Systematic review of bycatch hotspots for sensitive species of marine mammals, seabirds and elasmobranchs in the UK

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1 Introduction

Bycatch, the incidental capture of non-target organisms in fisheries, has been estimated to account for up to 40% of global fisheries catch (Davies et al., 2009). Bycatch has the potential for direct and indirect negative impacts at the level of individuals (mortality and welfare), populations and ecosystems (Lewison et al., 2004). Populations of some species are more sensitive to the effects of bycatch mortality, due to particular life history traits typical of k-selected species, including: long-life, slow-growth, late maturity, extended reproductive periods and low fecundity (Hall et al., 2000; Stevens et al., 2000). Sensitive vertebrate species exhibiting these traits include elasmobranchs, seabirds, turtles and marine mammals, with bycatch having been implicated in the decline of multiple species and even posing an extinction risk to some (Lewison et al., 2004; Read, 2008; Komoroske and Lewison, 2015). Acknowledging that sensitivity lies on a spectrum and is somewhat subjective, it is defined for the purposes of this review in 'Section 3'.

Bycatch, especially of sensitive species, also has social and economic costs to fishers, including: damaged gear, bait loss, fuel loss, reduced target catch, time lost processing and discarding bycatch, increased regulation, fishery closure and negative public relations (Gandini and Frere, 2012; Patrick and Benaka, 2013). Though these have received relatively little attention and are poorly quantified (Pott and Wiedenfeld, 2017). Additionally, though rarely discussed, there can be psychological impacts on fishers associated with the harm bycatch can inflict on charismatic marine mega-fauna (Piovano et al., 2012).

Recognition of bycatch as a significant issue, along with the more general trend towards ecosystem-based fishery management, has seen a rapid growth in bycatch research in recent decades (Soykan et al., 2008). This includes efforts to identify sensitive species 'bycatch hotspots' (e.g. Lewison et al., 2014; Queiroz et al., 2019; Bi et al., 2021), a term that is widely used, though in many cases poorly defined (addressed in 'Section 3'). The intention is that identifying bycatch hotspots will address gaps in our knowledge about patterns of bycatch in time and space, helping prioritise management measures and research efforts, where resources are limited. In the UK, the 'ecosystem objective' of the Fisheries Act 2020 (UK Government, 2020) and Joint Fisheries Statement (Defra, 2022a) sets out the government's ambition that "*incidental catches of sensitive species are minimised and, where possible, eliminated*". (Where, the ecosystem objective is one of eight objectives within the overarching 'fisheries objective'.) The UK Bycatch Mitigation Initiative (BMI) outlines how the fisheries policy authorities will achieve this ambition, including the specific policy objective to "*identify 'hotspot' or high-risk areas*" (Defra, 2022a; Defra, 2022b).

The objectives of this literature review are to:

- Consider how the term 'bycatch hotspots' has been employed in the literature and will be used in this review ('Section 3');
- Provide an overview of methodological approaches to identifying sensitive species bycatch hotspots ('Section 4');
- Conduct a systematic review of bycatch hotspots within the UK's exclusive economic zone (EEZ) ('Section 5');
- Provide illustrative case studies of 'coldspots', where mitigation has been successfully implemented to address sensitive species bycatch hotspots ('Section 6');
- Highlight priorities and recommendations for bycatch monitoring, mitigation and further research, including those that could be delivered as part of the BMI, based on the hotspots and knowledge gaps identified through the review. ('Section 6.1').

The findings and recommendation within in this report could be considered by Defra, Devolved Authorities and other actors when determining how best to implement and prioritise bycatch mitigation and monitoring in UK waters.

2 Methodology

2.1 Study area

The scope of the systematic review of sensitive species bycatch hotspots (‘Section 5’) is limited to fisheries operating in the UK EEZ, including both UK and foreign vessels (Figure 1). Conversely, the overview of the methodological approaches that may be employed (‘Section 4’) draws on wider literature beyond this geographic scope. In reviewing the literature, we sought to highlight case study examples of where bycatch hotspots had been effectively addressed through successful implementation of mitigation (‘Section 6’), although this is not intended to be an exhaustive or systematic account of sensitive species bycatch mitigation in the UK.

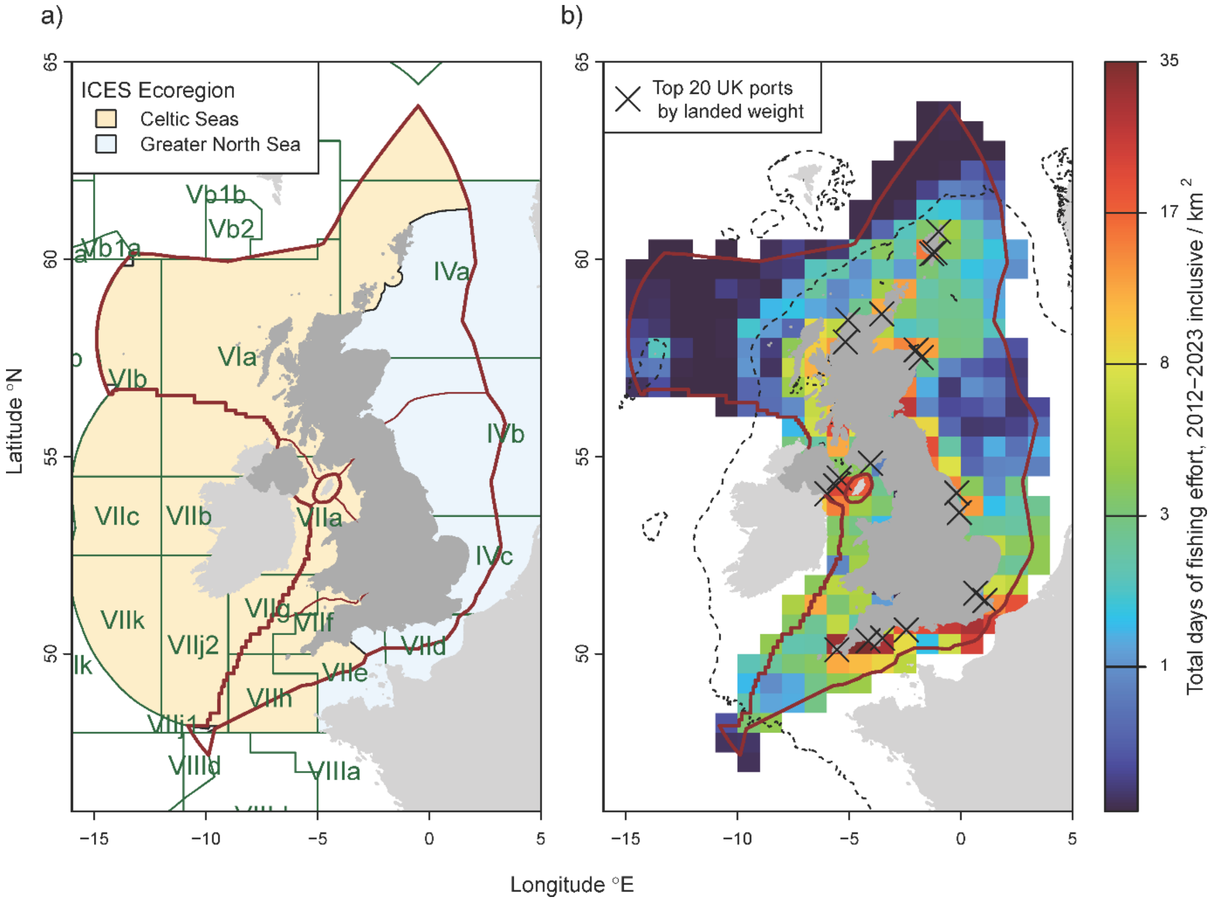

Figure 1: Map of: a) the UK EEZ in relation to ICES Divisions (green polygons) and Ecoregions (only those Ecoregions overlapping with the UK EEZ are shown); and b) total days of fishing effort, 2012-2023 inclusive per km^2. The 200m depth contour is indicated (dashed line), along with the location of major fishing ports (largest 20 by landed weight in 2023, black ‘x’s). For graphical clarity fishing effort data is log10-transformed, for ease of interpretation back-transformed values are presented on the legend. Data: fishing effort, Cefas (see description in ‘Appendix IV’); ports, Cefas; depth contour, EmodNet, ICES Divisions and ecoregions, ICES; maritime boundaries, UKHO; countries, ESRI.

The UK’s EEZ spans over 700,000 km^2, the majority of which is Scottish waters (Table 1). The study area supports a diverse fleet in terms of vessel size, gear and target species. The Seafish 2023 annual survey reports that whilst the English fleet is larger (number of vessels, Table 1), the Scottish fleet has double the capacity (vessel tonnage), lands more seafood and generates more income (Seafish, 2025). In total, the UK fleet landed 680 thousand tonnes of fish and shellfish in 2023, the majority into UK ports, mainly Peterhead, Lerwick and Newlyn. By weight, in 2023, the top species landed in the UK by domestic and foreign vessels were: mackerel (106,533 tonnes); herring (46,833 tonnes); haddock (38,397 tonnes); nephrops (27,402 tonnes); blue whiting (26,877 tonnes). Whilst by value, this was: mackerel (£132 million); nephrops (£111 million); king scallop (£60 million); cod (£45.2 million); and monkfish (£44.9 million) (Seafish, 2025). The total size of the fleet is reducing, mainly due to the loss of <10m vessels, a trend that began in the 1990s (Pascoe and Tingley, 2010), in part related to the concentration of quota among larger vessels (Stewart et al., 2022). Nevertheless, the <10m vessels are the largest segment of the fleet (1,607 vessels), compared with 10-24 m (951 vessels) and over 24m (79 vessels) (Seafish, 2025). Noting that these values exclude 1,148 low activity vessels (any vessel that recorded a total value of landings under £10,000 in the year considered) (Seafish, 2020).

Table 1: Breakdown of UK maritime zones. Data: maritime area, Lennan et al. (2022); vessel numbers, Seafish (2025).

Maritime area	Area (km^2)	Approx % of UK EEZ	Vessels
Scottish	462,315	63%	1,575
English	230,190	32%	1,833
Welsh	30,778	4%	223
Northern Irish	6,819	1%	193
UK EEZ	**730,102**	**100%**	**3,824**

UK vessels employ a diversity of gears, the most common main gear is pots and traps followed by demersal trawl/seines (Figure 2). Kingston et al. (2023b) report that demersal trawls/seines and pot fisheries typically account for 75% of total UK fishing effort (days at sea). There is considerable heterogeneity in the spatial distribution of fishing effort. The greatest levels of effort are in the Celtic Sea, Western Approaches and Northern North Sea, see Figure 1 and Witt and Godley (2007) who present vessel monitoring system (VMS) from >15m vessels. Astarloa et al. (2023) present VMS fishing effort data (2009-2021, vessels >12m) disaggregated by gear type with effort shown to be concentrated as follows: beam trawling in southern North Sea and English Channel; static nets in Celtic Sea; trawling (demersal and pelagic) is more evenly distributed around the UK than other gears; longlines along shelf edge north of Scotland and Celtic Sea; pot and traps predominantly in inshore waters; purse seines around Cornish coast; seines along the south coast and to a lesser extent northeast Scotland. Fishing effort by gear type is also presented in 'Appendix IV', showing trawling of effort is the most widely distributed.

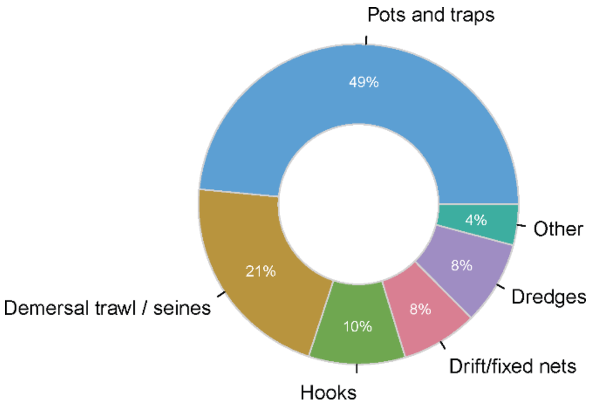

Figure 2: Main gear type used by active vessels (n=2,637) in the UK fleet, excludes low activity vessels. Data: Seafish (2025)

2.2 Systematic literature review

The systematic review of sensitive species bycatch hotspots employed the ROSES (RepOrting standards for Systematic Evidence Syntheses) protocol, which was specifically designed for systematic reviews in the field of conservation and management (Haddaway et al., 2018). The review consisted of three stages: search, screening and synthesis.

A systematic search was conducted using ISI Web of Science, Scopus and Google Scholar. This was complemented by an unstructured search, including: i) references found within literature identified by the systematic search, known as snowballing; and ii) submissions by subject matter experts within the authors' network.

Search terms used in the systematic search are detailed in Table 1. A wildcard character '*' was used to account for plural, prefixes and suffixes for some search terms (e.g. '*map*' to identify records employing any of the terms heatmap, maps, mapping etc). Recognising the shifting nature of both fisheries, species distribution and species abundance, a date range was used to restrict records to those published since 2000, on the basis that older information was less likely to be relevant. In Web of Science and Scopus searches were restricted to the abstract as this yielded a greater number of relevant results than searching on titles alone, whilst searching for terms anywhere within the body of text yielded a much higher proportion of irrelevant results. This is not an option in Google Scholar and so the query was applied to full texts. The exact query used for each search engine is detailed in Appendix I.

Table 2: Search terms and parameters by category used to query ISI Web of Science, Scopus and Google Scholar.

Category	**Search terms/parameters**
Bycatch	bycatch OR discard* OR incidental OR non-target
Spatial/temporal	**AND** (hotspot* OR distribution OR *map* OR rate* OR frequency OR pattern* OR trend* OR monitoring)
Geographic	**AND** (UK OR "United Kingdom" OR "Northeast Atlantic" OR Europe OR "North Sea" OR "Celtic Sea" OR Channel OR "Irish Sea" OR England OR "Northern Ireland" OR Scotland OR English OR Scottish OR "Northern Irish" OR Wales OR Welsh)
Taxa	**AND** (mammal* OR pinniped* OR phocid* OR cetacean* OR bird* OR seabird* OR elasmobranch* OR shark* OR skate* OR ray*)
Date	**AND** (2000-01-01 to 2024-04-09)

The number of results from the systematic search were: Web of Science, 277; Scopus, 151; Google Scholar, 8,410. Only the top 2% (168 results) of results from Google Scholar were retained, beyond this threshold results were invariably not of relevance. Thus, the combined results of the systematic search totalled 598 records, yielding 444 records after the removal of 154 duplicates. Screening for relevance was on the basis of the title and abstract, the full text was reviewed where there was uncertainty. This produced 31 relevant records. A further 26 records were outside of the geographic scope but contained relevant information about the methodology by which hotspots can be identified and were retained to inform that section of this review (Section 4). An additional 40 records were identified by the unstructured search, after screening submissions. No records were excluded due to the full text being unavailable. The resulting database is included here, Appendix II.

The full text of each document in the literature database was uploaded to Nvivo (QSR International, 2024), a qualitative data analysis software package. Each document was reviewed in Nvivo and sections of text given specific codes where pertinent. Codes were developed *ad hoc* during the review as topics emerged, e.g. regional, taxa-specific and methodological codes. This facilitated synthesis by allowing text from all sources relating to a specific topic to be viewed collectively. This approach to synthesis formed the basis of the following sections. Additional references (not subject to this review process) are cited in the text (and included in 'References') where they provided supporting information.

3 Defining 'bycatch hotspots' for sensitive species

The term bycatch is used widely but does not have a standardised definition. In its broadest sense it can be used to refer to: discarded catch; retained non-target catch; slipped species (released without being brought on-board, e.g. in a purse seine); mortalities due to abandoned, lost or otherwise discarded fishing gear (ALDFG); offal; and even broader ecosystem/habitat impacts (Pérez Roda et al., 2019). According to Gray and Kennelly (2018) bycatch is most commonly defined as being "*the unintended, non-targeted organisms caught while fishing for particular species (or sizes of species)*". This is then subdivided into non-target organisms that are retained (because they have economic value and/or that is a regulatory requirement) and 'discards', those returned (dead or alive) to the sea.

It is the discarded portion of bycatch that is typically most controversial. Discards are perceived as waste or collateral damage and includes species sensitive to bycatch, with impacts at the individual level (animal welfare, injury and mortality) and/or the population level (with population and wider ecological impacts), that may be of conservation concern. 'Sensitivity' is somewhat subjective, the term sensitive species overlaps with endangered, threatened and protected species (ETP, sometimes PETs). For the purposes of inclusion in this review, a definitive list of those species of marine mammal, seabird and elasmobranch considered sensitive is included in Appendix III. The ICES Working Group on Bycatch of Protected Species (WGBYC) maintains a list of ETP species at risk of bycatch within each ICES ecoregion (ICES, 2022a). For marine mammals and seabirds this review adopts the WGBYC list for the Celtic Sea and Greater North Sea ecoregions. The WGBYC list of elasmobranchs excludes any species for which quantitative or qualitative stock assessments are available. Here we adopt a more precautionary, inclusive, approach with respect to elasmobranchs. Our approach recognises that there may be a wider range of elasmobranch species that are unintentionally caught (i.e. are bycatch), whose life history and/or population status renders them sensitive, although they may be legally landed within the UK. Thus, for elasmobranchs, the WGBYC list for the Celtic Sea and Greater North Sea ecoregions is adopted, with the addition of those species that are i) assessed by the ICES Working Group for Elasmobranch Fishes; and/or ii) are known to occur in British waters and the North East Atlantic (Shark Trust, 2020).

3.1 What is a bycatch hotspot?

Conceptually, identifying bycatch hotspots is an attractive proposition because it, in theory, provides a clear steer for the prioritisation of research and mitigation efforts (voluntary, regulatory etc.). A challenge is that there is no consensus on what is meant by a bycatch hotspot.

Accepting that 'bycatch' can be broadly interpreted, it is worth recognising that ambiguity lies in both the 'hot' and 'spot' components of 'bycatch hotspot'. Intuitively, spot implies a fixed geographic point or area. In reality, fisheries, their targets and those species caught as bycatch, are subject to fluctuation in time and space, thus spots are inevitably transient (driven for example by oceanographic conditions, reproductive cycles etc) and thus require a dynamic approach to their identification (Žydelis et al., 2011). It may also be that specific gears or fishing practices are the 'spot' that should be prioritised for attention, rather than focus being tied to a time and locality. 'Hot' is perhaps more problematic because it begs the question: hot relative to what? Bastardie et al. (2021) observe that "*there are typically no guidelines defining bycatch limits for elasmobranchs, marine mammals, or marine seabirds for mortality levels that could be deemed as sustainable*". At present, there is no recognised consensus or adopted approach for determining sustainable bycatch thresholds in the Northeast Atlantic (Moyes et al., 2025). Although this is subject to ongoing work in Europe and is more well-established in some other regions (A. Kingston, pers. comm.). Depending on the audience or purpose the rate and/or quantity of bycatch may be considered hot where: it exceeds some ecological reference point (e.g. Maximum Sustainable Yield, Potential Biological Removal); is a significant proportion of the total catch, which is of potential interest to consumers and certifiers (wanting to support 'cleaner' fisheries) and fisheries (wanting efficient operations and to minimise their environmental impacts); affects species of societal concern/interest (often 'charismatic mega-fauna'); is elevated relative to other periods of time (typically season hotspots); or, is high relative to other fisheries within a specific region (e.g. jurisdictional or ecological). Thus, within this range of what is meant by 'hot' the term bycatch hotspot may be used to indicate situations where: the quantity of bycatch is high (potentially but not necessarily with population impacts); the bycatch per unit effort (BPUE) is high (again, potentially but not necessarily with population impacts); or, the quantity and/or BPUE is low but there are sufficient mortalities to have consequences of conservation concern to a small or declining population. Alternatively, it may be 'hot' simply because the bycaught species are of particular societal concern, sometimes irrespective of the rate, quantity or impacts at the population or ecosystem level. All of these situations warrant further research and/or interventions and whilst being clearly different, identifying them as 'hotspots' is of value to direct and prioritise limited resources.

It can be helpful to consider an example of where bycatch hotspots is used in different but legitimate manners. Bradbury et al. (2017) produced maps identifying areas where there was elevated predicted risk to seabird populations; the product of seabird density distribution data, expert assessment of sensitivity and fishing effort data. However, Northridge et al. (2023) highlight that this output is not very helpful when attempting to determine the best area/fishery to test the efficacy of bycatch mitigation measures. For that purpose, it is key to identify where there is "*the highest probability of a bycatch event occurring during a fishing operation as these will provide most power to quantify the effectiveness of any trialled mitigation measure*". Thus, Northridge et al. (2023) sought to identify bycatch hotspots where the bycatch per unit effort (BPUE) was high, the level of fishing effort and population impact were less relevant. This subtlety in usage, seen by comparing these two examples, could easily be missed in the pursuit of identifying bycatch hotspots.

The fluid nature of the term poses a challenge to a systematic review. One option is to adopt a specific definition and only to include research that conforms to that. However, that results in a less comprehensive albeit more precise account. Instead, here we adopt an inclusive approach, drawing on all literature within the geographic scope that identifies a bycatch hotspot, noting where appropriate the sense in which the term is employed, the intention(s) of the study and the methodology employed.

4 Methodological approaches for identifying hotspots

The literature identified in the search employed a diversity of methodological approaches for identifying bycatch hotspots. The following account provides an overview of the approaches used (though is not intended to be exhaustive) and includes examples from beyond the geographic scope of this review. The approaches detailed can be grouped into four categories, summarised in Table 3, with illustrative examples.

Table 3: Examples of methodological approaches to identifying sensitive species bycatch hotspots, in four categories.

Category Approaches/Examples	Required inputs	Advantages	Limitations/Challenges	Ref.(s)
Fishery dependent				
Observer Programmes, e.g. Bycatch Monitoring Programme (BMP)	At-sea observers. Total fishing effort to extrapolate to scale of fishery	Often regarded as the most reliable source of validated bycatch data. Direct insight into fishery sensitive species interactions. Can yield in-depth and nuanced insights.	Potentially relatively costly. Coverage is usually limited and may not be representative, may miss rare events. Risk of observer bias (though this can be mitigated). May not be practical for small vessels.	(Kingston et al., 2021)
Remote Electronic Monitoring (REM)	REM system. Effective data pipeline. Total effort to extrapolate to scale of fishery (unless 100% coverage)	Potential to achieve wider coverage (duration and proportion of fleet) per unit cost compared with observer programmes	Fishers have reservations about surveillance. Costs of ongoing maintenance and installation. Issues with ensuring efficient and reliable data processing.	(Glemarec et al., 2020)
Voluntary/self-reporting	Participating fishers Data collection protocol or system	Fishers have sense of ownership. Potentially low-cost. Real-time applications.	Hard to establish self-sustaining programmes at scale. Fishers are disincentivised especially where there are social sensitivities associated with bycatch species.	(Hetherington et al., 2016)
Fishery independent				
Tagging telemetry data	Telemetry data from species of interest Fishing effort	Can provide fine-scale insights into sensitive species movement ecology.	Fishing effort data is rarely available at the resolution of movement data. Costly. Usually only a small proportion of the population can be tagged.	(Queiroz et al., 2016; Cleasby et al., 2022)
Inference from strandings	Database of standings, can be complemented by necropsies	Can be employed at large spatial scales spanning jurisdictions.	Can be hard to determine bycatch as cause of death, or attribute bycatch strandings to specific gears. Stranding process introduces considerable uncertainty.	(Peltier et al., 2021)
Local ecological knowledge Social science	Fisher participation in interviews, focus groups etc	Draws on knowledge from those with direct lived experience. Can provide insights into patterns over the long-term.	Labour intensive. Requires voluntary participation. Fishers may be disincentivized to participate.	(Lucchetti et al., 2017; Leaper et al., 2022; Lin et al., 2023)
Predictive/model based				
Modelled species distribution and overlap with fishery	Fishing effort Species distribution data. Environmental covariates	Can generate predictions from limited species data. Can make future predictions under climate scenarios. Replicable methodology.	Resolution constrained by input data (fishing, environmental, species). Ideally outputs should be validated.	(Evans et al., 2021; Régnier et al., 2024)
Spatially explicit Productivity and susceptibility analysis (PSA)	Distribution data Fishing effort data Productivity and sensitivity trait data (or expert knowledge)	Can be applied to data-poor species (though still requires adequate distribution and fishing effort data to be spatially explicit. Can adopt a precautionary approach where data are missing.	It is subjective, sensitive to decision about attributes used, weighting and scores. Theoretical and statistical basis has been questioned, may perform badly for those species at intermediate risk.	(Astarloa et al., 2023)
Literature review				
Literature review or systematic review	Sufficient body of scientific and grey literature	May identify research gaps. Low cost. Makes existing knowledge more accessible.	Cannot fill research gaps. Grey literature can be hard to find. Time consuming.	(Carpentieri et al., 2021)

4.1 Fishery dependent

Bycatch data can be obtained directly from fisheries through: monitoring, including remote electronic monitoring (REM); statutory or mandatory reporting; voluntary self-reporting; and observer data. These data are sometimes used in conjunction with fishing effort (e.g. VMS data or logbook) to extrapolate to the scale of a fishery. Data collected by independent observers at-sea is often regarded as the most reliable source of bycatch data (Lewison et al., 2004; Gray and Kennelly, 2018). Observer data can be directly used to estimate bycatch rates and/or identify hotspots but it is also useful for validating or ground-truthing other approaches. However, two key limitations are commonly recognised. Firstly, observer effects may introduce bias, an extended discussion is provided by Babcock et al. (2003). Three principal issues have been identified: i) fishing practices/behaviours may change under observation, resulting in different rates of bycatch; ii) observation is typically voluntary, bycatch rates may differ between volunteers and non-participants; iii) logistical constraints mean sampling is rarely random, or appropriately stratified, for example challenges associated with accommodating an observer on smaller vessels. Secondly, the scale of fisheries and the costs associated with direct observation (either state-funded observer programmes, or independent scientific research) mean that achieving representative coverage can be extremely difficult and therefore resolution (in time and space) is usually limited (Lewison et al., 2004; Gray and Kennelly, 2018). The UK Bycatch Monitoring Programme (BMP) is a long-running, at-sea fishery dependent observer programme focused on sensitive species bycatch. This established programme has established significant trust with the industry, which is thought to mitigate the risk of observer bias (A. Kingston, pers. comm.). Limited resources necessitate a sampling strategy that is guided by policy drivers and adopts a risk-based approach. In 2019 sampling was carried out by observers during 215 days at sea (typically 400 days per annum, A Kingston, pers. comm.), this considerable undertaking only represents a tiny fraction of total UK fishing effort (Kingston et al., 2021). A recent review of the BMP and Commercial Catch Sampling Programme (CSP) found that although observer coverage of UK vessels was low, it was representative, as monitoring effort broadly reflected the distribution of fishing effort, notwithstanding some specific gaps identified (Kober et al., 2024). The ICES Working Group on Bycatch of Protected Species (WGBYC) collates and assesses information on bycatch monitoring and assessment for protected species. They report that average monitoring coverage (percentage of days-at-sea observed from total fishing effort) for the Greater North Sea ecoregion was 1.15% (due to missing data an equivalent figure was not reported for the Celtic Seas ecoregion) (ICES, 2023a). Similarly, Moore et al. (2023) employed ‘widespread’ and ‘substantial’ sampling within the Welsh pot fishery but their coverage was <1% of total fishing effort. Nevertheless, with appropriate design and statistical methods, robust bycatch estimates (with confidence intervals) can be produced from limited coverage, especially for more frequently encountered species. For further detail see ICES (2024b), for a detailed examination of the relationship between sampling design, the underlying bycatch rates and the precision and accuracy of resulting estimates.

As detailed above, there are clearly practical limits to what can be achieved by direct observation, whilst there are challenges associated with mandatory reporting (Calderan and Leaper, 2019). Mandatory reporting of marine mammal bycatch to the Marine Management Organisation (MMO) was introduced in 2021 as a vessel licence condition, allegedly only resulting in the reporting of “*one bycaught individual in 2021, two in 2022 and six in 2023*” (EIA, 2025). Consequently, there is growing interest in the potential for remote electronic monitoring and self-reporting as potentially cost-efficient approaches to improving coverage of fishery dependent bycatch data.

An example of electronic monitoring is provided by a nine-year study of seabird bycatch in Danish gillnetters, which found 40% of bycatch events were observed in just 0.2% of the hauls (Glemarec et al., 2020). This demonstrates the value of electronic monitoring programmes with extensive coverage, which may capture rare but significant events, likely to be missed with low observer coverage. However, there are numerous challenges associated with remote electronic monitoring, which include:

costs associated with installation and maintenance; finding efficient means of storing and processing large volumes of data; overcoming fishers' concerns about surveillance; reliably identifying species from imagery; and resolving technical issues (Mangi et al., 2015). Consequently, remote electronic monitoring has not yet been applied at scale in European fisheries (Calderan and Leaper, 2019).

In the UK, the Spurdog By-catch Avoidance Programme was a science-industry partnership, which compiled and shared self-reported spurdog (*Squalus acanthias*) bycatch data in near real-time, to allow fishers to avoid areas associated with elevated bycatch (Hetherington et al., 2016; Mangi et al., 2018). More recently, funded as part of the UK's BMI, there have been efforts to develop a smartphone-based self-reporting tool (Clean Catch App) and a low-cost remote electronic monitoring system (Insight360). These remain at the trial stage and are yet to have been used at scale to determine bycatch patterns in time and space or identify hotspots. Examples such as this are evidence of a paradigm shift away from scientists asking fishers to provide data, to genuine partnership or industry-led approaches where fishers are fully engaged in the process from design through to analysis (Dörner et al., 2015; Mangi et al., 2018). However, given the sensitivities associated with public perceptions of marine mammal bycatch (and perhaps to a lesser extent seabirds), fishers may justifiably be cautious about voluntary participation and the potential for adverse publicity in the bycatch space (Pierce et al., 2002). Partnership approaches to gathering fishery dependent data must therefore be the product of carefully considered co-design (for both bycatch monitoring and mitigation initiatives), to overcome barriers to participation and ensure equitable outcomes, rather than risk being tokenistic in their approach to engagement (Siddiqi, 2025; Siddiqi, in review).

4.2 Fishery independent

There is a considerable diversity in fishery independent approaches for identifying hotspots, examples include: inference from cetacean strandings and necropsies (Leeney et al., 2008); bycatch rates observed in stock-assessment or other scientific surveys (Piet et al., 2009); tagging to determine spatial behaviour of sensitive species in relation to fisheries (pelagic sharks, Queiroz et al., 2016; grey seals (Halichoerus grypus), Murray et al., 2021); citizen science, typically to obtain observations of sensitive species whose distribution is then considered in relation to fishing effort (Nielsen et al., 2021); shore and at-sea surveys to observe cetacean-fishery interactions (de Boer et al., 2012); social-science approaches, typically interviewing fishers (turtles in Italy, Lucchetti et al., 2017; whales in Scottish creel fishery, Leaper et al., 2022; marine mammals in the South China Sea, Lin et al., 2023).

Of these approaches, strandings data have been used repeatedly in the UK and adjacent waters to gain insights into sensitive species bycatch. In the UK, strandings of cetaceans (and some other marine megafauna) have been recorded by the Cetacean Strandings Investigation Programme (CSIP) and the Scottish Marine Animal Stranding Scheme (SMASS) since the early 1990s, see 'Section 5.1.1.5'. Although there has been some level of systematic recording since 1913 (Coombs et al., 2019b). There are also equivalent efforts in continental Europe. Depending on the condition of the carcass, necropsies allow the cause of death to be determined, which is commonly found to be bycatch. For example, bycatch was identified as the cause of death in 40% of stranding necropsies in the southwest from 1990-2019 inclusive (n=1,293 necropsies) (Long et al., 2022). However, there are biological, physical and social processes that make the interpretation of strandings data challenging, limiting the temporal and especially spatial precision with which inferences can be made (Coombs et al., 2019b). In the first instance it can be difficult to determine if bycatch is the cause of death (see discussion in Ijsseldijk et al., 2021). The ease of determining whether bycatch is the cause of death varies between taxa, for example, the external pathology of bycatch in seals is generally more subtle than in cetaceans (CWT, 2025). The overlapping nature of fisheries, means that it is extremely difficult to attribute bycatch strandings to specific fisheries to inform management (Peltier et al., 2021). Additionally, the likelihood of a bycaught carcass stranding varies according to several factors (e.g., currents, weather, distance to land), thus some hotspots may never be picked up, where carcasses are more likely to drift out to sea and/or sink. Nevertheless, the aggregation of these data has been used to identify temporal and regional hotspots (Leeney et al., 2008; Peltier et al., 2016; Long et al., 2022). The large spatial scale of strandings data, which can cut across administrative boundaries is a significant advantage (Peltier et al., 2016). Indeed this approach has been used to highlight potential shortcomings in bycatch estimates derived from observer programmes. Peltier et al. (2016) used strandings data to identify hotspots and estimate annual common dolphin (*Delphinus delphis*) bycatch mortality in the Celtic Sea, Western Channel and Bay of Biscay to be 3,650 to 4,700 dolphins year^{-1}, significantly more than an estimate of 550 dolphins year^{-1} based on their extrapolation from observer data. More recently, using French strandings data, bycatch mortality in the Bay of Biscay and along the Western Channel was estimated to be 9,040 common dolphins year^{-1} (95% CI, 6,640 - 13,300) between 2019 and 2021 (ICES, 2023b). These estimates highlight the uncertainty that persists around sensitive species bycatch and the value of employing multiple methods to gain understanding of patterns in time and space.

4.3 Predictive/model-based

Acknowledging the inevitable gaps in fishery dependent and independent data, a diversity of predictive or model-based approaches have been employed, typically to map predicted risk. The development and selection of these is often governed by data availability but also computational power and requisite expertise. This review of methods is not intended to be exhaustive and focusses on the most commonly employed approaches, which tend to have modest input data requirements and employ well-established, accessible techniques. Less common are spatio-temporal Bayesian models, which are powerful approaches able to handle ecological complexity and multiple source of uncertainty, though high computational costs and required expertise are barriers to implementation (for examples see Cosandey-Godin et al., 2015; Bi et al., 2021 and the citations therein).

4.3.1 Overlap between species distribution and fishing effort

One widely used approach is to map bycatch risk by combining modelled density distribution of sensitive species or habitat suitability, with fishing effort data from the fishery(-ies) of interest. The resulting output maps co-occurrence, as a proxy for bycatch risk and allows risk hotspots to be identified (e.g. seabird and cetacean species in the NE Atlantic, Evans et al., 2021; shark bycatch in Scottish waters, Régnier et al., 2024).

Fishing effort is usually sourced from: Automatic Identification System (AIS) data (vessels >15m), including publicly available Global Fishing Watch (GFW) data; VMS data and/or logbook data. Witt and Godley (2007) note in their analysis of UK VMS data that creating "*generalised, yet spatially and temporally explicit, understanding of fisheries effort…is far from trivial*". Access to and availability of fishing effort data, especially at finer resolution can be a challenge, particularly for smaller vessels in the inshore fleet, accordingly effort data is often biased towards larger vessels and offshore fisheries (Witt and Godley, 2007; Cleasby et al., 2022). For example, the vast majority of the UK static net fleet (>95% registered vessels) consists of smaller vessels (<12m) (Almeida et al., 2017), which are not mandated to carry AIS and only subject to the rollout of I-VMS from 2024. Glarou et al. (2022) circumvented this challenge, in a pilot study, by equipping small-scale fishery vessels with inexpensive off-the-shelf GPS loggers to predict overlap with marine mammals in the Mediterranean Sea.

Species data for input into distribution modelling is typically from: databases of presence records, e.g. the Ocean Biodiversity Information System (OBIS, 2021); dedicated fishery independent surveys, e.g.: Small Cetaceans in the European Atlantic and North Sea (SCANS), ship and aerial cetacean transects (SMRU, 2025); fishery stock assessment surveys (Régnier et al., 2024); tagging and telemetry data (Žydelis et al., 2011); and/or fishery dependent surveys, such as observer programmes (Elliott et al., 2020; Kingston et al., 2021) and discard data (Enever et al., 2007).

Species distribution models (SDMs) are widely used to predict the density distribution of marine (and terrestrial) species (Elith and Leathwick, 2009). Bioclimatic variables (e.g. depth, sea surface temperature, salinity) are combined with occurrence data, to model the bioclimatic envelope of a species and can be used to predict habitat suitability beyond the existing occurrence data (Guisan and Thuiller, 2005). This approach has been shown to work even with limited occurrence data (Elith et al., 2006), although some applications have been criticised, and it is argued that SDMs do not fully represent the underlying mechanism driving the distribution of species (Häkkinen et al., 2021). Density Surface Models (DSMs) build upon SDMs with a two-step approach. The first step accounts for detectability bias in the data, for example accounting for the fact that the detectability of cetaceans decreases with distance from a line transect (e.g. in SCANS surveys), before then modelling the effect of explanatory environmental covariates on distribution.

Both SDMs, DSMs and a multitude of other approaches can be sensitive to choices in the model selection and fitting process (Guisan and Thuiller, 2005). It can therefore be helpful to represent uncertainty in the prediction surface. It is also recommended that when considering model outputs, reference is made to the distribution of the underlying data: predictions will be less reliable in data poor areas. A further approach is to combine multiple distribution models, sometimes termed ensemble modelling. This recognises that each individual model will have weaknesses and that the 'average' prediction is more accurate and robust (Araújo and New, 2007), such multi-model approaches can also help quantify the variability in predictions (Jones et al., 2013). Whatever the approach, it is important to carefully consider the limitations and ensure that outputs are not over-interpreted. See Paxton et al. (2016) who discuss a cetacean DSM at 10 km resolution, advising that inferences are unlikely to be reliable at spatial scales less than 500-1,000 km^2. In general, all these approaches should be seen as useful tools at the regional level, rather than at local scales.

The marine environment is dynamic, the distribution of sensitive mobile mega-fauna, target species and associated fisheries respond to fluctuation in bio-physical conditions responding to meso-scale oceanographic features. Some have hypothesised that dynamic models, relating animal and fishery distribution to oceanographic characteristics may more accurately predict interaction between fisheries and bycaught species, than static modelling approaches described above (Žydelis et al., 2011). Žydelis et al. (2011) produced dynamic habitat models using telemetry data and concurrent remote sensing oceanographic data and found predicted overlap with fishing vessels correlated with actual bycatch recorded by observers in the Hawaiian long-line fishery. Such approaches could underpin adaptive management and may have increasing value in a context where anthropogenic climate change is resulting in greater environmental variability driving dynamic shifts in distributions.

The above modelling approaches can also be employed to predict future bycatch risk under different climate scenarios, given it is already recognised that the ranges of species and fisheries are shifting (Bastardie et al., 2021). In the absence of future fishing effort data, Jones et al. (2013) compare the predicted future distribution of threatened species vulnerable to bycatch with those of commercially targeted species. The latter serving as a proxy for fishing effort under the assumption that fishing effort is greatest where target species are most abundant.

4.3.2 Productivity and susceptibility analysis (PSA)

Productivity and susceptibility analysis (PSA) was originally developed as a semi-quantitative approach to assess the likely impacts of fisheries on data-poor bycatch species (Milton, 2001; Stobutzki et al., 2001). For potential bycatch species in a fishery, Stobutzki et al. (2001) assessed vulnerability on two axes: i) productivity, the "*capacity of a species to recover after the population is depleted*" defined by life-history characteristics; and ii) susceptibility, the propensity "*of a species to capture and mortality*", a product of how the fishing practices and gear interact with that species. Multiple criteria (or attributes) are then selected to determine the productivity (e.g. age at maturity, reproductive strategy) and susceptibility (e.g. spatial overlap with fishery, mortality rate when captured). A risk score is assigned to each criterion, from 1 (low), to 3 (high), based on the available information. For example, for ‘Age at maturity’ (an attribute of productivity), a species is scored: 1 (low risk, high productivity) where age at maturity is <5 years; 3 (high risk, low productivity) where it is >15 years; and scored 2 (medium risk, medium productivity) where age at maturity is from 5-15 years) (Hobday et al., 2011). In some instances, a weighting is also applied to each criterion, according to their perceived importance (e.g. Patrick et al., 2009; Astarloa et al., 2023). Where data are lacking, scores can either be based on similar taxa; or scored as higher risk adopting a precautionary approach (Patrick et al., 2009).

Those species with low productivity and high susceptibility are the most vulnerable to bycatch impacts and vice-versa. Whilst, PSA does not yield quantitative outputs to underpin management advice, it is seen as a practical first step, or triage approach, especially in data-poor situations (Cortés et al., 2015), informing or directing subsequent quantitative steps in a risk framework (see, Ecological Risk Assessment for the Effects of Fishing framework in: Hobday et al., 2011).

A PSA does not necessarily support the identification of geographic bycatch hotspots, though would identify specific (‘hot’) gears/fisheries posing greatest risk to species, or those species most at risk with a fishery. However, the incorporation of spatial (and temporal) information, relating to the distribution of the fishery and species of interest (see approaches in the previous section), supports a spatially explicit PSA, mapping vulnerability and identifying risk hotspots (Brown et al., 2013). Brown et al. (2015) scored a new susceptibility attribute (‘Exposure’) for each cell in a grid covering the study area, produced for each quarter to show seasonal variation. Exposure in a given cell is the product of the modelled abundance (density surface derived from survey data) and fishing effort (processed VMS data). A score is determined by logarithmic transformation of, the exposure in a given cell, divided by the mean exposure across the study area. This yields an exposure score for each cell which is treated as any other attribute in the PSA (i.e. assigned a score on a scale of 1-3). The resulting output maps relative risk in three categories (low, medium high) on a quarterly basis. Astarloa et al. (2023) provide a multi-taxa example of implementing a spatially explicit PSA partially in UK waters following the method of Brown et al. (2013). The Bycatch Risk Assessment (ByRA), a GIS toolbox, which implements a spatially explicit PSA, was developed using marine mammal bycatch by small scale fisheries in Vietnam and Malaysia as a test case (Hines et al., 2020; Verutes et al., 2020). It has subsequently been applied to map bycatch risk for 20 seabirds in time and space within the North East Atlantic Fisheries Commission (NEAFC) regulatory area, identifying hotspots (ICES, 2023c).

PSA has now been widely employed and adapted. The PSA structure and its simplicity make it accessible to scientists and other stakeholders in a wide range of contexts (Grewelle et al., 2021). Hordyk and Carruthers (2018) reported that in 23 separate studies it had been applied to over 1,000 bycaught species, including fish, elasmobranch, turtles, seabirds and marine mammals. This demonstrates a considerable strength of PSA: it has been used to evaluate the relative risk of bycatch across multiple species, fisheries and contexts. However, there are recognised limitations and criticisms. Clearly, there is an unavoidable degree of subjectivity in some elements (Tuck et al., 2011). Specifically, the selection of attributes and how they are weighted and scored. Consider the cut-offs for scoring of the ‘Age at maturity’ attribute (as detailed above) used by Hobday et al. (2011) developed for Australian fisheries. They specifically advise that *“values for the cutoffs between risk categories may need to be tuned for other regions*” as demographic rates and thus productivity will vary. Yet these cutoffs are often adopted in other studies without tuning or rational for their adoption (e.g. PSA in European waters, Astarloa et al., 2023). Despite the extensive application of PSA, only two studies have conducted an in-depth critical examination of the theoretical and statistical basis (Hordyk and Carruthers, 2018; Grewelle et al., 2021). Both studies, are critical of the standard approach to PSA, finding it performs poorly, especially for those species of intermediate risk from bycatch. Grewelle et al. (2021), propose a revised PSA addressing limitations of the standard approaches (i.e. Patrick et al., 2009; Hobday et al., 2011).

4.4 Literature review

A further approach to identifying hotspots is the review and synthesis of existing literature. To avoid biases, systematic reviews employ established protocols, such as ROSES (Haddaway et al., 2018), for searching, screening, reviewing and synthesising data, to ensure inclusion of all relevant information often from scientific and grey literature. Examples include reviews of: vulnerable species bycatch in Mediterranean and Black Sea Fisheries (Carpentieri, 2019; Carpentieri et al., 2021): seabirds in the Baltic Sea (Marchowski, 2021); and cetacean bycatch in the North Atlantic (including with reference to the Celtic Sea and North Sea) (Spencer et al., 2000). Two key challenges are apparent in such reviews. Firstly, depending on the volume of literature they can be time-consuming to undertake. Secondly, it can be difficult to synthesize different forms of evidence in a standardised manner (Žydelis et al., 2013), which would offer new insights into spatial (or temporal) patterns, and so such reviews often resort to providing a narrative account of findings.

4.5 Combining approaches

Many of the approaches described in the previous sections combine methods and data sources: using fishery dependent and fishery independent data as inputs to predictive modelling. For example, Cleasby et al. (2022) combine biologging data from three species of seabird and gillnet fishing effort to data predict UK bycatch risk hotspots in time and space. Elsewhere, this combination of telemetry tag data and fishing effort has been widely used to map bycatch risk, with applications including: leatherback turtles and Pacific longline fisheries (Roe et al., 2014); grey seals within the New England gillnet fishery (Murray et al., 2021); seabirds with longline and trawl fisheries in the Southern Ocean (Clay et al., 2019).

Others used independent approaches to validate (or reject) findings. Consider, the analysis of strandings data by Peltier et al. (2016), to assess the validity of common dolphin observer-based bycatch estimates, which highlighted the potential for significant underestimation. Runnebaum et al. (2020) used habitat suitability models for the target (American lobster, *Homarus americanus*) and bycatch species (cusk, *Brosme brosme*) to identify overlap and predict bycatch hotspots, which were then validated by graphically comparing to fishery dependent bycatch data. Similarly, Jubinville et al. (2021) modelled the distribution of three at-risk skate species and ten commercial targets, mapping co-occurrence to predict bycatch risk. The predicted bycatch risk was then included as an explanatory spatio-temporal covariate when modelling bycatch records from observer data. They report this approach to validating observer data as a proof-of-concept, noting concerns about spatial confounding effects, which prevented them from determining whether the explanatory power was significant.

4.6 Methodological challenges

A number of challenges were highlighted in the literature, that are of relevance to more than one of the methodological approaches detailed above. Many of these relate to the nature and availability of data. Obtaining reliable data on the bycatch of sensitive species faces two inherent challenges: i) events are often rare and patchily distributed in time and space, sometimes a product of the species involved often being endangered and/or existing at low density; and ii) bycatch of sensitive species is controversial and thus fishers are disincentivised from reporting bycatch, either voluntarily or in compliance with statutory obligations (Spencer et al., 2000; Gray and Kennelly, 2018). Bycatch issues within a fishery may also be cryptic and not readily apparent even to those directly involved. In a small cetacean population, the loss of a few individuals may have significant conservation consequences, however, if those bycatch mortalities happen across a large fleet then individual fishers may go years without a bycatch event and thus have no awareness that their fishery poses a threat (Pierce et al., 2002; Calderan and Leaper, 2019; EIA, 2025). This is seen in the Scottish creel fishery, where individual fishers experience entanglement events at a rate of <1 per decade, but the cumulative impacts are thought to have population-level consequences for minke (*Balaenoptera acutorostrata*) and potentially humpback whales (*Megaptera novaeangliae*) (MacLennan, 2021). Where bycatch data are available, in common with fisheries data more generally, these often exhibit zero-inflation, nonlinearity, nonconstant variance and spatio-temporal autocorrelation, which complicates the selection and implementation of statistical approaches (Ciannelli et al., 2008). Many studies highlighted the particular challenges of data availability in the coastal, inshore sector, where there can be large number of smaller vessels in diverse fleets, which are inherently difficult to monitor (Witt and Godley, 2007; Zydelis et al., 2009; Cleasby et al., 2022). Referring to observer data, though it applies more broadly, Spencer et al. (2000) observe the inherent challenges described above mean it is often difficult to collect sufficient data to test the relationship between bycatch rates and putative explanatory factors. For example, Moyes et al. (2025) relied on long-term BMP observer data (20,000 hauls from 1996-2023) to explore the relationship between marine mammal bycatch (harbour porpoise, common dolphins and seals) and potential explanatory variables in the UK static net fishery. A further issue is the lack of standard metrics across jurisdictions and fisheries for reporting bycatch, which reduces the potential for direct comparisons and integrated analyses (Žydelis et al., 2013; Lewison et al., 2014; Carpentieri et al., 2021). To combat this the ICES Working Group on Bycatch of Protected Species (WGBYC) have developed the Bycatch Evaluation and Assessment Matrix (BEAM), a methodology that systematically combines standardised fishing effort data, monitoring and bycatch data, provided by different jurisdictions in response to ICES data calls (ICES, 2024c). Using a traffic light system, data are evaluated across eight criteria. The application of the BEAM methodology allows estimation of bycatch for each species, providing a comparative approach to identifying hotpots across spatial units, noting it is currently applied at the ecoregion level (and more recently at the division level for selected species). The BEAM approach also assesses whether data are sufficient to implement a population impact assessment (PIA). Although at this stage in the development of BEAM, PIAs have not yet been made, largely due to a lack of quantitative reference points (A. Kingston, pers. comm.).

There are also issues specific to different groups of taxa. Identification challenges and amalgamation can impact data quality and taxonomic resolution, particularly among data relating to skate and ray bycatch data (Gray and Kennelly, 2018). Taxa whose movement spans both marine and terrestrial realms (principally seabirds but also seals) are often not adequately modelled by conventional approaches to species distribution modelling (Häkkinen et al., 2021).

A challenge downstream of identifying sensitive species bycatch hotspots is using them to inform mitigation measures, for example the design of spatial management measures. Bjørge et al. (2023) use a minimum convex polygon to encompass whale bycatch observations in identified hotspots in a Norwegian purse seine fishery, applying a 5 km buffer. This offers one practical approach that could be used to translate findings into evidenced-based management. Although, beyond the scope of this review, it is helpful to consider how findings relating to bycatch hotspots can be applied.

5 Systematic review of sensitive species bycatch hotspots

The 31 records from the systematic search were principally from the scientific literature, whilst the 39 records from the non-systematic search were largely drawn from the grey literature, including reports commissioned by government and produced by conservation NGOs. A higher proportion of these studies focussed on seabirds and cetaceans. Elasmobranchs were typically addressed in studies on discards, which often included, or focussed on, other fish species. Dedicated studies directed solely at elasmobranch bycatch, were comparatively rare. One exception, was the account of elasmobranch bycatch in the Welsh pot fishery by Moore et al. (2023), see 'Section 5.1.6'. Of those records reviewed, a minority had the explicit aim of identifying bycatch hotpots (or an equivalent term), for example, Northridge et al. (2023)'s analysis of seabird bycatch hotspots based on BMP observer data. Conversely, many of the studies presented data that offered some relevant insights (e.g. bycatch rates in a particular fishery) but without the specific aim of identifying hotspots. These provided less definitive evidence of bycatch hotspots, often lacking the comparison (with other areas, or reference points) to determine whether the issue was 'hot'. Such studies were nevertheless informative, especially in combination with other literature.

5.1 Hotspots by region

Six key multi-taxa datasets and analyses, with a geographic scope spanning the UK (or a wider area), that identify sensitive species bycatch hotspots were encountered through the literature search. These are detailed below along with the hotspots they identify. Further evidence of hotspots from other studies with narrower scope is presented subsequently, organised into five broad regions.

5.1.1 UK wide datasets and analyses

5.1.1.1 Bycatch Monitoring Programme (BMP)

Collecting data since 1996 (Northridge et al., 2023), the UK Bycatch Monitoring Programme (BMP) is an at-sea fishery dependent observer programme focused on sensitive species bycatch, with annual reports available online from 2011-2020, inclusive (more recent reports are anticipated shortly). Since 2005, seals, seabirds, marine reptiles and fish species of conservation interest have been formally included in the programme's remit. Observer sampling effort has been guided by perceived bycatch risk of specific gear and legislative drivers; it has been expanded from static net and pelagic trawl gears to include longline and ring-net fisheries. The BMP provides bycatch mortality estimates for harbour porpoise (*Phocoena phocoena*), common dolphin (*D. delphis*) and seals using a multi-annual ratio-based approach (estimation of bycatch per unit effort and extrapolation according to total effort, for each area/gear combination). Generic limitations of observer programmes (e.g. observer bias) are discussed above (see, 'Section 4.1'), with specific limitations noted here. Sampling is not wholly representative of the whole UK fleet. For example, there is very limited of coverage trap fisheries (Kober et al., 2024). Sampling was initially concentrated in static net and midwater trawl fisheries, as they were considered to pose the highest risk to marine mammals (the original focus of the BMP) (Northridge et al., 2023). Further, sampling and extrapolation is restricted to the UK fleet, so bycatch levels in UK waters may be substantially higher, especially in fisheries with a high proportion of non-UK vessels (e.g. demersal longline) (Anderson et al., 2022). Extrapolation relies on estimated bycatch per haul and days at-sea fishing effort data (logbook and sales notes from the IFISH database). However, effort data may be incomplete and contain inaccuracies and does not incorporate important variables (e.g. length of net fleet in static net fisheries, which would inform comparisons between metiers) (Kingston et al., 2021). Nevertheless, the BMP data are invaluable for identifying spatial patterns (including regional bycatch hotpots) and monitoring trends over time, particular in those fisheries thought to be of greatest bycatch concern. More detailed taxa-specific analyses and reports drawing on BMP data have sought to estimate bycatch mortality and identify hotspots for seabirds (Kingston et al., 2023a; Northridge et al., 2023) and marine mammals (Northridge, 2020; SCOS, 2022; Moyes et al., 2025). These and associated studies have sought to inform further research and/or management with respect hotspots, whilst considering the population scale response (seabirds, Miles et al., 2020; marine mammals, Northridge, 2020) and potential mitigation options (marine mammals, Northridge, 2020; seabirds, Anderson et al., 2022; seabirds, Kingston et al., 2023a).

The most recent available BMP derived UK bycatch estimates are for 2019 (excluding 2020, for which BMP bycatch estimates are available but both fishing and sampling was disrupted by Covid-19 pandemic) (Kingston et al., 2021; Kingston et al., 2023b). The estimated bycatch in the UK fleet was: 833 harbour porpoise (95% CI, 502 - 1,560); 278 common dolphin (95% CI, 165 - 662); and 488 grey (*H. grypus*) and harbour seals (*Phoca vitulina*) combined (95% CI, 375 - 872) (Kingston et al., 2021). Spatially, these as concentrated as follows: harbour porpoise in ICES Divisions VIId-g (English Channel & Celtic Sea) and IVc (Southern North Sea); common dolphin, in ICES Divisions VIIe-g (Western English Channel and Celtic Sea); and seal bycatch in ICES Divisions VIId-g (English Channel and Celtic Sea) with lower levels in ICES Subarea IV (North Sea) (Kingston et al., 2021; Kingston et al., 2023b). This pattern is driven by the distribution of static net fishing effort, as static nets are considered to pose the greatest threat to marine mammals (Northridge, 2020), with effort concentrated in ICES Subarea VII (Channel and Celtic Sea), with smaller amounts in the North Sea. Further analysis by Northridge (2020) indicates that within these areas bycatch rates for harbour porpoise (events per haul) are higher in offshore than inshore (<12nm) waters. The SCOS report that seal bycatch is also principally from static nets (gillnets, tangle nets and trammel nets), especially those with larger meshes (SCOS, 2022). Annual estimated combined harbour and grey seal bycatch in static nets is typically 400-600 seals per year, the majority being from the southwest: 74% of static net seal bycatch in 2020 was from ICES Subarea VII (SCOS, 2022). Northridge (2020) report that seal bycatch rates in the UK are generally highest in the Celtic Sea between 50° N and 52° N, and that bycaught seals are predominantly juvenile grey seals.

Using BMP data from 20,000 observed static net hauls (seven net metiers) between 1996-2023 spanning the UK, Moyes et al. (2025), sought to identify associations between bycatch per haul and explanatory variables (spatio-temporal, environmental and operational). They also used a subset of the data to assess the efficacy of acoustic deterrent devices (ADDs) at mitigating bycatch of harbour porpoise, seals and common dolphins (see, 'Section 6.2'). They found that harbour porpoise and common dolphin bycatch per haul were stable until 2014. Subsequently, harbour porpoise bycatch per haul has been decreasing, whilst it has been increasing for common dolphins. A trend which has been noted in an analysis of UK strandings necropsy data (Chadwick et al., in prep.). Seal bycatch per haul has been gradually increasing though the period covered by the study. Association between the observed bycatch per haul and those explanatory variables of relevance to this review are summarised in Table 4.

Table 4: Association of explanatory variables and observed bycatch per haul in the UK static net fishery. Based on BMP data from 20,000 observed static net hauls (seven net metiers) from 1996 to 2023. Summary of findings presented in: Moyes et al. (2025).

Taxa	**Association of variable with bycatch per haul**			
	Season	**Depth**	**ICES Division**	**Metier**
Harbour porpoise	Highest in autumn (August to October) and to a lesser extent early spring (February to March)	Decreases with depth across the range in which most observed hauls occur (10-150m)	Highest in VIa, VIIg and VIIf. Although these differences were not statistically significant in the predictive model.	Vulnerable across the range of metiers.
Common dolphin	Highest through the winter, with the highest rates between November and March	No clear pattern.	Highest in VIIg and VIIh. Although these differences were not statistically significant in the predictive model.	Highest in: i) Hake gillnets (offshore fishery, using nets ~6 m high, with a typical mesh size of 125 mm); and ii) Tangle/Trammel nets (<1 m high operated in both inshore and offshore waters).
Seals	Highest from late autumn to early spring (October to April).	Decreases with depth across the range in which most observed hauls occur (10-150m)	Highest in VIa and VIIj. Although these differences were not statistically significant in the predictive model.	Highest in Tangle/Trammel nets (<1 m high operated in both inshore and offshore waters)

Northridge (2020) determined that the estimated bycatch rates from UK vessels for harbour porpoise, common dolphin and seals are unlikely to represent a conservation threat, but that a fuller assessment would reflect bycatch from UK and non-UK vessels, see such assessment in 'Section 5.1.1.6'.

Using data from 21,000 BMP observed hauls, Northridge et al. (2020) made preliminary estimates of seabird bycatch by UK vessels in: i) the offshore longline fishery for hake (predominantly shelf edge north of Scotland but also in the Celtic Sea); ii) static net fisheries around the UK; iii) and the midwater trawl fishery in the English Channel. Northern fulmar (*Fulmarus glacialis*) bycatch in the offshore longline fishery was estimated to be 4,500 (95% CI, 2,200 - 9,100) per annum. Common guillemot (*Uria aalge*) bycatch was estimated to be 1,800 and 3,300 per annum, mainly from coastal static net fisheries, though they are also recorded offshore. Other seabird species caught in the fisheries covered by BMP observer effort are likely taken in the dozens per year, except for cormorant (*Phalacrocorax carbo*) and northern gannet (*Morus bassanus*), which may number in the hundreds.

There is considerable uncertainty in the estimated northern fulmar bycatch in the longline fishery, evident in the wide confidence interval (estimate 4,500; 95% CI, 2,200 - 9,100), which arises from a small sample size (Northridge et al., 2020). Kingston et al. (2023a) subsequently provided revised estimates for the offshore longline fishery, using additional data (from subsequent BMP sampling) and an alternative methodology. They estimated annual bycatch in the fishery of: 1,000 to 2,000 northern fulmars; 50 to 150 northern gannets; 10 to 20 great shearwaters (*Puffinus gravis*); and 10 to 20 great skua (*Stercorarius skua*). They also note that effort and associated bycatch, has been increasing in the fishery over the past two decades. This is part of the wider 'Gran Sol area' (ICES Subareas VI, VII and VIII) offshore longline hake fishery, which has an estimated total bycatch of 36,000 birds per year, making it one of the key priority fisheries for addressing bycatch in European waters (Ramírez et al., 2024). Although there is uncertainty around the accuracy of this estimate, which the authors note is based on limited available data.

Northridge et al. (2023) combined BMP data with at-sea commercial catch sampling programme (CSP) data from England and Wales collected by Cefas, to identify regional seabird bycatch hotspots. They highlight the bycatch of northern fulmars (and other seabirds) in the offshore longline fishery along the shelf edge north of Scotland. The highest gillnet bycatch rates, principally composed of guillemots, cormorants and razorbills (*Alca torda*), were off the Northeast of England, off southeast Ireland, along parts of the South coast of England and off Shetland. Guillemot and cormorant bycatch was most frequent in gillnets set in shallow water (<20 m), in winter months, particular in those areas identified. Among observed midwater trawling operations, most bycatches were of guillemots in the Western Channel. The CSP data provides some additional insights, including in fisheries not covered by BMP sampling (e.g. demersal trawling). However, the CSP's primary focus is on commercial species discard rates, consequently the dedicated BMP observation yields much higher bycatch rates. For example, CSP data indicates there is some seabird bycatch in demersal trawls, mostly of northern gannets. Northridge et al. (2023) caution that this observation "*should be viewed in the context of data collection protocols within the CSPs potentially leading to underestimates*".

Miles et al. (2020) assessed the potential population-scale response of ten seabirds to bycatch and the implementation of effective mitigation in the UK by combining population estimates with BMP derived estimates of bycatch mortality (Northridge et al., 2020). This does not identify any new hotspots, beyond those already highlighted by Northridge et al. (2020) but does provide insight into the 'hotness' (i.e. magnitude) of the potential population impacts. Miles et al. (2020) assessed population-level consequences at two spatial scales: UK-wide; and at the Marine Strategy Framework Directive (MSFD) region-level for Celtic Seas and the Greater North Sea. The median estimated bycatch mortality was greater than 1% of annual mortality for seven of the ten species in one or more of the regions. Miles et al. (2020) explain that the 1% threshold, has been applied in other contexts (e.g. windfarm impact assessment), and derives from European Union (EU) guidance on the concept of “small numbers” that may be hunted or taken judiciously under Article 9 of the Birds Directive. Those seven species being common guillemot (*U. aalge*), European shag (*Phalacrocorax aristotelis*), great black-backed gull (*Larus marinus*), great cormorant (*P. carbo*), great northern diver (*Gavia immer*), northern fulmar (*F. glacialis*), and northern gannet (*M. bassanus*). Modelling indicates that removal of bycatch mortality over a 25-year projection period would lead to at least a 1% population increase for three species (great cormorant, great northern diver and northern fulmar). The modelled impacts of removing bycatch mortality were greatest for cormorant and fulmar, with potential median estimated UK population increase of 2.0% and 6.9% over 25 years, respectively. Regionally there is the potential for greater population size impacts from bycatch removal, notably for fulmar in the Celtic Seas with an estimated increase of 19.8% (95% CI, 6.6 - 52.1%) over 25 years. Miles et al. (2020) note that these significant modelled population increases over a 25-year period are primarily a product of removing the observed bycatch mortality associated with inshore static nets (for great-northern diver, cormorant) and offshore longlines (for fulmar).

5.1.1.2 UK seabird bycatch risk assessment

Bradbury et al. (2017) sought to map the relative risk of seabird bycatch across the UK, in summer (April to September) and winter (October to March), by combining species distribution models with fishing effort. Risk, or vulnerability, was a product of sensitivity (a score based on expert assessment of conservation status, life history, behavioural traits etc.) and exposure to those gears to which species were deemed sensitive. Though the term was not used in this study, the approach is similar to the spatial PSA approach (see, ‘Section 4.3.2’). To determine vulnerability to different gears, Bradbury et al. (2017) reviewed the information provided by an ICES workshop to review and advise on seabird bycatch (ICES, 2013), which summarised the available evidence for marine bird bycatch from different fishing gears.

Table 5: Seabirds likely or known to be at risk of bycatch from specific gears. Reproduced from: Bradbury et al. (2017) based on ICES (2013).

Gear	**Species at risk**
Static nets	Auks, shearwaters, Northern gannets, Great cormorants, European shags, common scooters (*Melanitta nigra*) and other diving ducks and divers;
Longlines	Northern fulmars, Balearic shearwaters (*Puffinus mauretanicus)*, northern gannets, gulls, Cory’s shearwaters (*Calonectris borealis*), great cormorants, auks, terns, European shags and great skuas
Purse seines	Balearic shearwaters, Cory’s shearwaters, northern gannets, gulls and auks
Beach and boat seines	Common scooters and black-headed gulls (*Chroicocephalus ridibundus*)
Demersal trawls	Northern gannets, cormorants, European shags, shearwaters and gulls
Pelagic trawls	Northern gannets
Pots and traps	European shags

Fishing gear types were then allocated to one or more of three depth categories (‘surface, ‘pelagic’, ‘benthic’), according to where the gear posed a risk to seabirds. For example, pelagic trawls were allocated to both the pelagic category and surface category, as this gear was deemed to pose a risk both when fishing at midwater depths and at the surface during shooting and hauling. The sensitivity scores assigned allowed identification of the most at-risk species in each of the three depth categories (Table 6), often largely driven by factors such as entrapment risk at that depth, and high proportion of the population existing within the UK.

Table 6: Most sensitive species to bycatch in three depth ranges. From: Bradbury et al. (2017)

Depth	**Most sensitive species** (top 10% of sensitivity scores)
Surface	Northern gannets, northern fulmars, shags, guillemots, razorbills, black guillemots (*Cepphus grylle*) and Atlantic puffins (*Fratercula arctica*)
Pelagic	All the auks (except little auk for which the UK has only a small percentage of the biogeographic population), together with shags, great northern diver and northern gannets
Benthic	Shags, Greater scaup (*Aythya marila*), common eider (*Somateria mollissima*), scooters, guillemots, great northern divers and cormorants

Bradbury et al. (2017) produced six vulnerability/risk maps, one for each combination of season (summer and winter) and depth (surface, pelagic and benthic), highlighting risk hotspots summarised in Table 7. The authors note that comparison of their results with the literature, shows that there are a number of instances where previously reported bycatch hotspots can be predicted from the study's outputs.

Table 7: Summary of UK seabird bycatch risk hotspots, at three depths (surface, pelagic and benthic), in summer and winter as identified by Bradbury et al. (2017).

DEPTH	**SEASON**	
	Summer	**Winter**
Surface	Highest risk areas: south of Farne Deeps in the North Sea; and the Scottish coast, including Outer Firth of Forth, Moray Firth, The Minch, The Sea of Hebrides, Firth of Clyde and North Channel of the Irish Sea. Other relatively high-risk areas are: Fladen Ground in the northern North Sea, NE Scotland; Rockall Bank, NW Scotland; Scottish shelf break; Dogger Bank, North Sea; and the Western English Channel and Celtic Sea (Lyme Bay around the Devon and Cornish coasts to Lundy and Pembrokeshire). Smaller, scattered hotspots of higher risk are in: the Wash and Outer Thames Estuary in the North Sea; Eastern English Channel; and off Cumbria.	The pattern is similar to summer though with less fishing effort over Dogger Bank reducing risk here and risk increasing along England's south coasts due to increase in fishing effort and the seasonal movement of vulnerable seabird species such as gannets, guillemots and razorbills.
Pelagic	Highest risk areas: the Scottish shelf break; around Shetland, NE Scotland; North Channel of the Irish Sea; and to a lesser extent the Celtic Sea. Scattered hotspots such as off Flamborough head in the summer	Similar pattern to summer, with decreasing risk in Scottish waters and increases in Celtic Sea and Eastern Channel.
Benthic	Same pattern as surface partly a reflection that benthic gears were also scored as posing a risk at the surface when hauled	

However, others have noted these maps are "*quite difficult to interpret*" (Northridge et al., 2023). The allocation of gears to depth classes is somewhat counterintuitive, as all gears were included in the surface class, as they pose a risk during shooting and hauling, irrespective of the depth at which they are fished. Further, Kober et al. (2024) observed that "*the bird communities identified by Bradbury et* *al. (2017) to be potentially at risk from different gears did not always accurately reflect current knowledge about marine bird species bycatch in UK fisheries*". Whilst distribution and sensitivity were considered at the species level, risk was aggregated for all species to produce the six risk maps. These factors mean that it is hard to identify hotspots arising from the interaction between specific fisheries and species, on which to focus future efforts from the outputs. It is also important to recognise that fishing effort was determined from VMS data, which at that time was only available from UK vessels >15 m. The lack of representation of inshore fishing effort by small vessels means that significant bycatch hotspots may not be highlighted as a high-risk areas. For example, the authors note that Filey Bay was in relatively low risk grids cells, despite there being well-documented significant bycatch of razorbills and guillemots by small inshore gillnetters, at that time, see '6.1 Case study 1: Filey Bay' and Bradbury et al. (2017).

5.1.1.3 North-Eastern Atlantic cetacean and seabird bycatch risk assessment

Evans et al. (2021) produced maps of relative risk of bycatch for 12 cetacean and 12 seabird species in the North-Eastern Atlantic region between southern Scandinavia and the Iberian Peninsula. In this analysis risk is mapped "*almost entirely as a function of spatiotemporal overlap*" between fisheries and species, rather than incorporating life history information relating to sensitivity. This was achieved by multiplying AIS fishing effort data (representing different gears) and modelled species density to create quarterly rasters of relative bycatch risk. The susceptibility of each study species to each gear was scored (from 1=high risk interaction; to 3=low risk interaction) based on a literature review and expert opinion. Risk maps for all species-gear combinations were produced but only those deemed most susceptible (score of 1) were presented in the report and visually assessed to identify hotspots. These are summarised here for cetaceans (Table 8) and seabirds (Table 9). The use of AIS fishing effort data from GFW was validated by comparison with VMS data and was found to be broadly similar. However, AIS data is not available from vessels <15m. Thus, effort from smaller vessels, largely operating inshore is not represented. In the UK context, this results in underestimation particularly of the risk posed by the large inshore static net fleet. Evans et al. (2021) did not attempt validation of their findings. However, they did note that some areas and times with predicted high bycatch correspond with known high rates of bycatch. Examples in UK waters were: harbour porpoise in the eastern English Channel, as previously identified elsewhere (e.g. Calderan and Leaper, 2019); northern fulmars from long-lining on the shelf edge north of Scotland; northern gannet bycatch from a variety of gears and areas (Northridge et al., 2020).

Table 8: Areas identified as of relatively high bycatch risk for species and their interaction with specific gear types, for 12 cetacean species assessed by Evans et al. (2021).

Species	**Gear**	**Area (and season) of relative high bycatch risk**
Harbour porpoise (*P. Phocoena*)	Gillnets	Eastern part of the English Channel (year-round)
		Western English Channel (between July and September)
Bottlenose dolphin (*Tursiops truncatus*)	Gillnets	Celtic Sea to the south of Ireland
Common dolphin (*D. delphis*)	Demersal trawls	Celtic Sea and western English Channel (year-round)
	Demersal seines	Celtic Deep, in the Celtic Sea (July to September)
		Central English Channel (October to March)
	Gillnets	Gillnets in the Celtic Sea (year-round but particularly April to December)
	Gillnets	Western English Channel (July to December)
White-beaked dolphin (*Lagenorhynchus albirostris*)	Pelagic trawls and seines	North-western North Sea (July to December)
		Various locations north and west of Scotland (January to June), extending to North Channel and west of Isle of Mann in the Irish Sea
	Gillnets	North of the Shetland Isles (April to June)
Atlantic white-sided dolphin (*Leucopleurus acutus*)	Pelagic trawls and seines	Northwest of Scotland (April to June)
	Gillnets	Shelf edge north of the Shetland Isles (April-June)
Risso's dolphin (*Grampus griseus*)	Demersal trawls	Celtic Sea and western English Channel (year-round)
	Gillnets	Western English Channel (year-round)
		Celtic Sea (April to September)
	Set longlines	Shelf edge west of Scotland (mainly between October and June)
	Drifting longlines	Celtic Sea (July to September)
Sperm whale (*Physeter macrocephalus*)	Set longlines	West of the Scottish Hebrides (January to June)

Table 9: Areas identified as of relatively high bycatch risk for species and their interaction with specific gear types, for 12 seabird species assessed by Evans et al. (2021).

Species	**Gear**	**Area (and season) of relative high bycatch risk**
Red-throated diver (*Gavia stellata*)	Gillnets	Eastern English Channel/Strait of Dover (between January and June)
Manx shearwater (*Puffinus puffinus*)	Set longlines	Shelf edge north and west of Scotland (April and September)
	Drifting longlines	Offshore in Celtic Sea (July to September)
Northern fulmar (*F. glacialis*)	Gillnets	North and west of Shetland (January to June)
	Set longlines	Shelf edge west and north of Scotland (year-round)
Northern gannet *(M. bassanus*)	Pelagic trawls and seines	North-western Irish Sea (year-round, but particularly between July to September)
		Hebrides (year-round, but particularly April-September)
		North-east Scotland (year-round, but particularly July-September)
	Gillnets	Eastern English Channel (year-round)
		Celtic Sea (July to September)
Common guillemot (*U. aalge*)	Gillnets	Eastern English Channel (year-round)
		Celtic Sea (January to June)
Razorbill (*A. torda*)	Gillnets	Celtic Sea, south of Cornish peninsula (January to March)
		Eastern English Channel (year-round)

5.1.1.4 SEAwise risk assessment for selected species and areas

The SEAwise project conducted a spatially explicit PSA (see, ‘Section 4.3.2’) covering all gears in the North Sea, Bay of Biscay and Celtic Seas for: common skate complex (*Dipturus spp.*), spurdog (*S. acanthias*), tope (*Galeorhinus galeus*), spotted ray (*Raja montagui*), undulate ray (*Raja undulata*) and starry ray (*Amblyraja radiata*) (Astarloa et al., 2023).

The analysis identified extensive areas of high risk to common skate from otter trawling, static nets and beam trawling in the Celtic Sea and Western Channel, with moderate risk from otter trawling in northeast Scotland. The highest spurdog bycatch risk was from beam trawls, otter trawls and static nets in the Celtic Sea and from otter trawling in the North Sea east of Scotland. Tope were identified as being at high risk from beam trawls, otter trawls, static nets throughout the Celtic Sea, Channel and southern North Sea. Spotted ray were at the highest risk in the Celtic Sea, Channel and southern North Sea from beam and otter trawls. Undulate ray were at high risk from: beam trawling in the eastern English Channel and southern North, static nets in isolated patches in the Channel; and otter trawling throughout the Channel and eastern Celtic Sea. Starry ray were at highest risk from beam trawling in the southern North Sea and otter trawling in the central and northern North Sea. Additionally, a spatially explicit PSA was produced for blonde ray (*Raja brachyura*) beam trawl bycatch in the Greater North Sea ecoregion. The highest risk was in the central and southern North Sea, where beam trawl effort is concentrated, particularly off the southeast coast of England.

General criticisms of the PSA approach are briefly discussed above (see, ‘Section 4.3.2’) and acknowledged by Astarloa et al. (2023). A particular limitation in this application is the reliance on VMS data. The areas of higher bycatch risk identified are clearly a product of the underlying distribution of fishing effort. Given the under representation of small vessels, which represent a significant component of the UK fleet, this may underestimate areas of risk, for example inshore waters targeted by static nets, typically from smaller vessels. The study also only examines a handful of species within the study area of this review (other taxa and regions outside of the scope of this study are addressed), which does not provide as holistic a picture as other studies detailed in this section ('Section 5.1.1').

Astarloa et al. (2023) also discuss bycatch thresholds (the level of bycatch mortality that a population can sustain), specifically: MSY; fixed percentages of abundance; Potential Biological Removal (PBR) and modified PBR (mPBR); and the Catch Limit Algorithm (CLA) and the analogous Removal Limit Algorithm (RLA). For ten species in multiple regions, they determined the most appropriate threshold and estimate of bycatch mortality to assess whether current bycatch rates were sustainable. Those assessments within the scope of this review are shown in Table 10, noting that the bycatch of common dolphin in the Northeast Atlantic and harbour porpoise in the North Sea were assessed as unsustainable.

Table 10: Bycatch impact on populations based on the thresholds and total mortality estimates. From: Astarloa et al. (2023).

Species	Region	Threshold	Threshold procedure	Fishing mortality*	Unit	Impact
Mammals						
Common dolphin	NE Atlantic	985 4,927	mPBR PBR	6,404	Individuals	Unsustainable
Harbour porpoise	North Sea	1,622	RLA	1,627-5,929	Individuals	Unsustainable
Grey seal	North Sea	7,617	PBR	229	Individuals	Acceptable
Elasmobranchs						
Spurdog	NE Atlantic	17,353 17,855	MSY 2023 MSY 2024	1,178 (639)	tonnes	Acceptable
Undulate ray	Channel	4,836 4,675	MSY 2023 MSY 2024	2,959 (2,754)	tonnes	Acceptable

*sum of landings and discards for elasmobranchs. Discard quantity is indicated in brackets '()'.

5.1.1.5 Strandings investigation programmes

Strandings of cetaceans (and some other marine megafauna) have been recorded by the Cetacean Strandings Investigation Programme (CSIP) and the Scottish Marine Animal Stranding Scheme (SMASS) since the early 1990s. The programmes carry out necropsies on a subset of stranded cetaceans (and more recently seals) according to standard necropsy protocols (e.g. IJsseldijk et al., 2019). Necropsies are conducted in pathology laboratories, or in-situ where retrieval is not feasible due to size or location (Deaville et al., 2018). Each necropsied animal has a responsible veterinarian who contemporaneously determines the cause of death by gross examination, with ancillary testing (e.g. bacteriology, virology, histology) as required. There are two causes of death identified by the CSIP and SMASS programmes of relevance to bycatch.

1. Bycatch: *"Death due to incidental capture in fishing gear. Pathology usually characterised by healthy animals in good condition, evidence of recent feeding with lung pathology consistent with anoxic drowning (stable foam in bronchi and trachea) and congestion of several organs. Sometimes net marks visible on fins, flukes or flank occasionally trauma to beak, removal of tail flukes and rarely fractures to vertebrae."*

2. Entanglement: "*Usually only applies to large whales (particularly minke and other mysticetes)... Animals are often seen with gear still wrapped around their bodies, usually flukes and fins but occasionally through baleen plates in the mouth. Acute cases similar to bycatch, sub-acute cases result in exhaustion and impaired feeding. Chronic cases often very thin and debilitated and show chronic wounds caused by abrasion and pressure from entangled equipment*."

From: Brownlow et al. (2018)

Entanglement may include entanglement in other marine debris, as well as active or discarded fishing gear (Deaville et al., 2018), although fishing is the underlying cause in the vast majority of entanglement cases. Typically, entanglement is associated with static gears, principally strings of pots/traps (known as creels in Scotland).

As detailed in 'Section 4.2', biological, physical and social processes make the interpretation of strandings data challenging, limiting the temporal and spatial precision of inferences (Coombs et al., 2019a). It is worth reiterating that, bycatch and entanglement can be difficult to diagnose, as injuries (e.g lesions) are not always straightforward to distinguish from other causes, particularly when decomposition is advanced. Further, attribution to specific gear types or fisheries is rarely possible without recovered gear. Therefore, bycatch and entanglement may be underdiagnosed. It is also important to note that selection of carcasses for necropsy by CSIP, SMASS and partners is not random. The decision is based on carcass condition, species, logistics and available resources. This can lead to spatial biases towards more accessible or densely populated coastlines, where carcasses are more likely to be reported or easier to recover. Additionally, discovery and reporting effort vary temporally. Further considerations are that no data is presented here from continental strandings, which may be downstream (in terms of prevailing wind and currents) of UK fisheries. Similarly, strandings caused by bycatch or entanglement may originate from interaction with fisheries outside of the UK. Indeed, there has been at least one instance where the gear recovered from the stranded cetacean has been determined to have originated from a fishery outside the UK EEZ. Specifically, a stranded humpback whale (*M. novaeangliae*) recovered from Scrabster, northern Scotland, was found entangled in a rope and buoy whose marking indicated it originated from a fishing vessel operating in Nova Scotia, eastern Canada (Davison et al., 2019). Nevertheless, the broad spatial and temporal patterns in UK strandings necropsy data, can serve to corroborate hotspots (both spatial and temporal) identified through other methods.

A comprehensive analysis of 30 years (1991 to 2020) of UK cetacean stranding necropsy data is underway (Chadwick et al., in prep.). In this review we present stranding necropsy records provided by CSIP and SMASS for the period 2015 to 2024, inclusive. Older records were deemed not necessarily representative of current cetacean distribution and/or fishery operation. For example, it is thought that there have been significant shifts in the distribution of some cetacean species within UK waters in recent decades, as discussed in (Moyes et al., 2025), with associated changes in spatial distribution of strandings (R. Deaville, pers. comm.). From 2015 to 2024, there were 1,350 cetacean strandings subject to necropsy, for which cause of death was determined in 1,279 cases (Table 11). For the purpose of this review, these cases were assigned to one of three categories of cause of death: 'Bycatch; 'Entanglement' (including both acute and chronic cases); and 'Other'. The latter encompassing all other determined causes of death (infectious disease, starvation, attack by other animal etc).

Table 11: Summary of cause of death determined by necropsy, for stranded cetaceans from 2015 to 2024, inclusive (n=1,279). Those necropsies where cause of death could not be determined are not included (n=71). The number of records for each cause of death are presented followed by the percentage in parentheses '()'. Data: England, Wales and Northern Ireland, CSIP; Scotland, SMASS.

Species	**Cause of death as determined by necropsy**			
	Bycatch	**Entang.**	**Other**	**All**
Harbour porpoise (*Phocoena phocoena*)	48 (9%)	0	481 (86%)	529
Common dolphin (*Delphinus delphis*)	97 (22%)	0	320 (73%)	417
Long-finned pilot whale (*Globicephala melas*)	0	0	90 (100%)	90
Striped dolphin (*Stenella coeruleoalba*)	1 (3%)	0	33 (97%)	34
Common bottlenose dolphin (*Tursiops truncatus*)	3 (9%)	0	29 (83%)	32
White-beaked dolphin (*Lagenorhynchus albirostris*)	0	0	31 (97%)	31
Sowerby's beaked whale (*Mesoplodon bidens*)	0	1 (3%)	30 (94%)	31
Minke whale (*Balaenoptera acutorostrata*)	1 (3%)	7 (23%)	21 (70%)	29
Risso's dolphin (*Grampus griseus*)	2 (8%)	1 (4%)	22 (85%)	25
Sperm whale (*Physeter macrocephalus*)	0	0	13 (81%)	13
Fin whale (*Balaenoptera physalus*)	0	0	9 (75%)	9
Northern bottlenose whale (*Hyperoodon ampullatus*)	0	1 (11%)	7 (78%)	8
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	0	0	7 (100%)	7
Humpback whale (*Megaptera novaeangliae*)	0	5 (83%)	1 (17%)	6
Pygmy sperm whale (*Kogia breviceps*)	0	0	5 (100%)	5
Orca (*Orcinus orca*)	0	2 (33%)	3 (50%)	5
Sei whale (*Balaenoptera borealis*)	0	0	3 (100%)	3
Cuvier's beaked whale (*Ziphius cavirostris*)	0	0	3 (75%)	3
True's beaked whale (*Mesoplodon mirus*)	0	0	2 (100%)	2
All species	152 (12%)	17 (1%)	1,110 (87%)	1,279

Necropsies (where cause of death was determined) were conducted on 19 different species. Bycatch was found to be the cause of death in 12% of necropsies, affecting six species. Entanglement was found to be the cause of death in 1% of necropsies, affecting 6 species. The majority of necropsies were of two species: harbour porpoise (*P. phocoena*), common dolphin (*D. delphis*), which within UK waters are the two most abundant species of cetacean and are widely distributed (Waggitt et al., 2020; Gilles et al., 2023). The spatial distribution of these records is presented separately with the remaining species aggregated (Figure 3). In general, necropsied strandings where the cause of death is 'Other' are distributed more broadly, whilst bycatch and entanglement cases are clustered in specific areas.

Harbour porpoise bycatch strandings are predominantly in the Channel, Western Approaches and Celtic Sea coasts. Whilst common dolphin bycatch strandings are more concentrated in the Celtic Sea coasts, particularly the southwest coast of Cornwall. With one exception, entanglements (n=17) were confined to Scotland, involving five species, predominantly minke (n=7) and humpback (n=5) whales. Note, the single entanglement outside of Scotland was a minke whale stranded at Spurn Head, where cause of death was chronic entanglement in material that was "*consistent with marine debris rather than active set [fishing] gear*" (Deaville et al., 2020).

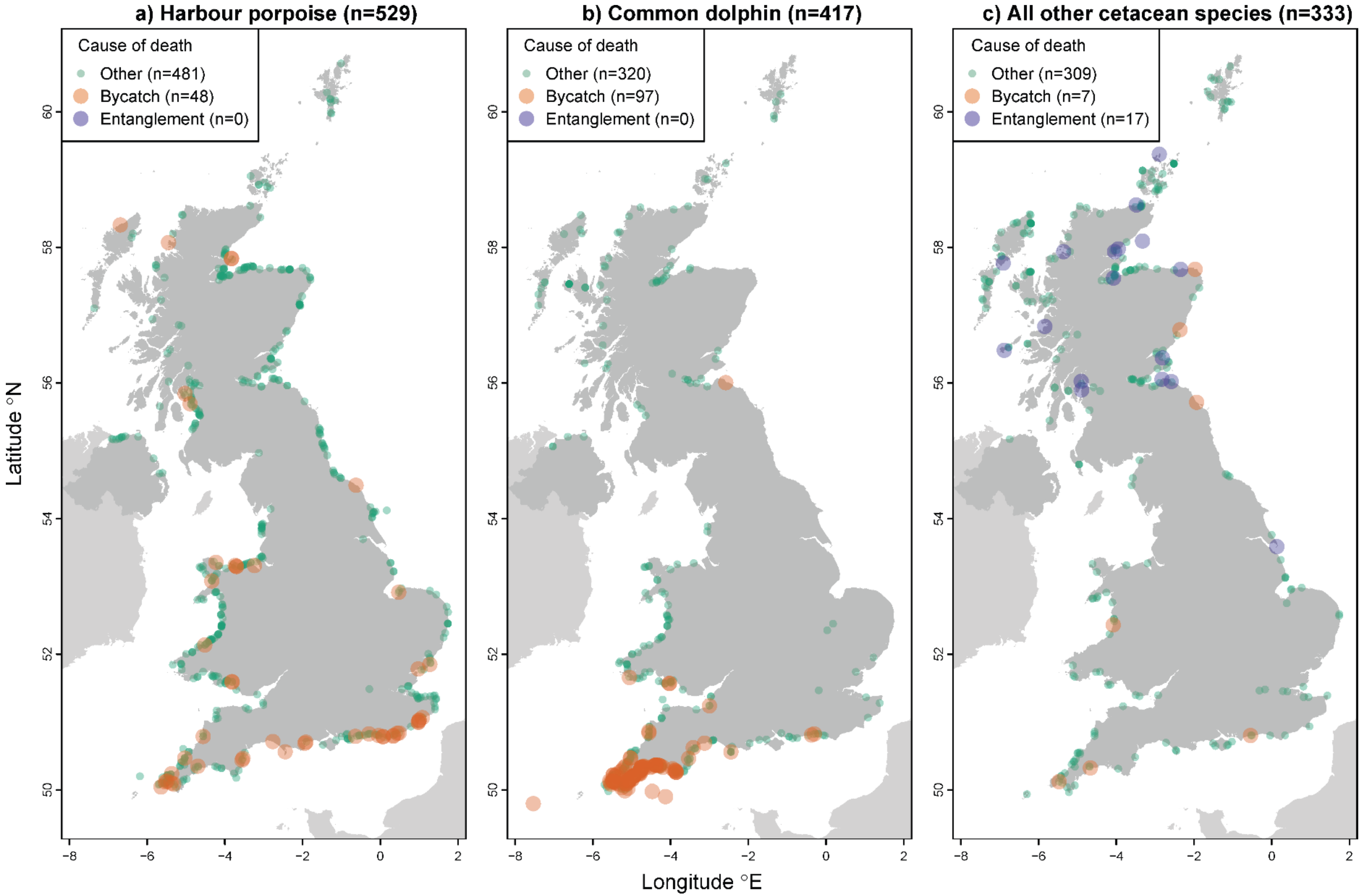

Figure 3: Spatial distribution of necropsied strandings (n=1,279), stranded from 2015 to 2024, inclusive. For: a) harbour porpoise (*P. phocoena*); b) common dolphin (*D. delphis*); and c) all other cetaceans. The two causes of death relevant to this review are highlighted: bycatch (orange); and entanglement (blue). Whilst, for reference all determined other causes of death are shown (green, smaller dots). Those necropsies where the cause of death could not be determined are not included (n=71). Data: England, Wales and Northern Ireland, CSIP; Scotland, SMASS.

Bycatch accounts for a greater proportion of necropsies from August through to February for harbour porpoise and September through to May for common dolphin (Figure 4). This partially aligns with patterns observed in static net observer data, see 'Section 5.1.1.1' and the summary of results from Moyes et al. (2025) in Table 4. The cause of death is not established in a higher proportion of harbour porpoise necropsies than common dolphin. The proportion of harbour porpoise necropsies for which a cause of death cannot be established also tends to be higher in those months associated with a higher proportion of bycatch. This suggests there may be underdiagnosis of bycatch as the cause of death in harbour porpoise due to the challenges inherent in the necropsy of that species.

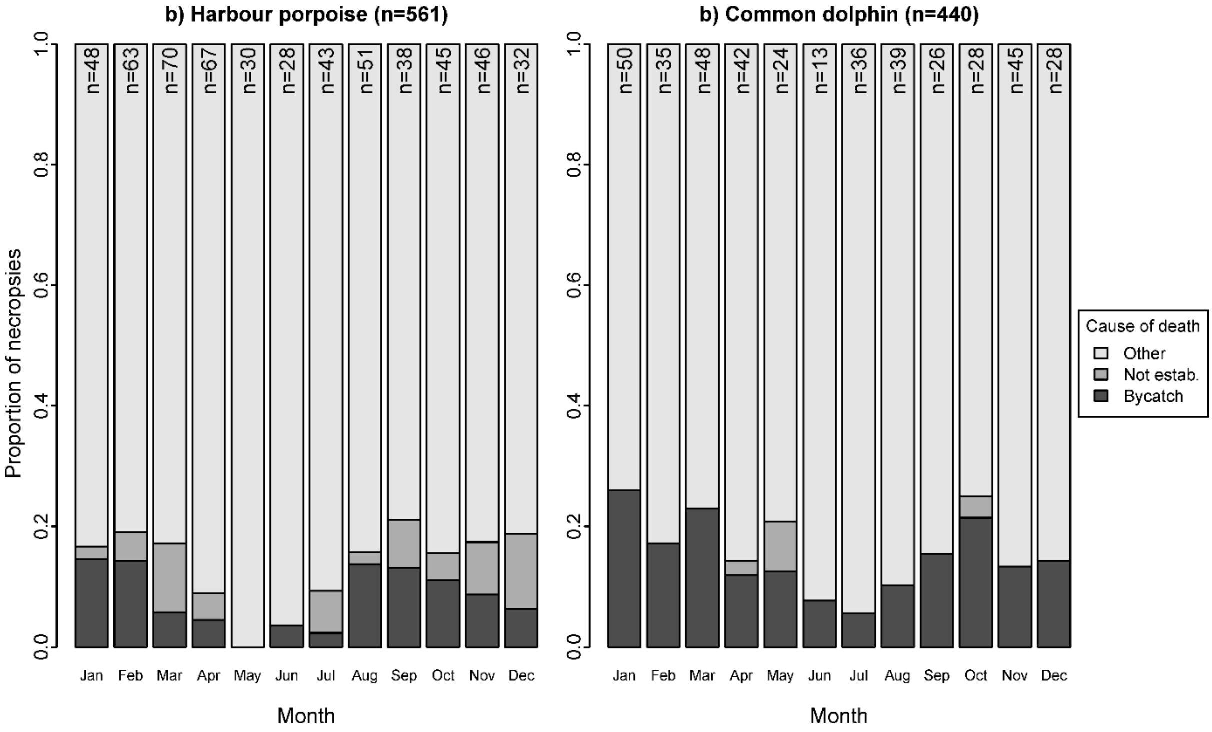

Figure 4: Cause of death determined by necropsy of strandings in the UK from 2015 to 2024, inclusive, for a) harbour porpoise and b) common dolphin. Where causes of death were grouped into: 'Bycatch'; 'Other' (all other determined causes of death); and 'Not established' (cause of death not determined). Note, there were no records of harbour porpoise or common dolphin necropsies where entanglement was found to be the cause of death. Data: England, Wales and Northern Ireland, CSIP; Scotland, SMASS.

5.1.1.6 OSPAR Maritime Area marine mammal bycatch assessment

Recognising that "*the primary human-induced cause of mortality of marine mammals in the OSPAR Maritime Area is incidental capture and entanglement in fishing gear*", Taylor et al. (2022) compares bycatch rates with thresholds for three species of marine mammal, harbour porpoise, common dolphin and grey seal. A detailed account of the methodology and analysis is provided by ICES (2022b). In brief, bycatch rates were modelled for selected metiers based on observer data. Rates were then multiplied by days at sea for each area (assessment unit) and metier combination to estimate annual bycatch. Thresholds were set using state-of-the-art methods, informed by a series of workshops (Palialexis, 2021; Wade et al., 2021; Taylor et al., 2022) and applied to the best estimates of abundance (Hammond et al., 2021). It is worth reiterating that currently, there is no officially adopted or widely held consensus with respect thresholding approach in use in the Northeast Atlantic (Moyes et al., 2025). The selected bycatch thresholds were exceeded for harbour porpoise and common dolphin in assessment units overlapping the UK EEZ, whist bycatch was below thresholds for grey seals (Table 12). Treating hotspots as areas where bycatch exceeds set thresholds, this assessment identifies four broad geographic bycatch hotspots within the UK EEZ for: harbour porpoise (Greater North Sea; Irish and Celtic Seas; and West Scotland and Ireland) and common dolphin (Northeast Atlantic).

Table 12: Threshold values and estimated bycatch per Assessment Unit for three species of marine mammal in the OSPAR maritime area. An asterisk '*' indicates where estimated bycatch exceeds the threshold. Threshold methodology is indicated where: RLA is Removals Limit Algorithm; PBR is Potential Biological Removal; and mPBR is modified Potential Biological Removal. Note, only those assessment units overlapping the UK EEZ are shown here. From: Taylor et al. (2022)

Assessment Unit	Threshold method	Abundance estimate (95% confidence interval)	Threshold value	Bycatch estimate
Harbour porpoise				
Greater North Sea	RLA	345,000 (239,000 - 483,000)	1,622	5,974 *
Irish and Celtic Seas	mPBR	47,000 (35,300 - 60,800)	82	751 *
West Scotland and Ireland	mPBR	44,300 (33,400 - 57,700)	78	305 *
Common dolphin				
North-East Atlantic	mPBR	634,000 (336,000 - 1,092,000)	985	6,406 *
Grey seal				
North Sea	PBR	Min. pop. est. 119,519	7,171	704
Celtic Seas	PBR	Min. pop. est. 60,780	3,647	1,632

5.1.2 Scotland

The Scottish pot fishery (locally known as creels, which are deployed in strings or fleets along a groundline connected to a surface buoy), is of local and national economic importance, operating throughout Scottish coastal and shelf waters (MacLennan, 2021; Rayner et al., 2024). The principal targets are: nephrops (*Nephrops norvegicus*), concentrated on the west coast; lobster (*Homarus gammarus*); and crab (*Cancer pagurus* and *Necora puber*) (Northridge et al., 2010; Leaper et al., 2022). Northridge et al. (2010) conservatively estimated that in Scotland there are 7,500 km of creel lines in the water at any one time and note that ghost fishing from lost creels (7-8% of those fished per boat per year) further increases the risk of entanglement.

Almost half of interviewed creel fishers (n=159), experienced at least one entanglement in a ten year period, reporting a total of 146 entanglements involving 12 species of cetacean, shark and turtle (MacLennan, 2021). Data from the Scottish Marine Animal Stranding Scheme (SMASS) and media reports suggest that the frequency and diversity of megafauna species becoming entangled in pots is increasing (Rya et al., 2016; MacLennan, 2021; Leaper et al., 2022). This may be linked to increasing effort (number of creel fleets) (MacLennan, 2021). Minke whales, grey seals and basking sharks (*Cetorhinus maximus*) are the most commonly reported species entangled in pots (MacLennan, 2021). Entanglement in pot fishing gear is the largest identified cause of mortality in baleen whales (principally minke and humpback whales) that have stranded around Scotland and been subject to necropsy (Northridge et al., 2010; MacLennan et al., 2019; SEA, 2021).

Using effort data (at-sea survey of creel deployments), strandings data and fisher interviews, it was estimated that six humpback whales and 30 minke whales are entangled annually in the Scottish creel fishery (Leaper et al., 2022). Strandings data shows some seasonality, with minke whale entanglements clustered in summer months and humpback whales in late spring (MacLennan, 2021). Entanglements have been reported from throughout Scottish coastal waters (Northridge et al., 2010; SEA, 2021). Leaper et al. (2022) stratified their estimated entanglements over a ten-year period by region (East, North and West). The majority (189) of total minke whale entanglements (302) were from the West, whilst the 64 humpback whale entanglements were from the North (35) and West (29). With respect to minke whale, this broadly aligns with the previous findings that risk was greatest in the Hebridean region (Skye, North Uist and South Uist), and to a lesser extent the Angus/Fife region and Orkney

(Northridge et al., 2010). Similarly, using modelled distributions of minke whales and pot strings, based on line transect survey observations, Rayner et al. (2024) were able to identify three areas of consistent high entanglement risk in western Scotland: the Inner Sound and Sound of Raasay; east of North and South Uist; and north of The Small Isles. Leaper et al. (2022) determined that there is risk of localised depletion of minke whales in the west coast of Scotland as estimated annual fatalities (15.9 individuals per annum, based on 84% or entanglements being fatal) is more than triple the PBR (4.6 individuals per annum). Examination of photo-identification records of minke whales on the west coast of Scotland taken between 1990 and 2017 showed 22.3% (n = 57) of individuals had scars attributed to entanglement (MacLennan, 2021). Rya et al. (2016) used limited humpback whale sighting records, including those with reported entanglement, to make a crude estimate of entanglement risk, concluding Scottish waters may be a high mortality area for humpback whales in the NE Atlantic.

Régnier et al. (2024) used fishery independent survey data to model the distribution of nine elasmobranch species in Scottish waters, by combining two SDMs to produce an ensemble model. Risk hotspots were then identified by mapping the overlap of species distributions with fishing effort in the scallop dredge and nephrops otter trawl fisheries, as these were considered to pose significant bycatch risk to demersal elasmobranchs. The Sound of Jura emerged as the most significant potential bycatch hotspot, owing to overlap across all nine species and both fisheries (nephrops and scallop). Within the scallop fishery, further hotspots were predicted in the Minch, between Mull and Coll and south of the Kintyre peninsula on the west of Scotland; and around Rattray head and offshore in the Forth and Tay region to the east of Scotland. In the nephrops fishery predicted bycatch hotspots were around the Small Isles and Inner Hebrides to the west, and in the Firth of Forth to the east of Scotland. Bycatch of squaliform species (e.g spurdog) was estimated to be most likely within the Sound of Jura, Small Isles and off Lewis, with skate and ray bycatch hotspots predicted within the Sound of Jura, Minch, Firth of Forth and Small Isles. The report identifies seven priority areas of conservation importance based on modelled elasmobranch species richness and diversity these were: Rattray Head and East of Montrose on the east coast; and northeast Arran, Kintyre, South of Jura, South of Barra and Skye to Red Point, on the west coast. All of these (except East of Montrose) were noted for the presence of critically endangered flapper skate (*Dipturus intermedius*). The authors stressed these priority areas partially overlapped with the existing marine protected area (MPA) network but that threats from mobile demersal gear could be better addressed by the introduction of additional measures to mitigate bycatch.

Pierce et al. (2002) present observer data from 67 days at-sea, predominantly on pelagic trawlers (but also purse seine vessels) targeting small pelagics (mackerel, herring and argentines) in Scottish waters. There was no observed marine mammal bycatch. Elasmobranch bycatch was low (5 sharks per 100h of fishing), with the following species reported: Greenland shark (*Somniosus microcephalus*), spurdog, velvet belly shark (*Etmopterus spinax*) and frilled shark (*Chlamydoselachus anguineus*). However, of note was gannet bycatch: 33 gannets per 100 h fished in herring fisheries and 19 per 100 h fished in the argentine fishery. This included 21 gannets being caught in two hauls in the herring fishery near Shetland. Scaling up using effort figures for 2000, the study estimated annual bycatch of around 620 and 160 gannets respectively in the herring and argentine fisheries, with only 10% survival. Note that gannet bycatch in this fishery is not included in the preliminary estimates of annual UK gannet bycatch presented by Northridge et al. (2020) and Miles et al. (2020) of 25 to 764 individuals, as that estimate only covers the static net, Channel midwater trawl and longline fisheries (other metiers were excluded due to low observation rates). Gannets are thought to be the most frequently bycaught species in northern hemisphere trawl fisheries (Phillips et al., 2024). Although, Phillips et al. (2024) determined that the scale is likely underestimated as mortalities maybe cryptic (unobserved), especially those associated with warp strikes. It has been estimated that gannets are the third most frequently bycaught seabird in the European waters of the NE Atlantic, with annual bycatch of 18,525 (Ramírez et al., 2024). More recent quantitative data specifically from this region or elsewhere in the UK are not available (Phillips et al., 2024). Estimates of seabird trawl bycatch would benefit from improved monitoring coverage especially in Scottish waters (Kober et al., 2024).

5.1.2.1 Northwest Scotland

A study of discarding by Irish vessels, reported that otter trawlers operating in the Stanton Banks fishing grounds (ICES Division VIa) discarded 34% of annual catch, of which 18% were dogfish species (*Scyliorhinus spp.*), no other elasmobranch exceeded a 10% threshold and so were aggregated in the 'other' category (Borges et al., 2005). This broadly aligns with the predicted distribution of lesser-spotted dogfish (*Scyliorhinus canicula*) and it's overlap with the nephrops fishery, as subsequently identified by Régnier et al. (2024).

5.1.2.2 Northeast Scotland (central and northern North Sea and Northern Isles)

To identify species and gear combinations of bycatch concern, Northridge et al. (2012), reviewed the literature, collated existing bycatch data and overlaid species density with fishing effort for the whole North Sea. There were multiple caveats associated with these preliminary conclusions stemming from the limited and biased data on which they were based. (See also reference to this study in 'Section 5.1.3'). They found static net bycatch of cormorants, seals and harbour porpoises may be at levels of conservation concern (exceeding PBR). Noting, a concentration of static net fishing effort around the Northern Isles (though to a lesser extent than the English North Sea coast). Calderan and Leaper (2019) compared the distribution of static net fishing effort (from multiple sources), with those areas identified by Heinänen and Skov (2015) as having persistent high densities of harbour porpoise. The waters immediately northwest of the Shetland Isles were identified as being an area of significant overlap and therefore a potential bycatch hotspot, with fishing effort being principally from a deep water (100-200m) bottom-set gillnet fishery for monkfish. Reportedly, data from this fishery are sparse and it has been subject to very little monitoring (Calderan and Leaper, 2019). Noting that, there has been intermittent sampling under the BMP and that vessels in this fishery are required to use pingers when working in ICES Division IVa (A. Kingston, pers. comm).

Of relevance to this and the subsequent section ('Section 5.1.3'), Piet et al. (2009) developed a spatially explicit model. The model combined abundance data for the main North Sea demersal fish species with international effort data and estimates of catch efficiency, to determine the mortality of non-target bycaught fish species (including elasmobranchs) by bottom trawling (otter and beam). For each elasmobranch species, they estimated the percentage of standing-stock biomass removed annually (Table 13) and concluded that about half the standing-stock biomass of larger-bodied elasmobranchs was removed annually by North Sea trawl fisheries. Spatially, within the UK's North Sea waters elasmobranch mortality is concentrated in the southern North Sea and to a lesser extent in Northeast Scotland, around the Shetland Islands. Within some North Sea ICES statistical rectangles mortality exceeded 100% of the estimated biomass suggesting catches in some areas are only maintained by immigration of elasmobranchs.

Table 13: Estimated percentage (%) of elasmobranch species biomass removed annually as bycatch by demersal trawling in the North Sea. For 10 elasmobranch species, where each contributes to >0.01% of total North Sea demersal fish biomass. The proportion of total North Sea demersal fish biomass contributed by each species is provided together with predicted estimates of the percentage of each species' standing-stock biomass removed annually by trawl fishing. Reproduced from: Piet et al. (2009).

Species	**Prop. of North Sea biomass** (%)	**Mortality** (% of standing stock biomass)		
		Beam	**Otter**	**Total**
Rays				
Starry ray (*Amblyraja radiata*)	3.8	20	17	38
Sandy ray (*Leucoraja circularis*)	0	0	36	36
Cuckoo ray (*Leucoraja naevus*)	0.8	2	27	29
Blonde ray (*Raja brachyura*)	0	97	1	98
Thornback ray (*Raja clavata*)	0.2	60	11	71
Sharks				
Tope (*Galeorhinus galeus*)	0.1	9	7	16
Black-mouthed dogfish (*Galeus melastomus*)	0	0	57	57
Smooth hound (*Mustelus mustelus*)	0.3	10	23	23
Lesser-spotted dogfish (*Scyliorhinus canicula*)	1.7	4	38	42
Spurdog (*Squalus acanthias*)	0.2	4	34	39

5.1.3 Central and southern North Sea

Cleasby et al. (2022) combined biologging and fishing effort data to assess the overlap of three diving bird species (common guillemot, razorbill and European shag) with UK gillnet fisheries. As no single comprehensive source of fishing effort data was identified, the authors combined data from multiple sources, spanning 2007 to 2017. They reported hotspots of elevated risk for all three species along England's northeast coast (and European shag in Cornwall). BMP data suggests that among observed gillnet hauls, the highest bycatch rates are off the coast of NE England (Northridge et al., 2023), see also 'Section 5.1.1.1'. However, gillnet fishing effort in this region has been declining in recent years (due to reduction in target stocks and issues with seal depredation) and so there may be decrease in the associated bycatch risk.

Harbour porpoise bycatch in North Sea static net fisheries has been of concern since at least the 1990s, see review by Spencer et al. (2000). A study by Northridge et al. (2012) (introduced above, see 'Section 5.1.2.2') concluded that static net bycatch of cormorants, seals and porpoises may be at levels of conservation concern (exceeding PBR) in the North Sea. Noting that the static fishing effort data presented showed this was concentrated in England's southeast and northeast coast (and also around the Northern Isles of Scotland). Calderan and Leaper (2019)'s review of static net fishing effort distribution in relation to areas identified by Heinänen and Skov (2015), highlighted the east coast of Norfolk and outer Thames estuary as an area of significant overlap. The BMP data suggest bycatch rates for harbour porpoise are higher in the central North Sea and that there are also higher rates of seal bycatch in northeast England's coastal waters (Northridge, 2020). It has previously been determined that harbour porpoise bycatch in the North Sea is at unsustainable levels, exceeding a 1% threshold proposed by the International Whaling Commission (IWC) for harbour porpoise (Spencer et al., 2000). As described above ('Section 5.1.1.6'), the recent OSPAR assessment for the Greater North Sea assessment unit suggests annual bycatch significantly exceeds the RLA threshold (Taylor et al., 2022). However, the majority of this bycatch mortality is likely from outside the UK EEZ, as there is now very limited static net fishing in the UK's North Sea waters (A. Kingston, pers. comm), see also Appendix IV.

As detailed above (see, 'Section 5.1.2.2' and Table 13), Piet et al. (2009) identified areas of high elasmobranch relative annual mortality (absolute biomass removed from the North Sea, expressed as a percentage of standing stock biomass) from demersal trawl bycatch. The areas with highest mortality were in southern North Sea, in the waters off England's east coast and south of Dogger Bank. A finding that aligns with a spatially explicit PSA produced for blonde ray (*R. brachyura*), where the highest bycatch risk was in the southern and central North Sea (ICES Divisions IVb, IVc, and VIId), in shallow waters targeted by beam trawlers (Astarloa et al., 2023). Walker et al. (2019) applied a data-limited approach to determine the exploitation status of demersal fish species impacted by towed demersal gears in the North Sea. This employed spawning potential ratio (SPR); a metric of exploitation that can be calculated from a minimal life history data, where SPR is the spawners per recruit produced at a given fishing mortality (F)/spawners per recruit at zero mortality, F = 0 (Le Quesne and Jennings, 2012; Walker et al., 2019). Four of the seven elasmobranch species assessed had an estimated SPR value below the critical threshold of 20%: the level of reproductive output linked to a high risk of population collapse. These were starry smooth hound (*Mustelus asterias*), spotted ray (*R. montagui*), common smooth hound (*Mustelus mustelus*) and thornback ray (*Raja clavata*). Collectively, these studies suggest that the North Sea is an elasmobranch bycatch hotspot, in the sense that bycatch rates may be having unsustainable population impacts.

5.1.4 English Channel

Enever et al. (2007) analysed data from Cefas's catch sampling programme (CSP) in ICES Subarea VII (English Channel, Western Approaches, Celtic and Irish sea) from 2002 to 2005. Data from 3,643 observed hauls were used to determine catch per unit effort and total annual fish discards (including elasmobranchs) by gear type, highlighting spatial patterns. They found beam and otter trawlers were responsible for more than 90% of all discards. Ranked by number discarded, the top 20 species included the following elasmobranchs for: a) beam trawl, 5th 6,400,000 lesser-spotted dogfish (*S. canicula*)/year, 13th 800,000 cuckoo ray (*Raja naevus*) and 15th 300,000 spotted ray (*R. montagui*); and b) otter trawl, 4th 3.5m lesser-spotted dogfish (*S. canicula*)/year, 14th 300,000 thornback ray (*R. clavata*). Spatially, the greatest numbers of discards (all taxa) were in the Irish Sea and English Channel (south of Start Point), with the highest discard catch per unit effort in Irish Sea, English Channel (south of Start Point) and Dover Strait. Note that discard behaviour has significantly changed since the introduction of landing obligations, although elasmobranch species with high survivability are exempt. Nevertheless, these data provide insights into hotspots for elasmobranch bycatch in terms of gear and areas. More recently, Elliott et al. (2020) used French observer data (from multiple metiers) to model the distribution of three overlapping skate species (undulate ray, thornback ray, spotted ray) in the southern North Sea, the English Channel, the Bay of Biscay and the Celtic Sea. Their analyses highlight that the narrower and more coastal distribution of undulate ray (at the time IUCN status 'Endangered' - now classified 'Near Threatened') makes it more vulnerable to bycatch impacts. They report that 1,452 undulate ray were observed in in 7,870 hauls but this was concentrated in the English Channel where they were present in 22% and 43% of hauls in ICES Divisions VIIe and VIId respectively. Temporally, undulate ray bycatch rates were higher in springtime.

The Western Channel has also been identified as among the highest areas of common dolphin bycatch within the NE Atlantic (along with the Celtic Sea, Bay of Biscay and Spain and Portugal's Atlantic shelf edge) (Murphy et al., 2021). It is known to be an area of high common dolphin abundance and is thought to be an important winter habitat (de Boer et al., 2008). There were formerly high levels of common dolphin bycatch in the pelagic pair trawl fishery for bass in winter months, with estimated annual totals in the hundreds in the mid-2000s (de Boer et al., 2012). Northridge et al. (2011) estimated that bycatch peaked in this fishery in the 2003-2004 winter season at 439 common dolphins

(95% CI, 379-512). This level of bycatch was thought to be sufficient to drive localised depletion (de Boer et al., 2008). This hotspot was addressed through a ban on pair trawling by British vessels within 12nm (The South-West Territorial Waters (Prohibition of Pair Trawling) Order 2004) and the voluntary adoption of acoustic deterrent devices (Northridge et al., 2011). These measures reduced bycatch mortality to single figures per year, prior to the closure of the fishery for bass stock management purposes (Northridge, 2020). Calderan and Leaper (2019) reviewed static net fishing effort distribution, in relation to areas identified by Heinänen and Skov (2015) as having persistently high densities of harbour porpoise. This approach identified the Western Channel south of Start Point as an area of significant overlap. Whilst strandings necropsy data show a cluster of harbour porpoise strandings along the south coast (Sussex and Kent) where bycatch was determined to be the cause of death (Figure 3).

5.1.5 Celtic Sea

The southwest fisheries are of considerable economic importance, these rich fishing grounds accounted for 12% (£232 million) of the value of UK fisheries in 2018-2019 (Bendall, 2021). The Celtic Sea is subject to significant fishing effort from mixed fisheries with a high proportion of polyvalent vessels (deploying more than one gear type) (ICES, 2020a). The region is also noted for the abundance and diversity of sensitive species of mega-fauna, including marine mammals, seabirds and elasmobranchs (Temple and Terry, 2009; Bendall, 2021). Consequently, the risk of sensitive species bycatch is of is of significant management and conservation concern in this region (Bendall, 2021).

Bendall (2021) conducted a desk-based study to determine the conservation threat to sensitive species present in the southwest. Those combinations of species and gear deemed to be of "*highest conservation threat*" in the region are summarised in Table 14, though many of these are by virtue of being data deficient. They observed that highest grossing gears (trawl and gillnets) are also thought to pose the greatest threats to sensitive species in this region (Bendall, 2021), however this limited review does not identify any spatially explicit hotspots.

Table 14: Combinations of species and gear in southwest fisheries of the 'highest conservation concern', defined as being species that have either: experienced significant population declines due to bycatch; and/or, been commonly recorded as bycatch or discards in southwest fisheries; and/or are data deficient. Adapted from: Bendall (2021).

Species	**Trawl**	**Static nets**	**Hooks and line**	**Dredge**	**Seine nets**
Marine mammals					
Bottlenose dolphin (*Tursiops truncatus*)	✓	✓			✓*
Common dolphin (*Delphinus delphis*)	✓	✓			✓*
Harbour porpoise (*Phocoena phocoena*)	✓ Demersal	✓			✓*
Elasmobranchs					
Angel shark (Squatina squatina)	✓	✓	✓	✓	
Porbeagle (*Lamna nasus*)	✓ Pelagic	✓	✓		
Basking shark (*Cetorhinus maximus*)	✓	✓	✓		
Birdbeak dogfish (*Deania calcea*)	✓ Deepwater	✓ Deepwater	✓ Deepwater		
Spurdog (*Squalus acanthias*)	✓	✓	✓		
Kitefin shark *(Dalatias licha)*	✓*	✓*	✓*	✓*	
Common thresher shark (*Alopias vulpinus*)	✓	✓	✓		
Leafscale gulper shark (*Centrophorus squamosus*)	✓* Deep demersal	✓*Deep demersal	✓* Deep demersal	✓* Deep demersal	
Little gulper shark (*Centrophorus uyato*)	✓* Deep demersal	✓*Deep demersal	✓* Deep demersal	✓* Deep demersal	
Sailfin rough shark (*Oxynotus paradoxu*)	✓* Deep demersal	✓*Deep demersal	✓* Deep demersal	✓* Deep demersal	
Knifetooth Dogfish (*Scymnodon ringens*)	✓* Deep demersal	✓*Deep demersal	✓* Deep demersal	✓* Deep demersal	
Blue skate (*Dipturus batis*)	✓	✓ Trammel nets			
Flapper skate (*Dipturus intermedius*)	✓	✓ Trammel nets			
Sandy skate (*Leucoraja circularis*)	✓*	✓*	✓*	✓*	
Undulate ray (*Raja undulata*)	✓*	✓*	✓*	✓*	
White skate (*Rostroraja alba*)	✓*	✓*	✓*	✓*	
Common stingray (*Dasyatis pastinaca*)	✓*	✓*	✓*	✓*	
Longnosed skate (*Dipturus oxyrinchus*)	✓*	✓*	✓*	✓*	
Norwegian skate (*Dipturus nidarosiensis*)	✓* Deepwater		✓* Deepwater		
Marbled electric ray (*Torpedo marmorata*)					
Seabirds					
Balearic shearwater (*Puffinus mauretanicus*)	✓ Pelagic	✓	✓	✓	
Northern fulmar (*Fulmarus glacialis*)	✓	✓	✓		
Atlantic puffin (*Fratercula arctica*)	✓	✓	✓	✓	

* Indicates identified due to data deficiency

There have been concerns about harbour porpoise bycatch in the Celtic Sea for several decades. Tregenza et al. (1997) produced the first estimate of annual porpoise bycatch from the Irish and UK Celtic static net fishery of 2,200 porpoises (95% CI, 900 - 3,500). Presently, harbour porpoise bycatch levels are thought to exceed sustainable thresholds for the Irish and Celtic Seas assessment unit, see Table 12 and Taylor et al. (2022). Using the methodology described in 'Section 5.1.1.6', the estimated bycatch of harbour porpoises in 2020 in the Celtic Seas assessment unit (includes waters beyond the UK EEZ) was 739 (95% CI, 284 - 2,240). The majority of which was from static nets (631 individuals) with the remainder from demersal trawls (108 individuals). Whilst, using BMP observer data, the estimated 2019 static net bycatch was 518 harbour porpoise (95% CI, 367 - 808) (UK vessels only, in ICES Divisions VIIe-j and VIII, assuming full acoustic deterrent device compliance) (Kingston et al., 2021). The Cornwall Wildlife Trust (CWT) Marine Strandings Annual Reports include a cetacean bycatch report (available online 2015-2023, inclusive) (CWT, 2025). Where possible, strandings and cause of death are assessed by post-mortem (ex situ), and/or the Bycatch Evidence Evaluation Protocol (BEEP) an external examination conducted in situ. From 2005 to 2022, inclusive, bycatch or probable bycatch, was identified as the cause of death for between 14% and 46% of common dolphin and harbour porpoise strandings (the two most common cetacean species stranding in Cornwall) (CWT, 2025). Leeney et al. (2008) report bycatch was found to be the cause of death in 61% (n=415) of necropsied marine mammal strandings between 1990 and 2006. These data indicate bycatch is a significant and variable contributor to strandings in this region, aligning with data from the BMP (see, 'Section 5.1.1.1') and literature from the 1990s onwards, including a review in Spencer et al. (2000).

The winter months (generally November to April) are consistently identified as having the greatest number of cetacean strandings where bycatch is identified as the cause of death (post-mortem or BEEP) (CWT, 2025). This temporal pattern aligns with the analysis of limited participatory common dolphin bycatch reporting in the region (Long et al., 2022); previous analyses of strandings data (Leeney et al., 2008; Pikesley et al., 2012; Chadwick et al., in prep.); and analysis of BMP observer data, see Moyes et al. (2025) summarised in Table 4. Additionally, a summer peak was highlighted in 2020 (August and September) and 2016 (August)(CWT, 2025). The majority of bycatch strandings were on the south coast of Cornwall (Leeney et al., 2008; CWT, 2025). This spatial pattern may be directly related to fisheries, marine mammal distribution and/or a product of prevailing winds and currents. Peltier et al. (2016) used strandings data and drift modelling to produce spatially explicit estimates of common dolphin bycatch mortality, in the Celtic Sea, Western Channel and Bay of Biscay (see discussion of methodology in '4.2 Fishery independent'). Their modelling suggested that there was recurrently high bycatch mortality south and southwest of Cornwall, though greater levels of mortality were associated with hotspots in the Bay of Biscay. The temporal and spatial findings concur with a separate analysis of 5,886 records of strandings in the southwest UK from the CSIP database, of which 1,293 were necropsied with bycatch found to be the cause of death in 40% of necropsied individuals, the vast majority of which were common dolphin and harbour porpoise (Long et al., 2022). Calderan and Leaper (2019) reviewed static net fishing effort distribution in relation to areas identified by Heinänen and Skov (2015) as having persistently high densities of harbour porpoise. This review highlighted the Bristol Channel, southwest Wales (Pembrokeshire and Carmarthen Bay) and the shelf edge off southwest Cornwall as areas of significant overlap. Calderan and Leaper (2019) suggest that a "*large proportion of the Celtic Sea [harbour porpoise] bycatch would be expected from UK fisheries [as opposed foreign vessels] in ICES area 7*". BMP observer data presented by (Moyes et al., 2025) showed bycatch per haul was generally higher for common dolphins and porpoise in the southwest. In particular, ICES Divisions VIIg and f for harbour porpoise and VIIg and h for common dolphin.

Data from the BMP suggests the majority of UK seal bycatch is from the Celtic Sea (see, 'Section 5.1.1.1') (SCOS, 2022; Kingston et al., 2023b). The Cornwall Wildlife Trust Marine Strandings Annual Reports present seal strandings data, with seal strandings assessed using the Seal Evidence Evaluation Protocol (SEEP), however this protocol is still in assessment and the nature of the skin and pelt makes definitive conclusions difficult (CWT, 2025). In 2023, 4% of assessed seal strandings (n=147), had "*definite or probable bycatch entanglement features*", though no seal bycatch hotspots within the region are identified by these data. Whilst species identification is uncertain, seal bycatch in the southwest is thought to be predominantly grey seals, as harbour seals are rare in this region (SCOS, 2022). Bendall (2021) only identified bycatch as being a 'moderate conservation threat' to harbour and grey seals in southwest fisheries. SCOS (2021) report that "*estimated bycatch levels in the Western Channel and Celtic Sea exceed the PBR [Potential Biological Removal] for the combined grey seal populations of SW England, Wales, and Ireland…[but the regional populations] are probably stable, suggesting that bycaught seals include animals that may have originated from the large, adjacent breeding populations in western Scotland*". The analysis of Moyes et al. (2025), summarised in Table 4, found static net seal bycatch per unit effort (hauls) had statistically significant relationships with season (highest October to April); depth (decreases across the range of observed hauls, 10-150m), and metier (highest in tangle/trammel nets). The highest observed bycatch per unit effort was in ICES Division VIIj, although ICES Division was not found to be statistically significant in the predictive model.

The Celtic Sea is noted for its diversity and abundance of elasmobranchs including a surviving population of critically endangered common skate complex (*D. intermedia* and *D. flossada*) (Shephard et al., 2012). Reviewing MMO logbook discard data (2018 and 2019), Bendall (2021), identified 20 species of IUCN Red Listed elasmobranch, discarded from southwest fisheries, including 12 they classified of "highest conservation concern". The majority of UK discards for nine of these 20 species were from "*western waters*" (though this area was not clearly defined). Nevertheless, the data presented by Bendall (2021) highlight the Celtic Sea as an elasmobranch bycatch hotspot relative to the rest of the UK in terms of the diversity of species impacted and their conservation status. Further, Silva and Ellis (2019) analysed data from English and Welsh fisheries (beam trawl, nephrops trawl, otter trawl and static nets) operating on the continental shelf of the North Sea and Celtic Seas from 2002 to 2016, from the Cefas catch sampling programme (CSP). The combinations of gears and areas encountering sharks most frequently were beam trawlers in ICES Divisions VIIe, VIIf and VIIg–k (97%–100% of observer trips encountered sharks), otter trawlers in VIIe and VIIf (> 97%) and netters in VIIg–k (97%). In contrast, observers on nephrops trawlers in IVa-b and beam trawlers in IVb-c only observed sharks in 23.6% and 32.9% of trips, respectively. Starry smoothound (*M. asterias*), greater-spotted dogfish (*S. stellaris*), porbeagle (*Lamna nasus*) and a number of less frequently encountered sharks were all more commonly observed in the Celtic Seas than in the North Sea ecoregion. Using demersal fish species in the Celtic Sea as a case study, (Le Quesne and Jennings, 2012) presented a method for assessing sensitivity and conservation management reference points using widely available life-history data. This rapid assessment assessed 29 elasmobranch species including six from the OSPAR list of threatened or declining species in OSPAR Area III (Celtic Seas). They reported that fishing mortality for all elasmobranchs assessed was below conservation reference points. These data highlight the Celtic Sea as a shark bycatch hotspot relative to the rest of the UK, with potentially unsustainable population impacts.

In this region, the five species with the greatest quantity of discards (by weight) were common skate, spurdog, Norwegian skate (*Dipturus nidarosiensis*), porbeagle and undulate ray (Bendall, 2021). In the Celtic Sea critically endangered common skate, a species complex consisting of blue skate (*D. batis*) and flapper skate (*D. intermedius*), are often recorded in large numbers of the same size and/or sex in demersal trawls and trammel net fisheries (Bendall et al., 2012; Ellis et al., 2016). Norwegian skate are commonly observed bycatch within deep-water demersal trawl and longline fisheries (Bendall, 2021). Porbeagle, are particularly vulnerable due to their large body-size, aggregative behaviour and high local abundance (Bendall, 2021). The most significant threats to porbeagle being from trawl, static nets (up to 80% observed mortality), and longline (20-40% observed mortality) (Bendall et al., 2012; Ellis et al., 2016). Analysis of data from the Cefas catch sampling programme (CSP), which collects data on catch, retention and discards, showed most records (72%) of porbeagle caught in static nets in the

Celtic Sea were from July to October, inclusive (Silva and Ellis, 2019). Undulate ray have a coastal distribution, are thought to be more vulnerable to bycatch, compared to thornback ray (*Raja clavata*) and spotted ray (*Raja montagui*), with bycatch rates in the core of its range (western English Channel) having been identified as of concern (Elliott et al., 2020).

A global analysis of longline fishing effort AIS data and satellite tracks of tagged pelagic sharks, including of relevance here porbeagle and blue sharks (*Prionace glauca*), highlighted moderate intensity overlap in the Celtic Sea (Queiroz et al., 2016). Noting, longline effort has shifted northward over the last decade (A. Kingston, pers. comm). There is considerable spatial bias originating from the locations at which sharks were tagged in this study, with only one from within the UK EEZ, so this likely underrepresents overlap and the intensity of hotspots within the Celtic Sea (and perhaps wider UK EEZ).

Among the Irish fleet targeting cod and whiting in ICES Division VIIg, Shephard et al. (2015) assessed bycatch (discarded and retained) of 14 demersal fish species, including four elasmobranchs: lesser-spotted dogfish (*S. canicula*); spotted ray (*R. montagui*); thornback (*R. clavate*) and cuckoo ray (*L. naevus*). Data from Irish Groundfish Survey (IGFS) were used to produce biomass estimates for each species. Data from the Irish observer programme (covering approximately 1% of total effort) was used to estimate annual removal of biomass by the fishery. They found that in one or multiple years (2008-2011, inclusive) the harvesting rate exceeded precautionary reference levels for all four elasmobranch species. Shephard et al. (2012), note the spatial heterogeneity of fishing effort identifying a *de facto* refuge in the northeast Celtic Sea, where low fishing effort is associated with higher elasmobranch diversity and biomass. This finding poses the question of whether levels of bycatch in heavily fished areas are impacting Celtic Sea elasmobranch populations.

Spurdog (*S. acanthias*) bycatch in the Celtic Sea has been subject to research (and management initiatives), which have developed our understanding of patterns in time and space. Analysis of participatory spurdog bycatch reporting, showed bycatch was concentrated in the winter months (October to January, inclusive) and was higher in offshore netters than inshore otter trawlers (Long et al., 2022). Further, it was found that the vast majority of spurdog bycatch was accounted for by large hauls events, with bycatch of ≥100 kg accounting for ~90% of all spurdog bycatch reported by offshore netters. Within the dataset there were instances of up to 8,900 kg being reported from a single haul. Whilst elsewhere individual 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). Seasonal aggregations of spurdog associated with reproductive events (spawning and/or parturition), including in the eastern Celtic Sea (Pawson and Ellis, 2005; Carlson et al., 2014), are thought to explain these large spurdog bycatch events. A pilot project explored the potential of using participatory spurdog bycatch reporting to identify hotspots in near real-time, allowing skippers to be notified and avoid areas of high-risk (Hetherington et al., 2016; Hetherington et al., 2022). Long et al. (2022) modelled the distribution of large spurdog bycatch events (≥100 kg) reported by fishers, using explanatory environmental variables, the resulting predictions broadly aligned with hotspots previously identified using fishery-dependent data in the NEPTUNE project (Ellis et al., 2016; Hetherington et al., 2016) and were partially validated by tagging data. Combining this model with GFW fishing effort data for set gillnets (AIS equipped vessels) showed a spurdog bycatch risk hotspot from October to January inclusive, to the northwest of the Scilly Isles (Long et al., 2022), as previously reported elsewhere (Hetherington et al., 2016; Hetherington et al., 2022).

In addition to those seabirds hotspots detailed in ‘Section 5.1.1’, further studies indicate there are seabird bycatch hotspots in the Celtic Sea. Cleasby et al. (2022)’s analysis of the overlap between gillnet fishing effort and three diving bird species (common guillemot, razorbill and European shag). They concluded that there was a hotspot of elevated risk to European shag along the Cornish coast. Lewison et al. (2014) assembled a global database of air-breathing megafauna (mammals, seabirds and turtles) bycatch records in longlines, trawls and static nets. Each record was assessed by an expert panel and assigned a bycatch intensity score from low (one) to high (five) to identify taxon/gear combination hotspots and cumulative hotspots across taxa and gear. The study identified two high intensity records (score of five) for seabird bycatch in static nets from the Celtic Sea (further spatial detail could not be obtained from the data presented). Whilst the coarse resolution of this study limits the insight, it does indicate that seabird bycatch in the Celtic Sea is considered 'hot' at the global scale. There are also reports of a significant seabird bycatch event, involving the capture of 150-200 birds (mostly guillemots and razorbills) in static nets deployed in St Ives Bay in January 2012, though this does not appear to have recurred, at least in that location (Žydelis et al., 2013; Anderson et al., 2022).

5.1.6 Irish Sea

Data presented by Enever et al. (2007), see discussion in 'Section 5.1.4', indicates that within ICES Subarea VII, the Irish Sea is a hotspot for fish bycatch, principally by beam and otter trawlers, whose elasmobranch bycatch includes the commercial species lesser-spotted dogfish, thornback ray, cuckoo ray and spotted ray. Enever et al. (2007) determined that 42% of beam trawl catch (fish and cephalopods) by weight was discarded but the highest bycatch rates were observed in nephrops trawlers, which predominantly fish in ICES Division VIIa (Irish Sea). These findings are comparable to previously reported fish discards in ICES Division VIIa by Irish beam trawlers (67% of total catch weight) and nephrops otter trawlers (25% of total catch weight) (Borges et al., 2005). Of those fish discarded by the Irish beam trawl fleet, 20% by weight were dogfish (*Scyliorhinus spp.*) (no other elasmobranch exceeded a 10% threshold and so were aggregated in the 'other' category) (Borges et al., 2005).

A study of the Welsh pot fishery (crab and lobster) spanning parts of the Irish Sea, Celtic Sea and Bristol Channel provides detailed insights into bycatch (Moore et al., 2023). In >10,000 pot hauls over four years (<1% of total fishing effort) bycatch of two species of elasmobranch was observed: 510 greater-spotted dogfish (*S. stellaris*); and 281 lesser-spotted dogfish (*S. canicula*). These elasmobranchs were the most abundant fish collectively accounting for 52% of all observed fish bycatch. On hauling elasmobranch were generally in good condition and vigorous, of those retained (13% of bycaught greater-spotted dogfish and 44% of bycaught lesser-spotted dogfish) all were intended for use as bait. Bycaught elasmobranchs (and other fish) retained for bait are not reported in landings data and so this may be a cryptic source of fisheries mortality. Greater-spotted dogfish are classified as Vulnerable on the IUCN Red List, principally due to a decline of 30-48% in the past 3 generations (48 years) (Finucci, 2021). Welsh waters are thought to be a greater-spotted dogfish stronghold, with the highest abundance in Britain and Ireland being found in Welsh coastal waters and increasing catch per unit effort in Irish Sea and Bristol Channel (Finucci, 2021; Moore et al., 2023). Whilst the population impact of the fishery is not considered, given the conservation status of greater-spotted dogfish, its importance within in coastal ecosystems and the significant volume caught as bycatch (and retained), Moore et al. (2023) suggest a precautionary approach to addressing greater-spotted dogfish bycatch retention in this fishery.

6 'Coldspots': effective bycatch mitigation case studies

6.1 Case study 1: Filey Bay

Fishery: Static net salmon and seatrout fishery
Where: Filey Bay, east coast of Yorkshire
Bycatch species: Seabirds, specifically razorbill (*Alca torda*) and guillemot (*Uria aalge*)
Mitigation measure (type): Multiple

Filey Bay, on Yorkshire's east coast, has been home to a salmon and seatrout fishery for over 100 years. In this fishery, small boats historically deploy J- and T-shaped static nets close to shore, extending from the surface to the seabed. The fishery overlaps with the Flamborough and Filey Coast Special

Protection Area (SPA)[1], designated to protect seabird colonies, some of which forage in the adjacent waters. In the mid to late 2000s it became apparent that the fishery was experiencing high levels of fatal seabird bycatch in summer months, predominantly razorbills and guillemots. For example, an estimated 323 razorbills and 200 guillemots were bycaught in 2008 (Quayle, 2015). Collectively the Environment Agency, Natural England (NE), the Royal Society for the Protection of Birds and the Filey Bay netsmen introduced mitigation measures (EA, 2020). These were designed to both reduce the incidence of bycatch and ensure post-capture survival.

Initially, a voluntary Code of Conduct required netsmen to: i) undergo training in the safe handling and release of seabirds; ii) prioritise releasing bycaught birds before attending to target catch; iii) support bycatch monitoring efforts; iv) attend nets the majority of the time, with 100% attendance mid-June to mid-July and when there were significant numbers of birds present in the vicinity; and v) remove or relocate nets in response to bycatch. The code was introduced in 2009 and updated in 2010. Although, the voluntary code was considered to have slightly reduced bycatch rates, it was limited by a lack of sign-up. Consequently, a new byelaw introduced in 2010, required that throughout June netsmen: i) attended nets at all times; ii) did not deploy nets overnight (from 9:30 pm to 5am); iii) used high visibility multifilament nylon in the net leader; iv) and ensured monofilament headpiece did not exceed 70m in length. The contribution of local fishers to the development of the code, byelaw and identifying solution was key. For example, netsman Rex Harrison trialled alternatives to monofilament mesh and found that black pigeon netting was a low-cost alternative that was more visible to seabirds without impacting catch (FITF, 2025).

Monitoring data was collected by an ecological consultancy, working with fishers. Data from 2009-2015 showed overall seabird bycatch reduced by 85% from 2009 and, of those birds that were caught in fishing nets, 60% were released alive in 2015 (EA, 2020). Subsequently, the fishery is now only for sea trout (since December 2018 all salmon must be released). Following consultation, the renewal of the North East Coast (Limitation of Net Licences) Order in 2022, seeks to continue to phase the fishery out, restricting licences to existing holders. Licences and effort in the fishery have declined, only 32 licences remain in the North East Coast fishery (Cefas, 2025), with around 4 or 5 remaining in the district in which Filey Bay lies (Anderson et al., 2022). The combination of reducing effort and effective mitigation means levels of seabird bycatch are currently considered negligible (EA, 2020).

6.2 Case study 2: Acoustic deterrents devices (ADDs) for static nets

Fishery: Static net, >12m vessels
Where: Celtic Sea, Channel and North Sea
Bycatch species: Harbour porpoise
Mitigation measure (type): Acoustic deterrent device (gear modification)

Static nets (gill, entangling, and trammel nets) are used around the UK, both in- and offshore, with effort concentrated in ICES Area VII (Celtic Sea). In the UK, static net fisheries are considered to pose the greatest threat to marine mammals, in particular bycatch per unit effort is highest in tangle and trammel nets (Calderan and Leaper, 2019; Northridge, 2020). Since 1996, ten marine mammal species have been recorded in static nets by BMP observers in UK waters, most frequently harbour porpoises followed by common dolphins and seals (Northridge, 2020). OSPAR assessments, suggest that total annual bycatch of harbour porpoise significantly exceeds thresholds for sustainable populations impacts in the three assessment units spanning UK waters (Greater North Sea, Irish and Celtic Seas, West Scotland and Ireland) (Taylor et al., 2022).

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[1] Formerly Flamborough Head and Bempton Cliffs SPA.

Acoustic deterrent devices (ADDs), sometimes referred to as ‘pingers’, are attached at regular intervals along nets. Each unit emits sounds in the auditory range of echolocating cetaceans, intended to make animals, aware of, and avoid entangling in nets. EU and subsequently post-Brexit UK legislation, has required ADDs on vessel over 12m deploying static nets in certain areas since 2005, which has been fully enacted since 2013. In the UK, ADDs are mandatory for all vessels over 12m fishing in: ICES Area VII (Celtic Sea and Channel); and, those vessel in ICES Area IV (North Sea), where the mesh size is larger than 220mm, or the total net length is less than 400m.

Data from the BMP were used to determine the impact of ADDs on harbour porpoise, common dolphin and seals (harbour and grey seals) (Moyes et al., 2025). The dataset contained 4,244 hauls between 2008 and 2023, of which 2,221 were equipped with ADDs. Modelling was used to estimate the impacts of ADDs on bycatch per haul. For harbour porpoise, ADDs were associated with a statistically significant reduction of 77%. However, for seals, ADDs were associated with a statistically significant increase of 143%. Whilst for common dolphins, ADDs were associated with an estimated 31% reduction but this was not statistically significant.

This new research shows that ADDs are effective at mitigating harbour porpoise bycatch in the UK, as has been repeatedly found elsewhere (see review in, Lucas and Berggren, 2023). However, there are significant challenges/issues associated with the wider roll-out of this measure, comprehensively reviewed by MMO (2025) and summarised here:

Ecological

1. *Behavioural disturbance to harbour porpoise*. Harbour porpoise have a high metabolic rate supported by a high rate of foraging, disturbance may be energetically costly (avoidance and reduction in foraging).
2. *Exclusion/displacement*. ADDs may result in individuals and populations being excluded from key habitats, impacting activities such as foraging or reproduction.
3. *Increased bycatch of other marine mammals*. ADDs have been found in some instances to have a ‘dinner bell’ effect on seals, attracting them to forage on fish caught in the net, resulting in increased rates of seal bycatch.
4. *Potential for habituation*. There is evidence from some studies that harbour porpoises may habituate to the sound emitted by ADDs, with the avoidance response decreasing over time. Although, newer ADDs incorporate random variation in the emitted sounds (volume, frequency, duration etc.) to reduce the chance of habituation.

Economic

1. *Costs associated with purchase, operation and maintenance of ADDs*. These may be significant and prohibitive, especially for smaller vessels.
2. *Costs associated with regulating and enforcing the use of ADDs*.
3. *Practical considerations*. Vessels require space/capacity to store spare units and charge batteries, which may not be feasible on smaller vessels.

Whilst the impact of ADDs on harbour porpoise bycatch in the UK is encouraging, these challenges mean that this mitigation measure may not be suitable for a wider, or blanket rollout, at this stage. It is worth noting that ADDs continue to be the subject of ongoing development and trials throughout Europe and elsewhere.

7 Summary and recommendations

7.1 Defining and identifying sensitive species bycatch hotspots

There is no consensus on what is meant by the term ‘bycatch hotspot’, which is broadly applied and interpreted. Consider just the word bycatch, which can simultaneously refer to marketable non-target species, contributing to fisher incomes and the mortality of critically endangered marine species. Whilst what constitutes ‘hot’ is perhaps even more variable. Nevertheless, ‘bycatch hotspot’ has an intuitive sense and is conceptually helpful for prioritising research, support and management.

Recommendation 1: Clearly define what is meant by the term bycatch hotspot in the context in which it is being used, tailored to the purpose and audience. Be explicit about what constitutes ‘hot’.

It is well established in the literature, that understanding patterns of bycatch in time and space is inherently challenging. Globally and within the UK, a diversity of approaches have been employed to identify sensitive species bycatch hotspots. This diversity of approaches reflects the differing availability of data, resources and practical constraints, as well as recent advances in statistical approaches and computing power. Inevitably each approach has its limitations. Often data-limited scenarios can be addressed by combining methods and data sources (e.g. whale entanglement, Leaper et al., 2022; elasmobranch bycatch, Régnier et al., 2024).

Recommendation 2: Employ a diversity of methodological approaches to determine trends in bycatch in time and space (and identify hotspots). Combining one or more methodologies allows hotspots to be triangulated, where multiple independent approaches converge, it forms a better evidence-base to inform policy or direct further research, rather than identifying a best, or preferred approach.

Fishery dependent data is a critically input for most approaches to identifying bycatch hotspots. Observer data is widely regarded as the most robust source of bycatch data and are typically used to produce annual bycatch estimates. However, in the UK and wider European context, coverage and representation are limited due to the associated costs. This is evidenced in the typically wide confidence intervals associated with sensitive species bycatch estimates (ICES, 2020b). Further, data from fishers themselves can be scarce, as fishers are understandably reticent about sensitive species interactions, while bycatch issues may not be apparent at the level of the individual. Therefore, an absence of evidence should not be taken as evidence of absence. In UK waters there may be un- or under-documented bycatch hotspots, especially in those sections of the fleet not routinely covered by the BMP observer programme. The fishing industry can play a central role in addressing data gaps, with an ever-growing list of successful science-industry partnerships (Northridge et al., 2011; Mangi et al., 2018).

Recommendation 3: Explore remote electronic monitoring and participatory data-collection ‘self-reporting’ (e.g. Clean Catch App), as potentially cost-effective approaches to gather bycatch data and complement observer programmes, particularly in the underrepresented inshore fleet of smaller vessels. For wider context, see the remote electronic monitoring consultation and Government response (Defra, 2024). Also noting the opportunity to learn lessons from the recent implementation of remote electronic monitoring in Scottish scallop dredge and pelagic fisheries (Scottish Government, 2024).

Recommendation 4: Fully incorporate the collection of bycatch data into existing systems and processes (e.g. the MMO’s Record Your Catch app, logbooks), not through separate initiatives, which increase complexity and workload for fishers. Noting there would need to be a strategy to ensure compliance.

Long-term monitoring (e.g. BMP observer and marine strandings programmes), applying a consistent methodology in time and space, provide invaluable insights that cannot be replicated by standalone studies. Such programmes allow monitoring of trends, comparison (i.e. how hot is this bycatch issue) and inform quantitative assessment of population impacts.

Recommendation: 5: Prioritise supporting and maintaining long-term bycatch monitoring and programmes of research rather than discrete research initiatives. Fully incorporate consistent recording of sensitive species bycatch in fisheries observer programmes (other than the BMP). For example, this includes the catch sampling programme (CSP) and the Scottish Pelagic Industry-Science Data Collection Programme (a partnership between the Marine Directorate's Science, Evidence, Data and Digital (SEDD) portfolio and the Scottish Fishermen's Federation (SFF). This is currently in progress for the CSP (J., Murray, pers. comm).

Given the paucity of data and associated costs, modelling approaches to predict bycatch risk can be a valuable tool. However, predicted risk may not always equate to actual risk because as Evans et al. (2021) observe: "*we are far from understanding the precise factors leading to capture, which may vary with age and experience, gender, physiological constraints, foraging behaviour, preferred prey, and so on*". Despite this predictive approaches tend not to incorporate any formal validation, instead they just note instances where predictions align with known hotspots (e.g. Bradbury et al., 2017; Evans et al., 2021).

Recommendation 6: Ground truth fisheries/areas identified by predictive modelling as having high bycatch risk. This could be achieved with dedicated monitoring and/or validation using existing independent datasets.

7.2 Wider perspectives on bycatch patterns in time and space

Global analyses tended not to highlight the UK EEZ, or European continental shelf more generally, as a bycatch hotspot (e.g. review of birds and gillnet bycatch, Žydelis et al., 2013; review of airbreathing mega-fauna bycatch hotspots, Lewison et al., 2014). Although, Karpouzi et al. (2007) produced a coarse resolution global map of the foraging distribution of seabirds and fisheries, highlighting hotspots throughout shelf areas of Europe, including the UK EEZ. In the most recent ICES advice on sensitive species bycatch in North Atlantic ecoregions, bycatch estimates in those regions overlapping the UK EEZ (Celtic Sea and Greater North Sea) are not among the highest (ICES, 2024a).

Comparatively low bycatch and/or the absence of hotspots, is not necessarily good news, as it may be a product of the historic loss of mega-fauna. The waters of the UK EEZ and wider European continental shelf, have a long history of exploitation spanning multiple centuries, which has accelerated with the industrialisation of fishing and increases in fishing power over the last 100 years (Thurstan et al., 2010). For example, increases in the power and extent of towed demersal gears has been linked to the extirpation of common skate complex from the Irish Sea and southern North Sea by the 1970s, with no evidence of recolonisation (Brander, 1981; Sguotti et al., 2016; McGeady et al., 2022). Whilst, whale populations are thought to remain below pre-industrial levels (Ryan et al., 2022). Thus, recovery of sensitive species populations, as threats are addressed, might be evidenced by increasing bycatch or BPUE.

Recommendation 7: Recognise shifting ecological baselines and consider the impact of bycatch (and hotspots) not just in relation to current (depleted) populations but also historic levels and recovery to those.

Bycatch hotspots are not static and do not necessarily persist. On the basis of their analysis, Bradbury et al. (2017) found "*risk shows seasonal variation imposed on enormous spatial variation*". Northridge et al. (2023) reviewed available data (literature and observer data) to identify seabird hotspots in the UK. A number of the existing studies identified bycatch in fisheries which have subsequently been closed (e.g. Scottish static net salmon fisheries, targeted bass gillnet fishery in Cornwall). Similarly, observer data indicated notable levels of seabird bycatch in the now closed gillnet fishery for deep-water sharks off the Northwest of Scotland and the inshore cod gillnet fishery in northeast England in which effort has greatly reduced since the 1990s. Further, future change can be expected as the distribution of target and sensitive species respond to climate change. Ensemble modelling of marine species distribution in the North Sea under climate change scenarios predicts northward shifts and changes in the overlap between commercially exploited and threatened species (Jones et al., 2013). Whilst in the Celtic Sea, fishing opportunities may be changing, as Boreal species at the southern limit of their distribution give way to Lusitanian species, driven by climate-induced temperature shifts (Lynam et al., 2010; Mérillet et al., 2020; Bastardie et al., 2021). Similarly, the distribution and magnitude of fishing effort is not static, socio-economic drivers can result in significant changes (e.g. effects of covid-19 pandemic and Brexit), as can new regulation (e.g. recent prohibition of towed demersal gear in some MPAs). These examples highlight the transient nature of species distribution, fisheries and bycatch hotspots, which are not fixed in time and/or space. This necessitates the timely collection and dissemination of data in order to identify bycatch hotspots.

The threat of bycatch does not occur in isolation. However, in the studies identified by the review the cumulative impacts of bycatch and other anthropogenic threats were rarely considered collectively.

Recommendation 8: Map bycatch (and hotspots) in relation to the distribution and impacts of other anthropogenic threats. For example, this would be of particular importance in areas where bycatch impacts were below but close to reference thresholds.

It was apparent in the literature reviewed that age and sex are rarely included in bycatch assessments, likely a product of data deficiency. However, a global analysis of seabird bycatch found it is highly biased by sex and age, which is suggested to arise from differences in the foraging distribution by sex and life-stage (Gianuca et al., 2017). In general, seabirds are long-lived, producing few offspring with low survivorship, and thus the bycatch of adult birds will have greater population impacts (Furness et al., 2012). Consequently, bycatch of adult birds foraging within range of colonies could pose a greater population risk than bycatch in areas used by non-breeding immature birds (Bradbury et al., 2017). Similar, considerations may apply for other sensitive species.

Recommendation 9: Where possible, bycatch hotspots research should consider movement ecology (seasonal migration, foraging distribution, breeding sites etc) by age and sex, in relation to fishing effort and observed bycatch to understand the risk that specific hotspots pose to populations.

Relative to marine mammals and seabirds, elasmobranch bycatch has been subject to less targeted research, for example there is no UK-wide analysis of elasmobranch bycatch rates, quantity, distribution or population impacts. In contrast to other sensitive species (seabirds and marine mammals) whose retention is prohibited, elasmobranchs bycatch retention ranges from prohibited, to managed (quota, landing size), through to not subject to management. Thus, a less clear overall picture of elasmobranch bycatch hotspots emerges from this review. Elasmobranch bycatch data gaps have also been identified elsewhere, including: the spatial and temporal distribution of bycatch; post-discard mortality; and mitigation (Silva and Ellis, 2019).

Recommendation 10: Conduct UK-wide research on elasmobranch bycatch, building a more comprehensive picture of distribution, quantity and impacts, as has previously been undertaken for seabirds (Miles et al., 2020; Northridge et al., 2020; Northridge et al., 2023) and marine mammals (Northridge, 2020). Noting work of this nature is in progress (A. Kingston, pers. comm).

7.3 Bycatch hotspots within the UK

Broadscale patterns of bycatch in the UK (or anywhere else) might reasonably be expected to align with the distribution of fishing effort. In their analysis of VMS data, Witt and Godley (2007), found fishing pressure is concentrated in the Western Channel, Celtic Sea, Northern North Sea and Goban Spur (the latter being outside of the UK EEZ). They note these are regions where topography and currents result in upwelling, mixing, aggregation of biological matter, and development of frontal systems, which support primary and secondary productivity within regional food webs. Thus, these physical features support an abundance of prey targeted by both marine mega-vertebrate (including sensitive species) and fisheries. Thus, it is in these regions where bycatch risk is likely to be concentrated at the mesoscale. Noting this analysis of VMS data does not adequately represent the under-reported small vessel, inshore fleet (see, Enever et al., 2017), which may be also responsible for bycatch hotspots. This broad pattern in fishing effort, described by Witt and Godley (2007) and evident in Figure 1, is supported by landings data (Seafish, 2017), where the greatest volume is in those ports proximal to the areas identified above. These areas of greater fishing effort (Western Channel, Celtic Sea, northern North Sea) are also generally the regions in which the review identified the greatest volume of evidence for bycatch hotspots (see ‘Section 5.1’).

The most compelling bycatch hotspots (to be prioritized for further research, support and/or mitigation) are those which:

1. Have been identified by multiple independent studies, spanning the categories of methodological approaches detailed above;
2. Are sizeable, in terms of the scale of the fishery, volume of bycatch and impacts;
3. Are thought to have population impacts on sensitive species of particular conservation concern;
4. Are current and have persisted for multiple years (a number of hotspots identified are no longer ‘hot’ due to changes in stocks, fishing effort, regulation etc.).

The review identified two particular hotspots, that meet the criteria above and relate to specific fisheries, each operating in a discrete area. These are:

1. **Longline fishery targeting hake on the continental shelf edge North of Scotland and in the Celtic Sea.** This hotspot has been identified by observer data (Northridge et al., 2020) and predictive risk modelling (Evans et al., 2021). The estimated annual bycatch by the UK fleet is 1,000 to 2,000 fulmar; 50 to 150 gannets; 10 to 20 great shearwaters; and 10 to 20 great skua (Kingston et al., 2023a). Of particular concern is the bycatch of northern fulmar (European Red List status: ‘Vulnerable’). Employing BMP data, Miles et al. (2020) modelled the impact of removing northern fulmar bycatch mortality (which is principally from this fishery), and projected this would result in a population increase of 6.9% over a 25-year period. Regionally, this was higher in some instances, notable with a median projected increase of 19.8% over 25 years in the Celtic Seas.

2. **Scottish pot (creel) fishery, especially west of Scotland**. Evidence of a hotspot is provided by predictive risk modelling, interviews with fishers and strandings necropsies (Northridge et al., 2010; MacLennan, 2021; Leaper et al., 2022). It is estimated that 6 humpback whales and 30 minke whales are entangled annually in the Scottish creel fishery (Leaper et al., 2022). With respect minke whales, the risk is greatest in the Hebridean region (Skye, North Uist and South Uist), and to a lesser extent the Angus/Fife region and Orkney (Northridge et al., 2010; Leaper et al., 2022; Rayner et al., 2024). Leaper et al. (2022) determined that there is risk of localised depletion of minke whales in the west of Scotland as estimated annual fatalities is more than triple a threshold for sustainable mortality. Whilst, Rya et al. (2016) conclude Scottish waters may be a high mortality sink for humpback whales in the NE Atlantic.

Additionally, the following gears which are widely deployed, meet the criteria above, with multiple spatial hotspots.

3. **UK-wide static net fisheries.** The static fishery has seabird, harbour porpoise and elasmobranch bycatch (Northridge et al., 2011; Bradbury et al., 2017; Silva and Ellis, 2019; Evans et al., 2021; Northridge et al., 2023). Hotspots have been identified by observer data (Northridge et al., 2020; Moyes et al., 2025), predictive risk modelling (Bradbury et al., 2017; Evans et al., 2021; Cleasby et al., 2022) and literature review (Calderan and Leaper, 2019). In the UK, static net fisheries are considered to pose the greatest threat to marine mammals, in particular bycatch per unit effort is highest in tangle and trammel nets (Calderan and Leaper, 2019; Northridge, 2020). Harbour porpoise are thought to be particularly vulnerable to static nets (Dolman et al., 2016). In the wider NE Atlantic, static nets are responsible for the majority of harbour porpoise bycatch (NAMMCO and IMR, 2019; ICES, 2024c). Since 1996, ten marine mammal species have been recorded in static nets by BMP observers in UK waters, most frequently harbour porpoises followed by common dolphins and seals (Northridge, 2020). The most impacted seabird species are thought to be guillemots, cormorants, shags, great northern diver and razorbills (Bradbury et al., 2017; Cleasby et al., 2020; Evans et al., 2021; Northridge et al., 2023). Spatially, the following hotspots have been identified for: i) seabirds, principally in the coastal waters of the Celtic Sea, Northeast England and the English Channel (Bradbury et al., 2017; Evans et al., 2021; Cleasby et al., 2022; Northridge et al., 2023); ii) harbour porpoise, NW of Shetland, in the English Channel and Celtic Sea (Calderan and Leaper, 2019; Evans et al., 2021); and iii) seals (predominantly grey seals) in the Celtic Sea (ICES Subarea VII) (Northridge, 2020; SCOS, 2022; Kingston et al., 2023b). Temporally, BMP data shows bycatch per haul is highest for: in Autumn and Spring for harbour porpoise; winter for common dolphin; and late autumn to early spring for seals (Moyes et al., 2025). These patterns broadly align with stranding necropsy data for harbour porpoise and common dolphin (Figure 4) (Long et al., 2022). There is evidence that for some species the population impacts of bycatch in this fishery are significant. Miles et al. (2020) predicted the removal of bycatch mortality (principally from the static net fishery) would result in an increase in population size of greater than 1% over 25 years for both cormorant, great northern diver. Whilst OSPAR assessments, suggest that total annual bycatch of harbour porpoise significantly exceeds thresholds for sustainable populations impacts in the three assessment units spanning UK waters (Greater North Sea, Irish and Celtic Seas, West Scotland and Ireland) (Taylor et al., 2022).

4. **UK-wide trawl fisheries.** Depending on the gear and context, this broad category (including pelagic and demersal otter trawls, seines and beam trawls) impacts marine mammals, seabirds and elasmobranchs) (Northridge et al., 2011), with evidence of multiple hotspots in this review. Of gear used in the UK, trawling has the largest spatial footprint (Appendix IV) and accounts for a significant proportion of total fishing effort (Kingston et al., 2023b). Seabirds, may be entangled in the wings, cod-end or subject to warp-strike, species thought to be impacted include gannets, cormorants, shags, shearwaters, guillemots and gulls (Bradbury et al., 2017; Northridge et al., 2020). There is some evidence that gannets may be most frequently bycaught and/or particularly susceptible (Pierce et al., 2002), aligning with observations elsewhere in Europe and the North Atlantic, where gannets are among the most commonly bycaught seabird in trawls (Phillips et al., 2024; Ramírez et al., 2024). Whilst, predictive modelling has identified a number of potential hotpots (Bradbury et al., 2017; Evans et al., 2021), there is historically limited BMP observer data. Thus there is considerably uncertainty around the rate, quantity and distribution of seabird bycatch from trawling, with a need for increased monitoring (Northridge et al., 2023; Kober et al., 2024). Increased monitoring, particularly in Scottish waters, would improve bycatch estimates for several

seabird species (Kober et al., 2024). Towed demersal gears generally account for higher elasmobranch bycatch rates and quantities than other any other gear (e.g. Enever et al., 2007; Condie, 2013). Elasmobranch bycatch formed a significant component of towed gear catch in the Irish Sea (Borges et al., 2005), English Channel (Enever et al., 2007), Celtic Sea (Shephard et al., 2015), North Sea (Piet et al., 2009), whilst Régnier et al. (2024) predicted a number of hotspots in Scottish inshore waters. Size-selectivity varies among gears, for example, beam trawls catch (and discard) a higher proportion of juvenile sharks than otter trawls (Silva and Ellis, 2019). Impact assessments are not always available but in some instances elasmobranch trawl bycatch has been shown to exceed precautionary thresholds (Celtic Sea, Shephard et al., 2015; North Sea, Walker et al., 2019). Marine mammal bycatch in UK trawl fisheries is generally rare, with the exception of common dolphin in the Channel pelagic pair trawl fishery for bass (Northridge et al., 2011), which has subsequently been addressed (Northridge, 2020). Thus, whilst trawls pose a risk to cetaceans, it is considerably less than static nets (Calderan and Leaper, 2019). Nevertheless, bycatch risk hotspots for common dolphin were identified in the Celtic Sea and Western Approaches to the English Channel (Evans et al., 2021). Seals have also been reported as trawl bycatch (Northridge et al., 2012).

7.4 Addressing bycatch hotspots

It should be acknowledged that all four of the hotspots highlighted above are subject to recent and ongoing efforts to address bycatch, through improved monitoring and mitigation. This includes but is not limited to:

1. Improving bycatch estimates and exploring mitigations in the longline fishery, see Kingston et al. (2023a) and the EU's Coordinated Development and Implementation of Best Practice in Bycatch Reduction in the North Atlantic, Baltic and Mediterranean Regions (CIBBRiNA) project;
2. Ongoing work by the Scottish Entanglement Alliance (SEA) in the Scottish creel fishery;
3. Trials of acoustic deterrents for cetaceans in the Celtic Sea static net fisheries (Clean Catch); and
4. Co-design of seabird bycatch monitoring and mitigation in a trawl fishery in Scottish waters (Clean Catch, in partnership with English and Scottish vessels). Increased sampling effort and revised protocols for BMP observation of demersal trawls to improve sensitive species bycatch estimates (A. Kingston, pers. comm).

See also ICES (2024c) for a recent account of ongoing mitigation trials in the UK and elsewhere in Europe.

Recommendation 11: Given the extent and distribution of trawl effort (which exceeds all other gears), further work should be directed at monitoring and mitigation of trawl bycatch. In particular with respect to elasmobranchs in towed demersal gears and seabirds in trawls (demersal and pelagic).

In seeking effective bycatch mitgation case studies, we were only able to identify two examples in the UK where sensitive species bycatch mitigation had been implemented at scale (i.e. across a fishery or segment of fleet) and adequate data had been collected to document a positive impact. Both case studies, demonstrate that mitigation measures are not universal. Whilst, successful in their respective contexts they were not necessarily suitable for immediate wider adoption.

Case study 1 (Filey Bay), underlines the values of working in partnership with the fishing community, which was critical in establishing monitoring and identifying solutions. A similar ethos underpins the work of the Scottish Entanglement Alliance (SEA), which has worked with fishers to trial sinking groundlines in the static pot (creel) fishery to mitigate cetacean bycatch. An initiative which has been successful in demonstrating a promising, practical gear modification (Calderan et al., 2024). Although the scale of trials to date means its efficacy with respect bycatch mitigation, is yet to be determined. Hence, it was not included here as a case study. Case study 2 (ADDs in static nets), highlights the value of long-term bycatch monitoring. Mitigation efficacy trials are inherently challenging, often in part because the relative rarity of bycatch events means that it can be hard to achieve the requisite statistical power. In spite of its relatively low coverage (<1% of static net fleet effort), the long-term BMP dataset, was invaluable in quantifying positive (and negative) effects of a bycatch mitigation measure (Calderan et al., 2024).

Conclusion

Some 25 years ago, Spencer et al. (2000) reviewed the available literature on cetacean bycatch in the NE Atlantic, characterising it as follows:

> *"In reviewing the literature…a recurrent theme becomes apparent. Most papers open with a statement about the problem of by-catch, followed by an account of anecdotal evidence that lends weight to the urgency of the problem. They conclude with an account of the difficulties inherent in trying to estimate the magnitude…A common outcome is that there are insufficient data available for extrapolation to an annual by-catch rate [or to determine spatial patterns]."*

To some extent these comments still apply, quantifying bycatch and elucidating patterns in time and space remains inherently difficult. However, significant progress is being made, evidenced by the volume of literature the search identified. Whilst gaps remain, the available data is growing at an increasing rate, consider for example, the availability of AIS and VMS fishing effort data. Nevertheless, there is still considerable uncertainty, as evidenced by the wide confidence intervals in most bycatch estimates.

There is now good evidence for a number of specific sensitive species bycatch hotspots and gears of particular concern in the UK. That evidence is sufficient to prioritise efforts, and in some instances that has already established and informed ongoing trials and interventions. Inevitably, a systematic literature review can only identify those bycatch issues that are already known. There is the potential that there are bycatch hotspots, which are un- or under-documented. Such instances will become increasingly rare as new methodological approaches are being applied to data limited scenarios, whilst simultaneously the availability of data is increasing. The continuation of existing long-term monitoring programmes (e.g. BMP, strandings programmes) could soon be complemented by the implementation of cost-effective participatory and remote electronic monitoring approaches at scale. This is increasing technologically feasible. Combining these data, and ensuring they are adequately accessible to relevant parties, will develop a more comprehensive picture of sensitive species bycatch in time and space, directing future mitigation efforts.

References

Almeida, A., Ameryk, A., Campos, B., Crawford, R., Krogulec, J., Linkowski, T., Mitchell, R., Mitchell, W., Oliveira, N. & Oppel, S. 2017. Study on mitigation measures to minimise seabird bycatch in gillnet fisheries. European Commission. Executive Agency for Small and Medium-sized Enterprises (EASME). Brussels, Belgium. Available: https://data.europa.eu/doi/10.2826/799958 [Accessed: 24/02/2026].

Anderson, O. R., Thompson, D. & Parsons, M. 2022. Seabird bycatch mitigation: evidence base for possible UK application and research. JNCC Report No. 717. Joint Nature Conservation Committee (JNCC). Peterborough, UK. Available: https://jncc.gov.uk/resources/dbed3ea2-1c2a-40cf-b0f8-437372f1a036 [Accessed: 24/02/2026].

Araújo, M. B. & New, M. 2007. Ensemble forecasting of species distributions. *Trends in Ecology & Evolution,* 22**,** 42-47.

Astarloa, A., Louzao, M., García-Baron, I. M., Bluemel, J., Couce, E., Carbonara, P., Romagnoni, G., Neglia, C., Zupa, W., Bitetto, I., Spedicato, M.-T., Kindt-Larsen, L., Glemarec, G., Lusseau, D., Maina, I., Chatzispyrou, A., Fotiadis, N., Kavadas, S., Lefkaditou, E., Vassilopoulou, C., Batts, L., Reid, D., Breen, P., Kempf, A., Taylor, M., Kuehn, B., Letschert, J., Northridge, S., Poos, J. J., Afranewaa, N. & Rindorf, A. 2023. SEAwise Report on the bycatch mortality risk of potentially endangered and threatened species of fish, seabirds, reptiles and mammals. Technical University of Denmark. Copenhagen, Denmark. Available: https://doi.org/10.11583/DTU.25041257 [Accessed: 24/02/2026].

Babcock, E. A., Pikitch, E. K. & Hudson, C. G. 2003. *How much observer coverage is enough to adequately estimate bycatch?*, Pew Institute of Ocean Science Miami, FL.

Bastardie, F., Brown, E. J., Andonegi, E., Arthur, R., Beukhof, E., Depestele, J., Döring, R., Eigaard, O. R., García-Barón, I., Llope, M., Mendes, H., Piet, G. & Reid, D. 2021. A Review Characterizing 25 Ecosystem Challenges to Be Addressed by an Ecosystem Approach to Fisheries Management in Europe. *Frontiers in Marine Science,* 7**,** 26.

Bendall, V. A., & Hetherington, S.J. 2021. Bycatch of Protected, Endangered and Threatened (PET) marine wildlife in the commercial fisheries, operating from the South-west of the UK: Bycatch risk status review and future recommendations. Project Report for Defra. Cefas. 39.

Bendall, V. A., Hetherington, S. J., Ellis, J. R., Smith, S. F., Ives, M. J., Gregson, J. & Riley, A. A. 2012. Spurdog, porbeagle and common skate bycatch and discard reduction. Fisheries science partnership: 2011/12. Cefas. Lowestoft, UK. 1-88. Available: https://data-api.cefas.co.uk/api/holdings/646 [Accessed: 24/02/2026].

Bi, R., Jiao, Y. & Browder, J. A. 2021. Climate driven spatiotemporal variations in seabird bycatch hotspots and implications for seabird bycatch mitigation. *Scientific Reports,* 11**,** 20704.

Bjørge, A., Moan, A., Ryeng, K. A. & Wiig, J. R. 2023. Low anthropogenic mortality of humpback (Megaptera novaeangliae) and killer (Orcinus orca) whales in Norwegian purse seine fisheries despite frequent entrapments. *Marine Mammal Science,* 39**,** 481-491.

Borges, L., Rogan, E. & Officer, R. 2005. Discarding by the demersal fishery in the waters around Ireland. *Fisheries Research,* 76**,** 1-13.

Bradbury, G., Shackshaft, M., Scott-Hayward, L., Rexstad, E., Miller, D. & Edwards, D. 2017. Risk assessment of seabird bycatch in UK waters. Report to Defra. Project MB00126. . Wildfowl & Wetlands Trust (Consulting) Ltd. Slimbridge, UK.

Brander, K. 1981. Disappearance of common skate Raia batis from Irish Sea. *Nature,* 290**,** 48-49.

Brown, S. L., Reid, D. & Rogan, E. 2013. A risk-based approach to rapidly screen vulnerability of cetaceans to impacts from fisheries bycatch. *Biological Conservation,* 168**,** 78-87.

Brown, S. L., Reid, D. & Rogan, E. 2015. Spatial and temporal assessment of potential risk to cetaceans from static fishing gears. *Marine Policy,* 51**,** 267-280.

Brownlow, A., Davison, N. & ten Doeschate M 2018. Scottish Marine Animal Stranding Scheme (SMASS) Final Contract Report, 1 April 2015 to 31 March 2018. For Marine Scotland, Scottish Government. Scottish Marine Animal Stranding Scheme (SMASS). Available:

https://strandings.org/wp-content/uploads/2021/05/Contract_Report_2015_2018.pdf [Accessed: 10/12/2025].

Calderan, S., Cisternino, B., De Noia, M., Leaper, R., MacLennan, E. & Philp, B. 2024. Successful collaborative trials of simple gear modifications to reduce entanglement of whales and other megafauna in Scotland's static pot (creel) fisheries. *ICES Journal of Marine Science,* 82.

Calderan, S. & Leaper, R. 2019. Review of harbour porpoise Bycatch in UK Waters and Recommendations for Management. *Nairobi: United Nations Environment Programme*.

Carlson, A. E., Hoffmayer, E. R., Tribuzio, C. A. & Sulikowski, J. A. 2014. The Use of Satellite Tags to Redefine Movement Patterns of Spiny Dogfish (Squalus acanthias) along the U.S. East Coast: Implications for Fisheries Management. *PLOS ONE,* 9**,** e103384.

Carpentieri, P. 2019. Monitoring the incidental catch of vulnerable species in Mediterranean and Black Sea fisheries Methodology for data collection. *FAO Fisheries and Aquaculture Technical Paper***,** I-81.

Carpentieri, P., Nastasi, A., Sessa, M. & Srour, A. 2021. Incidental catch of vulnerable species in Mediterranean and Black Sea fisheries–A review. Food and Agriculture Organisation (FAO). Rome, Italy. Available: https://doi.org/10.4060/cb5405en [Accessed: 24/02/2026].

Cefas 2025. Salmon Stocks and Fisheries in England and Wales in 2024. Cefas, Environment Agency (EA), Natural Resources Wales/Cyfoeth Naturiol Cymru (NRW/CNC). Available: https://assets.publishing.service.gov.uk/media/68b818863f3e5483efdba927/SalmonReport-2024-summary.pdf [Accessed: 22/09/2025].

Chadwick, H., Baillie, A., Barnett, J., Brownlow, A., Carter, M., Clarke, J., Davison, N., Deaville, R., Godley, B. J., Jepson, P., Penrose, R., ten Doeschate, M., Williams, R. & Nelms, S. E. in prep. Three decades of cetacean strandings data reveal spatiotemporal trends in bycatch: implications for conservation and management.

Ciannelli, L., Fauchald, P., Chan, K.-S., Agostini, V. N. & Dingsør, G. E. 2008. Spatial fisheries ecology: recent progress and future prospects. *Journal of Marine Systems,* 71**,** 223-236.

Clay, T. A., Small, C., Tuck, G. N., Pardo, D., Carneiro, A. P., Wood, A. G., Croxall, J. P., Crossin, G. T. & Phillips, R. A. 2019. A comprehensive large-scale assessment of fisheries bycatch risk to threatened seabird populations. *Journal of Applied Ecology,* 56**,** 1882-1893.

Cleasby, I. R., Owen, E., Wilson, L., Wakefield, E. D., O'Connell, P. & Bolton, M. 2020. Identifying important at-sea areas for seabirds using species distribution models and hotspot mapping. *Biological Conservation,* 241**,** 108375.

Cleasby, I. R., Wilson, L. J., Crawford, R., Owen, E., Rouxel, Y. & Bolton, M. 2022. Assessing bycatch risk from gillnet fisheries for three species of diving seabird in the UK. *Marine Ecology Progress Series,* 684**,** 157-179.

Condie, H. 2013. *Discarding in UK Commercial Fisheries. PhD Thesis.* University of East Anglia.

Coombs, E. J., Deaville, R., Sabin, R. C., Allan, L., O'Connell, M., Berrow, S., Smith, B., Brownlow, A., Doeschate, M. T. & Penrose, R. 2019a. What can cetacean stranding records tell us? A study of UK and Irish cetacean diversity over the past 100 years. *Marine Mammal Science,* 35**,** 1527-1555.

Coombs, E. J., Deaville, R., Sabin, R. C., Allan, L., O'Connell, M., Berrow, S., Smith, B., Brownlow, A., Doeschate, M. T., Penrose, R., Williams, R., Perkins, M. W., Jepson, P. D. & Cooper, N. 2019b. What can cetacean stranding records tell us? A study of UK and Irish cetacean diversity over the past 100 years. *Marine Mammal Science,* 35**,** 1527-1555.

Cortés, E., Brooks, E. N. & Shertzer, K. W. 2015. Risk assessment of cartilaginous fish populations. *ICES Journal of Marine Science,* 72**,** 1057-1068.

Cosandey-Godin, A., Krainski, E. T., Worm, B. & Flemming, J. M. 2015. Applying Bayesian spatiotemporal models to fisheries bycatch in the Canadian Arctic. *Canadian Journal of Fisheries and Aquatic Sciences,* 72**,** 186-197.

CWT 2025. Annual Summary Report: Marine Strandings in Cornwall and the Isles of Scilly (2015-2023 available online). Cornwall Wildlife Trust (CWT).

Davies, R., Cripps, S. J., Nickson, A. & Porter, G. 2009. Defining and estimating global marine fisheries bycatch. *Marine Policy,* 33**,** 661-672.

Davison, N., ten Doeschate, M. & Brownlow, A. 2019. Annual Report 2019, 1 January to 31 December 2019 for Marine Scotland, Scottish Government. Scottish Marine Animal Stranding Scheme (SMASS),. Inverness, Scotland. Available: https://strandings.org/wp-content/uploads/2021/05/SMASS_Annual_Report_2019.pdf [Accessed: 19/02/2026].

de Boer, M., Leaper, R., Keith, S. & Simmonds, M. 2008. Winter abundance estimates for the common dolphin (Delphinus delphis) in the western approaches of the English Channel and the effect of responsive movement. *Journal of Marine Animals and Their Ecology,* 1**,** 14-20.

de Boer, M. N., Saulino, J. T., Leopold, M. F., Reijnders, P. J. & Simmonds, M. P. 2012. Interactions Between Short-Beaked Common Dolphin (Delphinus delphis) and the Winter Pelagic Pair-Trawl Fishery off Southwest England (UK).

Deaville, R., Jepson, P., Perkins, M., Williams, R., Brownlow, A., Davison, N., ten Doeschate, M., MacLennan, E., Smith, B., Baillie, A. & Sabin, R. C. 2020. CSIP Annual Report for the period 1st January – 31st December 2020 (Contract number ME6008). Available: https://randd.defra.gov.uk/ProjectDetails?ProjectID=20101 [Accessed: 16/12/2025].

Deaville, R., Jepson PD, erkins M, Brownlow A, Davison N, ten Doeschate M, Smith B, Allan L, Clery M, Swindells K, Wilson S, Sabin RC, Penrose R, Barnett JEF, Astley K, Clear N, Crosby A & R, W. 2018. UK Cetacean Strandings Investigation Programme final contract report to Defra (MB0111 2011-2017). Available: https://randd.defra.gov.uk/ProjectDetails?ProjectId=17835 [Accessed: 27/11/2025].

Defra 2022a. Joint Fisheries Statement. Department for Environment Food and Rural Affairs (Defra). Available: https://assets.publishing.service.gov.uk/media/637cee048fa8f53f4af6850b/Joint_Fisheries_Statement_JFS_2022_Final.pdf [Accessed: 19/03/2025].

Defra 2022b. Marine wildlife bycatch mitigation initiative. Department for Environment Food and Rural Affairs (Defra). Available: https://www.gov.uk/government/publications/marine-wildlife-bycatch-mitigation-initiative/marine-wildlife-bycatch-mitigation-initiative [Accessed: 19/03/2025].

Defra 2024. Consultation outcome. Summary of responses and Government response. Department for Environment Food and Rural Affairs (Defra). Available: https://www.gov.uk/government/consultations/remote-electronic-monitoring/outcome/summary-of-responses-and-government-response#government-response [Accessed: 09/12/2025].

Dolman, S., Baulch, S., Evans, P. G., Read, F. & Ritter, F. 2016. Towards an EU action plan on cetacean bycatch. *Marine Policy,* 72**,** 67-75.

Dörner, H., Graham, N., Bianchi, G., Bjordal, Å., Frederiksen, M., Karp, W. A., Kennelly, S. J., Martinsohn, J. T., Murray, K. & Pastoors, M. 2015. From cooperative data collection to full collaboration and co-management: a synthesis of the 2014 ICES symposium on fishery-dependent information. *ICES Journal of Marine Science,* 72**,** 1133-1139.

EA 2020. Consultation report: Options for extending the sea trout beach net fishery in Yorkshire and North East England. Environment Agency (EA). Available: https://consult.environment-agency.gov.uk/north-east/yorkshire-and-north-east-coastal-sea-trout-fishery/supporting_documents/Sea%20trout%20net%20fishery%20consultation%20report.pdf [Accessed: 17/09/2025].

EIA 2025. Catch of the Day: The deadly impacts of cetacean bycatch in European waters. Environmental Investigations Agency (EIA). Available: https://eia-international.org/report/catch-of-the-day-the-deadly-impacts-of-cetacean-bycatch-in-european-waters/.

Elith, J., H. Graham, C., P. Anderson, R., Dudík, M., Ferrier, S., Guisan, A., J. Hijmans, R., Huettmann, F., R. Leathwick, J. & Lehmann, A. 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography,* 29**,** 129-151.

Elith, J. & Leathwick, J. R. 2009. Species distribution models: ecological explanation and prediction across space and time. *Annual review of ecology, evolution, and systematics,* 40**,** 677-697.

Elliott, S. A. M., Carpentier, A., Feunteun, E. & Trancart, T. 2020. Distribution and life history trait models indicate vulnerability of skates. *Progress in Oceanography,* 181**,** 10.

Ellis, J., Bendall, V., Hetherington, S., Silva, J. & McCully Phillips, S. 2016. National evaluation of populations of threatened and uncertain elasmobranchs (NEPTUNE) project report. . CEFAS.

Enever, R., Lewin, S., Reese, A. & Hooper, T. 2017. Mapping fishing effort: Combining fishermen's knowledge with satellite monitoring data in English waters. *Fisheries Research,* 189**,** 67-76.

Enever, R., Revill, A. & Grant, A. 2007. Discarding in the English Channel, Western approaches, Celtic and Irish seas (ICES subarea VII). *Fisheries Research,* 86**,** 143-152.

European Commission 2024. Fisheries landings & effort: data by c-square. European Commission, Joint Research Centre (JRC). Available: http://data.europa.eu/89h/f847528b-1734-4bb8-8361-f4877ba395ed [Accessed: 09/12/2025].

Evans, P., Carrington, C. & Waggitt, J. 2021. Risk Assessment of Bycatch of Protected Species in Fishing Activities. European Commission Contract No. 09029901/2021/844548/ENV.D.3. Sea Watch Foundation and Bangor University. Available: https://pure.bangor.ac.uk/ws/portalfiles/portal/52617216/RISK_MAPPING_REPORT.pdf [Accessed: 24/02/2026].

Finucci, B., Derrick, D. & Pacoureau, N. 2021. Scyliorhinus stellaris. The IUCN Red List of Threatened Species. International Union for the Conservation of Nature (IUCN). Available: https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T161484A124493465.en.

FITF. 2025. *The Fishing Porthole: Reducing bird bycatch in Filey Bay* [Online]. Fishing into the Future (FITF). Available: https://www.fishingporthole.co.uk/case-study/reduce-bird-bycatch/ [Accessed 17/09/2025].

Furness, R. W., Wade, H. M., Robbins, A. M. & Masden, E. A. 2012. Assessing the sensitivity of seabird populations to adverse effects from tidal stream turbines and wave energy devices. *ICES Journal of Marine Science,* 69**,** 1466-1479.

Gandini, P. & Frere, E. 2012. The economic cost of seabird bycatch in Argentinean longline fisheries. *Bird Conservation International,* 22**,** 59-65.

Gianuca, D., Phillips, R. A., Townley, S. & Votier, S. C. 2017. Global patterns of sex-and age-specific variation in seabird bycatch. *Biological Conservation,* 205**,** 60-76.

Gilles, A., Authier, M., Ramirez-Martinez, N., Araújo, H., Blanchard, A., Carlström, J., Eira, C., Dorémus, G., Fernández-Maldonado, C. & Geelhoed, S. 2023. Estimates of cetacean abundance in European Atlantic waters in summer 2022 from the SCANS-IV aerial and shipboard surveys. Final report published 29 September 2023.

Glarou, M., Kerametsidis, G., Akkaya, A., Beqiri, K., Nikpaljevic, N., Awbery, T., Bakiu, R. & Geijer, C. K. 2022. Using off-the-shelf GPS loggers to assess co-occurrence between marine mammals and small-scale fisheries: a pilot study from the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom,* 102**,** 322-332.

Glemarec, G., Kindt-Larsen, L., Lundgaard, L. S. & Larsen, F. 2020. Assessing seabird bycatch in gillnet fisheries using electronic monitoring. *Biological Conservation,* 243**,** 108461.

Gray, C. A. & Kennelly, S. J. 2018. Bycatches of endangered, threatened and protected species in marine fisheries. *Reviews in Fish Biology and Fisheries,* 28**,** 521-541.

Grewelle, R. E., Mansfield, E., Micheli, F. & De Leo, G. 2021. Redefining risk in data-poor fisheries. *Fish and Fisheries,* 22**,** 929-940.

Guisan, A. & Thuiller, W. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology letters,* 8**,** 993-1009.

Haddaway, N. R., Macura, B., Whaley, P. & Pullin, A. S. 2018. ROSES RepOrting standards for Systematic Evidence Syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence,* 7**,** 1-8.

Häkkinen, H., Petrovan, S. O., Sutherland, W. J. & Pettorelli, N. 2021. Terrestrial or marine species distribution model: Why not both? A case study with seabirds. *Ecology and Evolution,* 11**,** 16634-16646.

Hall, M. A., Alverson, D. L. & Metuzals, K. I. 2000. By-catch: problems and solutions. *Marine pollution bulletin,* 41**,** 204-219.

Hammond, P. S., Francis, T. B., Heinemann, D., Long, K. J., Moore, J. E., Punt, A. E., Reeves, R. R., Sepúlveda, M., Sigurðsson, G. M. & Siple, M. C. 2021. Estimating the abundance of marine mammal populations. *Frontiers in Marine Science,* 8**,** 735770.

Heinänen, S. & Skov, H. 2015. The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area, JNCC Report No. 544. Joint Nature Conservation Committee (JNCC). Peterborough, UK. Available: https://jncc.gov.uk/resources/f7450390-9a89-4986-8389-9bff5ea1978a [Accessed: 24/02/2026].

Hetherington, S. J., Bendall, V. A., Engelhard, G., Clare, T. K., Sibthorpe, E. & Ryan, K. 2022. Spurdog Bycatch Management Programme - A Three Year Review. A Clean Catch UK report for Defra. 23. Available: https://www.cleancatchuk.com/wp-content/uploads/2022/03/15377_ME6023_CCUK_Spurdog_Three_Year_Review.pdf.

Hetherington, S. J., Nicholson, R. E. & O'Brien, C. M. 2016. Spurdog By-catch Avoidance Programme. MB0142 Final Report. Cefas. 52. Available: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=19658 [Accessed: 24/02/2026].

Hines, E., Ponnampalam, L. S., Junchompoo, C., Peter, C., Vu, L., Huynh, T., Caillat, M., Johnson, A. F., Minton, G. & Lewison, R. L. 2020. Getting to the bottom of bycatch: a GIS-based toolbox to assess the risk of marine mammal bycatch. *Endangered Species Research,* 42**,** 37-57.

Hobday, A., Smith, A., Stobutzki, I., Bulman, C., Daley, R., Dambacher, J., Deng, R., Dowdney, J., Fuller, M. & Furlani, D. 2011. Ecological risk assessment for the effects of fishing. *Fisheries Research,* 108**,** 372-384.

Hordyk, A. R. & Carruthers, T. R. 2018. A quantitative evaluation of a qualitative risk assessment framework: Examining the assumptions and predictions of the Productivity Susceptibility Analysis (PSA). *PloS one,* 13**,** e0198298.

ICES 2013. Report of the Workshop to Review and Advise on Seabird Bycatch (WKBYCS). International Council for the Exploration of the Sea (ICES). Copenhagen, Denmark. 79.

ICES. 2020a. *Celtic Seas ecoregion – Fisheries overview, including mixed-fisheries considerations* [Online]. International Council for the Exploration of the Seas (ICES). Available: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2020/2020/FisheriesOverviews_CelticSeas_2020.pdf [Accessed 20/10/ 2021].

ICES 2020b. Working Group on Bycatch of Protected Species (WGBYC). International Council for the Exploration of the Seas (ICES). 216 pp. Available: http://doi.org/10.17895/ices.pub.7471

ICES 2022a. ICES Roadmap for bycatch advice on protected, endangered and threatened species. Report by the Working Group on Bycatch of Protected Species (WGBYC). . International Council for the Exploration of the Seas (ICES). Available: https://doi.org/10.17895/ices.advice.19657167.v1 [Accessed: 25/09/2024].

ICES 2022b. Workshop on estimation of mortality of marine mammals due to bycatch (WKMOMA). International Council for the Exploration of the Sea (ICES). 97. Available: https://doi.org/10.17895/ices.pub.9257 [Accessed: 11/02/2025].

ICES 2023a. Bycatch of endangered, threatened and protected species of marine mammals, seabirds and marine turtles, and selected fish species of bycatch relevance. In Report of the ICES Advisory Committee, 2023. . International Council for the Exploration of the Seas (ICES). Available: https://doi.org/10.17895/ices.advice.24681123.

ICES 2023b. Workshop on mitigation measures to reduce bycatch of short-beaked common dolphins in the Bay of Biscay (WKEMBYC2). International Council for the Exploration of the Sea (ICES). 96. Available: https://doi.org/10.17895/ices.pub.21940337 [Accessed: 10/02/2026].

ICES 2023c. Workshop on seabird bycatch monitoring in the NEAFC regulatory areas (WKBB). International Council for the Exploration of the Sea (ICES). 106. Available: https://doi.org/10.17895/ices.pub.23635305 [Accessed: 16/06/2025].

ICES 2024a. Bycatch of endangered, threatened and protected species of marine mammals, seabirds and marine turtles, and selected fish species of bycatch relevance. International Council for the Exploration of the Seas (ICES). Available: https://ices-library.figshare.com/articles/report/Bycatch_of_endangered_threatened_and_protected_species_of_marine_mammals_seabirds_and_marine_turtles_and_selected_fish_species_of_bycatch_relevance/27999401 [Accessed: 30/06/2025].

ICES 2024b. Third Workshop on appropriate sampling schemes for Protected, Endangered and Threatened Species bycatch (WKPETSAMP3). International Council for the Exploration of the Sea (ICES). 96. Available: https://doi.org/10.17895/ices.pub.25061522 [Accessed: 10/02/2026].

ICES 2024c. Working Group on Bycatch of Protected Species (WGBYC).
. International Council for the Exploration of the Seas (ICES). 237. Available: https://doi.org/10.17895/ices.pub.27762723 [Accessed: 24/02/2026].

IJsseldijk, L. L., Brownlow, A. C. & Mazzariol, S. 2019. European best practice on cetacean post-mortem investigation and tissue sampling. Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) and Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS).

Ijsseldijk, L. L., Scheidat, M., Siemensma, M. L., Couperus, B., Leopold, M. F., Morell, M., Gröne, A. & Kik, M. J. L. 2021. Challenges in the Assessment of Bycatch: Postmortem Findings in Harbor Porpoises (*Phocoena phocoena*) Retrieved From Gillnets. *Veterinary Pathology,* 58**,** 405-415.

Jones, M. C., Dye, S. R., Fernandes, J. A., Frölicher, T. L., Pinnegar, J. K., Warren, R. & Cheung, W. W. L. 2013. Predicting the Impact of Climate Change on Threatened Species in UK Waters. *PLoS ONE,* 8.

Jubinville, I., Lawler, E., Tattrie, S., Shackell, N. L., Flemming, J. M. & Worm, B. 2021. Distributions of threatened skates and commercial fisheries inform conservation hotspots. *Marine Ecology Progress Series,* 679**,** 1-18.

Karpouzi, V. S., Watson, R. & Pauly, D. 2007. Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment. *Marine Ecology Progress Series,* 343**,** 87-99.

Kingston, A., Northridge, S., Paxton, C. G. M. & Buratti, J. P. F. 2023a. Improving Understanding of Seabird Bycatch in Scottish Longline Fisheries and Exploring Potential Solutions. University of St Andrews. St Andrews, Scotland.

Kingston, A., Thomas, L. & Northridge, S. 2021. UK Bycatch Monitoring Programme Report for 2019. Sea Mammal Research Unit (SMRU), University of St Andrews.

Kingston, A., Thomas, L. & Northridge, S. 2023b. UK Bycatch Monitoring Programme Report for 2020. Sea Mammal Research Unit (SMRU), University of St Andrews.

Kober, K., Clarke, E., Kingston, A., Ribeiro Santos, A., Balestri, E., Coull, K. & Anderson, O. 2024. Gap analysis on the monitoring of marine bird bycatch by British vessels – Report to the Department for Environment, Food & Rural Affairs. JNCC Report 761. Joint Nature Conservation Committee (JNCC). Peterborough. Available: https://hub.jncc.gov.uk/assets/419e4128-c099-4be3-ae3e-35b313a59561.

Komoroske, L. M. & Lewison, R. L. 2015. Addressing fisheries bycatch in a changing world. *Frontiers in Marine Science,* 2**,** 83.

Le Quesne, W. J. & Jennings, S. 2012. Predicting species vulnerability with minimal data to support rapid risk assessment of fishing impacts on biodiversity. *Journal of Applied Ecology,* 49**,** 20-28.

Leaper, R., MacLennan, E., Brownlow, A., Calderan, S. V., Dyke, K., Evans, P. G., Hartny-Mills, L., Jarvis, D., McWhinnie, L. & Philp, A. 2022. Estimates of humpback and minke whale entanglements in the Scottish static pot (creel) fishery. *Endangered Species Research,* 49**,** 217-232.

Leeney, R. H., Amies, R., Broderick, A. C., Witt, M. J., Loveridge, J., Doyle, J. & Godley, B. J. 2008. Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot. *Biodiversity and Conservation,* 17**,** 2323-2338.

Lennan, M., Fernández, J. E. & Johansson, T. M. 2022. The Fisheries Act 2020 and Devolution. *Fisheries and the Law in Europe.* Routledge.

Lewison, R. L., Crowder, L. B., Read, A. J. & Freeman, S. A. 2004. Understanding impacts of fisheries bycatch on marine megafauna. *Trends in ecology & evolution,* 19**,** 598-604.

Lewison, R. L., Crowder, L. B., Wallace, B. P., Moore, J. E., Cox, T., Zydelis, R., McDonald, S., DiMatteo, A., Dunn, D. C. & Kot, C. Y. 2014. Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. *Proceedings of the National Academy of Sciences,* 111**,** 5271-5276.

Lin, M., Liu, M., Turvey, S. T. & Li, S. 2023. An interview-based investigation of marine megafauna bycatch in the northern South China Sea. *Biological Conservation,* 286**,** 110297.

Long, S., Barker, J., Deaville, R. & Yesson, C. 2022. Temporal and spatial mapping of vulnerable marine species and bycatch risk in the Celtic Sea. Zoological Society of London. London, UK.

Lucas, S. & Berggren, P. 2023. A systematic review of sensory deterrents for bycatch mitigation of marine megafauna. *Reviews in Fish Biology and Fisheries,* 33**,** 1-33.

Lucchetti, A., Vasapollo, C. & Virgili, M. 2017. An interview-based approach to assess sea turtle bycatch in Italian waters. *PeerJ,* 5**,** e3151.

Lynam, C. P., Cusack, C. & Stokes, D. 2010. A methodology for community-level hypothesis testing applied to detect trends in phytoplankton and fish communities in Irish waters. *Estuarine, Coastal and Shelf Science,* 87**,** 451-462.

MacLennan, E., Hartny-Mills, L., Read, F.L., Dolman, S.J., Philp, A., Dearing, K.E., Jarvis, D. and Brownlow, A.C. 2021. Scottish Entanglement Alliance (SEA) - understanding the scale and impacts of marine animal entanglement in the Scottish creel fishery. NatureScot Research Report 1268. NatureScot. Available: https://www.nature.scot/doc/naturescot-research-report-1268-scottish-entanglement-alliance-sea-understanding-scale-and-impacts [Accessed: 24/02/2026].

MacLennan, E., Leaper, R. & Dolman, S. 2019. Interim report from the Scottish Entanglement Alliance (SEA) on previously undocumented fatal entanglements of minke whales (*Balaenoptera acutorostrata*) in Scottish inshore waters. Paper SC/68A/HIM/02. International Whaling Commission. Nairobi, Kenya.

Mangi, S. C., Dolder, P. J., Catchpole, T. L., Rodmell, D. & de Rozarieux, N. 2015. Approaches to fully documented fisheries: practical issues and stakeholder perceptions. *Fish and Fisheries,* 16**,** 426-452.

Mangi, S. C., Kupschus, S., Mackinson, S., Rodmell, D., Lee, A., Bourke, E., Rossiter, T., Masters, J., Hetherington, S. & Catchpole, T. 2018. Progress in designing and delivering effective fishing industry–science data collection in the UK. *Fish and Fisheries,* 19**,** 622-642.

Marchowski, D. 2021. Bycatch of seabirds in the Polish part of the southern Baltic Sea in 1970-2018: a review. *Acta Ornithologica,* 56**,** 139-158.

McGeady, R., Loca, S. L. & McGonigle, C. 2022. Spatio-temporal dynamics of the common skate species complex: Evidence of increasing abundance. *Diversity and Distributions,* 28**,** 2403-2415.

Mérillet, L., Kopp, D., Robert, M., Mouchet, M. & Pavoine, S. 2020. Environment outweighs the effects of fishing in regulating demersal community structure in an exploited marine ecosystem. *Global change biology,* 26**,** 2106-2119.

Miles, J., Parsons, M. & O'Brien, S. 2020. Preliminary assessment of seabird population response to potential bycatch mitigation in the UK-registered fishing fleet. Report prepared for the Department for Environment Food and Rural Affairs (Project Code ME6024). Joint Nature

Conservation Committee (JNCC). Available: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=20461 [Accessed: 24/02/2026].

Milton, D. A. 2001. Assessing the susceptibility to fishing of populations of rare trawl bycatch: sea snakes caught by Australia's Northern Prawn Fishery. *Biological Conservation,* 101**,** 281-290.

MMO 2025. Stage 4 Harbour Porpoise Bycatch Management Options Draft. Marine Management Organisation (MMO). Available: https://assets.publishing.service.gov.uk/media/687100b981dd8f70f5de3e9a/MMO_Stage_4_Harbour_Porpoise_Bycatch_Management_Options_Draft_Version_1_-_11_July_2025.pdf [Accessed: 22/09/2025].

Moore, A. B., Heney, C., Lincoln, H., Colvin, C., Newell, H., Turner, R., McCarthy, I. D. & Hold, N. 2023. Bycatch in northeast Atlantic lobster and crab pot fisheries (Irish Sea, Celtic Sea and Bristol Channel). *Fisheries Research,* 265**,** 106745.

Moyes, F., Smout, S., Thomas, L., Kingston, A. & Northridge, S. 2025. Factors associated with bycatch of marine mammals in United Kingdom static net fisheries. *ICES Journal of Marine Science,* 82.

Murphy, S., Evans, P. G., Pinn, E. & Pierce, G. J. 2021. Conservation management of common dolphins: Lessons learned from the North-East Atlantic. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 31**,** 137-166.

Murray, K. T., Hatch, J. M., DiGiovanni, R. A. & Josephson, E. 2021. Tracking young-of-The-year gray seals Halichoerus grypus to estimate fishery encounter risk. *Marine Ecology Progress Series,* 671**,** 235-245.

NAMMCO & IMR 2019. Report of Joint IMR/NAMMCO International Workshop on the Status of Harbour Porpoises in the North Atlantic. North Atlantic Marine Mammal Commission (NAMMACO) and the Norwegian Institute of Marine Research (IMR). Tromsø, Norway.

Nielsen, K. A., Robbins, J. R. & Embling, C. B. 2021. Spatio-temporal patterns in harbour porpoise density: citizen science and conservation in UK seas. *Marine Ecology Progress Series,* 675**,** 165-180.

Northridge, S., Cargill, A., Coram, A., Mandleberg, L., Calderan, S. & Reid, B. 2010. Entanglement of minke whales in Scottish waters; an investigation into occurrence, causes and mitigation. Sea Mammal Research Unit (SMRU), University of St Andrews. St Andrews, Scotland.

Northridge, S., Coram, A. J. & Kingston, A. 2012. SMRU Contribution to the DefineIt Final Report. Task 3.2.2: The susceptibility of sensitive species through analysis of their distribution and the overlap with relevant fishing effort distribution. Sea Mammal Research Unit (SMRU), University of St Andrews. St Andrews, Scotland.

Northridge, S., Coram, A., and Kingston, Al. 2020. Understanding the Impact of Marine Mammal Bycatch in the UK. Final Report to Defra. . Sea Mammal Research Unit (SMRU), University of St Andrews. . St Andrews, Scotland.

Northridge, S., Kingston, A. & Coram, A. J. 2020. Preliminary estimates of seabird bycatch by UK vessels in UK and adjacent waters. Final Report to JNCC – Revised October 2020. Available: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=20461 [Accessed: 24/02/2026].

Northridge, S., Kingston, A., Mackay, A. & Lonergan, M. 2011. Bycatch of vulnerable species: understanding the process and mitigating the impacts. Final report to Defra Marine and Fisheries Science Unit, Project no MF1003. Sea Mammal Research UNit (SMRU), University of St Andrews. 99. Available: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=15987 [Accessed: 24/02/2026].

Northridge, S. P., Kingston, A. R. & Coram, A. J. 2023. Regional seabird bycatch hotspot analysis. JNCC Report No. 726. Joint Nature Conservation Committee (JNCC). Peterborough, UK. Available: https://sciencesearch.defra.gov.uk/ProjectDetails?ProjectId=20461 [Accessed: 24/02/2026].

OBIS. 2021. *Ocean Biodiversity Information System (OBIS)* [Online]. Intergovernmental Oceanographic Commission of UNESCO. Available: www.obis.org [Accessed 13/01/ 2021].

Palialexis, A., S. Korpinen, A. F. Rees, I. Mitchell, D. Micu, J. Gonzalvo, D. Damalas, M. Aissi, L. Avellan, A. Brind'Amour, A. Brunner, S. Camilleri, I. Carlén, D. Connor, M. Dagys, A. C. Cardoso, V.

Dierschke, J-N. Druon, S. Engbo, M. Frederiksen, P. Gruszka, F. Haas, J. Haldin, N. Häubner, P. Heslenfeld, L. Koehler, S. Koschinski, V. Kousteni, M-L. Krawack, A. Kreutle, E. Lefkaditou, L. Lozys, L. Luigujoe, C. Lynam, C. Magliozzi, I. Makarenko, G. Meun, T. Moura, M. Pavičić, N. Probst, M. Salomidi, F. Somma, F. Svensson, K. Torn, K. Tsiamis, M. Tuaty-Guerra 2021. Species thresholds: Review of methods to support the EU Marine Strategy Framework Directive. European Union. Luxembourg.

Pascoe, S. & Tingley, D. 2010. Fisheries Management in the United Kingdom. *In:* QUENTIN GRAFTON, R., HILBORN, R., SQUIRES, D., TAIT, M. & WILLIAMS, M. J. (eds.) *Handbook of Marine Fisheries Conservation and Management.* Oxford University Press.

Patrick, W. S. & Benaka, L. R. 2013. Estimating the economic impacts of bycatch in US commercial fisheries. *Marine Policy,* 38**,** 470-475.

Patrick, W. S., Spencer, P., Ormseth, O. A., Cope, J. M., Field, J. C., Kobayashi, D. R., Gedamke, T., Cortés, E., Bigelow, K. & Overholtz, W. J. 2009. Use of productivity and susceptibility indices to determine stock vulnerability, with example applications to six US fisheries.

Pawson, M. & Ellis, J. 2005. Stock identity of elasmobranchs in the Northeast Atlantic in relation to assessment and management. *Journal of Northwest Atlantic Fishery Science,* 35**,** 173-193.

Paxton, C. G. M., Scott-Hayward, L. A. S., MacKenzie, M. L., Rexstad, E. & Thomas, L. J. 2016. Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resources with Advisory Note: Report 517.

Peltier, H., Authier, M., Caurant, F., Dabin, W., Daniel, P., Dars, C., Demaret, F., Meheust, E., Van Canneyt, O. & Spitz, J. 2021. In the wrong place at the wrong time: identifying spatiotemporal co-occurrence of bycaught common dolphins and fisheries in the Bay of Biscay (NE Atlantic) from 2010 to 2019. *Frontiers in Marine Science,* 8**,** 617342.

Peltier, H., Authier, M., Deaville, R., Dabin, W., Jepson, P. D., van Canneyt, O., Daniel, P. & Ridoux, V. 2016. Small cetacean bycatch as estimated from stranding schemes: the common dolphin case in the northeast Atlantic. *Environmental Science & Policy,* 63**,** 7-18.

Pérez Roda, M. A., Gilman, E., Huntington, T., Kennelly, S. J., Suuronen, P., Chaloupka, M. & Medley, P. 2019. A third assessment of global marine fisheries discards. Food and Agriculture Oraganisation of the United Nations (FAO). Rome, Italy.

Phillips, R. A., Fox, E., Crawford, R., Prince, S. & Yates, O. 2024. Incidental mortality of seabirds in trawl fisheries: A global review. *Biological Conservation,* 296**,** 110720.

Pierce, G. J., Dyson, J., Kelly, E., Eggleton, J. D., Whomersley, P., Young, I. A. G., Santos, M. B., Wang, J. & Spencer, N. J. 2002. Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK). *Aquatic Living Resources,* 15**,** 327-334.

Piet, G., Van Hal, R. & Greenstreet, S. 2009. Modelling the direct impact of bottom trawling on the North Sea fish community to derive estimates of fishing mortality for non-target fish species. *ICES Journal of Marine Science,* 66**,** 1985-1998.

Pikesley, S. K., Witt, M. J., Hardy, T., Loveridge, J., Loveridge, J., Williams, R. & Godley, B. J. 2012. Cetacean sightings and strandings: evidence for spatial and temporal trends? *Journal of the Marine Biological Association of the United Kingdom,* 92**,** 1809-1820.

Piovano, S., Basciano, G., Swimmer, Y. & Giacoma, C. 2012. Evaluation of a bycatch reduction technology by fishermen: A case study from Sicily. *Marine Policy,* 36**,** 272-277.

Pott, C. & Wiedenfeld, D. A. 2017. Information gaps limit our understanding of seabird bycatch in global fisheries. *Biological Conservation,* 210**,** 192-204.

QSR International 2024. NVivo qualitative data analysis software, verison 14. QSR International Pty Ltd.

Quayle, H. 2015. Filey Bay: Safe Seas for Seabirds December 2015. Royal Society for the Protection of Birds (RSPB).

Queiroz, N., Humphries, N. E., Couto, A., Vedor, M., Da Costa, I., Sequeira, A. M., Mucientes, G., Santos, A. M., Abascal, F. J. & Abercrombie, D. L. 2019. Global spatial risk assessment of sharks under the footprint of fisheries. *Nature,* 572**,** 461-466.

Queiroz, N., Humphries, N. E., Mucientes, G., Hammerschlag, N., Lima, F. P., Scales, K. L., Miller, P. I., Sousa, L. L., Seabra, R. & Sims, D. W. 2016. Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots. *Proceedings of the National Academy of Sciences,* 113**,** 1582-1587.

Ramírez, I., Mitchell, D., Vulcano, A., Rouxel, Y., Marchowski, D., Almeida, A., Arcos, J., Cortes, V., Lange, G. & Morkūnas, J. 2024. Seabird bycatch in European waters. *Animal Conservation,* 27**,** 737-752.

Rayner, J., Embling, C. B., Ryan, C. & Hartny-Mills, L. 2024. Minke whale entanglement in static fishing gear: identifying consistent areas of high risk in Western Scotland. *Journal of the Marine Biological Association of the United Kingdom,* 104**,** e15.

Read, A. J. 2008. The looming crisis: interactions between marine mammals and fisheries. *Journal of Mammalogy,* 89**,** 541-548.

Régnier, T., Gibb, F., Clarke, J., Langton, R., Kinnear, S. & Boulcott, P. 2024. NatureScot Research Report 1365-Elasmobranch distributions and interactions with fisheries. NatureScot. Aberdeen, Scotland. Available: https://www.nature.scot/doc/naturescot-research-report-1365-elasmobranch-distributions-and-interactions-fisheries#3-distribution-models.

Roe, J. H., Morreale, S. J., Paladino, F. V., Shillinger, G. L., Benson, S. R., Eckert, S. A., Bailey, H., Tomillo, P. S., Bograd, S. J. & Eguchi, T. 2014. Predicting bycatch hotspots for endangered leatherback turtles on longlines in the Pacific Ocean. *Proceedings of the Royal Society B: Biological Sciences,* 281**,** 20132559.

Runnebaum, J., Tanaka, K. R., Guan, L., Cao, J., Brien, L. O. & Chen, Y. 2020. Predicting bycatch hotspots based on suitable habitat derived from fishery-independent data. *Marine Ecology Progress Series,* 641**,** 159-175.

Rya, C., Leaper, R., Evans, P. G., Dyke, K., Robinson, K. P., Haskins, G. N., Calderan, S., van Geel, C. F., Harries, O. & Froud, K. 2016. Entanglement: an emerging threat to humpback whales in Scottish waters. International Whaling Commission.

Ryan, C., Calderan, S., Allison, C., Leaper, R. & Risch, D. 2022. Historical occurrence of whales in Scottish Waters inferred from whaling records. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 32**,** 1675-1692.

SCOS 2021. Scientific Advice on Matters Related to the Management of Seal Populations: 2021. Natural Environment Research Council's (NERC) Special Committee on Seals (SCOS). Sea Mammal Research Unit (SMRU), University of St Andrews. St Andrews, Scotland. Available: https://www.smru.st-andrews.ac.uk/scos/scos-reports/index.html [Accessed: 30/04/2025].

SCOS 2022. Scientific Advice on Matters Related to the Management of Seal Populations: 2022. Natural Environment Research Council's (NERC) Special Committee on Seals (SCOS). Sea Mammal Research Unit (SMRU), University of St Andrews, Scotland. St Andres, Scotland. Available: https://www.smru.st-andrews.ac.uk/scos/scos-reports/index.html [Accessed: 30/04/2025].

Scottish Government. 2024. *The Sea Fisheries (Remote Electronic Monitoring and Regulation of Scallop Fishing) (Scotland) Regulations 2024. Available: https://www.legislation.gov.uk/ssi/2024/165/contents/made [Accessed: 08/04/2026].*

SEA 2021. Project Summary: Understanding the scale and impacts of marine animal entanglement in the Scottish creel fishery. Scottish Entanglement Alliance (SEA).

Seafish 2017. UK Sea Fish Industry Map. Seafish. Available: https://www.seafish.org/document/?id=10e3c608-71f3-4474-a751-c442ae1d76ec [Accessed: 04/06/2025].

Seafish 2020. UK Economic Fleet Estimates and Fleet Enquiry Tool. Methodology Report. Seafish Report No SR750. Seafish. Available: https://www.seafish.org/document/?id=35384 [Accessed: 27/11/2025].

Seafish. 2025. *Fishing data and insight. 2023 Annual Fleet Survey* [Online]. Available: https://www.seafish.org/insight-and-research/fishing-data-and-insight/ [Accessed 03/19 2025].

Sguotti, C., Lynam, C. P., García-Carreras, B., Ellis, J. R. & Engelhard, G. H. 2016. Distribution of skates and sharks in the North Sea: 112 years of change. *Global change biology,* 22**,** 2729-2743.

Shark Trust 2020. *Identification Guide: Sharks, Skates & Rays of the British Isles & Northeast Atlantic.,* Plymouth, UK, The Shark Trust.

Shephard, S., Gerritsen, H., Kaiser, M. J. & Reid, D. G. 2012. Spatial heterogeneity in fishing creates de facto refugia for endangered Celtic Sea elasmobranchs. *PloS one,* 7**,** e49307.

Shephard, S., Reid, D. G., Gerritsen, H. D. & Farnsworth, K. D. 2015. Estimating biomass, fishing mortality, and "total allowable discards" for surveyed non-target fish. *Ices Journal of Marine Science,* 72**,** 458-466.

Siddiqi, A. 2025. Barriers to, and opportunities for, improved engagement with Clean Catch. A Clean Catch Report. Zoological Society of London. London, UK. 18. Available: https://www.cleancatchuk.com/wp-content/uploads/2025/06/Full-report_Barriers-to-and-opportunities-for-improved-engagement-with-Clean-Catch_2025.pdf [Accessed: 04/11/2025].

Siddiqi, A. in review. Casting Wider Nets: Inclusive Fisher Engagement and Comprehensive Change Management for Bycatch Trial Co-Design in a Northeast Atlantic Fishery. *Oryx*.

Silva, J. F. & Ellis, J. R. 2019. Bycatch and discarding patterns of dogfish and sharks taken in English and Welsh commercial fisheries. *Journal of Fish Biology,* 94**,** 966-980.

SMRU. 2025. *SCANS-III* [Online]. Sea Mammal Research Unit (SMRU), University of St Andrews. Available: https://scans3.wp.st-andrews.ac.uk/ [Accessed 12/03/ 2025].

Soykan, C. U., Moore, J. E., Zydelis, R., Crowder, L. B., Safina, C. & Lewison, R. L. 2008. Why study bycatch? An introduction to the Theme Section on fisheries bycatch. *Endangered Species Research,* 5**,** 91-102.

Spencer, N., Santos, M. & Pierce, G. 2000. Evaluation of the state of knowledge concerning by-catches of cetaceans. Final Report Tender No XIV/1999/01 Lot 7 (31/12/99–31/10/00), European Commission.

Stevens, J., Bonfil, R., Dulvy, N. K. & Walker, P. 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science,* 57**,** 476-494.

Stewart, B. D., Williams, C., Barnes, R., Walmsley, S. F. & Carpenter, G. 2022. The Brexit deal and UK fisheries—has reality matched the rhetoric? *Maritime Studies,* 21**,** 1-17.

Stobutzki, I., Miller, M. & Brewer, D. 2001. Sustainability of fishery bycatch: a process for assessing highly diverse and numerous bycatch. *Environmental Conservation,* 28**,** 167-181.

Taylor, N., Authier, M., Banga, R., Genu, M. & Gilles, A. 2022. Marine Mammal By-catch. In: OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic. OSPAR Commission. London, UK. Available: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/marine-mammal-bycatch.

Temple, H. J. & Terry, A. 2009. European mammals: Red List status, trends, and conservation priorities. *Folia Zoologica,* 58**,** 248-269.

Thurstan, R. H., Brockington, S. & Roberts, C. M. 2010. The effects of 118 years of industrial fishing on UK bottom trawl fisheries. *Nature Communications,* 1**,** 15.

Tregenza, N., Berrow, S., Hammond, P. S. & Leaper, R. 1997. Harbour porpoise (Phocoena phocoena L.) by-catch in set gillnets in the Celtic Sea. *ICES Journal of Marine Science,* 54**,** 896-904.

Tuck, G. N., Phillips, R. A., Small, C., Thomson, R., Klaer, N., Taylor, F., Wanless, R. & Arrizabalaga, H. 2011. An assessment of seabird–fishery interactions in the Atlantic Ocean. *ICES Journal of marine Science,* 68**,** 1628-1637.

UK Government. 2020. *Fisheries Act 2020. Available: https://www.legislation.gov.uk/ukpga/2020/22/contents/enacted [Accessed: 19/03/2025].*

Verutes, G. M., Johnson, A. F., Caillat, M., Ponnampalam, L. S., Peter, C., Vu, L., Junchompoo, C., Lewison, R. L. & Hines, E. M. 2020. Using GIS and stakeholder involvement to innovate marine mammal bycatch risk assessment in data-limited fisheries. *PloS one,* 15**,** e0237835.

Wade, P. R., Long, K. J., Francis, T. B., Punt, A. E., Hammond, P. S., Heinemann, D., Moore, J. E., Reeves, R. R., Sepúlveda, M. & Sullaway, G. 2021. Best practices for assessing and managing bycatch of marine mammals. *Frontiers in Marine Science,* 8**,** 757330.

Waggitt, J. J., Evans, P. G., Andrade, J., Banks, A. N., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Camphuysen, C. J. & Durinck, J. 2020. Distribution maps of cetacean and seabird populations in the North-East Atlantic. *Journal of Applied Ecology,* 57**,** 253-269.

Walker, N. D., García-Carreras, B., Le Quesne, W. J. F., Maxwell, D. L. & Jennings, S. 2019. A data-limited approach for estimating fishing mortality rates and exploitation status of diverse target and non-target fish species impacted by mixed multispecies fisheries. *Ices Journal of Marine Science,* 76**,** 824-836.

Witt, M. J. & Godley, B. J. 2007. A step towards seascape scale conservation: using vessel monitoring systems (VMS) to map fishing activity. *PLoS One,* 2**,** e1111.

Zydelis, R., Bellebaum, J., Österblom, H., Vetemaa, M., Schirmeister, B., Stipniece, A., Dagys, M., van Eerden, M. & Garthe, S. 2009. Bycatch in gillnet fisheries - An overlooked threat to waterbird populations. *Biological Conservation,* 142**,** 1269-1281.

Žydelis, R., Lewison, R. L., Shaffer, S. A., Moore, J. E., Boustany, A. M., Roberts, J. J., Sims, M., Dunn, D. C., Best, B. D. & Tremblay, Y. 2011. Dynamic habitat models: using telemetry data to project fisheries bycatch. *Proceedings of the Royal Society B: Biological Sciences,* 278**,** 3191-3200.

Žydelis, R., Small, C. & French, G. 2013. The incidental catch of seabirds in gillnet fisheries: a global review. *Biological Conservation,* 162**,** 76-88.

Appendix I

The search engine queries used in the systematic search are detailed below:

Web of Science query:

> ((((((AB=(bycatch OR discard* OR (incidental AND catch) OR non-target)) AND AB=(hotspot* OR distribution OR heatmap* OR map* OR rate* OR frequency OR pattern* OR trend* OR monitoring))) AND AB=(UK OR "United Kingdom" OR "Northeast Atlantic" OR Europe OR "North Sea" OR "Celtic Sea" OR Channel OR "Irish Sea" OR England OR "Northern Ireland" OR Scotland OR English OR Scottish OR "Northern Irish" OR Wales OR Welsh)) AND AB=(mammal* OR pinniped* OR phocid* OR cetacean* OR bird* OR seabird* OR elasmobranch* OR shark* OR skate* OR ray*))))
>
> Date range: 2000-01-01 to 2024-04-09

Scopus query:

> ABS (bycatch OR discard* OR (incidental AND catch) OR non-target) AND ABS (hotspot* OR distribution OR heatmap* OR map* OR rate* OR frequency OR pattern* OR trend*) AND ABS (uk OR "United Kingdom" OR "Northeast Atlantic" OR europe OR "North Sea" OR "Celtic Sea" OR channel OR "Irish Sea" OR england OR "Northern Ireland" OR scotland OR english OR scottish OR "Northern Irish" OR Wales OR Welsh) AND ABS (mammal* OR pinniped* OR phocid* OR cetacean* OR bird* OR seabird* OR elasmobranch* OR shark* OR skate* OR ray*) AND PUBYEAR > 1999

Google Scholar query:

> (bycatch OR discard* OR (incidental AND catch) OR non-target) AND (hotspot* OR distribution OR heatmap* OR map* OR rate* OR frequency OR pattern* OR trend* OR monitoring) AND (UK OR "United Kingdom" OR "Northeast Atlantic" OR Europe OR "North Sea" OR "Celtic Sea" OR Channel OR "Irish Sea" OR England OR "Northern Ireland" OR Scotland OR English OR Scottish OR "Northern Irish" OR Wales OR Welsh) AND (mammal* OR pinniped* OR phocid* OR cetacean* OR bird* OR seabird* OR elasmobranch* OR shark* OR skate* OR ray*)
>
> Date range: 2000-01-01 to 2024-04-09

Appendix II

Literature identified in the search and reviewed. Full bibliographic details for those cited in the text are provided in 'References'.

Title	Author(s)	Year	Publisher	Link
Systematic search				
A data-limited approach for estimating fishing mortality rates and exploitation status of diverse target and non-target fish species impacted by mixed multispecies fisheries	Walker et al.	2019	ICES J. Mar. Sci	Link
A Review Characterizing 25 Ecosystem Challenges to Be Addressed by an Ecosystem Approach to Fisheries Management in Europe	Bastardie et al.	2021	Front. Mar Sci.	Link
A Step Towards Seascape Scale Conservation: Using Vessel Monitoring Systems (VMS) to Map Fishing Activity	Witt and Godley	2007	PLOS ONE	Link
Assessing bycatch risk from gillnet fisheries for three species of diving seabird in the UK	Cleasby, et al.	2022	Mar. Eco.	Link
Assessing the Effects of Banana Pingers as a Bycatch Mitigation Device for Harbour Porpoises (Phocoena phocoena)	Omeyer et al.	2020	Front. Mar. Sci	Link
Bycatch in gillnet fisheries - An overlooked threat to waterbird populations	Zydelis et al.	2009	Biol. Conserv.	Link
Bycatch in northeast Atlantic lobster and crab pot fisheries (Irish Sea, Celtic Sea and Bristol Channel)	Moore et al.	2023	Fish. Res.	Link
Bycatches of endangered, threatened and protected species in marine fisheries	Gray et al.	2018	Rev. Fish Biol. Fisher.	Link
Citizen science in the marine environment: estimating common dolphin densities in the north-east Atlantic	Robbins et al.	2020	PEERJ	Link
Discarding in the English Channel, Western approaches, Celtic and Irish seas (ICES subarea VII)	Enever et al.	2007	Fish. Res.	Link
Discarding in UK Commercial Fisheries	Condie, H.	2013	UEA, PhD thesis	Link
Distribution and life history trait models indicate vulnerability of skates	Elliott et al.	2020	Prog. Oceanogr.	Link
Distribution patterns and sexual segregation in chimaeras: implications for conservation and management	Holt et al.	2013	ICES J. Mar. Sci	Link
Distribution patterns of deep-sea fish and benthic invertebrates from trawlable grounds of the Hatton Bank, north-east Atlantic: Effects of deep-sea bottom trawling	Muñoz et al.	2012	J. Mar. Biol. Assoc. UK	Link
Effects of deep-sea bottom longlining on the Hatton Bank fish communities and benthic ecosystem, north-east Atlantic	Durán et al.	2011	J. Mar. Biol. Assoc. UK	Link
Estimating biomass, fishing mortality, and "total allowable discards" for surveyed non-target fish	Shephard et al.	2014	ICES J. Mar. Sci.	Link
Evidence of difference in landings and discards patterns in the English Channel and North Sea Rajidae complex fishery	Amelot et al.	2021	Fish. Res.	Link
Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots	Lewison et al.	2014	Proc. Nat. Acad. Sci.	Link
Global spatial risk assessment of sharks under the footprint of fisheries	Queiroz et al.	2019	Nature	Link
Modelling the direct impact of bottom trawling on the North Sea fish community to derive estimates of fishing mortality for non-target fish species	Piet et al.	2009	ICES J. Mar. Sci	Link
Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots	Queiroz et al.	2016	Proc. Nat. Acad. Sci.	Link
Progress in designing and delivering effective fishing industry–science data collection in the UK	Mangi et al.	2018	Fish Fisher.	Link

Title	Author(s)	Year	Publisher	Link
Results of a short study on by-catches and discards in pelagic fisheries in Scotland (UK)	Pierce et al.	2002	Aquat. Living Resour.	Link
Review of harbour porpoise Bycatch in UK Waters and Recommendations for Management	Calderan et al.	2019	UNEP	Link
Spatio-temporal dynamics of the common skate species complex: Evidence of increasing abundance	McGeady et al.	2022	Divers. Distrib.	Link
Towards an EU action plan on cetacean bycatch	Dolman et al.	2016	Mar. Pol.	Link
Bycatch and discarding patterns of dogfish and sharks taken in English and Welsh commercial fisheries	Silva and Ellis	2019	J. Fish Biol.	Link
Interactions Between Short-Beaked Common Dolphin (Delphinus delphis) and the Winter Pelagic Pair-Trawl Fishery off Southwest England (UK)	de Boer et al.	2012	Int. J. Biod. Cons	Link
Small cetacean bycatch as estimated from stranding schemes: The common dolphin case in the northeast Atlantic	Peltier et al.	2016	Env. Sci Pol.	Link
Spatio-temporal analysis of cetacean strandings and bycatch in a UK fisheries hotspot	Leeney et al.	2008	Biod. Conserv.	Link
The incidental catch of seabirds in gillnet fisheries: a global review	Zydelis et al.	2013	Biol. Conserv.	Link
Ad hoc search				
Winter abundance estimates for the common dolphin (Delphinus delphis) in the western approaches of the English Channel and the effect of responsive movement	de Boer et al.	2008	J. Mar. Anim. Ecol.	Link
2016 Annual Summary Report Marine Strandings in Cornwall and the Isles of Scilly	Crosby et al.	2016	CWT	Link
Regional Seabird Bycatch Hotspot Analysis. JNCC Report 726.	Northridge et al.	2023	JNCC	Link
Catch, discarding, age estimation, growth and maturity of the squalid shark Deania calceus west and north of Ireland	Clarke et al.	2002	Fish. Res.	Link
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)	Long et al.	2022	ZSL	Link
Preliminary estimates of seabird bycatch by UK vessels in UK and adjacent waters	Northridge et al.	2020	SMRU	Link
Gap analysis on the monitoring of marine bird bycatch by British vessels – Report to the Department for Environment, Food & Rural Affairs	Kober et al.	2024	JNCC	Link
Final Report to Defra. Understanding the Impact of Marine Mammal Bycatch in the UK	Northridge et al.	2020	SMRU	
Risk assessment of seabird bycatch in UK waters. Report to Defra. Defra Project: MB0126.	Bradbury et al.	2017	WWT Consulting	Link
Risk Assessment of Bycatch of Protected Species in Fishing Activities	Evans et al.	2021	Sea Watch Found., Bangor University	Link
Preliminary assessment of seabird population response to potential bycatch mitigation in the UK-registered fishing fleet	Miles et al.	2020	JNCC	Link
Seabird bycatch mitigation: evidence base for possible UK application and research. JNCC Report No. 717	Anderson et al.	2022	JNCC	Link
Bycatch of Protected, Endangered and Threatened (PET) marine wildlife in the commercial fisheries, operating from the South-west of the UK. Supplementary Tables for Bycatch Species Risk Status	Bendall and Hetherington	2021	Cefas	
Bycatch of Protected, Endangered and Threatened (PET) marine wildlife in the commercial fisheries, operating from the South-west of the UK: Bycatch risk status review and future recommendations. Cefas Project Report for Defra	Bendall and Hetherington	2021	Cefas	
SEAwise Report on the bycatch mortality risk of potentially endangered and threatened species of fish, seabirds, reptiles and mammals.	Astraloa et al.	2023	Technical University of Denmark	Link

Title	Author(s)	Year	Publisher	Link
Improving Understanding of Seabird Bycatch in Scottish Longline Fisheries and Exploring Potential Solutions	Kingston et al.	2023	University of St Andrews	Link
The susceptibility of sensitive species through analysis of their distribution and the overlap with relevant fishing effort distribution: SMRU Contribution to the DefineIt Final Report	Northridge et al.	2012	SMRU	Link
Conservation management of common dolphins: Lessons learned from the North-East Atlantic	Murphy et al.	2019	Aquat. Conserv.: Mar. Freshw. Ecosyst.	Link
Estimates of humpback and minke whale entanglements in the Scottish static pot (creel) fishery	Leaper et al.	2022	Endanger. Species Res.	Link
Working Group on Bycatch of Protected Species (WGBYC). ICES Scientific Reports. 6:103. 237 pp.	ICES	2024	ICES	Link
2.4. Published data on by-catch rates In: Evaluation of the state of knowledge concerning by-catches of cetaceans	Spencer et al.	2000	University of Aberdeen	Link
Elasmobranch distributions and interactions with fisheries. Research Report 136	Régnier et al.	2024	NatureScot	Link
Spurdog By-catch Avoidance Programme	Hetherington et al.	2016	Cefas	Link
Entanglement of minke whales in Scottish waters; an investigation into occurrence, causes and mitigation	Northridge et al.	2010	SMRU	Link
Entanglement: an emerging threat to humpback whales in Scottish waters	Rya et al.	2016	IWC	Link
Scientific Advice on Matters Related to the Management of Seal Populations: 2022	SCOS	2022	SMRU	Link
Project Summary: Understanding the scale and impacts of marine animal entanglement in the Scottish creel fishery	SEA	2021	SEA	Link
Interim report from the Scottish Entanglement Alliance (SEA) on previously undocumented fatal entanglements of minke whales (Balaenoptera acutorostrata) in Scottish inshore waters. Paper SC/68A/HIM/02	MacLennan et al.	2019	IWC	Link
Spurdog Bycatch Management Programme - A Three Year Review. A Clean Catch UK report for Defra	Hetherington et al.	2022	Clean Catch	Link
Minke whale entanglement in static fishing gear: identifying consistent areas of high risk in Western Scotland	Rayner et al.	2024	J. Mar. Biol. Assoc. UK	Link
Scottish Entanglement Alliance (SEA) - understanding the scale and impacts of marine animal entanglement in the Scottish creel fishery. NatureScot Research Report 1268	MacLennan et al.	2021	NatureScot	Link
Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment	Karpouzi et al.	2007	Mar. Ecol. Prog. Ser.	Link
Incidental mortality of seabirds in trawl fisheries: A global review	Phillips et al.	2024	Biol. Conserv.	Link
Catch of the Day: The deadly impacts of cetacean bycatch in European waters	EIA	2025	EIA	Link
Marine Mammal By-catch. In: OSPAR, 2023: The 2023 Quality Status Report for the Northeast Atlantic.	Taylor et al.	2022	OSPAR Commission	Link
Seabird bycatch in European waters	Ramírez et al.	2024	Anim. Conserv.	Link
Predicting species vulnerability with minimal data to support rapid risk assessment of fishing impacts on biodiversity	Le Quesne et al.	2012	J. App. Ecol.	Link
Discarding by the demersal fishery in the waters around Ireland	Borges et al.	2005	Fish. Res.	Link
Bycatch of endangered, threatened and protected species of marine mammals, seabirds and marine turtles, and selected fish species of bycatch relevance	ICES	2024	ICES	Link
Bycatch of vulnerable species: understanding the process and mitigating the impacts. Final report to Defra Marine and Fisheries Science Unit, Project no MF1003	Northridge et al.	2011	Defra	Link

Appendix III

Lists of marine mammal, seabird and elasmobranch species considered as sensitive for the purpose of this review.

Scientific Name	Common Name	IUCN Red List status (Europe)
Seabirds		
Aythya marila	Greater scaup	Least concern
Bucephala clangula	Common goldeneye	Least concern
Calonectris borealis	Cory's shearwater	Least concern
Cepphus grylle	Black guillemot	Least concern
Larus ridibundus	Black-headed gull	Least concern
Clangula hyemalis	Long-tailed duck	Vulnerable
Fratercula arctica	Atlantic puffin	Vulnerable
Fulmarus glacialis	Northern fulmar	Vulnerable
Gavia arctica	Black-throated diver	Least concern
Gavia immer	Great northern diver	Least concern
Gavia stellata	Red-throated diver	Least concern
Hydrobates pelagicus	European storm-petrel	Least concern
Hydrocoloeus minutus	Little gull	Least concern
Larus argentatus	Herring gull	Least concern
Larus canus	Common gull	Least concern
Larus fuscus	Lesser black-backed gull	Least concern
Larus glaucoides	Iceland gull	Least concern
Larus hyperboreus	Glaucous gull	Least concern
Larus marinus	Great black-backed gull	Least concern
Ichthyaetus melanocephalus	Mediterranean gull	Least concern
Melanitta fusca	Velvet scoter	Vulnerable
Melanitta nigra	Common scoter	Least concern
Mergus serrator	Red-breasted merganser	Least concern
Morus bassanus	Northern gannet	Least concern
Hydrobates leucorhous	Leaches Storm-petrel	Near threatened
Phalacrocorax aristotelis	European shag	Least concern
Phalacrocorax carbo	Great cormorant	Least concern
Podiceps auritus	Horned grebe	Vulnerable
Podiceps cristatus	Great crested grebe	Least concern
Podiceps nigricollis	Black-necked grebe	Least concern
Puffinus gravis	Great shearwater	Least concern*
Puffinus griseus	Sooty shearwater	Near threatened
Puffinus mauretanicus	Balearic shearwater	Critically endangered
Puffinus puffinus	Manx shearwater	Least concern
Rissa tridactyla	Black-legged kittiwake	Vulnerable
Somateria mollissima	Common eider	Near threatened
Stercorarius parasiticus	Arctic skua	Least concern
Stercorarius skua	Great skua	Least concern
Sterna dougallii	Roseate tern	Least concern
Sterna hirundo	common tern	Least concern
Sterna paradisaea	Arctic tern	Least concern
Thalasseus sandvicensis	Sandwich tern	Least concern
Sternula albifrons	Little tern	Least concern
Uria aalge	Common guillemot	Least concern

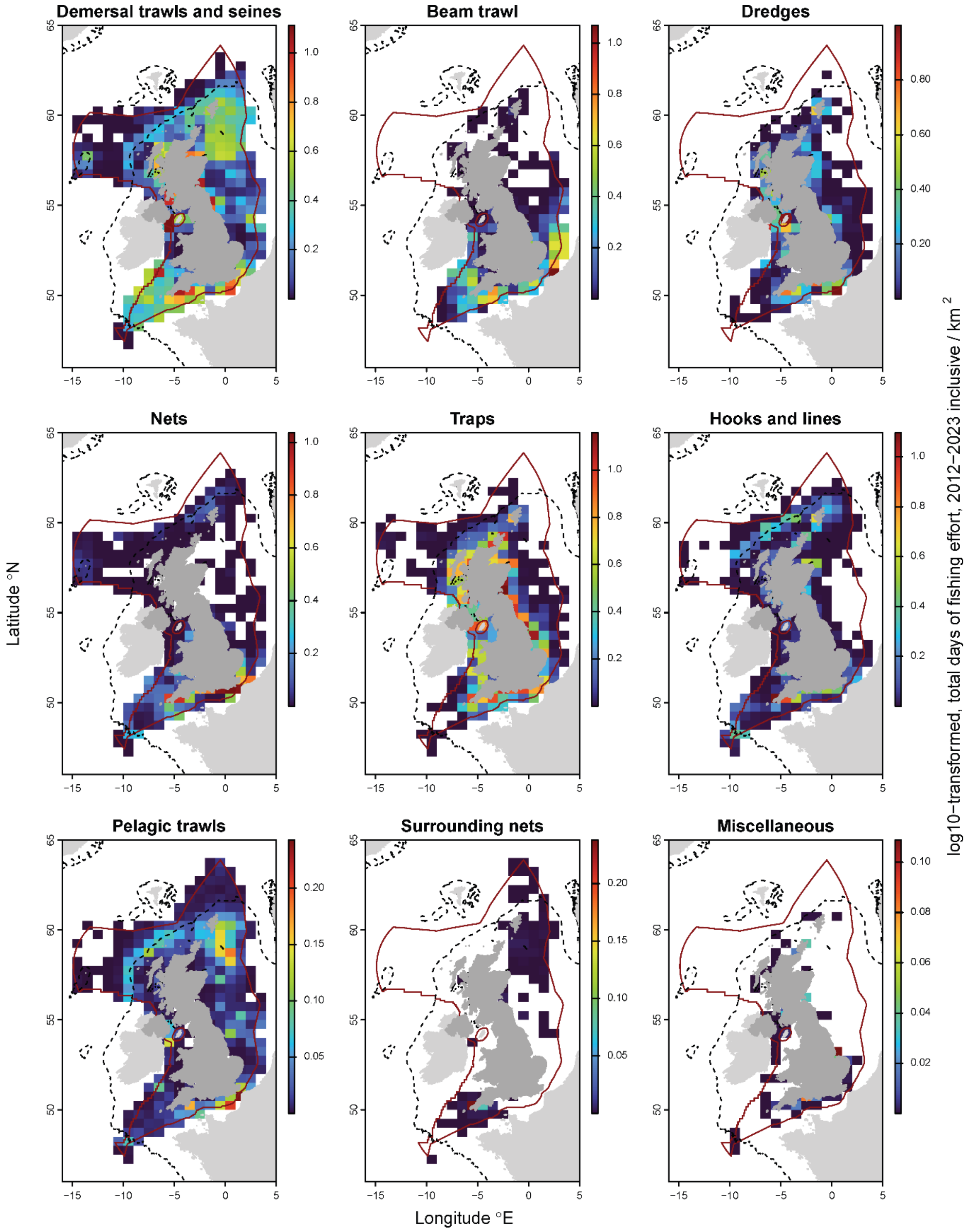
Scientific Name	Common Name	IUCN Red List status (Europe)
Alle alle	Little auk	Least concern
Alca torda	Razorbill	Near threatened
Elasmobranchs		
Alopias vulpinus	Thresher shark	Endangered
Amblyraja hyperborea	Arctic skate	Least concern
Amblyraja radiata	Starry ray/ Starry skate	Least concern
Apristurus laurussonii	Iceland catshark	Least concern
Apristurus manis	Ghost catshark	Least concern
Apristurus spp.	Deep-water catshark	n/a
Centrophorus squamosus	Leafscale gulper shark	Endangered
Centroscyllium fabricii	Black dogfish	Least concern
Centroscymnus coelolepis	Portuguese dogfish	Endangered
Centroscymnus crepidater	Longnose velvet dogfish	Least concern
Cetorhinus maximus	Basking shark	Endangered
Chlamydoselachus anguineus	Frilled shark	Least concern
Dalatias licha	Kitefin shark	Endangered
Dasyatis pastinaca	Common stingray	Vulnerable
Deania calcea	Birdbeak dogfish	Endangered
Dipturus batis	Common blue skate	Critically endangered*
Dipturus intermedius	Flapper skate	Critically endangered*
Dipturus nidarosiensis	Norwegian skate	Near threatened
Dipturus oxyrinchus	Long-nosed skate	Near threatened
Echinorhinus brucus	Bramble shark	Endangered
Etmopterus princeps	Great lanternshark	Least concern
Etmopterus spinax	Velvet belly lanternshark	Near threatened
Galeorhinus galeus	Tope	Vulnerable
Galeus melastomus	Blackmouth catshark	Least concern
Galeus murinus	Mouse catshark	Least concern
Heptranchias perlo	Sharpnose sevengill shark	Data deficient
Hexanchus griseus	Bluntnose sixgill shark	Data deficient
Isurus oxyrinchus	Shortfin mako	Data deficient
Lamna nasus	Porbeagle shark	Critically endangered
Leucoraja circularis	Sandy ray	Endangered
Leucoraja fullonica	Shagreen ray	Vulnerable
Leucoraja naevus	Cuckoo ray	Least concern
Mobula mobular	Giant devil ray	Endangered
Mustelus asterias	Starry smoothhound	Near threatened
Mustelus mustelus	Common smoothhound	Vulnerable
Myliobatis aquila	Common eagle ray	Vulnerable
Oxynotus centrina	Angula roughshark	Vulnerable
Oxynotus paradoxus	Sailfin roughshark	Data deficient
Prionace glauca	Blue shark	Near threatened
Pteroplatytrygon violacea	Pelagic stingray	Least concern
Raja brachyura	Blonde ray	Near threatened
Raja clavata	Thornback ray	Near threatened
Raja microocellata	Small-eyed ray	Near threatened
Raja montagui	Spotted ray	Least concern
Raja undulata	Undulate ray	Near threatened
Rajella bathyphila	Deep-water ray	Least concern
Rajella fyllae	Round skate	Least concern

Scientific Name	Common Name	IUCN Red List status (Europe)
Rajella lintea	Sailray	Least concern
Rostroraja alba	White skate	Critically endangered
Scyliorhinus canicula	Small spotted catshark	Least concern
Scyliorhinus stellaris	Nursehound/Greater-spotted dogfish	Near threatened
Scymnodon ringens	Knifetooth dogfish	Least concern
Somniosus microcephalus	Greenland shark	Near threatened
Sphyrna zygaena	Smooth hammerhead	Data deficient
Sphyrnidae	Hammerhead sharks	n/a
Squatina squatina	Angelshark	Critically endangered
Squalus acanthias	Spurdog	Endangered
Tetronarce nobiliana	Atlantic torpedo ray	Least concern
Torpedo marmorata	Marbled electric ray	Least concern
Marine Mammals		
Balaenoptera acutorostrata	Common minke whale	Least concern
Balaenoptera borealis	Sei whale	Least concern
Balaenoptera musculus	Blue whale	Near threatened
Balaenoptera physalus	Fin whale	Least concern
Delphinus delphis	Common dolphin	Least concern
Globicephala melas	Long-finned pilot whale	Least concern
Grampus griseus	Risso's dolphin	Data deficient
Halichoerus grypus	Grey seal	Least concern
Hyperoodon ampullatus	Northern bottlenose whale	Least concern
Lagenorhynchus albirostris	White-beaked dolphin	Least concern
Leucopleurus acutus	Atlantic white-sided dolphin	Least concern
Megaptera novaeangliae	Humpback whale	Least concern
Mesoplodon bidens	Sowerby's beaked whale	Least concern
Orcinus orca	Killer whale	Least concern
Phoca vitulina	Harbour/common seal	Least concern
Phocoena phocoena	Harbour porpoise	Least concern
Physeter macrocephalus	Sperm whale	Vulnerable
Stenella coeruleoalba	Striped dolphin	Least concern
Tursiops truncatus	Common bottlenose dolphin	Least concern
Ziphius cavirostris	Cuvier's beaked whale	Least concern

* Global Red List status (no European Red List status available)

Appendix IV

Overview of the distribution of fishing effort in the UK EEZ by gear type.



Total days of fishing effort, 2012-2023 inclusive, by gear type (modified metier Level 3). For graphical clarity effort is log10-transformed. The 200m depth contour is indicated (dashed line). The UK EEZ is drawn (dark red line). Data: fishing effort, Cefas; depth contour, EmodNet; maritime boundaries, UKHO; countries, ESRI.

Effort data are available from the European Commission's Scientific, Technical and Economic Committee for Fisheries (STECF) as part of the Fisheries Dependent Information (FDI dataset) (European Commission, 2024). The published data (STECF-FDI) provide spatial effort by c-squares (0.5° x 0.5° resolution) for: 28 European Union (EU) countries from 2012 to 2020, inclusive; and 27 EU countries from 2012 to 2023, inclusive. The latter excludes data from the UK, following its withdrawal from the EU (Brexit), though the UK continues to collect an equivalent dataset (UK-FDI). For the purposes of this review, a fishing effort dataset (2012-2023, inclusive) was compiled by Cefas consisting of:

i. STECF-FDI effort by vessels from 28 EU countries, from 2012 to 2020, inclusive;
ii. UK-FDI, effort by vessels from UK vessels from 2021 to 2023, inclusive; and
iii. STECF-FDI effort by vessel from 27 EU countries from 2021 to 2023, inclusive.

This was considered the most comprehensive available data representing fishing effort within the UK EEZ, including UK and foreign flagged vessels of all sizes. (Noting that higher resolution effort data may be derived from VMS or AIS data but only from larger vessels). Whilst the STECF-FDI data is available at c-square resolution, data were aggregated to ICES Statistical Rectangles (1° longitude x 0.5° latitude), which better represents the resolution at which the data are collected (T. Catchpole, pers. comm.). Effort is expressed as fishing days. Metiers were aggregated to modified metier Level 3 categories. These modified categories are intended to group gears posing similar risk in terms of their mechanism of bycatch. The metier Level 3 categories are detailed in the table below, detailing the modification (if any) to the existing schema (Appendix IV of Commission Decision 2010/93/EU). These complied effort data are intended to be used as an input in ongoing efforts to model bycatch risk (in time and space), within the UK EEZ, as part of the Bycatch Risk Prioritisation Framework project.

L3 Metier	Modified?	L4 code	L4 description
Demersal trawls and seines	Yes. Combines demersal trawls and demersal seines and excludes beam trawling	OTB	Bottom otter trawl
		OTT	Multi-rig otter trawl
		PTB	Bottom pair trawl
		SSC	Fly shooting seine
		SV	Boat seine
		SPR	Pair seine
		SX	Seine nets (not specified)
		SDN	Anchored seine
		SB	Beach seine
Beam trawl	Yes. Separated from other towed demersal gears	TBB	Beam trawl
Dredges	No	DRB	Boat dredge
		DRH	Hand dredge
		HMD	Mechanised/ suction dredge
Nets	No	GNC	Gillnets (circling)
		GND	Drift net
		GNS	Set gillnet
		GTN	Combined gillnets and trammel nets
		GTR	Trammel net
Traps	No	FPN	Stationary uncovered pound nets
		FPO	Pots and traps
		FYK	Fyke nets
Hooks and lines	Yes. Adopts Level 2 grouping	LLD	Drifting longlines
		LLS	Set longlines
		LTL	Trolling lines
		LHP	Handlines and pole lines (hand operated)
		LHM	Handlines and pole lines (mechanised)
Pelagic trawls	No	OTM	Midwater otter trawl
		PTM	Midwater pair trawl

Surrounding nets	No	PS	Purse seine
Miscellaneous	No	NK	Not known
		LA	Lampara nets