Temporal and spatial mapping of vulnerable marine species and bycatch risk in the Celtic Sea

Report for the Centre for Environment, Fisheries and Aquaculture Science (Cefas)

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Executive Summary

The Celtic Sea (ICES Division 7e-j) is home to a diversity of commercial fisheries, in which bycatch of protected, endangered and threatened species (PETS) including cetaceans (whales, dolphins and porpoises) and elasmobranchs (sharks, skates and rays) is known to occur. Effective management to reduce or eliminate bycatch of PETS requires a sound understanding of their populations, ecology and interaction with fisheries. However, knowledge and data are often limited, presenting a barrier to evidence-based bycatch mitigation. This project analysed seven existing datasets relating to bycatch, fishing effort and PETS distribution/abundance, which had not previously been examined collectively. Additionally, existing publicly available environmental data (temperature, salinity, bathymetry and seabed substrate) and AIS-derived fishing effort data (Global Fishing Watch) were obtained and processed. Spatio-temporal maps were generated, integrating multiple datasets by superimposing spatial layers. Where possible, statistical modelling was used to explore the relationship between bycatch and environmental variables, which could be combined with fishing effort data to produce predictive bycatch risk maps. Collectively, these analyses offer new insights to inform fisheries management in the Celtic Sea. For example, temporal trends in the bycatch of cetaceans (common dolphin and harbour porpoise) are described. Spatial and temporal trends in the bycatch of spurdog are modelled, allowing the production of predictive maps. There were significant challenges in integrating these datasets, related to dissimilarities in their spatio-temporal coverage and resolution. In some cases the coverage of these data limited the ability to identify trends. Where data is currently limited the approach presented here serves as a 'proof of concept' rather than offering definitive conclusions. It is therefore recommended that subsequent analyses should be conducted as datasets grow. A library of scripts, in the R programming language, provide a means to readily replicate the processing and analysis workflow, as new data becomes available, or the approach is expanded to new areas.

Acknowledgements

The work was undertaken by ZSL and funded by Cefas. The project would not have been possible without the support of Cefas staff, in particular: Stuart Hetherington, Victoria Bendall, Georg Engelhard, Will Procter and Maria Wild. A number of the datasets were produced in a participatory manner, thanks therefore go to the skippers and crew of all contributing vessels.

Ethics

The following ethics statements apply to the specified datasets.

Datasets A and C
No additional fishing activity was undertaken as part of this project. The data were collected during normal fishing activities, whilst these normal fishing activities carry a risk of cetacean and elasmobranch mortality, the data collected are intended to contribute to reducing bycatch in the future. The Marine Management Organisation (MMO) authorised the retention of dead spurdog bycatch in accordance with the EU TAC & Quota regulation for 2017 – 2019 (Dataset C).

Datasets E and F
All tagging procedures were approved by Cefas' Animal Welfare and Ethical Review Body (AWERB) and licensed by the UK Home Office under the Animals (Scientific Procedures) Act 1986. Tagging was conducted under project licence numbers PPL 70/7734 and PPL 9DCB3674 (both titled "Fish Movements and Behaviour") by trained and competent personal licence holders.

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1. Introduction

1.1. Background

Clean Catch UK (https://www.cleancatchuk.com/) is a collaborative research programme that brings together scientists and fishermen, to monitor and help reduce the accidental capture of wildlife by commercial fishing vessels. Clean Catch UK is developing solutions that work to reduce the bycatch and subsequent mortality of wildlife in UK commercial fisheries. This work is in support of Defra's commitments to (i) the Fisheries Act 2020, (ii) the 25 Year Environment Plan, (iii) the Marine Strategy Framework Directive and (iv) Defra's Plans of Action to minimise, and where possible, eliminate cetacean and seabird bycatch, through a stakeholder-led approach.

One of the greatest challenges to conserving and managing sensitive marine species is that often relatively little is known about them. With a lack of information and data, it is difficult to know the full impact that accidental capture can have on wildlife. Clean Catch UK helps collect robust data on the life histories, movements, distributions, behaviours, accidental capture and post-release survival of wildlife in UK commercial fisheries, with an initial focus on the Celtic Sea (ICES Division 7e-j).

This project seeks to develop a better understanding of cetacean (whales, dolphins and porpoises) and elasmobranch (sharks, skates and rays) bycatch by using data from multiple sources, including from fishing vessels as well as from fishery-independent surveys. To date these different datasets have not been reviewed collectively. The intention of the present study is that, by combining these different sources, better insights will be offered into spatial and temporal trends, supporting evidence-based fishery management to minimise future bycatch.

1.2. Study area

The study is focussed on the Celtic Sea (ICES Areas 7e-j) (Figure 1.1). A comprehensive overview of the region's fisheries is provided by (ICES, 2020b). In brief, the Celtic Sea supports a considerable diversity of commercial fisheries, with UK and foreign flag vessels targeting a wide range of species with a mixture of gears. Midwater trawl fisheries target pelagic finfish. Demersal fisheries employ bottom-trawls and fixed gears (gillnets, trammel nets and longlines) to target Nephrops, gadoids and other benthic species.

The fishery-dependent datasets used in this study are from UK vessels operating in- and offshore, employing trawls and static nets at depths up to ~200m (the limit of the continental shelf); these gears having been associated with elasmobranch and cetacean bycatch.

There are a number of designated marine protected areas (MPAs) in the Celtic Sea (Figure 1.1). Collectively these do not prohibit fishing over any extensive areas within the study area. Thus, these MPAs afford relatively little protection against bycatch for the highly mobile species of interest here.

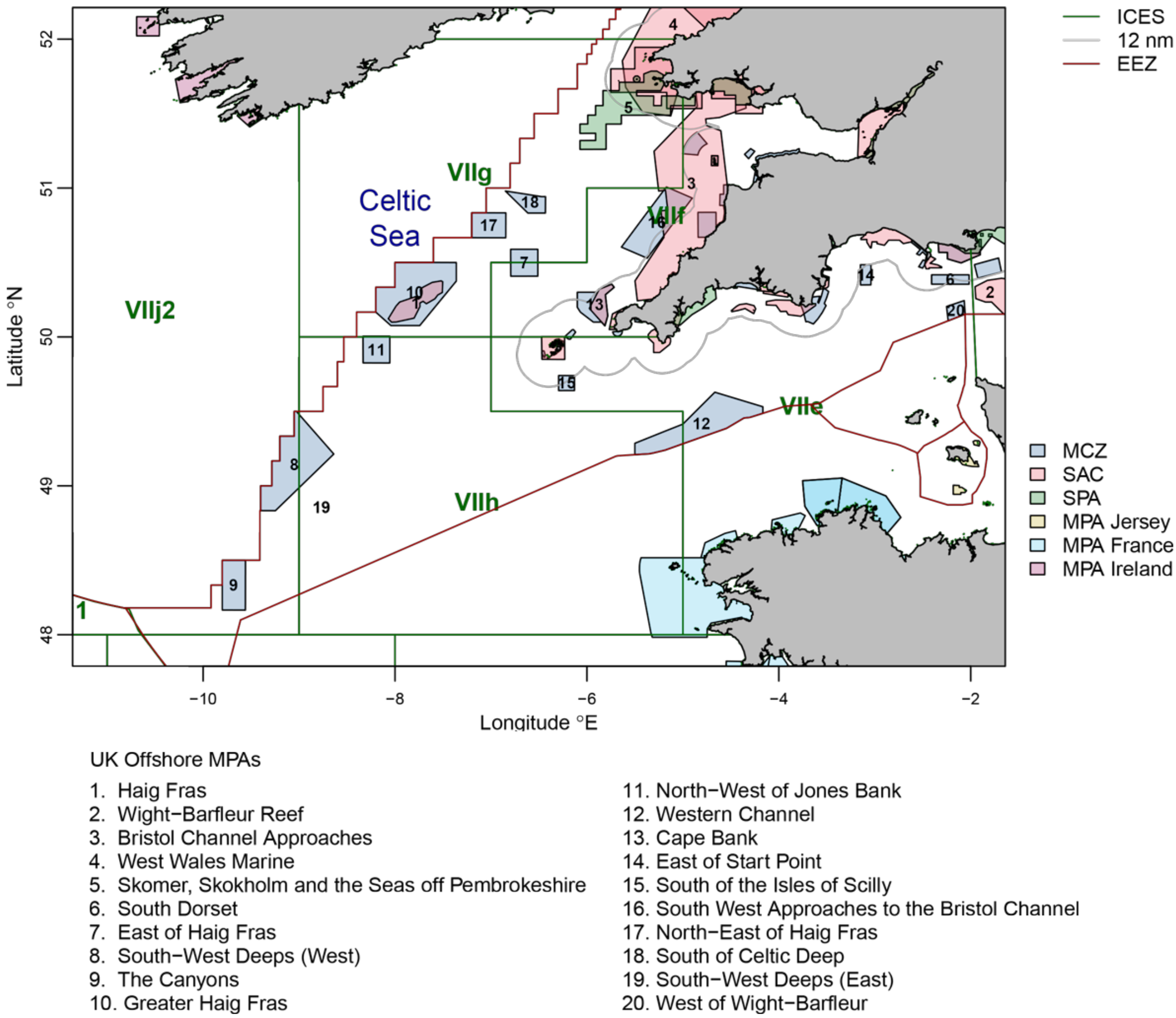

Figure 1.1 Map of the study area. All marine protected area (MPAs) recognised by the OSPAR Commission are shown. UK MPAs with an offshore component are labelled. The 12 nm territorial limit is drawn for the UK (grey line). Note, that '9. The Canyons' and '6. South Dorset' are currently subject to consultation on the introduction of byelaws prohibiting all fishing gears and towed gears respectively. Data: MPA data, OSPAR (2021); ICES areas, (ICES, 2021).

1.3. Aims

The project seeks to combine and analyse multiple datasets, which have not previously been collectively examined. The intention is that this will serve as a 'proof of concept' demonstrating an approach to obtain, combine and analyse data relating to bycatch, fishing effort and species distribution/abundance. The intention is that the approach is replicable, meaning that project's legacy will extend beyond the initial analyses conducted, facilitating future work as new data is collected. The analyses are intended to yield insights that can directly inform evidence-based fishery management to mitigate the bycatch of protected, endangered and threatened species (PETS) of cetaceans and elasmobranchs.

The success of this project will be defined by the extent to which the following specific objectives are met:

1. Collate eight core datasets, hosted in a data 'warehouse', where they can be accessed by the project team.
2. Identify, acquire and process, publicly available supplementary datasets (environmental and fishing effort) to aid the interpretation and analysis of the core datasets.

3. Produce spatio-temporal maps for each dataset.
4. Where appropriate, integrate datasets (core and supplementary) using mapping and/or modelling approaches.
5. Provide interpretation of the figures, maps and models produced, with specific reference to their implications for management, in terms of mitigating cetacean and elasmobranch bycatch.
6. Establish a replicable semi-automated workflow for the processing and analysis of each dataset (in the form of a library of R scripts), which mean analyses can be readily re-performed in the future.
7. Provide outputs (report, maps and figures) suitable for sharing with stakeholders to raise awareness, understanding and inform the evidence-based management of sustainable fisheries.

1.4. Methodology

At the project outset, eight datasets (Datasets A-H, 'the core datasets'; Table 2.1) were identified by Cefas and their partners. An overview and description of each core dataset is provided, see Section 2.1. The core datasets consist of both fishery-dependent and fishery-independent surveys providing information relating to bycatch, fishing effort and species distribution/abundance. Additionally, 'supplementary datasets', consisting of publicly available environmental and fishing effort data were obtained.

The project adopted a two-step approach to processing the datasets. Initially, each dataset was reviewed in insolation by means of exploratory plots and spatio-temporal map(s), which are presented here where informative. Subsequently, where appropriate, datasets were combined to identify common spatial-temporal trends and predictive relationships, with a view to gaining greater insights and informing the management of the region's fisheries to minimise bycatch. Two approaches to combining datasets were employed. These were: 1) graphically, by overlaying one of more spatial layers; and 2) statistically, using modelling to identify relationships with predictive power.

All data processing, analysis and the production of figures was performed in R (R Core Team, 2013), including automation of the acquisition of supplementary datasets. The intention is that this provides a (semi-) automated workflow that can be repeated subsequently. Further details of the data processing and statistical methodology are provided in the Appendix.

This report provides an overview of the core and supplementary datasets (Section 2). Findings from the analysis of each of the core datasets are then presented in turn, with management implications highlighted (Sections 3-9).

2. Overview of datasets

2.1. The core datasets

An overview of the core datasets is provided in Table 2.1. Further detail on each core dataset, spatio-temporal maps, analysis and discussion is provided in the subsequent sections (Sections 3 to 9). The datasets are ordered thematically: Datasets A, B and C are participatory, generated in collaboration with the fishing industry; Datasets D, E and F are from scientific survey and/or tagging programmes; Dataset G is on-board observer data; and Dataset H is an extract from a strandings database.

Table 2.1 Overview of core datasets. Providers: Centre for Environment, Fisheries and Aquaculture Science (Cefas); the French Muséum National d'Histoire Naturelle (MNHN), Cetacean Strandings Investigation Programme (CSIP).

Dataset	**Title: description**	**Provider**	**Coverage and Resolution**				**Ref(s)**
			Temporal		**Spatial**		
A	Multi-species bycatch self-reporting: participatory bycatch monitoring programme	Cefas	2019 – ongoing		Celtic Sea	Varies: VMS data and haul start end lat/long positions	
B	VMS data: vessel monitoring system (VMS) data from the 6 vessels contributing to Dataset A	Cefas	2019 – ongoing		Celtic Sea	VMS track data	
C	Spurdog bycatch self-reporting: from spurdog bycatch monitoring programme	Cefas	2013 – 2020	Daily records	Celtic Sea	Aggregated to grid with ~7x9 km cells	Hetherington *et al.* (2018)
D	Cefas common skate survey: Annual Common Skate scientific survey	Cefas	2011 - 2017	Annual survey		Lat/long locations along survey transect	Bendall *et al.* (2018)
E	Spurdog tagging: from electronic data storage tags (DST) and Mark ID tags (ID)	Cefas	DST:2010-2020 ID: 1960-2020	DST: Average daily data ID: Release and retrieval date	DST:Celtic and Irish Sea ID: UK	Lat/long locations	
F	Common skate tagging: from electronic data storage tags (DST) and Mark ID tags (ID)	Cefas	DST: 2011-2017 ID: 1959-2020	DST: Average daily data ID: Release and retrieval date	DST: Celtic Sea ID: UK	Lat/long locations	Bendall *et al.* (2018)
G	MNHN common skate observer data: onboard fishery observer data from French vessels	MNHN					
H	Cetacean bycatch: stranding records where bycatch has been identified as the cause of death	CSIP	1990 - ongoing	Ad hoc necropsies	English and Welsh coastline	Lat/long coastline stranding locations	CSIP (2021)

2.2. Supplementary datasets

Publicly available supplementary datasets were identified which complemented the core datasets and/or had the potential to serve as explanatory variables in models. The acquisition and processing of these can be readily repeated in the event of future iterations of this project as the core datasets grow and are updated.

2.2.1. Environmental

2.2.1.1. Bathymetry

Bathymetric data in the form of a digital terrain model (DTM), with a $^{1}/_{8}$ arc-minute grid resolution, were obtained from the EMODnet Bathymetry portal (EMODNet, 2021a). Higher resolution bathymetric data with 6 arc-second grid resolution were used for maps of smaller inshore areas in Section 3 (British Crown and OceanWise, 2021).

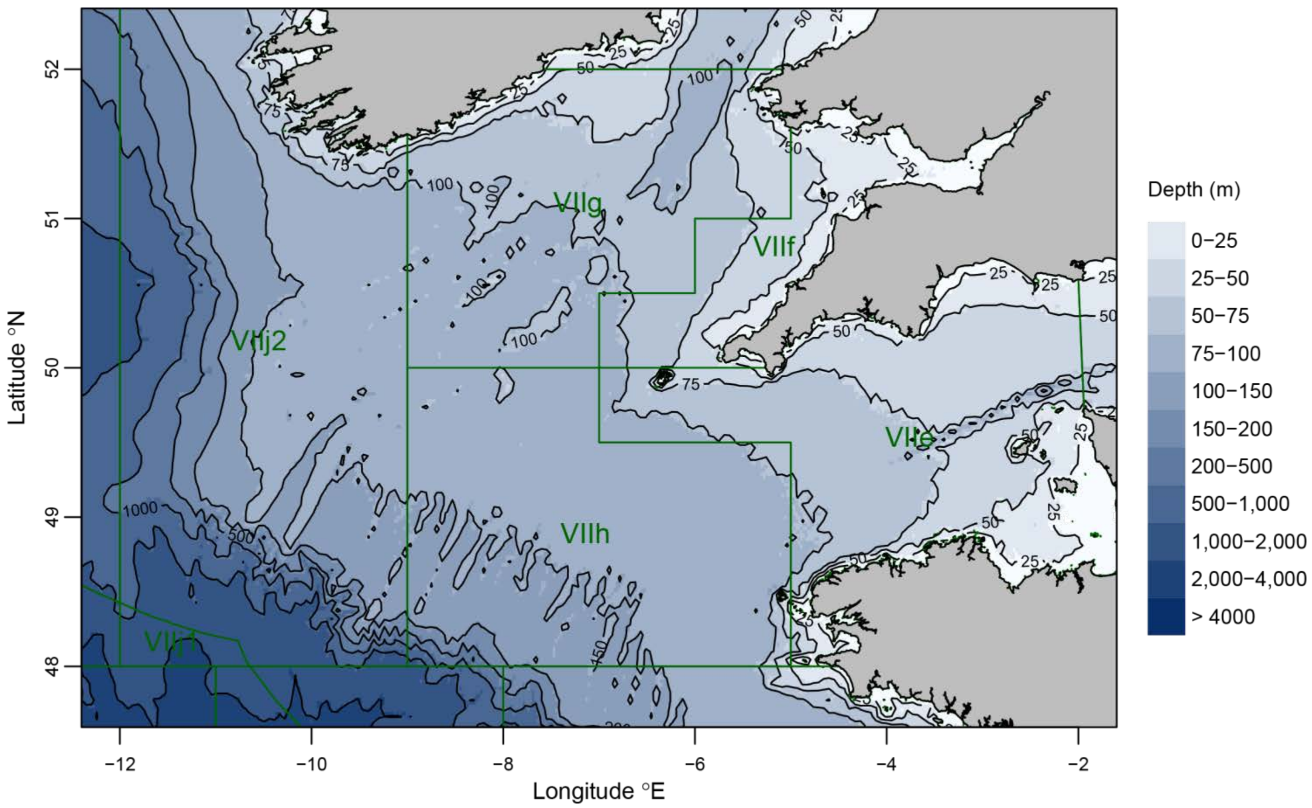

Figure 2.1 Celtic Sea bathymetry. Bathymetric contours are drawn (black lines, labelled). ICES Areas are shown (green polygons and text). Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

2.2.1.2. Sea Surface Temperature (SST)

Daily and mean monthly (2002 to present) sea surface temperature (SST) data on a global 0.01 degree grid interpolated from satellite and in situ observations (JPL MUR MEaSUREs Project, 2015) are available from the ERRDAP portal (Simons, 2016). This allowed the production of mean seasonal (e.g. Figure 2.2) and monthly SST rasters for the study region (Appendix I).

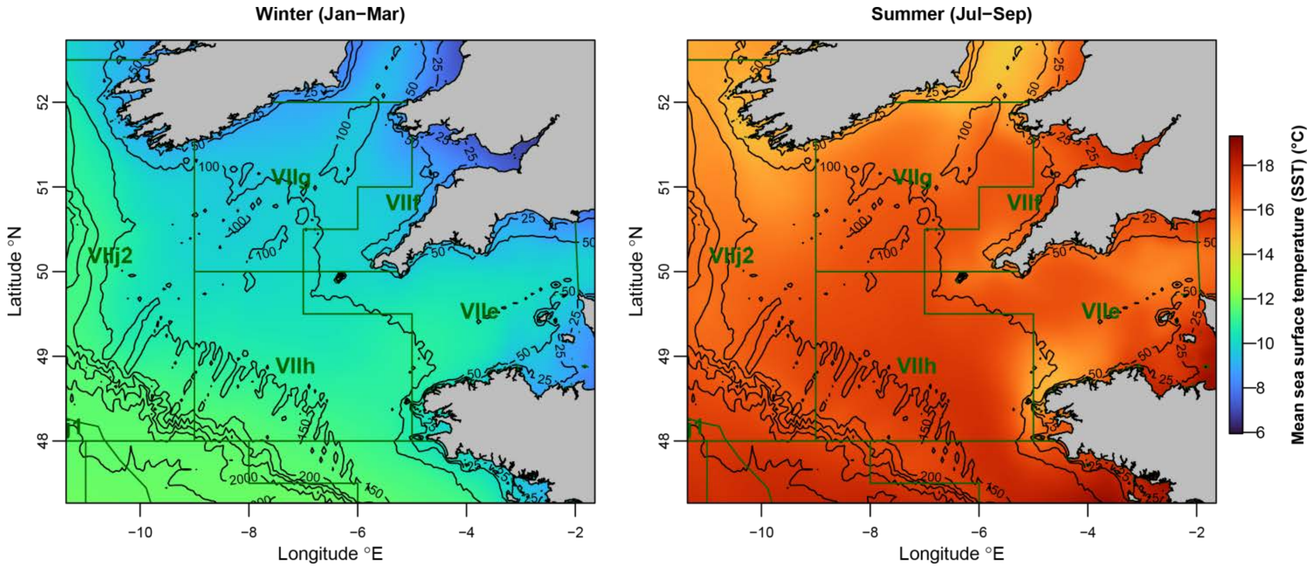

Figure 2.2 Seasonal (Winter vs. Summer) sea surface temperature. Sea surface temperature (SST) for Winter (January to March) and Summer (July to September), calculated as the mean of the monthly values obtained for each season between 2010 and 2020, inclusive. ICES Areas are shown (green polygons and text). Data: SSTs, Group for High Resolution Sea Surface Temperature (GHRSST) Multi-scale Ultra-high Resolution (MUR) SST Analysis fv04.1, Global, 0.01° Monthly (JPL MUR MEaSUREs Project, 2015); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

The high temporal and spatial resolution of this dataset meant that it could be processed to provide corresponding estimated SSTs for individual records in some of the core datasets to be used as a potential environmental variable in predictive modelling, see Section 4 and Appendix I for details of processing.

2.2.1.3. Substrate

A broad-scale predictive physical habitat map was obtained from the EMODnet seabed habitats portal (EMODNet, 2021b). In the interest of graphical clarity, similar substrate types were grouped in the map presented here (Figure 2.3). The EMODnet substrates types can be mapped to EUNIS Habitats classifications, see EMODNet (2021b) and Appendix I for details.

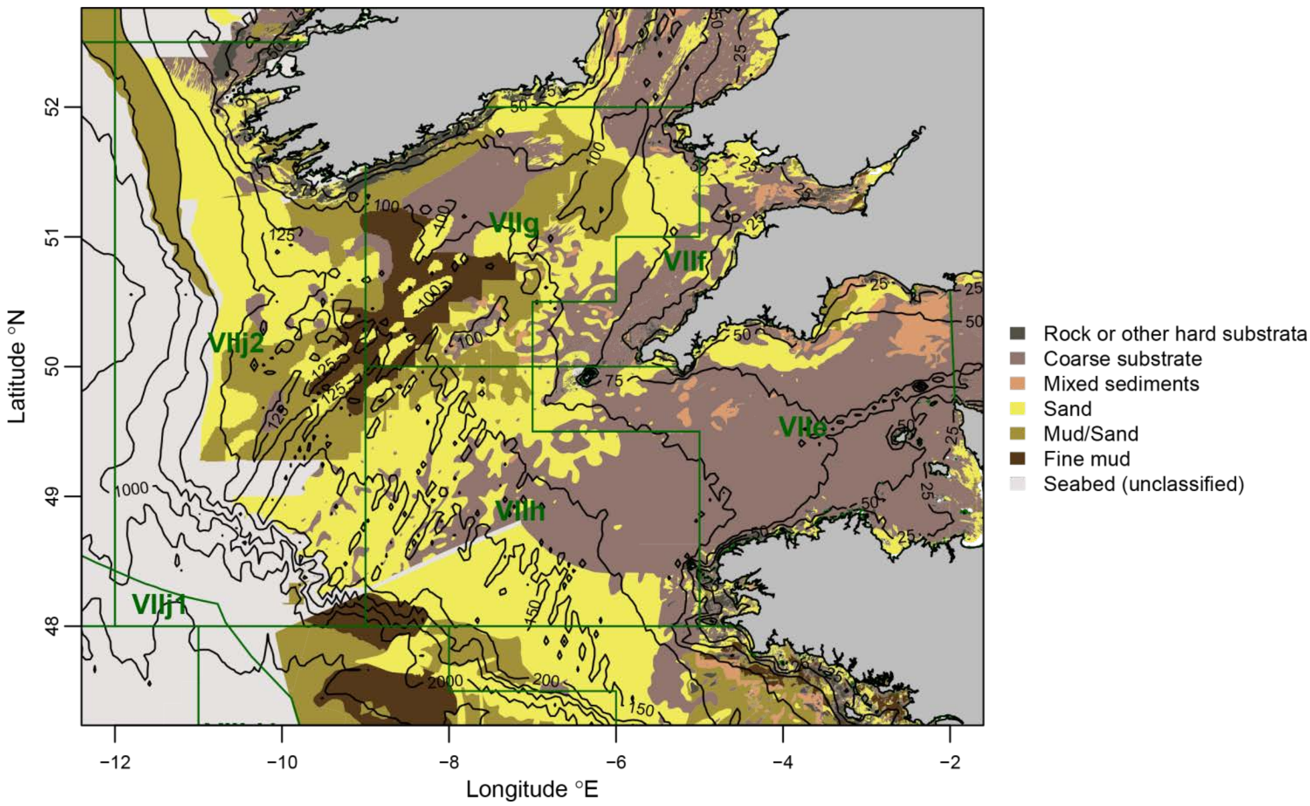

Figure 2.3 Broad-scale map of Celtic Sea seabed physical habitats. Substrates were grouped into the following categories (where two or more categories were combined, the original EMODnet classifications are indicated in parentheses): Rock or other hard substrata; Coarse substrate; Mixed sediments (Sediment and Mixed sediment); Fine mud; Mud/Sand (Muddy sand, Sandy mud or Muddy sand and Sandy mud), Sand and Seabed (unclassified). Data: substrates, EMODNet (2021b); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

2.2.1.4. Sea surface salinity (SSS)

Long-term monthly average sea surface salinity were obtained from the MARSPEC portal of high resolution climatic and geophysical spatial data layers (Sbrocco and Barber, 2013).

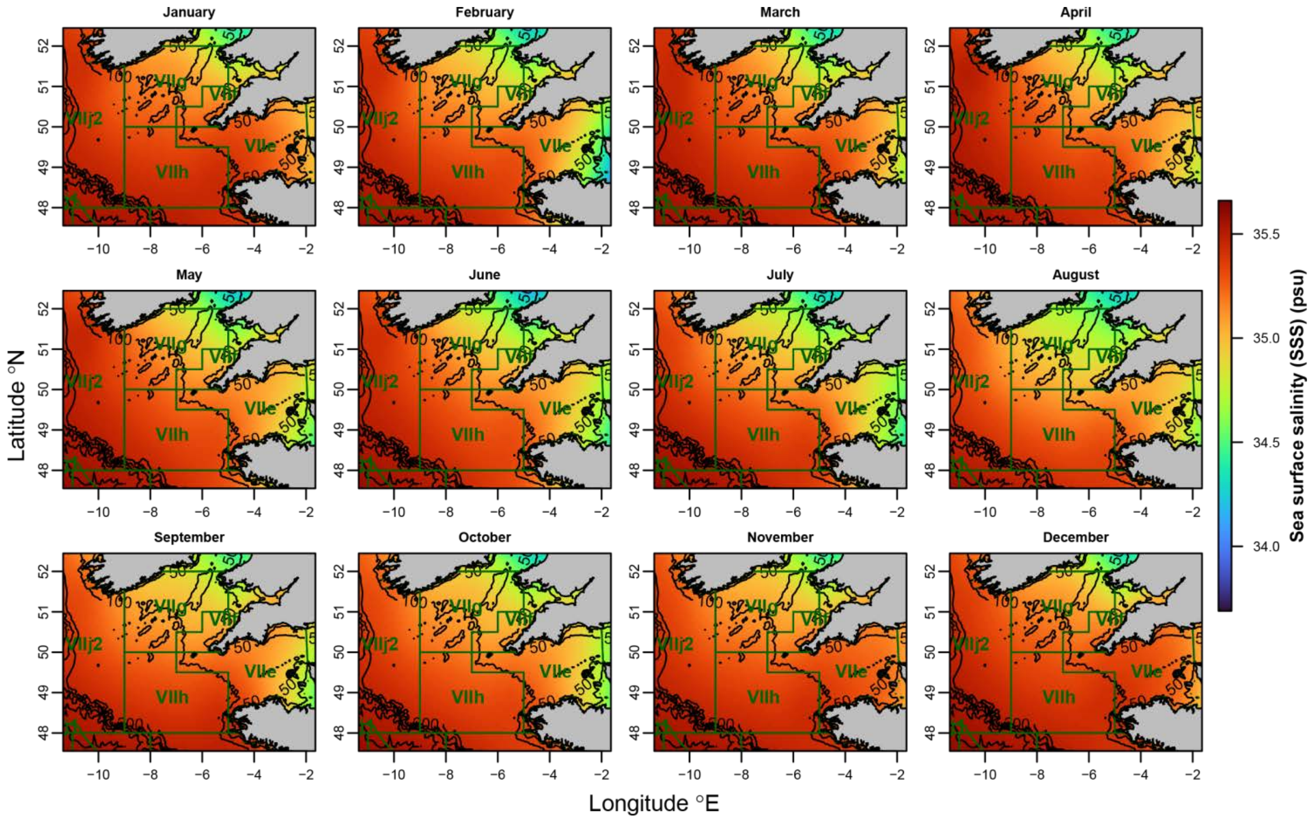

Figure 2.4 Monthly sea surface salinity (SSS) in the Celtic Sea. Data: SSS, Sbrocco and Barber (2013); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

2.2.2. Fishing effort

Fishing effort data was obtained from Global Fishing Watch (GFW). GFW applies a machine learning approach to process automatic identification system (AIS) tracking data to identify fishing activity and differentiate between types of fishing (Global Fishing Watch, 2021). Daily fishing effort data, by gear type, is available aggregated to 100th degree cells. Data were obtained from 2012 to 2020, inclusive, for trawling effort (GFW classification: 'trawler') and gillnets (GFW classification: 'set-gillnets') and was normalised to a 500 m grid. Note, the GFW data only represents the fishing effort of larger vessels (i.e those with AIS) and so is a subset of total fishing effort. It also only describes the fishing vessel activity not the effort expended by the gear; i.e. for gill netters it captures the fishing activity of the vessels associated with deploying and retrieving the gear, not the soak time of the nets. The gill net effort data was further processed to produce mean monthly effort rasters for use in the analysis of Dataset C (see, Section 4).

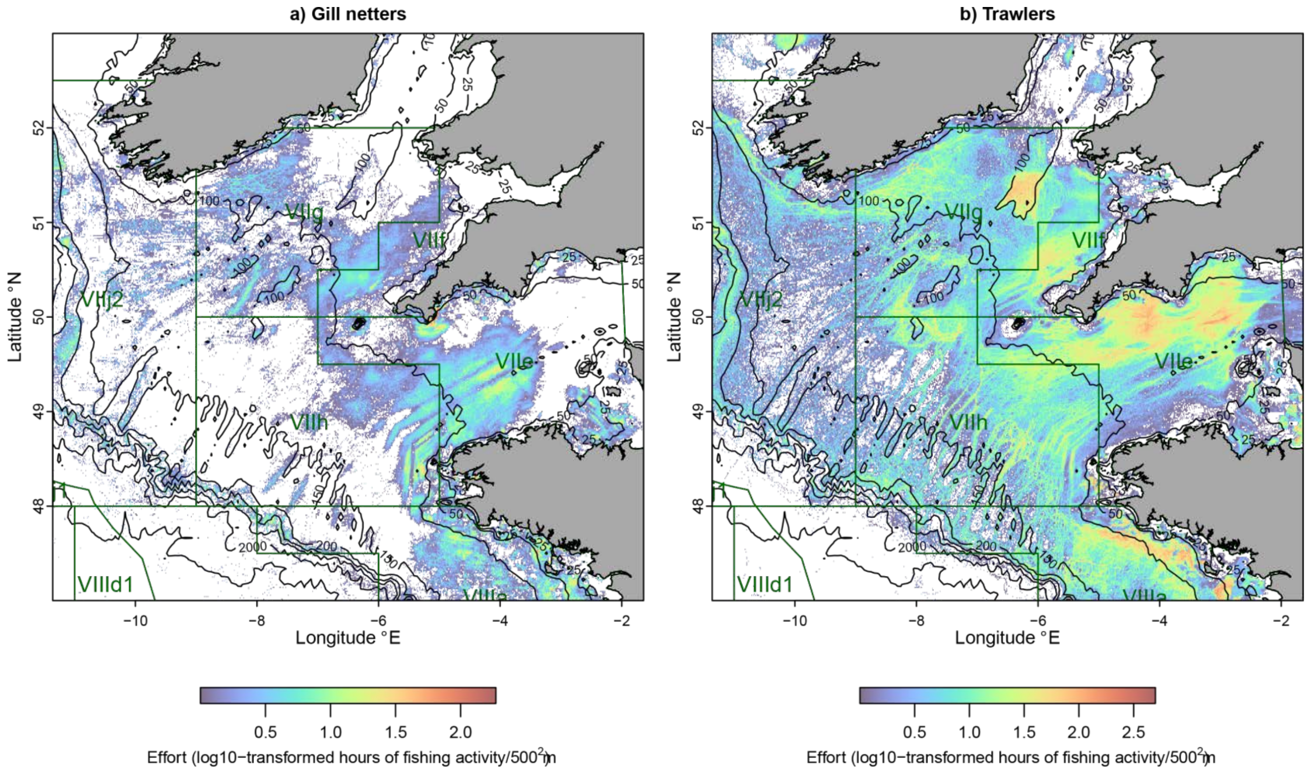

Figure 2.5 Global Fishing Watch (GFW) total fishing effort (2012 to 2020, inclusive) for a) Gill netters and b) Trawlers. Data: fishing effort, Global Fishing Watch (2021); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

3. Datasets A and B: Multi-species bycatch self-reporting and VMS data from self-reporting vessels

Datasets A and B are derived from an ongoing participatory bycatch monitoring programme. Participating vessels (inshore vessels <10m in length) record fishing activity and bycatch events using a smartphone application (the ‘App’) linked to an autonomous vessel monitoring system (AVMS). The programme and the App are in the initial trial phase working with a small number of vessels (n = 6), to capture cetacean bycatch data. The intention is to roll out the programme to a much larger proportion of the fleet in the future, recording both cetacean and other vertebrate bycatch.

Data collection began in January 2019 and is ongoing. The data presented here is from January 2019 to July 2021. During this period, skippers were asked to record all cetacean bycatch events using the App. Additionally, the App allows skippers to record the bycatch of other vertebrate fauna (e.g. birds, sharks, seals), though this was at the skippers discretion/convenience and is therefore only a partial record. Four of the six participating vessels also have on-board video. These videos were reviewed by Cefas as part of the quality assurance process for this dataset. This review suggested that all cetacean bycatch events were accurately recorded by skippers using the App (S. Hetherington, pers. comm.).

Version 1 of the App (App v1) recorded the vessel’s position from AVMS at approximately five minute intervals from the start to the end of each ‘trip’. In these cases, a trip consists of a journey, during which there are one of more fishing activities (i.e. hauling gear). Accordingly there are multiple records (position every five minutes) for trips recorded using App v1. Version 2 of the App (App v2) recorded the start and end position of each trip. In this case a trip is the hauling of a gear. In these cases there is a single record for each trip recorded using App v2.

Data exploration, analysis and interpretation

The dataset has 50,124 rows/records (after removing erroneous rows, e.g. no positional data). These are generated by six vessels (unique 'vessel_id's), although four of these vessels account for the bulk of the data (49,690 records = 99%). All six vessel fish with static nets.

Each record has a 'trip_id’, where trips are described by one or more records. There are 1,104 unique trips. 810 of these trips consist of multiple records. The remaining 294 trips have just a single associated record. For those trips with multiple records, each record has a position (latitude/longitude), so collectively the trip’s records describe a journey. Each journey can be represented by a line on a map and may include both fishing and steaming. Those trips for which there is only a single record can be represented by a line on a map joining the start and end position. Figure 3.1 shows all trips (multiple and single records), coloured by vessel. Figure 3.2 shows all trips with multiple records, with a panel for each vessel, within which each trip is represented by a different coloured line joining the recorded positions. Figure 3.3 shows all single record trips, with a panel for each vessel, within which a different coloured line joins the start and end position of each trip.

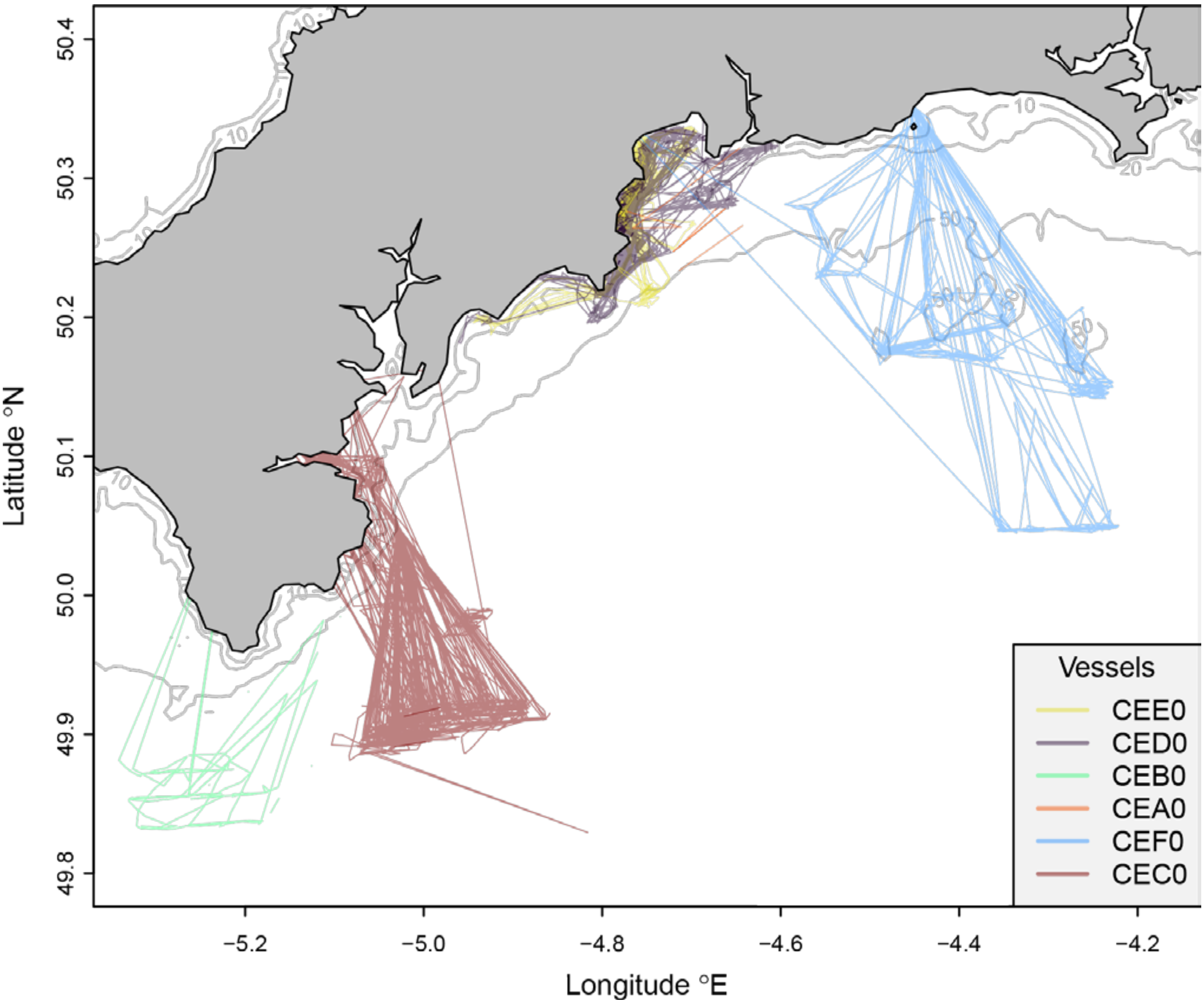

Figure 3.1 Map of all trips (single- and multi-record) colour-coded by vessel. Contours are drawn at 10, 20 and 50 m. Bathymetric data: British Crown and OceanWise (2021).

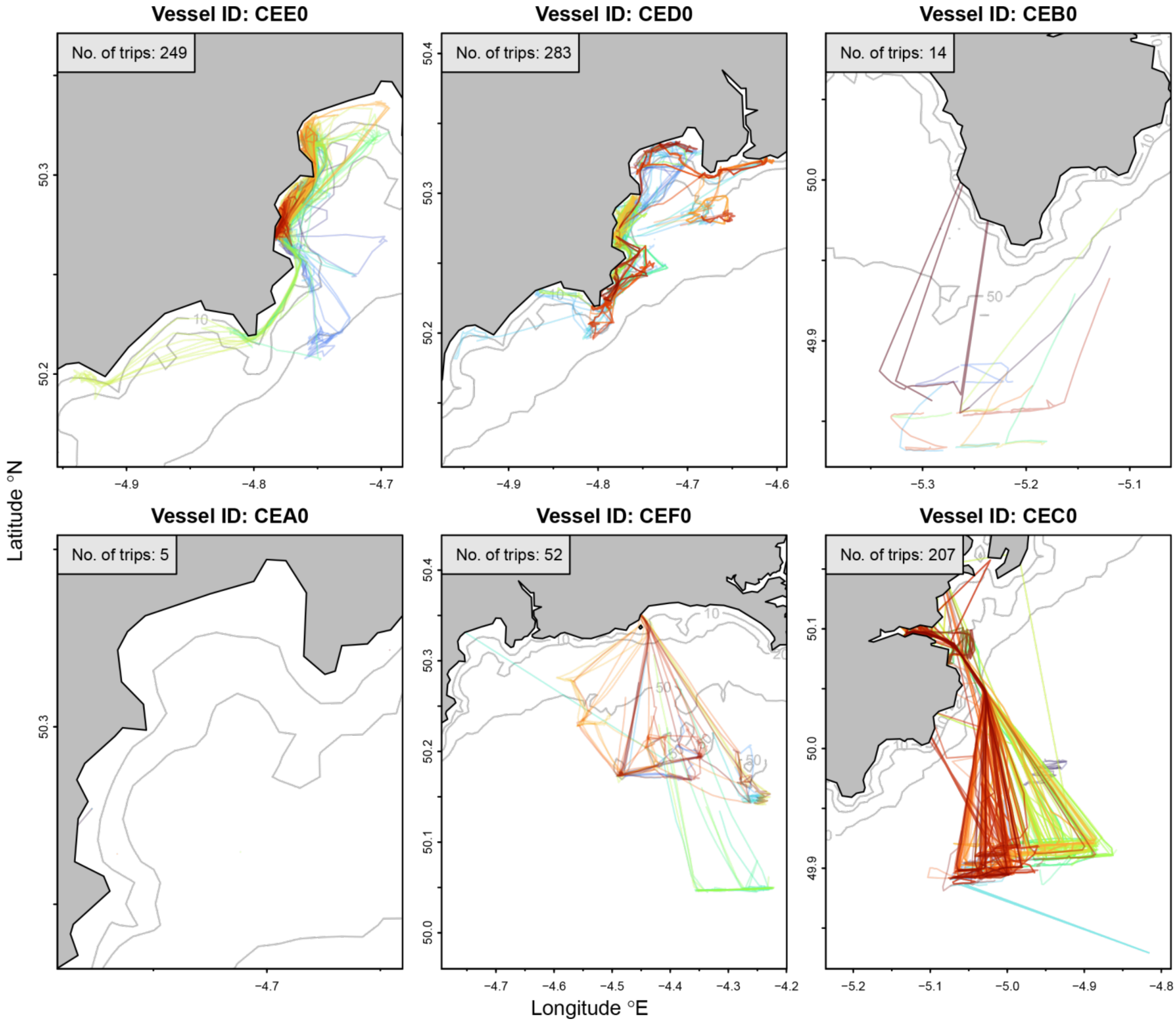

Figure 3.2 Maps of all multi-record trips by vessel, each trip is assigned a separate colour. Note that in a few instances the VME positions for a trip are all the same, in which case no track is drawn. Contours are drawn at 10, 20 and 50 m. Bathymetric data: British Crown and OceanWise (2021).

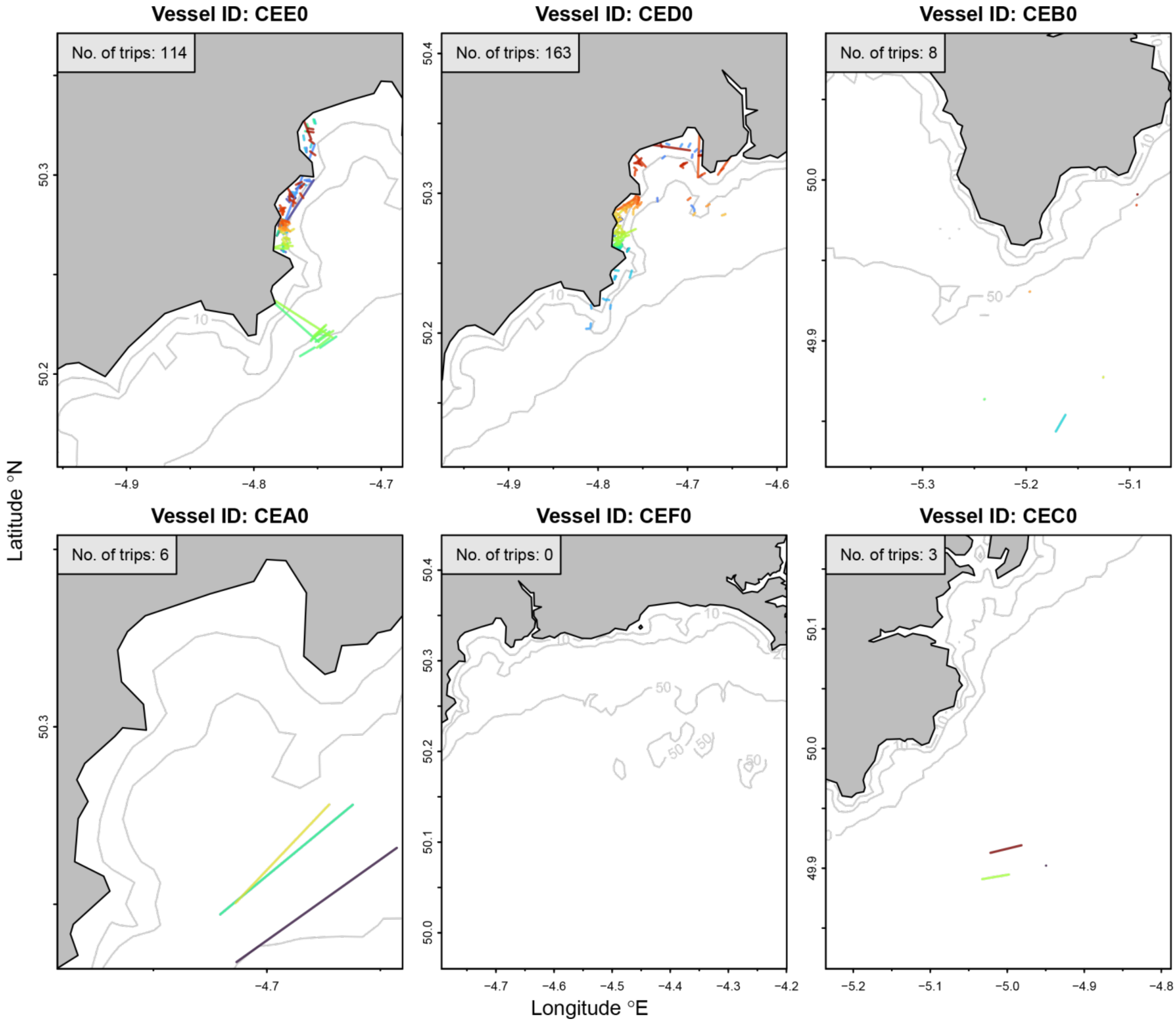

Figure 3.3 Maps of all single-record trips by vessel, each trip is assigned a separate colour. Note, some trips are missing an end position, in which case a line is not drawn. Contours are drawn at 10, 20 and 50 m. Bathymetric data: British Crown and OceanWise (2021).

The bycatch for each trip is recorded as the number of individuals of each taxon. There were a total of seven different taxa reported as bycatch. These were: basking shark (*Cetorhinus maximus*); short-beaked common dolphin (*Delphinus delphis*); harbour porpoise (*Phocoena phocoena*); grey seal (*Halichoerus grypus*); harbour seal (*Phoca vitulina*); guillemot (*Uria aalge*); and seabird (unidentified). Bycatch was only reported by three of the six participating vessels. Bycatch was reported on 1.7% of all trips (19 out of 1,104). On four trips, two different bycatch taxa were reported. The maximum number of individuals of any taxon reported on a trip was four (four common dolphins, on one occasion). Note, as reporting was optional, the number of non-cetacean bycatch individuals is not a complete account.

Cetacean bycatch was reported on 1.0% of trips (11 of 1,104). The maximum number of common dolphins caught in any trip was four, whilst the maximum number of harbour porpoise caught on any trip was one. The total number of individuals of all taxa reported as bycatch was 29, consisting of 15 cetaceans (common dolphin, 13; harbour porpoise, 2). The 13 common dolphins were caught on eight trips. Notably only one of these trips with common dolphin bycatch was in the summer (May-August). The remaining seven trips with common dolphin bycatch occurred in the autumn/winter months (Sept- March). The peak being December from in which there were three trips with common dolphin bycatch accounting for six individuals. The numbers are very small and so confidence in any temporal trends is very limited. However, the observed temporal pattern of common dolphin bycatch is broadly aligned with that of the bycatch strandings data (Dataset H, see Section 9), where the fewest bycatch strandings are also observed in the summer months.

The locations of reported bycatch was determined as the centre of the start and end positions of each trip (for single record trips) and the centre of all positions for multi record trips. Reports of bycatch were restricted to two areas; a) waters east of the Lizard; and b) from between Dodman Point and Saint Austell Bay (Figure 3.4). The dataset is small in terms of fleet representation and temporal-spatial coverage, thus at this stage the data cannot be used to identify hotspots or inform management measures. Nevertheless, the data do confirm Mevagissey Bay as an area where bycatches occur, highlighting the importance of ongoing monitoring and participatory data collection, here and elsewhere.

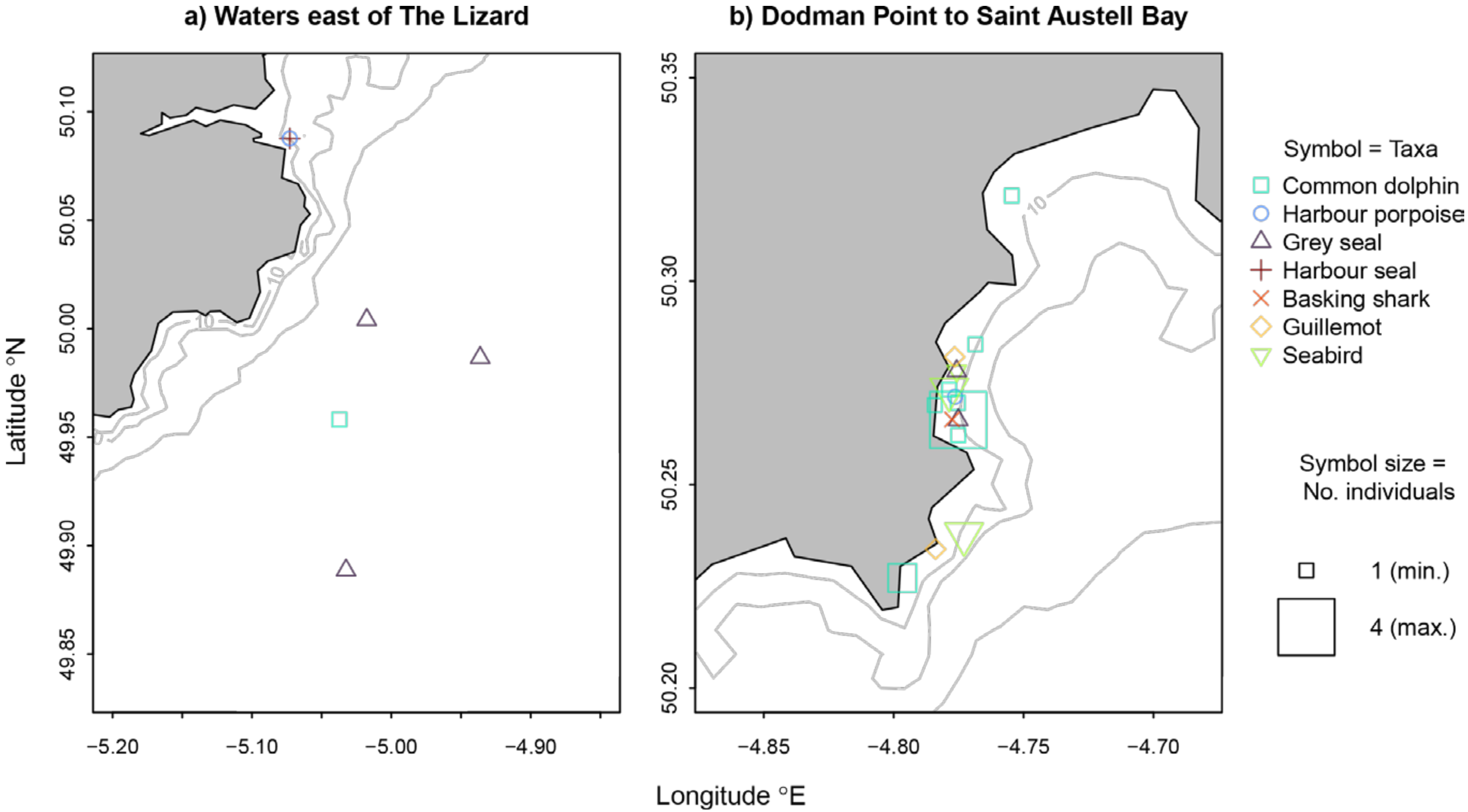

Figure 3.4 Locations of reported all bycatch reported in Datasets A and B. Contours are drawn at 10, 20 and 50 m; bathymetric data: British Crown and OceanWise (2021).

Limitations

The data is generated from six vessels, which operate from a number of different ports. This is only a small subset of region's under 10m fleet, with approximately 1,000 vessels operating in the southwest region (Cornwall, Devon and Dorset) (Cefas staff, pers. comm). Hence, the fishing behaviour and bycatch patterns do not necessarily represent the wider fleet. This is demonstrated by the non-spatially overlapping patterns of movement observed. Thus, the interpretation of this data is limited to understanding the activity of six particular vessels rather than being a reliable indication of the wider fleet. Given the very limited representation, *it is inappropriate to extrapolate from this dataset to estimate total cetacean bycatch by the region's under 10 m fleet.* In future, with a greater number of participating vessels that form a representative selection of the fleet, this may be possible. A further limitation is there is no specific location for bycatch events (i.e they cannot be localised within the trip). For example, the longest trip (linear path connecting the sequence of positions) with bycatch is ~60 km long but it is not possible to say where the bycatch event happened on this path.

4. Dataset C: Spurdog bycatch self-reporting

Dataset C was generated through the Spurdog Bycatch Management Programme, where skippers reported information on their daily spurdog bycatch in near real-time (Hetherington *et al.*, 2018, Hetherington *et al.*, 2016). Skippers then received compiled information in the form of an advisory traffic light system, identifying bycatch hotspots, to inform their fishing decisions.

Each row of the dataset is a record representing a report from a skipper detailing the bycatch of spurdog (kg), if any, from a reporting cell on a specific day. Thus, each record can report either no spurdog bycatch or in the event bycatch occurred, the quantity that was caught. The reporting grid consisted of ICES rectangles split into 64 equal cells (8x8), thus each cell is $^{1}/_{16}$ degree latitude by $^{1}/_{8}$ degree longitude (~7 x 9 km). The extent of the reporting grid is approximately ICES Areas 7e-j.

Data exploration, analysis and interpretation

Dataset C contains 4,580 records from December 2013 to January 2020, inclusive. The majority of records were from 2017, 2018 and 2019, with broadly even effort (number of records) across the calendar year (Figure 4.1). Records were from 11 vessels (primarily from six vessels) and from three fleets: 'inshore netter' (n = 25); 'offshore netter' (n = 3,096); and 'otter trawler' (n = 1,459). As there are only 25 records from inshore netters, subsequent analysis of data focusses on offshore netters and otter trawlers.

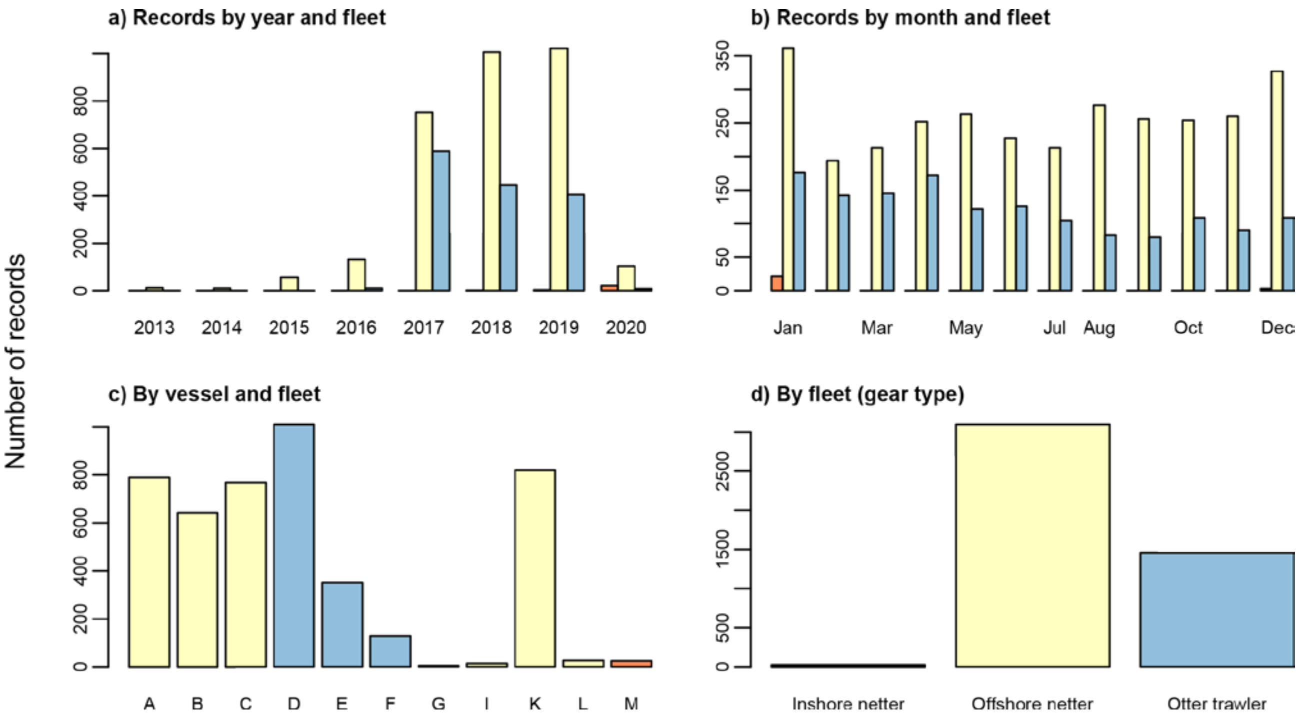

Figure 4.1 Overview of the distribution of records by category in Dataset C (spurdog bycatch). The fleet is indicated by colour (inshore netter=orange; offshore netter=yellow; otter trawler = blue).

Fishing effort by the offshore netters and otter trawlers occurred in spatially discrete areas, with offshore netters operating further offshore in deeper waters (~50-150m), whilst otter trawlers targeted inshore shallower waters (~25-50m) (Figure 4.2). There is potentially some seasonal variation in the intensity (Figure

4.1) and distribution of fishing effort in offshore netters (Figure 4.3) and otter trawlers (Figure 4.4), though a dataset with longer temporal range would support more detailed insights.

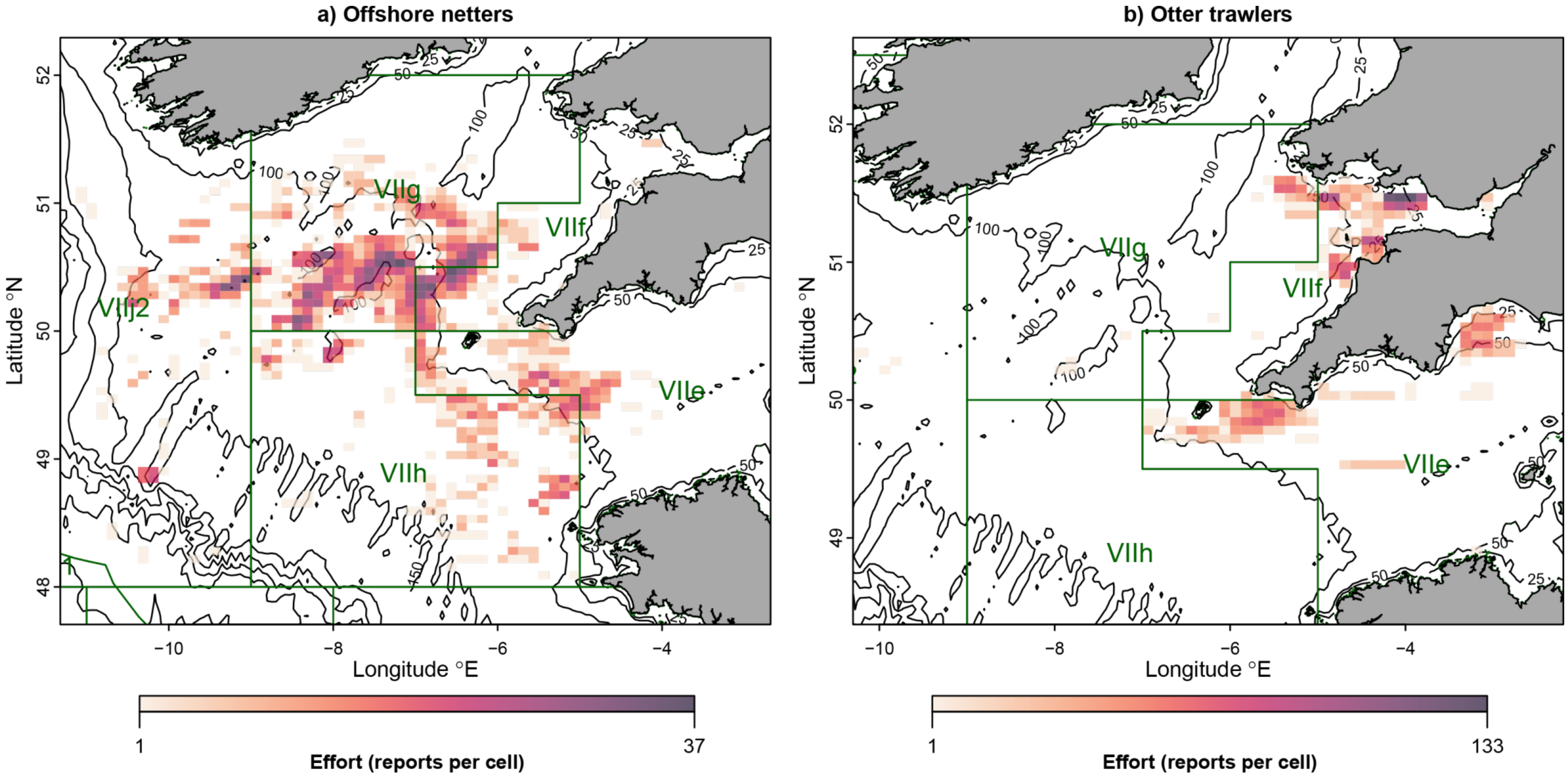

Figure 4.2 Fishing effort by gear type for a) offshore netters and b) inshore trawlers. Fishing effort (number of reports per cell) is log-transformed for plotting, the maximum and minimum actual values (i.e untransformed number of reports) are displayed on the legend. Data: bathymetry EMODNet (2021a); ICES areas, (ICES, 2021).

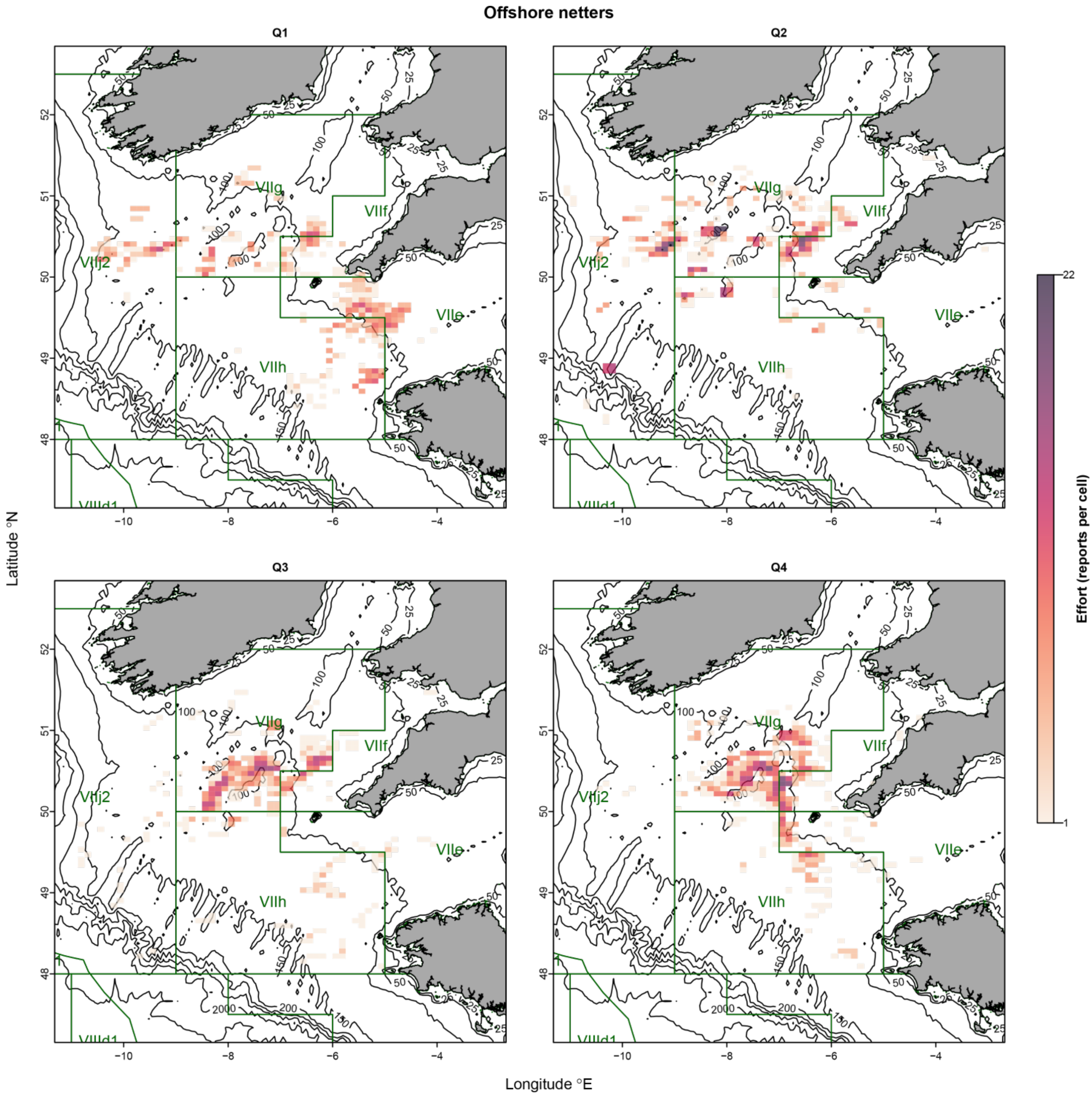

Figure 4.3 Seasonal variation in offshore netter effort. Fishing effort (number of reports per cell) is log-transformed for plotting, the maximum and minimum actual values for all quarters (i.e untransformed number of reports) is displayed in the legend. Data: bathymetry EMODNet (2021a); ICES areas, (ICES, 2021).

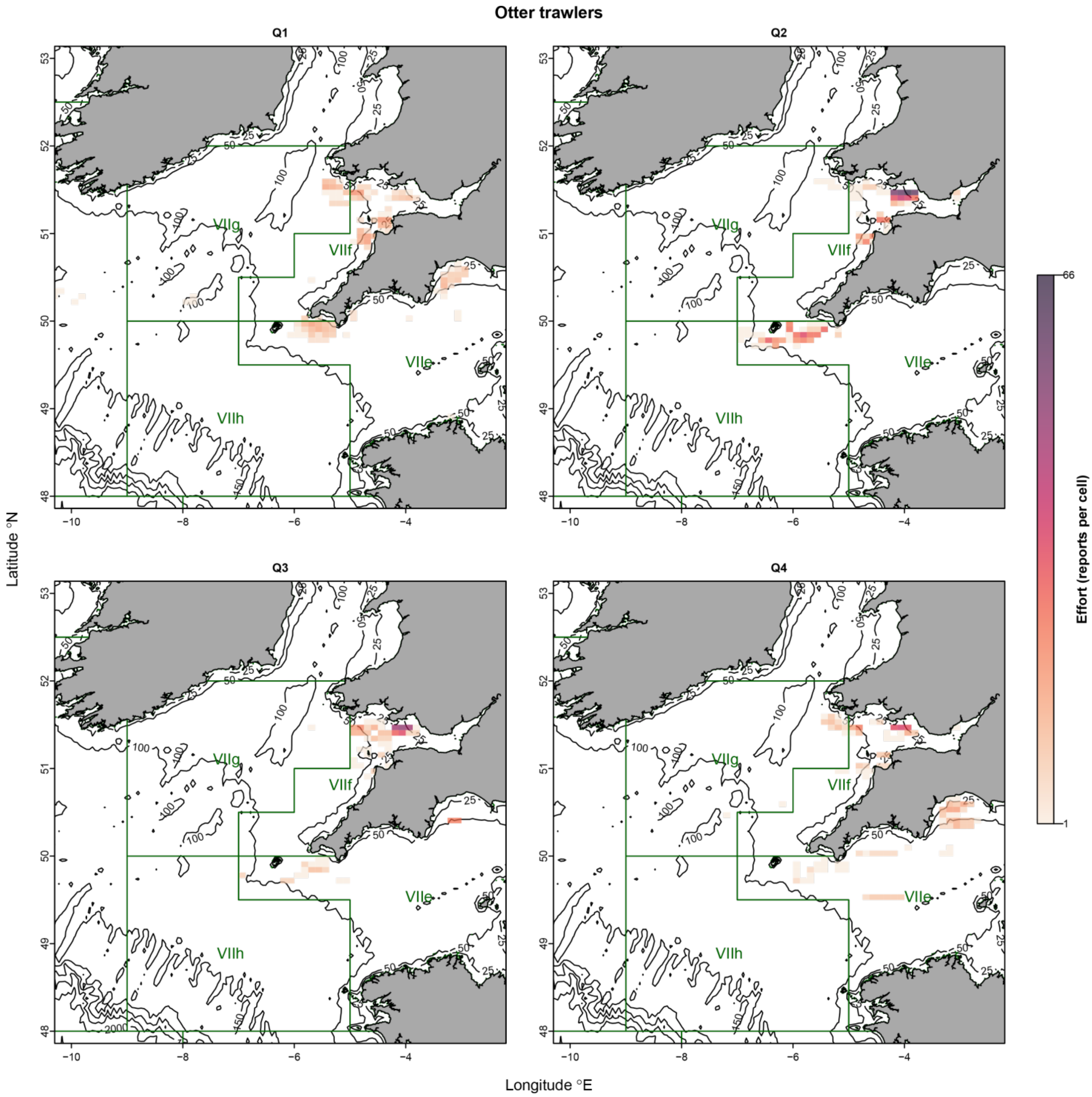

Figure 4.4 Seasonal variation in otter trawler effort. Fishing effort (number of reports per cell) is log-transformed for plotting, the maximum and minimum actual values for all quarters (i.e untransformed number of reports) is displayed in the legend. Bathymetric data: EMODNet (2021a); ICES areas, (ICES, 2021).

Of the 4,580 records, approximately half reported no spurdog bycatch (n = 2,618), the remaining 1,962 reports of bycatch totalled over 350,000 kg of spurdog (Table 4.1). Where spurdog bycatch was recorded, the range was considerable, from 0.2 to 8,900 kg. Netters (in- and offshore) more frequently reported bycatch, and where bycatch events did occur, these were typically of larger quantities than for otter trawlers (Table 4.1 and Figure 4.5). Both offshore netters and inshore trawlers showed seasonal variation in the bycatch of spurdog, with the larger catches being concentrated in the winter months (October to January, inclusive).

Table 4.1 Summary of spurdog bycatch by gear type/fleet. A record represents a report from a skipper detailing the bycatch of spurdog (kg), if any, from a reporting cell on a specific day.

Gear type/Fleet	Records	% of records reporting bycatch	For records with spurdog bycatch		Total (kg)
			Range, min-max (kg)	Median (kg)	
Inshore netter	25	100.0	6-8,900	120.0	11,025
Offshore netter	3,096	52.6	0.5-5,420	76.0	337,544
Otter trawler	1,459	21.2	0.2-960	7.7	10,766
All	4,580	42.8	0.2-8,900	55.8	359,335

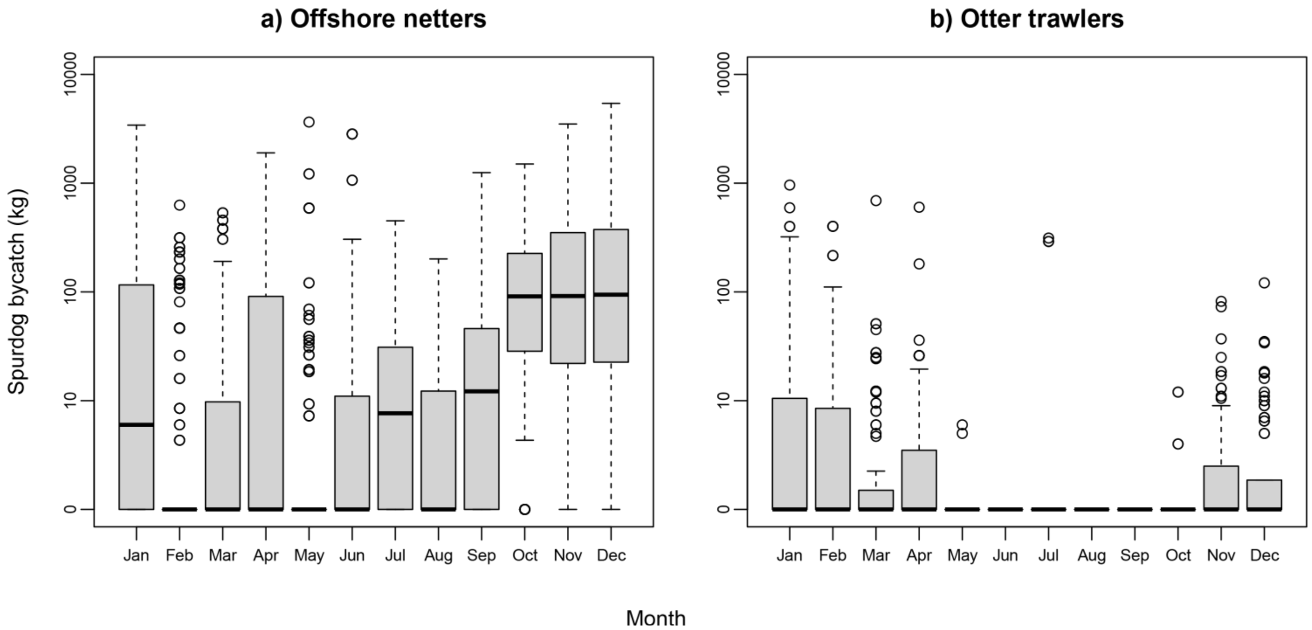

Figure 4.5 Boxplot of spurdog bycatch by month for a) Offshore netters and b) Otter trawlers. Outliers are drawn (open circles). A log-axis scale is used on the y-axis.

The occurrence of larger spurdog bycatch hauls in the winter months are likely the result of interactions between gear and aggregations or shoals of spurdog. Spurdog are known to aggregate in shoals of the same size and/or sex (Pawson and Ellis, 2005). Seasonal aggregations may be associated with reproductive events (spawning and/or partuation) (Carlson *et al.*, 2014). Pawson (1995) identifies the eastern Celtic Sea as an area where females aggregate to give birth during the winter and spring months. Genetic analyses of samples from the Celtic Sea and the observed inter-haul variation have suggested that aggregation events may be related to sub-populations and structuring with the spurdog population (Thorburn *et al.*, 2018).

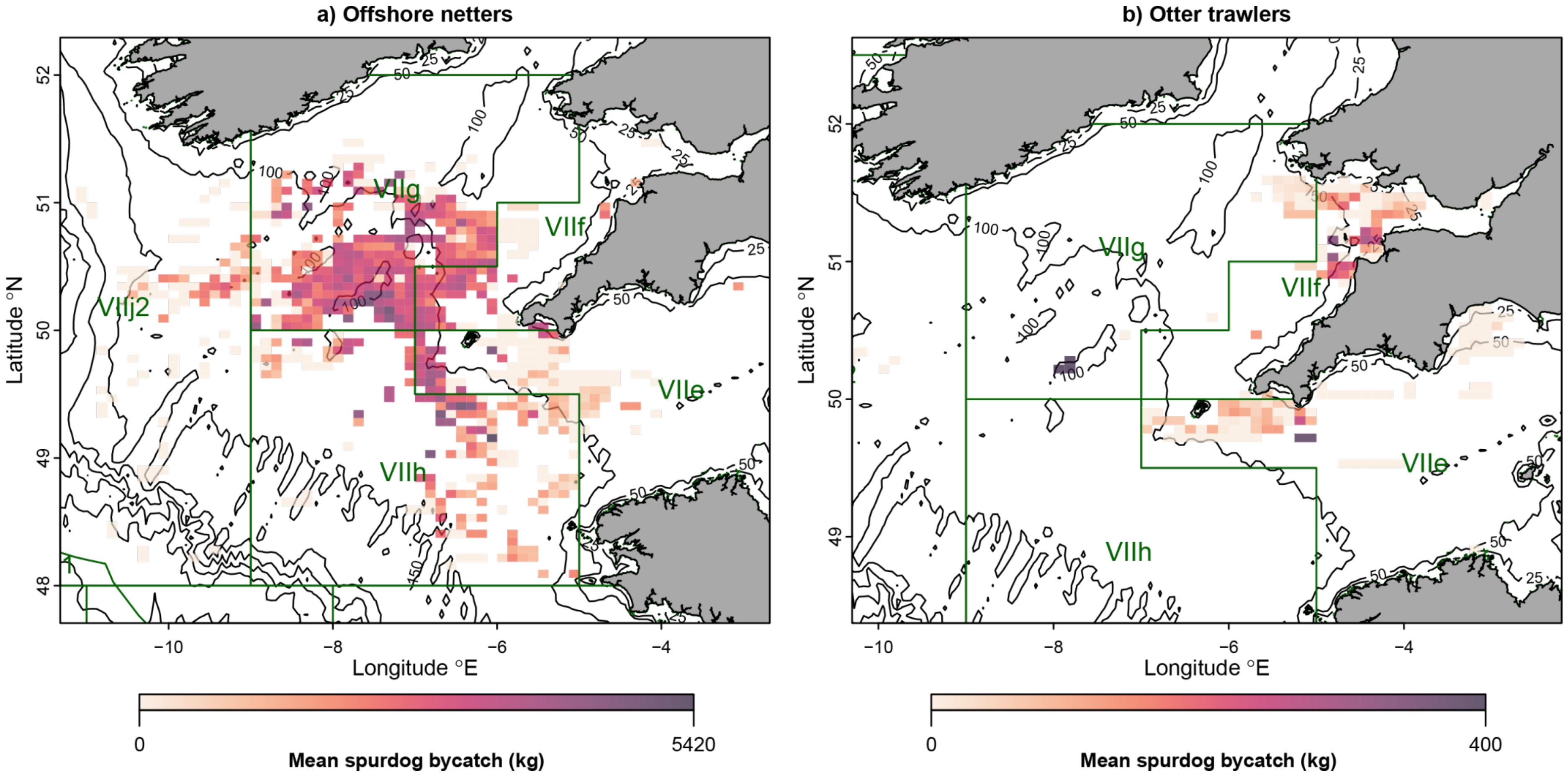

Figure 4.6 Map of mean spurdog bycatch per cell. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

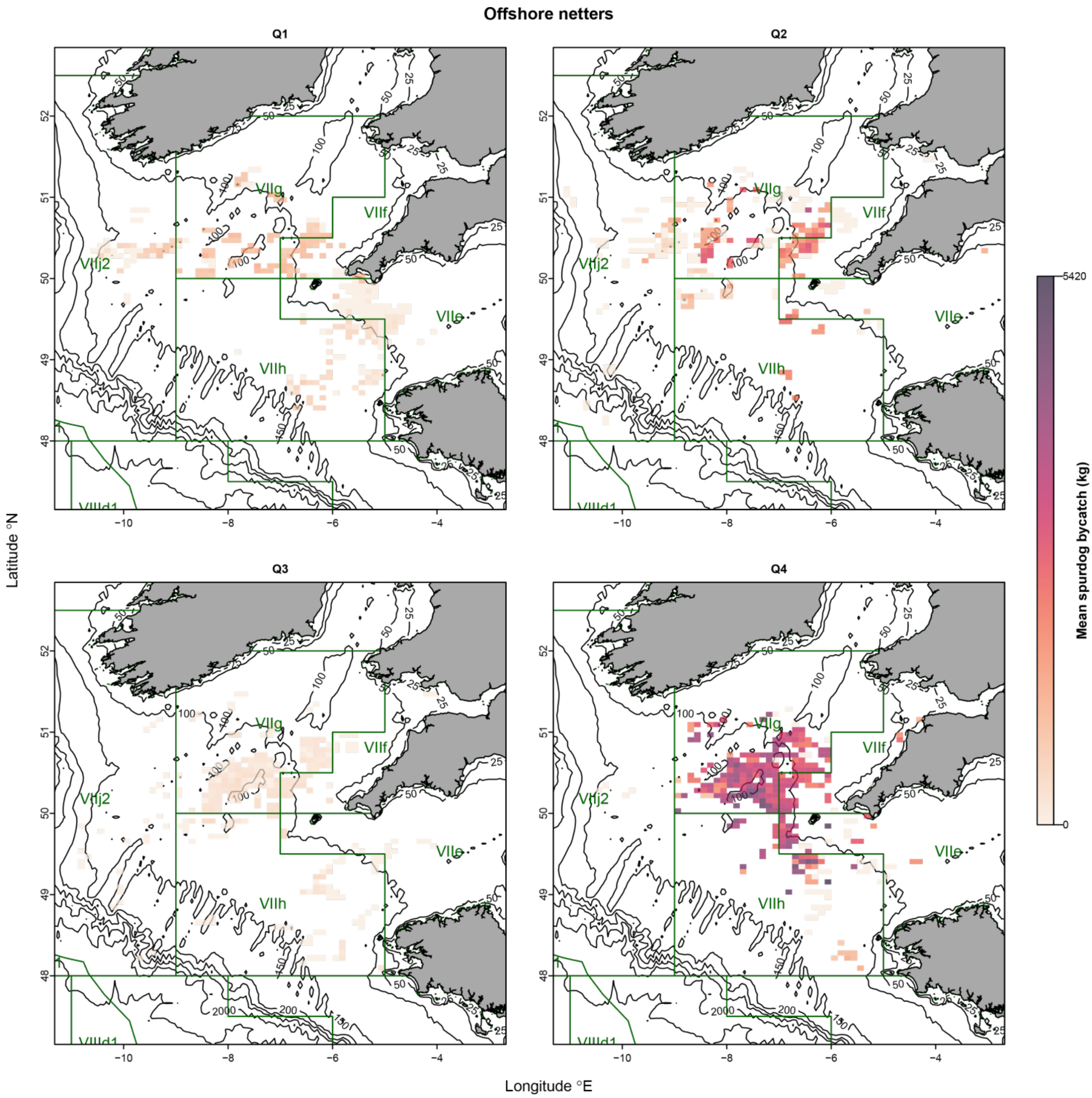

Figure 4.7 Seasonal variation in mean spurdog bycatch by offshore netters. Bathymetric data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

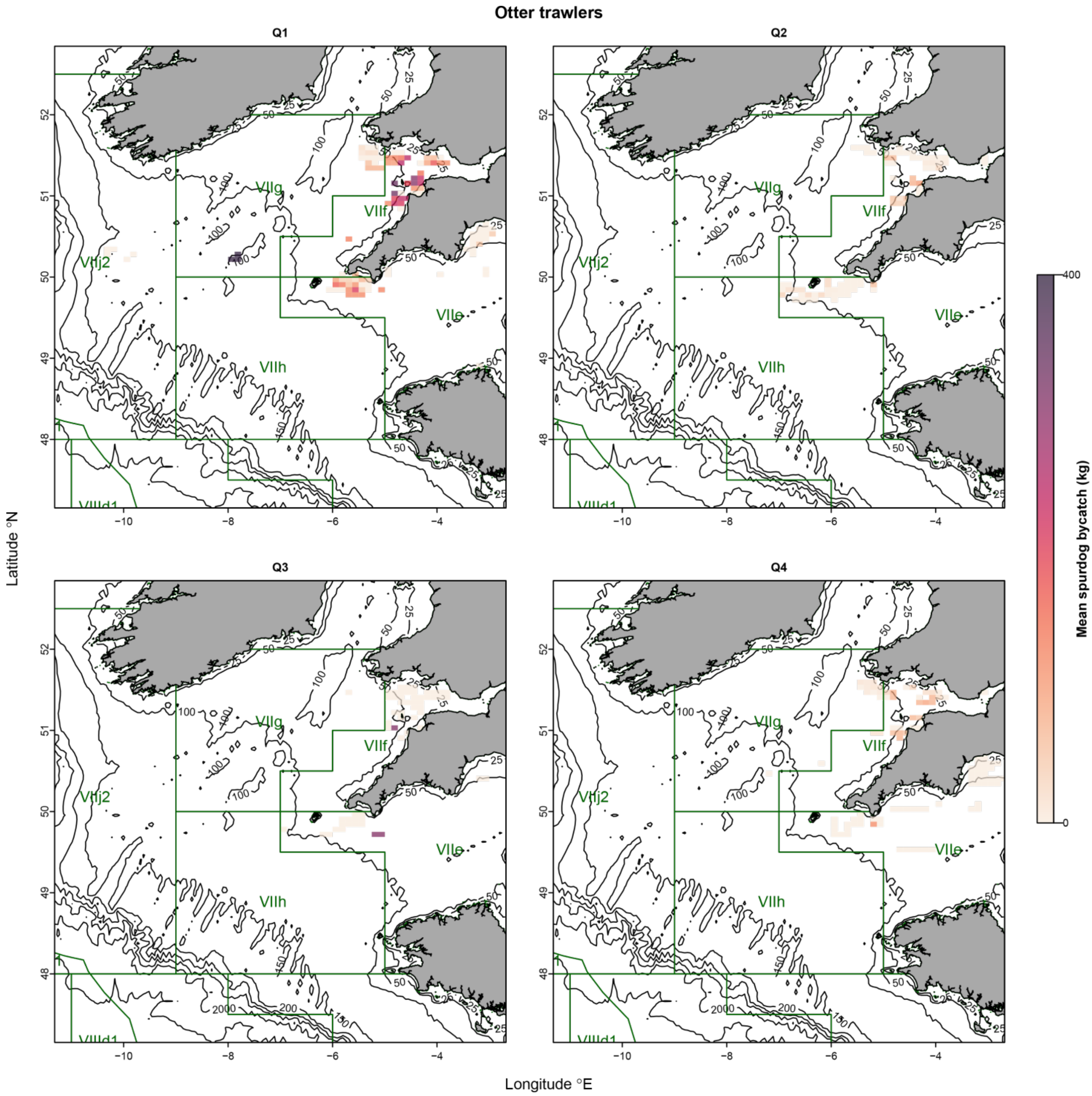

Figure 4.8 Seasonal variation in mean spurdog bycatch by otter trawlers. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

Spurdog is categorised vulnerable on the IUCN Red List. As such there is zero total allowable catch (TAC) and it is desirable to limit bycatch wherever feasible. However, the priority is to understand and address, those occasions where largest quantities of spurdog bycatch occur ("large hauls"), as these occasions have the greatest impact on the population. The occurrence of occasional large hauls, related to aggregative behaviour of spurdog especially during specific seasons, is well known among fishermen and managers. Individuals hauls of up to 10 tonnes have been previously reported, which have the capacity to damage gear and even endanger vessels (Hetherington *et al.*, 2016).

With this priority in mind, the following analysis focusses on the offshore netter data, which accounted for the vast majority of bycatch in Dataset C (337,544 kg of a total of 359,335 kg = 94%). Furthermore, among those reports with bycatch in Dataset C, the offshore netter records had a much higher median of 76.0 kg

(Table 4.1), this median bycatch weight would represent numerous individuals. Conversely, for otter trawlers the median (7.7 kg) would only represent one or a small number of individuals. In order to focus on large hauls, a threshold has to be applied to the data, thus allowing bycatch records to be classified in a binary manner (large haul? yes/no). Doing so circumvents some of the challenges posed by the nature of this bycatch data, specifically it being continuous, zero-inflated data with a large variance (see, Appendix I). The threshold for defining a large haul was determined by plotting an accumulation curve (Figure 4.9). The threshold selected was 100 kg, as occasions greater than or equal to this threshold (n = 669, 22% of reports), accounted for ~90% of all spurdog bycatch reported by offshore netters.

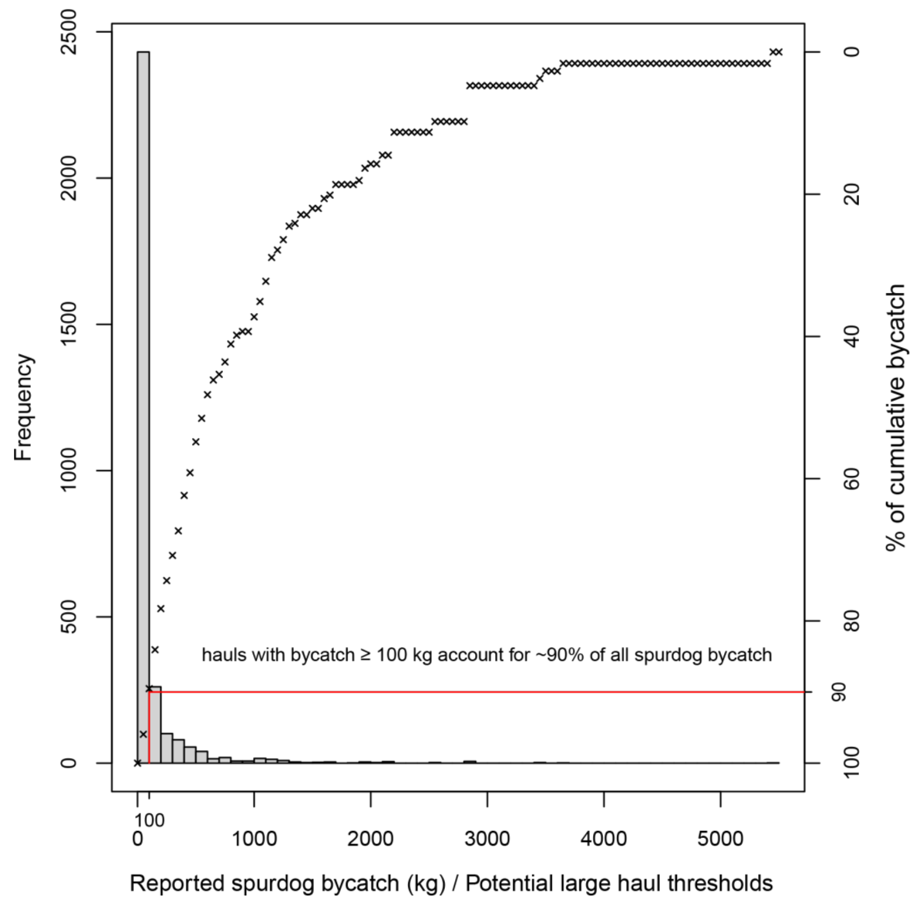

Figure 4.9 Histogram and accumulation curve for determine large haul threshold. Black 'x's indicate the percentage of the total spurdog bycatch from offshore netters that is accounted for by bycatch hauls in excess of the amount described by the x-axis.

Large haul bycatch events were modelled using a binomial generalised linear model (GLM), with large hauls as a binary response variable (spurdog bycatch; < 100kg versus ≥ 100 kg) and depth, sea surface temperature (SST) and month as explanatory variables (see, Appendix I). The model was used to produce a monthly prediction of large haul occurrences based on environmental predictors (mean monthly temperature, depth and month) at the spatial resolution of the Cefas grid (Figure 4.10). The observed spatial distribution of large hauls and the hotspots identified by the model prediction (Figure 4.10), are broadly aligned with hotspots previously identified using fishery-dependent data in the NEPTUNE project (Ellis *et al.*, 2016, Hetherington *et al.*, 2016).

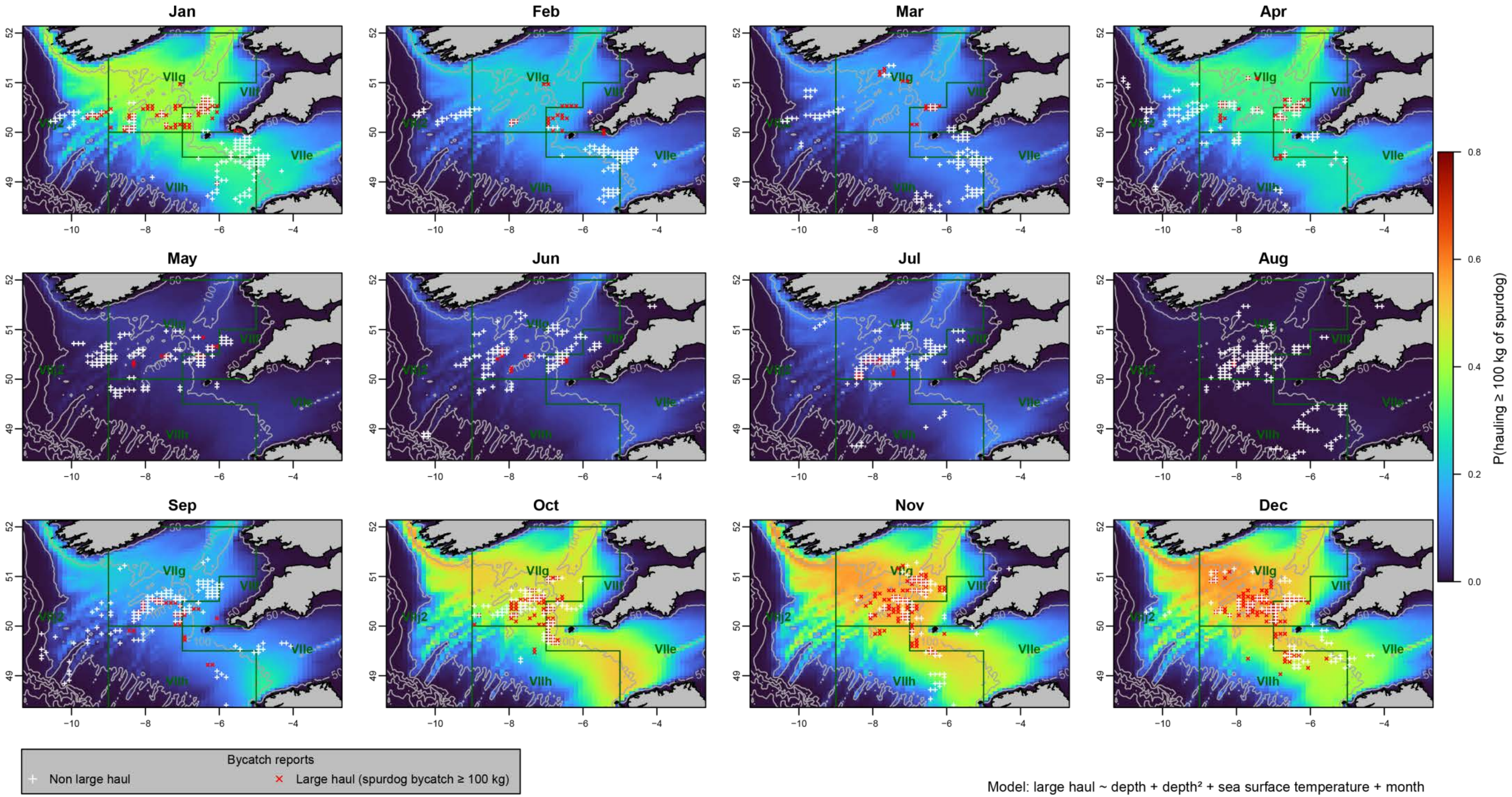

Figure 4.10 Predicted occurrence of spurdog large hauls (≥ 100 kg) in the offshore netter fishery based on environmental predictors. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

Dataset E (spurdog tagging, Chapter 6) contains 139 recaptures of tagged individuals within the area (ICES Areas 7e-j) for which the model was used to predict large haul occurrence of the (Figure 4.10). Whilst these records represent the recapture of individuals (not large haul events) they offer an opportunity to, at least partially, validate the model. The model prediction for each recapture event was obtained (based on the location and month) and compared with 12,000 spatially random samples from the model prediction surface (12 rasters, one for each month). Any random samples falling on land were excluded resulting in 10,055 random samples from the model. The distribution of prediction values from tag recoveries compared with randomly sampled locations suggests that the model is better than random at predicting the spatial occurrence of spurdog in the Celtic Sea (Figure 4.11). The model performance appears to better for male than female spurdog, though the sample size is smaller for female spurdog (n = 42).

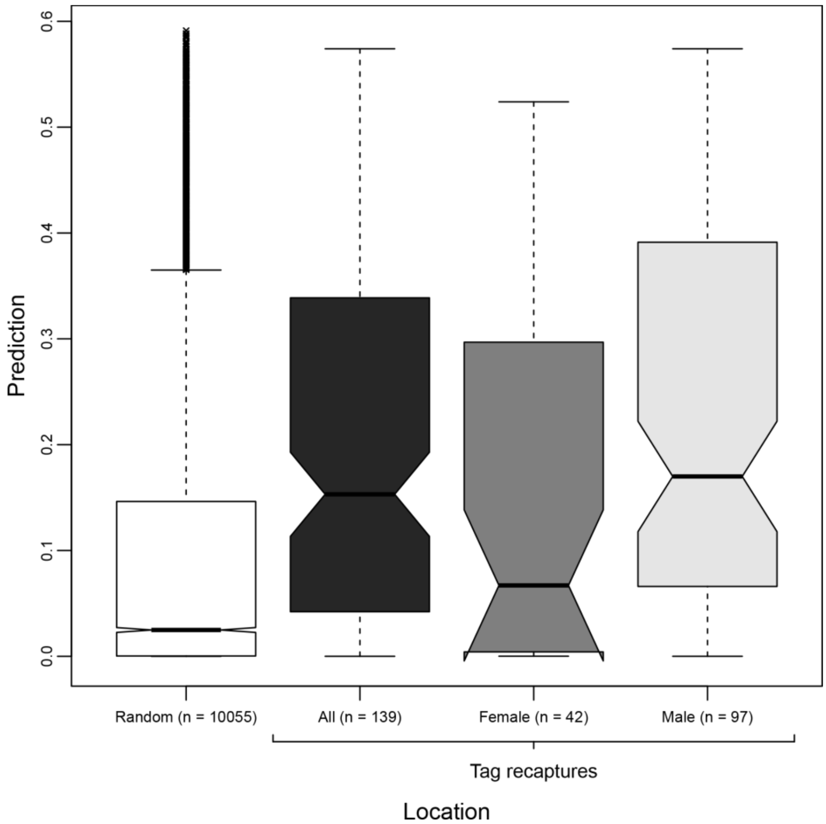

Figure 4.11 Boxplot presenting results on model validation using spurdog tag recapture data.

The environmental model can be combined with fishing effort data to predict the risk of large hauls in the study area. Risk is determined by multiplying the environmental model by fishing effort (scaled 0-1). This was performed using effort data derived from Dataset C (Figure 4.12) and using GFW effort data for gill netters (Figure 4.13). Note that, as the measures of effort are different, (number of reports per cell and the hours of fishing activity determined from AIS, respectively), the risk values in the resulting figures cannot be directly compared. Nevertheless, they provide an indication of the expected spatio-temporal variation in spurdog bycatch in two different components of the Celtic Sea fixed net fishery.

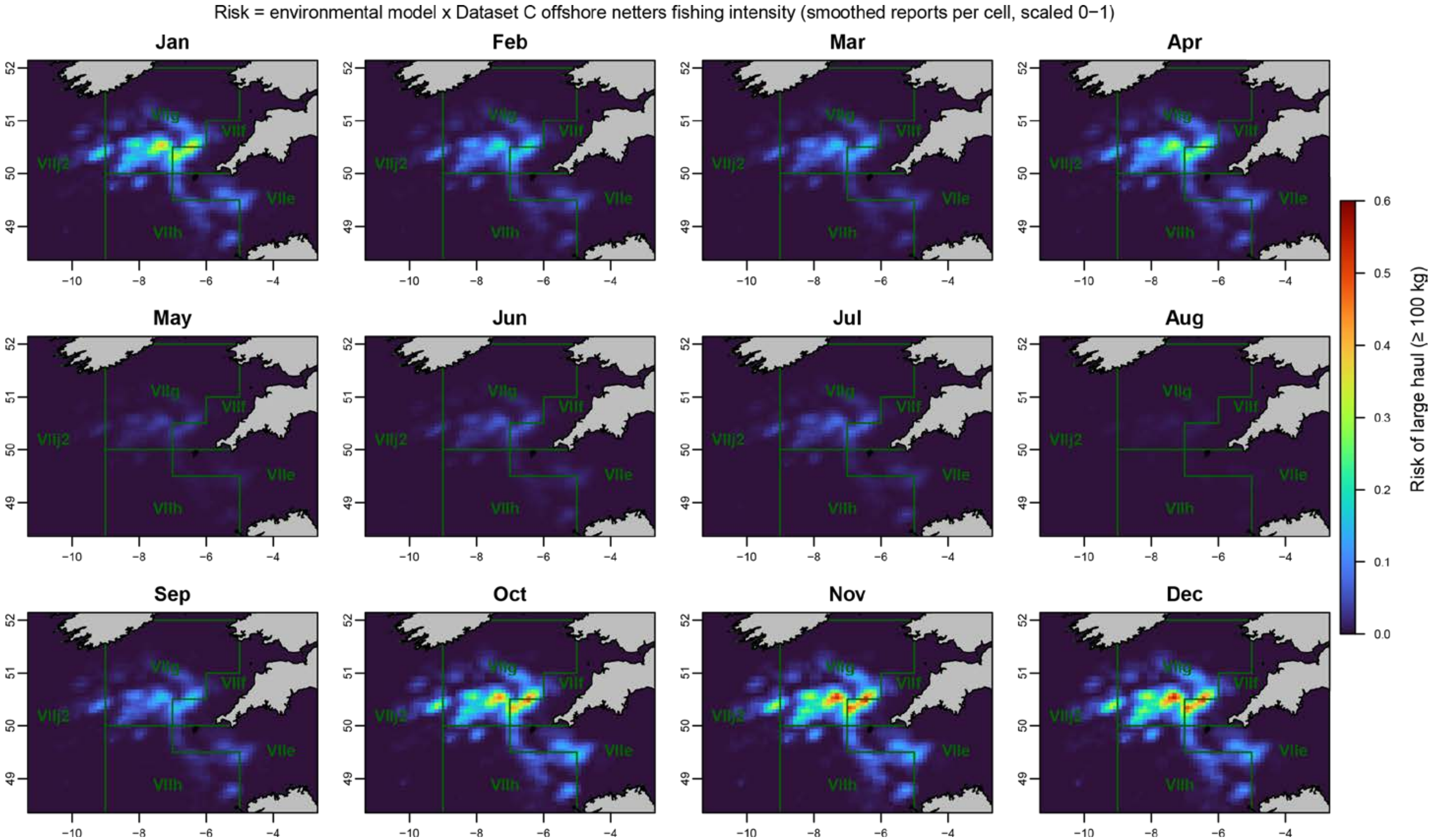

Figure 4.12 Predicted risk of the spurdog bycatch large hauls (≥ 100 kg) in the offshore netter fishery. Data: ICES areas, (ICES, 2021).

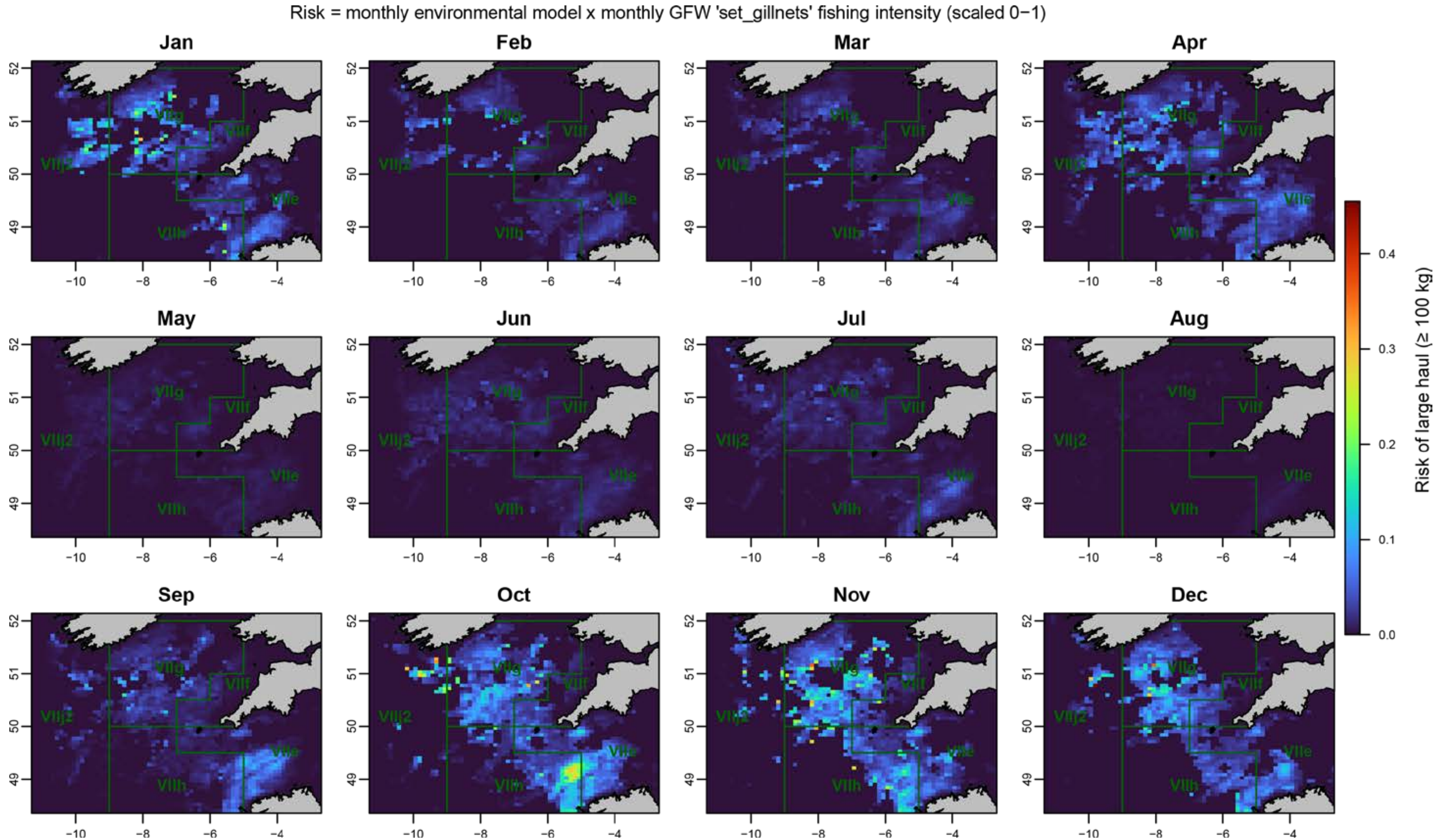

Figure 4.13 Predicted risk of spurdog bycatch large hauls (≥ 100 kg) by gill netters represented in GFW effort data (large vessel with AIS). Data: gill netter fishing effort, Global Fishing Watch (2021); ICES areas, (ICES, 2021).

Limitations

It is assumed that the vessels contributing to the dataset are representative of the wider fleet(s), in terms of their spatial behaviour and bycatch rates. However, this has not been tested here nor does this report detail the size of the sample (number of participating vessels) relative to the size of the total fleet.

Whilst the dataset includes data from three fleets (otter trawlers, inshore netters and offshore netters). The analysis has focussed on the offshore netters, this is partly because large bycatch events were more common on netter than trawlers but also because there were insufficient data to support further analysis of bycatch in the inshore netters. There are only 25 records from inshore netters, all of which report some spurdog bycatch including the largest reported bycatch event (8,900 kg spurdog). However, these records are restricted to just two months (January and December), identified elsewhere in the analysis as being peak. Thus, the bycatch of spurdog by inshore netters warrants further investigation supported by additional data, which was not possible here.

There is no effort component to this data, in terms of the gear (net dimensions) or duration of deployment (soak time), which likely varies, perhaps considerably and may therefore explain some of the variation in the bycatch data.

The limitations arising from the spatial resolution of the data should be acknowledged, specifically arising from the reporting grid. Environmental variables and GFW fishing effort used for modelling were available at higher resolution but required resampling to match the resolution of Dataset C. The temporal coverage of the data is limited, the majority of records come from just three years. If, as suggested here, large haul bycatch events are related to seasonal migrations and/or spawning aggregations then longer temporal coverage (i.e. more years of data) would yield better insights into inter-annual variation.

Whilst the model produced is informative and partially validated using the independent spurdog tagging, more sophisticated approaches may be possible, potentially supported by a growing dataset. This could include either, modelling bycatch as a continuous variable, or developing the binomial model employed here to include additional environmental variables and/or account for spatial auto-correlation in the observations.

5. Dataset D: Common skate survey

An annual Defra-funded common skate survey was undertaken from 2014–2017, inclusive, to collect field data on the abundance and distribution of the 'common skate complex' in the Celtic Sea (ICES Divisions 7e–h). The common skate complex consists of blue skate (*Dipturus batis*) and flapper skate (*Dipturus intermedius*), with the former being more common in this region and the focus of this section. Where used here, 'common skate' refers to the complex skate complex (*D. batis* complex), whilst 'blue skate' and 'flapper skate' refers to *D. batis* sensu stricto and *D. intermedius* sensu stricto, respectively, unless otherwise stated. The survey methodology, results and analysis are presented by Bendall *et al.* (2018). Relevant details are briefly summarised here. During each survey a series of stations were fished using trammel nets along a transect running southwest of the Isles of Scilly. Stations were a mixture of new locations and revisiting locations (within 3nm) from the previous year. Captured common skate were measured (total length) and their weight estimated based on Silva *et al.* (2013). Effort was the product of net length and soak time, allowing catch per unit effort (CPUE) to be expressed in terms of the number of individuals (individuals km^{-1} hour^{-1}) and biomass (kg km^{-1} hour^{-1}). Repeat stations, of which there were 14 in total are termed 'prime stations' (labelled CO 1-14).

Data exploration, analysis and interpretation

Given the longstanding taxonomic uncertainty around common skate historic records of blue skate (*D. batis*) should be considered sensu lato. Nevertheless, occurrence records for blue skate (*D. batis*) give some indication of the distribution within the British Isles (Figure 5.1). Recent studies have concluded that blue skate are predominantly found in the Western Approaches and Celtic Sea, extending out to Rockall in the northeast Atlantic (Bache-Jeffreys *et al.*, 2021), whilst the full range extends from Iceland to the Mediterranean (Frost *et al.*, 2020), with current patchy distribution being the product of fisheries-induced population declines and extirpations. The location of the Cefas common skate survey stations (Dataset D) are shown in relation to occurrence records obtained from the Ocean Biodiversity Information System (OBIS) (OBIS, 2021) (Figure 5.1). This illustrates that Dataset D only represents data from a small part of the full range of the blue skate, even within the Celtic Sea (Figure 5.1).

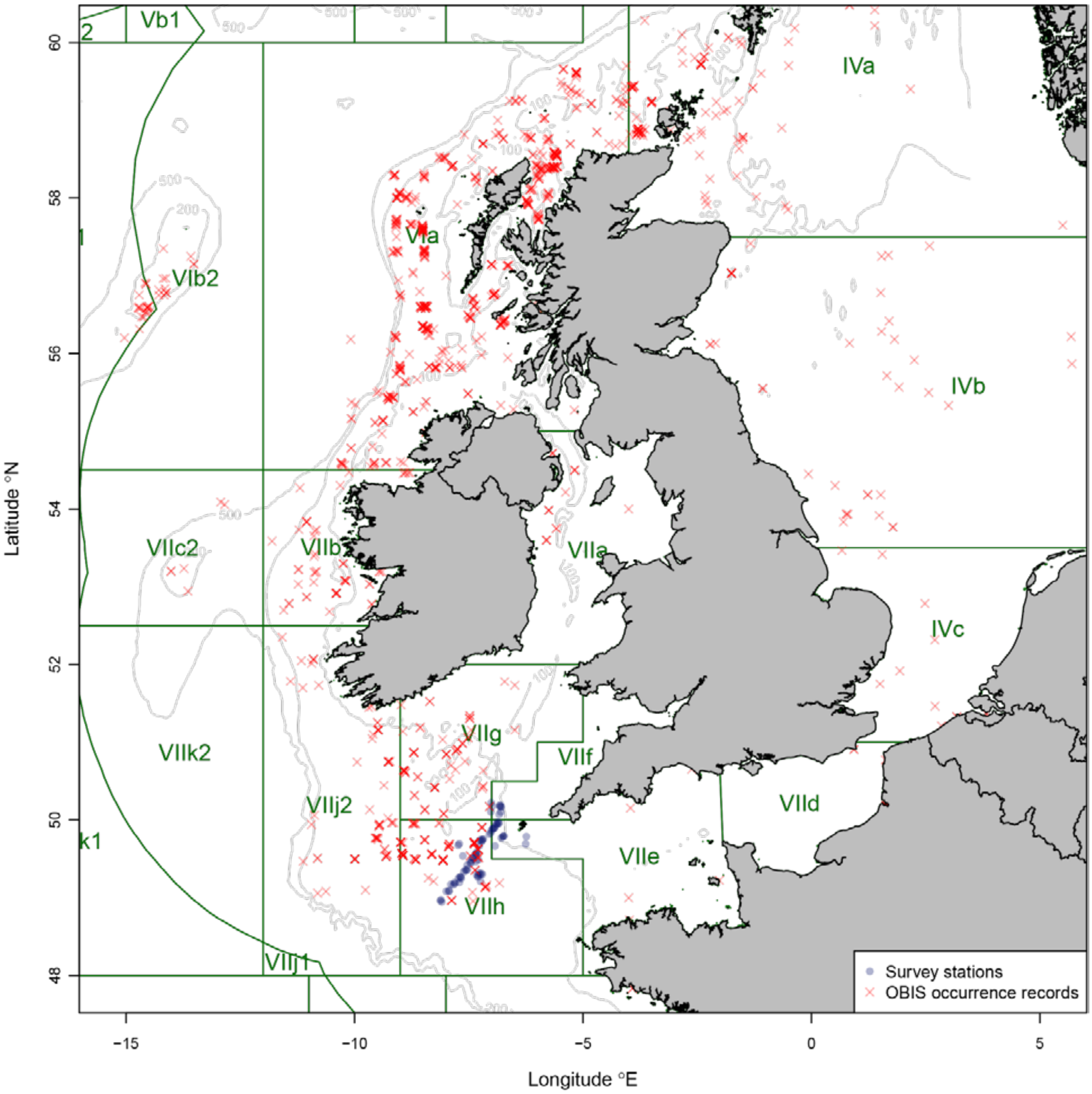

Figure 5.1 Cefas common skate survey stations shown in relation to occurrence records for blue skate (*D. batis,* sensu latu*).* Contours are drawn at 100, 200 and 500m. Data: *D. batis* occurrence records, OBIS (2021); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

Blue skate CPUE data is available for 76 stations (some of which are prime stations, repeated from the previous year) with individuals caught at all but two of these (Figure 5.2).

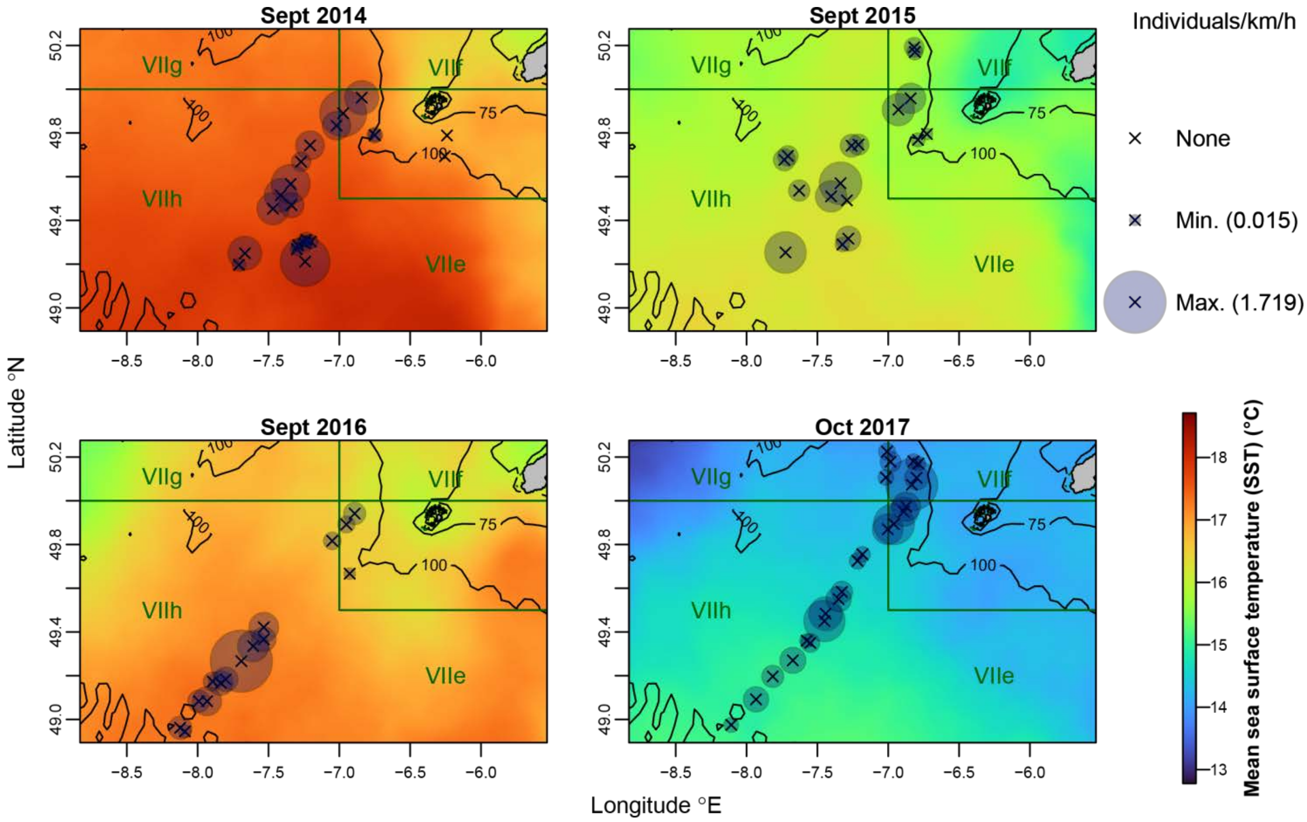

Figure 5.2 Catch per unit effort (CPUE) for blue skate (*D. batis*). The SST at the time of the survey is shown, represented by mean value for the month in which each survey was conducted. Data: SSTs, Group for High Resolution Sea Surface Temperature (GHRSST) Multi-scale Ultra-high Resolution (MUR) SST Analysis fv04.1, Global, 0.01° Monthly (JPL MUR MEaSUREs Project, 2015); bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

SST was obtained for each station (JPL MUR MEaSUREs Project, 2015). For those stations where blue skate were caught (n = 74), the range of SST was 13.4 to 18.2˚C. The SSTs fell into two groups according to the survey month (surveys in 2014 to 2016 were conducted in September with warmer SSTs; the 2017 survey was conducted in October with colder SSTs). The range of observed SST for September stations was 14.8 to 18.2 ˚C; whilst for October stations the range was 13.4 to 13.9 ˚C. Note, Figure 5.2 shows the mean SST for the month in which the survey was conducted, whilst the values reported in the text above are derived from the mean value of daily data between the shot and haul date for each individual station.

Substrate was determined at each station by sampling from the substrate raster detailed in Section 2.2.1.3. Blue skate were caught from stations with five different substrate types: Coarse substrate (n=13), Sand (n=55), Mixed sediment (n=2), Rock or other hard substrata (n=1) and Sandy mud or Muddy sand (n=1).

Limitations

The survey is spatially and temporal restricted and was not designed to support this exercise. The resulting dataset does not therefore support further modelling to identify the factors that explain the distribution and abundance of blue skate in the study region.

6. Dataset E: Spurdog tagging

Dataset E contains two types of tagging data from: i) mark ID tags (ID) which carry a unique identifier and ii) storage tags (DST), which are able to log data at regular intervals (depth, temperature and position). Mark ID and DST tagging has undertaken around the UK by Cefas. Dataset E contains all Mark ID tags and only those DST tags from the Celtic Sea region. Tag recovery was achieved either through the commercial fishery upon the capture of tagged individuals, scientific surveys or members of the public.

Data exploration, analysis and interpretation

There were a total of 13,675 mark ID tagged spurdog between 1960 and 2020, of which 1,386 were recovered (Figure 6.1). Releases were clustered in specific regions (Celtic Sea, Irish Sea, northern Scotland, southeast England), with the majority being in Scottish waters. The recoveries were more broadly distributed indicating considerable dispersal from tagging locations, with individuals recovered principally from eastern, western and northern waters of the British Isles and throughout the North Sea to the Norwegian coast. There were few recoveries in the English Channel. The most distant recoveries were in Iceland and the Norwegian Sea. The greatest density of recoveries was from waters at the north-western extremity of mainland Scotland.

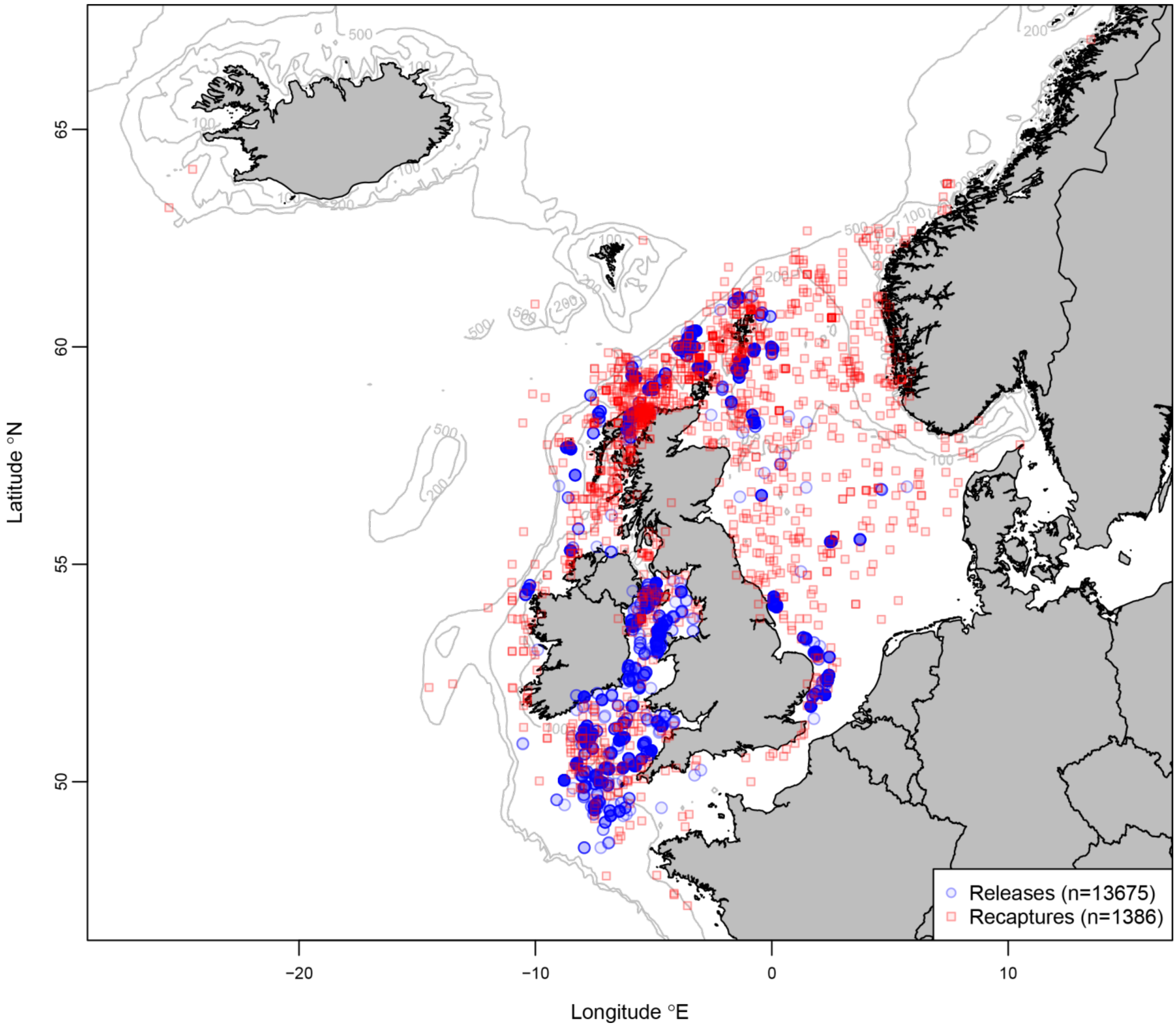

Figure 6.1 All spurdog Mark ID tag releases and recoveries, 1960-2020. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

The majority of the releases of spurdog (9,675 of 13,675) occurred in the 1960s and accordingly the majority of recaptures (1,049 of 1,386) were prior to 1975. These earlier data have been previously analysed by Holden (1965) and Vince (1991). Whilst the former study identified geographically distant stocks (termed ‘Scottish-Norwegian’ and ‘Channel’), the latter with the benefit of data from individuals with greater periods at liberty, suggests movement occurs throughout the continental shelf of north-western Europe.

Depth was obtained from a bathymetry raster at the recapture locations. The median depth at recapture locations was 93.7 m (interquartile range: 65.2 – 122.0 m). There were no clear differences in depth at recapture locations by sex or month.

Kernel density estimation highlights hotspots of spurdog recapture in the study area (Figure 6.2), though these may be related to fishing effort to some extent, see limitations discussed below.

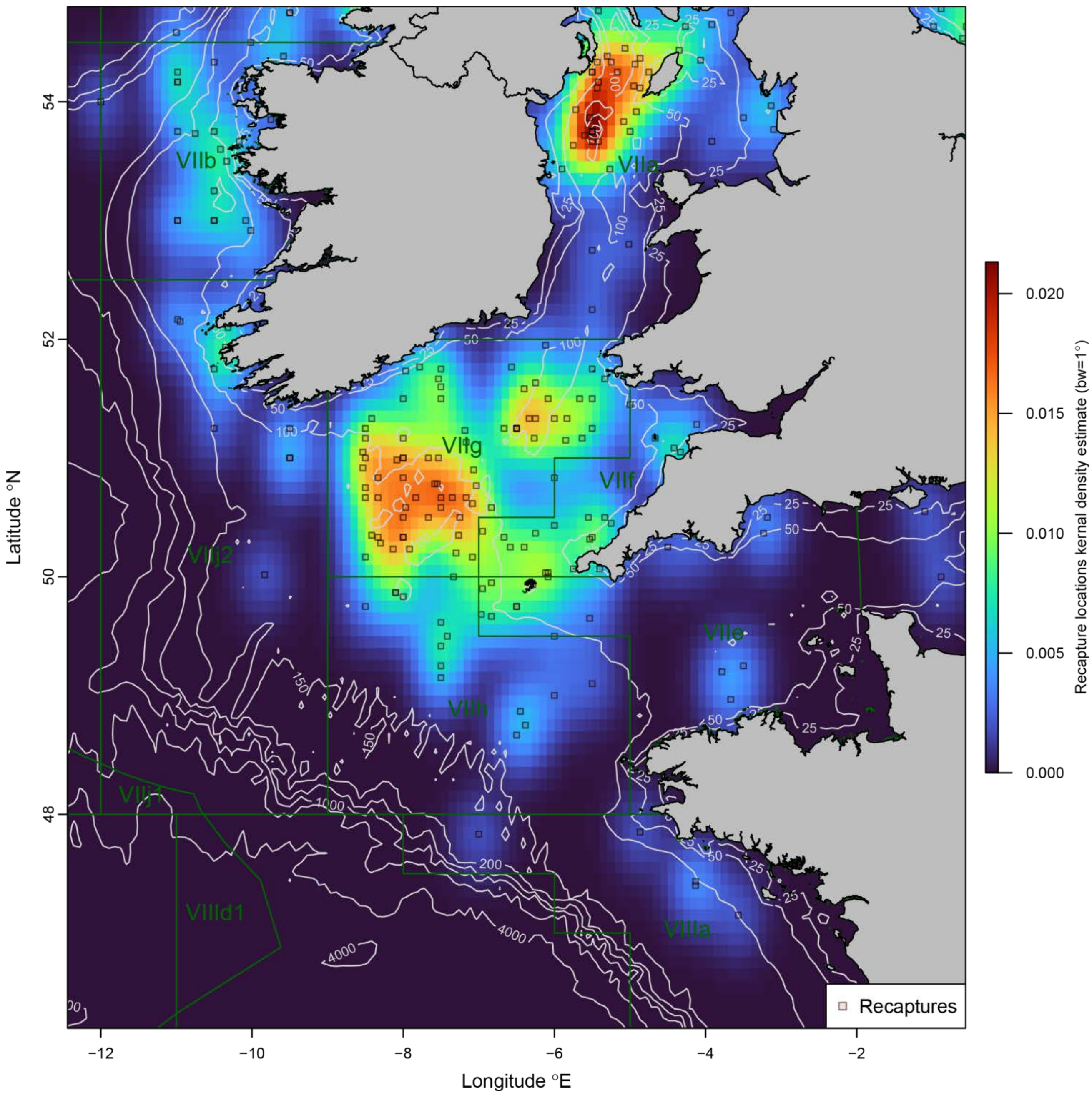

Figure 6.2 Map showing Mark ID tagged spurdog recapture locations in the Celtic Sea and adjacent waters with kernel density estimate. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

DST tag data were available from 18 recovered individuals, which had all been released in ICES Areas VII f-h from 2010 to 2014 (plotted collectively, Figure 6.3; plotted individually). The time at liberty ranged from 6 to 446 days (though only one individual was at liberty for longer than a year). The mean period at liberty was 150 days (± sd 130). For the recaptured DST tags, the majority of releases had been in September (Sept, n=7; Dec, n=5; Aug, n=3; Mar, n=2; Oct, n=1). Accordingly the distribution of the number of tag locations is not even across the months in the year.

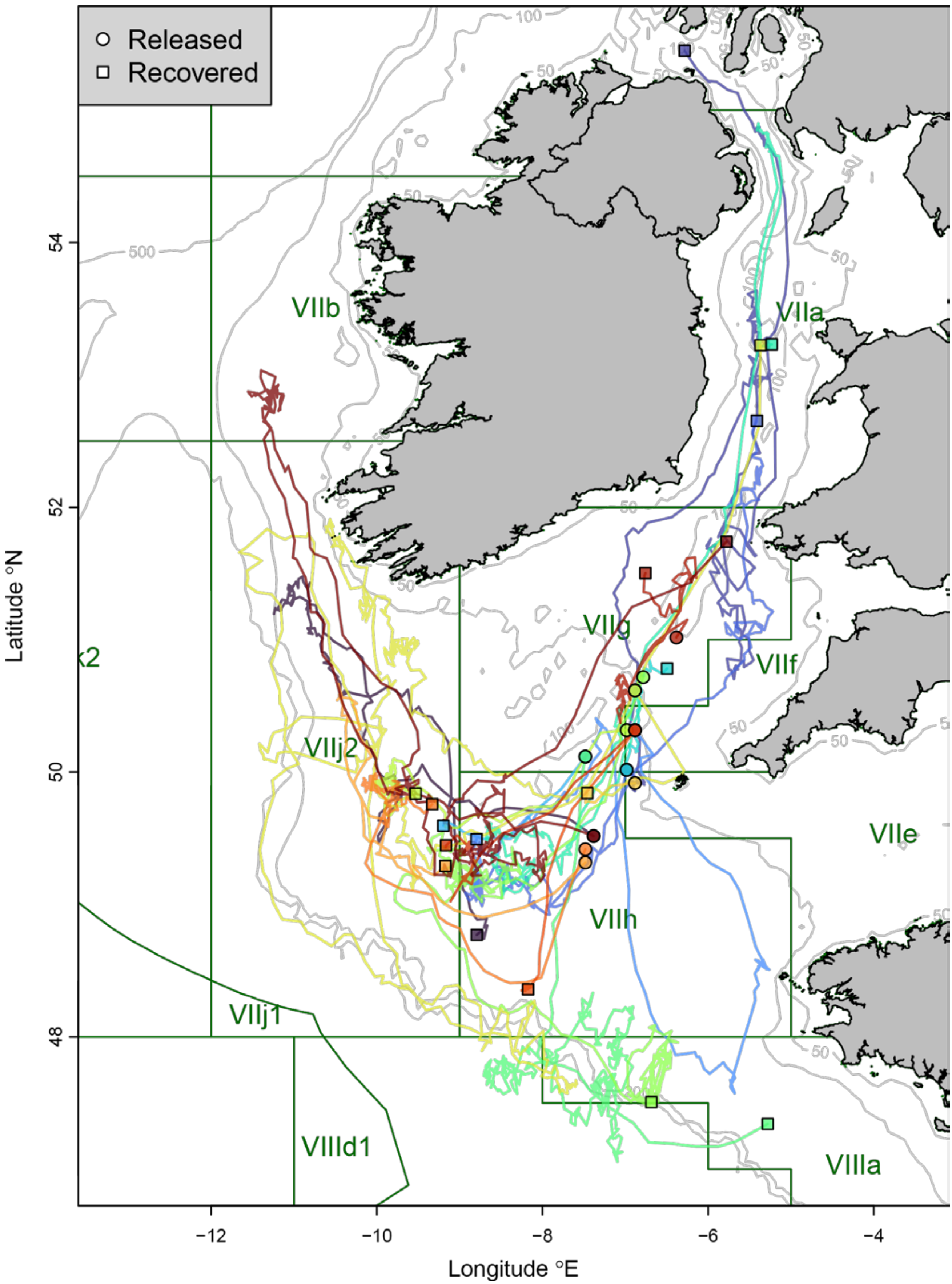

Figure 6.3 Spurdog DST tag tracks showing release and recovery locations. Depth contours are drawn at 50, 100, 200 and 500m. Data: bathymetry, EMODNet (2021a) ICES areas, (ICES, 2021).

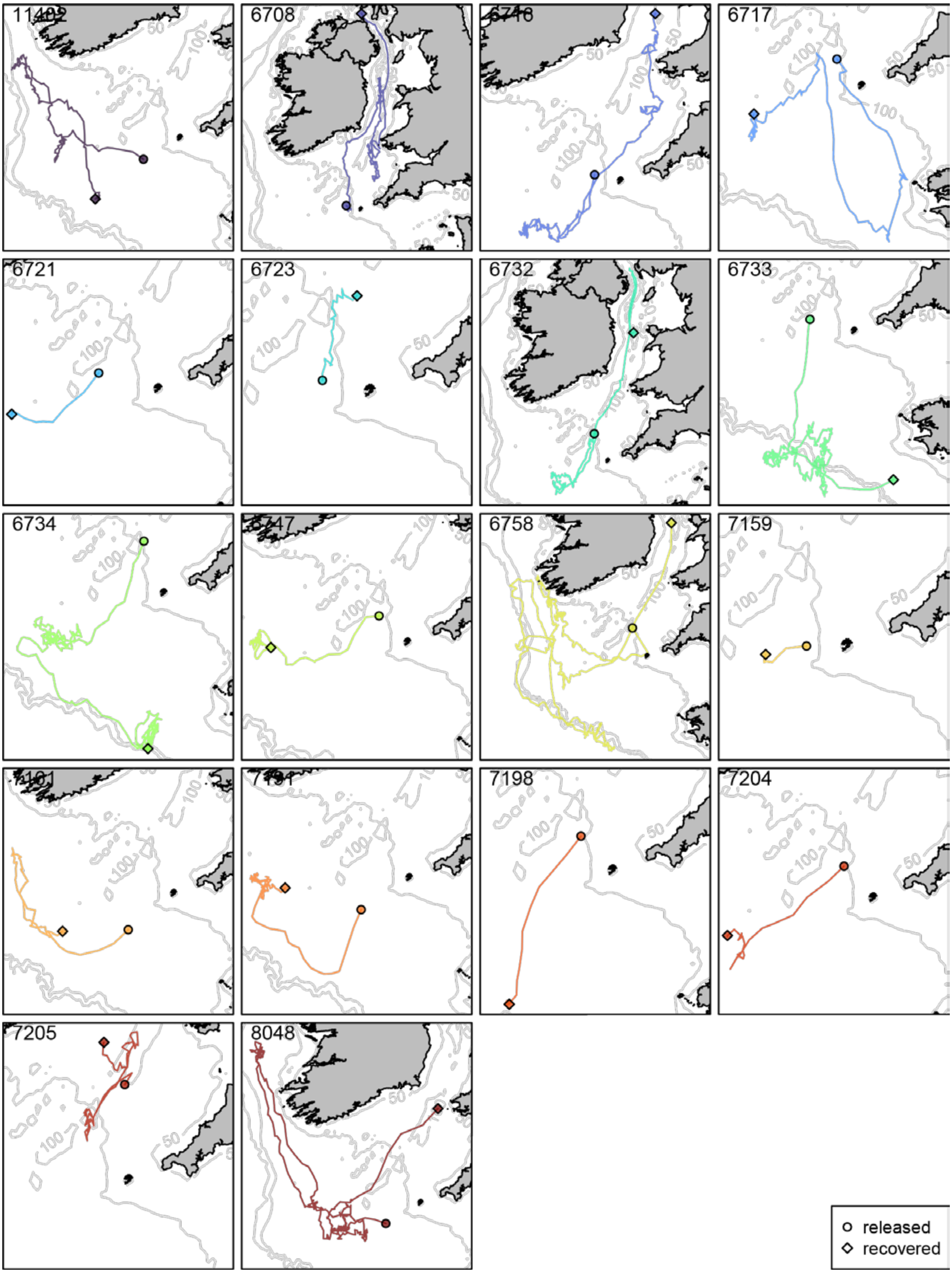

Figure 6.4 Individual spurdog DST tag tracks showing release and recovery locations. Depth contours are drawn at 50, 100, 200 and 500m. Data: bathymetry, EMODNet (2021a) ICES areas, (ICES, 2021).

The DST tags logs depth at 10 minute intervals (Hetherington *et al.*, 2018), the dataset provided gives daily minimum and maximum depths. The minimum recorded depth was 0.1 m, with the mean of daily minimums being 53.4 m (± sd 36.5). The maximum recorded depth was 337.4 m, with the mean of daily maximums being 131.6 m (± sd 51.1). The mean of the difference between daily minimum and maximum was 79.2 m (± sd 43.1), suggesting significant daily vertical movement. For each daily location the bathymetry raster was sampled to estimate the water depth at that location. The maximum depth was 4,247.9 m, suggesting that some individuals move off the continental shelf (whilst remaining in the epipelagic zone), which is seen in some tracks (Figure 6.3). The difference between the maximum daily depth logged by the DST tag and water depth (estimated from the bathymetric raster) was typically small (i.e within the range of error associated with estimating the seafloor depth at the tag location), suggesting the individuals are utilising benthic habitats on a daily basis.

The tracks show a broadly similar spatial pattern to that observed from the mark ID tags. Although, eight of the individuals were recovered from a similar area around the boundary of ICES Areas VIIj and VIIh (Figure 6.3), which did not appear as a hotspot in the mark ID tagging data (Figure 6.2). There is considerable variation in movement between individuals (Figure 6.4). Whilst some remain in the Celtic Sea, others undertake significant movements including: north through the Irish Sea (e.g. Tag ID 6732), north around the west coast of Ireland (e.g. Tag ID 8048), and south in deeper waters over the continental shelf (e.g. Tag ID 6733) (Figure 6.4).

Considered together, the mark ID and DST tag data show spurdog to be highly mobile, preferring to utilise waters at depths of ~50 to 200m. The Irish Sea appears to be an important route for dispersal/migrations connecting hotpsots in the Celtic Sea with those in Scottish waters. Given the highly mobile nature of this species, with individuals travelling over a wide area (e.g. Figure 6.3), spatial management measures are most likely to be effective where they are targeted at areas where aggregations are known to occur.

Limitations

There are strong biases in the temporal and spatial distribution of mark ID releases, the majority being in Scottish waters and in the 1960s. Since the 1960s, important climatic changes have taken place the region. Further the distribution of fishing effort, which determines recoveries, is not accounted for. Thus as noted elsewhere, the spatial (and temporal trends) observed in the recaptures, may be partly a product of variation in fishing effort, with the majority of recaptures being from Scottish and Norwegian waters in which major fisheries operated in the period during which most recaptures occurred (Pawson and Ellis, 2005). Given the relatively small number of recaptures and the unknown variation in fishing effort in time and space, the dataset did not support further exploration in terms of variation between seasons and sexes.

The number of DST tags (n=18) is relatively small, with the releases clustered in time and space.

7. Dataset F: Common skate tagging

Dataset F contains two types of tagging data from: i) mark ID tags (ID) which carry a unique identifier and ii) storage tags (DST), which are able to log data at regular intervals (depth, temperature and position). Mark ID tags were deployed between 1959 and 2020. Those DST tagged individuals, for which the tag was recovered, were deployed 2011 to 2016. Tag recovery was achieved either through the commercial fishery upon the capture of tagged skate or through beach recovery by members of the public following tag shedding, either naturally or via the pop-off mechanism.

Data exploration, analysis and interpretation

There were 2,717 releases of mark ID tagged common skate. The large majority of releases (and all recaptures, n=52) were in the south-west region of the British Isles (Figure 7.1). The releases in the Celtic Sea are predominantly from the Common Skate Survey (see, Chapter 5), and so lie along a sampling transect running southwest of the Isles of Scilly. The 52 individuals recaptured in the south-west are shown with a line joining the release and recapture locations (Figure 7.2). Depth was obtained from a bathymetry raster at the recapture locations. The mean depth at recapture locations was 110.4 m (± sd 35.8).

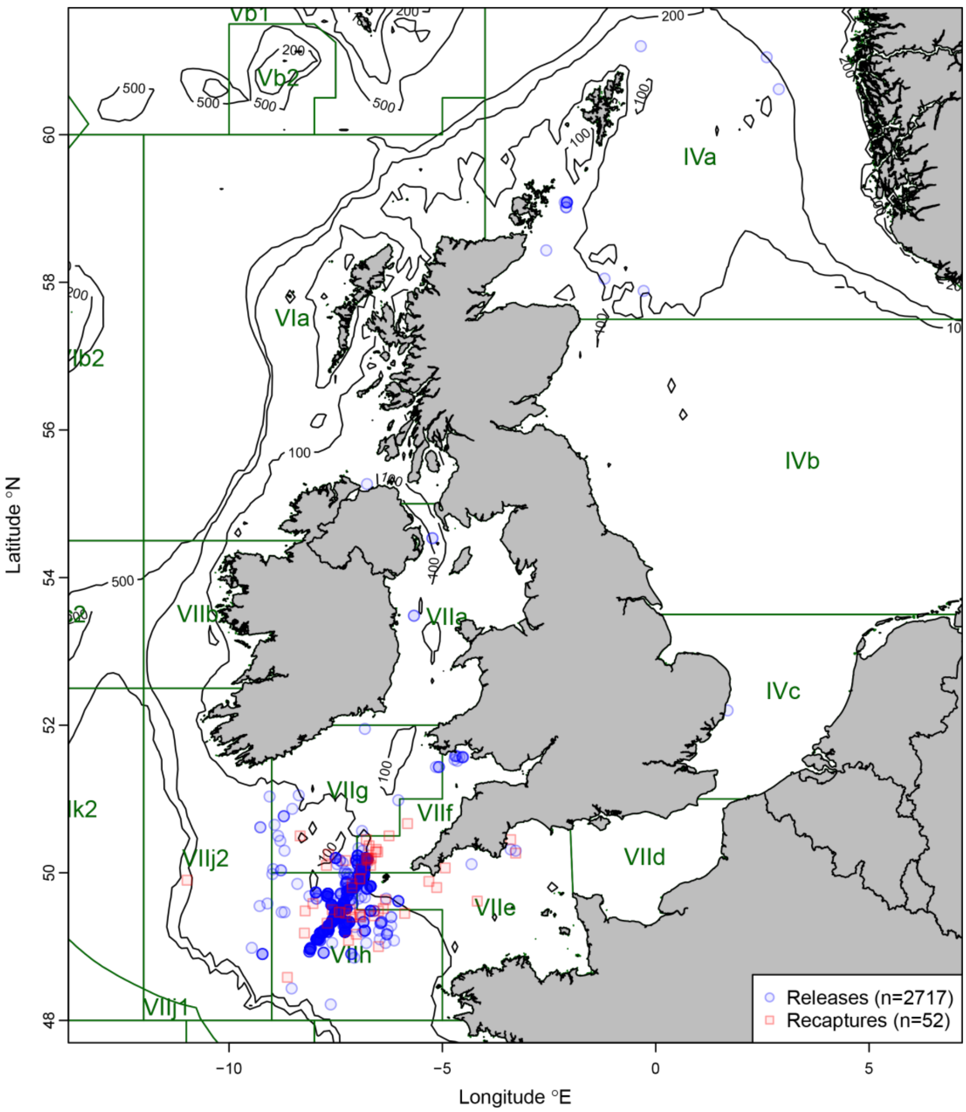

Figure 7.1 Release and recapture locations of all tagged common skate (*D.batis* complex). Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

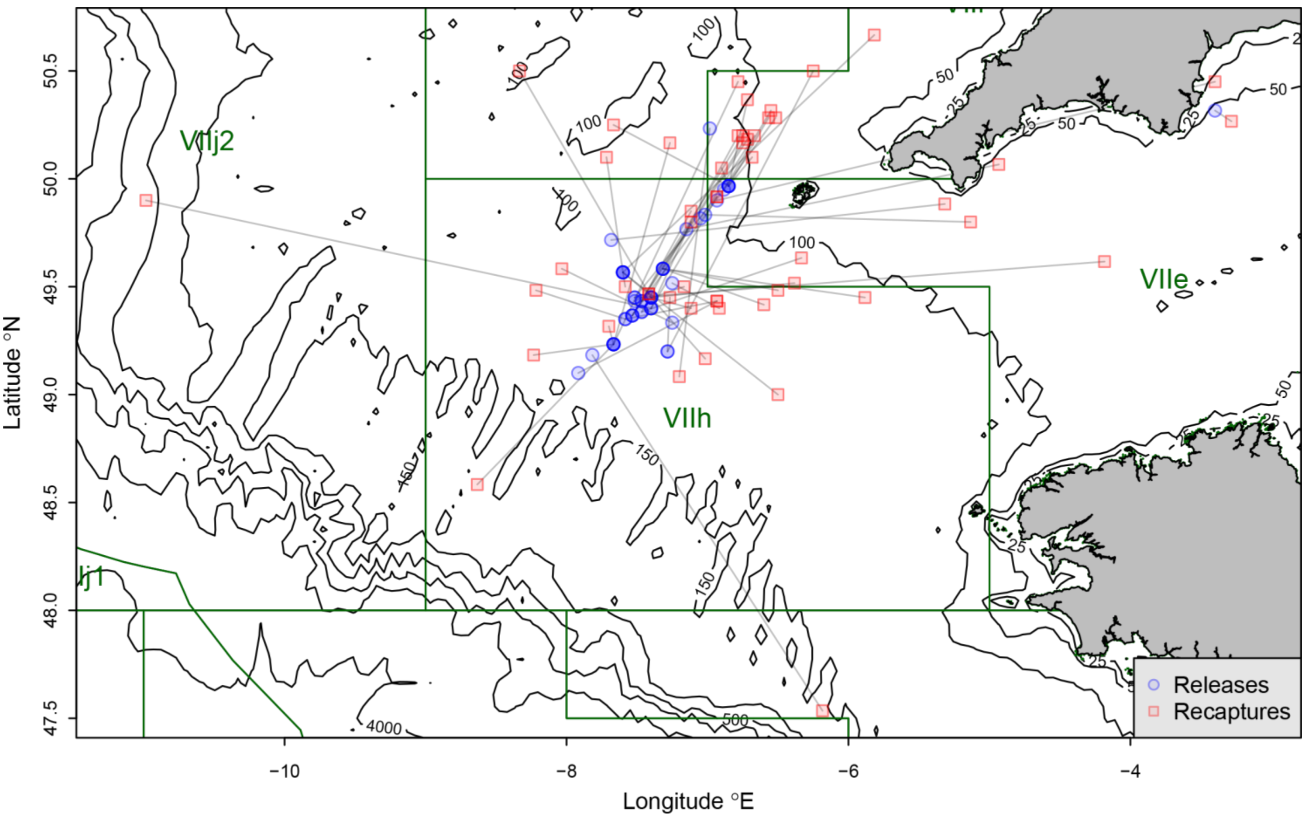

Figure 7.2 Release and recapture locations, joined by a line, of tagged common skate (*D. batis* complex; n=52) in the study region. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

DST tag data were available from 18 recovered individuals. Two of these were excluded from subsequent analyses as they were released and recovered in Scotland, with tracks that do not enter the study area. There was an error in the extraction of positional data for one tag (Tag #: 11498) (V. Bendall, pers. comm.), so this was also excluded from subsequent analyses. The combined tracks of the remaining 15 individuals is shown in Figure 7.3. The time at liberty ranged from 33 to 460 days, with the mean period at liberty being 224 days (± sd 133). Of the recaptured DST tags, the majority of releases were in September (Sept, n=14; Aug, n=1). Accordingly the distribution of the number of tag locations is not even across the months in the year, with the greatest number of locations from autumn/winter months and the fewest from summer months. Examination of individual tracks highlights the apparent importance of the inshore waters of the Isles of Scillies which are utilised by 11 of the 15 individuals (Figure 7.4).

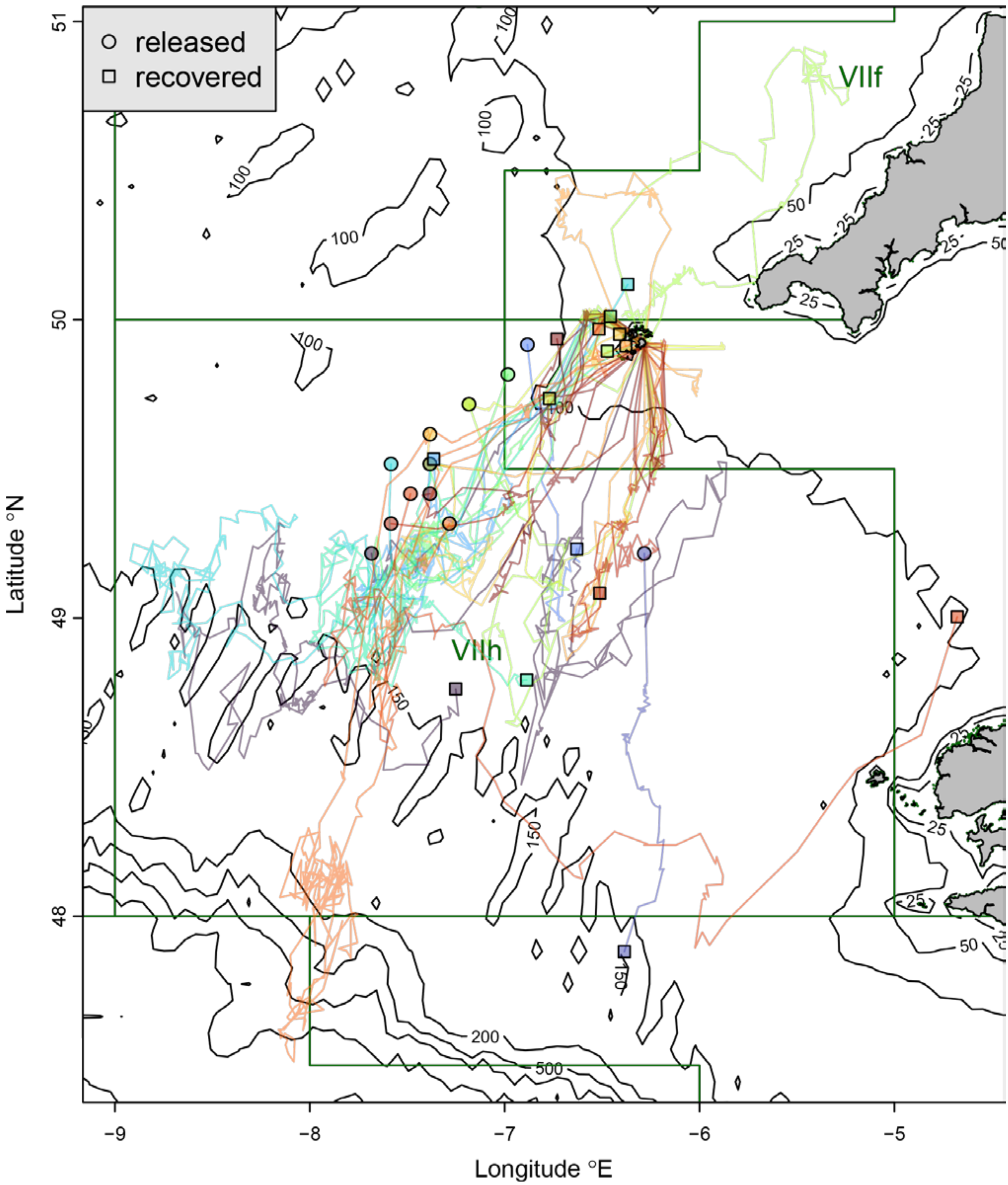

Figure 7.3 DST tag tracks for common skate (*D. batis* complex; n=15). Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

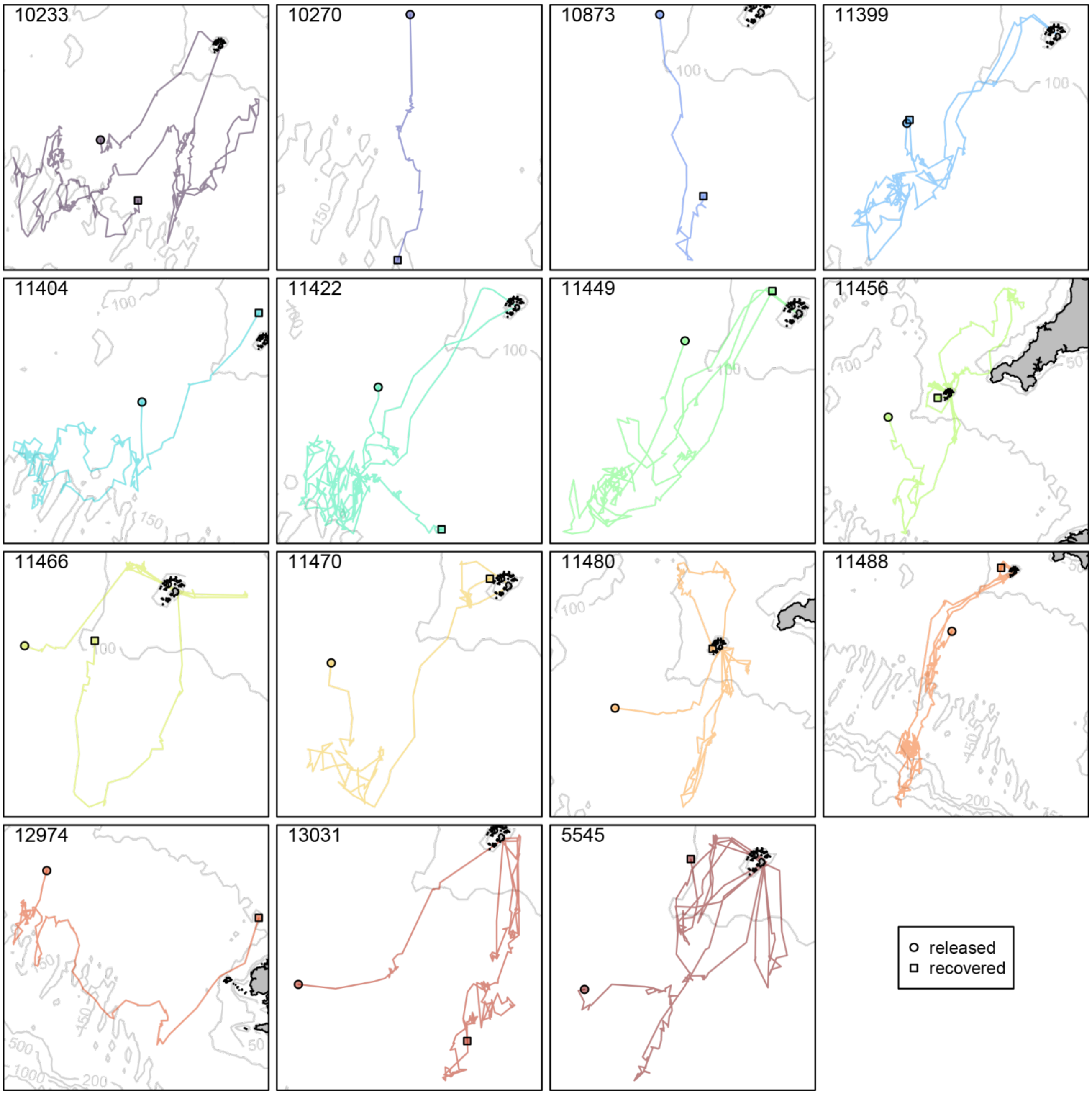

Figure 7.4 DST tag tracks for common skate (*D. batis*, complex; n=15) plotted individually. Data: bathymetry, EMODNet (2021a); ICES areas, (ICES, 2021).

Limitations

The number of DST tags (n=16) is relatively small, with the releases clustered in time and space.

8. Dataset G: Common skate bycatch observer data

Dataset G is derived from on-board observers on French fishing vessels. It was identified as a potential dataset for use in this study. However, the data were not obtained in time to be included. Given that there is limited data on the distribution and abundance of common skate there is value in pursuing this in future studies.

9. Dataset H: Cetacean bycatch strandings

Dataset H is an extract from the Cetacean Strandings Investigation Programme (CSIP) strandings database. The dataset contains all stranding records from the south-west UK from 1990 to 2019, inclusive. For a subset of these strandings, a necropsy is undertaken and the probable cause of death is determined using a standardised methodology. Although the CSIP also receive occasional reports of dead or entangled animals at sea, the vast majority of received reports are strandings on the southwest coastline of the UK.

Data exploration and analysis

The dataset contains 5,886 records of strandings in the study area, of which 1,293 were necropsied to identify the cause of death (Figure 9.1). In total, bycatch was determined to be the cause of death for 39.8% of necropsied standings. Dataset A (Section 3) confirms cetacean bycatch events do occur in the study region. The proportion of strandings attributed to bycatch is greater in the winter months (November to April), accounting for the majority of strandings from January to March inclusive.

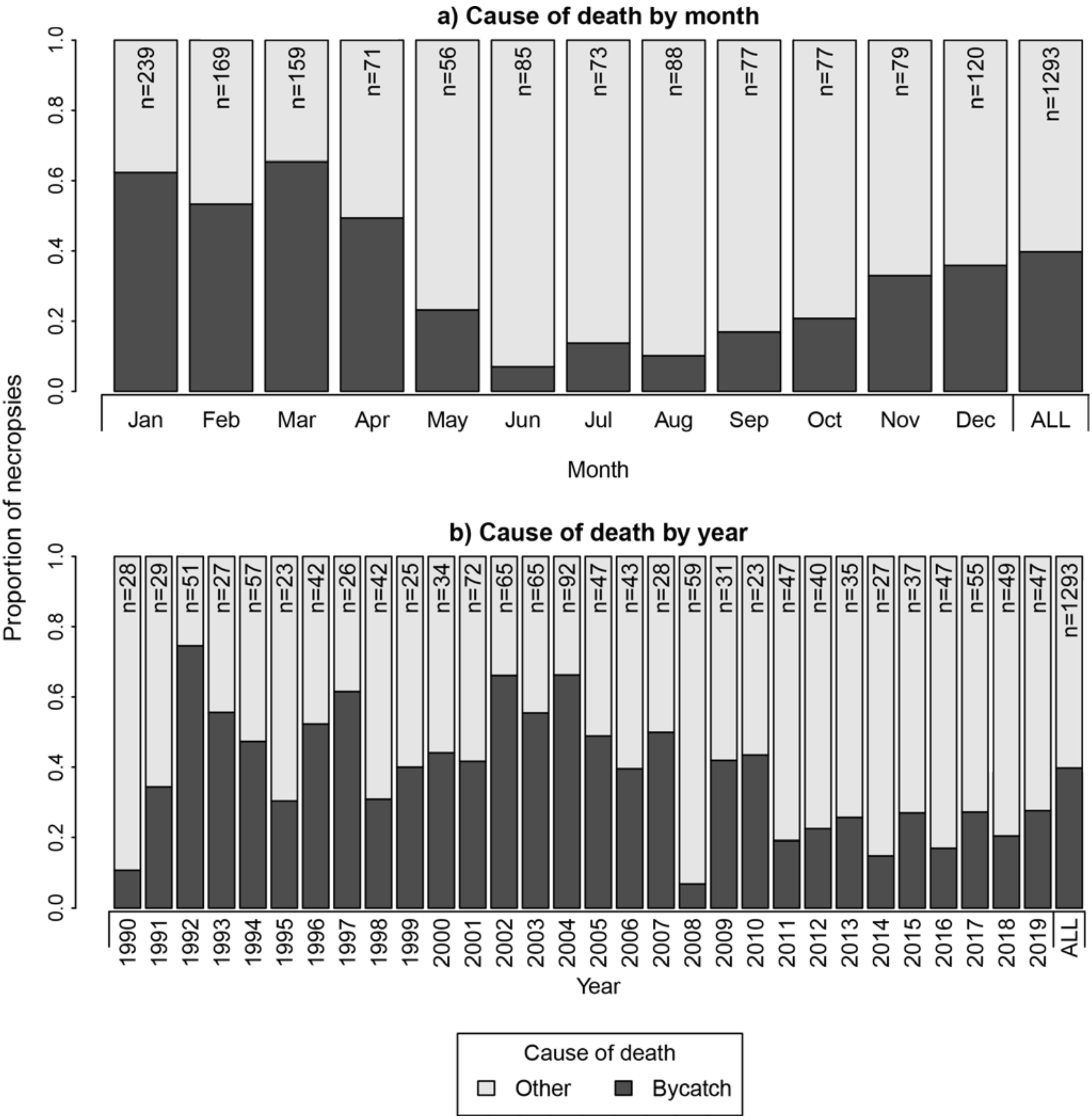

Figure 9.1 Cause of death for all necropsied cetacean strandings in southwest UK, 1990 to 2019. The sample size is detailed at the top of each bar.

Necropsies where bycatch was identified as the cause of death (n = 514) consisted of a total of eight species, which are all UK Biodiversity Action Plan (BAP) priority species. Short-beaked common dolphins (*Delphinus delphis*) and harbour porpoises (*Phocoena phocoena*) accounted for the vast majority of records (Table 9.1). These were also the only two cetacean species for which there were bycatch records in Dataset A (Section 3). For three of the species (*D. delphis, P. phocoena and Stenella coeruleoalba*), there were records of multiple strandings (two or more individuals found at the same location and time).

Table 9.1 Summary of cetacean bycatch strandings by species. Cetacean bycatch strandings in south-west UK between 1990-2019, inclusive.

Name	Scientific name	IUCN Red list status	UK BAP priority species	Number of records	Includes multiple strandings?
Delphinus delphis	Short-beaked common dolphin	Least concern	Yes	328	Yes
Globicephala melas	Long-finned pilot whale	Least concern	Yes	1	No
Grampus griseus	Risso's dolphin	Least concern	Yes	2	No
Lagenorhynchus acutus	Atlantic white-sided dolphin	Least concern	Yes	1	No
Lagenorhynchus albirostris	White-beaked dolphin	Least concern	Yes	2	No
Phocoena phocoena	Harbour porpoise	Least concern	Yes	171	Yes
Stenella coeruleoalba	Striped dolphin	Least concern	Yes	8	Yes
Tursiops truncatus	Common bottlenose dolphin	Least concern	Yes	1	No
All				**514**	Yes

The number of records of bycatch standings of *D. delphis and P. phocoena* are presented by month and year (Figure 9.2). For *P. phocoena* the maximum number of bycatch strandings in any year was 28 (2004) and minimum is zero (1992, 2018 and 2019). For *D. delphis* the maximum number of bycatch strandings in any year was 38 (1992) and minimum is zero (1990 and 2014). Care should be taken in interpreting the absolute number of bycatch strandings as the capacity of CSIP to undertake necropsies is not consistent through this period.

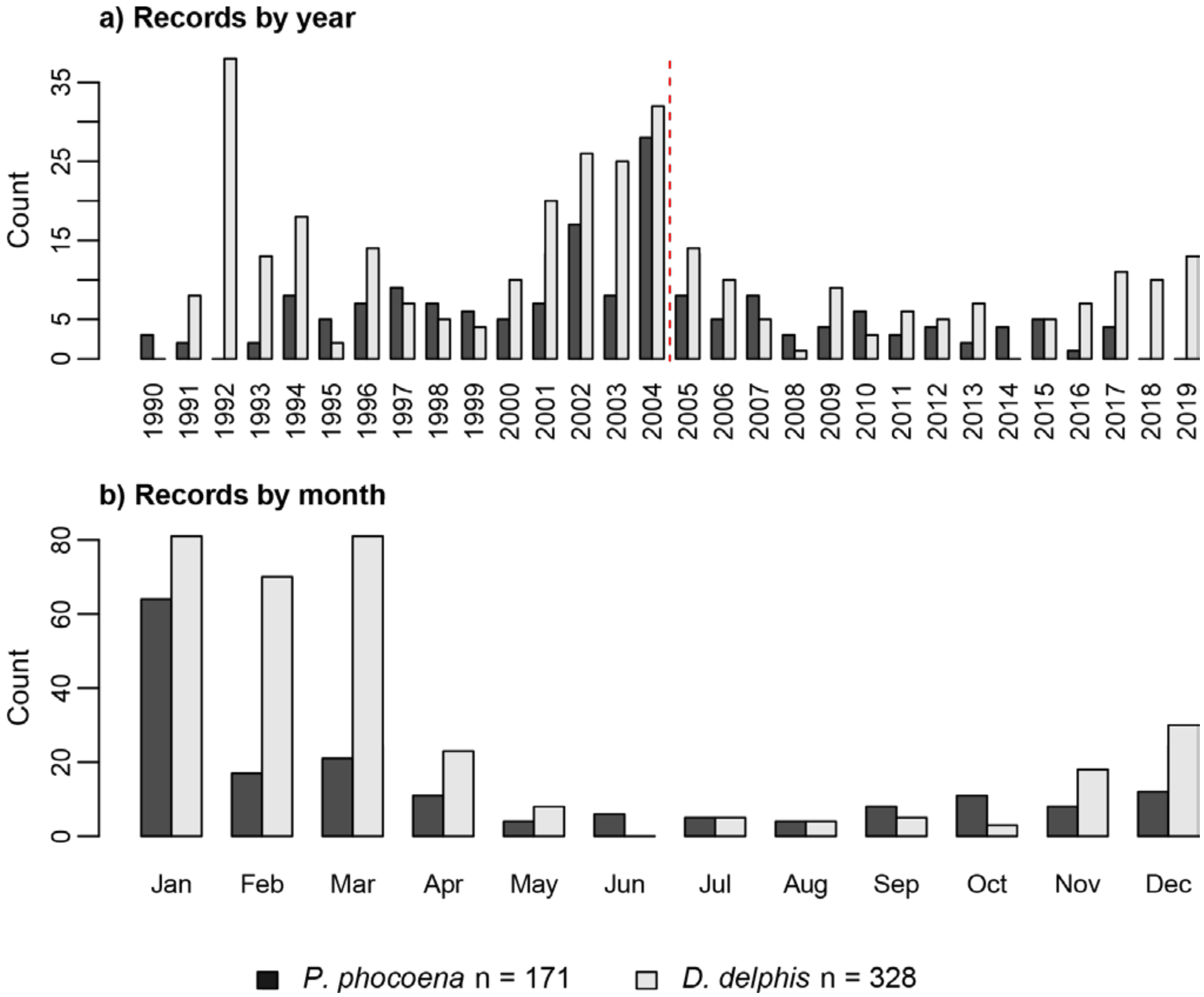

Figure 9.2 Number of records of bycatch induced strandings for harbour porpoise (*P. phocoena*) and common dolphin (*D. delphis*). The introduction in December 2004 of a ban on pelagic pair-trawling for bass within 12 nm by UK vessels in southwest England (The South-West Territorial Waters (Prohibition of Pair Trawling) Order 2004) is indicated (red dashed line).

The proportion of necropsied strandings where bycatch is the cause of death is presented by month and year for *P. phocoena* (Figure 9.3) and *D. delphis* (Figure 9.4). Bycatch was found to be the cause of death in 33.5% of *P. phocoena* and 50.3% of *D. delphis* strandings.

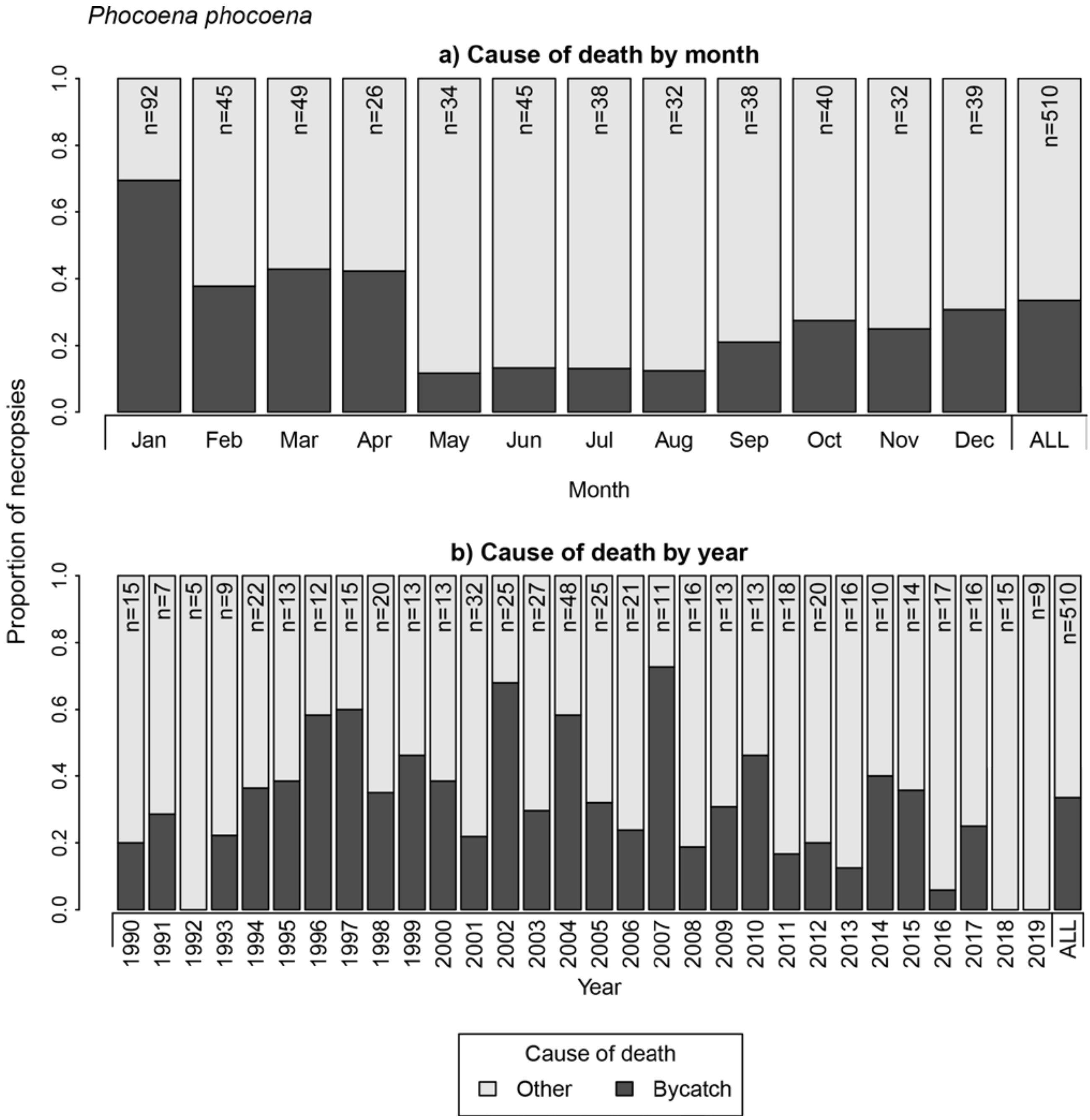

Figure 9.3 Cause of death for all necropsied Harbour porpoise (*P. phocoena*) strandings in southwest UK, 1990 to 2019. The sample size is detailed at the top of each bar.

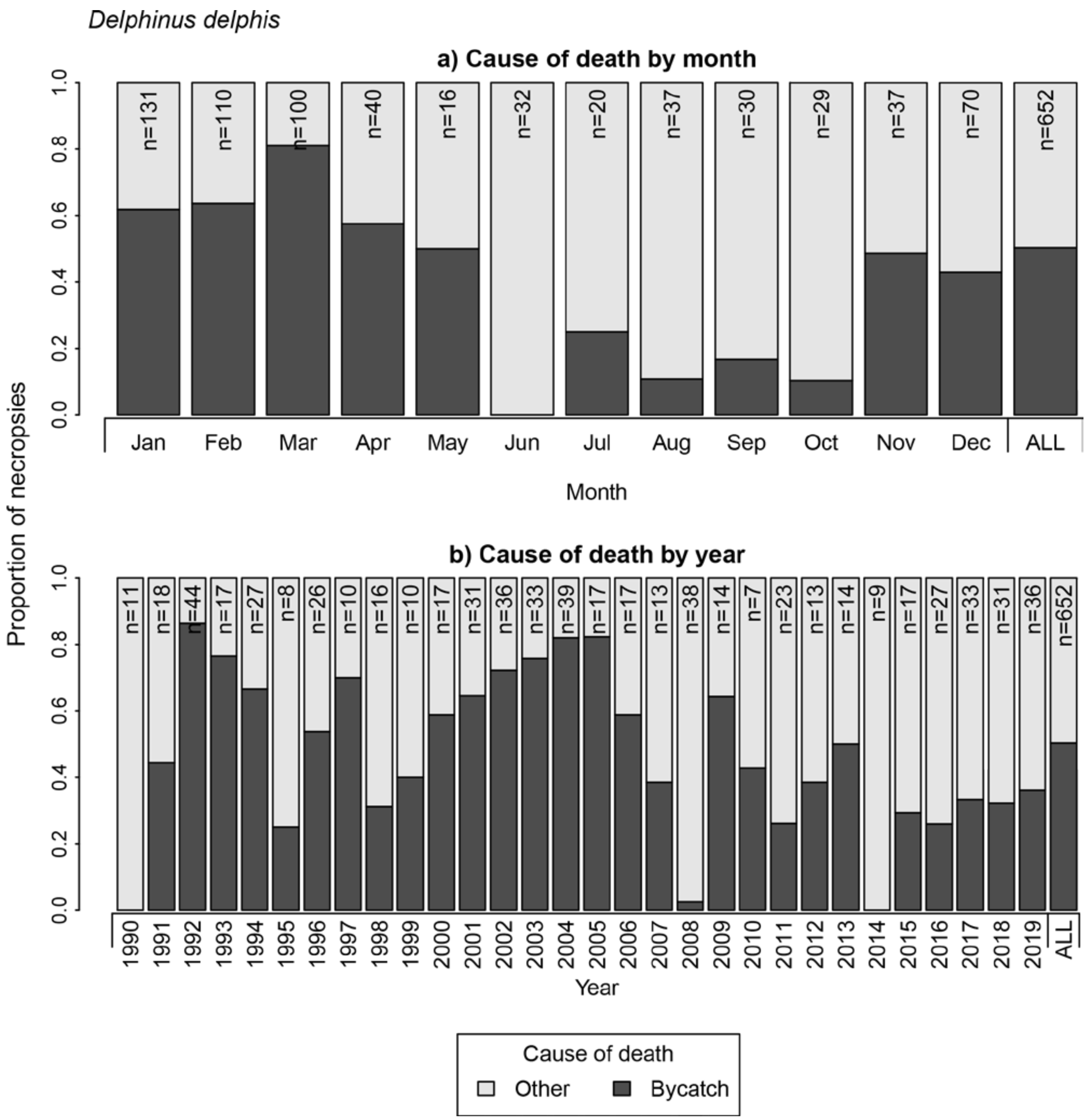

Figure 9.4 Cause of death for all necropsied common dolphin (*D. delphis*) strandings in southwest UK, 1990 to 2019. The sample size is detailed at the top of each bar.

Some of the highest proportion of *D. delphis* strandings attributable to bycatch were observed in the period 2001 to 2004. In December 2004, a ban on pelagic pair-trawling for bass within 12 nm was introduced in southwest England (The South-West Territorial Waters (Prohibition of Pair Trawling) Order 2004), in order to reduce bycatch of small cetaceans. This only applied to UK vessels, vessels from several other European Union states continued to employ pair-trawls in these waters. It is interesting to note that the proportion of strandings attributable to bycatch in years subsequent to the pair trawling prohibiton does not exceed the proportions observed prior to the prohibition.

For both species there was clear seasonal pattern, with a peak in bycatch-induced strandings in winter months, which has been previously identified in the literature (Leeney *et al.*, 2008, Pikesley *et al.*, 2012).. In *P. phocoena* the peak was January, whilst in *D. delphis* the peak months were January to March, inclusive.

The lowest number of records of bycatch-induced strandings for both species were observed in the summer months (May to September, inclusive). The observed temporal pattern of *D. delphis* bycatch is broadly aligned with that of multi-species bycatch self-reporting data (Dataset A, see Section 3), where the majority of bycatch events were outside of the summer months. However, this seasonality may be changing, in the past decade (2010s) a greater proportion of records for both species occurred outside of the peak months identified above (Figure 9.5).

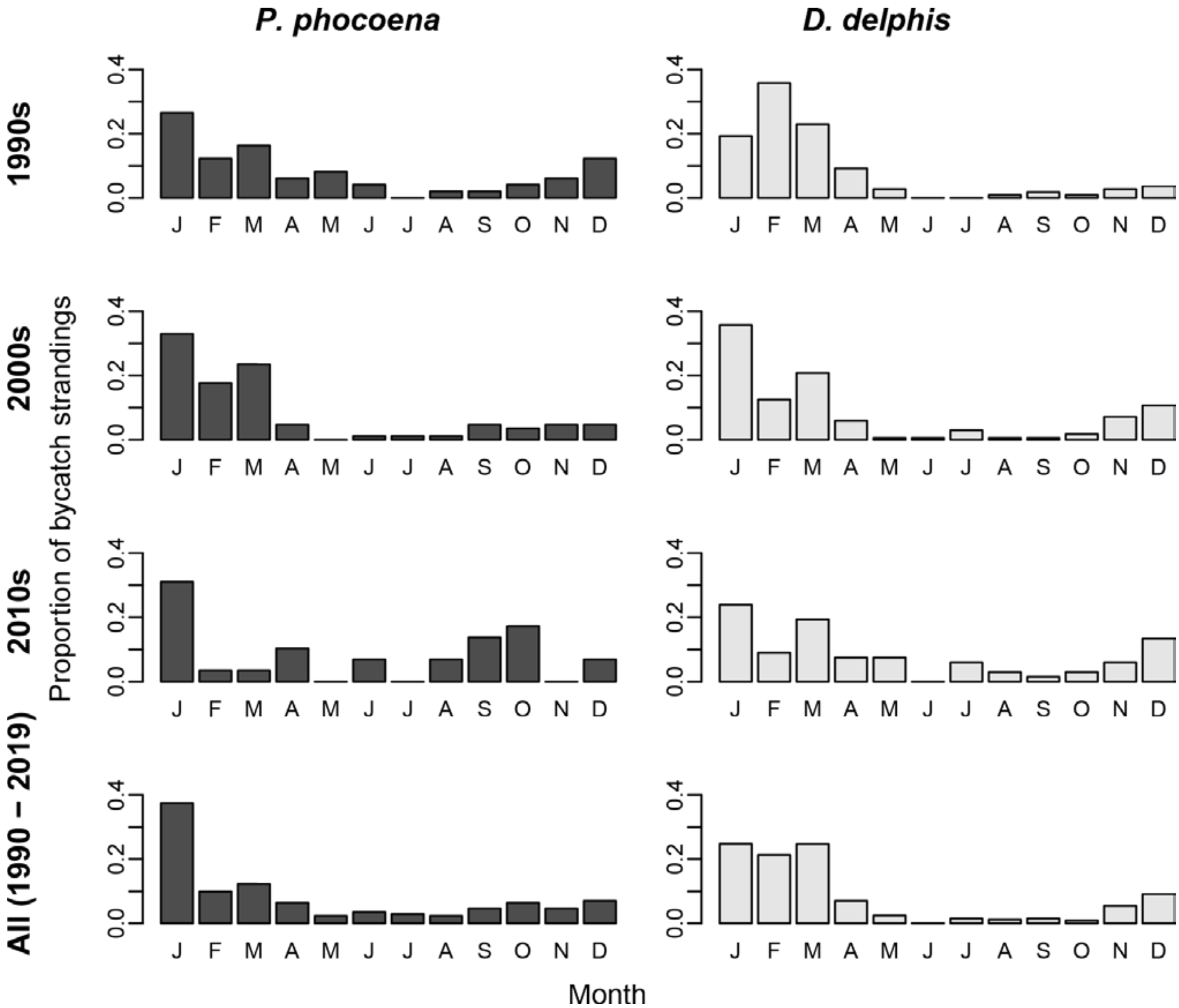

Figure 9.5 Temporal trends in the proportion of harbour porpoise (*P. phocoena*) and common dolphin (*D. delphis*) bycatch stranding records by month, disaggregated by decade.

Bycatch strandings of *D. delphis* and *P. phocoena* were recorded in all areas of coastline in the study region (Figure 9.6 and Figure 9.7). The majority of *D. delphis* and *P. phocoena* records were from the southern coast of the study region, for which separate larger scale maps are provided by quarter, with bycatch records from Dataset A overlaid for reference (*D. delphis*, Figure 9.8; *P. phocoena*, Figure 9.9). *D. delphis* bycatch strandings were predominantly from the south coast of Devon and Cornwall, between Land's End and Start Point (Figure 9.8). The distribution of *P. phocoena* records differed slightly, being restricted to more westerly regions of the study area's coastline. Notably, there are a large number of records from Mount's Bay and Penzance Bay (Figure 9.9). Compared with *D. delphis,* there was a greater proportion of records from the south coast of Wales (Figure 9.7).

In general, the observed spatial patterns align with those previously described by Leeney *et al.* (2008), who noted that the predominance of records from southern coast may in part be due to prevailing south-westerly winds and wind induced surface currents.

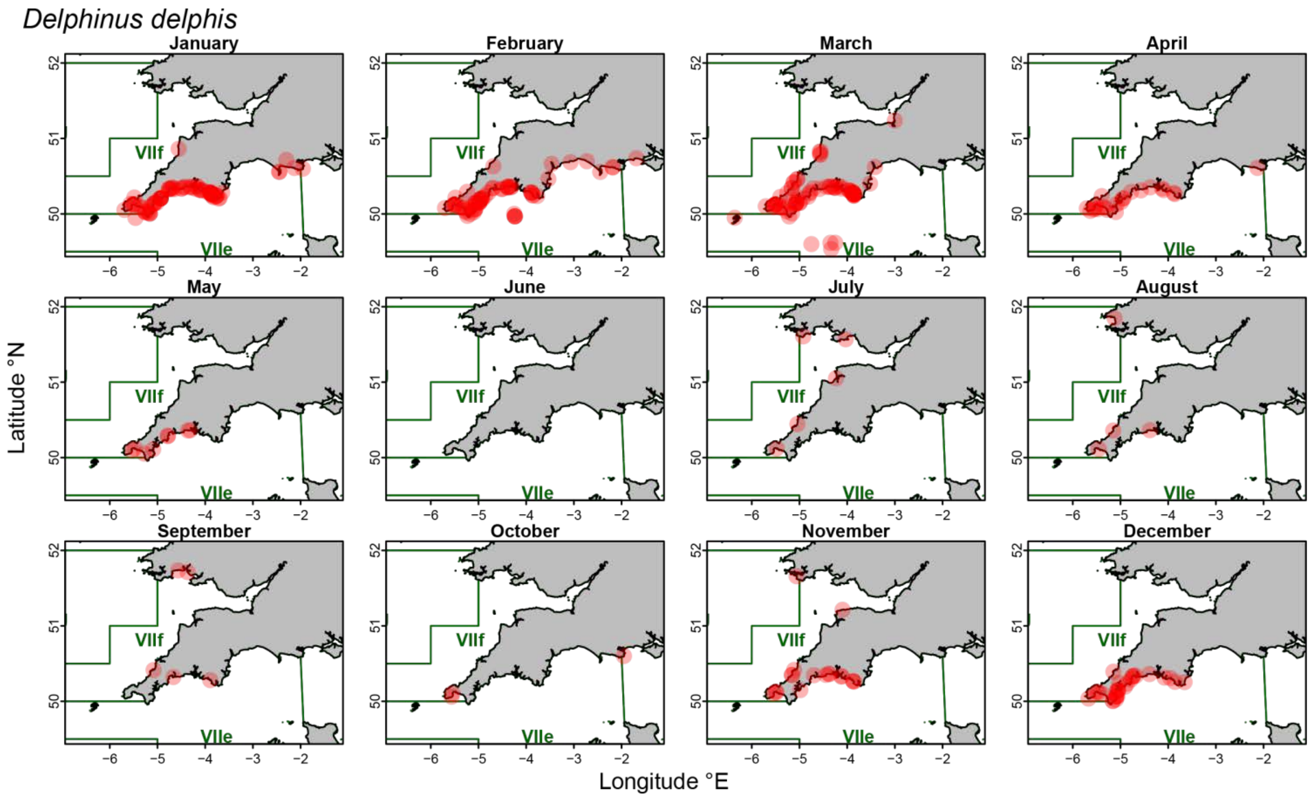

Figure 9.6 Monthly map of common dolphin (*D. delphis*) strandings where bycatch was identified as the cause of death by necropsy. Data: ICES areas, (ICES, 2021).

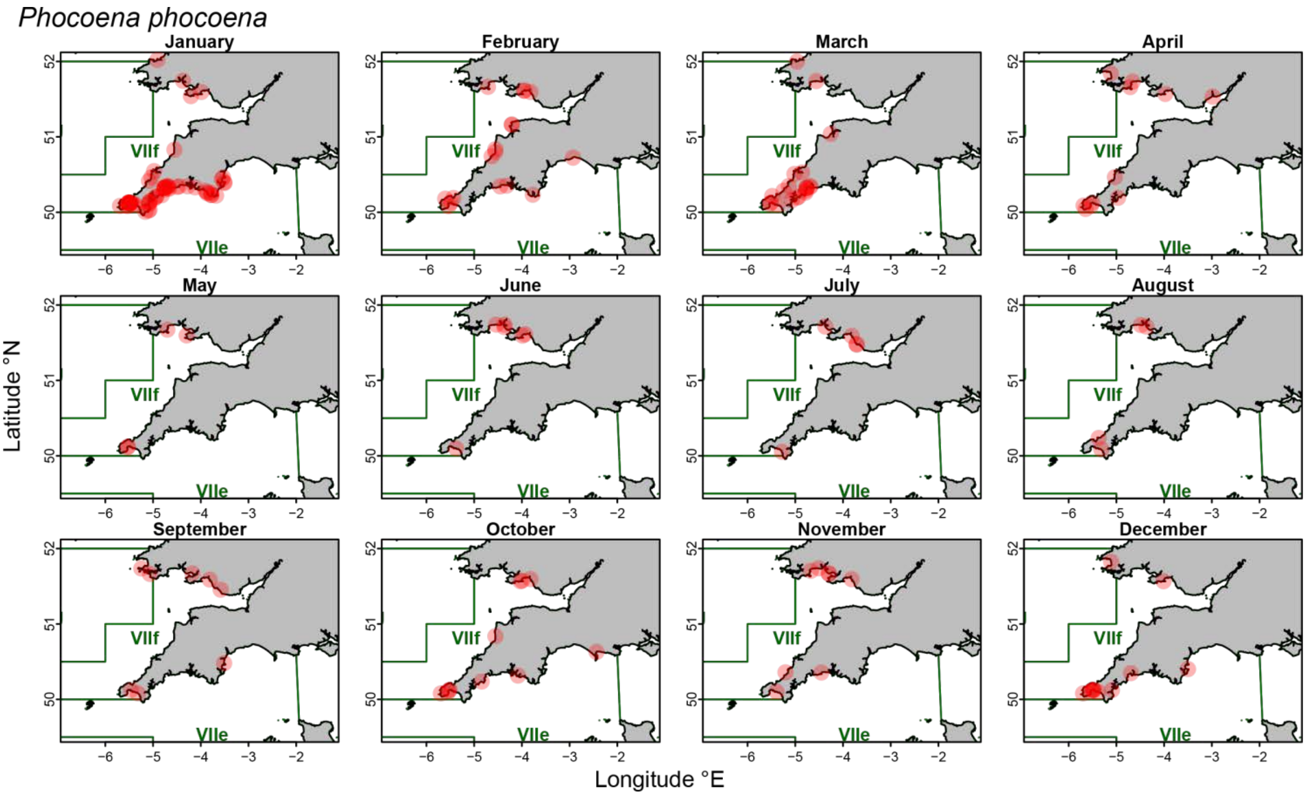

Figure 9.7 Monthly map of harbour porpoise (*P. phocoena*) strandings where bycatch was identified as the cause of death by necropsy. Data: ICES areas, (ICES, 2021)

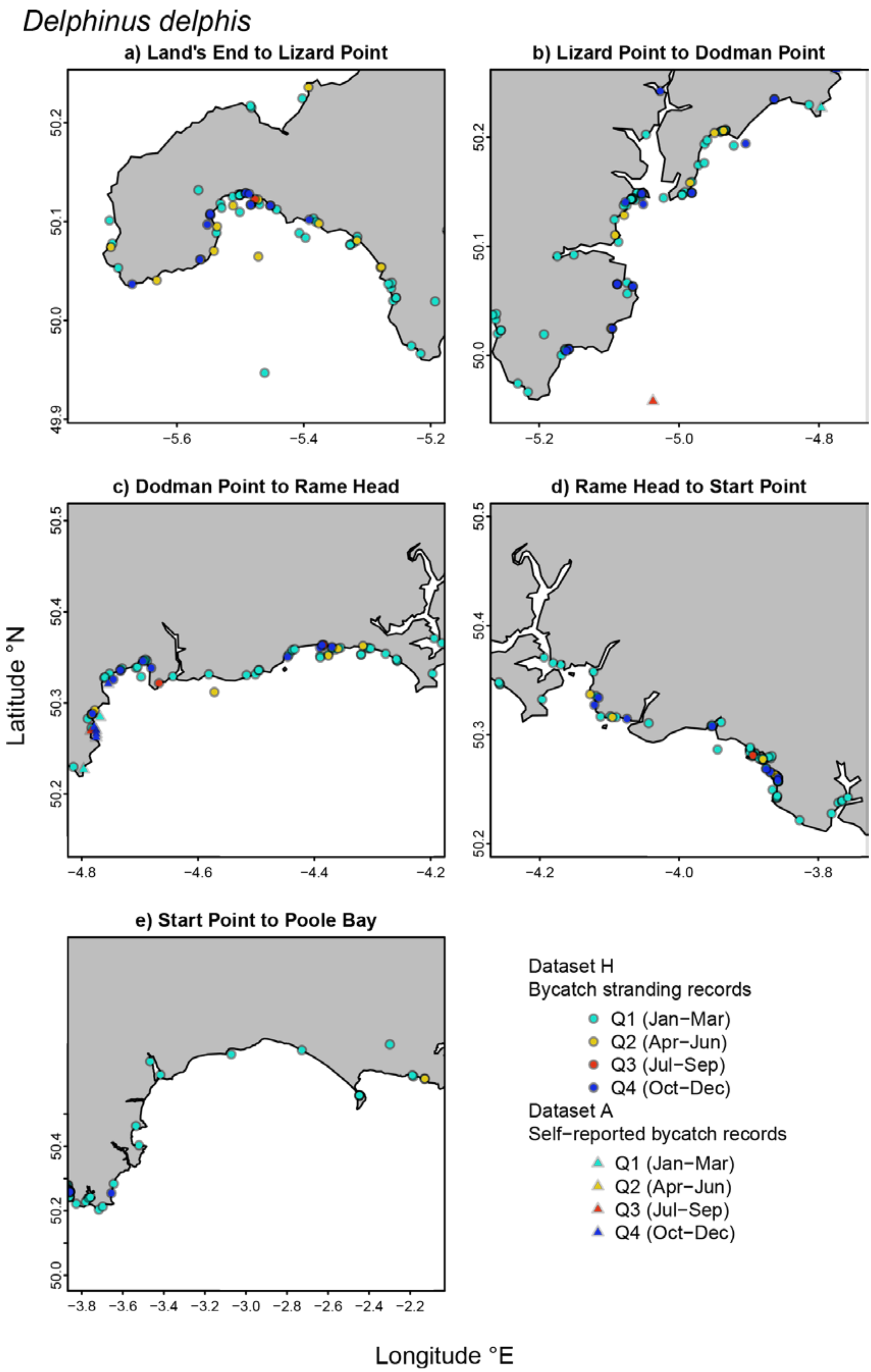

Figure 9.8 Maps of common dolphin (*D. delphis*) strandings where bycatch was identified as the cause of death by necropsy, for sections of the study region's southern coastline. Stranding records (filled circles) are coloured by quarter. Self-reported bycatch records (Dataset A) are also shown (filled triangles), coloured by quarter.

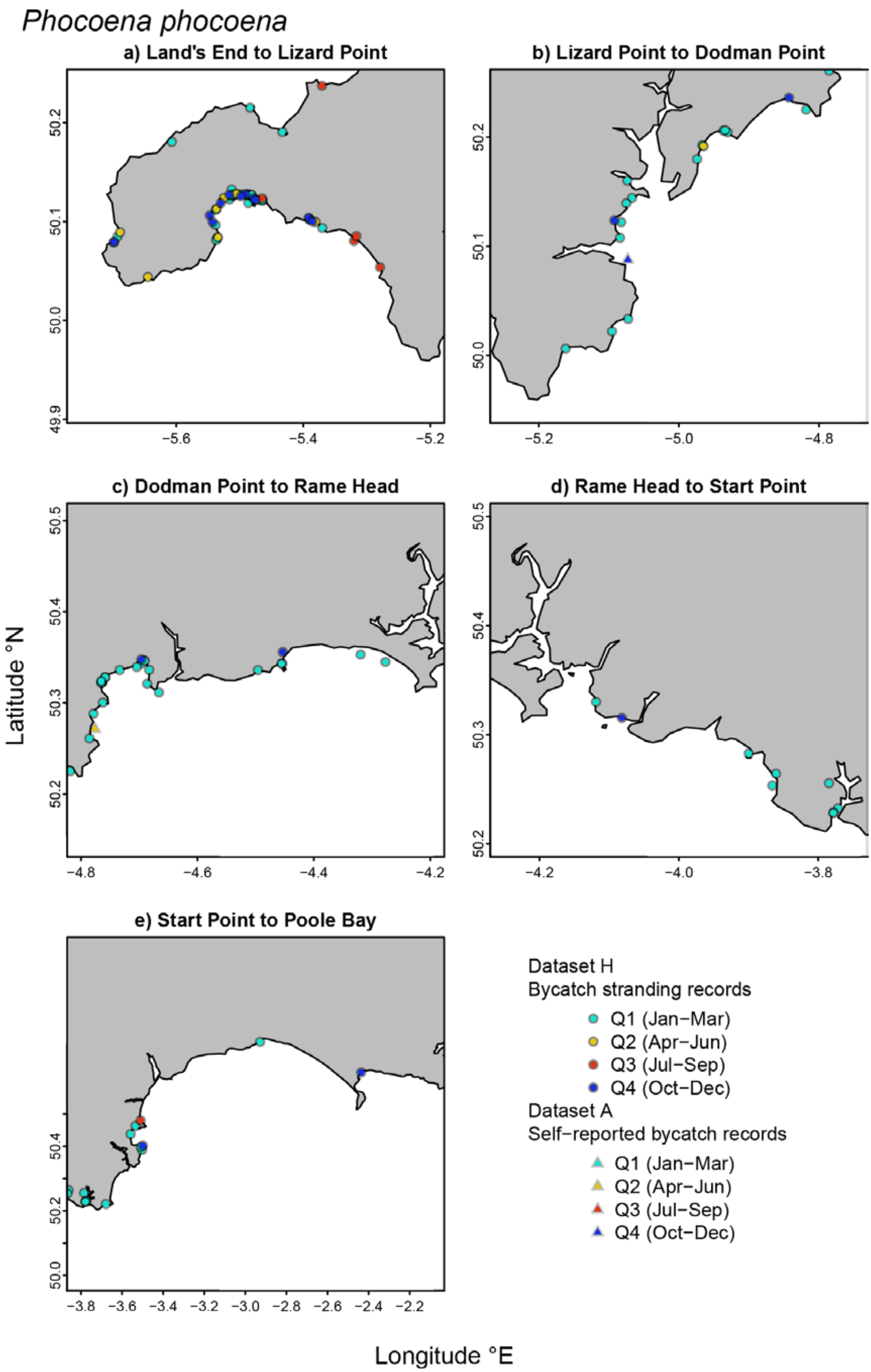

Figure 9.9 Maps of harbour porpoise (*P. phocoena*) strandings where bycatch was identified as the cause of death by necropsy, for sections of the study region's southern coastline. Stranding records (filled circles) are coloured by quarter. Self-reported bycatch records (Dataset A) are also shown (filled triangles), coloured by quarter.

Limitations

It is important to recognise that this dataset represents a subset of bycatch mortalities. Firstly, not all bycatch mortalities will result in a stranding as a proportion of carcasses will be predated upon, sink, or drift outside of the study area. Secondly, not all reported strandings can be attended, which is required for a necropsy to be conducted and bycatch identified as the primary cause of death. Thirdly, the condition of stranded carcasses may prevent the cause of death from being correctly attributed to bycatch. Finally, not all sections of the coast are readily accessible and so stranded individuals may not be discovered, reported or accessible for necropsy. The nature of strandings is that they occur along coastlines some (unknown) distance from the location of death. The spatial distribution of records may in part be determined by prevailing winds and currents and the orientation of coastline. Consequently, only broad insights into spatial patterns in bycatch mortalities can be drawn and it is hard to link mortalities to specific gears/fisheries. This dataset is therefore better suited to identifying temporal trends, inferences can only be made about broad-scale spatial trends

For reference, Peltier *et al.* (2016) attempted to address the limitations of stranding data. In their study, they estimated total bycatch mortality in the Western Channel and Bay of Biscay based on strandings data, accounting for the probabilities of dead animals floating, drifting to a coastline and being discovered. Notable, their estimate of total common dolphin bycatch inferred from strandings data was significantly higher than that based on observer data, leading to different management implications. Thus, whilst strandings data has limitations, it is nonetheless a valuable source of information. This is not least because of its large spatial scale, which spans administrative boundaries and the fact that it is free of biases commonly found in observer data (Peltier *et al.*, 2016).

10. Discussion

A significant challenge for the evidence-based management of fisheries is ensuring that adequate data is available to underpin advice and management decisions. This remains a challenge to the mitigation of elasmobranch and cetacean bycatch in the Celtic Sea, where knowledge of both species and their interaction with fisheries is often limited. However, the potential of existing data is not always fully realised, partly because the datasets that do exist are generally analysed in isolation. Exceptions, such as the combination of historic elasmobranch survey data and environmental variables to detect shifting distributions in the North Sea (Sguotti *et al.*, 2016), require careful processing of the data but yield important new insights. This project sought to obtain and process data from multiple sources and analyse them collectively, whilst highlighting the potential and limitations of each dataset. A total of eight core datasets (Datasets A-H) were identified of which seven were successfully obtained, hosted (Appendix II), processed and presented here. This was complemented by five supplementary datasets describing environmental conditions and fishing effort in the region.

Each dataset was initially reviewed in isolation and the resulting spatio-temporal maps offer some valuable insights into trends and patterns. However, perhaps the most powerful use of these data is where it is possible to combine two or more datasets, resulting in insights that are greater than the sums of their parts. The analysis of the spurdog bycatch self-reporting data (Dataset C, Section 4) is a prime example of this, where supplementary environmental datasets (bathymetry and temperature) supported the modelling of the occurrence of large bycatch events. It was then possible to partially validate this model using a further dataset, the independent spurdog tagging data (Dataset E). Finally, the resulting environmental model could be combined with AIS-derived fishing effort data to produce a risk map. Inevitably, in some cases the nature of the data defies synthesis, as the datasets were collected independently, have different intended purposes and have their own inherent limitations. The differing spatio-temporal coverage and/or resolution of the datasets present additional challenges. Nevertheless, where possible combining these data is an informative and powerful approach in a data limited-scenario, as is known to be the case for elasmobranchs and cetaceans in this region (ICES, 2020b). Key insights are outlined below.

The participatory monitoring datasets (Datasets A-C) confirm the occurrence of elasmobranch and cetacean bycatch in the Celtic Sea region by trawlers and gillnetters, these gears having previously been identified as posing the highest bycatch risk across species groups in the Celtic Sea (ICES, 2020b, ICES, 2020a). Further, the data suggest 'large' bycatch events occur, with instances of upto 8,900 kg of spurdog and four common dolphins being reported. Total bycatch for the taxa examined is not estimated, nor are the population impacts discussed, owing to the limitations of the datasets at present. Nevertheless, it is worth noting that the strandings data (Dataset H) indicate that bycatch is a significant cause of mortality in cetaceans, having been identified as the cause of death in 33.5% and 50.3% of necropsied strandings of harbour porpoise and common dolphin, respectively. Elsewhere, the estimation of common dolphin bycatch from strandings in the Western Channel and Bay of Biscay (Peltier *et al.*, 2016), has supported the conclusion that anthropogenic mortalities of common dolphin likely exceeds the upper limits of sustainable (ICES, 2020a). Scaling up of participatory data collection, in terms of coverage and fleet representation, would contribute to effective bycatch mitigation by allowing reliable estimates of bycatch, supporting long-term monitoring of trends and informing spatial temporal-design of mitigation measures.

In spite of the limitations identified throughout, the results presented can contribute to bycatch mitigation, by informing either management measures, and/or fisher behaviour. For example, the modelling of large spurdog bycatch occurrences and partial validation of that model using tagging data, demonstrates that aggregation events are predictable in time and space. Ideally, the resolution of the data and resulting models would support measures such as precisely targeted closures. However, in the absence of sufficient resolution, mitigations measures such as reduced soak times in high-risk areas/periods are a pragmatic

option. Similarly, on the basis of Datasets A and Dataset H, communication, compliance and enforcement activities related to cetacean bycatch (e.g. ensuring correctly installed and functioning pingers) are best employed during higher risk winter months.
The tagging datasets (Datasets E and F) provide insights into the movement ecology of two elasmobranch species of conservation concern, and provide a foundation for future research. For example, maps of individual common skates tracks (Dataset F, Section 7), highlight the apparent importance of inshore waters of the Isles of Scilly, which offers a potential target area for spatial management measures and warrants further investigation.

10.1. Legacy and impacts

A key output of the project is the creation of a replicable workflow for processing and analysing varied datasets. This provides the basis to extend the work presented here. The study area was restricted to the Celtic Sea, but the approaches taken are not specific to this region and so can be replicated elsewhere in the UK. Within the Celtic Sea region, a number of the core datasets examined here continue to be collected. There are also potentially other datasets not identified and employed here. The R-script library produced can be used to repeat and extend this exercise in the future achieving greater spatial and temporal coverage as new datasets are identified and existing datasets expand.

A number of the datasets have been produced in a participatory manner, with fishermen self-reporting bycatch, the product of partnerships between fishermen, scientists and managers. The importance of these approaches is evident. Data such as the multi-species bycatch self-reporting and associated VMS (Datasets A and B), will offer significant statistical power in the future, as they are scaled to provide adequate representation of the fleet and the dataset grows providing greater spatial and temporal coverage. This project provides outputs from the analysis of these participatory data that can be shared with stakeholders via the appropriate forum(s). Presenting data in accessible formats (i.e. maps) provides a valuable tool to raise awareness, develop understanding, promote buy-in for management measures and ensure continued cooperation through participatory data collection.

Finally, the project also built on an established working relationship between ZSL and Cefas, sharing knowledge, expertise and data.

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Appendix

Appendix I

Data processing and statistical methodology

Description of the approach taken for each of the supplementary and core datasets. All analyses and production of figures was undertaken in R (R Core Team, 2013). The R-script library is detailed in Appendix III.

Supplementary datasets

Bathymetry

Bathymetric data with a 1/8 arc-minute grid resolution, were obtained from the EMODnet Bathymetry portal (EMODNet, 2021a). Higher resolution bathymetric data with 6 arc-second grid resolution were used for maps of smaller inshore areas in Section 3 (British Crown and OceanWise, 2021). Contours were derived from bathymetric rasters and labelled using the 'contour' function of the 'raster' R package (Hijmans, 2021).

Sea surface temperature (SST)

Daily and monthly mean (2002 to present) sea surface temperature (SST) data on a global 0.01 degree grid interpolated from satellite and in situ observations (JPL MUR MEaSUREs Project, 2015) are available from the ERRDAP portal (Simons, 2016). Data were obtained and processed in R, the 'rerddap' package (Chamberlain, 2021) facilitates access to the ERRDAP server and the 'rxtractogon' function in the 'rerddapXtracto' package (Mendelssohn, 2021) allows data to be downloaded for a defined period and area. Mean monthly data (dataset ID: 'jplMURSST41mday') were used to produce a raster for each month from 2010 to 2020, inclusive. These monthly rasters were combined to form mean rasters for each month (12 rasters) and seasonal (winter/summer) rasters (2 rasters), used in modelling and figures. For modelling, rasters were resampled to a grid at the required resolution using the function 'resample' in the package 'raster' (Hijmans, 2021).

Substrate

In the interest of graphical clarity, the substrate classes in the EMODNet broad-scale predictive physical map (EMODNet, 2021b) were simplified/aggregated into seven classes for plotting (Figure 2.3). The EMODNet substrate types in each category used are detailed below, along with their relationship to EUNIS habitat classifications.

Simplified substrate class	EmodNet Substrate (EMODNet, 2021b)	EUNIS (Davies *et al.*, 2004)
Rock or other hard substrata	Rock or other hard substrata	A4.2: Atlantic and Mediterranean moderate energy circalittoral rock
Coarse substrate	Coarse substrate	A5.14: Circalittoral coarse sediment
Mixed sediments	Sediment	A5: Sublittoral sediment
	Mixed sediment	A5.45: Deep circalittoral mixed sediments
Fine mud	Fine mud	A5.37: Deep circalittoral mud
Mud/sand	Muddy sand	A5.37: Deep circalittoral mud
	Sandy mud or Muddy sand	A5.37: Deep circalittoral mud
	Sandy mud	A6.5: Deep-sea mud
Sand	Sand	A5.27: Deep circalittoral sand
Seabed (unclassified)	Seabed	n/a

Fishing effort

Fishing effort data for vessels with AIS was obtained from Global Fishing Watch (GFW) (Global Fishing Watch, 2021). Daily fishing effort (hours of fishing activity) data, by gear type, is available aggregated to 100th degree cells. Data were obtained from 2012 to 2020, inclusive, for trawling effort (GFW classification: 'trawler') and gillnets (GFW classification: 'set-gillnets') and was normalised to a 500 m grid.

To support spurdog large haul risk map predictions (Section 4), GFW data were processed as follows, to produce 12 monthly effort rasters at the resolution of the environmental model prediction: 1) all 'set-gillnets' effort data from 2012 to 2020 were obtained; 2) data were aggregated by month; 3) the 99th percentile was removed as there were a small number of exceptionally large values; the data were resampled to the Cefas grid; the raster values were log-transformed; the transformed values were rescaled from zero to one.

Sea surface salinity (SSS)

The MARSPEC monthly average sea surface salinity is interpolated from *in situ* observations, at a spatial resolution of 30 arc-seconds (nominally a 1km grid). No further processing was employed to produce Figure 2.4.

Core datasets

Dataset A and B

All trips (single and multi-record) with no positional data were removed from the dataset. Records missing a trip_id were removed from the dataset. The locations of reported bycatch was determined as the centre of the start and end positions of each trip (for single record trips) and the centre of all positions for multi record trips. For those single trips where they was only a start position (i.e the end position was missing) the start position was used.

Dataset C

The bycatch data has non-normal distribution, is zero-inflated (lots of zeroes representing fishing that did not result in spurdog bycatch) and has a large variance, with a number of very large values. The nature of this data therefore presents some challenges from a modelling perspective, as there are limited options for zero-inflated continuous data with a large variance. An alternative approach, used here was to focus on modelling the occurrence of large bycatch events ("large hauls"), using a binomial generalised linear model.

The model was implemented using the function ‘glm’ from the ‘stats’ package, a core package in R (R Core Team, 2013). Polynomial terms were included where the relationship was non-linear (depth).

A binary response variable, large haul (yes/no), was created based on the reported weight of spurdog bycatch in relation to a threshold. The threshold (≥100 kg) was set using an accumulation curve to select a value for which bycatch hauls in excess of that value that accounted for ~90% of all spurdog bycatch (Figure 4.9). Depth, sea surface temperature (SST) and month were used as explanatory variables.

Depth was extracted from the bathymetric raster (see Section 2.2.1.1), as the mean of all values within the reporting cell. The coarse resolution of the reporting cell means depth is overestimated in those cells close to the shelf edge. The range in a few cells is large (e.g. from 150m to over 1,000m), resulting in a mean value which does not represent the depth at which fishing occurs. Thus, outliers (values greater than twice the standard deviation from the mean) were removed from the dataset. Sea surface temperature was determined for each record as the mean of all values within the reporting cell, for a 7 day window up to and including the date of the record, from a daily from a 0.01˚ grid (JPL MUR MEaSUREs Project, 2015).

Monthly large haul occurrence predictions were made using the environmental model at the resolution of the Cefas grid. To achieve this, a depth (EMODNet, 2021a) and monthly SST raster (JPL MUR MEaSUREs Project, 2015) were made at the resolution of the Cefas grid.

The environmental model was combined with fishing effort data to predict the risk of large hauls by multiplying the environmental model by fishing effort (scaled 0-1). This was performed using effort data derived from Dataset C (Figure 4.12) and using GFW effort data for gill netters (Figure 4.13), which was aggregated by month (see ‘Fishing effort’ data processing, Appendix I).

Dataset D

The SST at each station was estimated as the mean of all daily values between the shot and haul date, in a 0.04˚ square around the station location, from daily 0.01˚ degree SST data, see Section 2.2.1.2 (dataset ID ‘jplMURSST41’, JPL MUR MEaSUREs Project, 2015).

Dataset E

Depth at each recapture location was sampled from the raster derived from EMODnet Bathymetry (EMODNet, 2021a).

Dataset F

Depth at each recapture location was sampled from the raster derived from EMODnet Bathymetry (EMODNet, 2021a).

Dataset H

Where records were missing latitude and longitude coordinates but did include a Ordnance Survey (OS) grid reference, coordinates were determined using the ‘osg_parse’ function in the ‘rnrfa’ R package (Vitolo *et al.*, 2018).

Appendix II

Outline of files in the data warehouse

The project established a Microsoft Sharepoint directory 'ByCatch', which is accessible to project team members (ZSL and Cefas) to serve as a secure, cloud-based data 'warehouse'. The file structure is outlined below:

> Documents	
> General	
> Datasets	
> Dataset A and B_Multi-species bycatch self-reporting	Contains datasets including accompanying metadata/reports
> Dataset C Spurdog bycatch self reporting	
> Dataset D_Common Skate Survey	
> Dataset E_Spurdog tagging	
> Dataset F_Common skate tagging	
> Dataset H_CSIP	
> Figures	Contains all figures in report as '.pngs'.
> GIFs	Contains SST and SSS GIFs
> GIS	
> Bathymetry	
> Digimap UK DEM	Bathymetry data, UK waters
> EMODNet DEM	Bathymetry data, NW Atlantic
> CEFAS Reporting Grids	Shapefiles of reporting grids used by Cefas
> GFW Fishing effort rasters	Rasters of total fishing effort 2012-2020 by gear type
> Monthly	Rasters of total fishing effort 2012-2020 by month (gear type: set gillnets)
> Habitats	EMODNet substrates shapefile
> ICES Areas	ICES Areas shapefile
> MPAs	
> Celtic Sea_OSPAR_MPAs_UK Ireland France	MPA shapefiles by nation (UK, Ireland, France)
> SSS	
> Monthly SSS	Monthly SSS rasters from http://www.marspec.org/
> SST	
> Mean Monthly SSTs	Mean monthly SST rasters (12 rasters)
> Monthly SSTs	Monthly SST rasters from 2010 to 2020 (132 rasters)
> Seasonal SSTs	Mean seasonal (winter/summer) SST rasters (2 rasters)
> R script library	Contains 29 R scriptsdetailed in Appendix III
> Report	Contains final report

Appendix III

List of scripts in the R-Script library

R scripts are listed by dataset and include a description of the function of the script.

Dataset	Script	Function
n/a	Background map v5.R	Produces study area overview map with labelled MPAs
Bathymetry	Produce bathymetry map.R	Produces bathymetric map of the study area from EMODNet Bathymetry.
	NW atlantic bathymetry.R	Combines multiple EMODNet Bathymetry titles to produce raster for North Atlantic for use in tagging maps.
Sea surface temperature	Generate Monthly SST Raster v4.R	Downloads and processes data from the ERRDAP portal to produce monthly SST rasters from 2010 to 2020, inclusive (132 rasters).
	Combine monthly SSTs to mean for each month 2010 to 2020.R	Combines monthly rasters 2010 to 2020 to produce a mean raster for each month (12 rasters).
	Combine monthly SSTs to Summer Winter.R	Combines monthly rasters 2010 to 2020 from: a) January to March, inclusive; and b) July to September, inclusive. Produces a) winter raster and b) summer raster (2 rasters).
	Plot Summer Winter Mean SST.R	Produces a/b figure, showing mean winter and summer months SST with common colour scale.
	Make Monthly Mean SST GIF.R	Combines the 12 monthly raster to produce a .gif visualisation.
Substrate	Substrates v3.R	Produces physical habitat map from EMODNet substrates data.
Sea Surface Salinity	Obtain Monthly SSS rasters for Celtic Sea v2.R	Downloads mean monthly MARSPEC sea surface salinity data, saves each month as a raster (.tif). Combines each monthly raster to produce .gif visualisation.
Fishing effort	GFW Big Query v2_set_gillnets.R	Download and process GFW gillnetter fishing effort data.
	GFW Big Query v2_trawlers.R	Download and process GFW trawler fishing effort data.
	GFW Fishing effort figures.R	Produce a/b figure showing GFW fishing effort data for gillnetters and trawlers.
	GFW Big Query v2_set_gillnets_monthly raster.R	Download and process GFW gillnetter fishing effort data and aggregate by month to produce input raster for bycatch large haul occurrence risk map.
Dataset A and B	Dataset A and B v1.R	Script processes dataset to remove erroneous records, produce summary statistics, map vessel activity and map bycatch occurrences.
Dataset C	Dataset C_v11.R	Produces figures, maps and summary statistics. For maps data are aggregated to the Cefas grid.
	Dataset C_Self reported spurdog	Extracts potential explanatory variables for each

	bycatch_extract SSTs month and week v4.R	modelling.
	Spurdog bycatch self-reporting_extract depth and substrate.R	Extracts potential explanatory variables for each modelling.
	Dataset C_Self reported spurdog bycatch modelling_v9.R	Produces environmental model for large haul bycatch occurrences and uses fishing effort data in conjunction with model to produce risk maps.
	Model validation v1.R	Validates model using spurdog tagging data from Dataset E.
Dataset D	Dataset D v2.R	Plot skate CPUE at survey stations with SST raster.
	OBIS skate occurrences.R	Download and plot *D. batis* occurrence records from OBIS.
Dataset E	Dataset E All Shark tags release and recaps v3.R	Plot all tagged spurdog release and recapture locations, in British Isles. Plot recaptures in study area with kernel density estimate.
	Dataset E Spurdog DST tags v2.R	
	spurdog tags sample depths from nw atlantic raster.R	Estimate depth at recovery location for all spurdog tag recoveries using EMODNet bathymetery data for North Atlantic.
Dataset F	Dataset F - All Skate tags release and recaps.R	Plot all tagged common skate release and recapture locations, in British Isles.
	Dataset F - Skate DST Tags v2.R	Plot all common skate DST tracks collectively with release and end locations and plot each track individually.
Dataset H	CSIP v5.R	Produce summary statistics, figures and maps.
	CSIP proportion bycatch vs non-bycatch.R	Produce figure to show proportion of necropsied stranding attributed to bycatch as opposed to other causes.