger for mixed groups (Figure 8). Both group types increased in group size during the summer months. The majority (64.2%) of adult groups recorded smaller groups of 1-4 individuals, compared to 37.6% for mixed groups. Mixed groups occupied the largest group sizes with 7.5% containing 20 or more individuals, compared to 1.6% of adult groups.

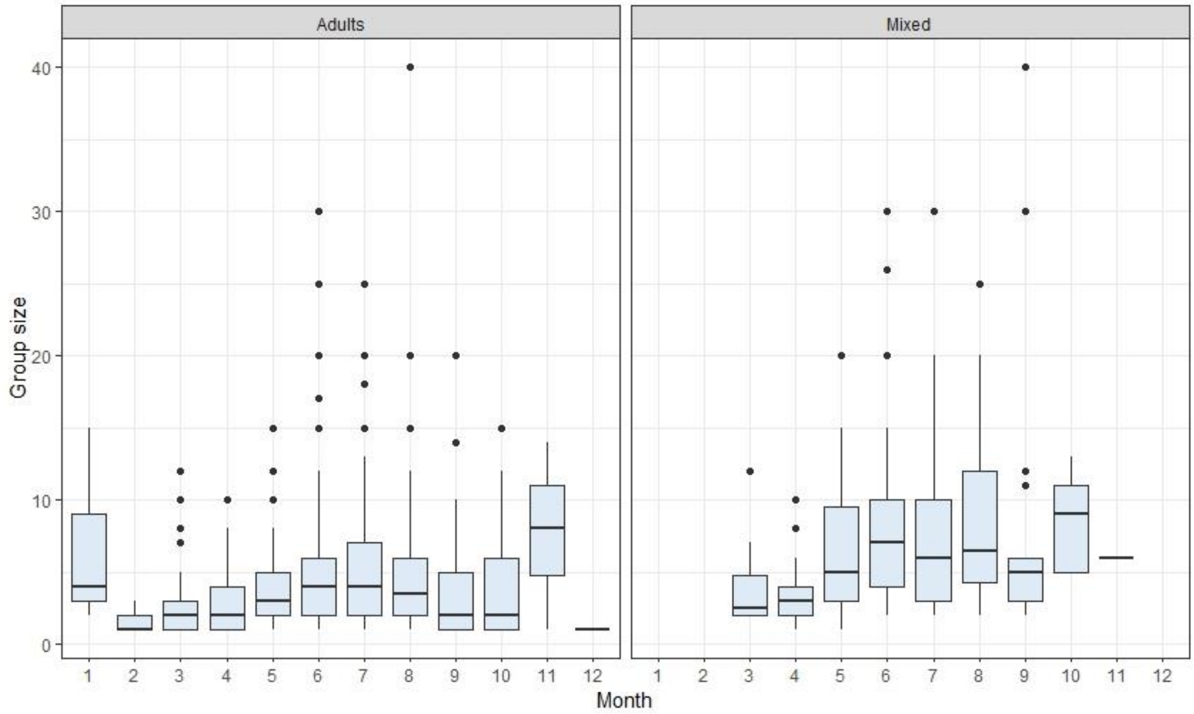


Figure 8. Boxplot showing Risso's dolphin (*Grampus griseus*) adults only group size and mixed group size for each month of the year. Medians are indicated by the bold line across the box and outliers are represented by the black circles.

Prey availability

1,820 *L. forbesii* presence points from 1951-2022 and 1,364 *E. cirrhosa* presence points from 1893-2022 were used in the Maxent habitat suitability models (Figure 9). Both species' datasets included data from every month of the year. 109 presence points were collected for *A. subulata* from 1997-2019 occurring from February to October (excluding June and September) but sample size was too small to be included in the analysis. A high number of *L. forbesii* presence points occurred off the west coast of the island and greater *E. cirrhosa* points in the west of the Irish Sea. Less data was available within the 3 nm zone and there were more occurrence points here for *E. cirrhosa* (n=172) than *L. forbesii* (n=12).

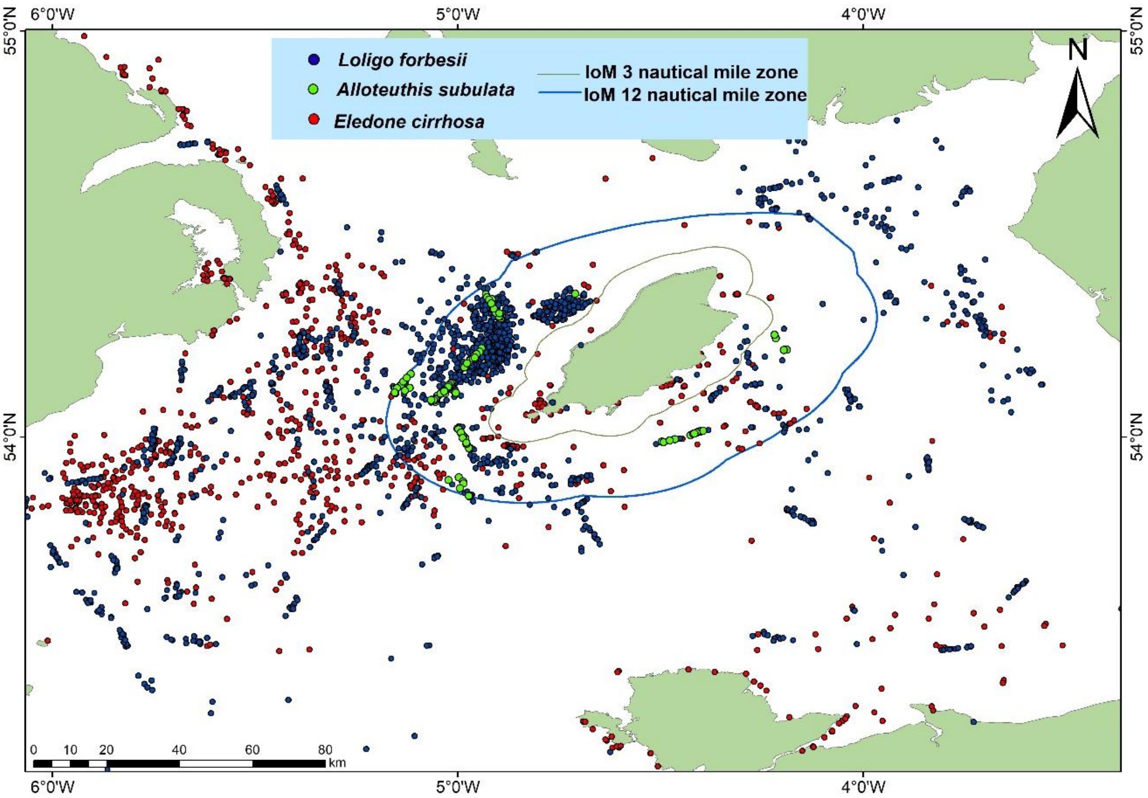
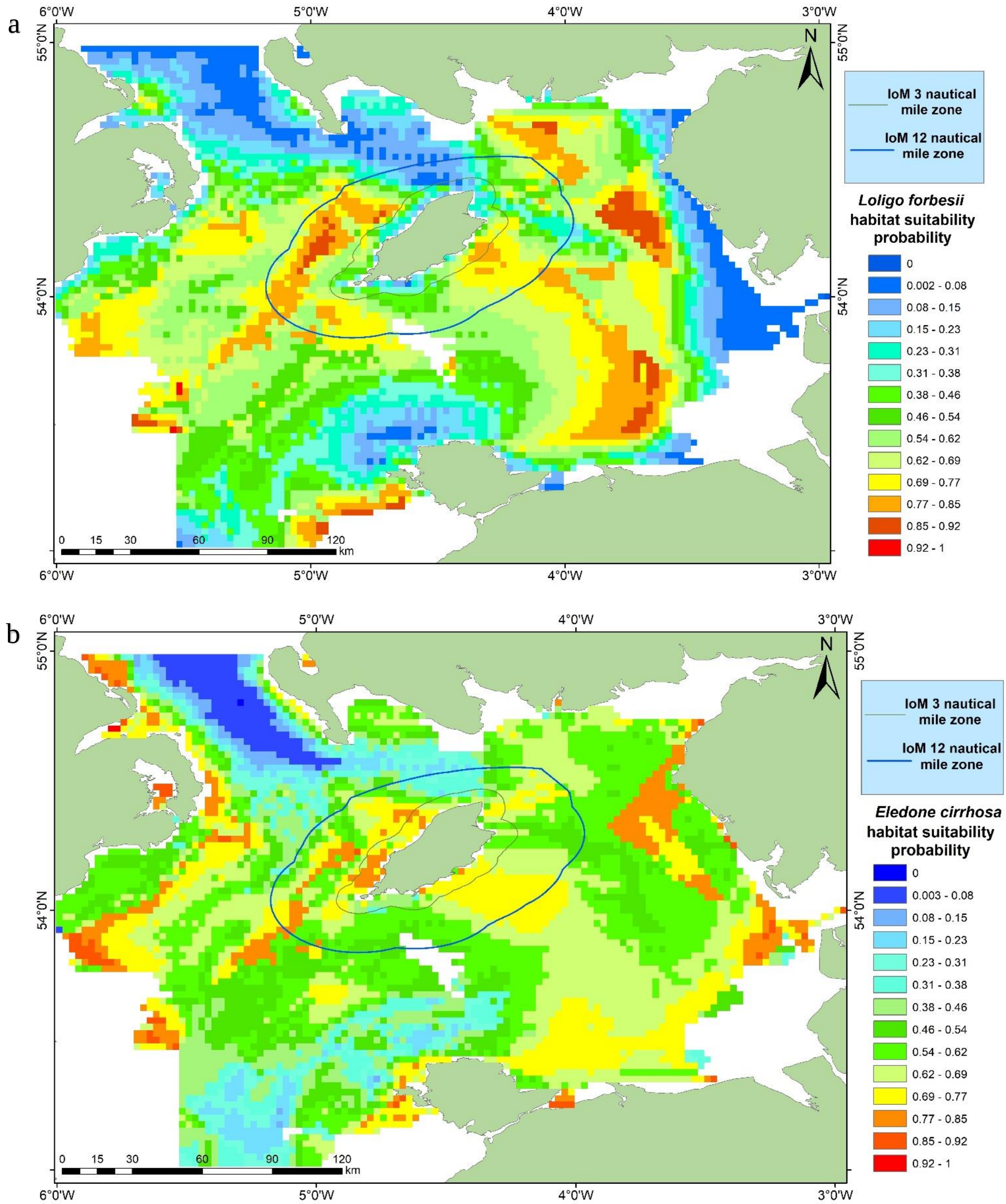


Figure 9. Cephalopod presence points collected from the various datasets, with *Loligo forbesii* (blue circles) and *Eledone cirrhosa* (red circles) used in the Maxent habitat suitability models. Green circles represent *Alloteuthis subulata* presence points.

Habitat suitability models

As the seasonally aggregated SST and chlorophyll α layers were highly correlated (r = 0.81-0.99), only the June-September layers were input into the models so as to coincide with peaks in Risso's dolphins sightings. Both model fits produced were determined as performing better than a random model would, with the *L. forbesii* model performing better with an average test AUC value of 0.740 for the replicate runs (SD = 0.02) than *E. cirrhosa* (AUC = 0.672, SD = 0.034) (Figure 10). Low habitat suitability for squid occurred around much of the island's coastline, particularly the south and south-east of the island, as well as West Coast MNR and the northern coast. The most suitable habitat for *L. forbesii* was within the 12nm zone to the south-west, with patches to the north-east. Greater habitat suitability existed inshore for *E. cirrhossa* around the whole island, in particular to the south-west and areas on the eastern side. Patches of less suitable habitat were predicted in the south-east (one of the key zones for Risso's dolphins) but not as large an area than was predicted for *L. forbesii*.



416 **Figure 10.** Cloglog output maxent habitat suitability model for **(a)** *Loligo forbesii* and **(b)**
417 *Eledone cirrhosa*. Warmer colours indicate suitable habitat and cooler colours less suitable
418 habitat.
419

Based on the jackknife analysis, the environmental predictor that contained the most useful information by itself (had the highest gain when used in isolation) in both cephalopod models was sediment (Supplementary Figure S2, Table 5). Furthermore, response curves showed sandy mud to be the most important sediment type determining suitability for both species (Supplementary Figures S3 and S4). Response curves also highlighted that *L. forbesii* was particularly sensitive to salinity. For *L. forbesii* bed shear stress was the variable that decreased gain the most when omitted, suggesting the most information that is not present in the other environmental predictors in the model, whereas for *E. cirrhosa* this factor was bathymetry.

Table 5. The relative percentage contributions of the environmental variables to the habitat suitability models for *Loligo forbesii* and *Eledone cirrhosa*

Species	Bed shear stress	Sediment	Bathymetry	Salinity	Chlorophyll α	Sea surface temperature (SST)
Loligo forbesii	30.1	28.9	28.8	7.4	3.7	1.1
Eledone cirrhosa	15.4	39.9	33.4	3.5	4.8	3

Questionnaire information

In the responses from the questionnaires distributed, IoM fishers stated that *L. forbesii* arrived to IoM waters late August/early September, first in the south of the island before moving north. Squid catches were confirmed within the queen scallop (*Aequipecten opercularis*) fishery extent until October (Figure 11a). However, squid jigging fishers stated they caught squid until December, adding that squid were also caught inshore east coast. *A. subulata* were also reported around March/April.

Information from scallop fishers confirmed that *E. cirrhosa* are regularly caught year round in all areas of the king (*Pecten maximus*) and queen scallop fishing extent, with inshore gaps where MNRs are located and fishing is not permitted (Figure 11b). The extent, however, does not include a large area on the west coast as this supports a *Nephrop*s fishery rather than scallop fishing activity due to the muddy sediment here. Similarly, only the isolated scallop fishing ground exists to the north of the island and so these areas are not a definitive extent of *E. cirrhosa* distribution but help support the habitat suitability model.

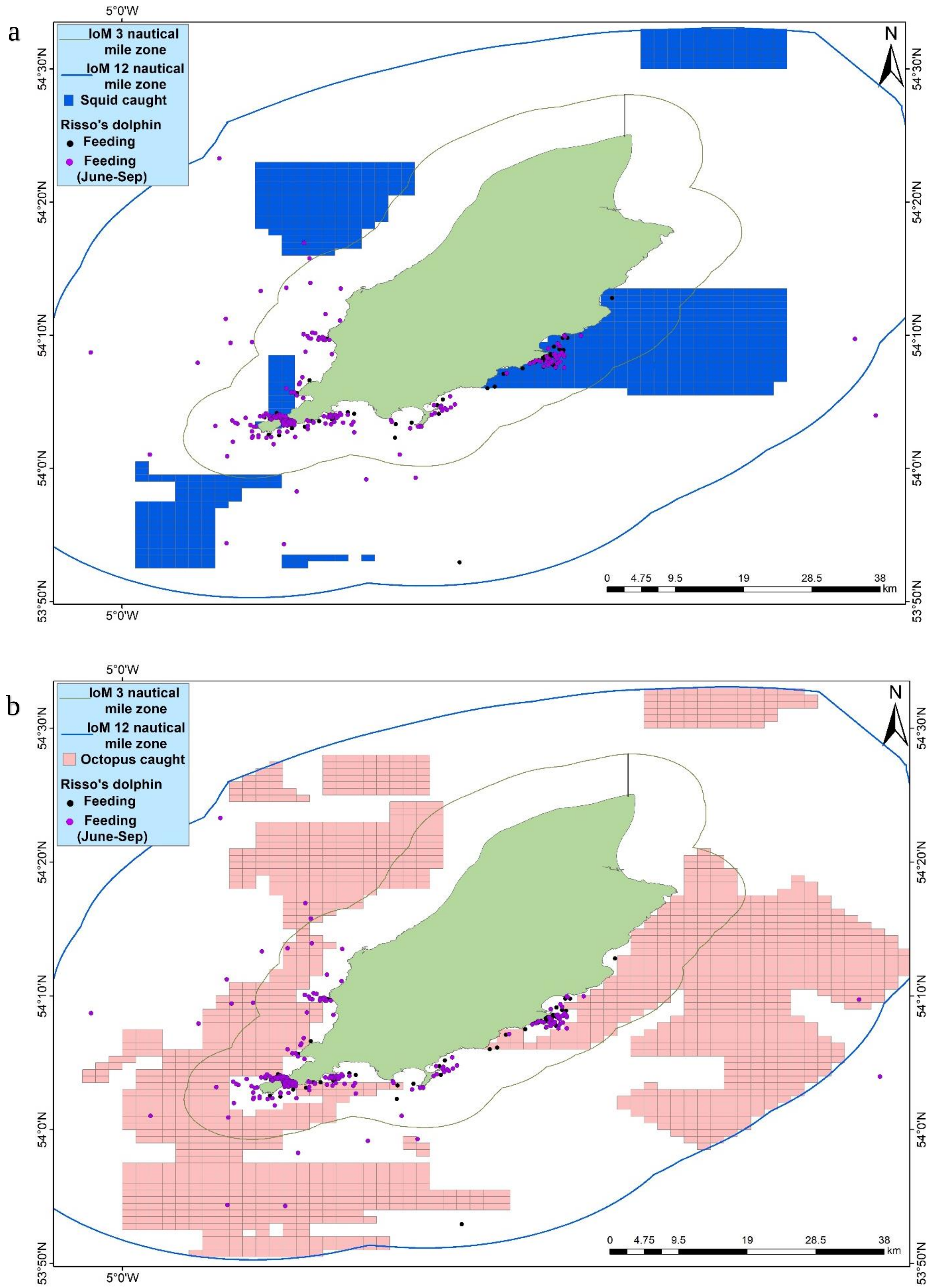


Figure 11. Answers from the fishers' questionnaire mapped around the Isle of Man. **(a)** Blue squares outline the extent in which *Loligo forbesii* are caught **(b)** Pink squares outline the extent in which *Eledone cirrhosa* are caught. Black circles show Risso's dolphin feeding observations, with pink circles highlighting feeding that occurred from June-September.

Prey overlap

As scallop fisheries are not permitted within the MNRs that are situated along the coast and the majority of Risso's dolphin sightings were recorded close to the coast, overlap between the different species' distribution could be more precise (Figure 11). Similarly, environmental data for the habitat suitability models was missing close to the coast, due to the nature of using satellite data. When comparing with *L. forbesii* habitat suitability, some Risso's feeding points between June-September occurred in the 12 nm zone in areas with better suitability, however the majority were recorded inshore in areas of low suitability (Figure 12a). The questionnaire responses provided some areas of feeding and squid overlap on the east coast and the area to the south-west above the Calf (Figure 11a). However, much better overlap was found with *E. cirrhosa* habitat suitability as more Risso's dolphin feeding points occurred in areas of better suitability (Figure 12b) as well as in multiple areas of the scallop fishery extent that confirmed the presence of octopus year round (Figure 11b). Feeding observations within Langness MNR, a large area on the south-east coast not covered by the scallop fishery (88.67km^2), overlapped with a patch of relatively high *E. cirrhosa* suitability (0.79).

Risso's dietary information

Cephalopod beaks were found during the stomach content analyses conducted on the stranded individuals. The individual collected in 2011 contained 4 pieces, as well as cephalopod remains of the radula attached to the buccal mass as well as part of a tentacle. A fragment of *Fucus sp.* (brown algae) was also found in the stomach of this individual, indicating feeding occurring close to the seabed. The individual that stranded in June 2023 contained 2 pieces whereas 21 disarticulated beaks (14 upper and 7 lower) were found in the stranded individual from August 2023. Preliminary identification from all three strandings indicated that all cephalopod beaks examined were octopus (*Eledone*), confirming that Risso's dolphins feed on octopus in IoM waters. Photographic samples from this study were sent for further expert validation, with results pending.

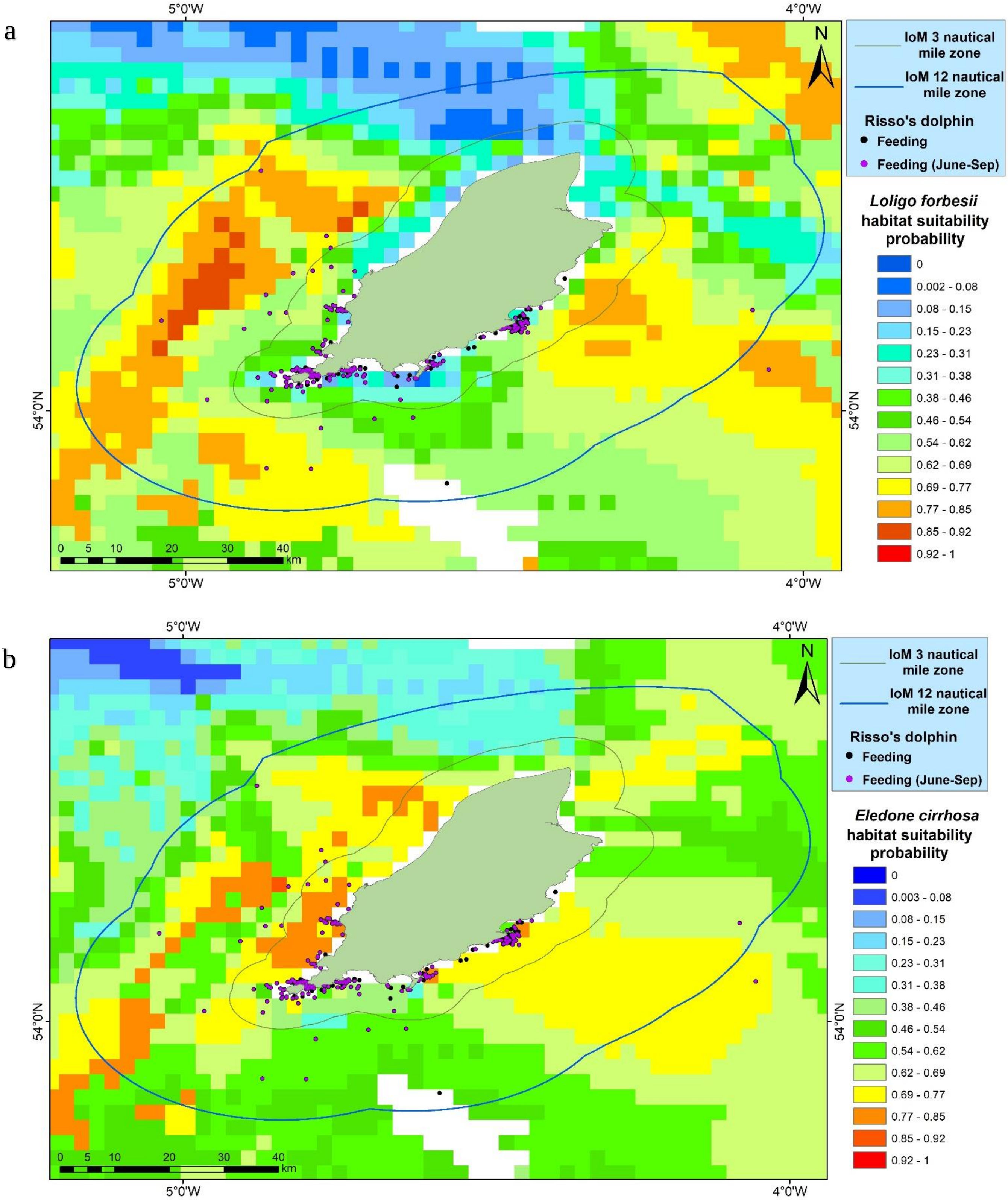


Figure 12. Risso's dolphin feeding observations (black circles – with pink highlighting feeding occurring from June-September) with the habitat suitability maps for **(a)** *L. forbesii* and **(b)** *E. cirrhosa*.

4 | DISCUSSION

The present study demonstrates the spatial and temporal patterns of Risso's dolphins around the Isle of Man and gives potential driving factors behind their distribution. Seasonality was exhibited through shifts in distribution and group size during summer, predominantly occurring from March to September. Behavioural and group differences support the hypothesis of Risso's dolphin nursery groups utilising IoM waters and contribute to the notion that IoM waters are critical habitat for the species. The examination of marine reserves provides supplementary information on how the species are using these areas and indicate the key zones for these cetaceans. Cephalopod distribution knowledge and Risso's dolphin dietary information acquired suggests octopus, rather than squid, to be a contributing driving factor behind Risso's dolphin distribution in IoM waters.

Variability in effort limited some conclusions on Risso's dolphin spatial distribution around the island. However, sightings showed predominant use of the eastern and southern sides of the island, from Douglas Bay down to the south-west of the Calf. Little Ness and Calf & Wart Bank MNRs were two important reserves. Although effort was not consistent around the island, these areas still maintained high sightings rates per hour in relation to effort. Ramsey Bay MNR contained the least observations. Although much less effort was made around the northern area, aerial studies conducted by Ørsted from August 2021- July 2022 off the north-east coast also confirmed a lack of Risso's dolphin sightings in this area (Pavat & Semple, 2022), suggesting that conditions in the north are not as preferable for this species. Multiple sightings occurred just outside of the Calf & Wart Bank MNR highlighting the need for expansion of this reserve. However, the Calf is a small area ($2.50km^2$) to cover when searching for cetaceans and so could bias the sightings data as it is easier to spot dolphins here compared to West Coast MNR which is a much larger area to cover. The majority of sightings came from the public which were mainly opportunistic and so less effort was made. Nevertheless, key areas appear to be predominantly on the east, south-east and south-west coasts of the island but more consistent effort both offshore and in the north is needed to further assess this.

The distribution of *E. cirrhosa*, rather than *L. forbesii*, overlapped more consistently with the key areas of Risso's dolphin distribution. The habitat in these key areas was predicted to be more suitable for *E. cirrhosa* and Risso's dolphin feeding behaviours overlapped more consistently with the extent provided by questionnaire answers. Although sample size was small, stomach content analysis conducted in this study confirmed that Risso's dolphins are feeding on octopus in these waters. However, Risso's dolphin feeding was rare further north than Douglas Bay despite fishers stating that *E. cirrhosa* are caught in the north-east. This indicates other factors at play that require further research, such as differences in octopus abundance or environmental conditions, making the south/east of the island particularly suitable for Risso's dolphins. Although the extent for squid described in the questionnaire answers does not show their definitive distribution around the whole island, it does not include the south and south-east areas that are key zones for Risso's dolphin. These key zones also coincide with the large areas of low habitat suitability from the *L. forbesii* model, suggestive that squid may not be the dominant food source. Strong currents situated around the Calf, where speeds can exceed $4ms^{-1}$ (Kennington & Hiscott, 2018), are unfavourable for squid as they need to glide on currents of appropriate speed to maintain the efficient swimming patterns vital for their survival and limit their energetically-costly jet propulsion (O'dor & Webber, 1991; O'Dor *et al.*, 1995, 2002). Data from the questionnaires was lacking close to the coast where the majority of Risso's dolphin sightings occur due to fishing being prohibited in MNRs. Including environmental variables at a higher resolution in the models would also improve data coverage close to the coast. Many cephalopod occurrence points for the models came from further offshore, which may not have provided enough coastal information, especially for migrating squid. Eliminating the biases in the cephalopod data, arising predominantly from the use of bycatch data, by including systematic surveys of the whole study area to assess cephalopod distribution may offer a more distinct picture of predator-prey overlap.

Temporal patterns found are further indicative of octopus being a more important indicator of Risso's dolphin distribution. Questionnaire responses for squid showed areas west of the Calf where squid are caught and on the east coast within Little Ness MNR where many encounters of Risso's dolphin feeding are seen. However, *L. forbesii* are observed from late August/early September, starting in the south of the island before moving north, with reported seasonal peaks in abundance around October and November that correspond to spawning squid in inshore coastal waters (Duncan, 2009). This highlights a mismatch between the earlier June/July peaks of Risso's dolphins in the south or, when considering relation to effort, the high SPUE in March with sightings distributed on the eastern shores, arriving to the IoM much earlier than the squid abundance peak. Cephalopods have short life spans and are highly sensitive to environmental fluctuations, creating variability in stock sizes (Pierce *et al.*, 2008). Variability in SPUE and IPUE could also highlight the variability in octopus stocks as a result of environmental conditions, potentially accounting for the high number of Risso's dolphins observed in 2018 as well as the dip from 2010-2012. Being present year round with a slightly longer lifespan (18-24 months), and therefore potentially less susceptible than migrating squid to variability in stock size (Boyle, 1983), *E. cirrhosa* present a more consistent and available food source for Risso's dolphins in IoM waters. *E. cirrhosa* abundance peaks have previously been reported in June within the IoM territorial seas (Veale *et al.*, 2001). Furthermore, evidence from Scotland suggests *E. cirrhosa* to be particularly common inshore from July-September (Boyle, 1986), describing sexual maturation reached during this period in which spawning occurs shortly after followed by death (Boyle, 1983). This coincides with high Risso's dolphin IPUE rates during the summer months, followed by a sharp decrease in IPUE after September.

Temporal changes that occur in summer can be linked with feeding behaviours. The higher IPUE in the summer months indicates larger group sizes, which were shown in both mixed and adult groups. Increased group size has been suggested to be a result of cooperative foraging in teuthophagous cetaceans in which collective searching proves beneficial, covering a larger area (Whitehead, 2003; Hartman *et al.*, 2008). Feeding behaviours may have been underrepresented in the behavioural data for this study. Aspects of travelling, associated with finding prey, and socialising behaviours can be involved in feeding behaviours, i.e. splashing, lunging, tail slapping etc, making some behavioural recordings easy to misidentify. Similarly, as the MWDW dataset records behaviours from differing cetacean species seen in IoM waters, the rapid surfacing and frequent direction change may not be as applicable to Risso's dolphins, who are known to predominantly feed on cephalopods (Clarke & Pascoe, 1985). The fragment of *Fucus sp.* found in the stomach content analysis may also indicate time spent close to the seabed. Therefore, the inclusion of long dives that suggest deeper diving would be more beneficial when recording Risso's dolphin feeding behaviours (Gunter, 1954; Bearzi *et al.*, 1999), especially if feeding on *E. cirrhosa* that are benthic organisms. A more in-depth focus on Risso's dolphin behaviour would be beneficial to further understand feeding in combination with prey availability as well as further stomach content investigation to increase sample size and provide a more thorough picture of whether octopus is the predominant food source in IoM waters.

Environmental factors may be at play in driving the temporal shifts observed in Risso's dolphin distribution. These shifts can be seen in Little Ness and Calf & Wart Bank MNRs, with Little Ness important from March-June and July seeing a shift from Little Ness to Calf & Wart Bank, suggestive of other factors during the summer causing this southerly shift. Seasonal patterns also occur in other areas of the UK, moving offshore October to May (Evans *et al.*, 2003; Reid *et al.*, 2003), and may coincide with changes in prey availability along with physical processes such as the often seasonal oceanic fronts that are enriched with nutrients, stimulating high biological activity due to tidal mixing (Miller & Christodoulou, 2014). Between the south coast of the Isle of Man and the coast of County Dublin, Ireland, the western Irish Sea Front forms (Pingree & Griffiths, 1978), undertaking daily movements over several kilometres due to strong winds and tidal advection. This seasonal front could be influencing Risso's dolphin distribution in IoM waters as was found for harbour porpoise (*Phocoena phocoena*) (Weir & O'Brien, 2000). Studies in Welsh waters have suggested a link between Risso's dolphin distribution and tidal state (de Boer *et al.*, 2013), topographic and dynamic cyclic variables, such as mixed waters (de Boer *et al.*, 2014). Examining the relationships between environmental variables and Risso's dolphin distribution through the use of Generalised Additive Models (GAM) could provide more details on the additional factors that make the Isle of Man an important habitat for this species and shed light on the temporal shifts.

As well as potentially being an important site for Risso's dolphin feeding, the presence of nursery groups in IoM waters further demonstrates the area as critical habitat. The larger group sizes for mixed groups shown in this study along with calves with foetal lines previously reported (Howe, 2018) are indicative of nursery groups, utilising social support whilst raising calves (Hartman *et al.*, 2008). Understanding cetacean behaviour is challenging, only witnessing a proportion of their activities at the surface during the day, with interpretations varying between observers. Although resting behaviour is difficult to decipher in the field and could be misidentified as normal swimming, the significant difference between adult and mixed groups shows the importance of nursery group resting behaviours. Due to the high expenditure of energy that comes with lactation and swimming with calves in the echelon position (Mann & Smuts, 1999; Williams & Noren, 2009) and nursing times often occurring during rest periods (Stensland & Berggren, 2007), nursery groups may spend a greater proportion of time resting. Furthermore, resting was the only behaviour that recorded more observations outside of MNRs than inside. Boats and other sources of anthropogenic noise have significant effects on dolphin resting behaviour (Würsig, 1996; Bejder *et al.*, 2006). Age class was not always recorded and so information on behavioural differences may still be lacking. Nevertheless, resting is a biologically critical behaviour, especially for nursery groups and as such the significant difference shown between mixed groups and adults demonstrates the necessity of providing ample opportunities, through the expansion of MNRs, for Risso's dolphins to rest in these waters. The further evidence for nursery groups utilising IoM waters as well as feeding information provided in this study supports the hypothesis of critical habitat.

Understanding the inter-relationships between abiotic and biotic variables that drive Risso's dolphin distribution is key for conservation and particularly insightful when assessing areas for marine-renewable energy developments. This species remains an understudied cetacean and with genetic variation found between Risso's dolphins in the UK and the Mediterranean Sea (Gaspari *et al.*, 2007) it is important to determine how these dolphins are using British waters. This study provides important information on Risso's dolphin distribution and the potential factors indicating the Isle of Man to be critical habitat for the species. Further research on environmental correlations as well as cephalopod abundances around the island could help to understand factors driving Risso's dolphin distribution to key areas and the temporal shifts in distribution observed in IoM waters.

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CONFLICT OF INTEREST

The author (s) declare none.

ETHICAL STANDARDS

Not applicable

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Questionnaire: Squid, octopus and Risso's dolphins in Isle of Man waters

Risso's dolphins (*Grampus griseus*) are one of the more understudied dolphin species. In most parts of the world they are considered a shelf slope, deep-diving, species (typically found in waters 400-1000 m depth) so their presence in the shallow coastal waters of the Isle of Man and British Isles is of interest. Current knowledge of Risso's dolphins indicates that they feed exclusively on cephalopods (i.e. squid, octopus and cuttlefish). A collaborative project among Bangor University, Manx Whale and Dolphin Watch and Isle of Man Government DEFA is exploring the spatial and temporal distribution of potential prey species (squid and octopus) to provide a better understanding of the presence of Risso's dolphins within Isle of Man territorial waters. Due to the lack of any substantial targeted commercial fishery for squid or octopus in the Isle of Man, we are looking to obtain local ecological knowledge (LEK) from commercial fishers on when and where they catch these cephalopod species as bycatch in other fisheries.

We would be grateful if you could take the time to complete the survey below and share your knowledge of squid and octopus distribution with us. The survey will take around 5 minutes to complete all 10 questions. All information collected in this survey will be anonymised and no individual responses will be published. Data will be stored in a safe and secure manner and held by DEFA for use in this study only. You have the right to remove consent to hold and process this data at any time. This study is part of a Master's thesis with the sole aim of increasing our understanding of the presence of Risso's dolphins in Isle of Man waters.

If you have any questions or concerns about this questionnaire, or would like to request a paper version, please contact Dr Isobel Bloor at i.bloor@bangor.ac.uk

Thank you for you cooperation.

If you are happy for us to know which vessel you fish from and your name, then please complete the details section here (otherwise please proceed to Q1):

Vessel Name: ________________________

Fishers Name: ________________________

Number of years commercial fishing in Isle of Man: ___________________

SQUID

1. Have you ever caught **squid** in your fishing activities?

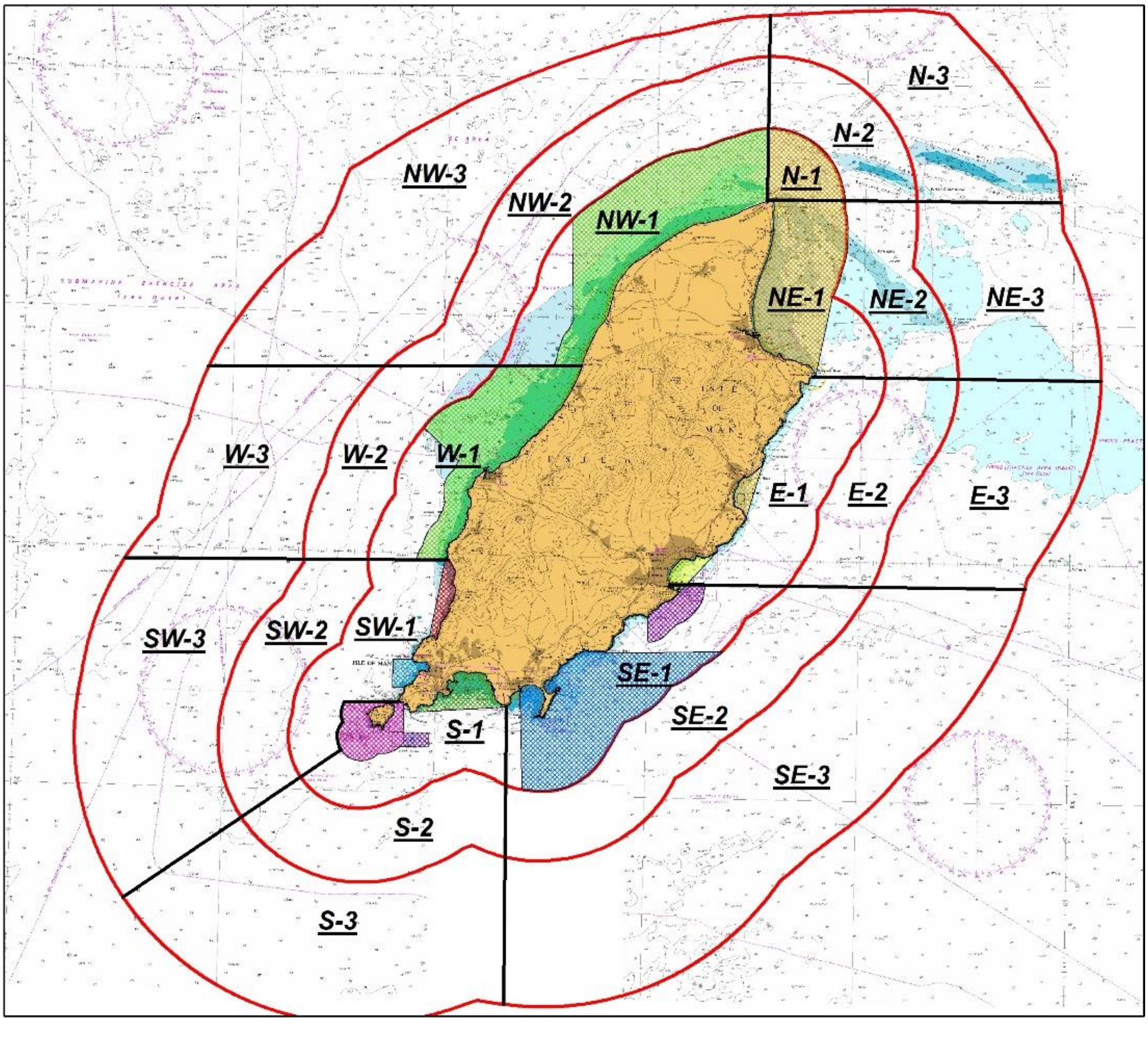
   Yes ☐ (if yes, please go to Q2)
   No ☐ (if no, please go to Q6)

2. In which fisheries/gear do you typically catch **squid**:

   King Scallop Dredge ☐ Crab and Lobster pots ☐
   Queen Scallop Trawl ☐ Whelk pots ☐

3. On the map below, please draw circles to show the rough location(s) and extent(s) where you typically catch **squid** (red lines indicate 3nm, 6nm and 12nm limits, coloured areas are MNRs):

   If you feel there is a 'best' location to catch squid within Isle of Man territorial waters, please add an 'x' to the centre of that circle



4. Please indicate in the table below which months you typically catch **squid** while fishing within IoM territorial waters. Place a tick against those months where squid are caught and if you have a sense of abundance, you can add L (Low), M (Medium) or H (High) with each tick:

Month	**Abundance**
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

5. From your experience do you have any other additional comments on the spatial and/or temporal distribution of **squid** within Isle of Man territorial waters that may be of interest:

Comments:
____
____
____
____
____
____

OCTOPUS

6. Have you ever caught **octopus** in your fishing activities?

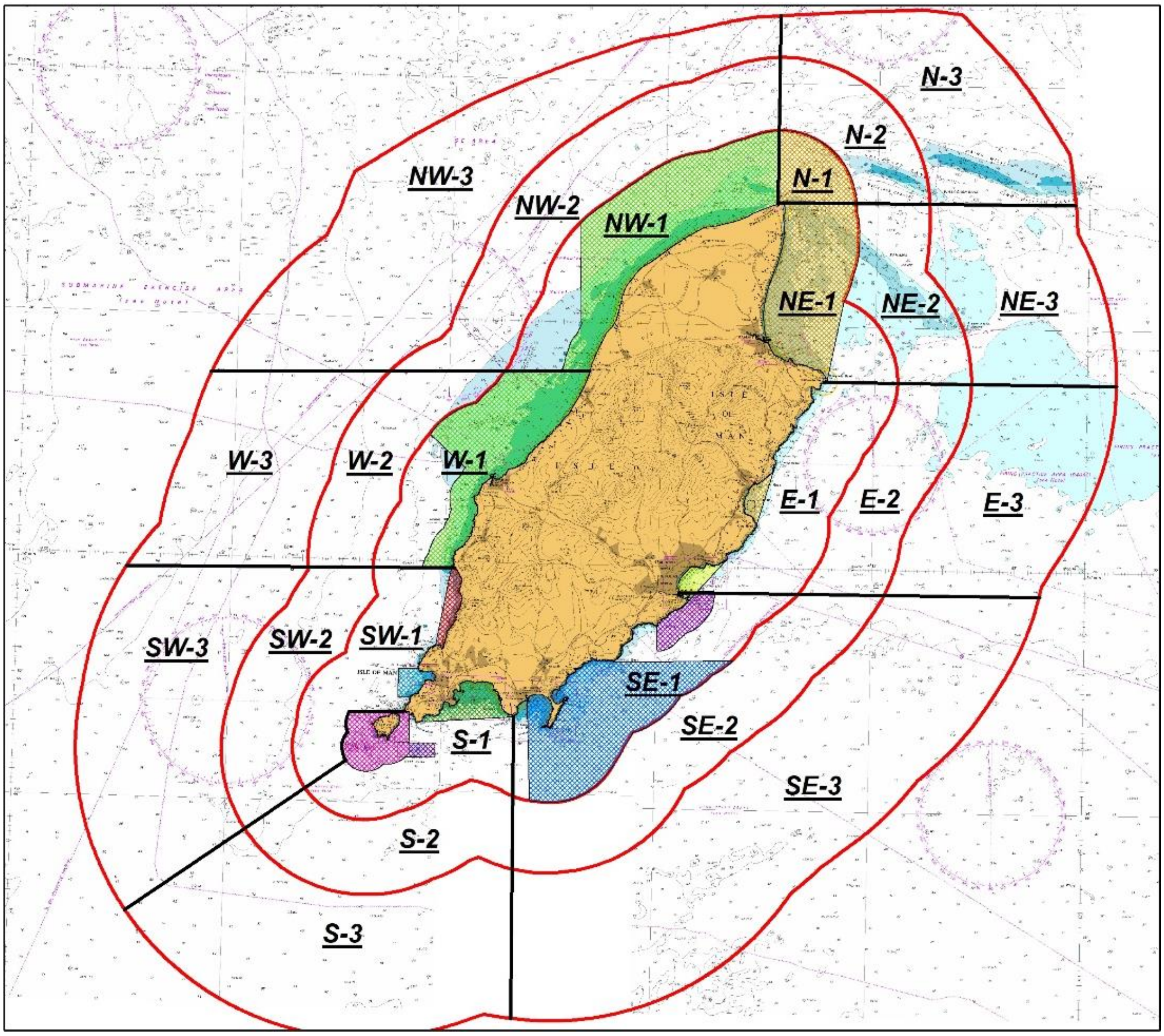
   Yes ☐ (if yes, please go to Q7)
   No ☐ (if no, that is the end of the questionnaire!)

7. In which fisheries/gear do you typically catch **octopus**:

   King Scallop Dredge ☐ Crab and Lobster pots ☐
   Queen Scallop Trawl ☐ Whelk pots ☐

8. On the map below, please draw circles to show the rough location(s) and extent(s) where you typically catch **octopus** (red lines indicate 3nm, 6nm and 12nm limits, coloured areas are MNRs):

   If you feel there is a 'best' location to catch octopus within Isle of Man territorial waters, please add an 'x' to the centre of that circle



9. Please indicate in the table below which months you typically catch **octopus** while fishing within IoM territorial waters. Place a tick against those months where squid are caught and if you have a sense of abundance, you can add L (Low), M (Medium) or H (High) with each tick:

Month	**Abundance**
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

10. From your experience do you have any other additional comments on the spatial and/or temporal distribution of **octopus** within Isle of Man territorial waters that may be of interest:

Comments:

____

____

____

____

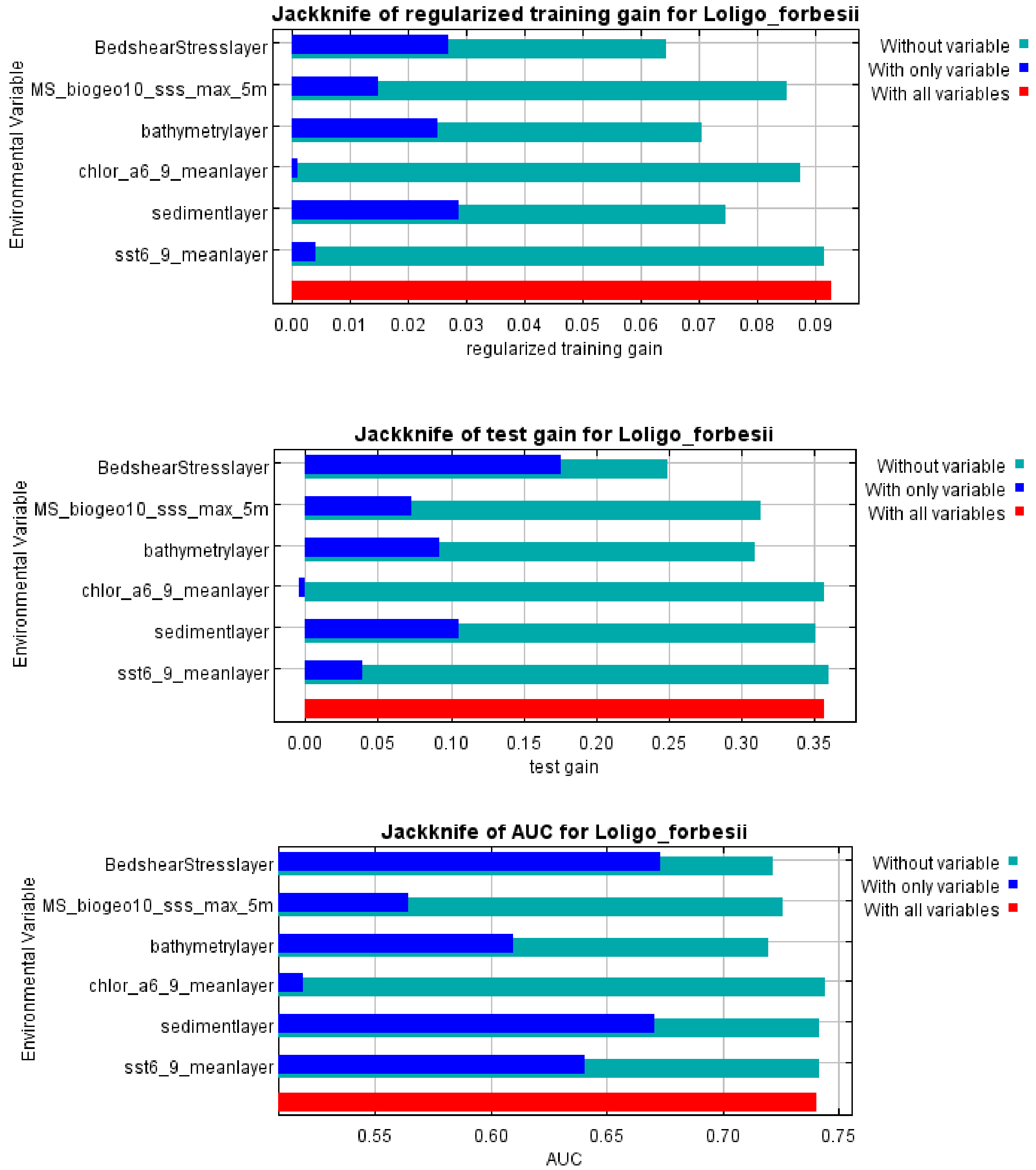
____

____

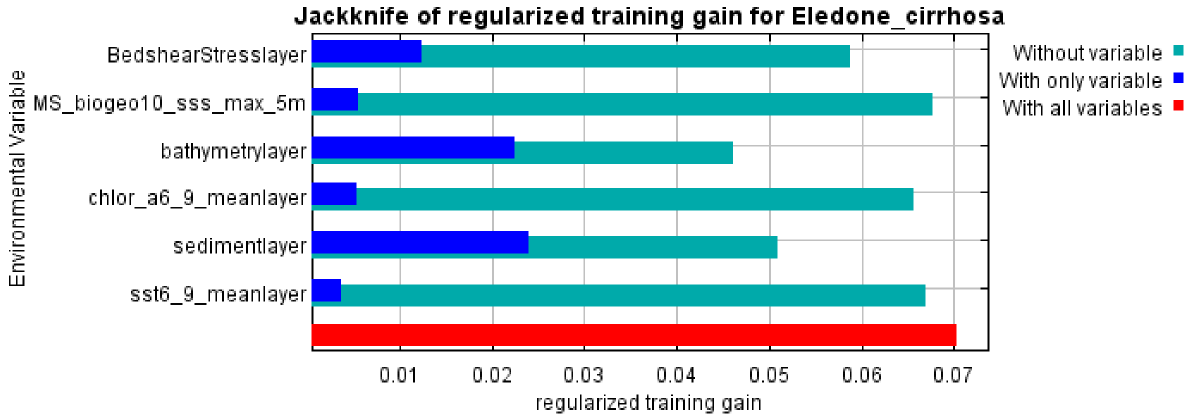
--END---

Many thanks for taking the time to complete this questionnaire and help further research and knowledge on the presence of squid, octopus and Risso's dolphins in Isle of Man territorial waters.

Figure S1. Questionnaires distributed to IoM fishers a


Jackknife of regularized training gain for Loligo_forbesii
BedshearStresslayer
MS_biogeo10_sss_max_5m
bathymetrylayer
chlor_a6_9_meanlayer
sedimentlayer
sst6_9_meanlayer
Environmental Variable
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09
regularized training gain
Without variable
With only variable
With all variables
Jackknife of test gain for Loligo_forbesii
0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35
test gain
Jackknife of AUC for Loligo_forbesii
0.55 0.60 0.65 0.70 0.75
AUC

b


Jackknife of regularized training gain for Eledone_cirrhosa
BedshearStresslayer
MS_biogeo10_sss_max_5m
bathymetrylayer
chlor_a6_9_meanlayer
sedimentlayer
sst6_9_meanlayer
Environmental Variable
0.01 0.02 0.03 0.04 0.05 0.06 0.07
regularized training gain
Without variable
With only variable
With all variables

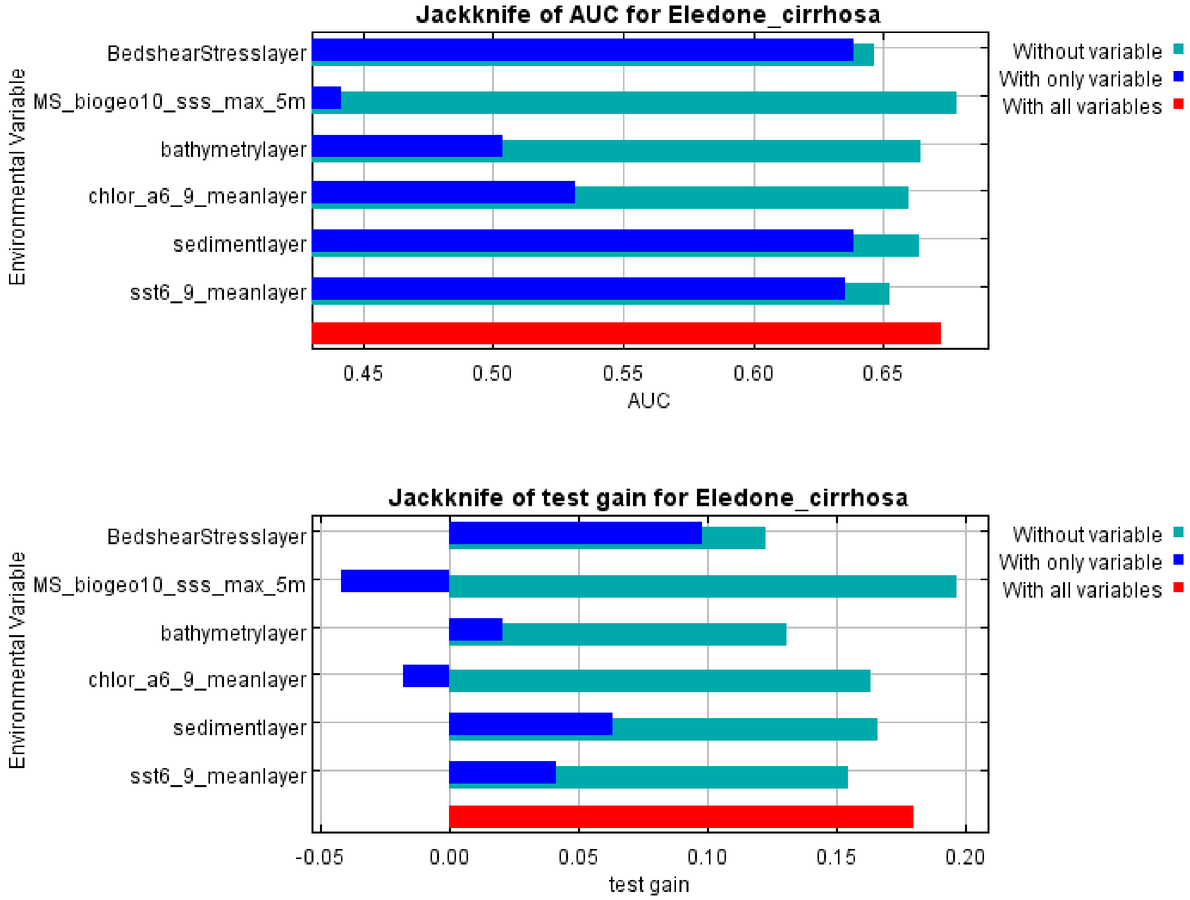
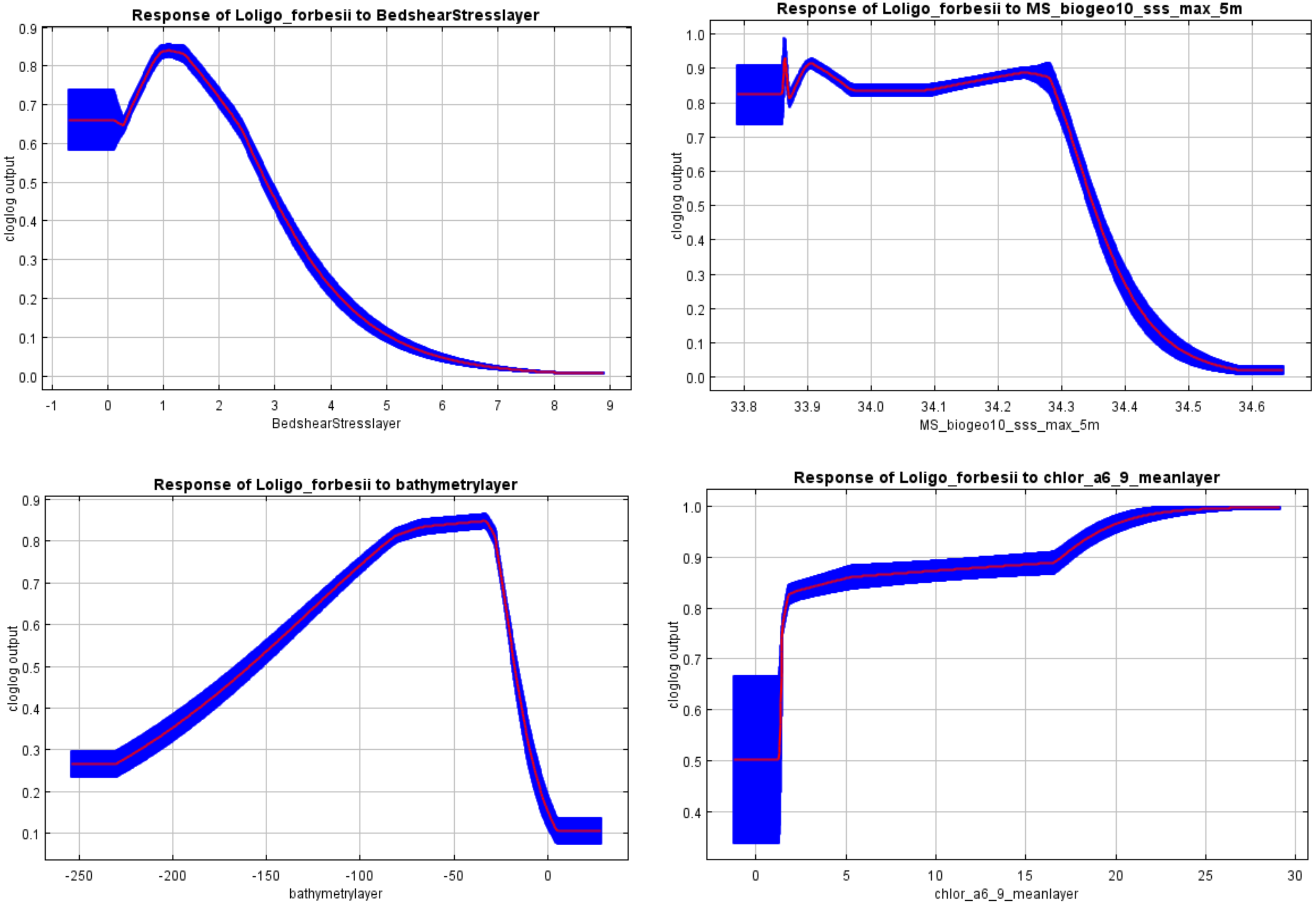


Figure S2. The results of the jackknife test of variable importance, using the training gain, test gain and AUC on the test data for **(a)** *Loligo forbesii* and **(b)** *Eledone cirrhosa*. Values shown are averages over the 15 replicate runs. Variables displayed are bed shear stress, max salinity, bathymetry, chlorophyll α from June - September, sediment and sea surface temperature (SST) from June – September.


Response of Loligo_forbesii to BedshearStresslayer
cloglog output
BedshearStresslayer
Response of Loligo_forbesii to MS_biogeo10_sss_max_5m
cloglog output
MS_biogeo10_sss_max_5m
Response of Loligo_forbesii to bathymetrylayer
cloglog output
bathymetrylayer
Response of Loligo_forbesii to chlor_a6_9_meanlayer
cloglog output
chlor_a6_9_meanlayer

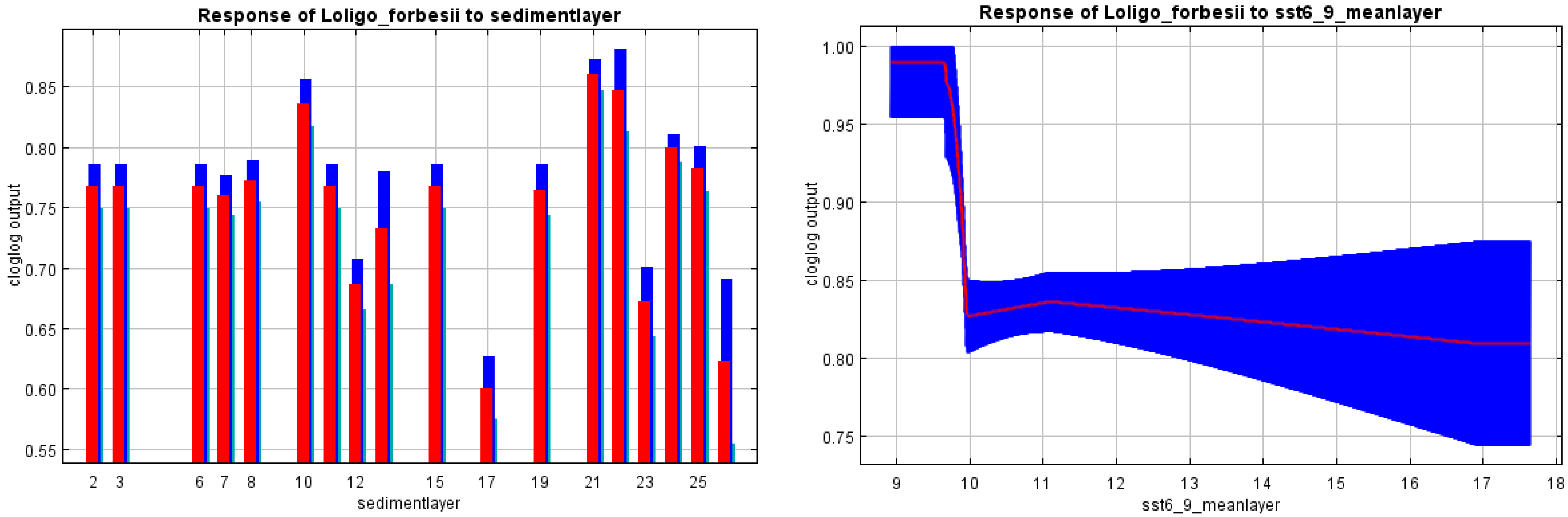
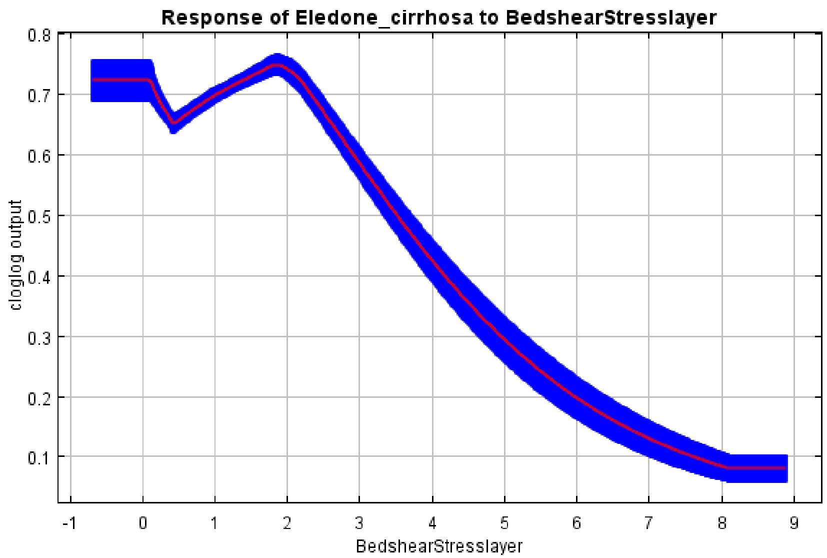
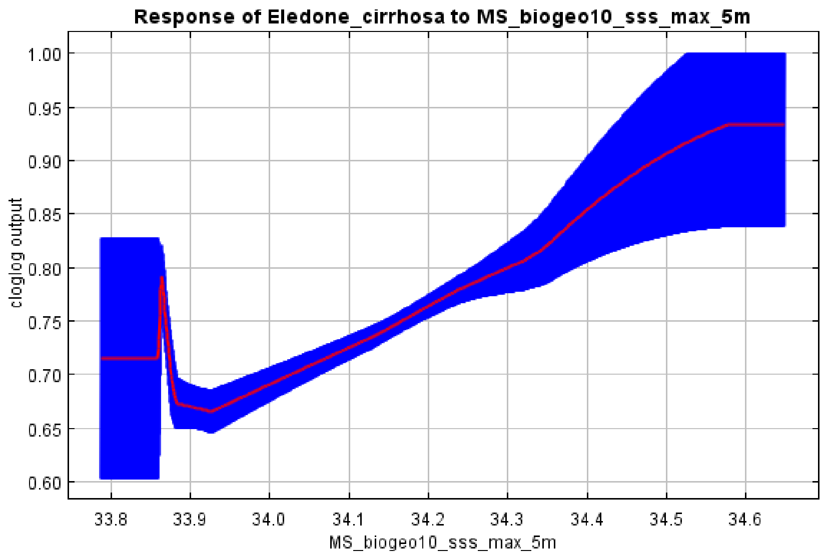
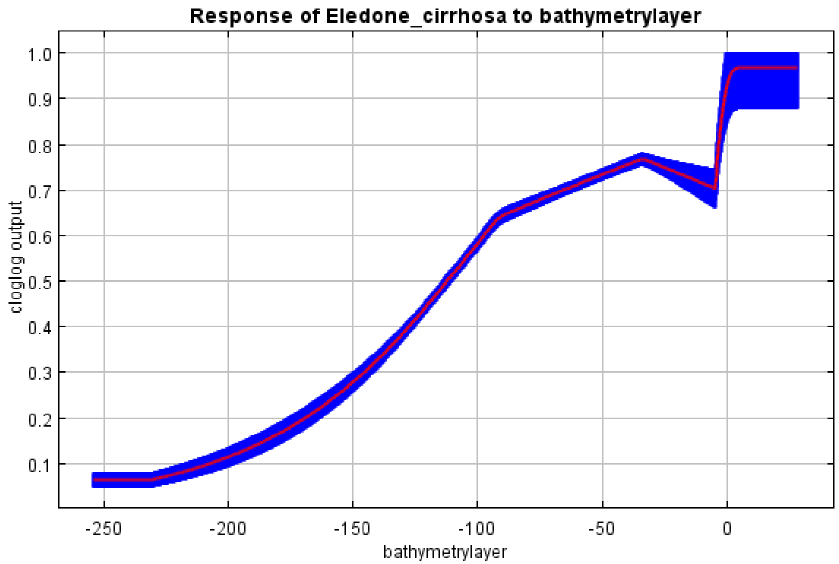
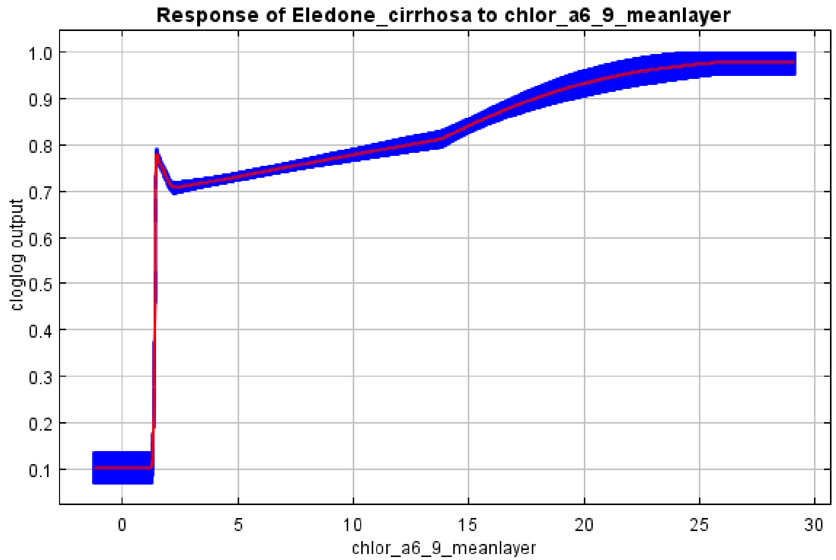


Figure S3. Maxent cloglog output of response curves for *Loligo forbesii*. Response curves show how bed shear stress, max salinity, bathymetry, chlorophyll α from June - September, sediment and sea surface temperature (SST) from June – September impacts the Maxent prediction. Curves give the mean response of the 15 replicate runs (red) as well as the mean +/- one standard deviation (blue, two shades for categorical variables).


Response of Eledone_cirrhosa to BedshearStresslayer
cloglog output
BedshearStresslayer


Response of Eledone_cirrhosa to MS_biogeo10_sss_max_5m
cloglog output
MS_biogeo10_sss_max_5m


Response of Eledone_cirrhosa to bathymetrylayer
cloglog output
bathymetrylayer


Response of Eledone_cirrhosa to chlor_a6_9_meanlayer
cloglog output
chlor_a6_9_meanlayer

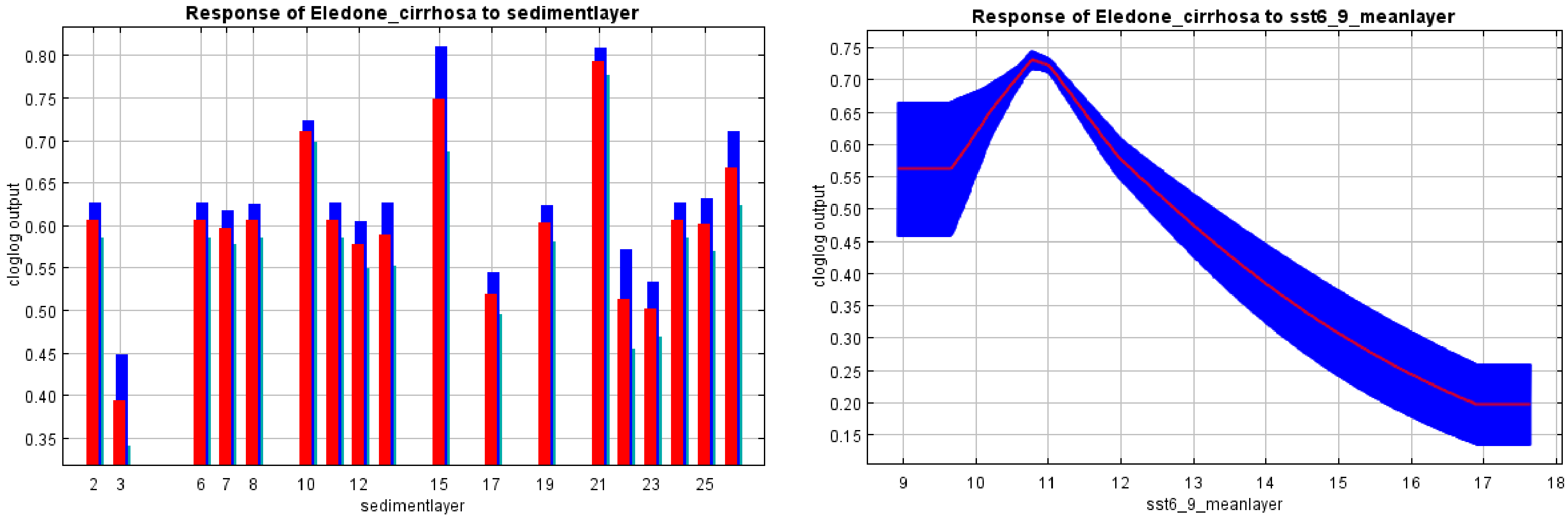


Figure S4. Maxent cloglog output of response curves for *Eledone cirrhosa*. Response curves show how bed shear stress, max salinity, bathymetry, chlorophyll α from June-September, sediment and sea surface temperature (SST) from June-September impacts the Maxent prediction. Curves give the mean response of the 15 replicate runs (red) as well as the mean +/- one standard deviation (blue, two shades for categorical variables.