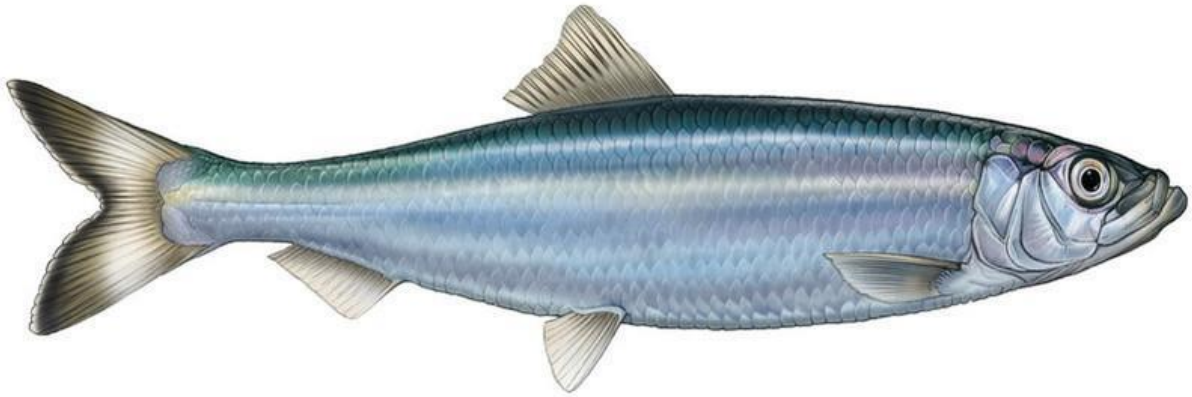
Fisheries Research & Management Plan

Atlantic Herring (*Clupea harengus*) in the North of Devon & Severn IFCA's District



Devon & Severn IFCA
Inshore Fisheries and Conservation Authority

NORTH DEVON BIOSPHERE

European Union
European Structural and Investment Funds

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Cover image – Atlantic herring (*C. harengus*) (Seafish, 2014, https://seafish.assetbank-server.com/assetbank-seafish/action/viewAsset?id=1920 [unedited]).

Contents

Introduction

Background

In 2017, the UK fishing fleet added an estimated £1.53 billion to the UK economy and provided employment to 23,000 people in Great Britain. Globally the demand for fish is expected to rise but growth in fish catches has stalled, with some regions experiencing declines of up to 35% between 1930–2010, primarily driven by overfishing. The fishing industry is also an integral part of coastal communities' cultural heritage and fishing has been passed down through generations, making the future of the industry an emotive issue.

The North Devon fishing fleet landed just under 1,000 tonnes of documented catch in 2019, with an estimated value of £1.7 million (MMO, 2020a). Much of the commercial fishing effort in the Bristol Channel is potting for shellfish and important trawl fisheries for skates and other demersal species. There are also traditional netting fisheries close to the shore for species such as herring and bass. Although these fisheries are low in financial value, they carry immense cultural value to the fishers and their communities, being seen as part of their history and way of life (FRMP Interviews, 2020).

UK Government 25 Year Environment Plan

In 2018 the UK Government published a 25 Year Environment Plan (25YEP) with goals and targets for "*improving the environment within a generation and leaving it in a better state than we found it*." These goals and targets include "*ensuring that all fish stocks are recovered to and maintained at levels that can produce their maximum sustainable yield*."

To inform the development and implementation of the 25YEP, the Government set up a series of pioneer projects including a Marine Pioneer in North Devon (see **Figure 1**). The pioneer projects have been created to test innovative ways of managing the environment using a natural capital approach. The intention is that successful measures can be scaled up and applied at a national level.

As part of the Marine Pioneer, the Devon and Severn Inshore Fisheries and Conservation Authority (D&S IFCA) and the North Devon Biosphere have produced a series of innovative Fisheries Research Management Plans (FRMPs) for commercially important species in the north of D&S IFCA's District (see **Figure 1**).

Fisheries Research & Management Plans

The FRMPs use a localised and ecosystem-based fisheries management (EBFM) approach. EBFM is a holistic way of managing fisheries. It considers interactions between species, the overall health of the ecosystem and pressures that can affect this such as aggregate dredging, poor water quality and marine developments.

The FRMPs are different from previous work in this area because they take local and historical knowledge into account and include the cultural and heritage value of the fisheries. The plans also account for ecosystem factors that are sometimes overlooked by traditional fisheries management such as the impacts of local marine developments and the relationships marine species have with one another.

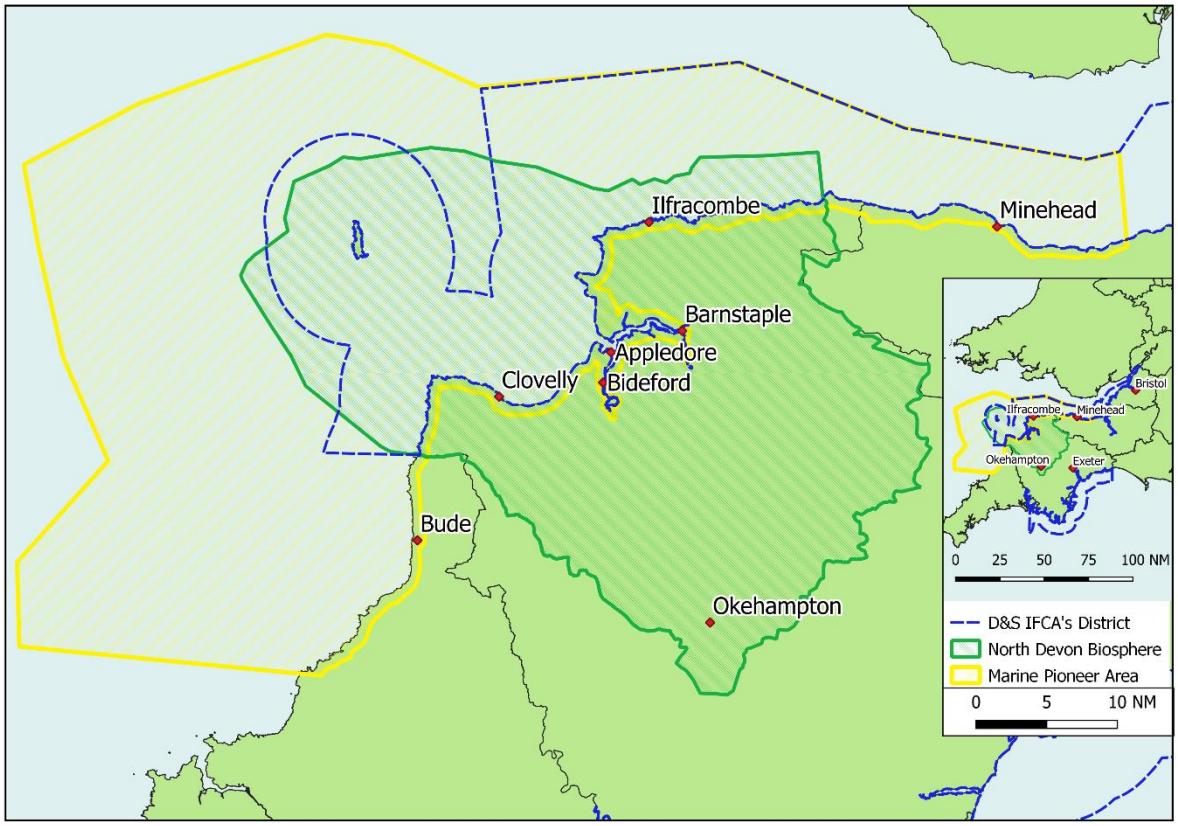

Figure 1 *- The Marine Pioneer area, North Devon Biosphere reserve, and Devon & Severn IFCA District on the North Devon and Somerset coastline.*

Methodology

Each FRMP has been developed using existing data and knowledge combined with information gathered through stakeholder engagement. There was a thorough review of the evidence available in academic journals, grey literature, regulator and industry reports and historical sources. Semi-structured interviews were held with 9 fishers who are or have been active in the north of the D&S IFCA's District, and with individuals who have fished in this area in the past and worked within the inshore fishing industry.

Each FRMP includes:

- A full ecosystem-based review of the ecology, fisheries, and management for the focal species, which can be used by a range of stakeholders as a comprehensive source of fish and fisheries knowledge.
- An evidence base that can be used to evaluate the impact of human activity on fisheries, fish, and habitats. This can also be used to engage with other organisations in the development of national policy and implementation of Fishery Management Plans under the Fisheries Act (2020).
- Identification of current gaps in evidence so that D&S IFCA and other organisations can take a rational and prioritised approach to future research.
- Recommendations for fisheries management, making the case for local, sustainable, ecosystem-based fisheries management where realistic and appropriate.

Atlantic Herring

This FRMP focuses on the Atlantic herring (*Clupea harengus*), one of three distinct herring species that support almost 90% of worldwide herring fisheries (Whitehead, 1985). The Atlantic herring is found in all UK waters and is one of the most numerous and commercially important fish harvested across Europe and North America. Some fisheries date back as far as the twelfth century (Heessen *et al.*, 2017). The most abundant stocks of herring in the UK are found in the North Sea, but there are many smaller, inshore stocks exploited locally by fishermen such as those in the Bristol Channel (Titmus *et al.*, 1978). Herring in the north of D&S IFCA's District are exploited by small-scale artisanal fisheries that appear to be targeting stocks that are distinct from the overexploited Celtic Sea stock. Further research is needed to investigate the stock structure of herring in the Bristol Channel and provide important ecological information that is needed to effectively manage these stocks.

Summary of Recommendations

Drawing on existing data and knowledge, and information gathered through stakeholder interviews, this plan makes a series of recommendations to facilitate the transition to a localised approach to managing Atlantic herring fisheries in the north of the D&S IFCA's District. Recommendations have been grouped into 'research' and 'management and fishery development'. Many of the recommendations are interconnected and would need to be delivered as a whole for them to be effective.

You can find the details of each recommendation in **PART 1** of this plan.

Research

Establish detailed knowledge of Bristol Channel herring stocks, including identifying and mapping important habitats for the herring life cycle.

Involve fishers in the planning of future research to make the most of local expertise and knowledge.

Identify and protect reported herring spawning grounds in the Minehead area.

Understand how herring stocks in the Bristol Channel move and interact with other stocks to establish if a localised approach to management is more appropriate.

Investigate the ecosystem roles and interactions of herring to better understand the ecology of inshore fish populations and assess whether this information can help predict the status of marine species and the health of their ecosystems.

Management

Improve integration between fisheries management and marine planning to make sure the exploitation of the marine environment is responsible and sustainable.

Improve communication and engagement with fishers to establish stronger fisheries enforcement presence in the north of D&S IFCA's District and combat illegal fishing and non-compliance in the area**.**

Improve landings data collection for recreational and commercial fishers so that management can investigate the effects of fisheries on local herring populations.

Trial local assessment and management of Bristol Channel herring stocks, if successful this could be applied to other distinct herring fisheries and to other species. (Please note: the research recommended above and improvements to landing data recommended below need to be completed before a trial is possible. This is explained in more detail in **PART 1**.)

Establish sustainability ecolabel for Bristol Channel herring fishery to add value to the fishery and help build the market locally and nationally.

Support viable investment in local infrastructure to complement the sustainability ecolabel.

PART 1. RECOMMENDATIONS FOR MANAGEMENT TO FACILITATE A TRANSITION TO A LOCALISED, ECOSYSTEM BASED APPROACH

*This section outlines the research and management changes that are needed to adopt a local, ecosystem-based approach to herring fishery management. The evidence to support these recommendations is outlined in **PART 2** of this plan. The recommendations have been categorised in terms of priority. Many of the high priority recommendations need to be addressed first to make it possible for the others to be carried out in the future. For example, many of the management recommendations can only be actioned once the research gaps have been filled.*

Summary of Current Fishery Status

Overall, Atlantic herring is classified as 'Least Concern' by the IUCN as numbers are growing. However, there is insufficient data to assess the status of distinct herring stocks and populations fished in the north of D&S IFCA's District.

Recent discoveries regarding population and stock structure of herring in the Bristol Channel suggest that the current scale for managing herring in the Atlantic might not be appropriate. The existence of several distinct breeding stocks in the Bristol Channel provides an opportunity to move towards a localised approach to fisheries management. Further research on these stocks should be a priority so that managers have the information they need to make this change.

Research Recommendations

The research recommendations are also available on D&S IFCA's website and will be shared periodically with interested parties to encourage collaborative research between fishers, scientists and managers that is relevant to management and policy.

Establish detailed knowledge of Bristol Channel herring stocks – *High Priority*

Detailed knowledge of herring stocks in the Bristol Channel is essential for effective management of the species in this area. Some early research as part of the Bristol Channel Herring Project has identified the presence of genetically distinct herring stocks, spawning locally in the Bristol Channel. Continuation of this research is needed to identify the presence of other regional stocks within and outside of the Bristol Channel. If complex population structure such as that already identified is widespread throughout the range of herring, restructuring of management at all levels may be necessary to ensure stocks are managed effectively and sustainably.

Next steps:

- D&S IFCA and stakeholders from the Bristol Channel Herring Project to explore options for conducting this research.
- Future monitoring or research should be designed in collaboration with Cefas and ICES to ensure the data is suitable for input to stock assessments.
- Findings can inform future Fisheries Management Plans (FMPs), and contribute to delivery of the ecosystem and scientific evidence objectives of the Fisheries Act 2020.

Identify and protect reported herring spawning grounds – *High Priority*

The existence of spawning habitat near Minehead and Clovelly needs to be investigated following recently documented nearby catches of herring in an advanced spawning state. If found, the spawning grounds must be mapped thoroughly and the implications of human activity on the habitat need to be incorporated into the management of fisheries (IFCA-level byelaws for relevant fishing activities) and other activities (through marine spatial planning, permitting and consultation processes), particularly if the herring stocks are small and show high local fidelity.

Next steps:

- D&S IFCA will explore collaborative research opportunities with relevant stakeholders to investigate the reported spawning areas near Minehead.
- D&S IFCA will support appropriate investigations of essential fish habitat in undersampled coastal and estuarine areas. This information would inform regional Marine Plans, marine licencing and permitting processes.
- Findings from this research could inform future FMPs and contribute towards delivery of the ecosystem and scientific evidence objectives of the Fisheries Act 2020.

Involve fishers in the planning of future research – *High Priority*

Engaging with fishers through the FRMP interviews has been invaluable in investigating local herring fisheries and arriving at these recommended next steps for research and management. Local fishing knowledge and fisher engagement should be used as much as possible in future to help direct research and benefit the local fishing industry.

Next steps:

- D&S IFCA is well-placed to facilitate fisher/researcher collaboration and will investigate what is needed to make this standard practice (for example, collaborations will require standardised protocols and terms of reference, including for shared use of vessels and research equipment).

Understand how herring stocks in the Bristol Channel move and interact with other stocks – *Medium Priority*

Research is needed to understand the migratory movements and interactions of Bristol Channel herring stocks. If the herring stay in the Bristol Channel for most of their lives, localised management in collaboration between fishers, IFCAs, Cefas and Defra would be able to effectively manage and prevent overexploitation of the herring. However, if they migrate to other areas, sustainable management of the stock becomes much more challenging as the herring are exposed to pressures elsewhere in their range.

Next steps:

- This will be of particular interest to researchers involved with the Bristol Channel Herring Project as it would build on their existing research. This research could also be conducted in collaboration with Irish universities and incorporate wider movements of distinct herring stocks in the Celtic Sea.

- Any future monitoring or research should be designed in collaboration with Cefas and ICES to ensure the data is suitable for input to stock assessments.

- Findings can help inform future FMPs and contribute towards delivery of the ecosystem, scientific evidence, and sustainability objectives of the Fisheries Act 2020.

Investigate the ecosystem roles and interactions of herring – *Medium Priority*

Herring are an important prey species for many fish, including bass and the migratory fish species that are features of the Severn Estuary SAC. Effective ecosystem-based management of human activities, in pursuit of Good Environmental Status and improved natural capital assets, will require knowledge of how human activities have and will affect the ecosystem roles of herring.

Research into the ecosystem roles of species are therefore worthy topics for timely, policy-relevant postgraduate research projects, supported as appropriate by D&S IFCA. Similarly, local herring fishers have suggested a competitive relationship between herring and mackerel that should be investigated, highlighting that the abundance of each of these species was highest during periods when the other was less abundant (FRMP Interviews, 2020).

Next steps:

- This research topic would make a good postgraduate research project as it is timely and relevant to policy. The findings would help inform future FMPs and contribute towards delivery of the ecosystem and scientific evidence objectives of the Fisheries Act 2020.

Management Recommendations

Improve integration between fisheries management and marine planning – *High Priority*

In areas beyond the Bristol Channel there is concern that the effects of human activity on marine organisms and environments is not being appropriately considered by planners. Detailed information about marine species and ecosystems is required to inform environmental impact assessments, Habitats Regulations Assessments, and other licensing and permitting assessments affecting marine developments. There is a strong need to realign and unify aspects of marine spatial planning, licencing, and permitting with fisheries and

environmental management so that these are more accurately and reliably considered in the process. This is particularly true in the Bristol Channel and Severn estuary, where there are high levels of interest for aggregate extraction and renewable energy developments.

Next steps:

- Findings from the recommended research in this FRMP should be incorporated into regional Marine Plans through discussions with D&S IFCA and the MMO.
- This would aid delivery of the Government's 25 YEP and Fisheries Act 2020 objectives, including utilising an ecosystem approach and prioritising sustainability.

Improve communication and engagement with fishers to establish stronger fisheries enforcement presence in the north of D&S IFCA's District – *Medium Priority*

There is a strong consensus among fishers in the north of the District that a stronger enforcement presence is needed to help combat non-compliance and illegal fishing in the inshore fishing industry. D&S IFCA has one of the largest districts of any IFCA and is the only IFCA with two separate coastlines to cover and monitor. The limited size of the enforcement team means it is not possible for IFCA officers to maintain a strong presence in every area of the District. Consequently, officers must implement an intelligence-led, risk-based approach to their work that is proportionate to the compliance requirements: officers must prioritise patrols in areas with high numbers of reports of illegal fishing activity, which is typically the south coast of the District.

To enable enforcement officers to focus more of their activities (e.g., patrols) in the north of D&S IFCA's District, there needs to be more comprehensive reporting of illegal activity from those in the area, and improved communication between officers, fishers, and other local stakeholders. Additional external funding to expand research and enforcement capabilities would also improve this situation.

Next steps:

- D&S IFCA will improve collaboration and engagement through activities such as virtual roadshows for ports, sectoral meetings and future FRMP interviews. More information about planned activities is available in the D&S IFCA's Annual Plan and Communications Strategy, accessible via the D&S IFCA website.

Improve landings data collection for recreational and commercial fishers – *Medium Priority*

Reliable data on fish mortality is essential for the effective management of fisheries. Until recently, national management stated that smaller commercial vessels (<10 metres) were not required by law to declare their landings, but any sales of fish over 30kgs to registered sellers required a sales note. It is unlikely that many sales from the artisanal fisheries in the north of D&S IFCA's District exceed 30kgs in weight so they will have gone unrecorded. Any catches of herring by recreational anglers or netters also go undocumented.

Progress has been made regarding the development of the <10 metre vessel catch recording app, and there are similar options for recording catch for recreational fishers (e.g. Cefas Sea Angling Diary), however, more detail is needed, particularly in a local context to properly understand the impacts of fishing on local fish populations.

Next steps:

- The IFCAs are well-placed to facilitate improvements in landings data. The need for additional data should be evaluated with the organisations that would use the information to make stock and distribution assessments (e.g., Cefas/ICES).
- If specific data needs are identified, for example, the mandatory recording of herring catch, a pilot study should be undertaken as part of D&S IFCA's Annual Plan.

Trial local assessment and management of Bristol Channel herring stocks – *Low Priority*

If the recommended research into Bristol Channel herring stocks suggests that a local approach to assessment and management may be beneficial, the different ways of approaching a more localised management approach to these herring fisheries should be investigated.

Next steps:

- If appropriate, D&S IFCA will work in partnership with Defra to investigate and test a localised approach to managing herring fisheries in the Bristol Channel (better recording of landings data needs to be in place for this trial to be successful - see above).

Establish a sustainability ecolabel for Bristol Channel herring fishery - *Low Priority*

The poor market for herring is currently the largest barrier to Bristol Channel herring fisheries. The nature of the fisheries - small-scale and low impact with little bycatch or destruction to habitats - makes them a suitable prospect for a sustainability ecolabel. The development of a sustainability ecolabel could support struggling inshore fisheries by adding value to their catch. It would also create an opportunity to build a brand for the fisheries on a regional and national scale, particularly if supported by reliable catch recording to demonstrate provenance. This would allow the herring fishery to continue and preserve this aspect of coastal heritage and culture. A local sustainability ecolabel would also need to be paired with education and outreach projects to show locals sustainable alternatives to overfished, popular species and the importance of looking after marine ecosystems.

Next steps:

- The North Devon Biosphere is well-placed to work with local fishers to investigate a sustainability ecolabel.

Support viable investment in local infrastructure - *Low Priority*

Management should collaborate with local fishers, the supply chain, and other relevant stakeholders to investigate and implement infrastructure changes to support local fisheries, for example, installing a community-based smokery. This could add value to herring and other local produce and complement the development of a local sustainability ecolabel.

Next steps:

- Fishers and other industry stakeholders are best placed to identify infrastructure needs and initiate developments and could be supported as appropriate by organisations such as North Devon Biosphere, Blue Marine Foundation and D&S IFCA.

PART 2. REVIEW OF EXISTING SCIENTIFIC RESEARCH AND FINDINGS FROM STAKEHOLDER ENGAGEMENT

Species Ecology

Herring are forage fish from the family *Clupeidae* that are often found moving together in large schools. Adult Atlantic herring tend to be around 30cm in length but can reach up to 40cm and weigh up to 0.68kg. They are silver in colour, often with a dark blue colouring on the upper half of their bodies and paler undersides. They are extremely streamlined, slender fish with round bellies, a deeply forked tail, and a single dorsal fin (see **Figure 2**). Atlantic herring can perceive and produce sound, they produce noise using air from their anal ducts that tend to be detected at night and may be social in nature (Blaxter and Batty, 1984; Wilson *et al.*, 2004; Kasumyan, 2008).

Figure 2 *- Atlantic herring (C. harengus) (Seafish, 2017,* https://seafish.assetbank-server.com/assetbank-seafish/action/viewAsset?id=9424 *[unedited]).*

Geographical Range, Migrations & Habitat

Herring tend to occupy continental shelf waters across the North Atlantic (see **Figure 3**). They are most commonly found from the surface to around 200m depth, including less saline areas in estuaries, fjords and the Baltic Sea (Whitehead, 1985; Huse *et al.*, 2002; Skjoldal and Saetre, 2004). Herring are abundant in all British waters, particularly near spawning and nursery grounds (Howson and Picton, 1997), though they are a complex migratory species whose changing movements over a year are influenced by the need to spawn, feed and overwinter (Huse *et al.*, 2002).

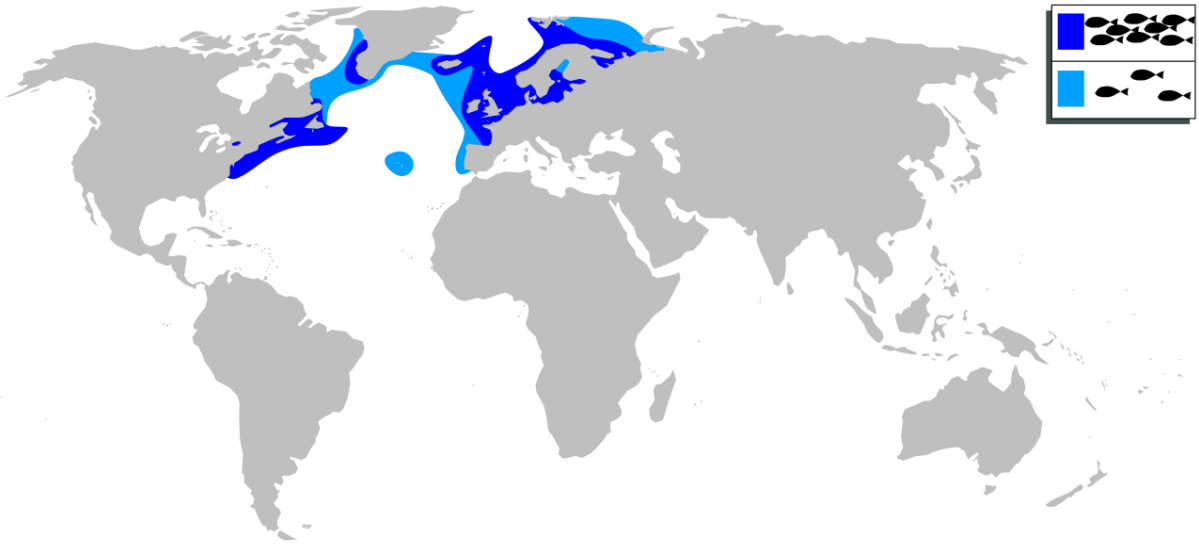

Figure 3 *- The global distribution of Atlantic herring .(Misigon, 2008, https://commons.wikimedia.org/wiki/File:Clupea_harengus_harengus_mapa.svg [unedited])*

The timing and locations of herring spawning migrations are relatively easy to predict as populations tend to return to the same site at the same time of year to spawn (Barnes, 2008); however, over time, some areas may become deserted and other areas newly occupied (Slotte, 1999). Herring feeding migrations are influenced by temperature as well as the distribution of their planktonic prey (see **Food Web & Interspecies Interactions**) and they overwinter in the deeper, warmer layers of the water column in nearshore and estuarine regions (Stevenson and Scott, 2005). Although initially difficult to obtain, information on herring spawning, feeding, and overwintering habits can be combined to identify their typical annual migratory routes. At smaller scales, within a single day herring show distinct vertical migrations through the water column related to prey pursuit and predator avoidance (Hureau *et al.*, 1984; Ferreira *et al.*, 2012).

Herring are considered in terms of multiple distinct spawning stocks, with stock identity determined based on the seasonal timing and location of spawning. Examples include the North Sea autumn spawners, the Celtic sea autumn and winter spawners, and the Irish sea autumn spawners (ICES, 2019a). These stocks are assessed individually by ICES (International Council for Exploration of the Sea) for management purposes (see **Fishery Management**).

Until recently, it has been generally assumed that herring in the Bristol Channel (ICES Division VIIf, see **Figure 4**) were part of the larger Celtic Sea stock (found in Divisions VIIa, g-h & j-k), however, new research incorporating local fisher knowledge suggests that locally spawning herring populations may be present within the Bristol Channel, independent from the larger Celtic Sea stock (Rees, 2019). Early results from samples taken in 2018 show distinct autumn/winter spawning stocks off Clovelly and Minehead that are genetically and morphologically distinct from the Celtic Sea herring (Clarke, 2020). This supports and expands on previous work that identified a spring-spawning stock of herring off Milford Haven (along the northern coast of the Bristol Channel; Clarke and King, 1985). These findings indicate that current assessments may not adequately reflect the fine spatial resolution at which stocks may be distinguished, and that separate management and stock assessment measures may

be required. This also demonstrates the value of local knowledge, and the importance of collaborating with local fishers to guide research and management.

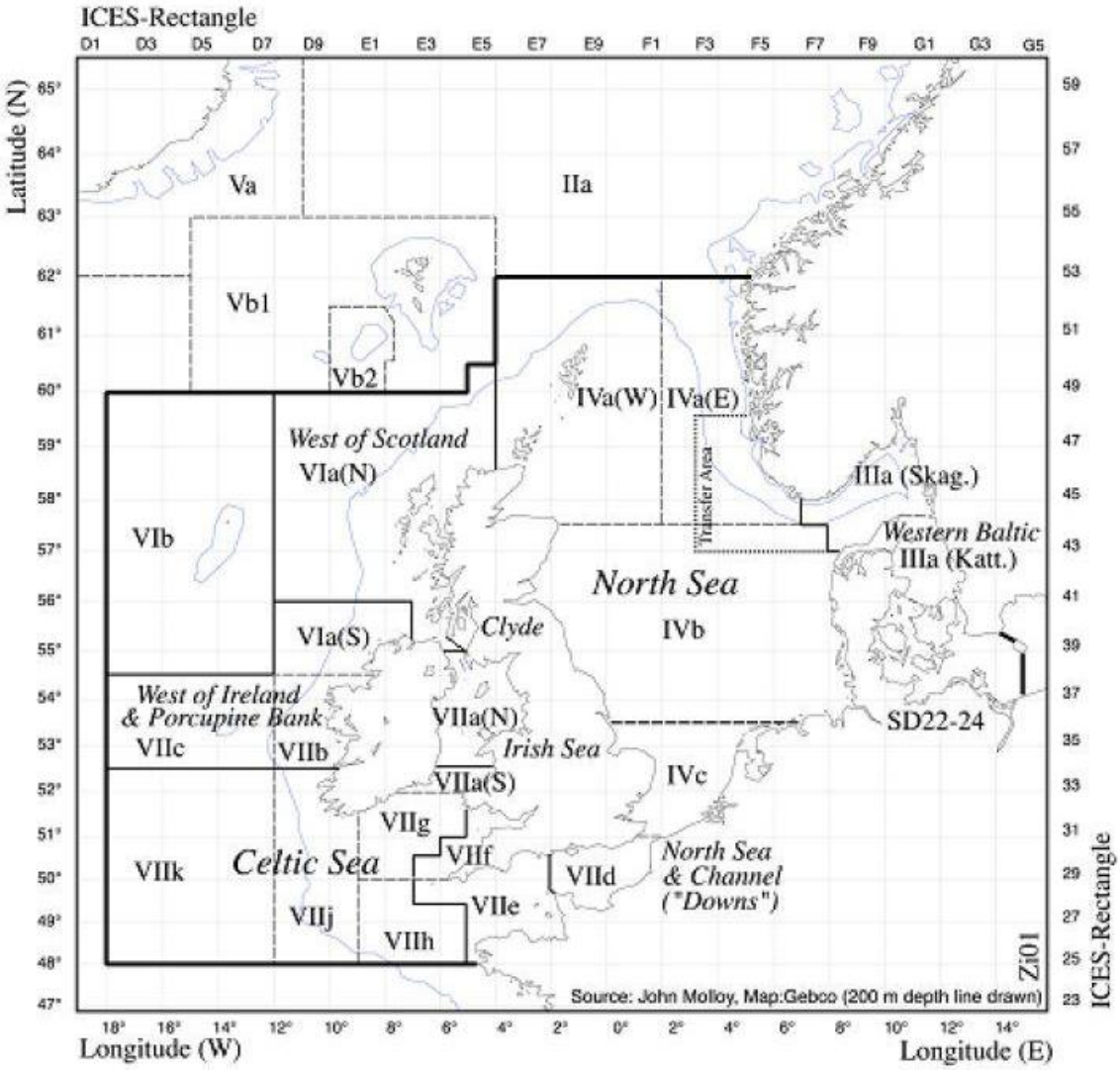

Figure 4 *- ICES divisions along the western coasts of the UK (ICES, 2019, http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2018/HAWG/01%20HAWG%20Report%202018.pdf [unedited]).*

Reproduction & Life History

Herring may have the richest spawning structure of all marine fish species (Iles and Sinclair, 1982): few other species have near as many separate stocks in relation to their range and distributions. Herring reproductive characteristics, such as egg size or maturation rate, can vary systematically between the different spawning populations and, as such, these groups are often referred to as different stocks or “races” (van Damme *et al.*, 2009). Although most herring return to the same spawning site they were born at for their entire lives, evidence from Norway suggests spawning sites can change with age (Slotte, 1999).

Spawning events are synchronised within populations, in which spawning occurs at fixed locations and times of the year. However, the location and timing of spawning events varies between herring populations. For example, in the North Sea, the smaller inshore populations tend to spawn in spring (Roel *et al.*, 2004), while the large North Sea herring population is

made up of three separate spawning groups (two summer-autumn stocks and a winter-spring stock) that travel to their different spawning sites after feeding further offshore during the summer (Dickey-Collas, 2004; Henderson, 2014).

At spawning sites, females deposit their eggs upon coarse and solid substrates, such as gravel or small stones and sometimes on beds of macro-algae or mussels. Herring have wide temperature and salinity tolerances, so spawning can occur in coastal waters, embayments or even open seas. Typically, the eggs are deposited between zero and 50 metres depth but have been observed at depths of almost 200 metres (Aneer, 1989). The eggs are fertilised by the males before becoming attached to the substrate or sometimes marine plants (Rajasilta *et al.*, 2006). Typically, the number of eggs deposited by a single female ranges between stocks, usually between 10,000 and 60,000 eggs. However, this number can be as high as 200,000 eggs for particularly large females (Lindemann, 2009). Egg masses can build up into multiple very dense layers (Nash and Dickey-Collas, 2005), so spawning sites must have a constant flow of well oxygenated water.

Depending on environmental conditions, eggs hatch between ten days and a month after fertilisation. In the cool, temperate waters of the UK most eggs hatch after approximately three weeks (Lindemann, 2009). The larvae, only 6mm long, form large schools and occupy the top 50m of the water column (Harden Jones, 1968). Larvae then need to wait until food abundance increases in spring before they can grow and develop past the larval stage, meaning summer-autumn spawners have longer larval periods than winter-spring spawners. Consequently, summer-autumn spawners are often transported further from their spawn site via ocean drifting (Fässler *et al.*, 2011). Once they have progressed past the larval stage, the fish are known as 0-group juveniles. They tend to concentrate in shallow, less saline habitats such as near-shore areas or estuaries (Titmus *et al.*, 1978). The fish venture further offshore with age and, upon maturity (typically three to four years), join the adult population and participate in spawning events. The natural lifespan of an Atlantic herring in unfished stocks is 12 to 16 years, during which it can reach lengths of between 25 and 30 cm (Hureau *et al.*, 1984).

Food Web & Interspecies Interactions

Herring distribution, growth rates and survival are largely determined by the abundance of prey, including copepods and other zooplankton such as larval herring and eggs of other species (Sherman, 1970; Smith and Reay, 1991). Herring predominantly feed on plankton (particularly copepods) throughout their entire lives, occasionally feeding on young sand eels as adults (Dickey-Collas, 2004; Skjoldal and Saetre, 2004). The dependence of herring on some copepod species is so strong that knowledge of the distribution and abundance of certain prey species may allow predictions of herring stock location and distribution (Alvarez-Fernandez *et al.*, 2015).

Herring at all life stages are vital food sources for other species, including predatory fish species such as haddock, silver hake, striped bass, tunas, and cod, many of which are commercially important (Overholtz and Link, 2007). Following spawning, pre- and post-hatch mortality can be high, with the rich layers of herring eggs attracting an array of predators including fish, whelk, crab and starfish (Toresen, 1991; Townsend, 1992; Richardson *et al.*, 2011). Herring larvae are often predated upon by jellyfish, mackerel, older herring and sticklebacks as they drift in ocean currents (Moller, 1984; Fuiman, 1989), while older herring are predated upon by larger predatory fish, marine mammals and seabirds (Heessen *et al.*, 2017). Herring schools can be vast, containing up to 40 billion individuals, and thereby

constitute a stable resource for larger marine predators (Tiews, 1978; Similä, 1997). Herring are therefore a critical link between the planktonic base of the food chain and top ecosystem predators, making them highly valuable to marine ecosystems.

Healthy herring populations can thereby support other fisheries, stable marine food webs and other ecosystem services. Forage fish such as herring can contribute as much as $16.9 billion to global fisheries, both directly and indirectly (Pikitch *et al.*, 2014), while other predators of herring – including marine mammals and sea birds –occupy vital roles in food webs, maintain ecosystem balance and provide tourism benefits to coastal communities through wildlife tourism and observing (Dickey-Collas, 2004; Lee, 2010). The populations of dolphins, porpoises, seals and seabirds that feed on herring (see **Figure 5**) within the Bristol Channel attract vast numbers of wildlife tourists and support a number of wildlife watching businesses (Hampshire Rose, 2017; National Trust, 2020). Further outside the Bristol Channel, areas of the Irish sea are important feeding grounds for several species of large baleen whales that feed primarily on sprat and herring during the autumn and winter months, that will also attract tourists and support whale watching businesses (O'Donnell *et al.*, 2005).

Figure 5 *- Lundy grey seal (Halichoerus. grypus) (Photo credit Mike Deaton; North Devon Biosphere, 2020,* https://www.northdevonbiosphere.org.uk/marinewildlife.html *[unedited]).*

Upon engaging with fishermen from North Devon and Somerset, it was mentioned that during their time fishing in the Bristol Channel they had noticed that herring and mackerel have a peculiar relationship (FRMP Interviews, 2020). During years where herring numbers are strong, with many seen swimming up the Bristol Channel, mackerel numbers will be comparatively low and much less abundant. And in turn, during years where mackerel numbers are strong, herring will be less abundant. This is likely because herring and mackerel occupy very similar ecological niches and are likely to compete over their copepod food supply where their distributions overlap (Bachiller *et al.*, 2016; Óskarsson *et al.*, 2016). This competition will result in one of the two species emerging slightly more dominant than the other, thus affecting population sizes and abundance of the two. It is possible that after follow-

up research, knowledge on relationships such as these can be incorporated into management to help predict possible changes in populations and abundances of certain species.

Fishery Information & Structure

Atlantic herring is thought to be one of the most populous fish in the world, unsurprisingly it has been exploited and harvested by humans for hundreds of years on both sides of the Atlantic Ocean (Whitehead, 1985). During this time, both heavy fishing effort and natural environmental phenomenon have caused stocks to fluctuate dramatically and even crash several times. Several large herring stocks are commercially exploited around the UK, including populations in the North Sea, English Channel, Irish Sea and the Celtic Sea (ICES, 2019a).

Importance & Value of Fishery

Despite huge fluctuations in herring stocks over the past few decades and large declines in landings compared to historical levels, the UK fishing fleet still harvests large amounts of herring each year from the oceans around the UK. In 2019, the MMO recorded that over 78,000 tonnes of herring were landed by the UK fleet valued at over £40 million (MMO, 2020a). Several of the herring fisheries around the UK carry Marine Stewardship Council (MSC) sustainability certifications, meaning their fishing practices have been monitored and assessed to be non-damaging to the long-term population health of their target species and their ecosystem. These certified fisheries can market their fish as MSC standard and therefore their catch has added value. In 2012, the Celtic Sea herring trawl fishery was certified as sustainable by the MSC, adding value to their fishery and catch, however, certification was later withdrawn in 2018 due to overfishing and decreasing herring populations (MSC, 2020).

Within the Bristol Channel, herring is not extensively or heavily fished today, though herring fisheries have operated in the area for centuries (Wordley, 2019; see **Historical Landings & Changes Over Time**). Much of the value associated with local herring is cultural as many of the fishermen targeting stocks in this area use traditional gear despite more modern and efficient fishing practises being available, making these local fisheries small-scale and artisanal in nature. When the MMO landings data from the North Devon and Somerset ports is observed, we see that only 0.1 tonnes of herring were landed in 2019 valued at £230, demonstrating the small-scale artisanal nature of the herring fishery within North Devon. It is likely however, that much of the herring caught in North Devon in recent years was sold locally without documentation, thus accounting for such low landings in the MMO data. Most of the fishing fleet in North Devon is under 10 metres in length, until recently there was no statutory requirement for fishermen using these smaller vessels to declare their catches. Any landings information was usually collected co-operatively using log sheets and sales notes from ports. In 2005, the UK Government introduced the First-Sale Fish Scheme, which declares that registered buyers must report their purchases of landed fish using sales notes (UK Government, 2020a). However, this only applies to individual sales over 30 kilograms in weight, and Clovelly herring fishers have reported earning over £4,000 in a single season from herring in recent years, meaning the majority of herring landings and sales go unrecorded (Masters, 2014). This “loophole” explains the lack of MMO documented landings and the complete absence of any records of herring landed in Minehead, despite the fact it is common knowledge netting for herring occurs there. Additionally, MMO landings data does not account for any fish caught by recreational fishers and anglers.

Progress has been made to fill these landings data gaps. Recently the MMO developed and launched the <10 metre vessel catch recording app for use by commercial fishers for use in mandatory recording of all catch data, and there are similar options for recording catch for

recreational fishers (e.g. Cefas Sea Angling Diary), however, more detail is needed, particularly in a local context to properly understand the impacts of fishing on coastal fish populations.

Even when considering the value of the non-documented herring landings, the North Devon herring fishery is still small-scale by commercial values and standards. Despite this, the fishery carries immense cultural and heritage values with it. Historically, Clovelly and Minehead were famous for their thriving herring fisheries and any mention of herrings from witness testimonies in the 1800s was closely followed by the name of Clovelly (Dickinson, 1987). However, at present less than a handful of fishermen currently fish for herring from these ports. Past collapses of the herring fishery have resulted in significant identity and cultural losses to these communities, because of this, there is a strong urge to protect and conserve the remaining fishers so that such a significant historical aspect of the area is not completely lost. For example, the annual Herring Festival takes place to help restore this lost identity and raise awareness among younger generations about the history of fishing in Clovelly and to support the remaining herring fishers (see **Figure 6**).

Figure 6 *- Clovelly herring festival (Stewart-Smith, 2016,* http://www.boatstories.co.uk/fishing-for-clovelly-herring.html *[unedited]).*

Historical Landings & Changes Over Time

As previously mentioned, herring stocks around the UK have fluctuated dramatically while being exploited by humans. Though herring populations have been documented to behave in this way naturally due to their dependence on plankton and other environmental factors, overfishing has played an important role in several stock crashes and recoveries throughout the last century (Bailey and Steele, 1992). For example, during the 1970s the North Sea herring stock collapsed due to a combination of high fishing pressure and recruitment failure (Clarke and Egan, 2017). At the time of collapse, the herring were being exploited by 14 different nations, and management was not implemented in time to avoid collapse. Catch reductions were not able to be agreed upon and so a herring fishing ban was put in place in 1977 to allow the population to recover. Even when the ban was partially lifted in 1981, TACs remained extremely low for several years (Dickey-Collas *et al.*, 2010). By the time the ban was lifted across other areas of the North Sea in 1983, many ship-owners had gone bankrupt and the lack of supply had led to a change in consumer behaviour, and the kipper was no longer a popular seafood of choice (Clarke and Egan, 2017).

There is evidence for fishing activity in the Bristol Channel and North Devon dating back as far as the Mesolithic era, with evidence of lines of stakes thought to be the remains of fish traps being found during excavations around Westward Ho! (Preece, 2008). Herring fisheries in both Europe and North America date back centuries, with some of the earliest records of fishing dating back to 12th century Holland (Jones, 1795). The sheer abundance of herring has made it one of the most commercially important fisheries in the world. Historical accounts note North Devon herring fisheries first developing during the 1580s and describe "*notable plenty*" shoals of herring travelling up the channel in the autumn and early winter months just past Lynmouth. These herring migrations would attract fishers from all over to come and join the fishing season, one such fisher was recorded to have caught over a quarter of a million herring during one season (Ashford, 2006). During this time, the majority of herring would be caught using drift and fixed netting (the same gear used by herring fishers in Clovelly and Minehead today). The herring fishery in North Devon continued to grow across the next couple of centuries, during the 1740s, Clovelly fishermen were recorded to net ~9,000 herring per day, earning approximately £1,500 (worth the equivalent of £354,387 today) in a single season (Ibrahim, 2019). This prosperity continued into the 1800s, during which time Clovelly was well known and considered famous for its fishing and abundance of herring. In 1810, Prince noted that over 400 horses were needed to unload the herring catch each day during the fishing season.

Figure 7 *- Clovelly herring fishermen in the 1800s (Stewart-Smith, 2016,* http://www.boatstories.co.uk/fishing-for-clovelly-herring.html [unedited]*).*

However, like many other fisheries during the 19th century, catches of North Devon herring began to consistently drop following the introduction of trawls and steam power (Ibrahim, 2019). This new technology meant that fishermen were able to travel further offshore and fish more efficiently, leading to large declines in the stocks of many commercial species (Roberts, 2010). In a book on the history of Clovelly, it is noted "*From the year 1840 herring fishing began to decline, trawling was just the beginning*" (Ellis, 1987). From this time Clovelly's small-scale fishing fleet began to depreciate with the number of active vessels dropping from 70 to 30 or 40 in the span of just fifteen years. Interestingly, when interviewed in 1866, the fishermen attributed this decline to the unpredictable movements of the herring and the fishery's vulnerability to bad weather rather than overfishing. A similar pattern of declines in herring catch and falling returns on herring sales was seen nationwide that continued into the 20th century (Wordley, 2019). Public demand for herring fell dramatically meaning the inshore fishermen were struggling to maintain their boats and gear due to decreased earnings. The landings in North Devon were not large or reliable enough to attract local fishmongers, meaning these herring vessels were operating at a loss and accumulating debt (Sea-Fish Commission, 1934). These troubles were added to in 1911 when trawling for herring began to develop at an alarming rate, so much so that the herring drift netters "started an agitation against it" which resulted in the Prime Minister appointing a committee to monitor the situation (Royal Commission, 1920). The development of trawl fisheries soon led to heavy overexploitation of the herring stocks and decline in the inshore fishing fleet to the point where there were only 15 vessels operating out of Clovelly by 1900. This decline in inshore fishing has continued over the last century leaving Clovelly with only a few fishing vessels and two remaining herring fishermen (see **Figure 8**; Smylie, 2011).

Figure 8 *- Netting for herring off Clovelly in North Devon (Stewart-Smith, 2016, http://www.boatstories.co.uk/fishing-for-clovelly-herring.html [unedited]).*

Historic declines in herring stocks are not isolated to the inshore fishing in North Devon, as previously mentioned, the North Sea herring stock has fluctuated dramatically in past decades and the Celtic Sea herring stock has collapsed twice since 1970, first during the 1970s, and again in 2004 (Dickey-Collas *et al.*, 2010). Low levels of herring recruitment combined with consistent overfishing were observed in the run up to both crashes. The Celtic Sea stock is managed under the European Union's (EU) Common Fisheries Policy (CFP), following the 2004 crash, management measures were put in place to rebuild stocks involving heavy stakeholder involvement through the Pelagic Advisory Council and a local Irish stakeholder committee. A formal rebuilding plan was put in place to run until 2012, by which time the stock had recovered. Analysis since then has shown that innovations in management measures were crucial for the rebuilding process as opposed to the stock being left to recover on its own (Clarke and Egan, 2017). Although stock recoveries such as this are possible, it is clear there has been a major reconfiguration in the structure of fish populations and food webs since the historic peaks of herring fishing. Historically important species such as herring and horse-mackerel are still caught commercially in the Bristol Channel, however, their abundance is a pale imitation of the "*notable plenty*" and "*vast shoals*" seen historically (Wordley, 2019; Ibrahim, 2019).

Gear Used

The majority of commercially caught herring in the UK is harvested using either midwater/pelagic trawls or seine/ring nets (Dickey-Collas *et al.*, 2010; Clarke and Egan, 2017; ICES, 2019a). Pelagic trawls are large, towed, open-mouthed nets designed to catch large shoals of fish from within the water column (see **Figure 9**). Bycatch in pelagic trawls is much less severe than demersal trawling as no contact with the seabed is made, leaving benthic marine life untouched (Seafish, 2020a). Seine or ring nets are also used to target herring in offshore fisheries, these are long nets that are shot out of moving vessels encircling a school

of the target fish. They can be operated by a single vessel or by two separate vessels working together. The nets are weighted down at the bottom, so they hang through the water column and surround the fish as the vessel circles around them. Once the vessel has completed its ring, the fish are completely encompassed by the net (see **Figure 10**), which is then slowly pulled into the boats, along with the entire school of fish (Seafish, 2020b).

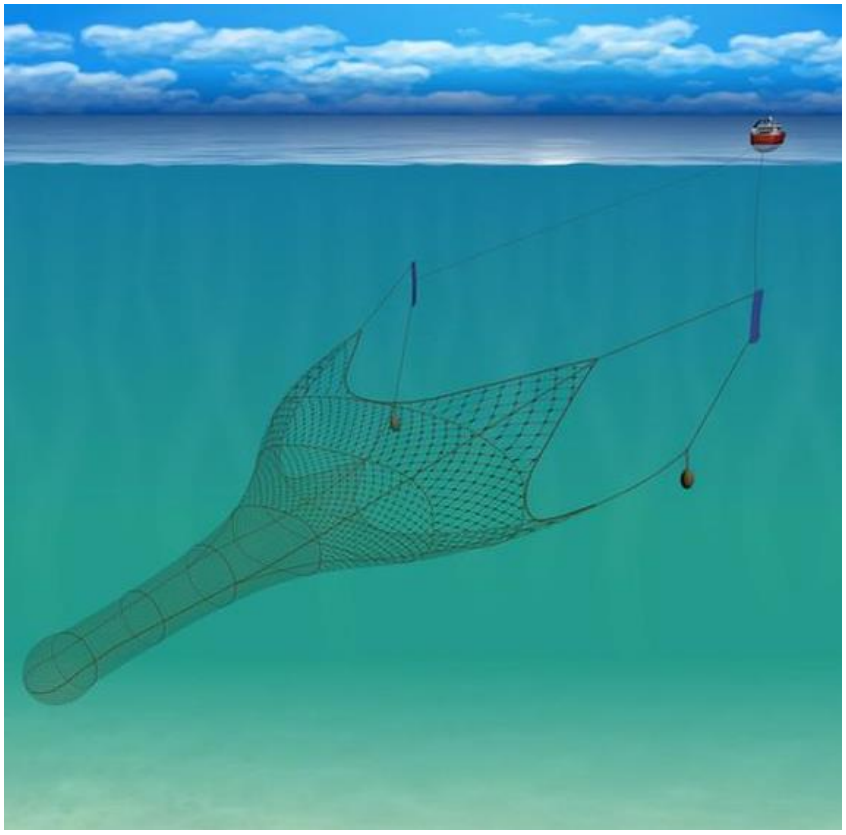

Figure 9 *- Pelagic trawling (Seafish, 2015,* https://seafish.assetbank-server.com/assetbank-seafish/action/viewAsset?id=4804 *[unedited]).*

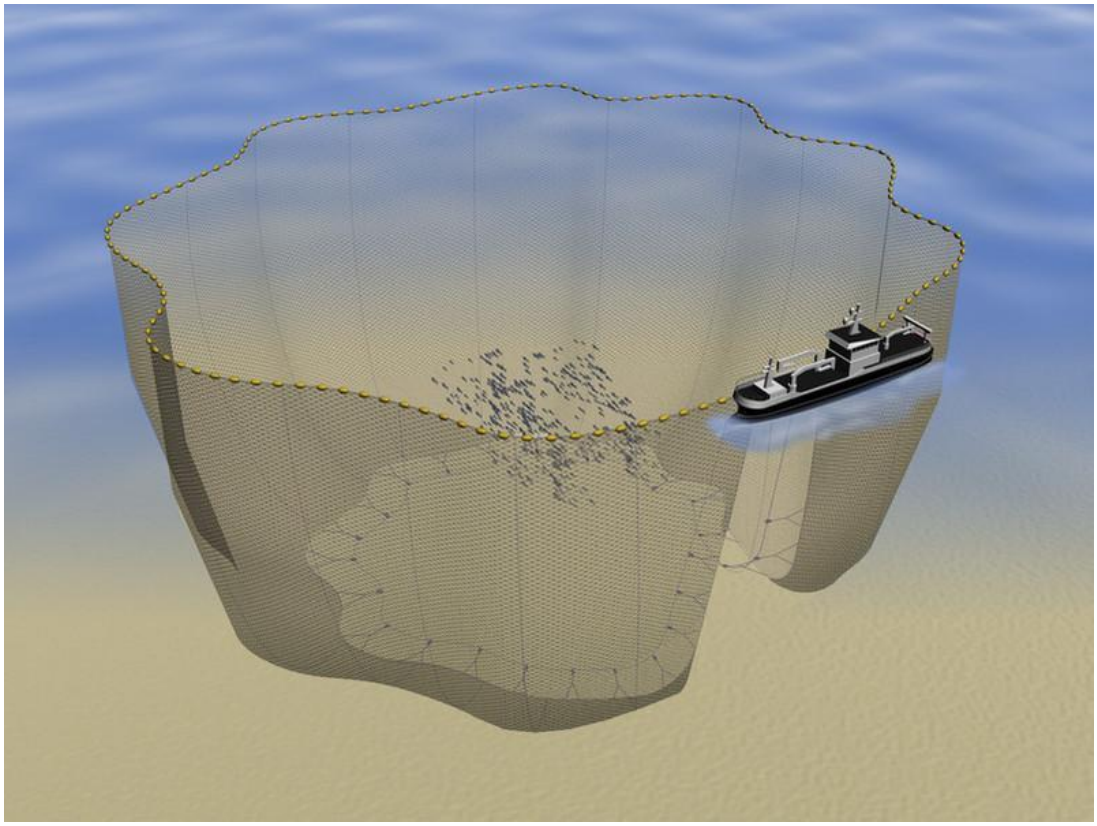

Figure 10 *- Purse seine netting for school of fish (Seafish, 2015b,* https://seafish.assetbank-server.com/assetbank-seafish/action/viewAsset?id=4808 *[unedited]).*

Most offshore fishing fleets utilise “fish finder” technology when targeting schooling, pelagic species (Hodges, 2011). This usually involves sonar devices that send pulses of sound waves down through the water. These sound waves are reflected back up to the boat after hitting large objects or schools of fish and the time taken for the waves to return to the boat are analysed, giving accurate measurements of how large and deep the school of fish is (Fernandes *et al.*, 2002). Equipment such as this, combined with extremely effective gear such as seine nets allows for fishermen to find, track, and catch huge numbers of herring during a single voyage.

In many inshore fisheries including North Devon however, herring is mostly caught using driftnets (see **Figure 11**), within two nautical miles of the shore. Driftnets are usually placed just beneath the surface but can be used anywhere in the water column. A major advantage of nets such as these is that the length of the nets and the mesh sizes can be used to specifically target certain species, reducing the amount of bycatch (Seafish, 2020c). Throughout the Bristol Channel, driftnet fisheries operate targeting herring, grey mullet, bass, and mackerel. In 2014, Sea Fish’s Report on the Current State of Driftnet Fisheries in the UK (Masters) recorded 20 boats (mostly < 6 metres in length) within Devon & Severn Inshore Fisheries and Conservation Authority’s District that commercially target fish using driftnets. It is important to note however, that these vessels will not all operate within the north of the D&S IFCA’s District and as mentioned in the report, do not all target herring, meaning the pressure on North Devon herring stocks from drift net fisheries is most likely minimal with little bycatch of other species. Traditional herring fisheries, such as those described in Clovelly and Minehead, operated using inshore stake and drift nets to capture the shoals of herring swimming along the coast (Ashford, 2006). The few herring fishermen still operating out of

Clovelly and Minehead continue to utilise these traditional netting practices and are proud to report they see minimal bycatch and environmental impact using this gear (Marine Pioneer Interviews, 2020).

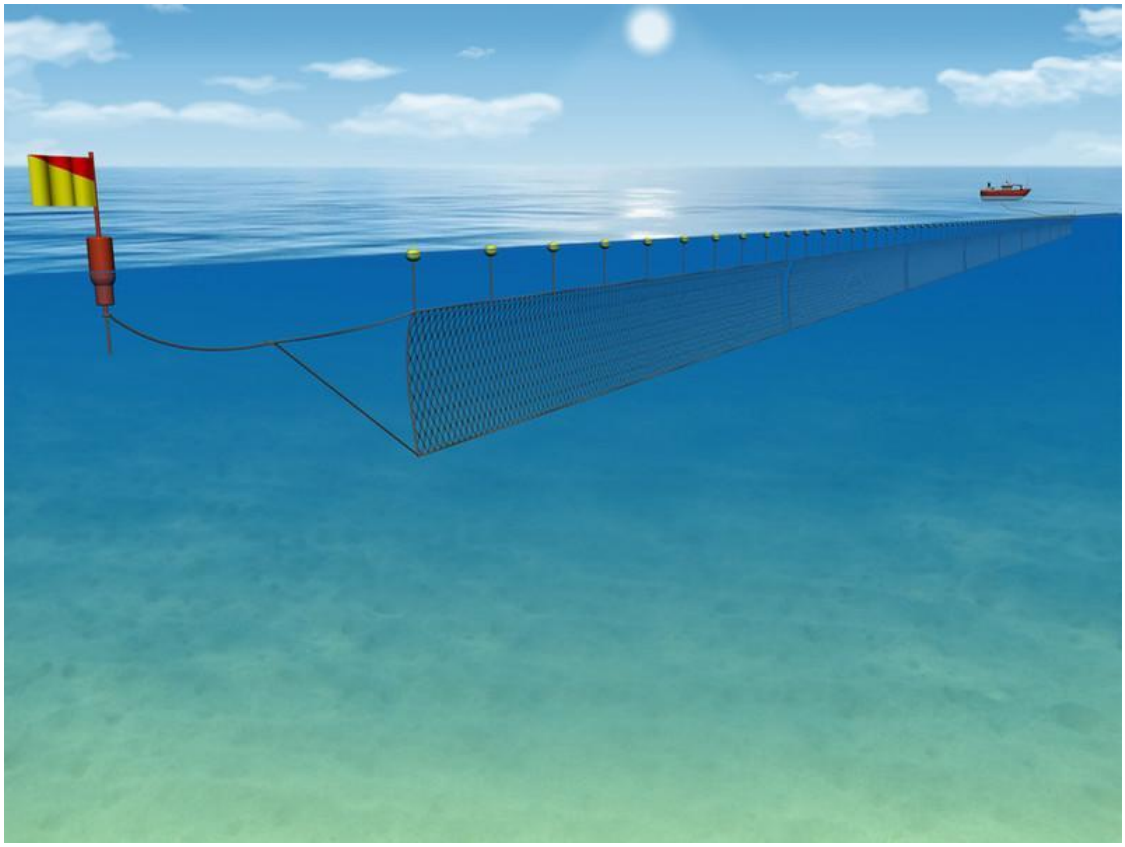

Figure 11 *- Drift netting (Seafish, 2015c, https://seafish.assetbank-server.com/assetbank-seafish/action/viewAsset?id=4770 [unedited]).*

There is very little bycatch associated with herring fisheries. Though no specific data are available for herring fishing within the Bristol Channel, in 2009, the Herring Assessment Working Group (HAWG) concluded that bycatch was not a significant issue for the herring fishery in the Celtic Sea (ICES, 2019a). Though anecdotal reports suggest that seals, blue sharks, tuna, and whitefish are caught incidentally from time to time in herring fisheries. Additional research focusing on bycatch conducted in the Celtic Sea have also shown that herring fisheries are relatively clean of bycatch and unwanted species (O'Donnell *et al.*, 2017; ICES, 2019a). During these studies, mackerel, whiting, and haddock are sometimes caught alongside herring, though no seabirds or marine mammals were caught despite being regularly sighted in the area. The Bristol Channel is home to several species of marine mammals including porpoise and seals, so the risk of marine mammal bycatch within the Bristol Channel is present. However, local herring fishermen have stressed that other than seals occasionally taking catch from nets, their fishing has no disturbing impacts on local marine mammal populations (Masters, 2014; FRMP Interviews, 2020).

Current Recreational & Commercial Fishing Effort

With many pelagic fisheries targeting schooling species, including herring, it is extremely difficult to accurately quantify fishing effort. Advances in fishing technology have led to these species being harvested at an alarmingly efficient rate, with entire schools of herring being harvested in the same net at one time in the larger, offshore, commercial fisheries (ICES,

2019a). Multiple countries harvest herring from the Celtic Sea stock including France, Germany, and the Netherlands, with the majority of the catch being landed by Irish and UK vessels (Clarke and Egan, 2017). Fishing effort in the Celtic Sea is dictated by quotas set by the EU based on advice from external bodies such as ICES. These quotas have varied due to stock crashes and natural variations in herring populations but average ~15,500 tonnes per year between 1988 and 2018 (ICES, 2019a). As of April 2016, there were 48 Irish vessels authorised to fish Celtic Sea herring (MSC, 2020), landings data shows that several non-Irish vessels also exploit the fishery, but the bulk of the fishing effort comes from the Irish fleet (ICES, 2019a). Overfishing of the Celtic Sea stock has led to lowered quotas and loss of MSC certification as a sustainable fishery, which has likely reduced fishing effort on this stock in recent years.

In most inshore herring fisheries, such as those in North Devon, herring are harvested using netting rather than mobile fishing gear. Catch efficiency in these inshore, netting fisheries is much lower than the offshore netting and trawling. From **Table 1** we can see there are currently 16 commercial and 22 recreational gear permits allowing fishing vessels to net for fish in the north of the D&SIFCA's District. There are also seven mobile fishing gear permits issued, and under the D&S IFCA byelaws, ring netting is classed as mobile fishing gear as well as trawling. However, currently no fishing vessels in North Devon are equipped with ring nets, so although small amounts of herring may be caught as bycatch in trawls, it is unlikely that herring is specifically targeted commercially with mobile gear in the Bristol Channel (FRMP Interviews, 2020; Marine Pioneer Interviews, 2020). It is also important to note that herring is not the only species targeted by North Devon fishermen during their winter season (see **Figure 12**), so herring are not directly targeted by fishers throughout the year.

In North Devon and Somerset, there are only four fishermen that directly target herring, two in Clovelly using drift nets, and two in Minehead using fixed netting (FRMP Interviews, 2020). This is only a minor fraction of the historic fishing effort for herring within the Bristol Channel, so despite large fluctuations in the large, offshore herring stocks, it is unlikely that fishing effort out of North Devon and Somerset is currently having a significant impact on herring populations. However, recent results from the Bristol Channel Herring Project indicate that the herring being caught in the Bristol Channel is in fact a separate, locally breeding stock to the larger Celtic Sea populations (Clarke, 2020). Little is currently known about this herring population; however, it is likely that this stock is small and if it is found to be highly localised it is possible that activities such as fishing and coastal developments may have a significant impact on the stock. It is vital to conduct research to clarify this and survey the newly discovered herring stocks to estimate size and ensure sustainable management.

***Table 1**- Number of fishing gear permits issued by the Devon & Severn Inshore Fisheries & Conservation Authority within or in close proximity to the North Devon Marine Pioneer Area (Devon & Severn IFCA, 2020a).*

Location	Gear						
	Commercial Netting	Recreational Netting	Mobile Fishing at Sea	Mobile Fishing in Estuary	Commercial Diving	Commercial Potting	Recreational Potting
Appledore	2	1				2	1
Barnstaple							2
Bideford		1	5			1	1
Braunton		1					1
Bridgewater							1

Bristol							2
Bude						2	
Clovelly	10	2	1			5	4
Fremington							1
Hele Bay						1	
Highbridge		1					
Ilfracombe			1			6	6
Lynmouth						2	
Minehead	4	11				2	
Padstow						2	
Taunton							1
Velator							1
Watermouth							3
Watchet		2					
Weston		1					
W.-Super-Mare		2					
Total	**16**	**22**	**7**	**0**	**0**	**23**	**24**

Figure 12 *- Seasonal catch and target species of North Devon fishermen (NDFA, 2019, http://www.northdevonfishermen.co.uk/our-catch [unedited]).*

Recreational effort is extremely difficult to quantify due to a lack of official landings data, but herring are rarely caught by shore anglers and is not a highly prized or sought-after species. The Mapping Sea Angling project led by the MMO in 2020 identified that in the South West, the most valuable species to sea anglers were bass, rays, cod, mackerel and pollack (MMO,

2020b). Additionally, from the dataset of Cefas' 2016-17 Impacts of Sea Anglers in the UK project (Radford *et al.*, 2020), herring was not present in the list of the top 20 most caught species by UK sea anglers. Charter boats that travel further offshore are more likely to catch herring than shore-based anglers (British Sea Fishing, 2020), and there are several such charter boats currently operating within the north of the D&S IFCA's District. However, during the Cefas angling project, it was found that 65% of the herring caught by anglers in 2017 were re-released into the sea after capture (Hyder, 2016). Therefore, low effort form anglers combined with this retention rate means the effect of recreational anglers on the North Devon herring stocks are likely minimal. There are recreational fishers that catch fish using netting in the Bristol Channel however, and herring is often directly targeted (FRMP Interviews, 2020). As seen in **Table 1**, in 2020 there were 22 active recreational netting permits within the north of Devon & Severn IFCA's District, however, due to the recreational nature of these permits, net sizes are limited to 25 metres and each permit holder is only authorised to catch fish for their own consumption, with additional licensing being required in order to sell their catch commercially (MMO, 2020c). Along with the commercial fishermen, recreational netters target herring in the Bristol Channel during the winter months.

Current Landings & Stock Status

Due to several years of fishing over MSY levels, the Celtic Sea herring stock is currently estimated to be at a very low levels (ICES, 2019a, 2019b). The stock has been in decline from a recent peak biomass in 2011 and the spawning stock biomass (total weight of all fish in population contributing to reproduction) is now below the target levels (see **Figure 13**). Recruitment has consistently been low since 2013 and has prevented recovery of the stock. In an effort to aid recovery of the stock, the TAC for 2020 was reduced by 82% from 2019, dropping from 4,742 to 896 tonnes for ICES areas VIIg, h and j (Council of the European Union, 2020a). ICES area VIIf (the Bristol Channel) is not as well surveyed as the other Celtic Sea regions and because of this there is a lack of data regarding the stock status of herring in this area. Following assessments of the entire Celtic Sea stock, ICES recommended a TAC of 0 tonnes for 2020 to effectively allow the stock to recover from previous overfishing. Despite this, TACs have been consistently set above this, possibly stalling the recovery of the stock. The TAC for VIIf was set at 930 tonnes for both 2019 and 2020. Fortunately, research has shown that the Celtic Sea herring stock has little interaction with other herring populations, so the effects of overfishing in this area will not have negative impacts on other UK herring stocks (Clarke and Egan, 2017).

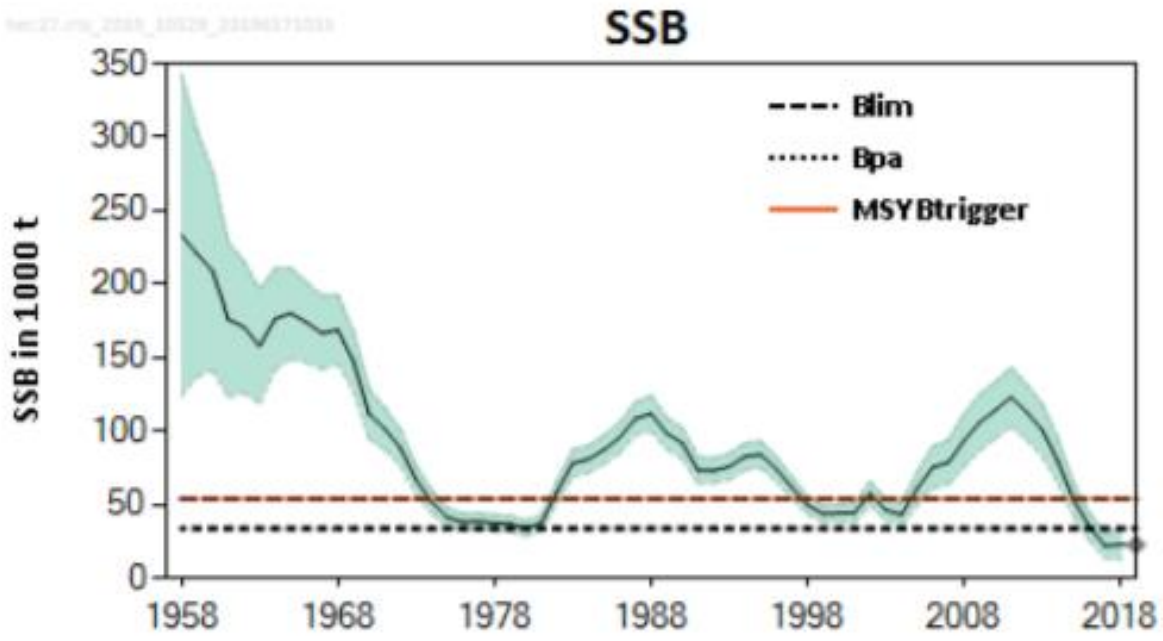

Figure 13 *- Celtic Sea (in divisions VII.a South of 52°30'N, VII.g–h, and VII.j–k) spawning stock biomass (ICES, 2019b, http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/2019/her.27.irls.pdf [unedited]).*

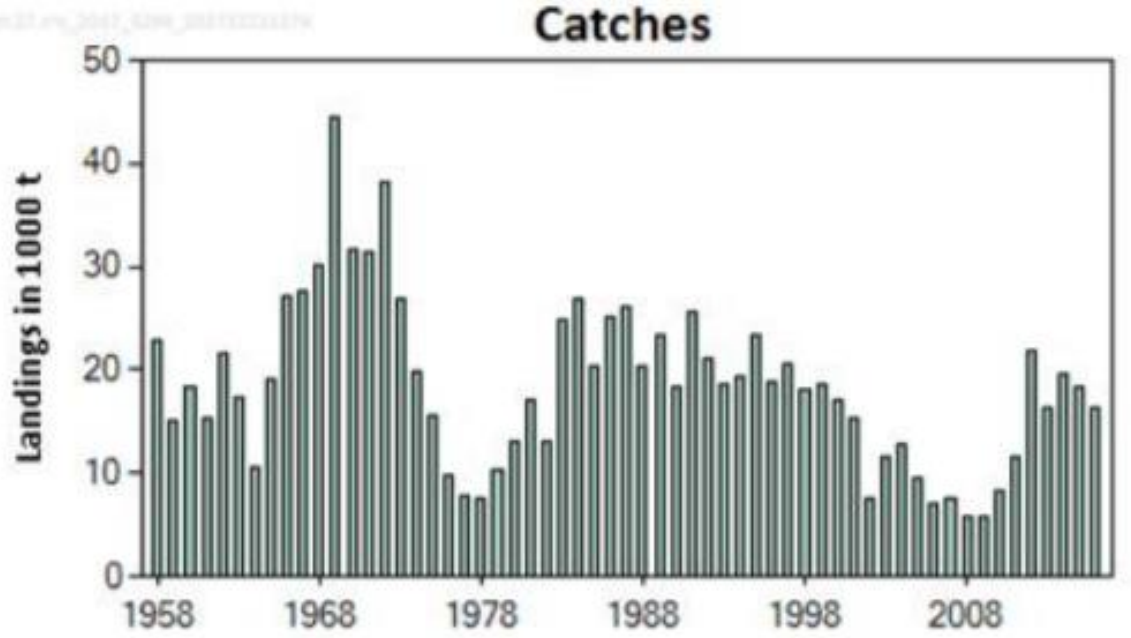

Figure 14 *- Annual herring catch from Celtic Sea stock (in divisions VII.a South of 52°30'N, VII.g–h, and VII.j–k) (ICES, 2019b, http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2019/2019/her.27.irls.pdf [unedited]).*

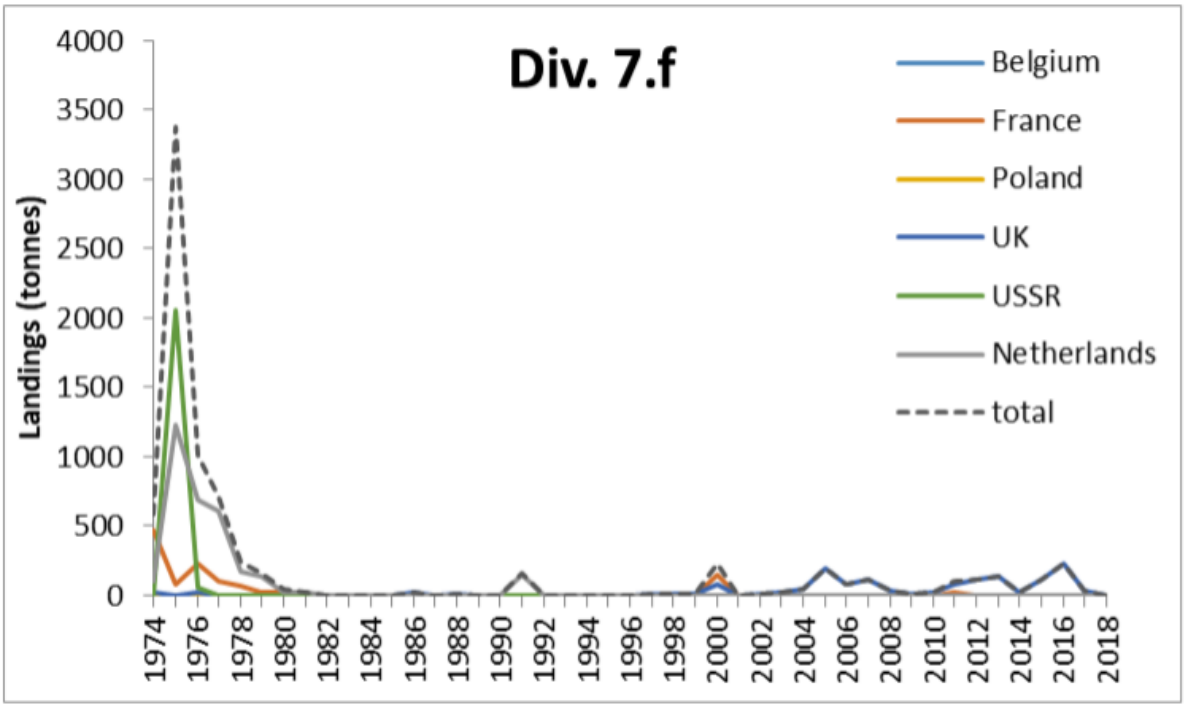

Figure 15 *- Herring landings over time from ICES Division VIIf (ICES, 2019a, https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2019/HAWG/01%20HAWG%20Report%202019.pdf [unedited]).*

As can be seen from **Figure 14**, herring landings from the Celtic Sea have fluctuated dramatically over past decades. A declining pattern in landings is present, though large amounts of herring have still been caught in recent years. However, herring landings within the Bristol Channel (VIIf) have dropped from historically high levels (see **Figure 15)**, fluctuating since the 1970s and not exceeding more than 200 tonnes per year (ICES, 2019b).

Recently, Bristol Channel herring landings are at an all-time low, with only 28 tonnes being landed from Division VIIf in 2017, followed by a mere three tonnes in 2018 (see **Table 2**). This may be due to overfishing, as is the case with the rest of the Celtic Sea herring stock, or from natural and environmental factors such as stormy winters leading to lower recruitment into the fishery. Regardless of the reason for this recent drop in catch, there is no question that stock health today is but a fraction of what it was historically. Despite greater fishing power and advances in technology, the daily catch from one small fishing village in 1888 equates to just under half the total annual weight of fish caught by an entire fishing fleet within the Bristol Channel and South East of Ireland in 2017. An article in the Bideford Gazette in 1888 reported that the average daily catch of herring in Clovelly at the time was 54 tonnes, compared to the 95 tonnes caught across the whole of ICES Areas VIIf and g in 2017 (Wordley, 2019).

***Table 2** - Annual herring catch from ICES Area VIIf (Bristol Channel (ICES, 2019a, https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/Fisheries%20Resources%20Steering%20Group/2019/HAWG/01%20HAWG%20Report%202019.pdf [unedited]).*

Division	Country	2011	2012	2013	2014	2015	2016	2017*	2018*
7f	UK (Eng, Wal, Scot, NI)	78	113	136	20	111	227	29	3
7f	Belgium	-	-	-	-	-	-	-	-
7f	France	26	-	-	-	-	-	-	-
7f	Netherlands	-	-	-	-	-	-	-	-
7f	Poland	-	-	-	-	-	-	-	-
	Total	104	113	136	20	111	227	29	3

* Preliminary data

Despite the Celtic Sea herring stock currently being at a record low strength, herring netters in North Devon and Somerset reported that their catch has stayed strong in recent years, with plenty of herring swimming up the Channel to spawn, suggesting that the herring within the Bristol Channel may not be closely linked to the Celtic Sea stock. The herring fishers have said that they have known for years that the herring were unique and has suspected they were spawning locally (Marine Pioneer Interviews, 2020). As previously mentioned, research conducted as part of the Marine Pioneer has shown that distinct winter breeding herring populations are present both off Minehead and Clovelly (Clarke, 2020). Now that scientific research is catching up with this local knowledge and early findings are being followed up with more research, more appropriate management may follow once more is known about herring stocks within the Bristol Channel.

Due to the recent discoveries of herring stock structure in North Devon and Somerset, it is currently not possible to assess the impact of inshore fishing on herring in this region until more information on stock structure is obtained. Low fishing effort and a lack of regular surveys or assessments for herring within the Bristol Channel means that it is extremely difficult to confirm if the current declines in herring seen in the wider Celtic Sea area are also occurring in the Bristol Channel. Once research investigating the movements of the Bristol Channel herring stocks has been conducted, it will be possible to assess if stocks will be subjected to fishing pressure outside of the Channel or if they are only fished off the waters off North Devon and Somerset. If the Bristol Channel herring are found to be completely isolated from other stocks and show high fidelity to the Bristol Channel, it is most likely that current fishing effort from Clovelly and Minehead is having a minimal effect on the population due to the low number of fishers and low-impact nature of their gear. Very few fishers target herring over the winter in North Devon and the Clovelly herring fishermen have stated "*it is the most sustainable form of fishing; it doesn't get more sustainable than netting for Clovelly herring*" (Marine Pioneer Interviews, 2020). Despite this, it is still vital to carry out investigative research to determine the stock structure and health of the Bristol Channel herring to correctly manage the stock and ensure the sustainability of the fishery. Under the current system of management and assessment, the herring being caught in the Bristol Channel are managed as part of the Celtic Sea stock, suggesting a disconnect between local knowledge, large-scale stock assessments and management. Despite the apparent sustainability and low impact of the North Devon and

Somerset herring fisheries, and fishing effort consistently falling in this region, recent TACs have been lowered in Division VIIf (the Bristol Channel) due to overfishing above MSY levels in other regions of the Celtic Sea.

Fishery Management

The management measures laid out in the following section have been summarised for the sake of this management plan. For full details of management regulations, please seek out the original legislation at either the EU-Lex, Legislation.gov or the D&S IFCA websites.

Herring fisheries are amongst some of the oldest and most important fisheries in Northern Europe. Since the 1980s herring has been managed under the EU's Common Fisheries Policy (CFP) with TACs being set and then divided up between member states. Species managed under the CFP are subject to EU fishing regulations applying to all Member States and then additional management measures can be applied at a national or regional level within member countries.

Since the UK's departure from the EU, and the coming into force of the Fisheries Act and related legislation, the British fishing fleet is not subject to EU regulations while operating in British waters, though many of the regulations brought in through the European Commission are still present in UK law (e.g., the landing obligation). The EU-UK Trade and Cooperation Agreement allows the UK to establish its own regulations for fisheries, as provided for by the UK Fisheries Act, and will not be bound to the EU's CFP rules. This ability to deviate from the CFP and establish regulations that can be more responsive and specific to the situation in UK waters has long been an important issue for UK policymakers and the fishing industry.

Marine activities in England are regulated by the Marine Management Organisation (MMO), who are responsible for managing fishing fleets, quotas and fighting illegal, unregulated, and unreported fishing. English inshore and regional fisheries are managed by the Inshore Fisheries and Conservation Authorities (IFCAs); IFCAs are responsible for enforcing national and EU-derived fishing legislation as well as ensuring local fishery exploitation remains sustainable through the implementation of byelaws in their regional districts.

Historical Management Measures

The European Union manages herring as distinct stocks, distributing separate TACs over the areas where the stocks are found based on scientific advice from ICES (Clarke and Egan, 2017). As well as TACs, restrictions are put in place such as fishery closures or gear restrictions in response to the constantly fluctuating herring stocks (see **Table 3**). Many of the management measures implemented over the last 50 years were introduced as stock restoration measures in response to various collapses of herring fisheries around the UK and Northern Europe (Dickey-Collas *et al.*, 2010).

Table 3 summarises the range of management measures implemented at various levels to manage herring fisheries in the UK:

Table 3 *- Past management measures for herring at EU, National and Regional level.*

Year of Implementation	Management Body	Management Measures	Areas Affected	Reasons for Implementation	Reference
1977	British Government	Ban on all direct herring fishing	Within British EEZ (within 200 nautical miles of shore)	Crash of stocks in North and Celtic Seas during the 1970s	The Herring (Specified North Sea Waters) (Prohibition of Fishing) Order 1977
	Various EU Nations	Ban on all direct herring fishing	North Sea (ICES Subarea IV & Divisions IIIa & VIId)	Crash of stocks in North and Celtic Seas during the 1970s	Council Regulation (EEC) No 350/77
1983	Council of the European Union	Herring fishing ban lifted Herring included in management under the Common Fisheries Policy with TACs in place and gear restrictions, e.g., net mesh size	All Member State Waters	Partial recovery of stocks	Council Regulation (EEC) No 1353/83
1997	European Union & Norway	EU-Norway North Sea herring management plan initiated	ICES Subarea IV & Divisions IIIa & VIId	Imminent North Sea stock collapse recognised in 1996	Commission Regulation (EC) No 1265/96
1998	Council of the European Union	MCRS of 20cm implemented	All Member State Waters	Aimed to reduce recruitment overfishing of stocks	Council Regulation (EC) No 850/98
		Temporal, spatial and gear restrictions when fishing for herring	Various locations including areas of Celtic and North Seas	Aimed to reduce fishing mortality of herring stocks and protect juveniles	Council Regulation (EC) No 850/98
2004	European Union & Norway	EU-Norway North Sea herring management plan revised	ICES Subarea IV & Divisions IIIa & VIId	To ensure sustainable exploitation of the North Sea stock	Fisheries Ecosystem Plan: North Sea
2005	Celtic Sea Herring Management Advisory Committee (CSHMAC)	Celtic Sea Herring Management Advisory Committee (CSHMAC) formed to give advice to help manage Celtic Sea herring stocks	ICES Divisions VIIa, VIIg-k & VIIj-k	Help to rebuild stocks after 2004 collapse	CSHMAC

2008	Council of the European Union	Implementation of multi-annual plan for stocks west of Scotland using TACs and fishing permits	ICES Division VIa	To ensure sustainable exploitation of the stocks	Council Regulation (EC) No 1300/2008
	European Union & Norway	EU-Norway North Sea herring management plan revised	ICES Subarea IV & Divisions IIIa & VIId	Changes in productivity of North Sea stock	EU-Norway North Sea Herring Management Plan
2014	European Union & Norway	EU-Norway North Sea herring management plan revised	ICES Subarea IV & Divisions IIIa & VIId	To ensure sustainable exploitation of the North Sea stock	(Dickey-Collas, 2016)
	Devon & Severn IFCA	Use of mobile gear is restricted in certain estuaries and MPAs throughout the District	Various locations throughout District, including the rivers Taw and Torridge in North Devon	Aimed to protect vulnerable fish populations and key habitats	Devon and Severn IFCA Mobile Fishing Gear Permit Byelaw
2016	European Union	Implementation of multi-annual plan for the stocks of cod, herring, and sprat in the Baltic Sea	ICES Subareas 22-32	To ensure sustainable exploitation of the Baltic stock	Regulation (EU) 2016/1139
2018	Devon & Severn IFCA	Netters are not authorised to use nets with mesh sizes between 71 and 89mm	Devon & Severn IFCA District	Aimed to protect vulnerable fish populations and key habitats	Devon and Severn IFCA Netting Permit Byelaw
		Netting restrictions within specified estuaries and coastal habitats, including Lundy MPA	Various locations throughout District, including the rivers Taw and Torridge in North Devon		Devon and Severn IFCA Netting Permit Byelaw
		Using sand eels as bait when fishing for bass is prohibited			Devon and Severn IFCA Netting Permit Byelaw
	Celtic Sea Herring Management Advisory Committee (CSHMAC)	Rebuilding plan for Celtic Sea stock implemented by CSHMAC	Celtic Sea and ICES Division VIIj	Loss of MSC Sustainability Accreditation and declines in stock	CSHMAC
2019	Celtic Sea Herring Management Advisory Committee (CSHMAC)	Closure of Celtic Sea fishery	Celtic Sea and ICES Division VIIj	Declines of stock and large numbers of juvenile fish being caught	Sea Fisheries Protection Authority
	Key:	No longer in place		Still in place	

Management Measures Currently in Place

As part of current EU management, a range of TACs are in place for the separate herring stocks across the North Atlantic, including the Celtic Sea and the Bristol Channel (see **Table 4**). There are various additional management measures in place for each of these stocks, for example, in most netting fisheries, herring must only be taken using nets with mesh sizes equal to or larger than 32mm and some important breeding areas are closed to fishing to protect the breeding stock and prevent recruitment overfishing (Council of the European Union, 2020b).

***Table 4** - Total allowable catches in place for EU herring fisheries in 2020.*

Area	TAC (Tonnes)	UK Share of TAC (Tonnes)
ICES Division IIIa	24,528	0
ICES Division IIIa (as bycatch)	6,659	0
Union and Norwegian waters of ICES Subarea IV	385,008	55,583
ICES Subarea IV, Division VIId and Union waters of Division IIa (as bycatch)	8,954	163
ICES Divisions IVc & VIId	385,008	3,950
ICES Divisions Vb, VIb & VIaN	3,840	2,102
ICES Divisions VIaS, VIIb & c	1,360	0
ICES Division VIIa	8,064	5,945
ICES Divisions VIIe & f	930	465
ICES Divisions VIIg-h & j-k	869	1

In addition to these TACs and the other restrictions in place through past management measures, the MCRS for herring is still in place at 20cm in UK waters (UK Government, 2020b). As well as these EU and national regulations, fishers targeting herring English inshore waters must comply with local IFCA regulations. IFCAs each have a set of byelaws in place regulating the fishing effort and gear in their Districts. Fishers targeting herring in D&S IFCA's District need to comply with regulations set out in both the Netting Permit Byelaw and Mobile Fishing Permit Byelaw established by D&S IFCA, most recently revised in 2018. These byelaws regulate inshore fishing throughout the District by placing catch, gear, temporal and spatial restrictions on fishers (outlined in **Table 5**) to manage fisheries effectively and sustainably. As well as these gear-specific byelaws, D&S IFCA has additional byelaws in place that were inherited from Devon Sea Fisheries and the Environment agency, described in the IFCA 'byelaw booklet.'

Available at: https://www.devonandsevernifca.gov.uk/Enforcement-Legislation/D-S-IFCA-Byelaw-Book-and-Minimum-Conservation-Reference-Size-List

***Table 5** - Fishing restrictions currently in place affecting herring fisheries as part of D&S IFCA byelaws.*

Regulation Type	Gear	Restrictions	Byelaws
Gear	Netting	Nets must be marked with floating markers displaying port, vessel and permit details as well as fixed with tags when required by the authority	Netting Permit Byelaw

		Nets with mesh sizes between 71 and 89mm are prohibited	Netting byelaw
	Seine netting	When using authorised seine nets, permit holders must remain with the net for the full time of deployment as well as deploy and haul the net in one continuous action	Netting byelaw
	Drift netting	When using authorised drift nets, permit holders must remain within 100 metres of the net for the full time of deployment	Netting byelaw
	-	The storing of crabs, lobsters, scallops, or bass in containers within the sea or estuaries is prohibited	Netting byelaw
Spatial	Netting	In the North Devon estuaries (defined in Annex 2), fishers are not permitted to use any nets other than seine and providing that they are no longer than 20 metres in length, all species other than sand eel are returned to the water and that the mesh size is no greater than 20mm	Netting byelaw, netting byelaw annex 2
	Netting	Only a single net, no longer than 25 metres may be used by recreational permit holders in the seaward areas defined in Annex 2	Netting byelaw, netting byelaw annex 2
	Netting	In the Annex 3 coastal areas, use of a net is only authorised when the headline of the fixed net is set at least 3 metres below the waters surface, and if the net used is a drift or seine net	Netting byelaw, netting byelaw annex 3
	Netting	In the areas off Lundy Island (defined in Annex 4) no netting of any kind is authorised	Netting byelaw, netting byelaw annex 4
	Netting	The use of fixed nets is prohibited in the Somerset areas (defined in Annex 5) unless in accordance with temporal restrictions in the netting byelaw	Netting byelaw, netting byelaw annex 5
	Demersal mobile gear	In the Lundy SAC and MCZ (defined in Annex 1) the use of demersal fishing gear is prohibited except for the authorised use of demersal trawl gear in the areas outlined in Annex 1a and the authorised use of demersal scallop gear in the areas defined in Annex 1b	Mobile gear byelaw, mobile gear byelaw annex 1, 1a and 1b
	Demersal mobile gear	In the Severn Estuary SAC (defined in Annex 6) the use of demersal mobile fishing gear is prohibited	Mobile gear byelaw, mobile gear byelaw annex 6
Temporal	Fixed nets	The use of fixed nets is authorised in the Somerset areas (defined in Annex 5) between 30th September and 1st April	Netting byelaw, netting byelaw annex 5

Many of the restrictions laid out in Devon & Severn IFCA's Netting Permit Byelaw were previously in place as part of older byelaws, however some were implemented to support the National Salmon and Sea Trout Protection Byelaws. For example, netting bans in certain estuaries in the District were implemented to protect migrating populations of salmon and sea trout (Environment Agency, 2018), however these regulations will affect other netting fisheries in the area, such as herring and bass.

The IFCAs are also responsible for managing recreational fisheries within their Districts, meaning recreational netting for herring in the Bristol Channel is regulated by Devon & Severn IFCA's Netting Permit Byelaw and the Byelaw Booklet. As part of these regulations, the Netting Permit Byelaw states that recreational netters may only use nets no greater than 25 metres in length when catching fish in the IFCA District. There are additional restrictions on netting fisheries (commercial and recreational) in estuaries within the District, meaning that only short seine nets (20 metres or less) can be used to catch sand eels within designated estuarine areas, with all other species caught being immediately returned to the sea. There are several of these designated areas along the north coast of the IFCA District, including a large area of the upper Severn Estuary (see **Figure 16**).

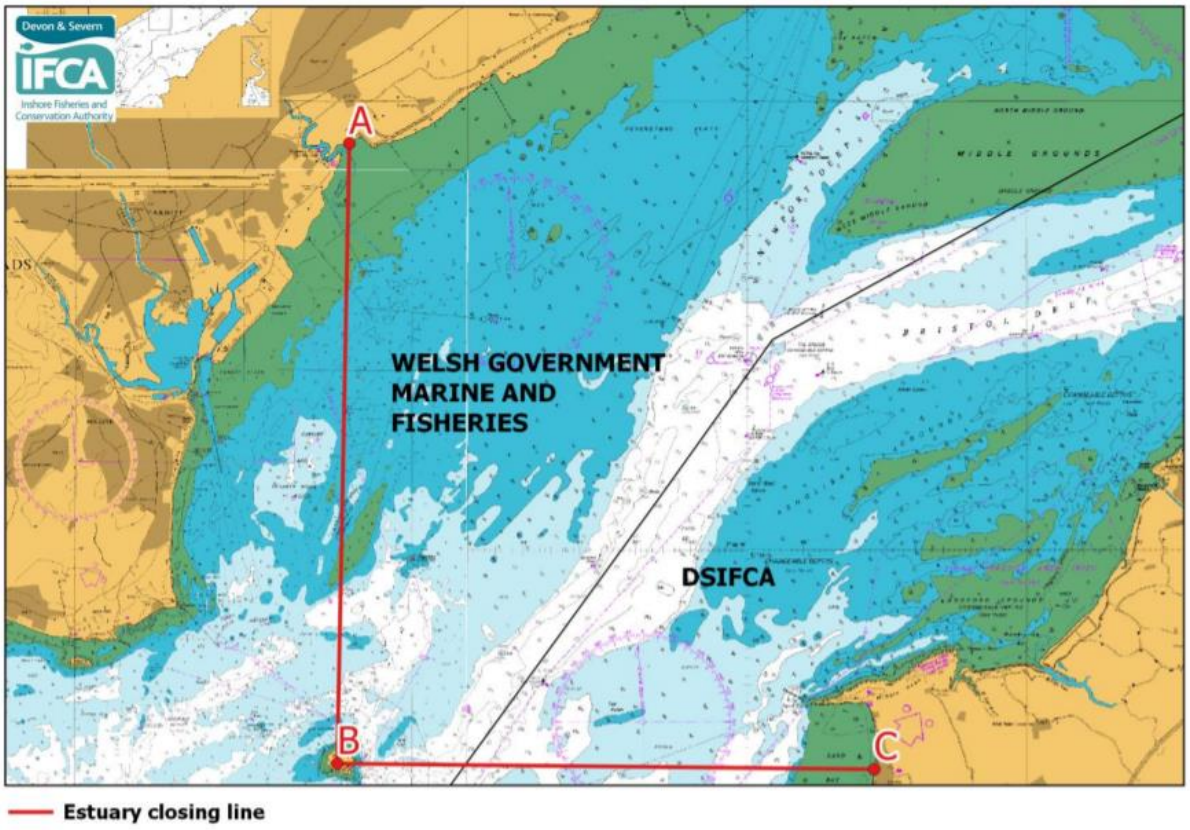

Figure 16 *- Chart of Severn Estuary closing line from Annex 2 of D&S IFCA Netting Permit Byelaw, permit holders may only use a seine net, no longer than 20 metres, to catch only sand eels within the shown area (Devon & Severn IFCA, 2020b,* https://www.devonandsevernifca.gov.uk/Enforcement-Legislation/Current-Permit-Byelaws-Permit-Conditions [unedited}*).*

Risks & Threats

Conservation Status

Herring is classified as 'Least Concern' by IUCN, with populations currently increasing across the Atlantic (IUCN, 2009). However, these Atlantic herring populations exist over such large areas, and are exploited by so many different countries, that assessing the conservation status of the species as a whole may not represent the status of distinct herring stocks and populations. It is also important to note that the IUCN has not reassessed the conservation status of the Atlantic herring since February 2009, and that since this assessment, the spawning stock biomass of herring in the Celtic sea has declined significantly (ICES, 2019b). Forage fish populations fluctuate dramatically naturally within short periods of time and Atlantic herring are threatened by overfishing, which leaves them highly vulnerable to further rapid declines (IUCN, 2009; Dickey-Collas *et al.*, 2010). For example, it is likely that fishing above MSY level has contributed to declines in the Celtic Sea herring stock. Fishing is one of a number of threats to herring and their ecosystems.

Threats to Species & Ecosystem

Natural Variation

Herring abundance and distribution are heavily influenced by environmental factors, including temperature and prey availability, which impact factors such as mortality, breeding success and migrations (see **Species Ecology**). Therefore, even in the absence of anthropogenic pressures, herring populations naturally fluctuate and can decline to population sizes that are just a fraction of those seen only a few years earlier (ICES, 2019a). One of the major challenges for management of herring stocks is understanding and predicting how stocks will respond to variable spawning, recruitment, and mortality, how these are linked to changing environmental conditions, and how this knowledge can be incorporated into management.

This natural variation in herring stocks, combined with high levels of exploitation by several countries has caused several collapses of different stocks over the past 50 years (see Historical Landings & Changes Over Time; Bailey and Steele, 1992; Dickey-Collas *et al.*, 2010; Clarke and Egan, 2017).

Overfishing

Overfishing remains one of the largest pressures on the species today. Several countries have large fishing fleets targeting herring across Europe, which has created a situation in which it is difficult to reduce fishing effort in the long term. Though herring populations can recover quickly from overfishing, this is highly dependent on favourable environmental conditions, and it is not unheard of for herring populations to remain depleted despite reductions in fishing effort (Bailey and Steele, 1992; ICES, 2019a). Reducing TACs can promote short-term stock recovery but, until there is a substantial decrease in fishing effort for herring across the board, the larger offshore stocks may continue to experience cycles of collapse and partial recovery. Until more research on the movements and distributions of herring in the Bristol Channel is undertaken, the effects of overfishing in the Celtic Sea on local herring populations will not be known.

Mismatch in Scales of Assessment & Management

In recent years, concerns have been raised over the correct spatial management of fisheries resources. It has long been assumed that populations of many fish species are large and homogenous, with little population structure. However, research is now indicating that this is not the case for many species (Hintzen *et al.*, 2015). Advances in the fish stock identification methods have begun to reveal inconsistencies between the distributions of biological populations of marine species and the definitions of stock units used in assessment and management (Kerr *et al.*, 2017). Mismatches such as this can lead to inaccurate stock assessments and undermine sustainable fisheries management efforts. A primary concern is the potential for overfishing of unique and distinct spawning groups of a species which will lead to decreases in productivity and biodiversity as well as have knock-on effects on other local and regional stocks. To avoid these scenarios, it is essential to identify and study unique spawning stocks of herring, such as those identified in the Bristol Channel Herring Project, and ensure they are properly represented and accounted for in assessment and management to avoid overexploitation (Clarke, 2020). Bearing this in mind, the overwintering behaviour of herring in coastal waters can prove problematic for management. During the winter, many herring group together in coastal waters and stay there for a number of months before spawning (Campbell *et al.*, 2007). Any herring caught and surveyed during these periods are unable to be correctly assigned to their correct breeding population, leading to biased population estimates and potential overfishing of certain populations (Hintzen *et al.*, 2015).

Bycatch & Discarding

There are some issues regarding bycatch with drift net fisheries in the Mediterranean, with endangered species being caught regularly (Masters, 2014), and anecdotal reports suggest that seals, blue sharks, tuna and whitefish are caught incidentally from time to time in herring fisheries. Though no specific data are available for the Bristol Channel, research has shown that herring fisheries are relatively clean of bycatch in the Celtic Sea (O'Donnell *et al.*, 2017; ICES, 2019a). During these studies, mackerel, whiting, and haddock were sometimes caught alongside herring, though no seabirds or marine mammals were caught despite being regularly sighted in the area. There is potential for marine mammal bycatch in the Bristol Channel, which is home to several species including porpoise and seals. However, local herring fishermen have stressed that, other than seals occasionally taking catch from nets, their fishing appears not to disturb local marine mammal populations (Masters, 2014). The few herring fishermen still operating out of Clovelly and Minehead continue to utilise inshore stake and drift nets, and report seeing minimal bycatch and environmental impact using this gear (Marine Pioneer Interviews, 2020).

Herring fishers in the Bristol Channel have noted that there are sometimes high levels of discarding seen with herring (FRMP Interviews, 2020). This is due to a few individuals catching large amounts of herring without having a market in which to sell it. Until the population size of the locally-spawning, locally exploited herring is known, it is unclear what impact this additional, unnecessary mortality may have. However, fishing activity has been steadily decreasing in this area over the past decade and is certainly much lower than a century ago.

Demersal Fishing

In some areas, mobile demersal fishing gear can threaten spawning sites of herring and other demersal-spawning species. Gear such as bottom trawls can damage benthic habitats, and any eggs deposited there (Jones, 1992). Such damage is unlikely in areas close to shore

within the Bristol Channel, but this may not be the case for spawning sites occurring further offshore, where operation of these gear types is more likely. Most herring caught in the north of the D&S IFCA's District is caught using small-scale drift and fixed netting, posing very little threat in terms of habitat damage (FRMP Interviews, 2020). However, early work in the North Devon Marine Pioneer identified that almost half of the nearshore habitats within the Pioneer Area were regularly subject to activities that can negatively impact the structure and functions of the habitats as well as their communities (Rees *et al.*, 2019). It is therefore important to consider threats to herring and their habitat from non-fisheries activities.

Marine Development & Resource Extraction

The Severn Estuary and Bristol Channel are the focus of several plans for marine development and resource extraction, each representing several pressures on fish populations. Herring are benthic spawners (see **Reproduction & Life History**), which makes them particularly susceptible to anthropogenic activities affecting the seabed, such as dredging or coastal development (De Groot, 1980). Herring have good hearing and can discriminate between different sources of sound (Enger, 1967; Olsen, 1975). Different bottom sediments, such as sand or gravel, have their own noise characteristics, which herring are thought to use for locating and returning to their parental spawning grounds. The harvesting of large amounts of sediment can leave the ground on or near spawning beds greatly altered, changing the sound characteristics of the spawning sites, possibly impeding the ability of herring to return to these sites successfully, lowering the reproductive potential of stocks (De Groot, 1980). Dredging can increase egg mortality through direct damage, by modifying the water (and oxygen) flow through the site, and by altering the depth at which eggs may be deposited (Nash and Dickey-Collas, 2005). Currently there are seven aggregate dredging licenses operating within the Severn Estuary, removing ~2.7 million tonnes of marine aggregate each year, with two more applications pending approval (Crown Estate, 2020). One of the largest sites for aggregate extraction is found near Minehead (see **Figure 17**), potentially threatening the herring spawning grounds that are likely to exist in that region. This demonstrates the importance of identifying and mapping spawning sites to feed into management and spatial planning in marine environments.

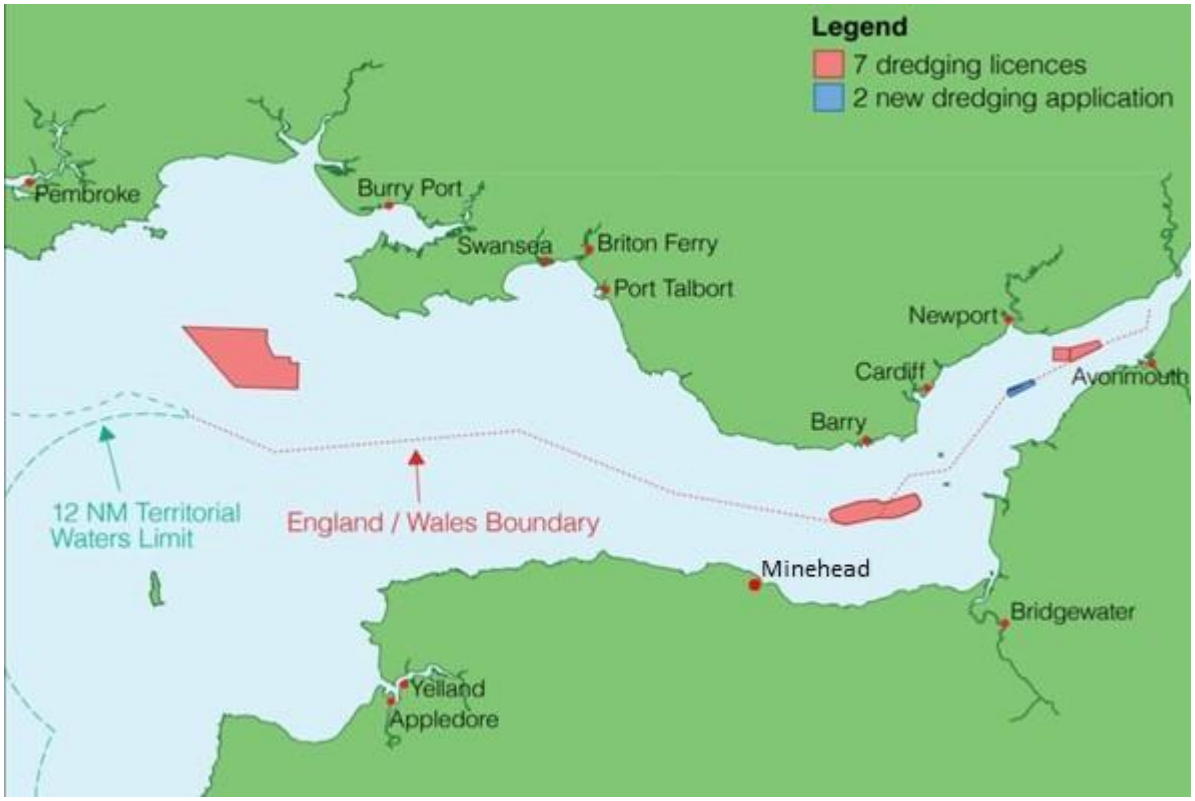

Figure 17 *- Active and potential aggregate extraction sites within the Bristol Channel (Crown Estate, 2020, https://www.thecrownestate.co.uk/media/3634/2020-capability-portfolio-report.pdf).*

The Severn Estuary is designated as a European Marine Site (EMS), with several large cities and industrial areas surrounding it. There are currently several existing or planned development projects within the EMS in various stages of development that could potentially negatively impact marine species and ecosystems. The discovery of the local herring populations in the Bristol Channel has added to these concerns regarding local conservation of marine life, particularly near Hinkley Point Nuclear Power Station. Hinkley Point C (HPC) is an ongoing project to construct a 3,200 MWe nuclear power station next to Hinkley Point A (decommissioned) and Hinkley Point B nuclear power stations in Somerset. This project includes plans to abstract 132 cumecs of water directly from the Severn Estuary (over 11 million cubic metres per day) to cool the two reactors at HPC. The extraction of this quantity of water, from intake heads situated on the seabed 3.3 km offshore, has raised significant concerns regarding impacts on the marine environment, including the assemblage of fish species (Devon & Severn IFCA, 2018, 2019, 2020c; Environment Agency, 2020a). The various permits and licences necessary for HPC to extract large quantities of cooling water from the Severn Estuary were conditionally granted in 2013 on the understanding that three mitigation measures would be implemented to reduce any impacts on the fish assemblage. The developers have sought to remove the requirement to install Acoustic Fish Deterrents (AFDs), which were the central part of the three mitigation measures. The Environment Agency have estimated that, without the AFD, the cooling water system of HPC would be responsible for 5% annual losses from the ICES VIIf herring population (Environment Agency, 2020b). This is a significant fish kill, particularly given that the status of this herring stock is uncertain and unassessed, and that adjacent ICES stocks are at increased risk of fishing pressures and have a reduced reproductive capacity. D&S IFCA are also concerned about

the effects of these fish kills on the recently discovered locally spawning herring populations, which may be too small to withstand or recover from this pressure.

The fish assemblage, including herring, is protected in the Severn Estuary as part of the Severn Estuary SAC and Ramsar site. It is only on this basis that the effects of HPC and other marine developments on fish can be considered in a regulatory and licencing context. In turn, this highlights the regulatory gaps for fish protection in other locations (e.g., the rest of the Bristol Channel) that do not fall within designated sites, or that fall within designated sites that do not include designations for fish or the fish assemblage.

Due in part to its funnel-like shape, the Severn Estuary has one of the largest tidal ranges in the world, around 14 metres (Xia *et al.*, 2010). There is increasing interest in harnessing this large tidal range for tidal power projects, especially after the Government's commitment to increase the usage of renewable energy sources. Although there is a strong desire and environmental justification to shift away from the usage of fossil fuels, tidal power developments can be damaging to marine life and greatly alter their habitats. In 2013, plans for a tidal barrage across the mouth of the Severn were rejected by MPs due to several economic and environmental problems (Harvey, 2013). Among these were concerns of fish mortality when passing through turbines, delays or prevention of reproduction/migrations and loss of habitat (House of Commons Energy & Climate Change Committee, 2013). Since then, smaller scale tidal lagoon projects have been proposed in the Severn Estuary, such as the Swansea, Cardiff, and Newport tidal lagoon projects, however, these projects still carry similar threats to marine populations on a more localised scale. Though some tidal energy proposals focus on Welsh waters of the Severn Estuary and Bristol Channel, these waters form part of a large and connected ecosystem. The movement of these waters and the fish within them transcends administrative boundaries; consequently, effects of tidal energy developments have the potential to impact ecosystems within the jurisdiction of D&S IFCA.

In addition to tidal energy generation, interest in offshore wind farms for energy generation has increased greatly in the last two decades, particularly in the Bristol Channel. In 2007, proposals were set out for the development of a 240 turbine offshore windfarm just off the island of Lundy (Quilter, 2013). However, the project met considerable resistance due to environmental concerns and the plans were eventually scrapped due to "*technical and financial reasons*". The development of offshore wind farms can trigger a variety of potentially damaging effects to marine life (Hiscock *et al.*, 2002). Damage to the seabed and benthic communities can be partly mitigated using floating turbines, however, these farms can still negatively impact wildlife, particularly birds and marine mammals (Bailey *et al.*, 2014; Bergström *et al.*, 2014). Despite this, the development of offshore wind farms is expected to increase with some experts stating that the development of a wind farm within the Bristol Channel is most likely inevitable, e.g., project Erebus off south Wales (Cooper, 2019; BBC, 2020).

Climate Change

After overfishing, one of the most pressing threats to marine life and the fishing industry is climate change (Stewart and Wentworth, 2019). Climate change is predicted to affect the oceans in many ways, including warming waters, changes in oscillations and currents, increases in dissolved carbon dioxide concentrations and rising sea levels (Petitgas *et al.*, 2013; Stewart and Wentworth, 2019). Changes in water temperature are expected to dramatically affect many fish species, especially those whose biology and reproductive

activities are dependent on temperature, including herring (Brunel and Dickey-Collas, 2010). For example, herring recruitment is stronger in cooler waters, meaning populations may undergo large changes in distribution and size in the future as waters warm (ICES, 2019a). Research has shown that water temperature within herring spawning sites affects the year-class strength, most likely through egg mortality (De Groot, 1980). Variations in annual air temperature in the past has coincided with key ecological shifts in herring; Southward *et al.* (1988) found that, in addition to other factors such as fisheries, changes in climate may have indirectly influenced both herring and pilchard populations in South Devon and Cornwall over the past few hundred years. Future changes in climate and temperature are expected to influence fish populations in a similar way.

Climate change is also causing key changes in the marine food web, by altering primary productivity (phytoplankton) and the distribution and abundance of zooplankton – including copepods, which are a key food source for herring (Dickey-Collas, 2004; Gregory *et al.*, 2009; Capuzzo *et al.*, 2018; Stewart and Wentworth, 2019). Warming waters have a detrimental effect on the size, reproduction and abundance of some zooplankton species, including copepods (Chassot *et al.*, 2010; Vehmaa *et al.*, 2013; Garzke *et al.*, 2014); though some species may respond positively to warming and become more abundant in British waters, their suitability as food for fish may not be equivalent to that of the copepod species they replace (e.g., Beaugrand *et al.*, 2003; Beaugrand and Kirby, 2010) As herring distributions, growth rates and survival are largely influenced by copepod abundance, it is only logical to expect changes in herring distributions and population health as ocean waters continue to warm (Sherman, 1970).

Climate change can also alter the abundance and distribution of predator species. For example, warming waters and overfishing have been linked to increasing jellyfish populations in both the North and Irish Seas (Attrill *et al.*, 2007; Lynam *et al.*, 2011). Jellyfish are a known predator of juvenile herring and other forage fish (Robinson *et al.*, 2014), and their abundance is predicted to increase over the next century (Purcell, 2005).

In addition to warming waters, the increasing frequency of hypoxic (very low oxygen) ocean “dead zones” have been attributed to climate change and the runoff of fertilisers into rivers (Diaz and Rosenberg, 2008). Dead zones have significant consequences for the functioning of marine ecosystems and the services they provide to society, including fisheries production, water filtration, and nutrient cycling (Altieri and Gedan, 2015). Fertiliser used on farmland will often run off into rivers and be transported downstream to estuaries. The increase in nutrients such as phosphorus and nitrogen in these environments (known as eutrophication) can cause blooms of marine algae ((Joyce, 2000). As the algae dies, it sinks to the bottom, where oxygen in the water is consumed by microbes as part of the decomposition process, lowering the oxygen concentrations in the water. Stratification, or layering, of the water column prevents mixing between these low-oxygen waters and surface waters. Stratification is linked to temperature and salinity concentration gradients in the water and is projected to increase due to warming waters, particularly in more northerly latitudes (Keeling *et al.*, 2010). This process continues until the area has been transformed into an oxygen-deficient or oxygen-free zone, devastating marine life in the area, particularly within benthic communities (Diaz and Rosenberg, 2008). The frequency at which these “dead zones” are occurring is increasing, and they are common across much of the range of herring (see **Figure 18**). Changes in EU legislation regarding fertiliser usage has led to improvements in oxygen conditions in the North Sea, though hypoxic zones are still present throughout areas of Europe (Townhill *et al.*, 2017).

Although hypoxic dead zones can pose a threat to all nearby inshore marine life, they are potentially devastating for fish species that use inshore and estuarine habitats as spawning areas and nurseries, such as herring, as these are the areas where dead zones are most likely to occur (Altieri and Gedan, 2015). Increases in the frequency of dead zones in or near herring spawning and nursery areas could cause further damage to the reproductive output of populations and hinder any recovery of damaged stocks, e.g., Celtic Sea stocks. There have been very few studies investigating the effects of hypoxic and anoxic zones specifically on herring, however, hypoxic conditions weaken and negatively impact the development of herring embryos as well as cause significantly higher rates of malformation, as seen in other fish species (Braum, 1973; Shang and Wu, 2004; Ekau *et al.*, 2010). In addition to developmental problems, hypoxic conditions alter the behaviour of herring schools, possibly making them more susceptible to predation or capture in fisheries (Domenici *et al.*, 2017). Even if the herring themselves are not caught within these zones, they could be indirectly affected through damage to their ecosystems and prey, placing further pressure on the already lowered herring stocks.

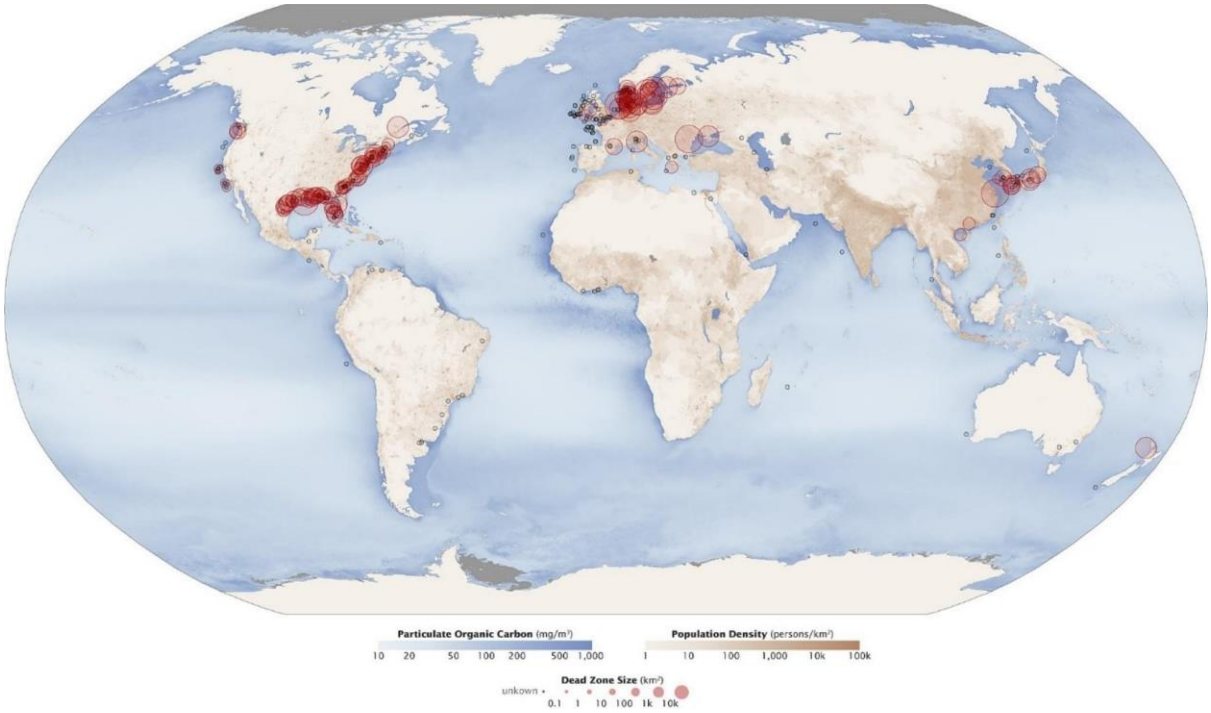

Figure 18 *- Locations of hypoxic and anoxic dead zones. Red circles on this map show the location and size of many of our planet's dead zones. Black dots show where dead zones have been observed, but their size is unknown (Allen, 2010,* https://commons.wikimedia.org/wiki/File:Aquatic_Dead_Zones.jpg [unedited]*).*

Climate Change: Coastal Squeeze & Flooding

With sea levels across the world rising due to climate change, a phenomenon known as coastal squeeze is an increasing concern to conservationists. As sea level slowly rises, the sea encroaches upon coastal areas causing terrestrial erosion and loss of habitat. In the marine environment, organisms and ecosystems "migrate" towards the shore to maintain their positions relative to the water level (Torio and Chmura, 2013). However, to combat rising seas, humans have installed flood defence systems such as sea walls and groynes to protect coastal areas from the rising water. Barrier defences such as sea walls prevent coastal marine life from migrating to maintain their position in preferred habitats, and thus reduce the availability

of coastal habitat (Pontee, 2013). This is a very slow process but poses a significant threat to coastal ecosystems, particularly for benthic organisms.

Figure 19 *- flood defence sea wall on Chesil Cove Beach, Dorset (BennH, 2014,* https://commons.wikimedia.org/wiki/File:Chesil_Cove_flood_defences.png [unedited]*).*

As weather patterns get more extreme and less predictable due to the effects of climate change, the potential for flooding within the Bristol Channel increases. There are many major cities and built-up areas surrounding the Severn that are at risk of flooding, with flood defences installed in such areas. The effects of coastal squeeze will be most severe in these developed and defended areas compared to the more rural coastal zones of the estuary, as the lack of flood defences and developments allow marine communities to retreat inland as the sea rises. In addition to causing coastal squeeze, there is concern that the construction of new flood defence installations could be damaging to fish populations within the Severn Estuary. For example, the planned construction of the new Bridgwater flood defence barrier on the river Parrett (which feeds into the Severn Estuary) will involve extensive construction work on and around the river, and local authorities have raised concerns that the potential impacts of such projects on local fish populations, particularly juveniles, are not being properly addressed and mitigated during planning (Devon & Severn IFCA, 2020d).

Threats to Fishery & Industry

From a large-scale, commercial perspective, the largest threat to herring fisheries will be restrictive management and reduced TACs due to overfishing of stocks. However, in the north of D&S IFCA's District, herring fishing is smaller in scale and artisanal in nature. Despite fluctuations in the Celtic Sea herring stocks, there has always been a sufficient herring available for fishers in North Devon and Somerset to catch and to keep the fishery viable, though this is likely due to so few fishers currently operating in the fishery compared to historical effort levels (FRMP Interviews, 2020; Marine Pioneer Interviews, 2020). The major problem, however, is that markets for herring have greatly decreased since the days of the thriving historic herring fisheries in this region, with relatively little commercial interest in landed

herring today. Because of this, the local herring fishermen are restricted to only catching what they think they will be able to sell, rather than how many fish are available to be caught. This combined with the short fishing season and challenging fishing conditions is why commercial effort for herring has dropped to the low levels seen today. It is possible that construction and use of smokers in Clovelly and Minehead could add value to the catch and provide an opportunity to build a local brand and promote sustainable, local fisheries.

As the number of active North Devon/Somerset herring fishermen has declined, there has been a risk of loss of important culture and local fisher knowledge from these coastal communities. The two herring netters in Minehead make up the only known stake net fishery for herring, meaning their fishery will die out when they leave the industry – unless new entrants to the fishery join and inherit these traditions and knowledge (FRMP Interviews, 2020). The same can be said for the two herring fishermen in Clovelly, with herring fishing being a major part of the village's history and traditions, dating back centuries. Even today, herring are closely associated with Clovelly and traditionally, a herring festival is held in Clovelly, to celebrate and promote the herring and the sustainable nature of their fisheries (Gussin, 2019). Unless new fishers emerge to continue the herring fishery, these traditions and a large part of Clovelly's historical identity could be lost.

While engaging with local herring fishermen from North Devon and Somerset, concerns were raised regarding the levels of illegal, unregulated, and unreported fishing taking place in the Bristol Channel (FRMP Interviews, 2020). It was reported that illegal netting for herring was common and that many of the landed herring would end up being discarded back into the sea due to the lack of market. Some fishermen were worried that this wasteful, illegal activity is undermining the sustainable nature of their fishing efforts and that a stronger enforcement presence was needed from D&S IFCA to discourage illegal fishing and ensure fishing regulations are followed by both commercial and recreational fishers (FRMP Interviews, 2020). The large size of D&S IFCA's District and a small enforcement team made up of only four officers, means patrols are limited to areas with high numbers of reports of illegal fishing, which is primarily the south coast. Engagement with fishers from the north of the District has highlighted a sense of mistrust towards the IFCA from the inshore fishing industry and shown some fishers have no confidence in the IFCA, which may contribute to illegal fishing activity remaining unreported (FRMP Interviews, 2020). It is important to work to rebuild this trust and engage with fishers as much as possible in order to encourage the reporting of illegal activity.

D&S IFCA is seeking to rectify this, including the improvement of collaboration and engagement through activities such as virtual roadshows for ports, sectoral meetings and future FRMP interviews. More information about planned engagement activities is available in the D&S IFCA's Annual Plan and Communications Strategy, accessible via the D&S IFCA website. It is hoped that this will improve stakeholder engagement with D&S IFCA's intelligence-led, risk-based approach to enforcement and compliance work, which is prioritised to areas with high numbers of reports of illegal fishing activity.

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Appendices

North Sea Herring

In the North Sea, summer-autumn spawners tend to produce fewer eggs of larger size and weight compared to winter-spring spawners, which produce more eggs of lower quality (van Damme et al., 2009). It is possible that this quality/quantity trade-off between stocks exists because the larvae of summer-autumn spawners need to survive for longer before food abundance increases in spring, and so their larger eggs better equip them to survive for this extended time of low food availability, however, little research has currently confirmed this.

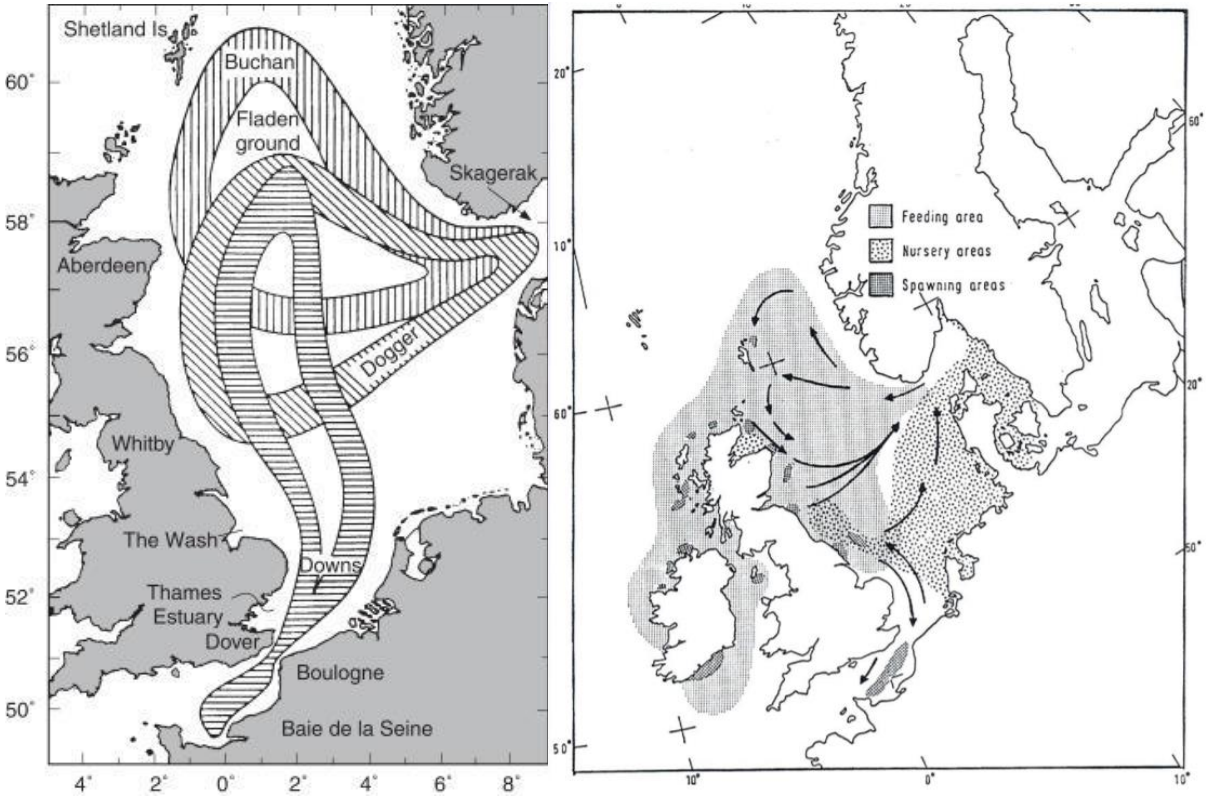

Figure 20 *- Predicted migratory routes between feeding, spawning and overwintering areas for North Sea Atlantic herring stocks (Alheit* et al.*, 2010,* https://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20(CRR)/CRR306.pdf [unedited]*).*

Herring Fishery Licenses

Some of the smaller herring stocks in the UK require special licenses called Minor Pelagic Fisheries licenses to be fished, this is due to the special access arrangements that apply to them (MMO, 2020c). Licensing of these herring stocks is regulated by the MMO for UK fishers and these licenses are required for the following herring fisheries:

- Atlanto-Scandian herring – issue of a licence involves surrender of the vessel's main domestic licence
- Firth of Clyde herring
- Mourne herring
- Thames and Blackwater herring

At present, no special licensing or authorisation is needed to fish for herring within the Bristol Channel other than IFCA permits.

Sustainability Ecolabels

The concept of sustainably sourced seafood has slowly been receiving more attention from consumers recently. More than ever, people are showing concern over the environmental implications of their actions, including where and how their food is sourced (Kaiser and Edwards-Jones, 2006). One way to encourage the sustainability of commercial fisheries, as well as the purchasing of sustainably sourced products, is through the use of ecolabels. In essence, these are labels or marks found on seafood products that assure consumers the seafood in question has been caught in accordance with certain principles or practices, namely the fishery being formally assessed and found to be non-damaging to non-target marine species and habitats (Gudmundsson and Roheim, 2000). These ecolabelled products are usually sold at a higher price than similar non-labelled products. In principle, this price premium serves to recompense producers for the extra effort required to uphold the ecolabel standards during production as well as serve as an incentive to continue to uphold these standards and practices (Kaiser and Edwards-Jones, 2006).

The most well-known ecolabel within the seafood industry is the MSC, who have been assessing and certifying fisheries on their sustainability since 1997, allowing their catch to carry the MSC ecolabel and be sold as sustainably sourced (Ponte, 2012). In 2012, the Celtic Sea trawl fishery for herring was certified as sustainable by the MSC, however, this certification was lost in 2018 due to surveys indicating the Celtic Sea herring stock had dropped to extremely low levels (MSC, 2020). Generally, only larger, high-catch commercial fisheries strive for MSC accreditation, as smaller fisheries are often at a disadvantage due to issues with remoteness, data availability and management. Ironically, it is these small-scale fisheries, such as Bristol Channel herring, that are more likely to be sustainable in practice compared to the larger, offshore operations (Jacquet and Pauly, 2008).