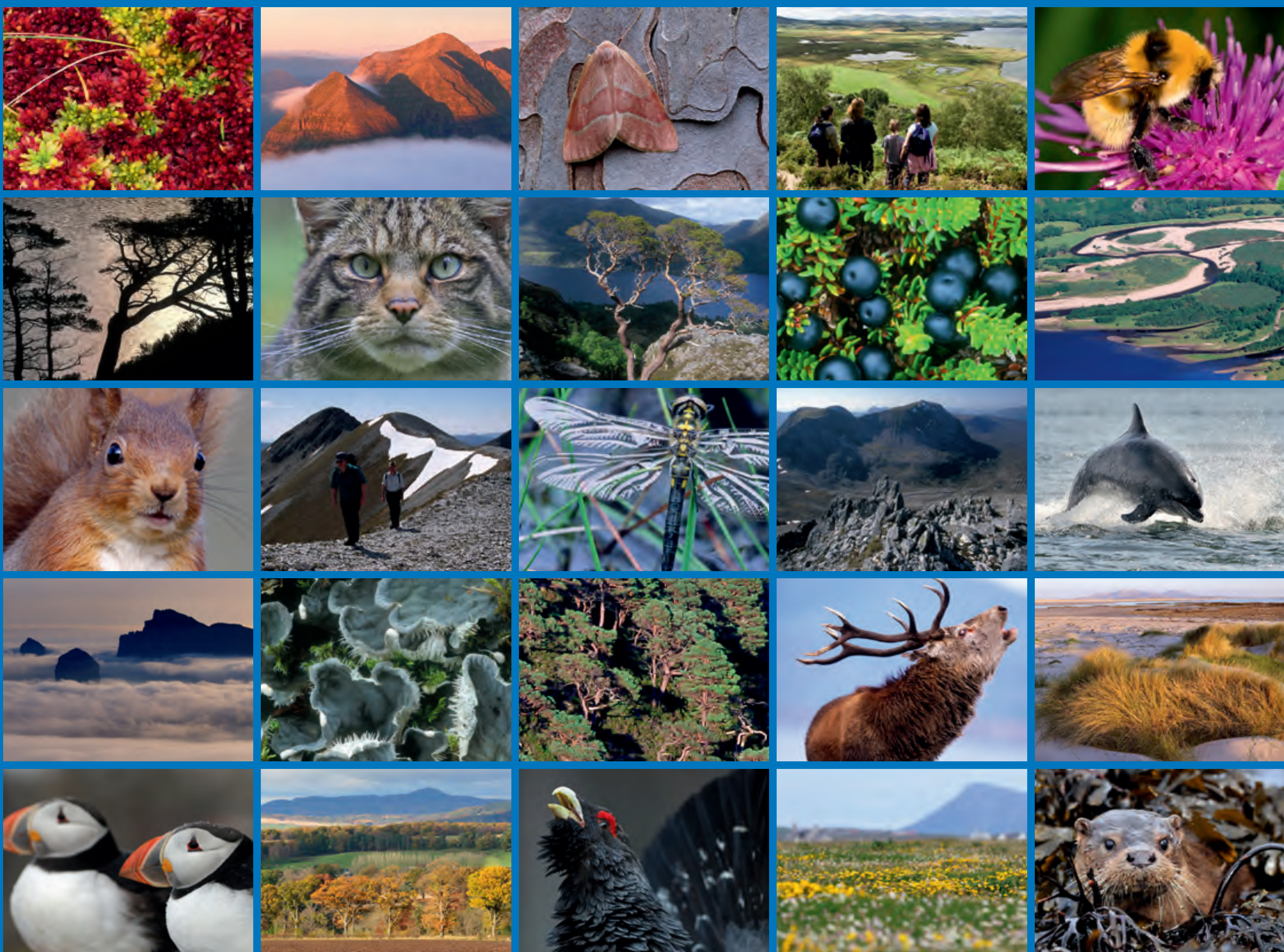
Scottish Natural Heritage
Commissioned Report No. 530

Can habitat modelling for the octopus *Eledone cirrhosa* help identify key areas for Risso's dolphin in Scottish waters?



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COMMISSIONED REPORT

Commissioned Report No. 530

Can habitat modelling for the octopus *Eledone cirrhosa* help identify key areas for Risso's dolphin in Scottish waters?

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COMMISSIONED REPORT

Summary

Can habitat modelling for the octopus *Eledone cirrhosa* help identify key areas for Risso's dolphin in Scottish waters?

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Keywords

Risso's dolphin; *Eledone cirrhosa;* modelling; Marine Protected Areas; Scottish waters.

Background

Marine Protected Areas (MPAs) are becoming an increasingly important tool for the conservation of cetacean species. However, establishing the best location for MPAs can be difficult. This is because, as mobile predators, cetaceans are not always present in their preferred habitats and may also be encountered when moving between locations that are particularly important for them.

This study aimed to investigate whether modelling the distribution of a key prey species for Risso's dolphin could help identify areas that are especially important for this species.

Main findings

- Analysis of stomach contents from stranded Risso's dolphins shows that by far the most important species in their diet in Scottish waters is the octopus *Eledone cirrhosa*.
- Analysis of data collected by research trawls between 2008 and 2012 found that there was a strong relationship between the distribution of *Eledone cirrhosa* and a number of environmental variables, such as water depth, variation in seabed topography and distance from the coast.
- This allowed us to model *Eledone cirrhosa* distribution in relation to environmental variables so as predict areas where the best habitat for this species occurs, and therefore, where they are likely to be most abundant.
- This modelled distribution suggests that *Eledone cirrhosa* is likely to be particularly abundant around the Outer Hebrides and the Northern Isles.
- However, when the modelled distribution of *Eledone cirrhosa* was compared to sightings data on presence of Risso's dolphin, it was found that there was no relationship between the two datasets. This suggests that Risso's dolphin may not preferentially occur in the best habitat for their key prey species, *Eledone cirrhosa*, at least at the resolution ($1km^2$) analysed in this study.
- The reasons for this disparity between the apparent distributions of the predator and its preferred prey remain unclear, but it may be related to a mis-match between the

resolution at which the distribution of the prey was modelled and the resolution that determines where Risso's dolphin can successfully forage.

- Regardless of the reasons, this study suggests that modelling the distribution of the preferred prey species, at the resolution currently available, does not provide additional information to help inform the placement of MPAs for Risso's dolphins, except in so far as *a priori* arguments may be invoked for protection of sites which are important for their prey.
- However, habitat modelling directed specifically at investigating the distribution of Risso's dolphin may prove useful in this context, and in such models, the distribution of *E. cirrhosa* could potentially be used as an additional explanatory variable.

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1. INTRODUCTION

Marine Protected Areas (MPAs) are becoming an increasingly important tool for the conservation of cetacean species. However, establishing the best location for mobile species MPAs can be difficult. This is because, as mobile predators, cetaceans are not always present in their preferred habitats (if indeed they have preferred habitats) and may also be encountered when moving between locations that are particularly important for them.

These difficulties have led to an increased interest in the use of species distribution modelling (SDM) to identify important areas for cetacean species. In SDM, a model is built of the relationship between the distribution (as measured by presence or local abundance) of a species and environmental variables that help define its niche. This model is then used to predict the distribution of a species across a wider area, including locations which have not previously been surveyed. While SDMs have proved successful for some species (e.g. white-beaked dolphin, *Lagenorhynchus albirostris* (Lambert *et al.,* 2014), common dolphin, *Delphinus delphis* (Lambert *et al.,* 2011) and harbour porpoise, *Phocoena phocoena* - Embling *et al.,* 2010), they typically only include information on environmental variables, such as water depth and seabed topography. However, it is generally assumed that any relationships with such variables are indirect and are mediated through the habitat preferences of preferred prey species. Based on this assumption, it could be argued that a better approach for identifying key areas for a specific species would be to model the distribution of its preferred prey in relation to environmental variables. This is because it is assumed that areas where the most prey is likely to occur are also likely to be key areas for predators.

One of the key limitations when implementing such a prey-based approach for cetaceans is that most are generalist predators and will take a wide range of prey species, all of which have different relationships with environmental variables. This means that models would need to be produced and combined across a wide range of species. Under such circumstances, it becomes easier to simply model the relationship between the cetacean species itself and environmental variables, despite the fact that any identified relationships are likely to be indirectly mediated through their effects on the distribution of prey.

However, in Scottish waters, Risso's dolphin *Grampus griseus* almost exclusively consumes a single prey species, the octopus *Eledone cirrhosa* (Pierce *et al*., 2007). Thus, it would seem that prey-based modelling could potentially prove useful for identifying key areas for Risso's dolphin, and therefore, for the establishment of MPAs for this species. This would be advantageous as previous attempts to model the distribution of Risso's dolphin directly have generally failed to produce a useful model, possibly due to the choice of dependent variables included within them or the resolutions at which the relationships were modelled (MacLeod, Unpublished Analysis).

This study used data on the distribution of *E. cirrhosa*, collected during routine trawling surveys carried out by Marine Scotland Science, to model the distribution of this species in Scottish waters. The aim was to assess whether prey-based modelling could be useful for identifying important areas for Risso's dolphins where it might be appropriate to establish MPAs. In addition we provide details of the available unpublished data on the diet of Risso's dolphins in Scottish waters collected over the last two decades. As *E. cirrhosa* is a benthic species, its distribution was modelled in relation to five environmental variables that help describe seabed habitat: water depth, seabed slope, the local variation in seabed slope, distance from the coast and the sediment type.

1.1 Ecology of *Eledone cirrhosa*

Eledone cirrhosa is a medium-sized octopus that is found throughout the shallower waters of the eastern North Atlantic, from northern Norway and the Faeroe Islands in the north to Morocco in the south, as well as in the Mediterranean (Boyle, 1983; Jereb *et al.,* In Press). Around the UK, it reaches a maximum size of 175mm mantle length and 2kg in body mass with males being generally smaller than females (Jereb *et al.,* In Press). *E. cirrhosa* has been recorded in waters depths of up to 700m, but is most common in water depths between 50 and 300m. In Scottish waters, fishermen report that *E. cirrhosa* are rarely caught when trawling over hard ground and are more commonly caught when fishing over softer ground, sand or muddy sand during mixed demersal fisheries. The highest catches in commercial fisheries occur during trawl fisheries for Nephrops over soft mud or muddy sand. However, this may be an artefact of the smaller mesh size used in this fishery (Boyle, 1986). Within UK waters, while *E. cirrhosa* occur as bycatch in fisheries (particularly those targeting Nephrops), they do not currently have any commercial value and are generally discarded. As a benthic species, the distribution of *E. cirrhosa* is likely to be linked to variables which describe seabed habitat rather than those which describe oceanographic elements higher up in the water column.

2. METHODS

2.1 Dietary analysis

We analysed stomach contents of 11 Risso's dolphins (*Grampus griseus*) collected between 1992 and 2004 by the Scottish strandings monitoring network. Methodology for sample processing and analysis was as described in Santos *et al.* (2004, 2007). The minimum number of fish and cephalopods in each stomach was estimated from hard remains, identified using reference material and published guides. Fish species were largely identified from otoliths, while cephalopods were identified from beak remains. Prey which could not be identified to species were assigned to species categories. The overall importance of each prey type was then assessed based on its frequency of occurrence, proportion of the total number of prey, and proportion of total prey wet mass. Multivariate and univariate analyses were used to assess dietary variation and the influence of factors such as geographic area, season, cause of death, Risso's dolphin size, sex, and year.

2.2 Data on *Eledone cirrhosa* distribution

Data on the distribution of *E. cirrhosa* were obtained from trawl survey data collected by Marine Scotland Science as part of their fisheries surveys conducted throughout the Scottish portion of the UK Exclusive Economic Zone (EEZ) between 2008 and 2012. These data were collected mainly during the first (International Young Fish Survey, West Coast Survey), third (North Sea groundfish, Rockall haddock and deep water surveys) and fourth (mackerel recruit surveys) quarters of the calendar year. Within the Scottish marine environment, these equate approximately to the seasons of winter, summer, and autumn respectively. Data from each haul included its date, location, and duration (normally 30 minutes), and the number of *E. cirrhosa* that were caught. This information allowed a catch per unit effort (CPUE) for *E. cirrhosa* to be calculated for each haul and its location to be plotted within a geographic information system (GIS).

2.3 Data on environmental variables

Information on water depth was obtained from the Digibath contour data set. These data were transformed into a transverse Mercator projection with the same origin as the British National Grid but with a WGS 1984 datum (rather than the OSGB 1936 datum used for true British National Grid projections). Next, the depth contour data were interpolated into a continuous 1km resolution grid using the ArcGIS 9.3 Topo-To-Raster tool. This depth raster data layer was then used to generate a second grid identifying the slope of the seabed. Then, the variation in the slope of the seabed around each grid cell was measured by calculating the standard deviation of slope for a 5 × 5 km box surrounding each individual grid cell. This provided a measure of the variability of the seabed topography. Next, a raster grid of distance to the nearest coast was created using the Euclidean Distance tool in ArcGIS 9.3, based on a polygon derived from the zero depth contour from the Digibath depth data set. The values for each of these variables for each haul were then extracted based on their locations. Finally, information on the sediment type was obtained from the British Geological Survey (BGS) sediment data set. This provided polygons that identify the sediment type for all areas of the seabed within UK waters at a resolution of 250m. The sediments were classified into four types with varying levels of hardness (mud, sand, gravel and rock) based on the primary sediment type they contained. This information was then extracted to each haul based on its location.

2.4 Model creation and visualisation

Once the environmental variables had been extracted for each haul, two models were created using Generalised Additive Modelling (GAM): (i) a model based on the presence or absence of *E. cirrhosa* within a specific haul, and (ii) a model based on its numerical catch per unit effort (CPUE, numbers caught per hour). Water depth, seabed slope, standard deviation of seabed slope and distance to coast were log-transformed and included as continuous variables within each model, while sediment type was included as a categorical variable. For the presence-absence model, a binomial distribution was used for the dependent variable, while a Poisson distribution was used for the model based on CPUE. In both cases, cross-validation was used to identify the most appropriate number of degrees of freedom for the smoothers for the continuous variables subject to the constraint that a maximum "knot" value of four was used to prevent over-fitting. In all cases, final models were selected using a backwards selection procedure (based on sequential removal of variables and evaluation of goodness of fit using Akaike Information Criteria, or AIC, values).

Once the models were completed, they were projected onto the original environmental data sets within the GIS to produce a visualisation that identified where *E. cirrhosa* were most likely to be found based on its modelled habitat preferences.

2.5 Comparing the models of *Eledone cirrhosa* distribution to the distribution of Risso's dolphin

Once both models of *E. cirrhosa* distribution had been visualised, the modelled distributions were compared to a data set of around 16,000 cetacean sightings that had been collected between the late 1970s and the late 2000s by the JNCC Seabirds at Sea Team, the Irish Whale and Dolphin Group (IWDG) and Marinelife. While this data set does not include a measure of survey effort as such, it provides a sample of ~16,000 locations where cetaceans have been recorded. Thus, they are considered to represent a sample of all habitat combinations where cetaceans occur in these waters, and so represent the general 'cetacean' niche in this region. It would be expected that the niche occupied by Risso's dolphin would be nested within this general cetacean niche. If this were the case, these locations would accurately capture the Risso's dolphin niche since it would capture its upper and lower limits in relation to any environmental variables. This assumption can be tested using a modified version of the Habitat Representativeness Score (HRS) outlined in MacLeod (2010). An HRS measures the suitability of a specific data set for habitat modelling by assessing whether it is representative of all available habitat combinations within a specific region. The modified HRS assesses whether a specific data set, comprising a set of locations where a range of species belonging a single taxa, samples a sufficiently wide range of habitat combinations to capture the niche limits of an individual species in the same data set. This was found to be the case for Risso's dolphin for this data set. Thus, this data set can be used to examine the distribution of Risso's dolphin in relation to environmental variables, including the modelled distribution of *E. cirrhosa*. To do this, the predicted occurrence for *E. cirrhosa* was extracted at each location where a cetacean was recorded. The relative occurrence of Risso's dolphin sightings was compared to occurrences of all cetacean species as a whole, to test the hypothesis that Risso's dolphins preferentially occur in locations where the occurrence of *E. cirrhosa* is greatest. This test is based on the more widely used Area Adjusted Frequency (AAF). If this hypothesis is correct, it would be expected that Risso's dolphin would occur more frequently in cells with higher modelled occurrence of *E. cirrhosa* than would all cetacean species in general.

3. RESULTS

3.1 Diet of Risso's dolphin

We examined a sample of 11 stomachs collected during 1992-2004 from stranded animals attended by the Scottish Agricultural College Veterinary Services Division (SAC) which has coordinated and investigated marine mammal strandings in Scotland since 1st January 1992. The animals were mainly stranded along the western and northern coasts of Scotland, many on island coasts, including individuals collected in Coll, Skye, Eriskay, Lewis, Orkney and Shetland.

The diet was dominated by octopus: 89.5% of prey by number was *E. cirrhosa*. Loliginid squid (7.6%) were the second most important category of prey, while remains of ommastrephid squid, sepiolids and haddock were also recorded. This set of samples included strandings from February, April, May, July, August and October, the second quarter of the calendar year being best represented (N=5).

3.2 Sampling for *Eledone cirrhosa*

In total, data were available from 1369 trawl hauls, of which 93 contained at least one individual of *E. cirrhosa* (Table 1, Figure 1). Most frequently, only one or two individuals were caught per 30-minute trawl, with the maximum number caught per haul being 31.

Table 1 - Number of hauls (numbers with Eledone cirrhosa *in parentheses) by quarter of the calendar year and individual years.*

	Quarter				
Year	1	2	3	4	SUM
2008	113 (7)	0	179 (11)	68 (0)	360 (18)
2009	107 (5)	0	161 (5)	76 (15)	344 (25)
2010	111 (10)	0	87 (3)	0	198 (13)
2011	107 (9)	23 (0)	162 (16)	55 (5)	347 (28)
2012	120 (7)	-	-	-	120 (7)
SUM	558 (38)	23 (0)	589 (35)	199 (20)	1369 (93)

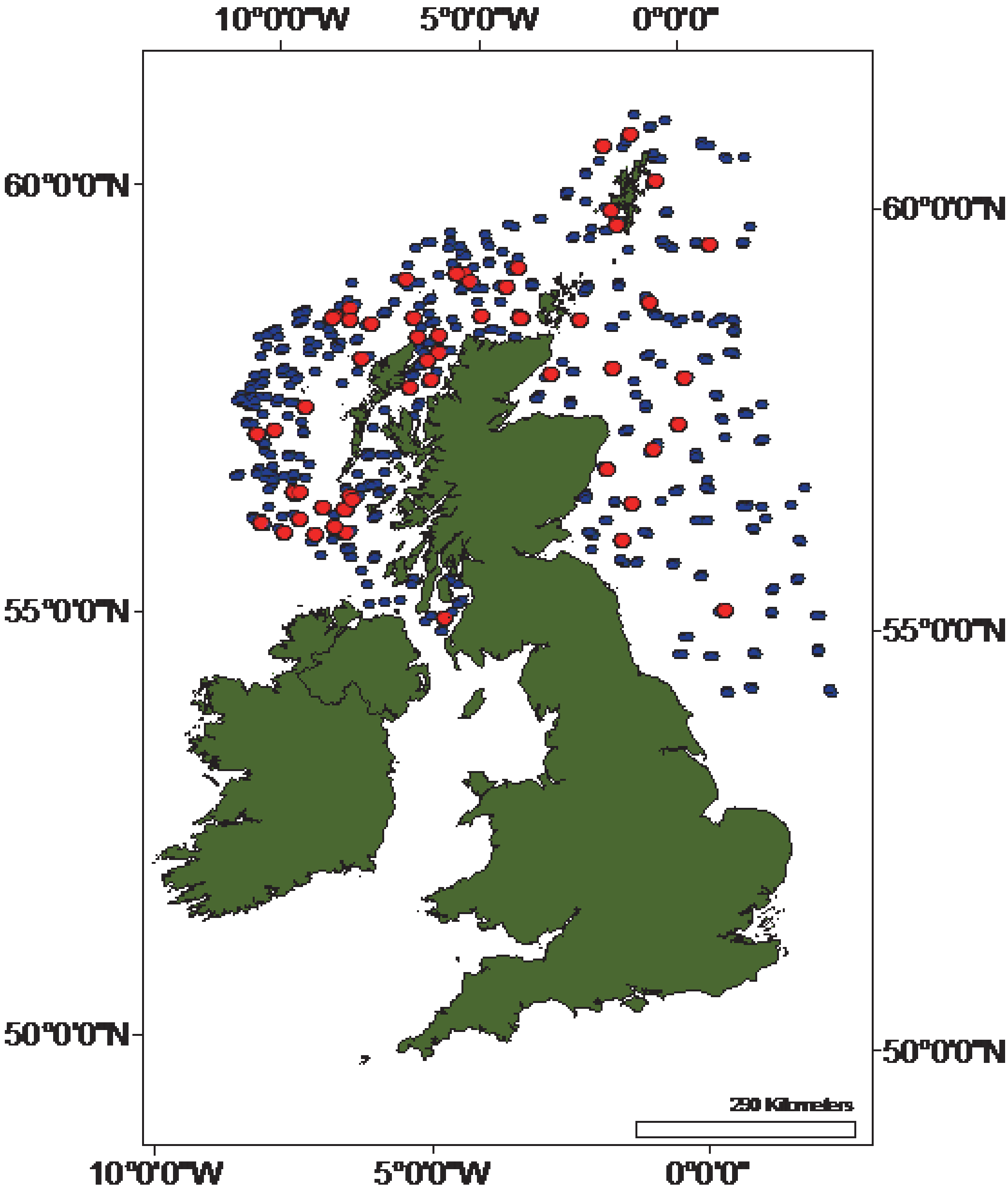

Figure 1. The distribution of research survey hauls (blue) and hauls where E. cirrhosa *were caught (red) used to model the occurrence of this species in UK waters.*

3.3 Presence-absence model

The model of *E. cirrhosa* presence in relation to the five environmental variables examined explained only 5.7% of the deviance in presence of the species. Thus, this model explained little of the variation in species presence. Within this model, there was only one significant relationship, with log distance from coast (p=0.02), with the other variables being retained as they improved the fit of the model to the data. When this model was applied to the UK Exclusive Economic Zone (EEZ), it identified the main areas of *E. cirrhosa* occurrence as being in near coastal waters, primarily in the north and west (see Figures 2 and 3).

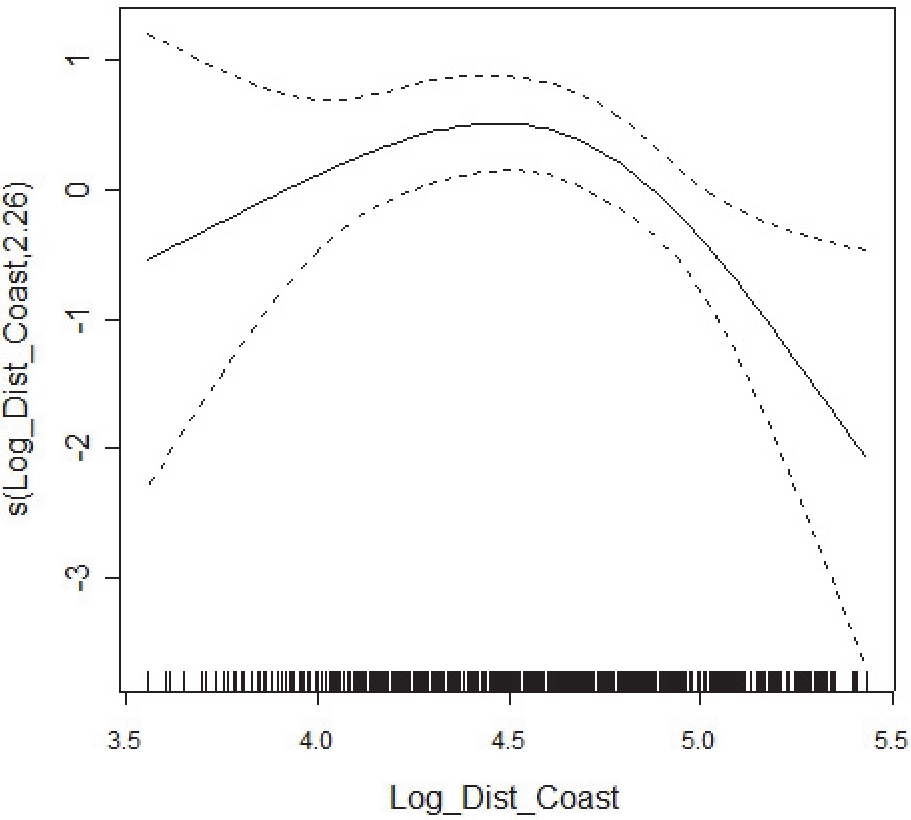

Figure 2. The modelled relationship between log-transformed distance to coast and the presence of E. cirrhosa *(EDF: 2.7; p=0.02).*

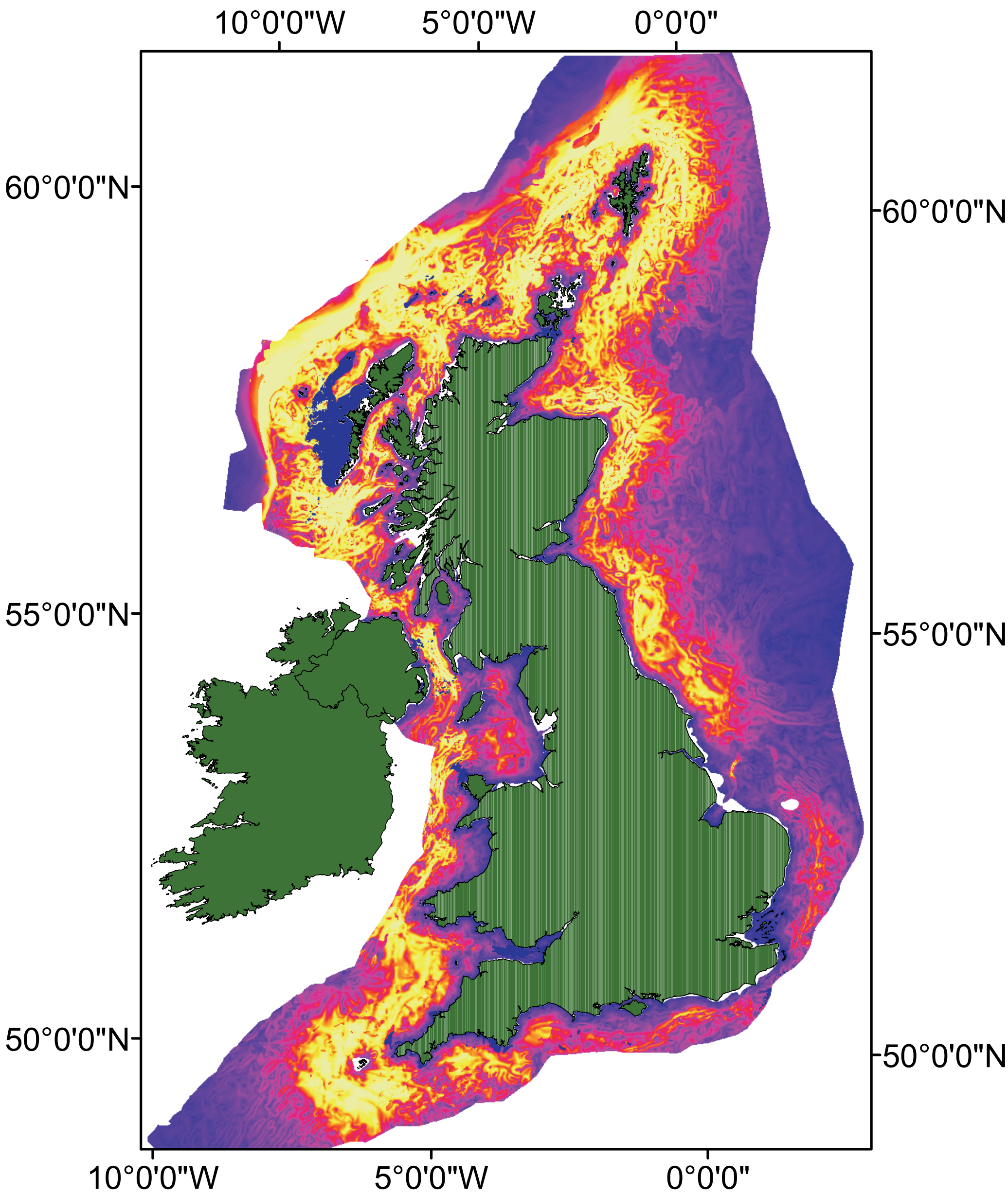

Figure 3. The visualisation of the E. cirrhosa *presence-absence model for UK shelf waters. (Pale yellow: Highest modelled presence: Blue: Lowest modelled presence).*

3.4 Abundance (catch per unit effort) model

The model of *E. cirrhosa* CPUE in relation to the five environmental variables examined explained 33.6% of the deviance in local abundance of the species, i.e. it was considerably more satisfactory than the presence-absence model. Within this model, there were four significant relationships. These were the relationships with log water depth (p=0.002), log seabed slope (p=0.009), log standard deviation of seabed slope (p<0.0001) and log distance from coast (p=0.03 – Figure 4). Sediment type had no significant effect but was retained as it improved the fit of the model to the data. When this model was applied to UK shelf waters, it identified the main areas with the highest CPUE of *E. cirrhosa* around the Outer Hebrides and Northern Isles near the continental slope as well as off Norfolk, Cornwall and in the eastern Irish Sea (Figure 5).

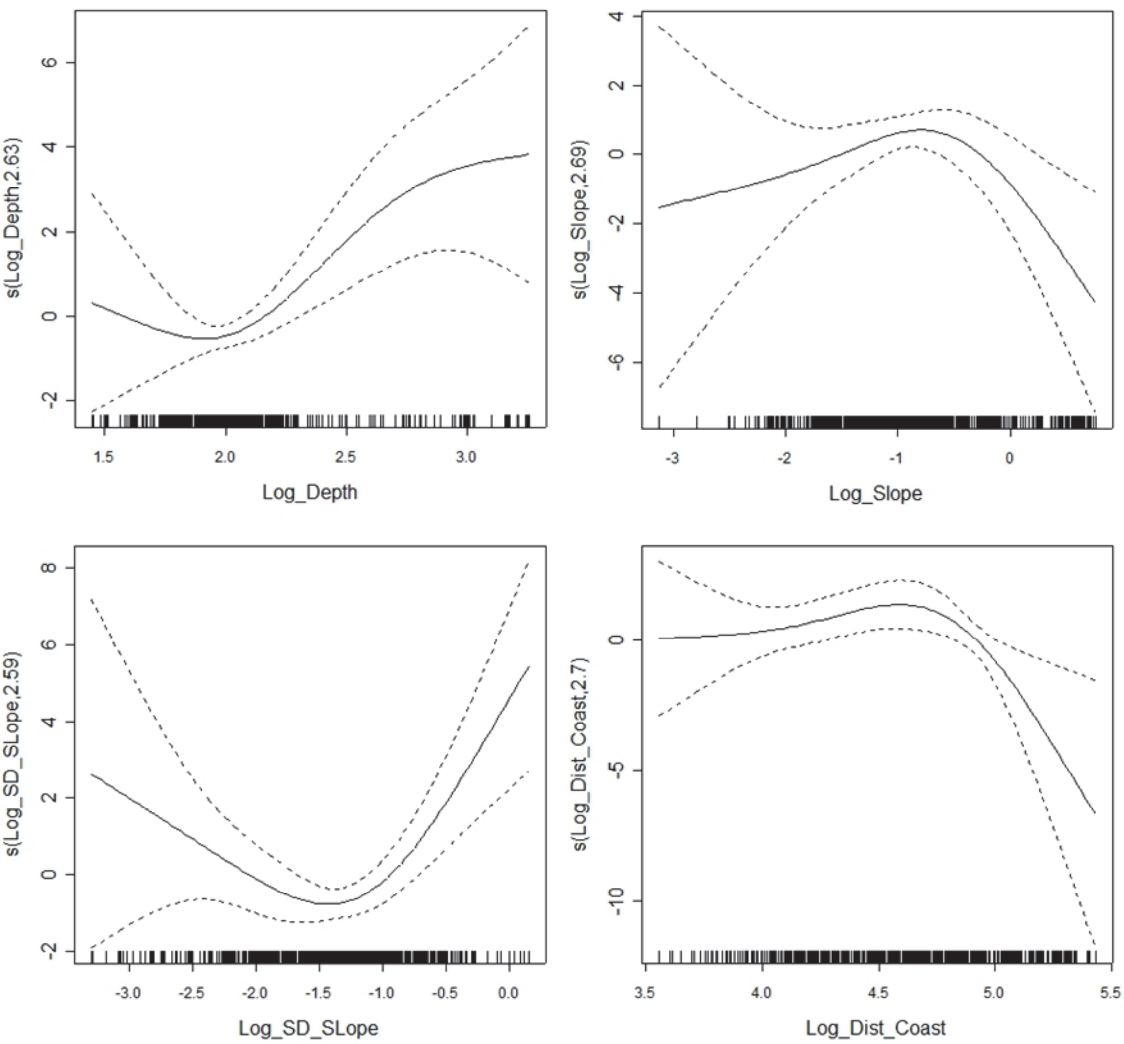

Figure 4. The modelled relationships between the catch per unit effort of E. cirrhosa *and log-transformed water depth (EDF: 2.6; p=0.002), seabed slope (EDF: 2.7; p=0.009), standard deviation of seabed slope (EDF: 2.6; p>0.001), distance to coast (EDF: 2.7; p=0.03).*

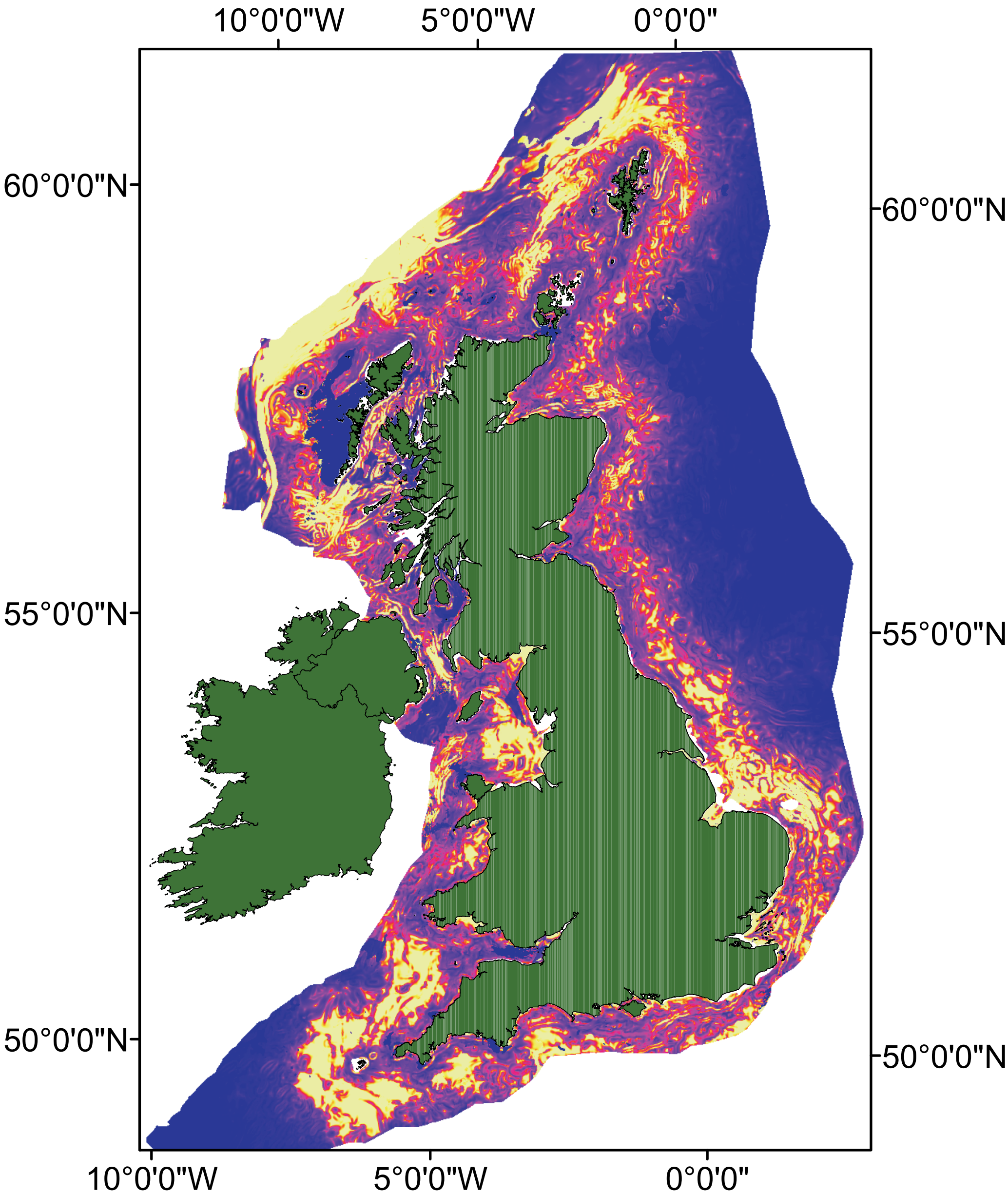

Figure 5. The visualisation of the E. cirrhosa *CPUE model for UK shelf waters. (Pale yellow: Highest modelled CPUE: Blue: Lowest modelled CPUE).*

3.5 Comparison with Risso's dolphin distribution

Of the 16,000 sightings available for this analysis, 3003 fell within the areas covered by the models of *E. cirrhosa*. Of these 88 were Risso's dolphin (Figure 6). When the distribution of these Risso's dolphin sightings was compared to the modelled distributions of *E. cirrhosa* (Figures 3 and 5), no apparent relationship was found between Risso's dolphin occurrence and either modelled *E. cirrhosa* presence or CPUE. Indeed, this comparison suggests that Risso's dolphin most frequently occurs in areas where the modelled occurrence of *E. cirrhosa* is lowest and not where it is highest (Figures 7 and 8). This means that the modelled distribution of this key prey species cannot be used to predict the distribution of Risso's dolphin, at least at the resolution analysed in this study (see discussion for further consideration of this issue).

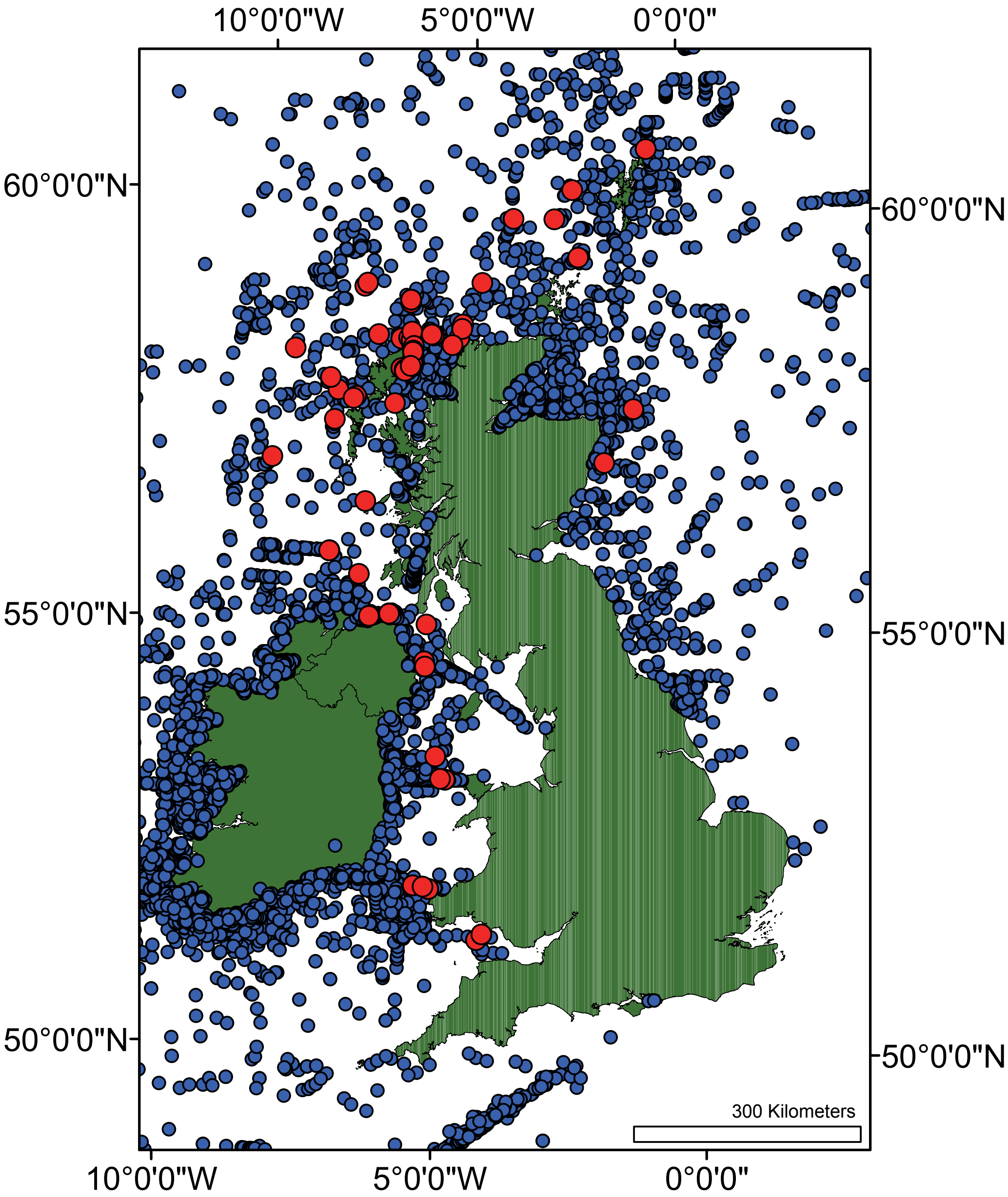

Figure 6. The distribution of all cetacean sightings (blue) and Risso's dolphin (red) used to test the relationship between the modelled occurrence of E. cirrhosa *and Risso's dolphin in UK waters.*

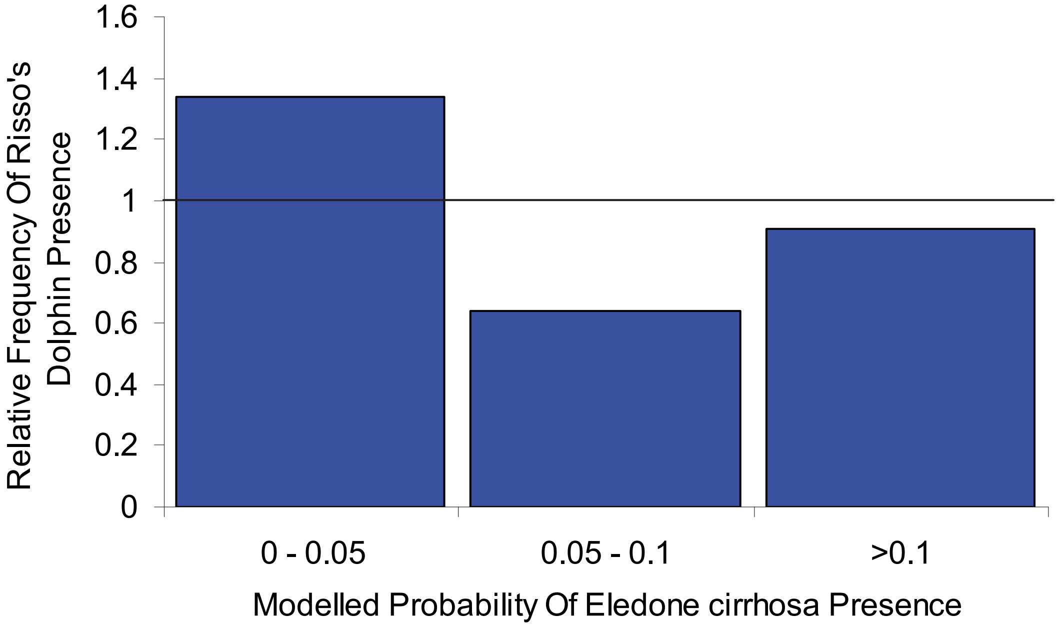

Figure 7. A comparison of the relative frequency of Risso's dolphin presence and the modelled probability of the presence of E. cirrhosa*. If Risso's dolphin occur more frequently in areas where* E. cirrhosa *is present, it would be expected that the relative frequency of occurrence of Risso's dolphin would be higher in areas with higher modelled* E. cirrhosa *occurrence. A value of 1 indicates that Risso's dolphin do not preferentially occur in a specific category in comparison to other cetacean species, while a value of greater than one indicates preferential occurrence and a value of less than one indicates preferential avoidance.*

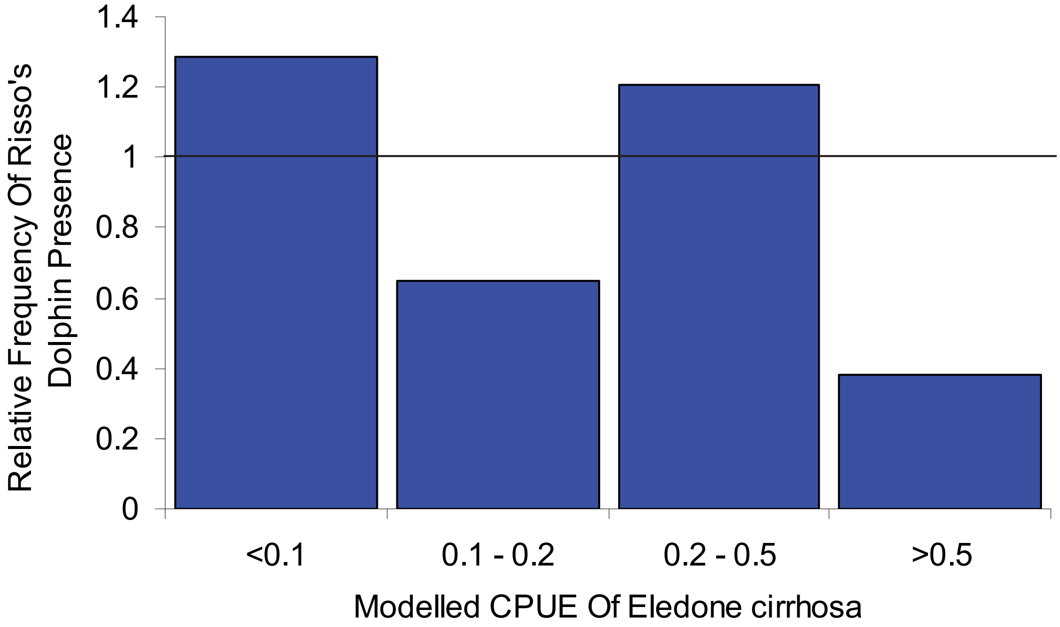

Figure 8. A comparison of the relative frequency of Risso's dolphin presence and the modelled CPUE of E. cirrhosa*. If Risso's dolphin occur more frequently in areas where more* E. cirrhosa *occur, it would be expected that the relative frequency of Risso's dolphin occurrence would be higher in areas with higher modelled* E. cirrhosa *CPUE. A value of 1 indicates that Risso's dolphin do not preferentially occur in a specific category in comparison to other cetacean species, while a value of greater than one indicates preferential occurrence and a value of less than one indicates preferential avoidance.*

4. DISCUSSION

The octopus *E. cirrhosa* is a key species in the diet of Risso's dolphin in Scottish waters, as shown by the dietary data presented here, and it might be expected that there would be a strong relationship between the occurrence of this predator and its prey species. However, the habitat modelling analysis suggests that while there is a relatively strong relationship between the CPUE of *E. cirrhosa* and a number of relevant environmental variables, such as seabed topography, there is no evidence that Risso's dolphin preferentially use areas where the occurrence of *E. cirrhosa* is likely to be highest. This suggests that modelling the distribution of the preferred prey species, at the resolution currently available, does not provide additional information to help inform the placement of MPAs for Risso's dolphins.

There are a number of possible explanations for this apparent lack of a relationship between the occurrences of these two species observed in this study. Firstly, the data on *E. cirrhosa* distribution come from research trawl surveys. These surveys are mostly targeted at estimating the abundance of commercially important demersal fish. Although there is no specific intent to target particular seabed habitats, it may be that such trawls are biased towards habitat patches where the gear is unlikely to become entangled on snags on the seabed, and sampling thus excludes features such as rocky pinnacles or wrecks. If *E. cirrhosa* were to preferentially occur in such places, and indeed Risso's dolphin to hunt them there, it may be that these habitats remain unsampled within the data set used to model *E. cirrhosa* distribution. Thus, it is possible that the research trawl surveys do not sample an important portion of the niche occupied by *E. cirrhosa* where it is targeted by Risso's dolphin.

A related question concerns whether the diet as recorded from 11 animals can be regarded as representative. There is little doubt that Risso's dolphin specialises in feeding on cephalopods (Clarke and Pascoe, 1985; Blanco *et al.,* 2006; M.B. Santos, Unpublished Data). In addition, data for this species in Galicia, based on 16 stomachs collected over the last 20 years, reveal a diet that is remarkably consistent with that recorded in Scotland. Octopuses made up 88.1% of the diet (by number), albeit mostly comprising *Octopus vulgaris*, a species that is absent from Scottish waters, with loliginid squid making up 9.6% of the diet (M.B. Santos, Unpublished Data). Thus, the 11 animals examined are consistent with the known diet of Risso's dolphin and so this seems unlikely to be an issue in this study.

Thirdly, it may be that there are biases within the cetacean data set used to test the relationship between the modelled occurrence of *E. cirrhosa* and Risso's dolphin presence. While the cetacean data set did not include information on survey effort as such, and while it may not reflect the spatial distribution of Risso's dolphin, through the modified Habitat Representativeness Score, its ability to capture the distribution of Risso's dolphin in relation to available habitat combinations has been found to be relatively good. Thus, it seems unlikely that the lack of a relationship between the modelled distribution of *E. cirrhosa* and Risso's dolphin presence is due to a bias within the cetacean data set used to test it. This lack of bias in the cetacean data set for this type of usage is supported by the fact that this same data set has been successfully used in previous modelling studies for other cetacean species (e.g. Lambert *et al*., 2011). In addition, this data set has been specifically assessed for possible biases in Risso's dolphin distribution and has been found to be relatively unbiased (MacLeod *et al.,* 2014).

Finally, the lack of a relationship between Risso's dolphin occurrence and the modelled distribution of *E. cirrhosa* may relate to differences between the scale/resolution used to model the species occurrence and the scale at which Risso's dolphins interact with oceanographic variables when foraging. Specifically, this study modelled *E. cirrhosa* distribution at the resolution of 1km, due to the resolution of the available environmental data. While there is a strong relationship between *E. cirrhosa* occurrence and these variables at this 1km resolution, it may be that Risso's dolphin select foraging habitats based on a very different scale. In particular, it is likely that Risso's dolphin seek and capture *E. cirrhosa* individually rather than in large groups (if indeed any large groups exist). Thus, they may be able to exploit very small patches (<~10m in size) of suitable *E. cirrhosa* habitat in otherwise apparently unsuitable areas. Such patches would not be detected when habitat is examined at a 1km resolution and this could give the false impression that there is no relationship between the distribution of Risso's dolphin and its preferred prey. Thus, the outcome of this study may have differed if the environmental variables were considered at a different resolution. However, at this time, information on the required environmental variables is not available at sufficiently smaller resolutions to allow this possibility to be further investigated. In addition, different variables may be relevant in determining distribution at different spatial scales. Thus, while the distribition of prey may be important for Risso's dolphin at relatively fine spatial scales (e.g. 10s to 100s of metres), it may be that different factors influence their distribution at lower resolutions (1s to 10s of kilometres). Again this may explain why the distribution of Risso's dolphin is not related to the distribution of its prey species at the scale examined.

The relatively low spatial resolution of the sampling for *E. cirrhosa* reflects the normal design for fish surveys, with one haul taken per ICES rectangle across the surveyed area. This limitation can be overcome to some extent by combining data from different months and years since precise locations of hauls within rectangles vary between surveys. Data on *E. cirrhosa* occurrence were collected throughout the year, which could be an issue in a species with a highly seasonal life cycle. Although eggs and juveniles of *E. cirrhosa* are known from most months of the year, there is evidence from ovary weights of a seasonal peak in breeding around July (Boyle, 1983), a period of the year that is under-represented in the trawl samples.

5. CONCLUSIONS

The findings of this study suggest that the relationship between the observed distributions of a predator and its preferred prey may not necessarily be as clear cut as might be anticipated. In the case of the Risso's dolphin, the distribution of the key prey species, *Eledone cirrhosa*, is evidently relevant given the well-established trophic link between Risso's dolphins and octopuses. Therefore areas which are important for *E. cirrhosa* (defined and identified using habitat modelling) could be defined as "essential habitat" for Risso's dolphin, *a priori*. However, in practice there is no evidence from the current modelling study that Risso's dolphins prefer areas of high *E. cirrhosa* abundance or use them with greater frequency than any other area. On this basis we would have to say that information on *E. cirrhosa* distribution does not help us identify important areas for Risso's dolphins in Scottish waters, at least at a resolution that is achievable with the currently available information. These findings highlight the need to investigate and test any assumptions, such as the relationships between prey and predator distributions, before using them to help implement conservation and management strategies.

Several additional lines of work could be pursued. Firstly, the data set used to test the possible relationship between Risso's dolphin and the modelled distribution of *E. cirrhosa* only contained a relatively small number of Risso's dolphin sightings. If further data sets on cetacean distribution become available, it might be possible to enlarge this data set to provide a better measure of where this species occurs. While modelling the distribution of the preferred prey species does not appear to be useful for identifying important areas for Risso's dolphin, it is still possible that direct modelling of Risso's dolphin may be a useful exercise. Within such a process, it may be that the modelled distribution of *E. cirrhosa* could prove useful as an additional explanatory variable to help improve the fit of the model to the actual distribution of Risso's dolphin. In addition, it would also be useful to obtain more data on *E. cirrhosa* distribution, and data from the remainder of 2012 will become available in due course. However, such data were not routinely recorded in trawl surveys in Scottish waters before 2008 and the lack of commercial value means commercial fishery data (except perhaps data from monitoring of discards) are unlikely to be informative about *E. cirrhosa* distribution. It is also worth exploring any correspondence in distributions of Risso's dolphins and the second most important prey category, loliginid squid.

Finally, if suitable data were available, it would be worth exploring the relationship between *E. cirrhosa* distribution, environmental variables and Risso's dolphins at finer spatial resolutions. In particular, if very fine scale information, of the type that can be collected by side-scan sonars, were available on seabed topography for some areas where Risso's dolphin occur, this would allow the exploration of relationships at a spatial resolution that might be closer to the resolution at which Risso's dolphin actually forage. However, for such a finer resolution modelling project to be successful, there would need to also be finer resolution data available for *E. cirrhosa*, as the survey trawl data analysed in this study are not of sufficiently fine resolution for such a project. It may be possible to obtain such fine resolution data of *E. cirrhosa* from targeted sources specifically aimed at collecting such data on *E. cirrhosa* and/or from opportunistic sources, such as creel fishermen who could be encouraged to report the location where they capture *E. cirrhosa* within their creels.

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