Traceability in the UK Seafood chain

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Traceability in the UK Seafood chain

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...ambitious for our seas and coasts

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1 Executive Summary

Traceability in seafood supply chains is vital for ensuring food safety, proving legality and tackling illegal, unregulated and unreported (IUU) fishing, and verifying sustainability. UK seafood supply chains vary in complexity. As complexity across a supply chain increases, the importance of seafood transparency and traceability at each stage of the supply chain increases.

The project sought examples of different supply chains of seafood landed in the UK to examine the current levels of traceability across the supply chain, examples of best practice, challenges to traceability and improvements that could be recommended for implementation in UK seafood supply chains. Case studies were sought from three UK seafood supply chains: i) Case study A: (Demersal) Dover (common) sole landed into ports in South West England; ii) Case Study B: (Pelagic) Mackerel from vessels landing into Peterhead, Scotland; and iii) Case Study C: (Shellfish) Brown crab / lobster from vessels landing into Bridlington, England. An initial seafood supply chain mapping exercise was undertaken for each case study through stakeholder structured interviews followed by in-depth semi structured interviews with actors across the supply chain.

Key recommendations for improving traceability within the UK seafood supply chain include:

- **Focus on improving traceability up to the point of first sale.**
- **Definitions of traceability need to more clearly stated to stakeholders.**
- **Digitalise and integrate information systems.**
- **Improve stakeholder engagement around data submission.**
- **Minimise duplication of catch reporting by MMOs and IFCAs**
- **Improvements to traceability systems are needed to allow for the distinction between sustainable versus non-sustainably caught seafood**.
- **Increase transparency in how data submissions are used to increase data accuracy**
- **Improve monitoring of wholesale markets.**

It should be acknowledged that the current approaches to improving traceability in seafood supply chains are already implementing some of the recommendations highlighted in this report. The recommendations from this report should serve to strengthen areas of traceability work that are already ongoing and to provide further impetus for development of best practice across UK seafood supply chains.

2 Introduction

This report has been co-authored by SRUC and the University of Hull as part of a Marine Management Organisation (MMO) commissioned research project investigating traceability in the UK seafood supply-chain.

Seafood is promoted as a key part of a healthy balanced diet and is an important source of protein, fats, micronutrients and vitamins to more than three billion people worldwide. The global and UK importance of seafood to sustain a healthy human population necessitates complex supply networks to deliver seafood from the oceans to the consumer. The complexity of supply networks makes traceability, the extent to which seafood products can be verifiably tracked as they move through the supply chain, challenging. However, the ability to trace seafood through these supply chains is recognised as an important feature of robust, ethical, and economically sound business operations.

In the UK, the importance of improving seafood supply chain traceability is recognised as a key priority for Defra's Control & Enforcement policy team and the MMO. It is a legal requirement in the UK for produce from fisheries to be traceable at all supply chain stages, from catching, through processing, and distribution to retail. The UK's departure from the European Union (EU) offers an opportunity for UK governments to achieve the vision of a "vibrant and prosperous seafood sector" by reviewing and improving domestic seafood production policies, producing plans for the control of fishing activity in UK waters and tackling Illegal, Unreported, and Unregulated (IUU) fishing, and ensuring sustainability through the supply chain. Improving traceability of seafood products will be central to achieving this vision.

2.1 UK Seafood Market

The UK's "in home" seafood consumption (includes retail purchases and takeaway food eaten in home), peaked in the 1940s at a time when other proteins were under rationing restrictions (Seafish 2022). Seafood consumption declined to its lowest recorded levels in the mid-1970s, rising in the 1980s to a relatively stable 150g/person/week (Seafish 2022). Out of home seafood consumption has remained relatively stable since 2001 at 15g/person/week (Seafish 2022). Current UK governments' recommendations suggest that two portions of fish or seafood (a portion is considered 140g), with at least one portion consisting of oily fish, should be consumed by individuals each week (NHS 2021). However, the UK public currently consumes on average 162.98g/person/week, just over half of the recommended amount (Seafish 2022). There have been increasing calls from the sector to promote seafood consumption in line with dietary guidelines (Seafish 2021).

It has been estimated that 60-80% of the UK's seafood consumption is comprised of five main seafood groups which include: haddock, cod, salmon, prawns and tuna (Tetley 2016), and efforts by UK retailers and processors to introduce lesser-known seafood species, for example, saithe and hake, have resulted in mixed success (WWF 2022). The demand for a narrow range of seafood poses some challenges for sustainable management, with some species such as tuna, and warm-water prawns having a high environmental and social footprint (Tetley 2016, WWF 2022).

To meet demand for strong UK consumer preferences, the UK is almost entirely reliant on imports of some species, including large pelagic species and farmed whitefish species (Tetley 2016). In 2021, imports were highest for salmon (117,500 tonnes, 17% of all fish imports excluding fish products); tuna (113,500 tonnes, 16%); and cod (85,400 tonnes, 13%) (MMO 2021). Salmon was also the largest import category in terms of value (£672 million, 21% of all fish imports), followed by shrimps and prawns (£623 million, 20%) and cod (£428 million, 14%) (MMO 2021). Although the UK imports large quantities of seafood for consumption, significant quantities of seafood are still caught or farmed in the UK and exported (around 70% is exported) (WWF 2022).

In 2021, the main seafood exports were salmon (113,200 tonnes, 32% of all fish exports excluding fish products), mackerel (54,100 tonnes, 15%) and herring (15,600 tonnes, 12%) (MMO 2021). Salmon was the highest value export (£723 million, 45% of all fish exports), followed by *Nephrops* (£112 million, 7%), and mackerel (£96 million, 6%) (MMO 2021). Shellfish (all types combined) accounted for 17% of fish exports out of the UK by weight (58,200 tonnes), but for 27% of exports in terms of value, given their higher price per tonne on average than other sea fish (MMO 2021).

2.2 UK Seafood Supply Chains

The UK Seafood Supply Chain, connecting the catching sector with the end consumer has changed dramatically over the past 40 years, particularly with regards to the sourcing of seafood and the sophistication of the operation (Symes and Phillipson 2019). In the mid-1970s the main function of the supply chain was to ensure efficient distribution of regular and high volume landings of demersal catches from distance water fisheries in the north-east Atlantic (fresh and frozen at sea) to small retail and catering outlets nationwide (Symes and Phillipson 2019). Landings of distant water demersal catches at Hull and Grimsby accounted for nearly 30% of UK landings in 1975 (Symes and Phillipson 2019). Hull and Grimsby had the necessary infrastructure, processing capacity and skilled workforce, and were geographically well placed to serve the national consumer market (Symes and Phillipson 2019). However, from 1976 onwards, the UK trawler fleet were excluded from distant water fishing grounds, which presented a major challenge to the domestic supply chain (Symes and Phillipson 2019). Hull and Grimsby continued to act as a main hub for distribution, but on a reduced scale (Symes and Phillipson 2019). The UK seafood supply chain was changed from largely domestic landings, with imports contributing 13% of fish supplies, to one where domestic consumption is heavily dependent on imports, and most of the domestic caught seafood is exported (Symes and Phillipson 2019). In addition, the proportion of fish landed abroad has increased since the 1980s. In 2021, 40% of the total weight of fish landed by UK vessels was landed abroad (Uberoi et al. 2022).

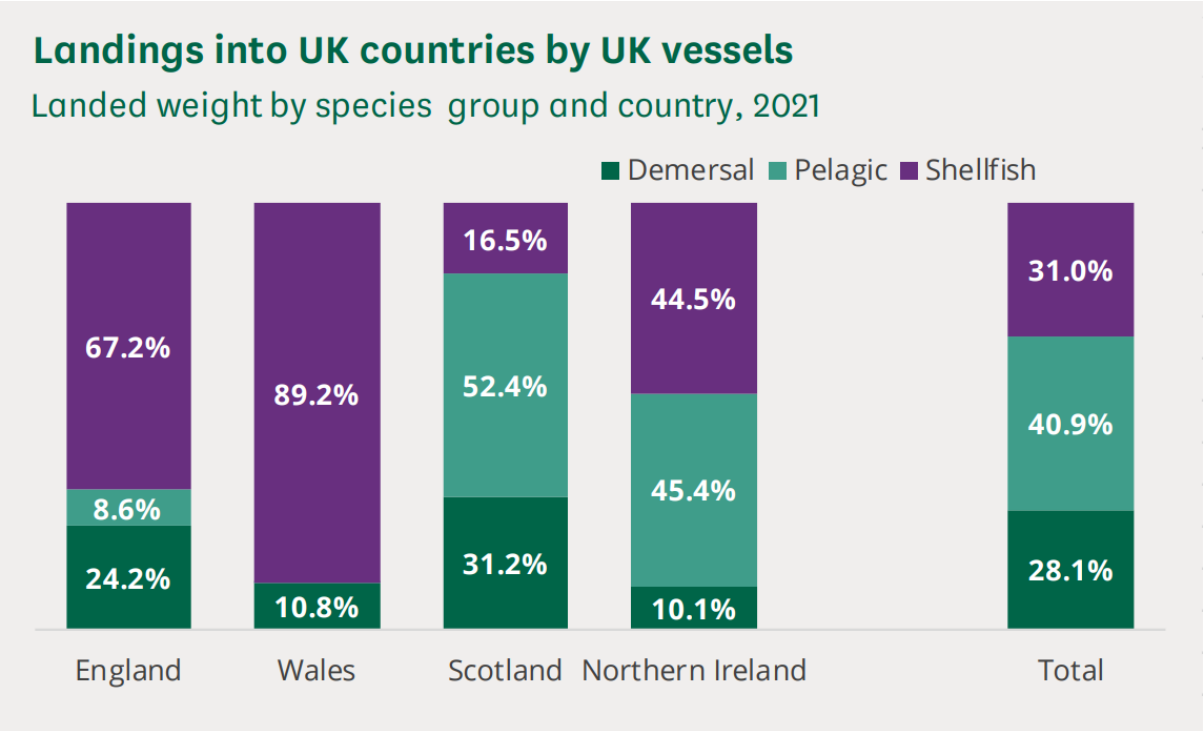
The UK fishing fleet catches and lands different types of fish and seafood, for the purposes of this report we refer to demersal, pelagic and shellfish as the main species groups. Demersal refers to fish which live and feed primarily on or near the seabed and includes species such as: cod, haddock, plaice and turbot. Commercial demersal species are regulated by fishing quota. Pelagic refers to fish that live above the seabed, in the water column, and includes species such as: herring, sardine, and mackerel. Commercial pelagic species are covered by fishing quota. Shellfish is a

collective term for commercial molluscs (e.g. scallops, whelks and clams), and crustacea (lobster, crab, prawns and *Nephrops*). Fishing activity for shellfish (excluding *Nephrops*) is usually inshore, within 12nm, and is licensed rather than falling under the quota system (Uberoi et al. 2022).

Pelagic fish are now the largest group of species by landings fished by the UK fleet. From 282 000 tonnes in 2011, landed catches of pelagic fish increased to 392 200 tonnes in 2021, showing an increase of 11% from 2020 (Uberoi et al. 2022). Demersal fish landings by volume have been declining; in 1998, 456 7000 tonnes were landed and in 2021, landings feel to 128 700 tonnes, the lowest figure since 1994 and a 13% decrease from 2020 (Uberoi et al. 2022). In 2021, shellfish catches were 121 100 tonnes, an increase of 8% since 2020 (Uberoi et al. 2022). Overall, there has been a decrease in the weight of landings over time, but an increase in the value of landings by the UK fleet. The recent focus on high value shellfish has been driven by a combination of loss of fish stocks, lack of quota and the availability of shellfish export markets (Uberoi et al. 2022). In terms of value, pelagic fish was the second largest group in 2021 at £315 million, demersal fish were worth £275 million, and shellfish the largest group by value at £331 million (Uberoi et al. 2022).

The types of fish landed varies across the different parts of the UK, reflecting differences in the fishing industries of each country (Figure 1). In 2021, English landings include a substantial proportion of demersal fish (22 400 tonnes); landings in Wales are mostly shellfish (such as crabs, scallops and whelk; 4,900 tonnes); Northern Irish landings include a substantial proportion of pelagic fish (9,600 tonnes) and Scottish landings are mostly pelagic fish (142,100 tonnes) with a substantial amount of demersal fish and some shellfish (Uberoi et al. 2022).

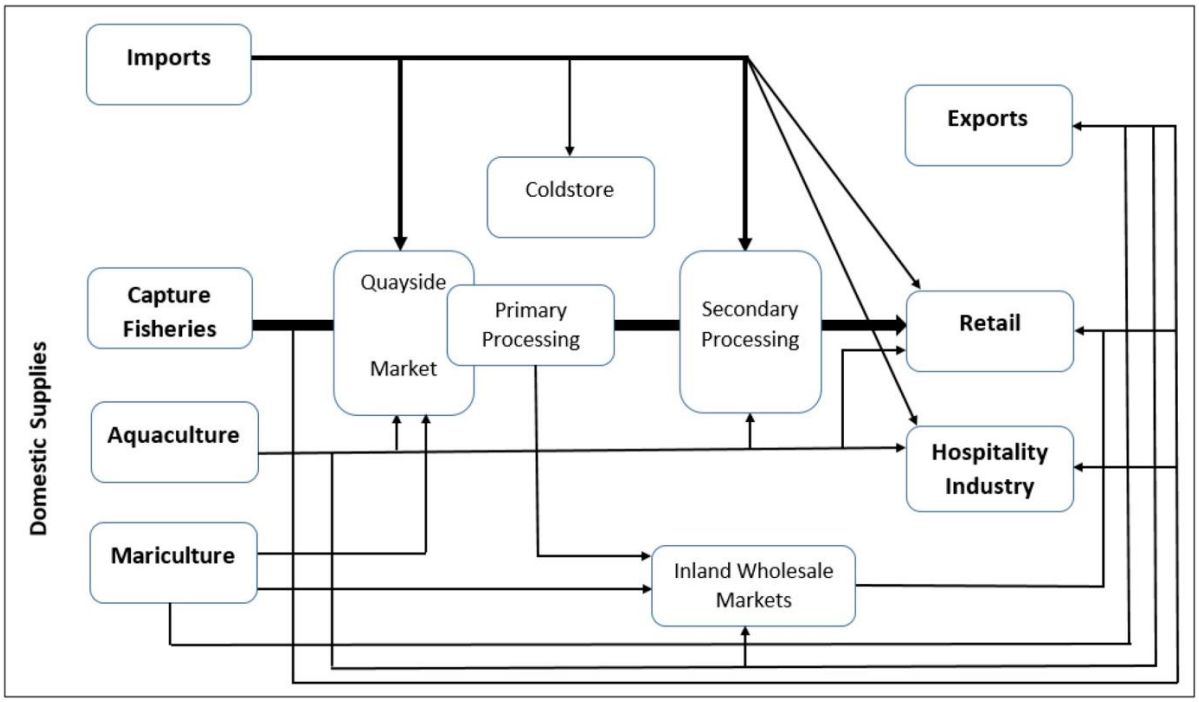
Figure 1. Types of fish landed in different parts of the UK in 2021 (by ships from all parts of the UK) (Source: Uberoi et al. 2022).



The UK almost completely relies on imports for large pelagic species groups such as tuna; only 0.3% of UK consumption is produced domestically (WWF 2022). Denmark, Germany and the Netherlands export large pelagics to the UK, but it is likely these countries act as intermediary trading countries rather than producers (WWF 2022). The UK also exports large pelagics, implying that the UK re-exports imported seafood (WWF 2022). In terms of small pelagic species groups such as sardines, herring and mackerel, the UK is a large producer and exporter (WWF 2022). The UK imports small pelagics from Europe, Morocco, China and Thailand, and also re-exports some small pelagics (WWF 2022). For some demersal species such as sole and plaice, the UK production provides approximately half of the annual UK consumption; importing product comes from Iceland, the Netherlands, Denmark and the Faroe Islands (WWF 2022). In terms of shellfish, the UK imports crustaceans from countries globally and exports half of the UK domestic production to other countries; significant quantities of UK produced molluscs are consumed domestically, approximately one third of production is exported, but some of the UK supply is also imported (WWF 2022).

The UK fishing industry now contributes little to the seafood chain in terms of volume of landings (Symes and Phillipson 2019). In 2021, the UK imported 791 000 tonnes of fish and related products, at a value of £3.3 billion; by weight this is more than twice the total imports in 1983 [UK fisheries statistics 2022]. In 2021, the UK exported 363 000 tonnes of fish and related products (value £1.6 billion) (Uberoi et al. 2022). The UK Seafood Supply Chain has undergone changes due to a combination of factors including: economic rationalisation, greater international competition, the emergence of a free market approach to fisheries management, and changes in the perception of fish from UK consumers (Symes and Phillipson 2019). The UK Seafood Supply Chain now has fewer registered landing points, wholesale markets, processing facilities and small retail outlets handling fish (Symes and Phillipson 2019). The UK Seafood Supply Chain has also been shortened due to the rise of supermarkets, growth of delivery from quayside markets and secondary processing links to the supermarket depot (Symes and Phillipson 2019). A simplified UK Seafood Supply Chain (Figure 2) consists of the catching sector, aquaculture and mariculture as the sources of domestic supply, in addition to imports, leading to, primary and secondary processing and onto retail, or export.

Figure 2. Basic UK Seafood Supply Chain (Source: Symes and Phillipson 2019).



A more complete UK Seafood Supply Chain is complicated by the practice of exporting and reimporting seafood products. For example, some larger processing companies export unfinished product for processing (e.g. filleting) by countries in Asia or Eastern Europe, before reimporting the semi-finished product for value added processing (Symes and Phillipson 2019). Another example is the practice of importing bulk frozen prawns from South East Asia to be washed and glazed by a UK based company before re-exporting to southern Europe (Symes and Phillipson 2019). Seafood processing in the UK therefore uses a combination of fish caught and landed in UK waters, and global fish imports. Seafood processors can be divided into three categories i) primary processors (cutting, peeling, gutting and washing seafood); ii) secondary processors (brining, smoking, freezing and canning); and iii) mixed processors (mixture of primary and secondary processing activities). (Seafish 2019).

In 2020, there were 348 fish processing sites in the UK (defined as sites that derived over 50% of their turnover from fish processing), typically located near major fishing ports (Uberoi et al. 2022). In 2008 there were 560 fish processing sites, showing that there has been considerable consolidation in the industry (Seafish 2019). Fish processing businesses had a turnover of approximately £3.5 billion in 2020 (Uberoi et al. 2022). The fish processing sector is labour intensive, and in 2018 was heavily reliant on non-UK workers, particularly those from other EU countries (Uberoi et al. 2022); in 2020 fish processing sites accounted for 17,988 full time equivalent jobs (Uberoi et al. 2022). North East Scotland, East Yorkshire and Northern Lincolnshire (the Humber) are the key regions for seafood processing in the UK in terms of number of sites and number of jobs (Table 1) (Uberoi et al. 2022). In the Humber

and North East Scotland, the industry is mainly focused on wild caught fish and shellfish from local ports (Seafish 2019).

Table 1. The top ten areas for fish processing sites and jobs in the UK (Source: UK Fisheries Statistics, 2022).

Fish processing sites and jobs by region			
Top ten areas for sites and jobs			
	Sites		FTE jobs
North Eastern Scotland	51	The Humber	5546
The Humber	50	North Eastern Scotland	3563
Highlands and Islands	42	Southern Scotland	1535
Cornwall and Isles of Scilly	23	Highlands and Islands	1434
Eastern Scotland	19	Eastern Scotland	929
Northern Ireland	15	Devon	767
Southern Scotland	15	Cornwall and Isles of Scilly	569
Devon	14	Northern Ireland	412
Lancashire	14	Outer London - South	400
East Anglia	14	West Central Scotland	346

The perishability of seafood introduces specific challenges and specialist handling requirements to preserve quality and ensure safety across its supply chains (Aung and Chang, 2014). Temperature fluctuations can result in spoilage of fresh seafood, largely the result of microbial activity (FAO, 2007). Maintaining appropriate temperatures from production to consumption, known as assurance of the “cold chain”, is a critical consideration of seafood supply chain logistics (Selamoglu, 2023). Maintenance of the cold chain can be a substantial logistical challenge, particularly when perishable goods pass through multiple parties before reaching the consumer.

The domestic UK seafood market focuses on processed products rather than whole fish as a result of consumer preferences (WWF 2022). Seafood products may be processed multiple times, with multiple countries involved in the supply chain at different stages of processing. A recent WWF report identified China as the main processing country in the UK supply chain, followed by Germany, Poland, Thailand and Denmark (WWF 2022). A processed seafood product may have significantly changed its form, shape or content, however, current labelling regulation does not require these products to report what species they contain, or the country of origin i.e. the fishing nation, for the product (WWF 2022). As a result of the complexity within the seafood supply chain and the drive to meet consumer demand, maximise profits and reduce costs, there are risks of product mislabelling, a lack of traceability, fraudulent activity and environmental and social issues (Fox et al. 2018, WWF 2022).

2.3 Traceability in UK Seafood Supply Chains

Traceability is a critical component in modern food supply chains, providing access to non-distorted, factual, relevant and timely information about supply chain products (Wognum et al. 2011, Astill et al. 2019). Current food supply chains are often complex, containing numerous stakeholders and many outsourced procedures such as food product storage and transportation (Astill et al. 2019). As complexity across

the supply chain increases, the importance of food production transparency and traceability at each stage of the supply chain, increases. The motivations for increased traceability in the supply chain include an increase in the frequency of food safety crises which require the ability to identify the source of food production and cause of contamination (Dabbene et al. 2014, Astill et al. 2019). In addition, calls for food supply chains to become sustainable and ethical require traceability along the supply chain to provide information on food source areas, labour, production methods, carbon footprint and wider ecological considerations.

The highly complex and global seafood industry makes it particularly difficult to track a seafood component to an end product of a particular producer, therefore a robust traceability measures is required (Fox et al. 2018). The numbers of traceability systems providing more information about seafood products has been increasing, to address concerns over product provenance, quality and safety, fraud, sustainability and illegal, unregulated and unreported (IUU) fishing (Jacquet and Pauly 2008, Helyar et al. 2014, Bailey et al. 2016). Seafood supply chain traceability primarily emerged to aid product recall in the face of product safety concerns, but government regulation and commitments by the retail sector are now key drivers (Bailey et al. 2016). Increased traceability can also help address the different types of fraud within the seafood supply chain: species substitution, species adulteration[1], undeclared product extension, chain of custody abuse, fishery substitution, illegal, unreported and unregulated (IUU) substitution, catch method fraud, animal welfare, modern day slavery, illegal processing and illegal or unauthorised international trade (Elliott 2014, Fox et al. 2018, Lawrence et al. 2022).

Across the seafood supply chain, there are different types of traceability: i) management traceability ii) regulatory traceability iii) consumer traceability and iv) public transparency (Bailey et al. 2016). Management traceability is related to the provision of information between actors in the supply chain to increase logistical efficiency (Bailey et al. 2016). Regulatory transparency is related to the provision of information to comply with regulatory goals set by public authorities (Bailey et al. 2016). Consumer traceability refers to information on production and product information (e.g. origin and sustainability related information) provided from the supply chain actors to the consumer (Bailey et al. 2016). Public transparency refers to broader demands for information on production practices, for example Non-Governmental Organisations (NGOs) providing information to civil society (Bailey et al. 2016).

Management traceability or Business to Business (BTB) traceability can aid food safety and quality assurance (e.g. safe handling and shelf life for products can be improved) (Bailey et al. 2016). By ensuring a flow of information between businesses within the supply chain, operating costs can be reduced and productivity increased (Regattieri et al. 2007). Minimum BTB traceability requirements exist in the EU for imports to ensure seafood safety, but while BTB for food safety and quality offers incentives for businesses, these incentives may not extend to environmental or social sustainability (Bailey et al. 2016).

[1] Species adulteration in seafood refers to undisclosed processing methods, including: over-treating, using undisclosed additives, using excessive glaze water in frozen seafood, or short-weighting are not disclosed to the consumer (Spiegel and Beyranevand 2022).

Traceability has been applied across UK Seafood Supply Chains for several years in compliance with legislative and market requirements (Table 2). There are regulations on seafood safety, labelling and traceability requiring UK seafood traders (e.g. producers, suppliers and retailers) to provide basic information (e.g. fishing areas and fishing methods) to consumers (WWF 2022). Documentation is a key component in meeting legislative requirements for traceability, and for certification processes (e.g. ecolabels or Marine Council Stewardship certification) (Bailey et al. 2016, Pramod and Pitcher 2019).

Table 2. Legislative and regulatory requirements for traceability across the UK Seafood Supply Chain

Legislation	Region	Requirements
UK Fisheries Act (2020)	UK	Lays out the high-level fisheries objectives for UK fisheries management following departure from the EU. It defines traceability as "the ability of any person to discover information about how, where or when the fishery products were (a) caught, harvested or made, or (b) transported, stored or sold".
Control Regulation 1224/2009	EU (requirements retained into UK Law by the UK Fisheries Act (2020))	Establishes a system for control, inspection, and enforcement to ensure compliance with the rules of the EU common fisheries policy. This regulation also specifies that all lots of fisheries and aquaculture products shall be traceable at all stages of production, processing and distribution, from catching or harvesting to retail stage.
EC Regulation No. 178/2002 (EU, 2002)	EU*	General requirements for food safety and traceability. Stipulates that food companies must be able to identify where they get their products from and who they sold them to, termed 'one up one down' traceability.
Food Information to Consumers Regulation 2011	EU*	Establishes the general principles, requirements and responsibilities governing food information, and in particular food labelling.
Fish Labelling Regulations 2014	UK	Specify the fish labelling data and traceability requirements for seafood businesses. This includes the requirement to produce and keep product records, and that seafood products must be labelled with the following: • Commercial and scientific species names • Production method (e.g., caught at sea) • Best before date • Category of fishing gear used • If fish have been defrosted • Other treatments and additives

*EU laws currently kept by the UK as part of the UK/EU and EAEC:Trade and Cooperation Agreement [TS No.8/2021]

Full seafood supply chain traceability often relies on extensive documentation, but this documentation can be subject to falsification (Bailey et al. 2016). Some mislabelling may be unintentional (e.g. confusion over species names), yet fraud and mislabelling can be intentional in order to secure economic advantage (e.g. lower value species labelled as higher value species) (Jacquet and Pauly 2008, Bailey et al. 2016). Regulatory traceability is therefore critical for validating product origin and species for both import and export, and to help counter IUU fishing (Bailey et al. 2016). IUU fishing is facilitated by practices such as flags of convenience, relaxed import and export regulations, illegal fishing methods and human rights abuses, and the lack of transparency and traceability associated with transhipments (Jacquet and Pauly 2008, Bailey et al. 2016, Pramod and Pitcher 2019). Post-harvest processing and subsequent re-export, as occurs in some UK seafood supply chains, also provides multiple opportunities for mixing legally and illegal sourced fish. Fraud can often go undetected in these complex supply chains due to false documentation, repacking and obfuscation of traceability (Pramod et al. 2014).

In consumer and public traceability, the flow of information from the supply chain is to consumers or civil society (Bailey et al. 2016). Consumers are provided with information on seafood product characteristics (e.g. quality, origin and sustainability), which in part has emerged due to NGO driven information demands (Bailey et al. 2016). “Third party” verification of certification systems has helped build consumer and civil society trust in certification (Bailey et al. 2016), and chain of custody as an element of traceability has been essential in enabling retailers prove they procure seafood from credible sources (Bailey et al. 2016). Additionally, a chain of custody is essential for allowing producers (and consumers) to differentiate between the increasing number of seafood certification schemes (Bailey et al. 2016). It is also evident that certification schemes are also targeting ethical issues such as human rights and seafood welfare in response to growing public awareness of such issues (Jennings et al. 2016, Fox et al. 2018).

Despite an increasing regulatory and information requirement for traceability, there are still some instances of fraudulent and illegal activity across the seafood supply chain. A study of 100 samples from UK retailers identified that 15% of ‘wild’ salmon, 11% of ‘wild’ sea bream and 10% of ‘wild’ sea bass were actually farmed and not wild as claimed (Jacquet and Pauly 2008). A more recent study of UK retailers found that just over 5% of sampled whitefish products were mislabelled (Helyar et al. 2014). With raw seafood materials now being increasingly processed for novel products, the seafood supply chain is becoming more opaque (Fox et al. 2018). Fraudulent activity such as mislabelling is commonly performed at the processing and manufacturing supply chain stages by agents, middlemen or final retail customer before sale to the consumer (Fox et al. 2018). The Elliot Review into the integrity and assurance of food supply networks (2014) also identified the worrying scale of hidden human exploitation across seafood supply chains that support UK consumption.

3 Aims and Objectives

Improving traceability, the extent to which fish can be verifiably tracked as it moves through the supply chain, is a key priority for Defra's Control & Enforcement policy team and the MMO. In order to make progress on improving traceability within UK Seafood Supply Chains, this project focuses on: (i) the accuracy of linking physical fish products with the data, which is reported by fishers, and (ii) maintaining this accuracy as fish moves through the supply chain, to help inform the development of management and policy measures.

3.1 Case Study Selection

The project takes a case study approach, investigating three examples of UK Seafood Supply Chains. The UK fishing fleet catches and lands different types of fish and seafood; landing statistics are often grouped into three main species categories for reporting: i) demersal, ii) pelagic and iii) shellfish. A case study from each category was selected for the purposes of this report following consultation within the MMO in the project planning stages.

- **Case study A: (Demersal) Dover (common) sole landed into ports in South West England**
- **Case Study B: (Pelagic) Mackerel from vessels landing into Peterhead, Scotland**
- **Case Study C: (Shellfish) Brown crab / lobster from vessels landing into Bridlington, England**

Dover (common) sole is a commercially important species, caught as part of a mixed demersal fishery, predominantly in the south of the UK. The supply chain for Dover sole is an example of one containing a mixture of direct selling and selling via auction house, and varying levels of processing prior to consumption. Pelagic species make up a large proportion of fish landed in Scotland. Mackerel is one of the UK's most commercially valuable fish. The Scottish mackerel supply chain is an example where a small number of fishing vessels make large volume landings, and where there are relatively few stages in the supply chain. Brown crab/lobster are increasingly important commercial species in the UK, particularly in the north east. Brown crab is often initially sold live, but then can undergo a high degree of processing. Lobster is an example of a supply chain with live product.

The three case studies selected represent: a range of species (demersal, pelagic and shellfish); a variety of fishing methods used for capture (trawl, purse seine, creel), different geographic locations across the UK (South West England; Peterhead, Scotland; North East England), and different levels of complexity within the supply chain (mixed species catches, auction houses and direct selling; relatively few supply chain stages; aggregated processing batches and live product selling).

Using these three specific examples of UK Seafood Supply Chains, we aim to:

- Identify areas of traceability best practice

- Identify challenges and barriers to improving traceability in UK Seafood Supply Chains
- Produce recommendations for improving traceability in UK Seafood Supply Chains
- Validate our findings with key stakeholders within the supply chain

3.2 Ethical Statement

This study involving human participants was reviewed and approved by the Faculty of Science and Engineering Ethics Committee, University of Hull (FEC_2023_14). Prior to the start of each stakeholder interview, written, informed consent was secured from each participant. Participants were provided with a project brief outlining that the interview was part of a commissioned project by the MMO to conduct a research study on traceability within UK seafood supply chains. A further information sheet was provided which outlined the aims of the project and that any participation was completely voluntary and participants were free to withdraw at any time, the interview should take no longer than one hour, and no personally identifiable information would be reproduced in written outputs. Contact information for the lead researcher and an independent contact within the University of Hull Faculty Ethics Office was provided if the participant had any questions about the research.

4 Implementation of stakeholder engagement

4.1 Stakeholder mapping

An initial stakeholder mapping exercise was undertaken for each supply chain using desk-based research of the industry and discussions with subject matter experts identified through prior contact with industry. Following initial desk-based research, a diagram of each of the 3 case study supply chains (mackerel, crab/lobster and sole) was produced which was later verified and refined by stakeholders at interview. Purposive selection of relevant organisations and stakeholders within each supply chain was used to contact potential participants. Stakeholders were selected on the basis of their expertise and/or knowledge of the selected supply chain case study and/or their position along a simplified three-step supply chain (fishing – processing and distribution – marketing).

Contact details were sourced from prior industry contacts, relevant industry meetings attended by the project team and snowball sampling of participants. Potential participants were approached via email or telephone with a brief description of the project and an invitation to participate, including:

- 21 organisations relevant to the mackerel industry,
- 15 organisations relevant to the crab/lobster industry,
- 32 originations relevant to the sole industry,
- 5 organisations with involvement across the seafood industry relevant to all three case studies.

However, several organisations declined to participate owing to stakeholder fatigue, particularly concerning traceability with the supply chain, and limited capacity in the organisation.

4.2 Stakeholder Interviews

Qualitative, semi structured interviews with 37 stakeholders across the mackerel, crab and lobster, and Dover sole supply chains were undertaken over a four-month period in 2022/2023. The aim of the interviews was to gather stakeholder knowledge and perceptions regarding (i) the supply chain of their fishery (ii) current traceability along the chain; and (iii) barriers to improving traceability in the supply chain. Interviews were conducted via video conference. The duration of the interviews was between 30 minutes and one hour. The interviews were not recorded; two researchers conducted the interviews and made detailed notes which were consolidated, and clarifications sought from participants after the interview if required.

Participants were first asked to verify the initial supply chain diagram, produced as part of the mapping exercise, relevant to their fishery. These supply chain diagrams were iteratively refined over the course of the research following input from each participant interviewed. The semi-structured interview questions were tailored to four stakeholder groups (0):

- Port Authorities & Fishing Authorities
- Fishers & fishing association groups
- Supply chain actors (Processors/ auctioneers/ wholesalers/ exporters/ distributers etc.)

- End market actors (Fishmongers/ retailers/ food services etc.)

The questionnaires covered four topic areas: systems and technologies, regulations, and market drivers, and general attitudes towards traceability.

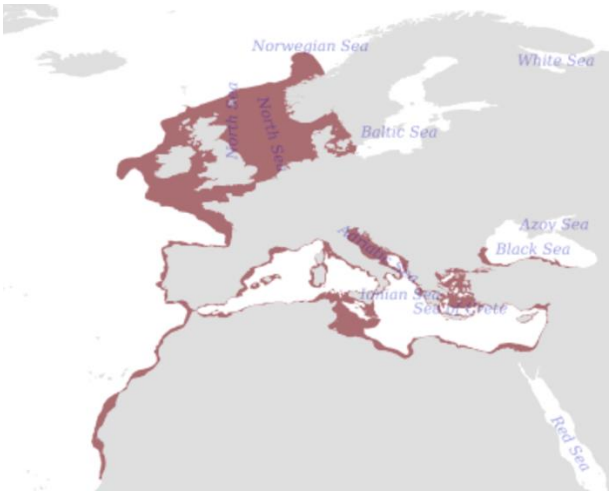
5 Case Study A: Dover (common) sole landed into ports in South West England

5.1 Dover sole Northeast Atlantic stock

Dover sole (*Solea solea*), also known as common sole, is a commercially important species of the *Soleidae* family, found within the coastal waters of the northeast Atlantic (ICES, 2014). Dover sole are usually found buried in sandy and muddy seabeds and estuarine habitats (ICES, 2014). Dover sole spawning occurs during spring at shallow coastal grounds in waters typically less than a few metres deep such as offshore banks, estuaries, and intertidal habitats (ICES, 2014). For their first year or so, Dover sole juveniles remain in shallow coastal waters until they gradually disperse to deeper waters (ICES, 2014). Adult can grow to as large as 60 cm in length, with females generally attaining a larger size than males (ICES, 2014).

Dover sole have a biogeographical distribution ranging from the southern Black Sea, the Mediterranean and the northwest coast of Africa to the Celtic Sea, Irish Sea, North Sea, and southern coast of Norway (ICES, 2014). Figure 3. FAO Aquatic Species Distribution for Dover sole. Figure 3 displays the Aquatic Species Distribution Map for Dover sole produced by the Food and Agriculture Organisation of the United Nations (FAO).

Figure 3. FAO Aquatic Species Distribution for Dover sole. Reproduced from FAO Aquatic Species Distribution Map Viewer at https://www.fao.org/figis/geoserver/factsheets/species.html (FAO, 2023)



Dover sole has a high market value, and many fisheries target the species using specific gear types such as demersal trawls and beam trawls (Cornwall Good Seafood Guide, 2019). As Dover sole bury into the sediment, heavy gear is required to drive them into trawl nets (ICES, 2014). Gill nets are also used to target Dover sole within inshore waters, particularly during the spawning season (ICES, 2014).

Substantial variations in stock levels of Dover sole across the northeast Atlantic have been observed over the last 50 years, attributed to shifts in gear use, variability in

breeding success, and high mortalities during severe winters (Seafish, 2013). The International Council for the Exploration of the Seas (ICES) provides yearly data-based recommendations for total allowable catch (TAC) of Dover sole in the northeast Atlantic to ensure the sustainability of Dover sole stocks. For instance, ICES advises that the 2023 TAC for Dover sole should be no more than 1,394 tonnes within ICES division 7e, a 23% decrease from the 2022 advised TAC (ICES, 2022b).

Across the northeast Atlantic, Dover sole is targeted by vessels from Belgium, Denmark, France, Germany, Netherlands, Ireland and the UK. UK vessels made up to 75% of reported landings within ICES division 7e, 29% within divisions 7f-g, 13% within division 7d and 5% within subarea 4 in 2021 (ICES, 2022c, 2022d, 2022b, 2022e). The EU has fishery management measures in place for Dover sole facilitated though EU regulation 2019/472 which covers stocks fished in ICES subareas 5,12 and 14 and division 6b, 7d – 7k, 8a – 8c and 9a (EU, 2019). EU regulation 2019/472 establishes a multiannual management plan including catch limits in the form of TACs, targets for population sizes and fishing mortality, and effort restrictions limiting the number of days at sea for vessels using certain gear types including beam trawls and static nets (EU, 2019). These regulations are a continuation of the EU Sole Recovery Zones demarcated for the sustainable exploitation of the stock of sole in the Bay of Biscay, Western Channel, and North Sea (EU, 2007a, 2007b, 2006). There is a lack of an agreed shared management plan between the EU and UK for Dover sole stock in the northeast Atlantic.

5.2 UK Dover sole fisheries

UK landings

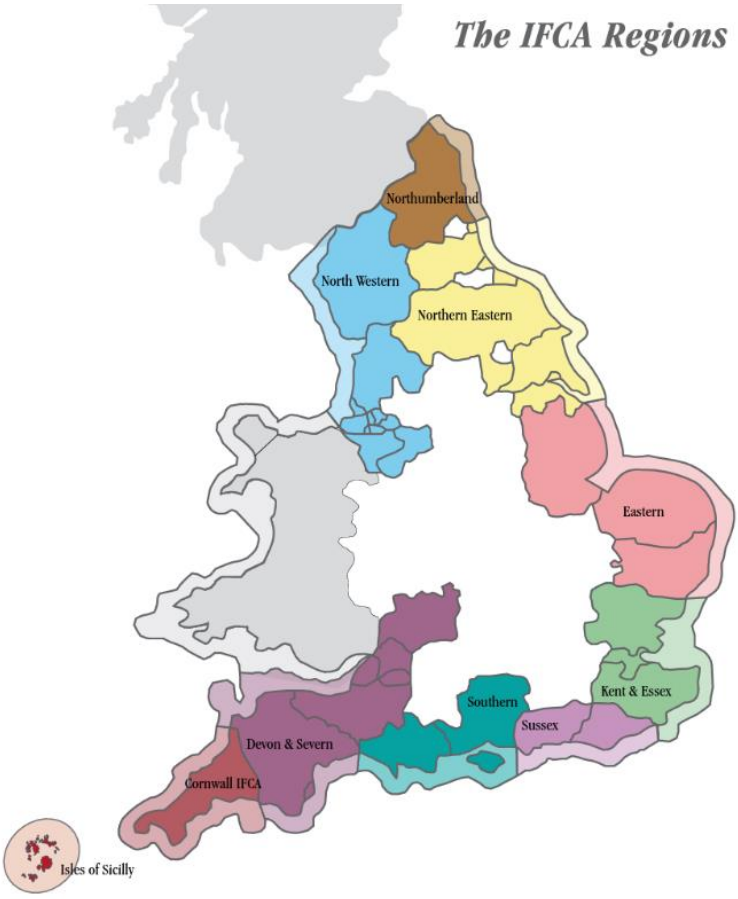
Dover sole is a commercially important species within the UK, with 2021 landings into the UK by UK vessels valued at £21.3 million, the fourth highest demersal species behind monks/anglers, cod and haddock (MMO, 2021). Dover Sole, along with, halibut and turbot, typically fetch the highest prices per kg for UK landed demersal species, with 2021 costs per tonne averaging over £10,000 for these three species (MMO, 2021). For Dover sole, these high prices can in part be attributed to the impact of the Sole Recovery Zone reducing supply.

For certain gear types and catch areas around the UK, Dover sole is one of the highest total value of species landed. For instance, in 2021, Dover sole was the largest landed species by value for beamers within ICES division 7e, the second largest for under 10 m vessels using drift and/or fixed nets within 7d, and the second largest for beam trawls over 300kW in power within ICES subarea 4 (Seafish, 2021). The largest ports for Dover sole landings into the UK are Brixham, Newlyn and Plymouth respectively, which collectively make up 65% of total Dover sole landings into the UK by UK vessels in 2021 (MMO, 2021). In 2021, the UK exported 4,400 tonnes of Dover sole, attributing to 79% of the total value of landings into the UK by UK vessels.

Management of UK Dover sole fisheries

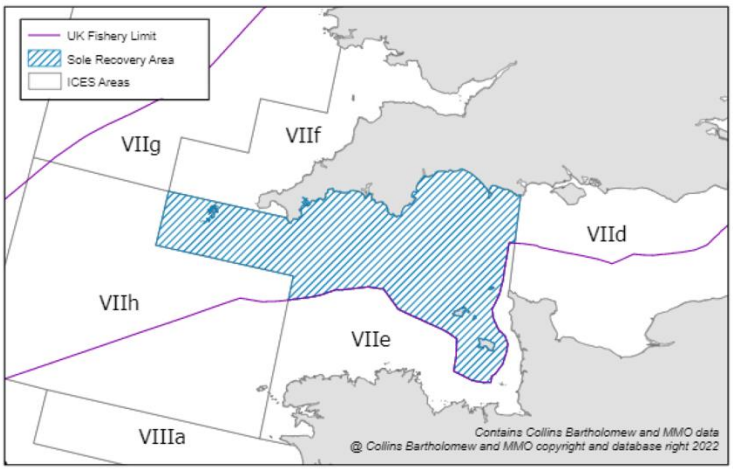
Within England, fishery management jurisdiction is divided between the Inshore Fisheries and Conservation Authorities (IFCAs) from the coast out to a distance of 6 nautical miles (known as 'inshore waters'), and Defra/the MMO beyond 6 nautical miles. The mixed fisheries of the southwest fall under the jurisdiction of the Devon and Severn IFCA (D&S IFCA) and the Cornwall IFCA (CIFCA), see Figure 4.

Figure 4. IFCA regions (IFCA Association, 2023)



Management of the Dover sole stock in UK waters is through monthly catch limits specified by the MMO for under 10m vessels and the non-sector, and Fish Producer Organisation's (PO) management of their TAC allocations from the MMO between their members. The Minimum Conservation Reference Sizes (MCRS) of Dover sole is 24 cm under National legislation and the bylaws of the D&S IFCA and CIFCA (CIFCA, 2000; D&S IFCA, 2020). It is estimated that only around half of undersized Dover sole survives after being caught and discarded (Catchpole, 2016). Additional restrictions apply over the Sole Recovery Zone (SRZ) which was introduced in 2004 as part of the efforts to recovery sole stocks. Figure 5 displays the boundaries of the SRZ.

Figure 5. Sole Recovery Zone and ICES areas (MMO, 2021)



The rules of the SRZ only apply to vessel of over 10 m and include restrictions on mesh size of beam trawls (equal to or larger than 80 mm), on mesh size of static nets including gill nets, trammel nets and tangle-nets (equal to or larger than 220 mm), and limits on the allocated effort days (basic allocation of 222 days) (UK Government, 2022). Since the implementation of the SRZ, the number of UK registered beam trawlers active in the SRZ is reported to have fallen substantially (MMO, 2021).

5.3 Interview responses from Dover sole industry stakeholders

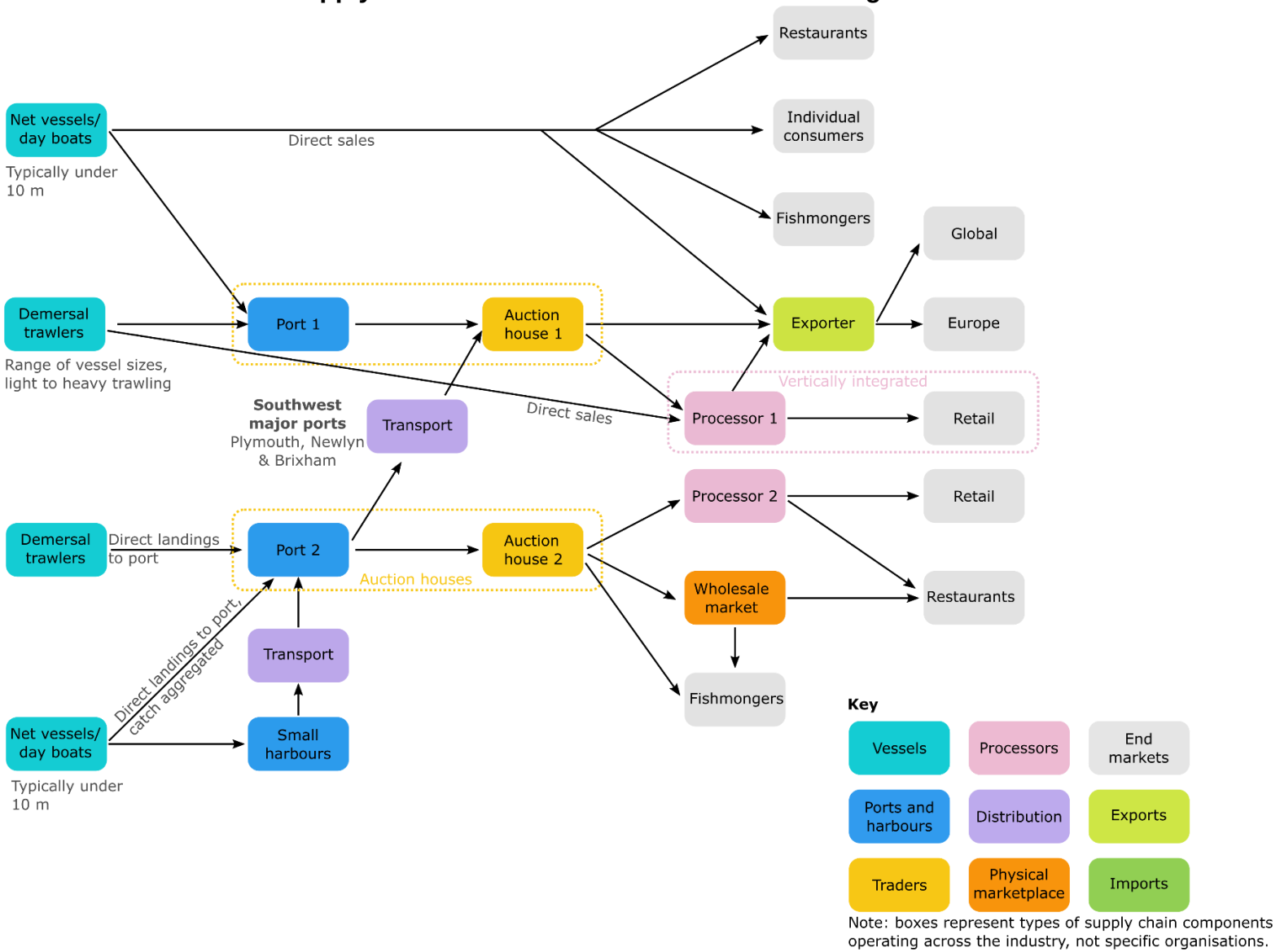
5.3.1 UK Dover sole supply chain overviews

A large portion of the seafood landed in the southwest of England goes through the auction houses at Brixham, Newlyn, and Plymouth. Due to the high prices that can be received for Dover sole at these auctions, the first point of sale of a large portion of the Dover sole landed into the southwest is facilitated through the Brixham, Newlyn, and Plymouth auctions. There are multiple routes that Dover sole (and other species) can take into the auctions:

i) direct landing to the port of auction,
ii) transport to the auction from nearby harbours without auction houses,
iii) transport to the auction from nearby ports with auction houses due to vessel owner preference of auction house.

In addition, direct selling from vessels to individuals and supply chain actors also occurs. Dover sole is both exported and sold to the UK market. Within the UK, Dover sole can undergo primary processing and can be sold whole and gutted by processors and wholesalers for high end food services, retail, fishmongers and to individual consumers, often at wholesale markets such as Billingsgate. One instance of the vertical integration of a processor and retailer purchasing from southwest auction houses was identified (Figure 6).

Figure 6. UK Dover sole seafood supply chain based out of the southwest of England.



Note: boxes represent types of supply chain components operating across the industry, not specific organisations.

Beyond the southwest, the closest auction house is located in Grimsby. One fishing organisation representative stated that fishers operating along the south coast who cannot reach the southwest and Grimsby auction houses tend to sell to local merchants. However, there are some examples of vertically integrated organisations in the early stages of the Dover sole supply chain in the south of England. For example, one organisation which owns and operates vessels, undertakes primary processing, and sells via a physical fish market, an online sales platform and as a wholesaler to UK based food services.

5.3.2 Traceability during fishing

Dover sole fleet

Dover sole is part of a mixed fishery within the southwest of England. Fishing industry stakeholders stated that the fleet which catches Dover sole is predominantly comprised of demersal beam trawl fishing boats on multiday trips typically lasting 3-7 days, and also by day net vessels and stern trawlers. Multiple industry stakeholders stated that Dover sole, along with other species of sole, is directly targeted by fishers due to its high value, particularly by smaller boats with trammel nets. Industry and MMO interviewees also highlighted that Dover sole is often caught as a valuable by-catch of scallopers, and also by non-UK vessels operating in UK waters as part of the agreed terms of the UK-EU Trade and Cooperation Agreement (TCA). MMO stated that post EU Exit, it is no longer common for foreign vessels to land into the ports in the southwest of England due to new export requirements.

When discussing vessel ownership in the southwest, the stakeholders interviewed described that many fishers independently own a small number of vessels. However, there are larger fishing organisations owning and operating higher numbers of vessels (e.g., one organisation owns over 20 vessels) that also operate within the southwest. In addition, several POs also operate within the southwest and collectively manage their catch allocations.

Multiple stakeholders shared a lack of trust in EU authorities to ensure compliance of EU vessels operating in UK waters, and felt that there is a higher risk of non-compliance post-EU Exit as there is less MMO inspection of non-UK vessels. The MMO stated that they perform approximately equal numbers of at-sea vessel checks on UK and non-UK vessels. Conversely, multiple industry stakeholders shared their belief that the MMO is too focussed on the “low-hanging fruit” of surveillance of the UK fleet, and that a larger focus should be put on surveillance of the non-UK fleet fishing in UK waters due to the associated higher risk of non-compliance. One stakeholder outlined their concerns of non-compliance by non-UK vessels particularly in bad weather when MMO patrol vessels are less likely to perform at-sea checks.

One fishing organisation noted that larger retailers can request additional data on social metrics, such as vessel safety standards and crew composition including number of migrant workers and recruitment methods. However, they indicated that this is not commonplace and the bulk of buyers are not interested in social data.

Catch recording

Catch and landing reportings to the MMO for Dover sole are via a combination of e-logbooks, paper-based logbooks, and the CatchApp as the fleet targeting Dover sole are of varied sizes. A fishing organisation shared that the general consensus across the fishing industry in the southwest is that the use of e-logbooks for reporting daily fishing activity versus paper logbooks submitted on landing, is effective and a useful governance tool to facilitate vessel inspections. A fisher and an auction house representative commented that an additional benefit of the e-logbooks is that an extract of submitted catch data can be sent to auction houses to notify them of what quantities and species of seafood will be delivered for sale in advance of vessel landing.

A stakeholder estimated that roughly half of landing declarations of vessels over 12 m are not supplied within the 24 hour deadline, and questioned the reasoning for this time frame, arguing that the focus of catch reporting should be on accuracy not speed. A stakeholder stated that in some instances, skippers may wait for their product to go through an auction and use the weights provided by the auction house within their landing declarations. To avoid late fines, a stakeholder stated that in some instances skippers will submit placeholder weights within landing declarations to be updated once the auction house has provided them with a weight. As there is no auction over the weekend, it was stated that declarations of the exact weight of fish landed after the early hours of Friday may not be declared till Monday. A fishing organisation stated that they sometimes miss the 24 hour landing declaration deadline when selling directly to processors and do not receive the final weight provided by processors within the 24 hour time frame.

A stakeholder stated that they have heard mixed feedback from fishers regarding the CatchApp. Multiple stakeholders across the supply chain stated that the introduction of the CatchApp has resulted in large improvements in visibility of the operations of the under 10 m vessels due to the requirement for daily catch reporting. Several stakeholders stated their belief that much higher levels of unreported fishing occurred prior to the introduction of the CatchApp.

Concerns were raised by a number of stakeholders regarding the requirement to provide weight estimates for every species of fish within the CatchApp, no matter how small the quantity. As under 10 m vessels often operate within mixed fisheries and may only catch a small number of individuals per species, the difficulty of estimating the weights of individuals within the 10% margin were highlighted. Fishers and auction house representatives noted the imbalance in granularity between CatchApp and e-logbook catch reporting, as within e-logbooks, weight estimates do not need to be provided if under 50 kg of a species is caught. Several stakeholders commented that comparatively, catch reporting is more onerous for smaller scale fishers, and that small scale fishers are at higher risk of be penalised for providing weight estimates beyond the 10% margin. One stakeholder commented that if regulations are not to be consistent across different contexts, then as a minimum, regulations should reflect the level of risk. The stakeholder argued that this inconsistency in catch weight estimations is the reverse, as high levels of accuracy are required for lower risk operations.

Multiple fishing organisations highlighted the difficulty in accessing historical catch data for business analysis and quota management purposes, though MMO staff interviewed responded that fishers are able to request their data. Several of the larger fishing organisations mentioned they use a third party tool which interfaces with MMO reporting systems and allows for queries to be run on fish landed against quota use and for spatial analysis of catch information from different areas and vessels.

Cross reporting

When discussing Dover sole and IUU, multiple stakeholders mentioned catch area misreporting, also known as cross reporting. Interviewees attributed historical catch area misreporting to differences in catch limitations on ICES Fishing areas 7E compared to 7H, J, K, which resulted in suspicions that high levels of Dover sole were misreported as caught in 7E. Stakeholders stated that the introduction of VMS and iVMS acts as a deterrent to this type of misreporting. In addition, single catch area licenses which only permitting fishing activity within a particular region were mentioned as also assisting to resolve the issue.

Some stakeholders stated that they believed that misreporting occurs within the Belgian fleet as they are seen to be fishing in one area yet large quantities of fish on the Belgian market is tagged to other areas. A stakeholder stated that they have submitted Suspicious Activity Reports (SAR) for Dover Sole to report this to the MMO. There was perceived difficulties in regulating UK waters without full access to the systems of other nations' fishing governing bodies. In addition, stakeholders highlighted concerns around the UK government being unable to implement regulatory changes to catch area licences to non-UK vessels whilst under the TCA until 2027.

Governance

The local MMO staff stated that they perform at sea and port-side checks of seafood on vessels against daily catch and landing declaration reportings. Due to resourcing constraints, the local MMO staff suggested that they have to focus on performing checks on vessels landing species with higher risks of non-compliance and history of misreporting, such as sole species.

5.3.3 Traceability across landing activities

Auction Houses

There are three auction houses that operate in the southwest of England, located at Brixham, Plymouth and Newlyn. The auction houses use electronic clock auctions which enable selling to both UK and international markets. Fishing organisations and a PO representative stated that product landed from their vessels is sold to a combination of these auction houses, along with direct sales to individuals and supply chain actors such as processors, fishmongers, and food service organisations. Multiple stakeholders across the supply chain stated that the vast majority of Dover sole landed within the southwest of England is sold at the Brixham,

Plymouth and Newlyn auctions due to the high prices for Dover sole that can be received at the auctions.

All three auction house representatives stated that fishers tend to be in communication with auctioneers to provide details of the number of boxes of each species that they expect to deliver to be sold, particularly for fishers with larger vessels and fishing organisations owning multiple vessels. These prenotifications use various communication channels such as WhatsApp, email and text, and were described as for the mutual benefit of auction houses and fishers to allow preparation for product arrival and to mitigate the risk that some product will be held back from auction if grading is not completed in time.

The Brixham, Plymouth and Newlyn auction house representatives described similar operating processes for the movement of seafood though to the first point of sale. The three auction house representatives listed several ways in which seafood product can arrive at the auction houses to be sold:

1. Seafood can be landed at a port and sold at that port's auction. One auction house representative stated the number of fish sold at their auction is low compared to what is landed at their port. However, another representative stated that large portions of seafood are landed at their port to be sold at their auction.
2. Seafood can be landed at a port but transported to be sold at a different port's auction. Stakeholders stated that choice of auction house is largely down to a skipper's preference. A fisher stated that they use their own transportation to deliver seafood to their desired auction but are aware that some fishers and fishing organisations use third party transport to move fish between ports of landing and auction houses.
3. Seafood can be landed at smaller nearby ports and harbours and transported to be sold at an auction. One auction house representative stated that WhatsApp groups are used to communicate with fishers that land at nearby harbours to organise collection of seafood by auction house transportation. Another auction house stated that routine collections are scheduled three times a week. It was stated that seafood may be stored harbourside overnight or for a number of days in refrigerated warehouses before being collected. All auction houses noted that they do not have a mechanism for determining the exact landing date of the seafood transported to the auctions. It was specified that multiple vessels' catch can be transported within a single truck, however there is no amalgamation of fish caught by different vessels to maintain traceability back to the vessel owner for payment purposes.

For each method of entry into auction for first sale, fishers and auction house representatives described the use of branded crates and tallies to ensure that seafood delivered to auctions can be identified back to the vessel and skippers can be paid accordingly. Tallies were described as containing vessel name as a minimum, but some also containing vessel PLN, skipper name and fishing organisation name. The MMO have minimum labelling requirements (Control Regulation.) Auction house representatives stated that they store details on the gear types used by each vessel so the catch method of seafood is known when processed by the auction. One auction house representative stated that for some multipurpose boats, typically under 10m vessels using a mix of netted and hand line capture, fishers will add the method of capture to their tallies.

Grading

All three auction house representatives stated that a combination of machine and hand grading is used to grade seafood according to weight and quality, and that different species have different numbers of grades. It was reported that Dover sole is machine graded, and that the different auction houses use different numbers of grades for Dover sole: Brixham (10), Newlyn (7) and Plymouth (7). It was described that the computerised grading machines print off tallies including details such as the vessel name, PLN, species, weight, and grade. One auction house representative stated that tallies are manually filled out for seafood that is hand graded. Stakeholders stated that tallies are added to boxes on landing so seafood product can be identified as it is processed through the auction house.

The auction house representatives then described sorting a single vessel's catch into auction-owned boxes of a single species and grade. One auction house representative described the "multiplier effect" of separating the fish according to the species and grade, as most fisher's boxes are split into at least three or four auction house boxes, and some fishers' boxes of mixed species could require division into 16 or so auction boxes. The auction house representative stated that this places logistical and resource based constraints on the auction houses, limiting the further division of product according to other factors such as landing date.

It was confirmed by all three auction house representatives that seafood from multiple vessels is never amalgamated into a single box, however boxes with smaller quantities of a species may be grouped for collective sale. They stated that the portion of seafood from each vessel is recorded within the auction online system so each fisher can be paid according to their contribution.

The three auction house representatives stated that scales and grading machines are linked to the electronic auction system, and a catalogue of the following day's auction containing details on the seafood weight, grade, and presentation (whole, gutted, frozen etc.) vessel, name and PLN is published once all grading is complete for advance viewing by prospective buyers. One auction house representative stated that prospective buyers are also able to view the length of a vessel's trip at sea for an additional insight on quality, however, are unable to know which day at sea the fish was caught. A fishing organisation stated that on larger boats a skipper will have an idea of where a particular day's catch is stored aboard vessels, but date of catch is not captured or required for selling. An auction house noted that some supertrawlers can separate catches on multi-day trips, however, there are relatively few of these within the UK fleet. Industry stakeholders concluded that is it unlikely for fishers to segregate each day's catch without a clear business incentive or provision of funding for expansion of storage space.

A fishing organisation and several auction houses stated that large quantities of Dover sole are sold to buyers in Belgium, France, and the Netherlands, and also to high-end UK restaurants and food services. An auction house stated that some buying and freezing of Dover sole occurs to release into market at later date due to price fluctuations.

Auction house representatives from two of the auction houses in the southwest stated that the resale of seafood back into their auction houses does not occur. Representatives from the third auction house stated that resale of seafood does occur, however much less frequently than it used to. The auction house representative stated that in instances of resale, only species, grade & weight data is provided with no vessel details, so buyers are aware that they are re-purchasing from another buyer. This does introduce a loss of traceability back to the vessel, however, is beyond the first point of sale.

It was noted by one auction house representative that there is some differentiation of auction house process for seafood with the MSC chain of custody certification, for example, hake (*Merluccius merluccius*). However, they stated that the only difference is that the MSC label is added to the tally, and MSC and non-MSC certified hake is sold separately within the auction. The stakeholder commented that at this stage of the supply chain, the MSC hake has an equal level of traceability to the other seafood sold at the auction.

Landing date uncertainty

Multiple industry and MMO staff members discussed the use of the day before sale as the landing date by the auction houses in the southwest of England. The auction house representatives commented that majority of seafood product that is landed or delivered to the auction houses are graded that day and then are sold at the following day's auction. Therefore, in most cases, the allocation of landing date as the day before sale is accurate. However, it was highlighted that there are a number of instances when the landing date may not be correct:

- Landings and deliveries over the weekend (Friday, Saturday, and Sunday). Auction house representatives described that the seafood is typically kept in cold storage at the auction house premises and weighed, graded and sorted on Sunday for sale at Monday's auction.
- Landings and deliveries over bank holidays. Similarly, seafood landed and delivered is stored and sold at the following auction.
- Overlanded fish from small (mostly under 10 m) vessels. Auction house representatives stated that they have no means of identifying which day seafood was landed and if a consignment includes seafood landed on more than one day.

The auction house representatives stated that in the above situations, there are logistical, operational, and financial blockers to identifying and separating seafood according to the day of landing. For instance, many of the smaller harbours where seafood is stored before being transported to auction houses do not have sufficient storage capacity to separate boxes according to the date of landing. One stakeholder estimated that 30% of the inshore fleet disappeared due to Covid, and that further administrative burdens may cause additional fishers to be pushed under profitability. Furthermore, seafood within fishers' boxes is separated out and moved into auction boxes according to species, quality, and weight during the grading process. Auction house representatives stated that there is not enough space at the auction houses to accommodate the number of boxes that would be required to further segregate according to the day of landing. In addition, they highlighted that there would be major staffing implications as the workload within the auction hall and

auction back office would increase considerably. The auction house representatives also argued that the additional cost for staffing, boxes, and extending the physical size of the auction hall's chilled storage and staff facilities would be prohibitive. As efficiency of operation is critical to maintaining the quality of perishable goods, auction house representatives also stated that any delays to the existing processes would devalue UK seafood for exports. Finally auction house representatives stated that there is no demand from buyers for additional accuracy in the data points currently provided.

On discussions as to the value of removing the degree of uncertainty currently associated with the landing date provided by the auction houses, several stakeholders highlighted that e-logbook 'return to port' notifications are submitted to the MMO and landing dates are provided on landing declarations submitted for each vessel. As sales notes also provide vessel details, it was argued that the MMO should be able to marry up catch submissions with sales notes submissions in order to cross check data for compliance purposes. However, the local MMO staff stated that the uncertainty of landing date data entry within sales notes does cause issues when cross checking data, making it harder to perform analysis. Local MMO staff suggested that alternative solutions to the issue other than the segregation of boxes according to landing date could be investigated. They also suggested that a complementary step could be increased flexibility within MMO computer systems to enable analysis that accounts for a degree of uncertainty within submitted data.

Post-auction

The auction house representatives stated that on completion of the auction, they provide buyers with invoices and sale information including the species, weight, grade, vessel name, vessel PLN, area of capture, presentation, and landing date (date before sale) of the seafood purchased. They also provide the additional details xrequired to populate export documents. The auction house representatives also stated that they send sales notes to the MMO. Finally, they provide fishers with final weights and prices received for seafood sold within 24 hours of the auction completion.

The auction house representatives stated that post purchasing, the seafood is picked up by buyers using personal transport and through the use of third party transportation firms, particularly for exports. Industry stakeholders commented that beyond the auction houses, there is no control over the amalgamation of seafood purchased from different vessels. One auction house discussed that smaller scale buyers (e.g., some fishmongers and food services providers) tend to use intermediaries rather than purchasing directly from the auctions themselves, due to the costs and logistical difficulties of transporting perishable seafood. They noted the "fear" of some industry stakeholders that increased traceability could "cut out the middleman" but argued that there is not a high risk of this as the use of intermediaries fits within the business models of many seafood purchasers.

Unreported landings at first point of sale

Multiple industry stakeholders stated that they believe that 'black landings' and cross reporting were more prevalent when there were much lower levels of registration of

buyers and sellers and less at-sea monitoring of vessels. However, suspected instances of unreported landings were described by several stakeholders. In addition, many industry stakeholders and MMO staff indicated that as auction houses will not buy from un-registered vessels and sell to un-registered buyers, that instances of non-regulated landings might occur outside of the auction houses.

5.3.4 Traceability across primary processing

A small scale processor of Dover sole stated that they purchase from the Brixham, Newlyn and Plymouth auctions, and occasionally purchase directly from local fishers. They shared their policy of only purchasing from line, net, and light-weight bottom trawler boats as they believe these are more sustainable catch methods and cause less damage to the seabed. The processor stated that they receive all the required vessels details and catch information required by their customers (e.g., gear type, region of catch) in the label provided to them by the auction house.

In order to ensure the traceability of each individual fish back to the vessel, the processor stated that they manually ensure that the label provided by the auction house follows each fish around their processing facility. Vessel and catch details are then transferred onto paper labels on packaging within their processing area. Though this is a labour intensive process, the processor stated that they do so due to their commitment to providing vessel to plate traceability to their customers.

The processor stated that for “typically undervalued species” (e.g., dogfish), they are able to offer higher prices to fishers than would be received at the southwest auctions due to the premium their customers are willing to pay for the sustainability focus of the brand’s ethos. However, as Dover sole is a highly sought after species, very high prices are often received at auction and as a result the processor stated that fishers have less incentive to sell Dover sole to them.

A different processor stated that they also purchase from the Brixham, Newlyn and Plymouth auctions, and have their own fleet of refrigerated vehicles to transport seafood from the auctions to their own processing facilities. The processor stated that they store the traceability data received from the auction house within their sales and stock management IT system. They also stated that details such as catch location and landing date are transferred onto packaging labels on seafood products and receipts provided to their buyers. The processor stated that they rarely receive additional requests for data beyond that already provided, though occasionally some basic anecdotal data is requested for adding to menus at high-end restaurants. From a food safety perspective, the processor stated that they use the Safe and Local Supplier Approval (SALSA) accreditation which certifies that they are able to provide safe and legal food products to their customers.

A fishing organisation stated that they were aware of one large primary processor owned by a large retailer, which is an example of vertical integration further down the supply chain. The processor advertised that they have direct relationships with fishers, purchase from the three auction houses in the southwest, import and export several seafood species. As this processor was not available for an interview for this study, it is unclear what mechanisms are used to manage internal traceability between the two organisations.

5.3.5 End market

In discussions of the end markets of Dover sole landed in the southwest, stakeholders discussed that a substantial portion of Dover sole sold via the auction houses is sold to non-UK buyers and directly exported to Europe. The electronic bidding enables these non-UK buyers to purchase from the auctions, and stakeholders suggested that as a result there is lower price disparity between UK and EU fish markets. An auction house representative stated that intermediaries buying from the auction houses also sell to fishmongers, high-end UK restaurants and other food services. Stakeholders confirmed that the high market value of Dover sole limits it to high paying consumers within the UK. A producer organisation noted the differences between the UK domestic and international market for Dover sole, with countries like the Netherlands, France and Belgium having a substantial market for home consumption.

Wholesale markets

Many stakeholders noted that a portion of the seafood sold at all three of the southwest auction houses is transported to be sold at the seafood market at Billingsgate. Several stakeholders suggested that wholesale physical markets can be one area where ‘black fish’ can be introduced into the legal market. As such, several stakeholders suggested that additional scrutiny could be placed on checking first point of sale invoices at markets such as Billingsgate to validate the legality of product sold.

5.3.6 General attitudes towards traceability

When the purpose of traceability and the interviewees’ general attitudes towards traceability were discussed, stakeholders generally highlighted the prevention of illegal fishing and the assurance of public health as the core rational for traceability systems. Many shareholders highlighted that illegal fishing can undermine legitimate pricing across the seafood market. Interviewees also stated that the purpose of traceability systems is to provide confidence and trust in the UK fishing industry and legitimise the UK as a fishing nation.

An auction house representative shared their frustration that the detailed data sets submitted as part of catch reporting and landing declarations is not propagated down through early stages of seafood supply chain and as such there are duplications of manual input, for instance within auction systems. They also stated that the true meaning of traceability needs to be understood across the industry, particularly the distinction between traceability and full transparency, highlighting that only necessary data should be propagated along supply chains to those that need it, and only with the permission of the data owner. Another fishing organisation stated that they invest in collaborative activities with other industry stakeholders such as quota shares, so are comfortable with transparency and data sharing.

Another industry stakeholder shared their desire for the MMO not to be focussing on improving traceability across the board but on facilitating and appropriate level of traceability where it is needed. They stated that there are various negative implications of traceability and transparency which are commonly disregarded, such

as issues of competition, cumbersome reporting processes reducing profitability, and lack of desire of certain markets to advertise product origin (such as some European markets not wishing to advertise seafood as from the UK).

Existing traceability systems

Multiple stakeholders stated that there have been great improvements to the technologies, processes and systems used within the fishing industry over the last 40 or so years. They noted the introduction of digitised catch reporting, a better protected cold chain, and supply chain efficiencies which have resulted in increased quality of fish and legality across the sector. A number of stakeholders suggested that the data submission steps to the MMO are a bit repetitive, but cross-checks on consistency of data submitted gives confidence to the whole system.

Several stakeholder stated that tight control over the early stages of the supply chain is vital for protection against illegal landings, and that the highest risk of illegal activity is between catch and the first point of sale. One stakeholder stated that traceability to a specific vessel should be required up to first point of sale, but beyond this, traceability back to a port or region should be enough for labelling. One stakeholder stated that the nature of the fishing industry is that seafood from multiple vessels and ports tends to be consolidated after the first point of sale, but if traceability up to first point of sale can be maintained and legality confirmed, there is no need to propagate traceability data along the supply chain. One stakeholder stated that enforcing a higher level of traceability, such as vessel to plate, would be more detrimental to fisheries commerce.

Customer demand

When discussing the buyer driven demand for traceability of seafood, multiple fishers, auction house representatives and processors stated that the vast majority of the buyers are primarily interested in the grade and price of the seafood. Numerous stakeholders stated that for some external markets, there is disincentive for traceability, as some markets do not want to advertise the origin of UK caught seafood (e.g., French and Belgian markets). However, it was noted that some auction buyers restrict their purchasing according to certain criteria, such as from vessels under 10m, or from less destructive fishing methods (e.g., excluding bottom trawl), as they believe these practices are more sustainable. In addition, auction house representatives highlighted that little to no requests have been received from buyers to confirm that fishing activity is not undertaken within conservation areas or complies with conservation regulations, as buyers likely assume that seafood sold at auctions is legal.

One processor described their awareness of customer demand for sustainably caught fish. They described their frustration at the lack of enforcement of the UK's legal requirement to specify the method of catch on seafood labels (UK Government, 2013), and highlighted that many labels currently list many possible methods of catch. They stated that this undermines the purpose of the legislation, masks destructive fishing practices, and does not provide consumers with sufficient data to make ethical purchasing decisions.

A small scale processor shared their belief the MSC certification does not serve small scale or low-impact fishers. The processor indicated that they are in discussion with the Soil Association regarding a possible expansion of the Soil Association's certification programme to include an accreditation to differentiate ethical and sustainable fishing. They described their awareness of resistance within the wider fishing industry for differentiation of seafood product sourced via ethical and sustainable fishing practises as this would highlight how much of the seafood available on the market has a "damaging" impact.

Exports and Imports

Many industry stakeholders shared their frustration at the disparity between the level of regulations and resulting paperwork required for UK fishers to export to the EU comparable to the "minimal checks" performed on EU exports into the UK. Stakeholders emphasised the negative impact of this on the competitiveness of the UK seafood industry within the global market. It was highlighted that there is onerous paperwork even for non-UK buyers, making UK products undesirable to non-UK markets. A wholesaler stated their desire for the UK government to renegotiate the TCA after its expiry in 2027 to facilitate easier trade for the UK seafood industry.

The TCA was also highlighted as a blocker to the UK's ability to implement conservation and stock management actions as part of Fisheries Management Plans (FMPs). Any management steps, such as species tonnage limitations or single area licenses, will not be meaningful for EU vessels if they contradict the permitted catch tonnage of non-quota species within UK waters as agreed within the TCA. Again, stakeholders shared their hope that stricter governance over EU vessels fishing in UK waters will be negotiated after the expiry of the TCA.

5.4 Good practice, challenges, and suggested improvements

Dover sole is an example of where the use of monitoring technologies and changes to regulation have had an impact in reducing IUU. According to the stakeholders interviewed, the introduction of VMS and single area licences reduced the historical issue of mis-reporting area of capture of Dover sole. However, Dover sole is a high value quota species, and instances of 'black fish' landings are still suspected. The MMO has the largest oversight into the areas of the supply chain with the potential highest levels of compliance, such as auction houses, instances of illegality could more likely occur outside of these regulated systems.

Various suggestions of general improvements to catch, landing, sales, and export reporting mechanisms, regulations, and compliance were suggested by interviewees. Many stakeholders across the industry suggested that improved MMO surveillance to ensure adherence to existing regulations is required to identify and deter IUU, as opposed to additional regulations or paperwork which can already be cumbersome. Several stakeholders stated that the current regulations, if appropriately enforced, would provide an acceptable guarantee of provenance and deterrence for IUU. One stakeholder suggested that MMO should invest in additional CCTV within ports.

Multiple stakeholders stated that they believe all types of fishers should be moved onto the digitised systems for catch reporting, including producer organisations and 10 – 12 m vessels. This would remove the variations in submission deadlines for fairness, and allow for timely cross checking of data submissions. There was a perception that a new generation of skippers moving into the industry, there may be generally less resistance to the adoption of new technologies within the fishing industry.

One auction house representative stated that catch data submitted to the MMO should be made accessible and designed so data collected can be used for wider purposes than traceability, e.g., for marine planning and conservation purposes. One example suggested was an increased level of detail of certain catch reporting data points. Currently, reporting of gear type does not provide enough detail for useful insights to be made. Certain gear type options are too high level (e.g., “pot” description should be more precise) and the number of pots hauled that day should be made a mandatory catch reporting field along with total number of pots at sea so that catch per unit effort (CPUE) can be assessed. This type of additional data could be used for scientific purposes, stock assessments, industry analysis reports and contribute to fisheries management plans.

Fishers described their desire for easy access to their own historical catch data for business analysis purposes and checks against quota use. Though a third party application which provides an interface to MMO systems was mentioned as being used by larger fishing organisations, not all fishers have the means to access this tool. Fishers also shared a request for the MMO to be more open around the wider uses of the data gathered and suggested that this would encourage accurate and timely data submissions. Multiple stakeholders across the industry stated that a greater level of trust needs to be developed between the MMO and the fishing industry. Several participants also commented that a wider understanding of the necessity of the existing traceability regulations is required, as many fishers perceive current traceability requirements as MMO tick box exercises.

One wholesaler dealing in exports highlighted the difficulty in providing vessel specific information within catch certificates and stated that a huge amount of effort is required to align catch certificates with landing declarations. The wholesaler stated that permitting mixed substitutions (multiple vessels that contributed to an export batch and their weight contribution) within catch certificates would be a significant improvement to the existing system.

One auction house representative and a wholesaler stated that an improvement to the auction system for buyers would be providing the day of capture for seafood caught on multi-day trips. The wholesaler stated that though they consistently purchase specific grades of Dover sole, they often receive product of varying quality. They stated that they would benefit from additional insight on the catch date of Dover sole and other species they purchase. One stakeholder described the Belgian system as a good example of a system which provides this level of detail to buyers, where distinctions are made between fish caught in the penultimate days of a trip, and fish caught earlier in the trip. They highlighted that this presents an opportunity for premiums to be charged for more recent catch. An initial step towards greater

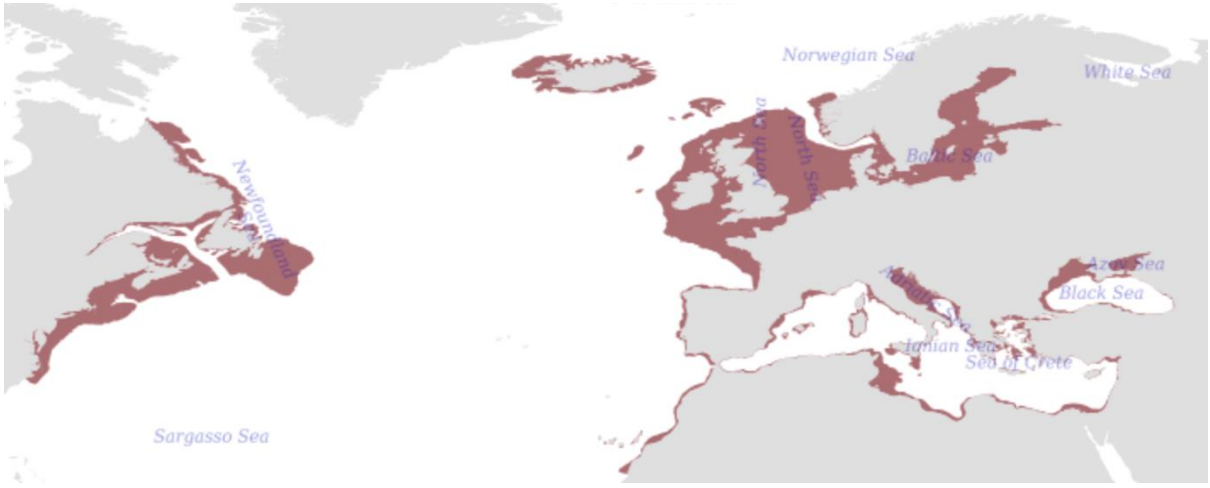
consistency of quality suggested was uniform grading mechanisms implemented across the three southwest auction houses.

6 Case Study B: Mackerel landed at Peterhead, Scotland

6.1 The northeast Atlantic mackerel stock

Atlantic mackerel (*Scomber scombrus*) is a migratory, pelagic fish abundant across Atlantic shelf seas and usually found in dense shoals at depths shallower than 200 m (ICES, 2005). Mackerel distribution ranges across both sides of the Atlantic as well as being found in the Mediterranean and the Black Sea (Nøttestad et al., 2016). Mackerel spawning areas are distributed from the Bay of Biscay up to the western shelf waters including the central North Sea and along the southern coast of Norway (ICES, 2005). Mackerel are considered to have a single stock specific to the Northeast Atlantic. The stock boundaries extend from Iceland and northern Norway down to southern Portugal in ICES Division subareas 1–8 and 14, and in Division 9.a (Seafish, 2022a). **Error! Reference source not found.** displays the Aquatic Species Distribution Map for Atlantic mackerel produced by the Food and Agriculture Organisation of the United Nations (FAO).

Figure 7. FAO Aquatic Species Distribution for mackerel. Reproduced from FAO Aquatic Species Distribution Map Viewer at https://www.fao.org/figis/geoserver/factsheets/species.html (FAO, 2023)



The International Council for the Exploration of the Seas (ICES) provides data based recommendations for total allowable catch (TAC) of mackerel in the northeast Atlantic to ensure the sustainability of mackerel stock. For instance, in 2023 ICES advises that mackerel TAC should be no higher than 782,066 tonnes, down from 794,920 tonnes in 2022 and 852,284 tonnes in 2021 (ICES, 2022a). National TACs are either set unilaterally, or via annual negotiations on catch limits and other stock management measures with between coastal countries, often through regional fisheries management organisations such as the North-East Atlantic Fisheries Commission (NEAFC). For the UK, these negotiations resulted in mackerel TAC of 210,820 tonnes in 2022, down by 5% from 2021 (Defra, 2022a).

For the UK and other northern European countries, Atlantic mackerel commercial fisheries operate primarily over the winter months, with the largest landings seen in January and February and September to November. Exhausted quotas often lead to typically lower landings in December (MMO, 2021). The largest landings of mackerel

in the UK by weight and value are at Peterhead and Lerwick by pelagic trawls. The October/ November landings are typically from catches within ICES division 4a, with the January/ February landings largely from catches within ICES division 6a (ICES, 2005). For example, in 2021, 95% of commercial landings were from pelagic trawls, with the remaining caught by purse seine and handline fishing methods (MMO, 2021).

Frequent lack of agreement and adherence to TAC allocations between northeast Atlantic fishing countries led ICES to state that Northeast Atlantic mackerel stock was being overexploited and had fallen below sustainable levels in 2018. ICES have estimated that from 2010 to 2021, the sum of unilateral mackerel quotas and resulting catches have exceeded the ICES scientific advice by an average of 41% over precautionary thresholds (ICES, 2022a). The unsustainable status of the stock and the absence of a long-term management strategy agreed by all involved parties resulted in the Marine Stewardship Council (MSC) suspending its sustainability certification of all northeast Atlantic mackerel fisheries in March 2019 (MSC, 2019a).

Negotiations between the UK, EU, Faroe Islands, Greenland, Iceland, Norway, and Russia resulted in agreement for the 2022 and 2023 TACs for mackerel, herring (*Clupea harengus*) and blue whiting (*Micromesistius poutassou*) to be in line with the maximum sustainable yield (MSY) as advised by ICES (DEFRA, 2022; European Commission, 2021). However, ongoing disputes over the national allocations of these quotas has prevented the MSC from reinstating the certification of northeast Atlantic mackerel fisheries at the time of publication (March 2023). Changes to stock modelling methods now estimate that mackerel stocks are now above sustainable threshold levels (MSC, 2019).

6.2 UK mackerel fisheries

Mackerel is one of the UK's most commercially important fish. In 2021, mackerel landings into the UK by UK and non-UK vessels valued £106 million, making up 15% of the total value of all species landed. This is the highest contribution of any one species (Seafish, 2021a).

As of Jan 2023, the active Scottish pelagic fleet is comprised of 21 UK registered vessels all of which are over 50 m in length, and four primary processing companies. Mackerel and herring are the main species targeted by the Scottish pelagic fleet, with some vessels also catching blue whiting. The major Scottish ports for mackerel landings are Peterhead in the northeast (76%)[2] and Lerwick in the Shetland Isles (21%), with the remaining 3% being landed across Scottish ports such as Fraserburgh and Ullapool by inshore handline vessels (MMO, 2021). Landings of over 10 tonnes of mackerel can only be made at specified ports.

Mackerel products are both imported to and exported from the UK. The UK is a net exporter of mackerel, exporting 54,000 tonnes of mackerel valued at £92 million in 2021. The initial points of export receiving highest volumes of mackerel are Lithuania, Netherlands, France, China, and Ukraine, from which mackerel is also exported to range of other EU and African countries (Scottish Government, 2021). A

[2] Percentage of total mackerel landings into Scotland by UK vessels by tonnage in 2021

large proportion of mackerel caught by UK vessels is landed abroad, notably in Denmark (6%)[3] and Norway (43%) (MMO, 2021). The high proportion of mackerel landings to non-UK ports is in part due to the high prices available at European market auctions, but also for logistical and business relation purposes.

Prior to 2023, Scottish vessels which landed more than two tonnes of a species subject to TACs were required to demonstrate an economic link to the UK through landing 50% of their quota to UK ports, employing 50% British crew, or by incurring 50% of operating expenditure in the UK. However, as of 1st January 2023, amendments to the economic link licence condition have taken effect, in that the economic link cannot be met via the UK crew employment or operations mechanisms alone. Furthermore, in Scotland, the economic link demonstrated though landings must be to Scotland as opposed to UK wide. Landings targets have also increased 30% in 2023, 40% in 2024 and 55% by 2025 (Scottish Government, 2022a). These changes will likely lead to an increase in the volume of mackerel and herring landings into Scotland (Scottish Government, 2022a).

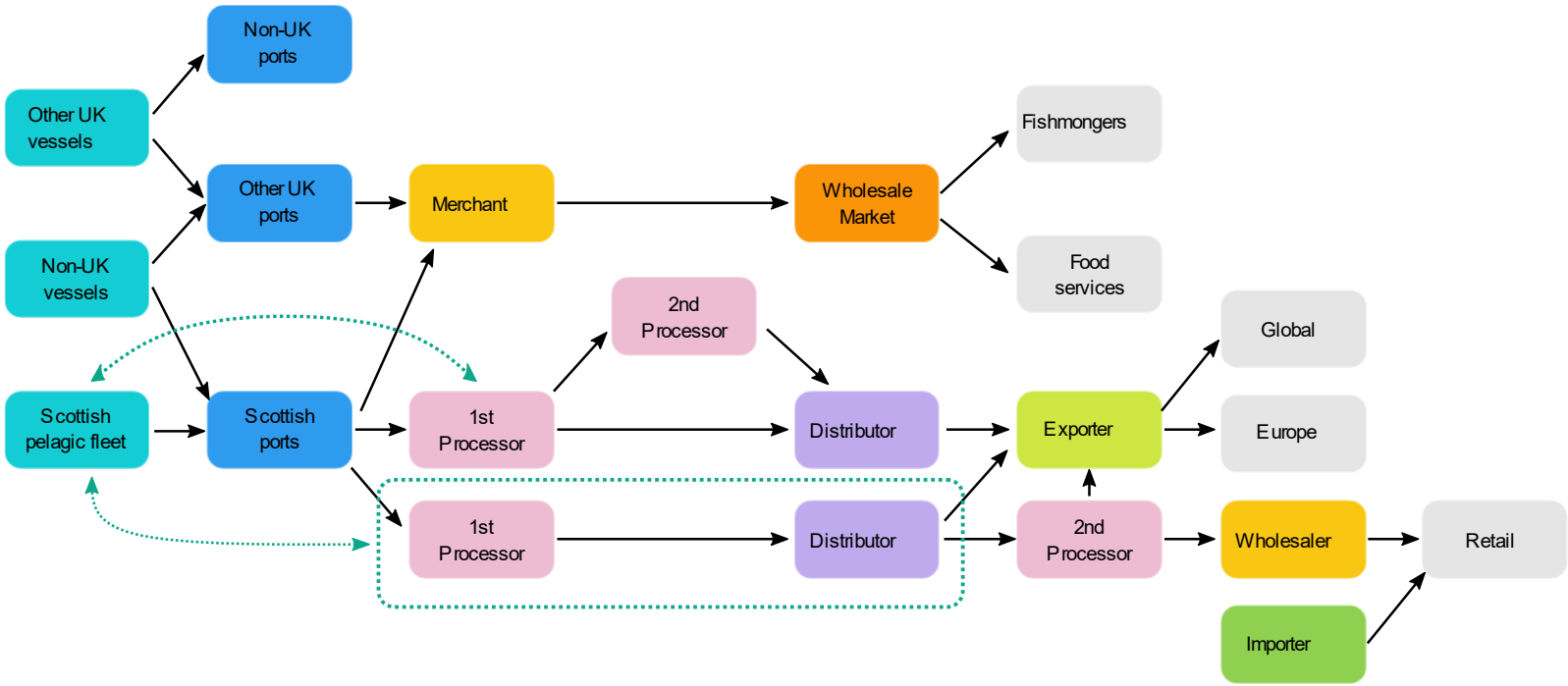
6.3 Interview responses from mackerel industry stakeholders

6.3.1 UK Atlantic mackerel supply chain overview

A relatively small number of organisations handle a large portion of the mackerel landed into the UK. The supply chain of the UK mackerel industry predominantly operates from Peterhead, Scotland where three of the four processing companies are based. The fourth is located in Lerwick, Shetland. Many of these organisations have some degree of vertical integration across multiple stages of the supply chain. Of note is the full or partial ownership of vessels in the Scottish pelagic fleet by the four primary processor organisations. The result is a UK mackerel supply that has low complexity compared to other fishery supply chains. This simplicity is especially true in the early stages (fishing and processing) of the supply chain (Figure 6).

[3] Percentage of total mackerel landings into the UK and abroad by UK vessels by tonnage in 2021

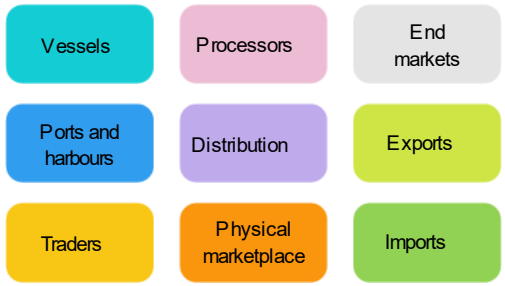
Figure 8. UK mackerel seafood supply chain including percentage tonnage of mackerel landings into the UK and abroad by UK vessels in 2021.



Percentage tonnage of mackerel landings into the UK and abroad by vessels in 2021 (UK Statistics Authority 2021)

Scottish landings	**38.9%**	**Other UK landings**	**1.2%**
Peterhead	29.7%	N. Ireland	1.0%
Shetland	8.1%	England	0.2%
Fraserburgh	0.5%	Wales	0.0%
Other	0.6%		

Non-UK landings	**59.9%**
Norway	42.7%
Netherlands	9.6%
Denmark	5.9%
Ireland	1.4%
Other	0.3%



6.3.2 Traceability during fishing

Fishing industry interviewees reported that the Scottish pelagic fishing fleet which land mackerel to the four Scottish primary processors is made up of 22 high-tech pelagic trawlers. The primary processors stated that the vessels in the Scottish pelagic fleet are either under full or partial ownership by one of three primary processors, and also target other pelagic species such as Atlantic herring (*Clupea harengus*). The exception to the full or partial ownership are the vessels which land into Shetland. Though the vessels landing into Shetland are not directly owned by a primary processor, interview participants indicated that long-standing relationships between the vessel owners and primary processers exist. Therefore, there are high levels of vertical integration in the initial stages of the Scottish mackerel industry. In addition, it was reported that there are some instances of non-UK vessels landing into Scottish ports for sale to mackerel primary processing factories.

All the primary processors interviewed described similar activities carried out by their vessels when fishing for mackerel. A typical fishing trip was described as involving one to three hauls, each taken from locations relatively close to each other, in the same catch area and during a 12-to-24-hour period. The vessels typically had at least 12 holding tanks containing refrigerated seawater kept at -1°C. Multiple processors indicated that individual hauls are kept in separate tanks, allowing hauls to be segregated. Processors also stated that no trans-shipment takes place from the Scottish pelagic fleet, with all hauls being landed directly into Scottish factories, when the catch is landed in Scotland, or abroad.

The primary processors indicated that, while at sea the vessels are in regular communication with processing factories. As all the vessels in the Scottish pelagic fleet are over 12 m long, Scottish (and UK) regulation requires them to record fishing operations in e-logbooks, in line with EU retained regulations (EC) 1224/2009 and (EU) No 404/2011 (EU, 2009, 2011a). The data captured in e-logbooks must include the species and quantity of target species and any discards, as well as the time, location, and the fishing method used. The primary processors and stakeholders representing fishers both considered the e-logbooks adequate for catch recording purposes and for catch data submission following regulatory deadlines.

The use of Vessel Monitoring Systems (VMS), which transmit a vessel's geospatial location data to Marine Scotland every two hours, is also a regulatory requirement for the Scottish pelagic fleet. If the transmission signals fail, the VMS continues to record geospatial data, which is then later sent in a batch to Marine Scotland once a signal is regained and so data gaps are prevented. Vessels are prohibited from returning to sea with a non-functioning VMS.

The Scottish pelagic fleet are all certified by the Responsible Fishing Vessel Standard (RFVS), a voluntary programme certifying high standards of vessel management and safety. A core principle of the certification is catch traceability management. To become certified, vessels must have management structures and systems in place that ensure accurate catch information is available at the point of landing, and vessels must adhere to the legal landing requirements of the country into which the catch is landed (Best Seafood Practices, 2021). The catch data specified in the RFVS is consistent with data submissions required in UK regulations

of e-logbook catch recording and landing declarations. An additional requirement of the RFVS which goes above UK regulation is the requirement to segregate catches made in different areas, from different fish stocks (of the same species) or made using different types of fishing gear (Best Seafood Practices, 2021). The RFVS provides an additional level of assurance of traceability at this stage in the UK mackerel supply chain beyond government regulation and compliance through third party auditing based on industry agreed best practice. The RFVS also allows vessel owners to showcase that their operations meet high level of environmental, social and food safety standards.

Several mackerel industry stakeholders mentioned that a small number of Scottish inshore hook and line vessels, mostly under 10 m, also fish for mackerel in the summer months for sale to fresh market suppliers. The Scottish registered under 10 m vessels are required to submit their landing declarations via FISH1 forms on a weekly basis[4]. The mackerel industry stakeholders noted that the quantities (by weight) of mackerel landed by these vessels are insubstantial compared to the winter landings of the Scottish pelagic fleet described above.

Marine Scotland outlined an additional monitoring mechanism currently applied to a portion of the Scottish fleet in the form of the Fully Documented Fisheries (FDF) scheme, which involves CCTV cameras and sensor technologies on vessels to monitor at sea catch activity. Marine Scotland indicated that currently the FDF unit in Peterhead has only been applied to certain vessels such as scallopers and some inshore crab and lobster vessels. In 2022 Marine Scotland put forward a proposal for the introduction of a Remote Electronic Monitoring (REM) scheme as part of their Future Fisheries Management Strategy (FFM), for which a consultation with industry was undertaken (Scottish Government, 2022b). The proposed legislation would include a legal requirement for UK and non-UK registered pelagic vessels to have a compliant REM system on-board when fishing in Scottish waters. Benefits of the REM proposed by the Scottish Government include additional validation of catch and landing data, improved ability to demonstrate sustainability, and improved input data for stock assessments (Scottish Government, 2022b).

6.3.3 Traceability across landing activities

Peterhead Port, operated by the Peterhead Port Authority, is the UK's biggest white fish and pelagic port. Albert Quay and Merchant’s Quay are used by the pelagic fishing sector for the handling and cold storage of large volumes of pelagic fish landed at the port. In 2021, Mackerel accounted for around 44% of fish landings by tonnage into Peterhead (Scottish Government, 2021). Peterhead Port holds the Seafish Responsible Fishing Ports Scheme (RFPS) certification and the Marine Stewardship Council (MSC) chain of custody accreditation. Prior to the MSC certification being withdrawn from Northeast Atlantic mackerel fisheries, participants recounted that chain of custody audits by the MSC would have taken place every few years across vessels and processing.

As part of UK regulation, vessels in the Scottish pelagic fleet are required to give a four-hour advance notice of their expected arrival to port to local Marine Scotland

[4] The CatchApp system is currently only used in England, orchestrated by the MMO.

fisheries officers. During this window, the local fisheries officers at Peterhead reported that they perform an initial review of e-logbook and VMS data submissions of the trip. Once vessels have arrived at port, the fisheries officers perform various checks to validate that the catch data submitted by masters in e-logbooks matches the catch aboard the vessels. As part of this validation, dock-side weight estimates of catch are performed via dipping tanks which is supervised by the fisheries officers. Weight estimates of catch performed at sea by masters are compared with these port side weights. Marine Scotland specified that they aim to check every pelagic vessel landing into Peterhead and Lerwick.

Mackerel operations in the UK are largely vertically integrated across vessels and primary processors, streamlining this section of the UK mackerel supply chain. As a result, the catch of a Scottish pelagic vessel will be transported to the same processing factory post-landing, often by pipe and conveyor systems, bypassing merchants and wholesale markets. While there is vertical integration of vessels and primary processors, sales notes are still generated as a regulatory requirement of primary processors further ensuring that traceability is optimised.

Peterhead Fish Market, located in Peterhead Port, opened mid-2018 and is certified by the Brand Reputation through Compliance of Global Standards (BRCGS), currently holding an AA rating. Peterhead market is capable of handling 10,000 boxes of fish per day and includes temperature control throughout the market buildings. As all the mackerel landed by the Scottish pelagic fleet is transported direct to the primary processing factories, the only mackerel sold at Peterhead market is landed by the inshore hook and line vessels. Though, as highlighted by several mackerel industry stakeholders, this is a very small quantity comparable to the volumes landed by the Scottish pelagic fleet.

6.3.4 Traceability across primary processing

Each primary processor reported having internal production managers and quality control teams who supervise the traceability processes from landing to the point of sale to downstream supply chain actors. The processors reported that, during landing, these teams assign a batch code (also known by some primary producers as a production code) to the total landing of a vessel which makes up multiple hauls. This is in line with the retained EU regulation 852/2004 on the hygiene of foodstuffs, which specifies traceability of food within a supply chain as a critical component in ensuring food safety and outlines the requirement for food safety management procedures based on Hazard Analysis Critical Control Point (HACCP) principles (EU, 2004).

The batch codes are added to the primary processors' internal documentation which records the details of product entering the processing factories, known by one processor as a 'species intake form', and records the vessel details, e-logbook number, and date of landing. During the interviews one processor indicated that a landing may be split and assigned multiple batch codes in the instance that a customer wishes to buy a pre-determined proportion of a landing or has other specific requests (e.g., Japanese market requirement for top grade raw fish for sushi). Another processor specified that a landing may be split if fish of different hauls are different sizes (± 10 g) or quality (if damaged). Another industry

stakeholder indicated that if a landing takes more than one day, a new batch code is assigned for the second day.

Across all the processors, it was reported that the batch codes are used as the central markers appearing on all internal documentation used throughout the processing process, including species intake forms, sales notes, reconciliation sheets used in quality checks, and invoices supplied to downstream buyers. The use of batch codes therefore facilitates the traceability of catch from vessels through to its sale by the primary processors. All primary processors also reported adding the batch codes to the labels added to the boxes used to move the product around the factories. These batch codes therefore also facilitate the link between traceability catch data captured (vessel details, landing date etc.) and the physical product.

The processors stated that belt weighers are installed in each factory and provide the final weight of each landing. Marine Scotland confirmed that they perform regular verification checks of the weighing equipment and use the final weights for quota usage calculations. According to the UK's fishing license conditions, catch weights estimations performed by the master onboard the vessels and that performed port side must be in a 10% margin of tolerance of this final value (accounting for 2% of final calculated weight attributed to additional water) (UK Government, 2023). All processors interviewed stated that deviations of more than 4% aren't common as the pelagic vessels have high-tech facilities for estimating catch weights. For example, several of the vessels have water displacement technology in their pump and tank systems, allowing for highly accurate weight estimates to be performed onboard. Marine Scotland indicated that the flow scale weights are cross checked against the landing declarations submitted to them as a deterrent against under-reporting of catches.

All processors interviewed specified that raw fish received from the vessels is typically graded according to size, though in some instances it may also be separated according to quality if some degradation has occurred (e.g., net tangling), though this is rare. It was noted that sample weighing of individual fish is performed every 3 minutes when pumping mackerel onboard to deduce the haul's average size profile. One processor mentioned that some buyers request grading sheets detailing the average size profile if they require a particular size of fish. Each primary processor described a similar set of stages for processing a single batch of mackerel, known as a processing run. The primary processors also stated that their factories only process one batch of mackerel (i.e. one landing) at a time. Post weighing, raw fish is either frozen whole or undergoes processing (e.g., removal of head & viscera) and is stored in boxes (often 20 kg though dependant on customer requirements). Though the fish of a particular batch may be sorted according to variables such as size, quality, or processing type, fish from different batches are never mixed. A single day's processing run can therefore be traced back to a single landing.

All processes stated that labels including batch numbers are added to the 20 kg boxes before freezing. One processor mentioned that bar codes had been used to identify boxes previously. However, scanners deteriorated during long exposure to cold temperatures and the processor reverted back to handwritten labels. Another processor stated that they still use barcodes to track fish around their factory. There

was variation between the primary processors regarding the information added to the labels, though all used batch codes. Additional data points added to labels were vessel name, catch area, fish average size profile, production run date, shelf-life, and temperature of storage. In some instances, processors mentioned that labels translated into different languages are produced for certain exports. Racks of fifty 20 kg boxes are then placed in cold storage facilities as required, with one processor stating they have facilities capable of storing 30,000 tonnes across three sites.

The primary processors stated that they complete production sheets which detail the type of processing undertaken, and that these are a requirement for onward selling to buyers. As production sheets are a business requirement as opposed to being regulatory driven, different formats exist between processors, though the content described was largely consistent. For instance, processors listed batch codes and e-logbook numbers as key data points included on production sheets. Production sheets therefore establish the link between the vessels and primary processing factory for downstream buyers, establishing traceability back to vessels for later stages in the supply chain.

The primary processors described many checks that are performed throughout processing as part of quality management, for example work in progress temperature checks, hourly box weight checks, and landing reconciliations. Several processors stated that the paper documentation used for these checks is digitally scanned and stored on internal IT systems to be available for audits and customer requests. It was indicated that customer demand for this type of information varies, with some customers visiting factories, some requesting documentation, and others buying fish without stipulating additional data requirements. Processors stated that fresh fish tends to be sold to secondary processors while frozen fish is exported abroad.

A variety of paper-based and technological systems exist across the factories for data and stock management. For example, one processor described a bespoke IT system which integrates with an e-Sales system and utilises barcodes to track fish around the factory. A different processor uses hand-written labels on boxes, and scans paper documentation into a central archive system. Another processor uses an Excel-based system and is in the process of installing an integrated stock management and sales system. As different as these systems are, they enable the primary processors to link existing stock and historical sales back to the production run in which the raw material was processed using batch codes. These systems and processes therefore function as internal traceability systems and can be used to recall catch and processing data if requested by downstream actors of the mackerel supply chain.

For compliance purposes, Marine Scotland stated that they perform audits of the processing factories in the form of scheduled annual visits and spot checks, in which reviews of paper documentation and IT systems and physical inspections occur. This provides a level of assurance to downstream actors of the mackerel supply chain and consumers that reported catch and processing data is accurate. Marine Scotland specified that a key element of these audits is validation that the weight of the fish reported to have entered the factories corresponds to what is reported as sold, as this provides assurance against underreporting of fish. For the factories that

sell whole fish or undertake only basic processing, the two weights can be relatively simple to equate. However, where more substantial processing steps have been undertaken, such as various forms of filleting, conversion factors must be applied to the end weights, which reduces the certainty of the comparison. Furthermore, Marine Scotland stated that the presence of ice during transport, and the seasonal and geographical differences in catch, such as variations in fat content, also impact the weights which adds further complexity to the conversation factor calculations. Marine Scotland indicated that there is ongoing work to improve the accuracy of these conversion factors.

Local authority Environmental Health Officors (EHOs) will perform audits on factory premises to check compliance with food hygiene and safety management regulations. Two of the processors stated that their factories and storage facilities are BRCGS grade AA certified, which predominantly provides food safety standard assurances, along with other environmental and social metrics, to other downstream actors of the supply chain.

The by-products of processing (viscera, head, bones, and broken fish) are commonly used for fish meal, fish oil and shellfish bait. Two of the primary processors stated that the by-product from their mackerel processing runs is used for this purpose. In discussion of the traceability of the by-products once they have left the primary processing factories, those processors stated that by-product remains traceable back to a specific vessel, as by-product from one day's processing run will be transported. However, once the by-product reaches the fishmeal factories, the processors speculated that traceability is often lost as the by-product material is merged with by-product from other processing runs and with the by-product of other factories and species and stored in large silos.

6.3.5 Traceability across secondary processors

Canned mackerel

There is one secondary processor that purchases whole fresh mackerel from the four primary processors in the UK mackerel supply chain. This secondary processor is the only manufacturer of canned fish in the UK (hereafter known as the 'canned mackerel processor') and is located in the northeast of Scotland. The secondary processor advertises that it has made a commitment to buy mackerel only from Scottish processors.

The canned mackerel processor stated that their procurement department receives traceability data in the form of production sheets from the primary processors. These sheets provide the data elements required for the traceability of the mackerel product to be maintained between the processing organisations. This canned mackerel processor also uses an IT based system stock and sales management, into which the procurement department manually inputs the data received in production sheets. Data points include processor name, vessel name & registration number, catch area and catch method, species, trip departure and arrival date, landing port, landing date, and batch number. The canned mackerel processor stated that, though data entry is manual, this is not an onerous process subject to errors, as the large quantities of mackerel that make up a primary processing run require only one set of

data to be inputted into the system. In the IT system there is a catch enquiry programme from which data on product attributes can be retrieved for internal purposes, or if requested by up or downstream supply chain actors.

When the 20 kg boxes of mackerel are received from the primary processors, the labels on boxes are also received. The canned mackerel processor indicated that verification checks are performed to ensure that the boxes received match details on the documentation provided. In addition, physical copies of labels are stored, and digital scans taken, and these records are kept for seven years. This record keeping ensures that regulatory 1-up traceability requirement can be met beyond the expiry date of the canned mackerel end product.

The canned mackerel processor stated that for their own internal traceability and production management systems, a production code for each daily production run is generated. This production code includes reference to factory site, the product type, and data of the production run. To establish the link between the mackerel input product and output product, the secondary producer stated that the production code is added into the internal IT systems and mapped to the primary processor's batch code. If multiple batches of input product are used in one day's processing run, the percentage volume of raw material from each input batch is also recorded.

To propagate this production code as a traceability marker down the supply chain, the secondary producer specified that all cans processed in a day's processing run will be physically tagged with this daily production code, either lithographically on blank cans or via printed labels. The secondary producer stated that if a raw materials enquiry is received for a particular can, this production code is the marker used to identify the primary processor and other data via its mapping to the primary producer's batch code in the internal IT system. This mapping of the two codes facilitates the traceback mechanism.

Can labels and packaging are also printed by the canned mackerel processor for retailers, largely supermarket own brand labels. The secondary produced confirmed that whilst design and data requirements vary per retailer, the legal information provided on can labels is consistent with the Fish Labelling Regulations 2013 (species, catch area, method of capture, production method, expiry date, etc.) (UK Government, 2013).

The canned mackerel processor also stated that their factory holds the BRCGS certification with an AA rating, providing food safety assurances the downstream supply chain. During the BRCGS certification audits, physical paperwork and internal IT systems are checked against safety, quality, and traceability metrics. In preparation for these audits, end-to-end traceback checks are performed and documented each year by the factory Quality Control Manager. An example recall exercise is also undertaken annually as part of the Food Standards Scotland or Local Environmental Health audits.

The canned mackerel processor shared that one of their main buyers is a trader who acts as an intermediary selling to six large retailers in the UK. The canned mackerel processor stated that they do not share production sheets or other documentation to their buyers as traceability is facilitated via the production codes on cans. However,

the canned mackerel processor mentioned that some buyers do request additional information. For example, one high-end brand who advertises catch-to-can traceability requests various source material data for their purchased cans, including vessel name and license holder, catch area and method and landing port and date. Consumers of this brand are then able to trace their purchased fish back to the specific vessel by entering the code on the can into their website.

Smoked & other value-added mackerel products

Additional secondary processors exist which specialise in smoked mackerel for the UK chilled retail sector and frozen foodservice sector (hereafter known as the 'smoked mackerel processor'). A smoked mackerel processor stated that they also purchase mackerel from the Peterhead primary processors. Similar to the canned mackerel producer, the smoked mackerel processor stated mackerel is received frozen in pallets containing multiple boxes, each labelled with the supplier's batch code. Production sheets detailing the supplier's name, batch code, species, method of processing and production run date are also supplied by the primary processors, and data added into the smoked mackerel processor's IT stock management system.

When outlining their production processes, the smoked mackerel processor stated that their production team selects pallets for the day's production run to be transferred from cold storage to the factory to be defrosted and processed. If input batches from multiple suppliers are used in one day's production run, the smoked mackerel processor stated that a break in the processing activities is initiated, such that the output batches are segregated, and each output batch only corresponds to one input batch. Furthermore, the smoked mackerel processor stated that the output batches will be assigned different production codes, and colour-coded tags are added onto the trolleys on which the processed fish is loaded. The smoked mackerel processor described the tags as containing the newly assigned production code, method of processing, species, box weight, and customer (if known). These tags are kept with the physical fish as it progresses through the factory for value-add processing such as smoking/ brining/ flavour add and into blast chill rooms. The smoked mackerel processor stated that details of the processing run, including the value-add processing steps and production code, are recorded in their IT stock management system, and mapped to the batch codes and corresponding catch and processing information supplied by the primary processors.

The smoked mackerel processor stated that detailed packing sheets are populated during packing, including the time the stack is added to the packing line, the customer, and the colour-coded trolley tag details for every stack of fish removed from the chill storage. Post packing, these details are then cross checked against the final products packaged. The smoked mackerel processor indicated that if anomalies are found, the times recorded on the packing sheets can be compared with the real time stamp printed on the outer case packaging labels in order to identify which batch of fish was used.

The smoked mackerel processor also stated that the shelf-life date is added to the mackerel packaging on pre-printed labels, along with the finished product weight, price, and customer bar code. The smoked mackerel processor stated that each

day’s production run will have a different ‘use by’ date allocated dependent on the customers’ shelf-life requirements. The shelf-life date and the real time stamp are the traceability markers through which a particular day's processing run can be identified. In addition, the health and identification mark added identifies the specific manufacturing site of the final product as per retained EU 1169/2011 on the provision of food information to consumers (EU, 2011b). From these markers, stages up and down the supply chain can be traced.

6.3.6 End market

In 2018, the highest proportion of mackerel sales by value in the UK market was chilled (62%), with ambient (shelf stable products such a tins) making up 36% of sales and frozen only 2% (Seafish, 2018). While tuna still dominates as the highest ambient seafood species by value share (67%), sales of mackerel have steadily increased and now mackerel is the second most valuable ambient seafood species in the UK making up 10% of the market value (Seafish, 2022b).

6.3.7 General attitudes towards traceability

When the purpose of traceability and the interviewee’s general attitudes towards traceability was discussed, mackerel industry stakeholders highlighted the transparency between businesses in the mackerel supply chain to demonstrate the quality and sustainability of their products. Several mackerel industry stakeholders described good working relationships between vessels, primary processors, secondary processors, and retailers, and that this promotes transparency across the mackerel supply chain for the benefit of all parties. The mackerel primary processor extended this, describing horizonal transparency amongst each other, including the sharing of best practice and collaboration on industry initiatives such as a Mackerel sampling scheme. The primary processors stated that organisations such as the Scottish Pelagic Processors Association (SPPA), which represents all four primary and both secondary processors, helps to facilitate these positive relationships, trust and transparency between the mackerel industry stakeholders.

When discussing the effectiveness of the existing processes, regulations, and technologies in place for traceability across the mackerel supply chain, several stakeholders shared that they believe the existing mechanisms work well. Two stakeholders attributed the small number of supply chain actors, and good relationships between the mackerel industry stakeholder as the reasons why existing mechanisms are effective. One stakeholder mentioned the mutual trust that other supply chain actors also put high importance on traceability as an important factor in the efficacy of the existing traceability systems. The stakeholder mentioned use of voluntary third party certification schemes such as RFVS, and the stringent regulatory checks of vessel and factories performed by marine officers helps to build this trust.

During discussion of the potentially negative implications of high levels of traceability and transparency across a supply chain, no mackerel stakeholders mention any negative implications of data sharing. However, some hesitancy was expressed by multiple processors at the prospect of any extensions to existing regulations, due to the potential for higher administrative burdens and cost. The mackerel supply chain

stakeholders described little to no customer drive for higher levels of transparency, indicating low market drive for changes to existing systems and data provided.

With regard to additional technologies that could be used to facilitate traceability, multiple stakeholders responded that, though self-contained (i.e. lacking in interoperability), the existing IT systems are adequate. One stakeholder shared their negative views on blockchain, highlighting their perception of the negative environmental impacts of its intensive energy usage, while stating that it offers little advantages above the existing processes and systems in place across the mackerel supply chain.

6.4 Good practice, challenges, and suggested improvements

The Scottish mackerel industry is an example of a supply chain with effective traceability structures and processes in place, largely the result of the vertical integration of its vessels and primary processors, and the use of batch codes and production codes as marker to facilitate traceability through the supply chain. Furthermore, an environment of trust facilitated in part by organisations such as the Scottish Pelagic Fishermen's Association (SPFA) and SPPA promotes transparency across the UK mackerel industry.

Though large quantities of mackerel are landed into the UK comparable to other species (Scottish Government, 2021), the UK mackerel industry has a relatively small number of organisations acting across the supply chain, with the vast majority of UK mackerel passing through only six organisations from capture through to processing and export. This small number of organisations simplifies the UK mackerel supply chain. In addition, many of the vessels and primary processors are vertically integrated, with one organisation operating at multiple stages of the supply chain. The small number of organisations results in fewer opportunities for breakdowns in traceability as data is only transferred between parties a small number of times.

The high economic value of the mackerel industry (Seafish, 2021b), and the large market share of the key organisations to enables them mackerel industry stakeholders to invest in the technologies and resources that allow effective management of their own internal traceability. Examples included sophisticated vessels that can determine catch weights with high accuracy, to stock and sales management IT systems, and procurement and quality assurance managers that own and manage traceability data and processes from landing onwards.

Both Marine Scotland and the mackerel industry stakeholders stated that regulatory requirements and deadlines regarding data submission are routinely met with no delays or omissions. Furthermore, internal systems and processes tend to go beyond regulatory requirements. Though there is little interoperability between the individual IT systems of different supply chain actors, documentation detailing key traceability data is passed between the initial stages of the supply chain. In addition, traceability markers in the form of batch and production codes are used throughout the industry. Each organisation assigns their own markers to identify a landing or production run, and upstream actors supply their markers to downstream actors through documentation and adding them to packaging. This enables the mapping of

multiple organisations markers and facilitates end-to-end traceability or mackerel product as it moves through the supply chain.

The characteristics of the UK mackerel industry, including the small number of actors, high levels of trust and transparency between the actors, and high investment in technologies and resources, enable effective traceability across the supply chain. These factors are also what make the mackerel supply chain unique, as seafood supply chains are typically characterised by slim margins, limited interoperability of technical systems, and lack of cooperation between the large numbers of supply chain actors (Bhatt et al., 2016; Fox et al., 2018). The only species with a supply chain that could be considered comparable to mackerel is herring as it largely caught and processed largely by the same organisations as mackerel.

When conversing on possible areas of improvements for traceability across the mackerel supply chain with mackerel industry stakeholders, one area proposed was maintaining traceability back to the haul level. Primary processors responded that this would not add additional value, as hauls making up a landing are segregated in this instance that this allows the processors to meet a particular buyers request, or if hauls have differences in fish quality or size. Furthermore, traceability back to a specific haul is not a regulatory requirement.

An additional improvement could streamline of the reporting processes for the under 10 m vessels, through this would not impact the bulk of the UK mackerel industry which used over 50 m vessels. One improvement suggested by Marine Scotland was better integration of Fish1 catch recording system with Marine Scotland's other systems, to allow for easier analysis into compliance. In addition, there is ongoing work to move to a fully digital reporting system to remove administrative burden and reduce the risk of data entry error associated with manual data input.
An ongoing activity undertaken by Marine Scotland aiming to improve their ability to detect possible instances of underreporting is the work to improve the accuracy of processing conversion factors. An additional improvement to existing compliance systems suggested by Marine Scotland is the introduction of REM systems on the Scottish pelagic fleet. Though the vessels are highly sophisticated, Marine Scotland states that they do not have real-time oversight into the fishing activity which FDF systems provide. However, Marine Scotland did indicate that, although improvements can always be made from a compliance perspective, the existing systems are considered thorough and well-equipped to monitor the fleet's activity to deter and prevent IUU.

7 Case Study C: Brown crab and European lobster landed at Bridlington, England

7.1 North Sea shellfish industry

Shellfish is a fisheries term for aquatic invertebrates caught and harvested for human consumption. Shellfish primarily includes crustaceans (*Crustacea*) such as crabs, lobsters, crayfish and prawns, and molluscs (*Mollusca)* such as squid, mussels, oysters, and scallops (Gökoğlu, 2021). The shellfish seafood industry is comprised of both aquaculture and wild capture, collectively making up 25% of global aquatic food consumption in 2019 (FAO, 2022). A key distinction for shellfish supply chains in comparison with other seafood products is that shellfish are often stored and transported live as they are highly susceptible to bacterial contamination once they die (Wittman and Flick, 1995). Therefore, efficient live transport and storage of shellfish is a key component of shellfish supply chains to preserve value and ensure food safety of shellfish products (Gökoğlu, 2021).

7.1.1 Brown Crab

Brown crab (*Cancer pagurus*), also known as edible crab, is a decapod crustacean with an oval carapace and a distinctive 'pie-crust' edge (EUMOFA, 2021). Brown crab live in a broad range of benthic habitats, from soft muds to rocky substrata at the littoral zone to depths of 100m (Mesquita et al., 2021). Brown crabs are distributed widely across the eastern Atlantic, ranging from northern Morocco to northern Norway (EUMOFA, 2021), (**Error! Reference source not found.**).

Figure 9 FAO Aquatic Species Distribution for brown crab. Reproduced from FAO Aquatic Species Distribution Map Viewer at https://www.fao.org/figis/geoserver/factsheets/species.html (FAO, 2023)

In 2019, the global catch of brown crab was 50.5 tonnes, 60% of which was caught by the UK. All UK landings were registered to FAO fishing area 27 (EUMOFA, 2021).

Brown crab is usually caught by commercial fisheries using baited pots and traps but are also caught as bycatch in trawl and net-based fishing activity (Seafish, 2023a). Shellfish pots and traps are considered to have lower environmental impact compared to mobile fishing gear as they cause less damage to the seabed, are more size selective and limit bycatch compared to mobile gear types (Seafish, 2023a; Stevens, 2021). However, the use of static fishing gear such as shellfish pots and traps has been found to have various environmental impacts including increased sediment suspension, changes to the benthic communities and changes to the physical structures within benthic habitats (Fennell et al., 2021). Typically, brown crab is initially sold live, and then once dead is either sold whole (chilled or frozen) or sold as value-added products which involves the processing of crab meat (e.g., dressed crab, crab cakes or crab paste) (EUMOFA, 2021).

7.1.2 European lobster

The European lobster (*Homarus gammarus*), often known as the common lobster, is a clawed decapod crustacean with a hard carapace covering both head and thorax (Seafish, 2003). European lobsters are typically found on hard and rocky substrata from the low tide line to 150m deep (Jenkins et al., 2019). The European lobster is widely distributed across the eastern Atlantic Ocean from the Norwegian Arctic to Morocco and is also found in the Mediterranean Sea and parts of the Black Sea (FAO, 2023) (**Error! Reference source not found.**).

Figure 10 FAO Aquatic Species Distribution for European lobster. Reproduced from FAO Aquatic Species Distribution Map Viewer at https://www.fao.org/figis/geoserver/factsheets/species.html (FAO, 2023)

European lobster populations are of high importance to local fishing communities and regional economies due to the European lobster's high market value. Similar to

brown crab, European lobster is caught using baited pots and is sometimes caught as bycatch in crab fisheries using inkwell style pots (Seafish, 2023b). Within UK supply chains, European lobster is usually delivered live and stored in vivier tanks and flow through trays until sold. European lobster is also sold frozen (raw or cooked) and to a lesser extent processed into products such as bisque (EUMOFA, 2018).

Over the past 25 years there have been numerous improvements to lobster hatchery techniques used across Europe and North America, leading to more viable hatchery-reared juvenile release programmes aimed at stock enhancement and improvement of natural habitats (Hinchcliffe et al., 2021). Though improvements to the fitness of cultured lobsters have been observed as a result of developments in lobster hatchery techniques, further investigations into their impact on the assurance of lobster stocks are required. Furthermore, lobster hatcheries as a stock enhancement method can be substantially more costly than other conventional fishery management tools, such as minimum landing sizes and protecting brood-stock (Seafish, 2003).

7.2 UK brown crab and European lobster fisheries

Since the 1940s, there has been a steady increase in shellfish landings into the UK by the UK fleet. In 2021, shellfish made up 20% of total UK landings by weight (MMO, 2021). Between 2015 and 2019, the UK caught around 60% of the total global catch of brown crab, making the UK the largest brown crab catching nation (EUMOFA, 2021). Bridlington, in the North-east of England, aims to be recognised as the 'Lobster Capital of Europe', as it consistently lands the highest tonnage of European lobster for the continent (OECD, 2023).

During the period from 2015 to 2019, UK crab and lobster landings increased by 78% and 43% respectively, leading to concerns over the sustainability of some UK crab and lobster fisheries (Seafish, 2020). As such, the UK fisheries authorities have confirmed crab and lobster fisheries stock assessments will be incorporated into a Fisheries Management Plan (FMP) (Seafish, 2022), which are a requirement under the Fisheries Act 2020 (UK Government, 2020). A decrease in the total value of UK shellfish landings was experienced in 2020 which can be attributed to the effects of Covid-19 (MMO, 2021). While the fishing industry generally was severely impacted by the Covid-19 pandemic, the UK shellfish industry suffered more significant decreases in total landings value compared to demersal and pelagic fisheries (MMO, 2021). This more severe impact was the result of Covid-19 restrictions on the hospitality sector which reduced demand for fresh shellfish products (EUMOFA, 2021).

7.3 Management of UK crab and lobster fisheries

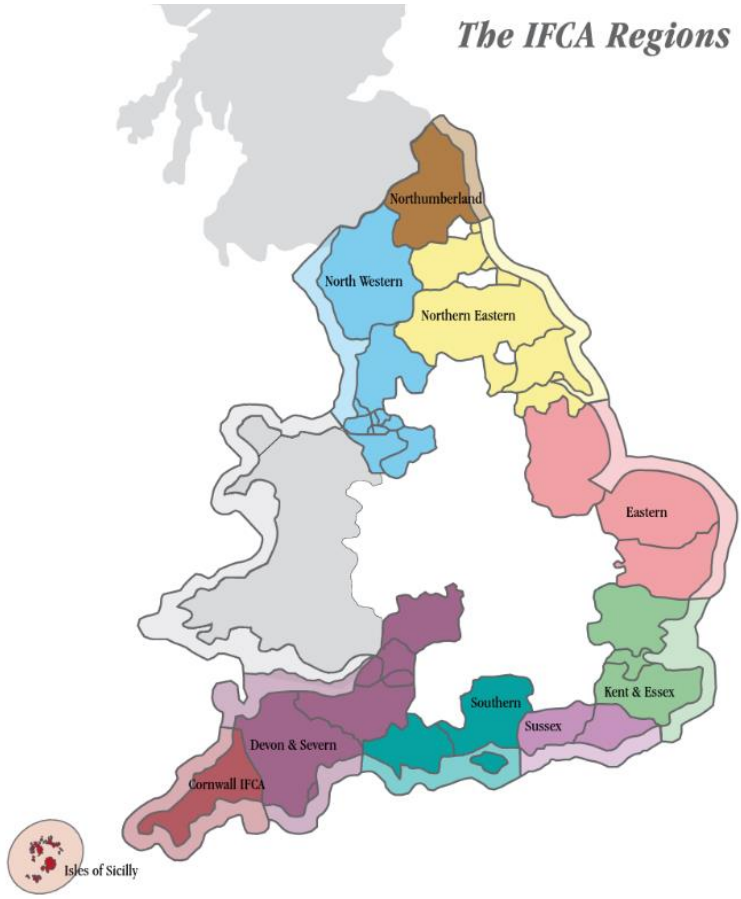
In the UK, several shellfish species are non-quota, including, among others, brown crab and European lobster, with a notable exception being the quotas applied to *Nephrops* (MMO, 2023). Though brown crab and European lobster are non-quota species, a daily catch limit is applied to licensed fishing vessels across the UK that do not hold a shellfish entitlement, permitting the daily landing of a maximum of 5 lobsters and 25 crabs (UK Government 2015a).

In England, fishery management jurisdiction is divided between the Inshore Fisheries and Conservation Authorities (IFCAs) from the coast out to a distance of 6 nautical miles (known as ‘inshore waters’), and Defra/the MMO beyond the 6 nautical miles (see see Figure 4.

Figure 4. IFCA regions (IFCA Association, 2023)

). IFCAs are responsible for the sustainable management of fisheries, including fishing activities in Marine Protected Areas. Additional permit requirements and byelaws are in place in these regions which differ between the IFCAs. In Scotland the Fisheries Management and Conservation Group (FMAC), chaired by Marine Scotland, holds a similar remit to the IFCAs, and is responsible for sustainable management and conservation of Scottish seas and inshore fisheries.

Figure 11. IFCA regions (IFCA Association, 2023)



In England there are five Crab Fishery Units (CFU) and six Lobster Fishery Units (LFU) based on understanding of larval distributions, hydrographic conditions, and distribution of the fisheries (Cefas, 2020a, 2020b). Local legislation may differ between regions due to lack of correlation between the CFU and IFCA boundaries. Cefas produces stock assessments for each CFU every two years, and Cefas highlights the uncertainty of assessing shellfish stocks due to changes to reporting systems over time impacting comparability between annual data sets, and the use of

the Length Cohort Analysis[5] (Cefas, 2020b). Bridlington, on which this report focuses, falls under the Southern North Sea CFU and the Yorkshire Humber LFU. In 2019, the Cefas stock status assessments determined the brown crab exploitation rate to be high (beyond the maximum sustainable yield for males and females) for both the Southern North Sea CFU and the Yorkshire Humber LFU (Cefas, 2020a, 2020b).

Case Study: Crab and lobster management at Bridlington

This case study is focused on Bridlington Harbour, in the North-eastern Inshore Fisheries & Conservation Authority (NEIFCA). NEIFCA byelaws relevant to shellfish include:

- Crustacean conservation fishing prohibitions such as vessel length (less than 14m) and minimum sizing (140mm for edible crab).
- Requirements for the appropriate redepositing of any shellfish prohibited to catch by any NEIFCA byelaws or Acts of Parliament.
- Closure of areas of the shellfish fishery if stock levels are found to be depleted.
- Regional permit requirements for the catch of European lobster, brown crab, velvet crab and whelk (NEIFCA, 2009a).

In addition, the NEIFCA requires the submission of monthly catch return forms detailing the daily catch weights, along with catch area, gear type, and vessel details. This is a paper-based form, through the NEIFCA is currently in the process of developing a new online catch reporting system. This is alongside catch data submissions to the MMO to collect different requirements, though formal engagement and data sharing agreements exist between the NEIFCA and the MMO. One of the NEIFCA's key priorities in 2022/2023 is detailed assessments of the crab and lobster stocks in the NEIFCA region (NEIFCA, 2022).

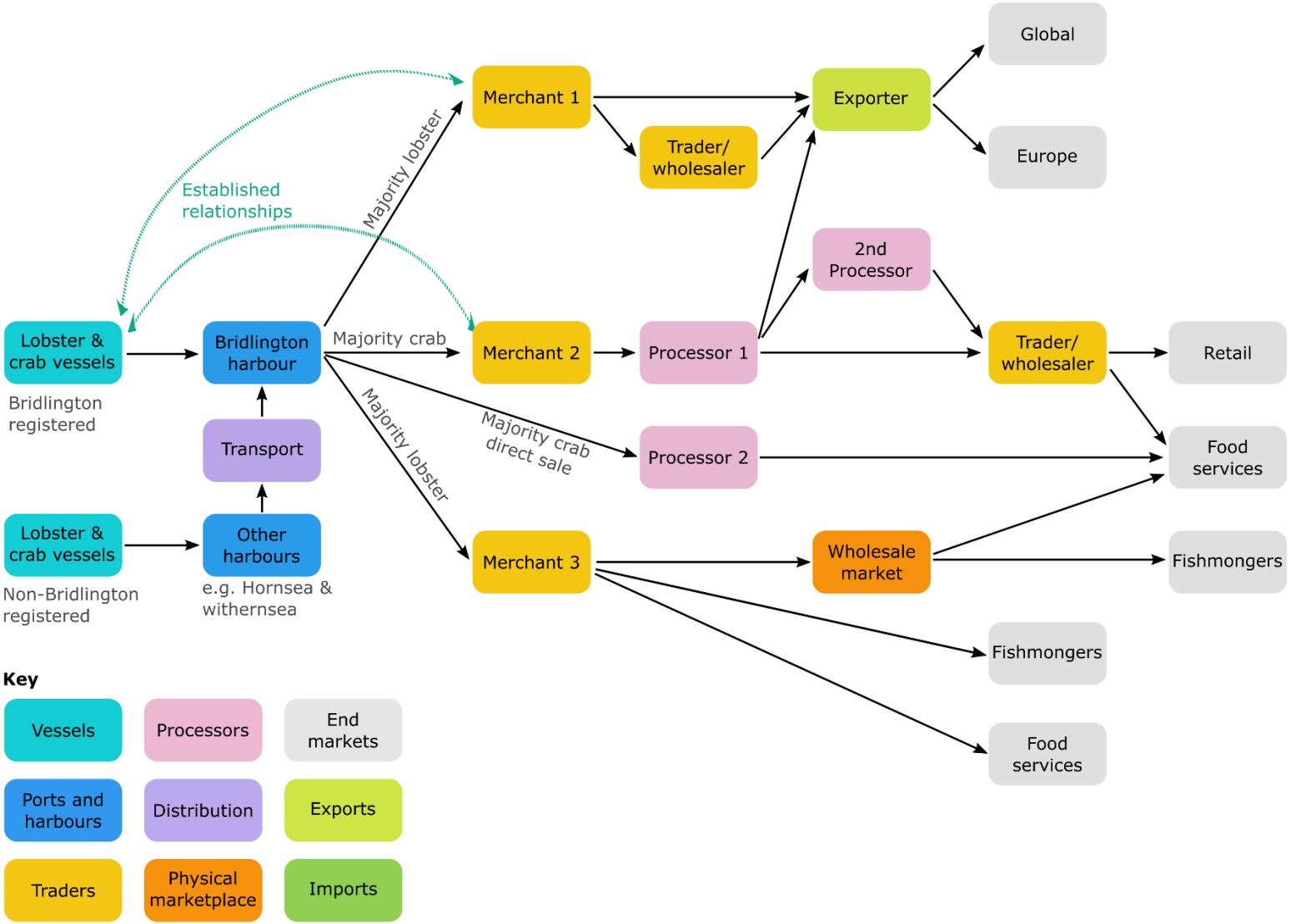
7.4 Interview responses from crab and lobster industry stakeholders

7.4.1 UK brown crab and European lobster supply chain overview

A large portion of the UK brown crab and European lobster industry supply chain is based out of Bridlington. Three merchant organisations handle the crab and lobster that is landed into Bridlington or transported to Bridlington from nearby ports. The first point of sale is the purchasing of crab and lobsters by these merchants from the fishers, though some direct selling from fishers to other supply chain actors does occur. Though there is no reported vertical integration of fishers, merchants or processors, well-established relationships were described between these early supply chain actors, **Error! Reference source not found.**.

[5] Typical stock assessments that make use of annual growth rings to determine an individual's age cannot be used for crustacean stock assessment as they moult their shells. Length Cohort Analysis is an alternate approach which analyses changes in the shape of length-frequency curves between years (Cefas, 2020b).

Figure 12. UK brown crab and European lobster supply chain based out of Bridlington, UK



Note: boxes represent types of supply chain components operating across the industry, not specific organisations.

Once in the possession of the merchants, there is a distinction in the handling of crab and lobsters, with lobsters stored in vivier tanks for multiple days, and crabs stored in crates for immediate onward transport. Lobsters are typically transported live to fishmongers, food services, and wholesale markets, with a significant portion exported to the continent either directly by the Bridlington merchants or indirectly via traders. Logistical constraints on the successful transport of live lobster result in a 'streamlined' supply chain, with lobster passing through relatively few supply chain actors before being sold to final consumers.

Some high quality crab follows a similar route to lobster. However, large quantities of crab are also purchased for processing into a diverse range of end products. In some instances, crab meat from various vessels, ports and regions can be amalgamated, limiting traceability capabilities. The result is fairly complex and diverse brown crab supply chains across the industry, with numerous primary processors, secondary processors, and traders/wholesalers in various configurations beyond the first point of sale.

7.4.2 Traceability during fishing

Fishing industry interviewees reported that there are around 45 vessels of varying lengths (8m to 15m) that berth in Bridlington harbour. The crab and lobster vessels described by interviewees are UK registered and privately owned by the fishers. Fishers and merchants confirmed that there is no vertical integration of the catch and first point of sale stages of the crab and lobster supply chain based out of Bridlington, however, longstanding relationships between merchants and vessel skippers/owners exist. Fishing industry interviewees stated that the fleet are predominantly potters targeting crab, lobster, and whelk, and that most trips are daily, though some of the larger vessels with vivier tanks aboard (only 4-5 of the vessels within the fleet) may do multi-day trips. The merchants and local MMO officers confirmed that non-Bridlington registered vessels do occasionally land at Bridlington, however, this is a rare occurrence.

Fishing industry interviewees stated that Vessel Management Systems (VMS) are in use by the larger vessels of the Bridlington fleet (greater than 12m), which capture and transmit positional data to MMO marine monitoring centres. One merchant mentioned the 'teething-issues' experienced by the fishers regarding the introduction of the Inshore Vessel Management Systems (iVMS), which have been adopted by some of the smaller vessels in the fleet (lesser than 12m) in preparation for upcoming 2023 regulatory change requiring their use whilst fishing in UK waters (UK Government, 2022). Fishers and merchants mentioned complaints made about the associated upfront costs of iVMS to fishers.

The range of vessel lengths mean that catch and landing reporting to the MMO are via a combination of e-logbooks, paper-based logbooks, and the CatchApp. The merchants relayed that there has been mixed feedback from the fishers regarding the introduction of the CatchApp, with some reporting time savings and others complaining of its lack of usability. The local MMO staff stated that there were implementation challenges increasing fisher uptake, though this improved with training. They also described effective use of e-logbooks for catch reporting at Bridlington, with accurate records submitted within regulatory timeframes.

Discussing paper-based reporting, the local MMO staff mentioned that there can be delays in receiving paper-based catch reports via post, impacting regulatory submission deadlines of paper-based submissions. They discussed the inconsistency of this with other submission mechanisms. MMO staff stated an improvement to traceability could be achieved be moving all vessels across to consistent digital systems.

One of the merchants stated that some of the smaller vessels in the Bridlington fleet operate within the 6 nautical mile region that is managed by the NEIFCA and are therefore subject to the NEIFCA byelaws and catch reporting requirements. There are some inconsistencies between the NEIFCA bylaws and wider National legislation, such as the Crustacean Conservation Byelaw which prohibits the catch of brown crab with a carapace width less than 140mm (NEIFCA, 2009b). Beyond the NEIFCA district, the UK Sea Fisheries legislation within the Central North Sea CFU prohibits the catch of brown crab with a carapace width less than 130mm (UK Government, 2000). The merchant stated that the larger minimum size leads many vessels to operate solely beyond the 6 nautical mile boundary. NEIFCA stated that the inconsistency in carapace sizing is due to be addressed within FMPs.

It was highlighted within interviews that though there is a joint data sharing agreement between the MMO and NEIFCA, improvements could be made to reduce the duplicate data submission requirements on the fishers from both organisations. However, an NEIFCA representative emphasised their requirement for catch location reporting is to the ICES sub-rectangles level, which is not required within MMO sanctioned catch reporting. A stakeholder suggested that the duplicate requirements for licences and catch recording and the inconsistencies between byelaws and UK legislation are arguments for the integration of IFCAs into the MMO to streamline the existing two-tier enforcement.

Many industry stakeholders described little need for scrutiny of social metrics (e.g. for prevention of bonded labour) as the crab and lobster industry at Bridlington is characterised by family-owned boats with small numbers of local crew members. It was stated that though there are no specific checks on social metrics in place, if issues were suspected then the relevant government agencies (e.g. border force/ local authorities) would be notified. One of the merchants stated that lists of crew information which are compiled for health and safety reasons for the Maritime and Coastguard Agency can mitigate against illegal labour.

With respect to Illegal and Unreported and Unregulated fishing (IUU), MMO staff, merchants and a processor interviewed discussed their suspicions that the scrubbing of egg-bearing lobsters (also known as ‘berried lobsters’) takes place on some of the vessels, an activity which is prohibited within UK law (UK Government, 2017). Multiple stakeholders shared their frustration with this practice due to its negative impact on the sustainability of lobster stocks, but also the financial losses experienced due to higher mortality rates and poorer quality meat as a result of the stress inflicted on the animal. The MMO interviewee discussed the challenges in enforcing prohibition of scrubbing of lobsters due to evidential standards.

7.4.3 Traceability across landing activities

Bridlington Harbour in north-east England is operated by Bridlington Harbour Commissioners. In 2021, 447 tonnes of lobster and 2126 tonnes of crab were landed into Bridlington. This makes Bridlington the largest UK port for lobster and the second largest port for crab, accounting for 17% and 24% of total UK landings respectively (MMO, 2021). There are three merchant organisations located at Bridlington, two of which sell primarily to UK markets, with the other selling to UK and exporting abroad. Merchants reported that vessels typically sell to a particular merchant with whom a pre-existing relationship exists.

The local MMO staff reported that they perform port side checks of submitted catch data against physical shellfish when the vessels land. They also reported that they perform minimum size checks and aim to rotate which vessels are inspected. The MMO staff also reported performing port checks to verify the shellfish quantities stored within merchant tanks against merchant's documentation. The MMO annually performs full inspections of port premises and occasionally undertake vessel inspections at sea. Checks of vessels at sea and port side are also performed by NEIFCA, along with checks of merchant live storage facilities to investigate possible non-compliance with NEIFCA bylaws. Regular port side sampling is also undertaken by NEIFCA's environmental and scientific team to record biometrics from landed catch.

The two merchants interviewed described that they receive the crab and lobster from the fishers in crates for weighing once a vessel has landed and undergone any MMO port-side vessel checks. One merchant stated that they populate an internal document called a 'landing sheet' which details daily purchasing information, including species, weight, vessel details and a daily batch code assigned for each species. The merchant specified that the details captured in the landing sheet are manually entered into an internal sales and stock management system. As crab and lobster are brought to shore alive, they do not need to be graded for quality. The merchants then described informing the fishers of the weights of catch that had been purchased.

The merchants reported selling crab predominantly to processors and to traders who sell at wholesale markets such as Billingsgate, with smaller volumes also being sold to food services (e.g. restaurants, caterers, and to local fishmongers). Merchants reported that a large portion of the lobster landed at Bridlington is exported, either directly by one of the merchants or sold via traders who export the lobster to Europe, though they also sell lobster to UK based food services. Due to price fluctuations for onward selling, the merchants stated that prices may not be agreed with fishers for a number of days, and that fishers are paid on a weekly basis. Potential for delays in sales note reporting to the MMO were discussed as a result of this business model.

Multiple stakeholders interviewed were interested in the rationale for the 24 hour deadline on the submission of sales notes. One stakeholder suggested that speed is being prioritised over accuracy, and suggested that the submission window should be lengthened, or pricing estimates (e.g. based on recent sales prices) could be acceptable on sales note submissions.

Lobster

After weighing, lobsters are stored live within vivier tanks owned by merchants in a building within Bridlington port. One merchant described grouping lobsters that are landed over a small time period (typically 2–4 days) into a single vivier tank. Though it is not possible to identify which lobster came from a particular vessel or day's landing, a lobster can be attributed to a group of vessels and a small range of possible landing dates.

When the lobsters are sold, one of the merchants specified that they aim to select the oldest stock first and have their own undocumented process for tracking which tanks of lobsters were landed earliest, though no labels are added onto tanks. The merchant stated that lobsters landed up to three weeks ago may be stored within the vivier tanks at the dock, and that there is little noticeable deterioration in quality over this time period as the lobsters are fed and kept in stable environmental conditions. In addition, lobster's claws are banded to prevent fighting within the vivier tanks for the preservation of quality.

A merchant mentioned that the local council had previously suggested that lobsters should be individually tagged with identifiers of the vessel and date of landing. However, it was reported that perceived low demand from consumers for this data and the additional cost and time of tagging prevented any uptake. The merchant speculated that is it unlikely that customers would be willing to absorb the additional costs of tagging for the higher degree of traceability. On discussion of this with other stakeholders, none were aware of the council's suggestion, and none thought it would be feasible.

One of the merchants stated when providing landing dates to onward buyers, they sequentially work through the available landing dates listed on their daily landing sheets. The merchant stated that the invoices provided to onwards buyers contain this assigned date of landing, along with the vessel (or group of vessels if grouped), the merchant name, port, species, weight, and batch code. The merchant stated that there is no 1-2-1 mapping of individual lobster to vessels, so all vessels that contributed to that particular day's landing are listed on documentation to buyers. In addition, the merchants stated that they provide 'traceability sheets' to exporters, which provide the data required to submit export health certificates and catch certificates. A margin of error is therefore associated with the landing date supplied to buyers.

As per the landing and first point of sale processes described by the interviewees, there should be an alignment between lobster weights, vessels and landing dates provided within the landing declarations submitted by fishers and sales notes data by merchants to the MMO. However, after lobsters have been stored in vivier tanks for a number of days, merchants cannot identify which lobster within a tank was landed on a particular day by a particular vessel. When lobsters are sold, the vessel and landing date data supplied to the buyers may not correspond to the lobster provided. If the buyer is requested to submit documentation to the MMO (e.g. catch certificates or transport documents), there may be discrepancies between the data submitted before and after the first point of sale. An example described by the MMO staff and the merchants of where discrepancies may exist within MMO systems are the

weights added to landing declarations/sales notes, and weights on export documentation.

The use of vivier tanks at Bridlington results in potential for data discrepancies within data submitted to the MMO pre and post first point of sale. However, interviewees suggested that these data discrepancies do not have a substantial impact for assuring legality or food safety across the supply chain. Firstly, for health and safety reasons, the merchants reported that the lobster's quality does not deteriorate over a small number of days within the tanks. Secondly, the lobsters can still be traced back to a group of Bridlington-registered vessels. The fishers, merchants and MMO local staff agreed that the practicalities of storing live lobster at Bridlington are such that they cannot introduce further traceability systems that trace back to the specific landing date and vessel. One interview participant stated that there has to be a degree of pragmatism when dealing with the practicalities of live catch, and that merchants and fishers would be opposed to being required to pay for the expansion of storage facilities when the existing system fits their needs and those of their buyers.

Crabs

Due to poor survivability in vivier tanks and difficulties with binding their claws, the merchants specified that the majority of brown crabs landed in Bridlington are stored in boxes in a refrigerated room and sold daily after being graded for quality and size. In some instances, the merchants stated that a day's landing of crabs may be stored overnight and sold the following morning. The merchants and the MMO staff stated that the crabs are sold in this short time period post landing, and therefore it is very rare that multiple days' worth of crab landings would be stored together within the port. As such, it was reported that labels are not used on the boxes storing crabs, as there is not the need for segregation between groups of daily landings.

The merchants and processor stated that the quantities of crabs landed from larger vessels may be sold as a single batch of 200–300kg (also known as a 'bin'), would be assigned a daily batch code, and can typically make up one run of daily processing. However, merchants indicated that the catch from multiple smaller vessels tends to be aggregated into a single batch. This batch of aggregated catch would also be assigned a daily batch code by a merchant which would be linked to multiple vessels. The merchants stated that the percentage weight contribution of each vessel is recorded and supplied to buyers through documentation such as invoices and 'traceability sheets' (if required for exports).

7.4.4 Traceability across primary processing

One processor was interviewed within this study. The processor described buying crab from multiple merchants at Bridlington, but also directly from vessels and from nearby ports such as Grimsby. The processor stated that they have made a commitment to only buy from local businesses. In advance of the daily purchasing, the processor stated that they receive nightly reports of catch landed from Bridlington port managers, including species and weights of products of interest.

The processor described dealing with large quantities of crab, processing around 1,500 tonnes of crab per year, with varied processing steps according to the desired end product. They described the necessity of the high quantities processed and using as much of the extracted meat as possible due to tight profit margins. The processor stated that as many as 10,000 individual crabs can be processed within a single day's production run. The processor described the impossibility of tracing an individual crab or an end product back to a vessel, particularly after the amalgamation of extracted meat. The processor stated that even if large loads of crab from a small number of vessels were delivered to the processing factory, the cooking process cannot be halted for separation between the batches from different vessels. As a result, the processor described the highest degree of certainty for traceability that can be realistically achieved is to the day of processing, and therefore all the vessels that contributed to that day's input product.

The processor stated that an internal IT system is used for recording the catch and sales data, which is supplied by merchants via an invoice. The processor commented that the availability and quality of catch and landing data has improved in recent years due to the systems for catch reporting required by the MMO. Within the processor's IT system, the invoice data of the input product and the date of processing run is logged, along with the processor assigned species-specific daily batch code. This daily batch code is stamped onto all packaging of final products (no secondary processing takes place within this primary processor's supply chain). In addition, the processing factory's UK code is also added to packaging, linking the final product back to the factory.

The processor also reported that they export live and processed product. For live exports, the processor specified that the vivier tanks are labelled. When selling to buyers that will export, the processor stated that they provide all information required to populate catch certificates and export health certificates. In addition, the processor stated that they send a spreadsheet detailing processing information to all buyers, including processing steps, freezing and storage data, and catch information. The processor commented that most customers only care about the quality information, and don't request any additional information regarding catch data.

The processor indicated that they sell to a mixture of food services, exporters and to wholesalers and traders. The processor discussed the logistical difficulties of transporting live and processed shellfish due to the temperature requirements. They stated that they use their own delivery mechanisms for Yorkshire, however beyond this a third party transporter or wholesalers with their own transportation are used as this is more cost effective.

A current issue facing the shellfish industry outlined by the processor is a decrease in quality and yield of lobster and crab meat. The processor stated that historically, the average yield returned from a batch could be reliably predicted based on the fishing season. However, this is no longer the case, and crab and lobster meat yields vary substantially based on the catch areas and associated environmental factors. In addition, shellfish caught in different areas undergo different soak times which also impacts meat quality. The processor also stated this change in meat quality and meat yield post extraction is due to the movement of the crab and lobster stocks targeted by Bridlington fishers, which are thought to be moving northwards. The

proposed cause of this reported by the processor is that the shellfish are tracking the summer oceanic front in the central North Sea that is shifting northwards due to climate change, however further research is needed to investigate this. The processor stated that variable environmental conditions across recent shellfish catch areas has also had an impact on the live product, with large variations of survival weight and mortality rate reported by the port based live sellers. The processor stated that it is therefore no longer commercially viable for them to deal with large quantities of lobster.

In response to issues of quality, the processor stated that they have started requesting more detailed catch location data from fishers and are performing analysis on meat yields derived from samples of crab and lobster captured in different areas. This is an example of where more detailed catch traceability can be used to tackle issues of quality for the seafood industry.

7.4.5 Traceability across secondary processors

During discussions with a secondary processor that sells crab to retailers within the UK domestic market, a separate strand of the supply chain was described. The secondary processor indicated that high quality crab is often sold by port-based merchants directly to retail and food services, and that lower quality product which does not meet the specifications of this market is sold onto processors who require large volumes of crab meat. The secondary processor stated that their immediate supplier is a primary processor based in Scotland who are also sourcing brown crab from various ports around the UK, including Bridlington via an intermediary primary processor that also serves as a distributer. Brown crab from Bridlington may therefore pass through multiple hands and be amalgamated with other crab meat that is sourced from a range of UK locations before it reaches its final market. It was unclear as to whether brown crab from different ports or regions is segregated by the primary or secondary processors during transportation and processing. Given the multiple stages of processing and transportation, tracing specific batches of brown crab back to the port of landing is very challenging.

7.4.6 Traceability across wholesalers and traders

One shellfish wholesaler buying from two seafood merchants at Bridlington was interviewed for the study. As their purchase of shellfish is past the first point of sale, there is no requirement for them to submit sales data to the MMO. After purchasing the crab and lobster, the wholesaler stated that they receive an invoice from the merchants detailing catch data and landing date, and a delivery note.

The wholesaler stated that crab and lobster is transported live using their own vans down to their factory and storage facilities for a minimum 48 hour conditioning. The wholesaler stated that their live holding systems comprise of discrete 8kg flow-through trays, temperature-controlled seawater chillers, biofilters, an oxygen generator and spargers to dissolve the oxygen to 98% saturation, which has allowed for a mortality rate of less than 0.05%. For traceability purposes, the wholesaler stated that each holding unit is tagged with date of reception and origin. The wholesaler stated that their factory and storage facilities are routinely inspected by Cefas and Defra. The wholesaler stated that a portion of their crab and lobster is

transported for sale to Billingsgate market (occasionally using third party transportation), and that they also sell direct to other wholesalers and food services. The wholesaler stated that though catch data and landing date for their live product is available via their paper-based systems, they receive little interest from end customers regarding this data, as the main interest is price.

7.4.7 End market

In discussions of end markets for Bridlington crab and lobster, the merchants described a substantial shift away from direct exports by fishers and merchants to Europe. Post Brexit, only one Bridlington based merchant exports directly, with the other two selling to domestic traders who then feed product into the export market. One of the main drivers cited by a merchant for no longer directly exporting shellfish to Europe was the high administrative burden of completing Export Health Certificates and other HMRC paperwork, and the resulting increase to staffing costs. As catch certificates are issued retrospectively to the exportation of seafood, merchants discussed the potential difficulties of reconciling exported product with landings data.

The merchants interviewed indicated that a substantial portion of shellfish exported to Europe goes to the French market. They noted that buyers in France are perceived to have very little interest in traceability and have heard of instances where lobster landed in Bridlington has been rebranded as ‘Brittany lobster’ due to negative perceptions of UK seafood by French consumers. Fishers also commented on the ‘huge’ influence of the Chinese market on the operation of the UK shellfish industry. For example, increased demand from the Chinese market several years ago contributed to a threefold increase of the value of crab per kg, leading to an increase in the targeting of crab at Bridlington and the purchase of additional crab vessels. The fisher also commented on the impact of the industry’s dependency on one market, evidenced by the impacts of the overnight shut down of the Chinese market due to Covid.

Bridlington Bay Lobster

East Riding of Yorkshire Council launched the ‘Bridlington Bay Lobster’ initiative, a five-year plan to promote Bridlington as the lobster capital of Europe, to attract food tourists and to generate a product that is more accessible to be sold in the local area. Stakeholders across the industry discussed several points of contention regarding the scheme, and local confusion around what it is trying to achieve. Fishers and merchants commented that lobster is typically out of the price range of local communities and residents, and that local fishers and merchants should continue to sell lobster at premium prices to food services and export markets in order to best support the local economy.

Local stakeholders also noted issues with the naming of the scheme, as lobsters landed in Scarborough, Whitby, and Hornsea etc. may be considered ‘Bridlington Bay Lobster’, which may add confusion to the reported catch area. One stakeholder suggested that ‘Yorkshire Coast Lobster’ may be more accurate. Furthermore, merchants and fishers highlighted concerns that perceived higher market value of lobster caught within Bridlington Bay as a result of the scheme may encourage non-

local vessels to operate in the area and exploit local resources, particularly through the use of vivier tanks. Aside from introducing additional competition to local fishers, stakeholders highlighted risks to the sustainability of the lobster stock if this additional catch pressure is not accounted for within robust fisheries management plans.

A processor also commented that the scheme has unclear objectives and possible unintended consequences for lobster supply chain stakeholders. The processer argued that marketing should be done at an organisational level, not regional, or distinctions between organisations used for marketing purposes can be undermined, such as hand processing rather than mechanical extraction. In addition, regional marketing can create associations with positive or negative industry issues for which specific businesses are not impacted, for instance, association with the water pollution issues.

7.4.8 General attitudes towards traceability

When general attitudes towards traceability were discussed, fishers, merchants and processors described good relationships between the early supply chain actors based out of Bridlington. They stated that this promotes transparency, and that as a group they are open to discussions regarding improvements to existing processes and systems to ensure that collectively they are doing the right thing for industry. Regarding traceability regulation, supply chain actors stated that a ‘common sense approach’ must be taken when applying seafood industry-wide regulations to this subsection of the industry which involves the handling of live product. Local MMO staff also stated that enforcement mechanisms must be considered in the writing of regulation.

When discussing the effectiveness of the existing processes, MMO staff described the need for the integration of MMO systems so that vessel, catch, landing, sales and export data can be easily viewed and compared to monitor compliance and investigate possible instances of IUU. One processor, who has previous experience as a fisher, requested that government bodies be more transparent about how data submissions by the industry are used, and gave the example of catch data being used for the locations of wind farm sites as an example. They stated that if fishers and other supply chain actors had a greater understanding of the use of data for prevention of IUU, it would provide a greater incentive to the industry for data submission, rather than being completed as a ‘tick box exercise’. Furthermore, stakeholders stated that the rationale for the submission deadlines is required before changes in existing business processes would be made. Multiple stakeholders suggested that any increases to the existing reporting burdens in terms of quantity of data or speed of returns may result in decreases in quality of information the MMO receives.

7.5 Good practice, challenges, and suggested improvements

Based on the insight from the interviews held, it can be argued that there is an appropriate level of traceability within the early stages of the Bridlington based crab and lobster supply chains when considering the industry is dealing with live product.

Though there is a degree of uncertainty in landing date and vessel introduced through the use of vivier tanks, no significant deterioration of lobster is observed over the window in which they are stored (normally only 2-3 days), and merchant records allow traceability back to a group of vessels. Traceability is also maintained to a group of vessels when crabs purchased from multiple vessels are amalgamated, as daily batch codes are assigned by merchants and the percentage contribution of each vessel is also recorded. Interview participants stated that a ‘degree of pragmatism’ must be used when applying seafood industry-wide regulations to supply chains that handle live product, and that considerations of local business models and operating mechanisms must be made.

Improvements suggested by stakeholders include moving all vessels onto digital systems for MMO catch, landing and sales reporting for enforcement consistency and data quality purposes. Furthermore, data submitted to the MMO should be collated into a single data repository to enable easy, simple, potentially automated analysis so that any instances of non-compliance and IUU can be identified and investigated. Finally, greater transparency is asked of the MMO regarding how traceability data is being used, and the rationale for the regulatory deadlines enforced.

Beyond the first point of sale, there are varied levels of traceability maintained for crab and lobster supply chains. An example of good practice would be a processor that uses daily batch codes which are added onto the end product and can be linked back to the input product of a day’s processing run. However, additional research is required to determine how batch-level traceability is met across the rest of the industry. For lobster, though one wholesaler described the availability of traceability data, it is not clear whether this is available across the industry, and multiple stakeholders described that the key factor across domestic and foreign markets is price.

8 Additional Information from Retailers

8.1 Supplier due diligence

One of the retailers interviewed stated that they have thorough supplier due diligence processes in order to meet their sourcing standards and codes of practice. The retailer reported that their suppliers are required to provide proof of accreditations, details of their upstream suppliers and their accreditations. The retailer also stated that they require their suppliers to populate questionnaires on environmental standards, ethics, and health and safety to ensure they meet the retailer's desired standards. Specifically for seafood, the retailer described performing checks on sourcing to ensure that the origin of seafood purchased is not from countries on the EU "red list" of non-compliance with the EU's IUU regulations.

Another retailer specified that they have long-term contracts (typically 3 – 5 years) with their suppliers and perform in depth due diligence before contracts are signed. The retailer described keeping a detailed register of the vessels which meet their supplier standards, and wholesalers sourcing on their behalf will only purchase from this approved vessel list. The retailer specified that they have internal purchasing policies on social issues (e.g. proportion of migrant workers) and environmental issues (e.g. sustainability of catch methods). The retailer specified that their vessel standards therefore include gear type specifications and metrics on crew welfare. The retailer noted that historically these checks were only performed on 'high risk' fisheries, however, this due diligence is now applied over all their seafood purchasing. The retailer also described their ongoing work to expand their crew welfare standards, for instance through compiling detailed crew lists which include capturing data on methods of recruitment and fairness of wages.

8.2 Recall mechanisms and product sampling

One retailer indicated that they have product recall mechanisms in place and practise recall exercises are performed. The retailer highlighted that much of their sourcing is UK based, and as a result their supply chains are relatively short and recall exercises are largely simple. The retailer reported that their suppliers deliver to a specific depot for each store, and that in the instance of a recall, the onus is placed on their supplier to identify the source of an issue.

Another retailer specified that all their processing sites run routine traceability audits. The retailer specified that they purchase all their mackerel products from a single UK processor, and as such mackerel trace back and recall mechanisms are relatively straight forward. The retailer stated that all their Dover sole is sourced from a single wholesaler that purchases from auction houses in the southwest. As the Dover sole purchased at the auction houses is amalgamated after the first point of sale, the retailer specified that trace back exercises are performed to a group of vessels, and that their vessel register ensures that the desired standard on social and environmental metrics has been adhered to.

8.3 Customer demand

One retailer indicated that as ethical and environmentally responsible sourcing are core elements of their branding, there is high demand from their customers for their products to perform highly against social, environmental and sustainability metrics. As such, there is the expectation from customers for products to hold relevant certifications and for this be advertised on packaging via logos, such as the Soil Association, Red Tracker, MSC, and Fair Trade. The retailer suggested that their customers are more interested in products holding these certifications over the provision of specific traceability data points such as port of landing for seafood. However, the retailer commented that, though a small number of customers queried the removal of the MSC logo on mackerel, this did not result in any noteworthy decrease in purchasing. The retailer specified that they do not deal with Dover sole or crab, so could not comment on consumer interest in traceability of these products. The retailer stated that they deal in very small numbers of lobster, for example, limited Christmas products, and stated that price is the main driver for customer purchasing, with little interest received in lobster sourcing information. The retailer also noted that a higher degree of customer interest is on the place of origin and farming methods of vegetable and meat products over seafood.

8.4 General Attitudes

One retailer specified that they do not have a large amount of oversight into the operations of the fishing industry up to the first point of sale. However, they believe that the MMO must focus on having effective control and enforcement mechanisms in order for there to be trust in legality for supply chain stakeholders further along the supply chain. Another retailer suggested that initiatives to prevent IUU should focus on activity up to the first point of sale, and that any changes to existing traceability processes beyond this should be driven by market demand.

A retailer described their wish for the UK government to invest in bringing UK fisheries up to the MSC standard through effective stock management schemes. The retailer described their desire to purchase more UK caught seafood. However, in order to adhere to their purchasing standards, they are forced to purchase seafood from abroad that holds the MSC certification. The retailer also suggested that the UK government should invest in marketing initiatives to promote UK seafood that is currently ‘unpopular’ with UK consumers, to grow the UK market for UK seafood products (e.g. species such as gurnards).

9 Key Findings from supply chain traceability case studies

9.1 Dover sole landed in the south west of England

Dover sole is caught with a range of other demersal fish species in a mixed fishery operating in the south west of England. It is predominantly caught by demersal trawlers over multiday trips typically lasting 3-7 days, a smaller volume is also caught by day vessels using static nets. The range of different types of vessels, capture methods, and trip duration in the Dover sole fishery has implications for traceability and the need for accurate recording of this information during landing and first sale.

Most of the Dover sole landing in the south west goes through three auction houses. The majority of seafood product landed or delivered to the auction houses are graded that day and then are sold at the following day's auction. However, landings over weekends and Bank Holidays will be kept in cold storage prior to the auction, and may mean the landing date stated at auction is inaccurate, with a margin of error of up to three days.

Branded crates and tallies ensure that the seafood delivered to auctions can be identified back to the vessel so that skippers can be paid accordingly. The auction house keeps a record of the gear types used by each vessel, so the catch method of seafood is known when processed by the auction. For some vessels that use a mix of netted and hand line capture, fishers will add the method of capture to their tallies.

On completion of the auction, the auction houses provide buyers with invoices and sale information. After first sale, Dover sole from different vessels may be aggregated into batches for onward transportation. Small scale buyers (e.g., some fishmongers and food services providers) tend to use intermediaries rather than purchasing directly from the auctions themselves, due to the costs and logistical difficulties of transporting perishable seafood.

A small processor of fish landed in the south west (including small volumes of Dover sole) had end-to-end traceability in place in their supply chain. They receive all the required vessels details and catch information required by their customers (e.g. gear type, region of catch) in the label provided to them by the auction house. In order to ensure the traceability of each individual fish back to the vessel, fish is clearly labelled at all times to, during and from their factory. Vessel and catch details are stated on paper labels on the final packaging within their processing area, and this information is provided to the final consumer.

A larger processor stated that they store the traceability data received from the auction house within their sales and stock management IT system. Details such as catch location and landing date are transferred onto packaging labels on seafood products and receipts provided to their buyers. The processor stated that they rarely receive additional requests for data beyond that already provided, though occasionally some additional anecdotal data is requested for adding to menus at high-end restaurants.

9.1.1 Conclusions

The level of traceability achieved in Dover sole supply chain will vary depending on end market requirements. If the final customer requires additional information on the vessels, this information can be passed on from the auction houses. It will be up to the first buyer to ensure that they keep catch from individual vessels segregated and clearly labelled as it is transported to their factory. Processors dealing with larger volumes will unlikely be able to keep the catch from individual vessels separated during transportation and processing, and therefore traceability will only be achievable to a group of vessels.

9.2 Mackerel landed at Peterhead, Scotland

Mackerel supply chains in the UK are relatively simple and linear, with a high level of vertical integration. The main supply chain of the UK mackerel industry predominantly operates from Peterhead, Scotland where three of the four primary processing companies are based. These processors have full or partial ownership of vessels in the Scottish pelagic fleet. The catch of a Scottish pelagic vessel will be transported to the owning processing factory post-landing, often by pipe and conveyor systems, bypassing merchants and wholesale markets. Most of the primary processed product goes to secondary processing for canning, or is exported.

The landings of all pelagic mackerel vessels are inspected, with dock-side weight estimates of catch performed via dipping tanks which is supervised by the fisheries officers. Each pelagic vessel landing typically forms a processing batch. In some instances, a landing may be split and assigned multiple batch codes in the instance that a customer wishes to buy a pre-determined proportion of a landing or has other specific requests (e.g., Japanese market requirement for top grade raw fish for sushi). Additionally, a landing may be split if fish of different hauls are different sizes (± 10 g) or damaged. Batch codes link to the vessel name and landing date. Belt weighers are installed in each factory and provide the final weight of each landing. Readings from these are used in the final weights for quota usage calculations.

Both primary and secondary processors use a variety of paper-based and technological systems across their factories for data and stock inventory management. Although IT systems may differ between processors, production codes are used as the unique identifiers to trace back processed products to their supplier's raw ingredients.

9.2.1 Conclusions

Despite batch level traceability being achieved in mackerel supply chains, for most mackerel cans, only the legal minimum information is provided to consumers (species, catch area, method of capture, production method, and expiry date) (UK Government, 2013). Information on the fishing vessels is only being passed on to consumers in a few cases. One high-end brand who advertises catch-to-can traceability enables consumers to trace their purchased fish back to the specific vessel. The consumer can find vessel information by entering the product code into a website search feature.

9.3 Brown crab and European lobster landed at Bridlington, England

Brown crab and lobster supply chains vary in their complexity, export supply chains can be simple and linear, processing supply chains more complex. Particularly for brown crab, complexity increases at the secondary processing stage where crab originating from multiple locations may be combined into processing batches. There is no vertical integration of the catch and first point of sale stages of the crab and lobster supply chain based out of Bridlington. However, longstanding relationships between merchants and vessel skippers/owners exist.

The MMO performs port side checks of submitted catch data against physical shellfish when the vessels land. MMO staff also perform minimum size checks and aim to rotate which vessels are inspected. Port checks are also undertaken annually to verify the shellfish quantities stored within merchant tanks against merchant's documentation. The MMO also occasionally undertake vessel inspections at sea. Inspections of vessels at sea and port side are also performed by NEIFCA, along with inspections of merchant live storage facilities to investigate possible non-compliance with NEIFCA bylaws. Merchants record daily purchasing information, including species, weight, vessel details and a daily batch code assigned for each species on an internal sales and stock management system.

Lobsters are stored in vivier tanks for multiple days, and crabs stored in crates for immediate onward transport. Lobsters are typically transported live to fishmongers, food services, and wholesale markets, with a significant portion exported to the continent either directly by the Bridlington merchants or indirectly via traders. Logistical constraints on the successful transport of live lobster result in a 'streamlined' supply chain, with lobster passing through relatively few supply chain actors before being sold to final consumers.

Large quantities of crabs landed from larger vessels may be sold as a single batch and assigned a daily batch code, typically making up one run of daily processing. Catch from multiple smaller vessels tends to be aggregated into a single batch. This batch of aggregated catch would also be assigned a daily batch code by a merchant which would be linked to multiple vessels. The percentage weight contribution of each vessel is recorded and supplied to buyers through documentation such as invoices and 'traceability sheets' (if required for exports). It is not possible to trace an individual crab or an end product back to a vessel. The highest degree of certainty for traceability that can be realistically achieved is to the day of processing, and therefore all the vessels that contributed to that day's input product. The input product and the date of processing run is logged, along with the processor assigned species-specific daily batch code. This daily batch code is stamped onto all packaging of final products along with the processing factory's UK code, linking the final product back to the factory.

For value-added products such as potted white crab meat (from claws) and crab pates, crab may be amalgamated from multiple landing sites. Secondary processed brown crab products should still be able to be traced back to a port and group of

vessels through reconciling batch codes across the supply chain. However, given that the brown crab may have passed through several primary processors and distributers before it reaches the secondary processor, there is an increased risk of breakdown in traceability.

9.3.1 Conclusions

Brown crab and lobster supply chains demonstrate the concept of one-up one-down traceability. Products can be traced internally from a customer back to the supplier of production inputs. Full chain trace backs from a secondary processing level are challenging and time-consuming to undertake, and at best will only be able to identify a production batch to a vessel group.

9.4 Comparisons of levels of traceability across the case study supply chains

Processes, technologies and verification for and of traceability are compared across five stages of each case study supply chain: i) catch; ii) landing; iii) point of first sale; iv) processing/distribution v) end market (Table 3 below). The mackerel supply chain is a good example of an end-to-end traceability system where key data is linked to production batches as they move through the supply chain. This end-to-end traceability is facilitated by having a small number of fishing vessels making large volume landings, with one landing typically forming a production batch. For Dover sole, and brown crab and lobster, there are many smaller fishing vessels landing relatively small volumes. Landings from these two supply chains will often by combined by the first buyer to form a production batch, meeting minimum legal requirements, though ultimately only linking production batches back to a group of vessels. Compared to crab and lobster, there is greater variation in the level of traceability that is achieved in the Dover sole supply chain with smaller processors potentially achieving end-to-end traceability in their supply chain, whereas for the larger processors, traceability to vessel level is often lost when the auction lots post sale are aggregated and re-boxed for onward transportation.

Table 3. Comparison of differences in traceability at various stages of the supply chain for three case studies: A. Dover sole; B. Mackerel; C. Brown Crab and European lobster

		Case Studies		
Supply chain stage		**A. Dover sole**	**B. Mackerel**	**C. Brown crab and European lobster**
Catch	Processes	- Dover sole targeted by day vessels and larger multi-day vessels - Some vessels reporting estimated catch to auction houses in advance of landing	- Mackerel targeted by Scottish pelagic fleet. - 1-3 hauls segregated into separate tanks - Vessels in regular communication with factories, informing factories of catch	- Brown crab / European lobster targeted by daily vessels, some storage within vivier tanks aboard multi-day vessels
	Technologies	- VMS and iVMS - E-logbooks - Communications between fishers and auction houses via WhatsApp/ text/ emails	- VMS - E-logbooks - Haul weight estimates performed using onboard technologies such as weight displacement within pump and tank systems	- VMS and iVMS - E-logbooks - NEIFCA monthly catch return forms
	Verification	- Daily catch submissions - MMO vessel inspections at sea	- Daily catch submissions - Marine Scotland initial review of e- - logbook and VMS data submissions, prompted by prior notification of arrival	- MMO and NEIFCA vessel inspections at sea
Landing	Processes	- Seafood landed into port of auction or transported to auction. - Tallies containing vessel name/PLN added to crates when delivered to auction houses	- Dock-side weight estimates of total catch performed via dipping tanks	- Crab / lobster transferred to and weighed by merchants.
	Technologies	- Catch app, E-logbook & paper-based reporting - Mobile working app	- E-logbooks	- Catch app, E-logbook & paper-based reporting - Mobile working app
	Verification	- Transport and transfer documentation required for moving seafood between ports and auction houses - Landings declaration	- Each landing inspected by Marine Scotland enforcement officer, including supervision of port side weighing and	- Port side checks of submitted catch data against physical shellfish by MMO

		- Port side checks of submitted catch data against physical seafood by MMO	comparison with at-sea weight estimates - Landings declaration	- Minimum size and under byelaw checks by NEIFCA.
1st point of sale	Processes	- Seafood graded according to weight and quality - Seafood from multiple vessels is never amalgamated into a single box, however, boxes with smaller quantities of a species may be grouped for collective sale - A catalogue of the following day's auction containing details on the seafood weight, grade, and presentation, vessel name and PLN is published once all grading is complete for advance viewing by prospective buyers - Invoices of above details provided to buyers	- Entire vessel's landing 'sold' and transported to processing factory - Whole landing typically assigned one batch code - Final weighing by flow scales	- Vivier tanks store lobsters of multiple days catch onshore for up to three weeks - Brown crabs may be amalgamated from multiple vessels before sale (usually within 24hr of landing) - Merchants populate 'landing sheets' which detail daily purchasing information including species, weight, vessel details and a daily batch code assigned for each species
	Technologies	- Electronic clock auctions - Machine grading integrated with auction system	- Flow scales	- Merchant sales and stock management system
	Verification	- Sales note submissions post auction - MMO checks of auction house facilities	- Sales note submission - Feed from flow scales to Marine Scotland for checks and quota monitoring	- Sales note submission on a weekly basis - MMO checks of merchant live storage facilities
Processing / distribution	Processes	- Beyond first sale at auction houses, there is no control over the amalgamation of Dover sole purchased from different vessels - Some processors/ wholesalers providing catch-to-plate traceability to customers - Other processors/ wholesalers provide catch location and data of landing on packaging labels and receipts provided to their buyers	- Factories typically process one landing at a time. One production run typically has one batch code. - Grading according to size and quality - Primary processors produce production sheets detailing input batch info and processing steps - Secondary processors receive production sheets from primary processors and assign their own production codes	- Some local processors receive notifications of night catch reporting from port managers. - Processors typically produce production sheets detailing input batch info and processing steps - Typically, a single processing run for the daily crab purchase, assigned a single batch code - Daily batch code is stamped onto all packaging of final products

			- Batch codes/production codes used to identify mackerel as it moves around the factories. Some batch/ production codes on paper labels and tags, some on bar codes, all on documentation - Final production coded added to end product packaging	- The processing factory's UK code also added to packaging - Some loss of traceability to port/source during amalgamation of input batches for secondary processing - Some wholesalers of live lobster tag holding units with date of purchase and origin
	Technologies	- IT or paper based stock management and sales systems of processors and wholesalers	- Some digital scanning of documentation used to perform quality checks - Stock management and sales systems recording traceability data (mapping of e-logbook numbers, batch codes, production codes) via bespoke IT systems, excel sheets and paper-based processes	- Some processors have stock management and sales systems recording traceability data of crab batches - Some lobster wholesaler using paper-based systems
	Verification	- Weekly MMO checks of wholesale markets	- Quality management checks of product performed by processors - Marine Scotland annual factory visits and spot checks, reviews of paper documentation, IT systems and physical product - Marine Scotland checks of factory input against output product - Some customer led factory checks. - End-to-end traceback exercises are performed and documented by factories.	- Quality management checks of product performed by processors Factory and storage facilities are routinely inspected by Cefas and Defra
End Market	Processes	- Catch data added to some products packaging - The processing factory's UK code also added to packaging -	- Broad catch area (i.e., NE Atlantic), catch method, species name information found on final product packaging	- The processing factory's UK code added to packaging - For live product, little marketing of product origin, particularly for exports

	Technologies	- Varied degree of traceability facilitated by labels on packaging dependant on processor	- Traceability facilitated by production code on packaging - One example of retailer providing consumers with catch-to-can traceability information via website	- Varied degree of traceability facilitated by labels on packaging dependant on processor
	Verification	- Food Standards Agency (FSA) labelling requirements - If exported, catch certificate validated (MMO) and export health certificate (vet or certifying officer through Local authorities) submitted	- FSA labelling requirements - If exported, catch certificate validated (MMO) and export health certificate (vet or certifying officer through Local authorities) submitted Trace back processes documented, and exercises undertaken for products sold by retailers	- FSA labelling requirements - If exported, catch certificate validated (MMO) and export health certificate (vet or certifying officer Local authorities) submitted Trace back processes documented, and exercises undertaken for products sold by retailers

10 Traceability best practice in UK seafood supply chains

10.1 Defining traceability best practice

There are various guidelines for achieving traceability best practice in seafood supply chains (see Zhang and Bhatt, 2014; National Fisheries Institute 2011 and GDST 2022a,b). To achieve best practice, traceability programmes are needed across the entire seafood supply chain (Zhang and Bhatt, 2014). Timely and accurate capture, storing and sharing of information up and down the supply chain and within a company is a critical component for supply chain traceability (Zhang and Bhatt, 2014). Best practice involves building a process that allows for this capture of information in electronic format, and allows for the retrieval of critical product traceability information or Key Data Elements (KDEs) (Zhang and Bhatt, 2014).

Traceability occurs in UK seafood supply chains to varying degrees (WWF 2022). The performance of a traceability system can be characterised according four criteria; i) breadth (amount of information recorded), ii) depth (how far up or downstream the information is tracked), iii) precision (degree of accuracy in identifying product movement) and iv) access (speed and availability of data disseminated across supply chain actors including governing bodies) (Golan et al. 2004).

10.1.1 Minimum traceability requirements

At a minimum, all legally compliant seafood supply chains in the UK are required to comply with legislative and market requirements as defined in the UK Fisheries Act (2022) and Fish Labelling regulations (2014). Retained EU law from the Control Regulation 1224/2009 and the Food Information to Consumers Regulation (2011) require ‘lots’ of fisheries and aquaculture products to be traceable. Seafood lots must also meet minimum labelling requirements from the point of catching or harvesting all the way through to sale to the consumer, not just first sale.

10.1.2 End to End traceability

There is increasing interest from regulators in End to End (also known as catch-to-plate) electronic traceability, typically defined as the ability to trace a seafood product from a producer (i.e. a fishing vessel) through to the consumer (Tamm et al 2016). The key principle of end-to-end electronic traceability is that Key Data Elements (KDEs) (Tamm et al 2016), that refer to product attributes (e.g. species, vessel name, landings date, catch area, and capture method) as the product moves from the fishing vessel through the supply chain, are linked with the product at all stages of production through the supply chain. One of the main advantages of an end-to-end electronic traceability system is that data can be retrieved almost instantaneously from any point across the supply chain. As data can be retrieved at any access point, the need for manual trace back exercises are reduced (Tamm et al 2016). This also improves food safety, as in the event of a recall, potentially affected production batches can be more quickly identified (Tamm et al 2016).

In terms of defining best practice for end-to-end electronic traceability in seafood supply chains, the Global Dialogue on Seafood Traceability (GDST) provides global standards defining the types and format of KDEs (GDST 2022a) and standards for designing electronic traceability systems that are interoperable (GDST 2022b). The GDST identifies 35 wild capture KDEs in contrast to the 11 KDEs that are mandated by UK law. This means that businesses meeting the UK minimum legal data requirements are only meeting one third of the data requirements defined at best practice level.

At a global level, full chain traceability initiatives have been identified as mainly occurring in vertically integrated seafood supply chains (GDST 2023). If companies under the same parent company ownership are using the same policies and technology system to transfer information between entities, this makes traceability more straightforward (though still a challenge). An additional aspect of vertically integrated supply chains is that there is no commercial interest to keep things hidden, and there are commercial incentives for businesses to keep investing in improving the efficiency of the operation.

10.2 Examples of Traceability Best Practice in UK Seafood Supply Chains

Traceability “best practice” can be defined relative to the complexity of the supply chain. End-to-end traceability is relatively easier to achieve with simpler supply chains, such as Mackerel, landed at Peterhead, Scotland, in this study. The more complex supply chains of Dover sole, and crab and lobster met the minimum legal requirements for traceability. Table 4 summarises the extent to which the performance criteria set by Golan et al. (2004) is met in the three case-studies. Across the three case studies, all business operations interviewed stated that they had effective internal traceability systems, managed through the use of technology and/or paper-based record keeping. These internal traceability systems ensure that processing batch codes always link with invoice receipts for raw materials, and order numbers from their customers.

Table 4. Summary of the level of traceability in each supply chain by the four performance criteria set by Golan et al. (2004)

Traceability criteria	Dover sole (demersal gears)	Mackerel (purse seine)	Crab / lobster (pots)
Breadth	Minimum legal data requirements met	Minimum legal data requirements exceeded	Minimum legal data requirements met
Depth	One-up one-down traceability, internal traceability of production batches	Batches can be traced back from batch code on a mackerel can to vessel and landing date	One-up one-down traceability, internal traceability of production batches
Precision	In the auction houses (and transport to auction houses), traceability is	Products traced internally through individual batch codes,	Merchants keep landing sheets for the vessels they buy from

	ensured back to the vessels (to ensure fishers get paid correctly), though could be multiple days landings at Monday auctions The first buyer may aggregate lots of similar grades into their own 'batch' for onward distribution, meaning traceability limited to a group of vessels	processing sheets, and stock inventory software	After first sale can typically trace back to a group of vessels (crabs & lobsters), and range of landing dates (lobsters only) For secondary processed crab relying on multiple sources of raw ingredients, production batches may only be able to be traced back to multiple-points of first sale
Access	Complexity of supply chains varies, there was one example of end-to-end traceability (paper-based)	Trace backs relatively quick to make due to relatively few stages in the supply chain, data sitting in Enterprise Resource Planning (ERP) systems can be quickly interrogated	Complexity of supply chains varies, export may be simple and linear, reconciliation of paper-based records across traders and wholesalers may be time consuming

As an example of good practice, within the mackerel supply chain, one landing will form a production batch, and the small number of stages in the mackerel supply chain means traceability back to each vessel can be easily achieved. There is also a high level of cooperation and trust between actors in the mackerel supply chain. For example, the Scottish Pelagic Processors Association (SPPA) works closely with the fishing vessels and fisheries scientists to improve the precision of data recorded during hauls, landing and processing for fisheries science purposes. For most of the mackerel processors, information sits within ERP systems meaning that traceability information can be exported and queried with relative ease.

10.2.1 Meeting minimum legal traceability requirements

The digitalisation of vessel reporting systems (such as e-logbooks, the CatchApp for under 10m vessels, and improvements to VMS) have improved levels of compliance up to the first point of sale. The CatchApp in particular was praised for improving traceability in the under 10m sector, as historically there was no statutory requirement for fishers in this sector to declare their catches (UK Gov 2021).

For each of the three case studies, all supply chain operators interviewed were achieving one-up one-down traceability (EC Regulation No. 178/2002), meeting the

minimum data requirements for lot level traceability (UK Government 2021). Businesses could trace a production batch through their business to their customer, and trace back the final product to the raw materials from their supplier. It was beyond the scope of this study to check whether labels on actual products complied with the regulations.

10.2.2 Business certifications covering internal traceability requirements

There are numerous third-party standards and certification schemes covering traceability requirements such as Global GAP chain of custody v6.1, MSC chain of custody v5.0, and many of the leading food safety standards (e.g. BRCGS Issue 9). These standards will define the fundamental principles of a business's internal traceability system, covering the clear identification of the raw materials or processed product as it moves through the business and segregation of raw materials and unfinished products to avoid accidental mixing of products with different attributes, particularly important when a labelling claim is to be made (e.g. "MSC certified").

Many of the mackerel processors were covered by BRCGS certification (BRCGS 2021), and would have also been previously certified against the MSC chain of custody standard (MSC 2019b). Generally, all large seafood processors selling to UK retailers will need to be covered by an internationally recognised food safety standard such as BRCGS. Some port fish markets will also be certified to BRCGS (e.g. Peterhead has an AA rating).

10.2.3 End to End initiatives in the UK

No completely electronic end-to-end initiatives were identified in the supply chains studied that would fully meet the GDST requirements (GDST 2022b). Traceability within the mackerel supply chain is approaching the best practice level defined by the GDST, yet there is still some opportunity to further automate information transfer between businesses, which often relies on a degree of manual data entry and transfer between businesses. Additionally, not all the KDEs defined by the GDST are met in the mackerel supply chains. In terms of the wider UK seafood sector, the GDST have facilitated a pilot project looking at electronic data transfer between giant tiger prawn (*Penaeus monodon*) producers in Vietnam, a UK seafood processor, and UK retailer (GDST 2023). However, the electronic transfer of data only goes as far as the secondary processor, and is currently not being demanded by retailers.

Based on the lack of evidence, the extent to which end-to-end electronic traceability is happening across UK wild-capture supply chains can be considered minimal. Where end-to-end traceability is occurring, it is limited to higher value seafood commodities (GDST 2023). A paper-based end-to-end traceability system was observed for a Dover sole supply chain selling to premium market consumers. However, there are calls to end the reliance on paper-based systems, which can be falsified in the supply chain (NOAA et al. 2022). There was general consensus across the case studies that best practice and end-to-end initiatives should be driven by market-based initiatives such as the GDST and market need.

11 Challenges to full supply chain traceability

Generally, traceability in the seafood industry is lagging that of other food sectors (Caveen et al 2021). Traditionally the seafood industry has been more fragmented than other food industries due to the existence of many niche markets and small business owners (Jouffray et al. 2019). Within seafood supply chains, there is limited vertical integration between vessels and processing (Warmerdam et al 2018). Additionally, the complexity of seafood supply chains (Lawrence et al 2022) makes investment in traceability improvements across a supply chain challenging (Hardt et al 2017).

Seafood consumed in the UK falls into two main categories: i) retail for at-home consumption, and ii) food service for eating out. The majority of retail seafood sales are driven by the nine national supermarket chains (Tesco, Sainsbury's, Asda, Morrison's, Co-op, Aldi, Lidl, Waitrose, M&S), whereas food service spans thousands of Small Medium Enterprises (SMEs) each relying on a network of seafood wholesalers and distributers (FASFA 2023). The level of interest in traceability and risk of fraud differs between the two categories of consumption (WWF 2022). Retailers generally experience more public scrutiny than restaurants (WWF 2022, ODP 2023), and face more pressure to have rigorous sourcing procedures and risk management systems (WWF 2022). Restaurants (except perhaps the larger chains) face less reputational pressure and may have less well-developed supply chain risk management systems (WWF 2022). Due to the business models of small restaurants (i.e. buying relatively small volumes of seafood frequently to meet customer demand) they may engage more frequently in potentially riskier buying activities, and some may mislabel the fish they sell (FSA 2016).

Many businesses, particularly retailers will often be dealing with portfolios of in excess of 50 types of seafood product (ODP 2023), each with a specific supply chain. Improvements in traceability through a supply chain will be very much dependent on the effort and costs required to address challenges versus the market and regulatory need for data. For certain types of seafood product there may be economic and logistical reasons why costs may unworkable (Hardt et al 2017). Inevitably, businesses may have to prioritise which supply chains they make improvements to traceability in (BSI, 2017).

A recent horizon scan of UK seafood consumption suggests tough market conditions for the sector over the next five years (Garrett et al 2023). In light of this economic uncertainty, businesses may be unwilling to make investments in their traceability systems, even though it might improve efficiencies in their operations over the longer-term. Larger businesses may be more able to absorb the upfront costs of installing new software and hardware, smaller operators less so (Hardt et al 2017). However, for other food supply sectors, business owner perception of the limited benefits of enhancing their traceability beyond achieving the minimum regulatory requirements remains a primary barrier to making improvements (Amuno 2019). Therefore, changing stakeholder perceptions on traceability may be as important as addressing potential cost barriers (Amuno 2019). Further, the bureaucratic and financial burden of enhancing traceability often falls to actors early in a supply chain while at the same time receive few direct benefits.

11.1 Challenges to traceability across the UK seafood supply chain

11.1.1 Vessel monitoring and reporting requirements

There have been a few technical issues reported by the UK fishing fleet regarding the introduction of the Inshore Vessel Management Systems (iVMS), which has been adopted by some of the smaller vessels in the fleet (less than 12m) in preparation for upcoming 2023 regulatory change (UK Gov 2022). The associated upfront costs of iVMS to fishers can also act as a burden on implementation of vessel monitoring systems. Vessels (usually under 12 m) still using a paper-based reporting system currently causes problems by delaying the receipt of catch reports and landing declarations by the MMO. Data submitted in paper format then needs to be processed internally by the MMO which requires staff resource.

An electronic catch recording application (the 'CatchApp') for under 10m vessels has received mixed feedback from fishers, with some reporting time savings and other complaining of the lack of usability. The requirement to provide weight estimates for every species of fish reported within the CatchApp, and the difficulty of estimating the weights of small numbers of fish within the 10% margin have been viewed as more onerous for smaller scale fishers. For vessels operating inshore (less than 6 nautical miles) additional reporting requirements to the Inshore Fisheries and Conservation Authorities (IFCAs), that require catch location reporting to International Council for the Exploration of the Sea (ICES) sub-rectangle level have also been perceived as creating an additional reporting burden on smaller vessels.

11.1.2 Landing activities

For Dover sole supply chains, the auction houses of the south west have identified logistical, operational, and financial blockers to identifying and separating seafood according to the day of landing. For example, many of the smaller harbours where seafood is stored before being transported to auction houses do not have sufficient storage capacity to separate boxes according to the date of landing. Landing days (defined as the day before sale) may also not be accurate, for example landings and deliveries over the weekend (Friday, Saturday, and Sunday) will be kept in cold storage at the auction house premises and weighed, graded and sorted on Sunday for sale at Monday's auction. Additionally for fish arriving overland from smaller ports, the auction houses have no means of identifying which day seafood was landed and if a consignment includes seafood landed on more than one day.

The use of vivier tanks for lobster at Bridlington can result in potential for data discrepancies within the data submitted to the MMO pre and post first point of sale. It is also not possible to trace a brown crab back to the vessel that caught it when after weighing, the catch from multiple smaller vessels tends to be aggregated into a single batch and sold. However, the percentage weight contribution of each vessel is recorded and supplied to buyers through the invoice.

Bridlington merchants and auction houses in south west England predominantly rely on landings from smaller ports in the region for their businesses, typically sending their own transport to pick-up landings from the small ports. While traceability records would be kept ensuring traceability back to each vessel prior to sale, it is

unclear whether the actual port of landing would be recorded in transportation documents.

11.1.3 First sale

Post purchasing after auction in the south west, seafood is picked up by buyers using personal transport and through the use of third-party transportation firms. After first-sale, there is no control over the amalgamation of seafood purchased from different vessels and therefore traceability to individual vessels after first-sale may be lost. When Bridlington lobsters are sold, the vessel and landing date data supplied to the buyers may not correspond to the lobster sold. If the buyer is requested to submit documentation to the MMO (e.g. catch certificates or transport documents), there may be discrepancies between the data submitted before and after the first point of sale. For Bridlington brown crab, due to price fluctuations with onward selling, prices may not be agreed with fishers for a number of days, and fishers are paid on a weekly basis, creating a challenge for the timely submission of sales notes.

11.1.4 Primary processing

Pelagic primary processors in Scotland have experimented with using Radio Frequency Identification (RFID) tags in their own operation to track data with the physical product. However, the technology remains challenging, not working properly in cold storage areas. Where seafood from individuals is amalgamated into an end product (e.g. brown crab meat), the highest degree of certainty for traceability that can be realistically achieved is to the day of processing, and therefore all the vessels that contributed the raw materials to that day’s production run.

11.1.5 Wholesalers

There is a perception that the greatest risk in terms of illegal (undeclared) seafood entering the supply chain is at wholesalers and large markets (e.g. Billingsgate). MMO staff undertake weekly checks at Billingsgate including checks on seller registration and adherence to minimum sizing regulations. However, additional scrutiny could be placed on checking first point of sale invoices at markets to validate the legality of product sold.

11.1.6 Secondary processing

Brown crab may have passed through several primary processors and distributers before it reaches the secondary processor, which could lead to an increased risk of breakdown in traceability. Some secondary processors also rely on excess crab bodies and claws (for white meat) from primary processors that source from ports across the UK. It is unclear the level of traceability that can be achieved, if aggregated crab caught from different ports is used for processing.

11.1.7 Exporting

As catch certificates are issued prior to export and validated retrospectively during the exportation of seafood, there are potential difficulties in reconciling exported

product weights stated on the catch certificate with landings data. Another challenge is the export market drive for traceability, with many export markets primarily interested in the grade and price of the seafood. For some external markets, there may actually be a disincentive for traceability, as some markets do not want to advertise the origin of UK caught seafood (e.g., French and Belgian markets) owing to negative perceptions of UK seafood by French consumers.

There is continuing frustration at the perceived disparity between the level of regulations and resulting paperwork required for UK fishers to export to the EU comparable to the “minimal checks” performed on EU imports into the UK. While greater product scrutiny can ensure higher quality, the disparity in regulations and the increasing data requirements for export markets (Dinu and Sanz 2021) is leading to a perception of reduced competitiveness of the UK seafood industry within the global market.

11.1.8 End Market Requirements

There is a perception around a lack of enforcement of the UK’s legal requirement to specify the method of catch on seafood labels (UK Gov 2013). Labels often list many possible methods of catch, which undermines the purpose of the legislation, and does not provide customers with sufficient data to make ethical purchasing decisions. However, studies in Europe have shown a low level of awareness from consumers around sustainable seafood products, (Potts et al. 2011) and a generally mixed signal from consumers for eco-labelled products (e.g. MSC ecolabel), of which traceability is a key component (Jaffrey et al. 2004; Pierucci et al. 2022). In the context of the UK seafood industry, business Corporate Social Responsibility (CSR) requirements are becoming more onerous requiring businesses to trace back to vessels for Illegal, unreported and unregulated fishing (IUU) and human rights due diligence (BSI, 2017).

Retailers have highlighted that focus should be on having effective fisheries control and enforcement mechanisms in order for there to be trust in legality for supply chain stakeholders further along the supply chain. Initiatives to prevent IUU fishing should focus on activity up to the first point of sale, and that any changes to existing traceability processes beyond first sale should be driven by market demand.

11.2 General challenges for UK Seafood Supply Chains

11.2.1 Governance Challenges

One of the main governance challenges for the UK seafood supply chain is that harvesting and downstream businesses often have different interests and strongly contrasting perspectives on issues making it challenging to build consensus (Symes & Phillipson 2019). The catching sector is focused on the allocation of fishing opportunities and regulatory intervention, and the focus of downstream businesses is on meeting customer demands, assuring product quality, and securing market access (Symes & Phillipson 2019). Despite these differences, many actors and

organisations have an interest in aspects of seafood traceability and data that is captured across a supply chain (Table 5).

Table 5. The broad types of data of interest to the supply chain that may be linked to a given seafood product

Broad data category	Types of data	Actors and organisations with an interest in collection
Stock information	Stock status (fishing mortality, biomass), size structure, spawning areas, functional unit (Nephrops)	Cefas, ICES (science and management advice), MMO (management), processors, retailers, restaurants, consumer, fishers, NGOs
Other environmental information	Bycatch, seabed impact, spatial data, water quality (shellfish aquaculture), energy use	Cefas, ICES (science and management advice), MMO (management), Crown Estate, processors, retailers, restaurants, fishers, NGOs
Social information	Vessel information, crew information, employment terms	MCA, Border Force, processors, retailers, NGOs
Landings information	Date, species, weight, catch method, catch area, kill method, transhipment	MMO, ports (harbour dues), auctions (volumes), Cefas, ICES, fishers, first buyers, processors, retailers
First sale information	Weight, value, grades, catch date	MMO (cross checking), Seafish (levy)
Quality information	Fresh / frozen, nutritional composition, protein yields, temperature profile	Processors, retailers, restaurants, consumers (nutritional data), fishers (optimising harvesting), FSA, audit bodies
Food safety data	Test results for contaminants / microbes, recall data	FSA, processors, retailers, restaurants, audit bodies
Supply chain information	Processing data, cold chain data	Processors, retailers, restaurants, audit bodies
Consumer information	Sales numbers, customer profiles	Retailers, restaurants

Regulations governing the catching sector up to the point of first sale are enforced by MMO, and the regulations post first sale down the supply chain are enforced by the FSA which further complicates supply chain governance. The MMO has responsibility to enforce traceability up to the point of first sale and export, and has a remit to prevent IUU fish from entering the supply chain. Whereas the main interest of the FSA is food safety, and the FSA devolves power to local authorities to undertake food safety inspections on businesses in the supply chain after the point of first sale. Despite there being minimum traceability labelling requirements for seafood lots (UK Government 2021) the scope of the current study did not include investigating the role of the FSA during inspections.

The need to develop a ‘common language’ on seafood related issues has been previously emphasised (see Symes & Phillipson 2019, Seafish 2023). The definition of traceability needs to be more clearly stated to industry, particularly the distinction between traceability and full transparency. Necessary data should be transferred along supply chains to those that need it, but only with the permission of the data owner. Wider, but appropriate, use of data gathered would potentially encourage more accurate and timely data submissions. Additional traceability regulation is adding to the administrative burden of businesses, a burden which has increased many businesses since Brexit (Stewart et al 2022). Therefore a drive for improved traceability across the UK seafood industry may need to address increasing administrative costs.

11.2.2 IUU Fishing

There is a perception within the UK seafood supply chain that there is a higher risk of IUU post-Brexit as the non-UK vessels are no longer landing into UK ports. The MMO perform at sea-vessel checks on both UK and non-UK vessels, but there is also a desire for greater enforcement controls on seafood imported into the UK, where potentially there is the greatest risk of IUU fished products entering the supply chain.

11.2.3 Technical challenges

Many smaller businesses are using a combination of paper-based records and computer spreadsheets to manage their internal traceability and are sceptical of the need to invest in more sophisticated software systems. Paper documentation detailing key traceability data is also still often used to pass on information between the initial stages of the supply chain. While paper based mediums allow businesses to meet current regulatory requirements for their internal traceability, the use of paper systems can hinder the transfer of information across a supply chain and the timely submission of data to regulators (Hardt et al 2017). Paper based documentation can also be easily falsified (Bailey et al 2016).

Within the context of electronic end-to-end traceability, lack of interoperability between businesses internal software systems is often cited as the main barrier to achieving full end-to-end traceability across a supply chain (Hardt et al 2017). Even for the mackerel supply chain where some of the processors are using ERP systems, there is little interoperability between the IT systems of different supply chain actors. Integration of separate systems into a single data repository would provide huge improvements to cross-checking mechanisms as manual checks of data submitted between multiple systems are difficult and time consuming to undertake.

12 Improving Traceability across UK Seafood Supply Chains

12.1 Drivers for improving traceability

Traditionally, the management of food safety risks and prevention of food fraud have been the key drivers for improving traceability within food supply chains (Dabbene et al. 2014, Astill et al. 2019, Lawrence et al 2022). More recently, the ability to trace seafood through supply chains is recognised as an important feature of robust, ethical, and economically sound business operations. There are now drivers for business-to-business improvements in traceability and risk management (Bailey et al 2016, BSI, 2017), particularly the requirements for businesses to know the group of vessels a seafood product has come from (BSI, 2017), and the ability to retrieve this information quickly without having to do time consuming trace backs (BSI, 2017).

There is growing interest in the digitalisation of the seafood sector and the potential benefits of this for improving traceability and the efficiency savings this brings for businesses (Hardt et al 2017, Fleming et al 2021) and regulators (Fleming et al 2021, EMSA 2022). Initiatives such as the GDST are promoting electronic end-to-end traceability through their global standards (GDST 2022a, 2022b), though most of the GDST case-studies have only achieved electronic traceability at a business-to-business level (GDST 2023), with it being unclear how much additional information is being passed on to the consumer.

There appears to be little demand from consumers for extra traceability information on the seafood products purchased. However, there is greater interest from consumers in the products being certified to third-party standards such as the MSC. Eco-labels are the primary tool used by retailers for providing consumers with assurance on the sustainability attributes of a product (SSC 2021, WWF 2022). While there is a small but growing market segment of ‘eco-consumer’ in the UK (Co-op 2021), better understanding the needs of this market segment in respect to the provision of extra sustainability data on seafood products will be key. This will be particularly important in determining whether market incentives could be created to facilitate improvements in the transfer of sustainability data through seafood supply chains (Roheim et al 2018). The creation of incentives will help if there are new demands from export markets for sustainability and traceability information (Dinu and Sanz 2021).

12.1.1 Business CSR commitments

Corporate Social Responsibility (CSR) has become increasingly important to retailers and seafood businesses since the 1990s (Packer et al 2019). Initiatives such as the Ocean Disclosure Project (ODP 2023) have made the supply chains of retailers and large processors more visible, and led to businesses being increasingly wary of any reputational risks (such as modern day slavery) associated with the fisheries they are sourcing from (WWF 2022). Many UK retailers and larger seafood companies are also members of the Sustainable Seafood Coalition (SSC), and as such, have to meet the SSC’s sourcing and labelling codes of conduct (SSC 2021).

Retailers are becoming increasingly more demanding that their source fisheries meet minimum environmental and social requirements, and that the fishery is putting improvement actions in place (SSC 2021). In the context of the Dover sole supply chain, processors in south west England are being requested by retailers to only source Dover sole from vessels that meet a set of predetermined criteria (for example, no seine netting, and vessels are part of a bycatch reduction project).

The social and human rights dimension of CSR has become an additional area of focus for UK seafood businesses over the past decade. Business due diligence has expanded from understanding the environmental impacts of a fishery, to also include the social data on fishing vessels (BSI, 2017). This has been driven by international (ILOc188 Work in Fishing Convention) and national regulations (e.g. UK Modern Slavery Act 2015). These regulations have put a duty on supply chain actors to know what activities are happening on the fishing vessels that they source from, who is working onboard the vessels, and working conditions (UK Government 2021b, BSI, 2017).

12.1.2 Market Access

The key seafood markets, in particular the EU and US are continually raising standards (Dinu and Sanz 2021, US FDA 2023) to ensure that imported seafood products meet a minimum set of traceability requirements. For example, the European Commission is considering changes to its fisheries and aquaculture marketing standards to introduce sustainability criteria (Dinu and Sanz 2021). While discussions are still ongoing, the provision of stock sustainability information to the consumer could become a future market requirement for seafood being exported into the EU (Dinu and Sanz 2021).

12.2 Current and Future Improvements

12.2.1 Current improvements

Fisheries management regulators are also making ongoing improvements in their monitoring, control and enforcement systems up to the first point of sale. The recent rolling out of the CatchApp for under 10m fishing vessels has been praised for improving traceability and compliance in this sector as historically there was no statutory requirement for fishers in this sector to declare their catches (UK Government 2021). Through the MyCatch portal, fishers can also request their catch data for business analysis and quota management. There could be opportunity to raise greater awareness of this tool with fishers.

Movement from traditional to electronic fish auction systems is gaining momentum, due in part to the better price fishers can get from selling to a larger pool of remote buyers. Electronic fish auctions have reduced administrative costs associated with issuing paper invoices and submission of sales notes, and reduce the operational costs of running an auction manually. Other large fish auctions around the UK (such as Shetland) are also moving to digital systems (Fishing News 2021).

Key industry stakeholders are making improvements to their internal traceability systems, for example, many larger seafood processors have their own ERP

systems. Investing in such systems helps improve efficiencies in how their stock inventories are managed, and data can be quickly pulled out to satisfy customer queries. Other companies have their own information system that links with the MMO to help them better manage the quota of their members. While not specifically relating to traceability, it highlights that there is interest from companies to invest in technology when it serves a specific purpose.

12.2.2 Future Improvements

The MMO (and regulators in the devolved administrations) are making ongoing improvements to its traceability systems up to the point of first sale and at export. From an enforcement and compliance perspective, improved integration of existing MMO systems will help with automated cross-checking of landings and sales-notes. Providing exporters with permission to view landings and sales note information, may also make it easier for them to reconcile weights of seafood products exported with the actual landings that attributed to this. Currently, in some cases the exporter has to make a best guess in the completion of the catch certificate.

Currently, data exists in silos for IFCAs and the MMO with duplicative reporting raised as a particular challenge for the smaller scale fishing sector. Application Programming Interfaces (APIs) are a potential technical solution to enable the sharing of data across different software systems. Ensuring that the MMO's systems are developed in line with international standards (GDST 2022a, 2022b) will ensure interoperability with software systems used by supply chain actors.

The MMO will need to work closely with businesses in specific sectors that currently experience challenges in meeting data submission requirements due to how their operations are run. For example, with auction houses, the MMO would need to determine the level of accuracy in the date of landing recorded on the seafood product prior to first sale that would enable cross checking with landings declarations submitted by vessels. Similarly, for the submission of sales notes by the merchants in Bridlington, the MMO would need to work closely with the merchants to see where improvements could be made without creating additional administrative burden for each merchant.

In terms of wider engagement across the supply chain, the MMO should consider closer collaboration with organisations such as the FSA and Seafish. The purpose of this would be to develop joint guidance and training materials on traceability that is consistent in its messaging, and also facilitating ongoing policy dialogues between stakeholders at different points in the supply chain. A market focused traceability working group could be established to better understand the needs of retailers and restaurants for information, and consumer interest in traceability.

A more in-depth legislative review might help the MMO understand where existing regulations may impact data sharing and potentially impede traceability within the supply chain. Within the context of sharing business data, the MMO would need to be compliant with relevant UK laws, for example the UK Data Protection Act (UK Government 2018). In the terms of provision of information to the consumer and

claims made on a product, UK consumer laws will have implications for this (UK Government 2015b).

The European Commission is considering changes to its fisheries and aquaculture marketing standards to introduce sustainability criteria (Dinu and Sanz 2021) with implications on UK export requirements. This could mean ensuring traceability to a stock and accurate reporting of the type of catch method, and ensuring this information moves with the product to final sale. If there is a regulatory interest in ensuring sustainability data travels with the product, new laws and powers may have to be developed to enforce this (as this currently sits outside of the remit of the FSA).

13 Key Recommendations for improving UK seafood supply chain traceability

13.1 Recommendations from stakeholders across the case study supply chains

1. **Focus on improving traceability up to the point of first sale.** Traceability post-first sale that goes beyond the minimum regulatory requirements should be driven by market need for additional data (e.g. information on fishing vessels) or assurance (e.g. MSC certification).
2. **Definitions of traceability need to more clearly stated to stakeholders.** The benefits of digitalisation and moving from paper based systems could be better communicated to stakeholders to enable wider supply chain transparency initiatives.
3. **Digitalise and integrate information systems.** Ensuring that all 10-12m fishing vessels are on digital reporting systems, and improving the integration of current MMO digital systems with automated cross checking between different databases (i.e. catch, landings, sales, and exports) will reduce administrative and enforcement costs.
4. **Improve stakeholder engagement around data submission.** Improving stakeholder engagement around data submission could help improve quality of data submission and increase understanding of the current administrative challenges for stakeholders.
5. **Minimise duplication of catch reporting by MMOs and IFCAs.** Joint data sharing agreements could be agreed between the MMO and IFCAs to reduce duplication. Additional functionality could be added to the CatchApp to improve the resolution of spatial data captured to satisfy IFCA and wider marine spatial planning requirements.
6. **Improvements to traceability systems are needed to allow for the distinction between sustainable versus non-sustainably caught seafood**. Better enforcement of the legal requirements to state catch method on seafood labels with more collaboration between the MMO and FSA could allow greater distinctions between sustainably caught and non-sustainably caught seafood.
7. **Increase transparency in how data submissions are used to increase data accuracy**. Providing stakeholders with a greater understanding of how their data is used to prevent IUU and in wider marine spatial planning decisions, increase the accuracy of traceability data submissions.
8. **Improve monitoring of wholesale markets.** Increasing cross reference checks between sales notes and invoices could improve traceability across the supply chain.

13.2 Further considerations

The following considerations were not raised directly during the interviews, though reflect other issues identified and ideas formed over the course of the project that may be of interest to the MMO.

1. Good traceability practices should be defined relative to the fisheries context and operational complexity of the supply chain. The reality is that most UK seafood supply chains are not simple and linear and therefore it is not always currently possible to trace production batches back to specific vessels.
2. Intermediaries such as wholesale traders and distributers play a crucial role in getting seafood products to markets. However, the traceability systems in place for this sector are not properly understood.
3. Consumer facing businesses, particularly the major retailers, have an interest in being able to trace seafood products back to the vessels for IUU and human rights due diligence. However, this may not require traceability back to a specific vessel, a list of vessels which contributed to the production batch could be sufficient to meet these requirements.
4. There needs to be better understanding of the market need for data, particularly what data may be of additional value to the consumer. The information needs of the ‘eco-conscious’ consumer may differ from the market average. Improved understanding of the interest in traceability from different market segments will be key to determining the market incentives for traceability improvements.
5. Current traceability and fisheries data initiatives in the UK are part of a complicated landscape, with many different organisations involved. Mapping of current and planned traceability initiatives UK-wide would be a useful exercise to undertake, avoiding duplication of effort between initiatives and to identify opportunities for collaborative working.

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Annex A. Glossary

Ambient seafood – shelf-stable fish and seafood products, for example fish and seafood sold in jars, tins and shelf-stable vacuum packs.

Batch – a defined quantity of product that is typically sold collectively at the first point of sale or has undergone production or transformation at the same time and place, and under the same conditions (also known as a 'lot').

Batch level traceability – the ability to track information about a group of seafood products (referred to as a batch) that have a similar attribute (e.g., species name, catch area and date, processing location and method).

Chain of custody – the list of all organisations in a supply chain that take ownership or control of a product both physically and/or administratively during production, processing, transport, and retail.

Critical Tracking Events (CTEs) – a specific point along a supply chain where certain key data elements need to be captured for the purpose of enabling traceability of a product, such as receiving, packing, transport, and auction events.

End-to-end traceability – the ability to fully trace a product from the point of sale to a consumer back to its point of origin.

Fish grading – the process of separating product based on a particular feature, such as size or quality, in order to send higher-value products into more premium markets.

Interoperability – the ability of different information technology systems or software programs to communicate seamlessly for the purpose of exchanging, interpreting, and using data is a critical component of full chain digital traceability.

Internal traceability – the ability to monitor the movement and trace the parts or finished products in a limited area of a supply chain, such in a single company or factory.

Key Data Elements (KDE) – the different pieces of information that capture the who, what, where, and when of a product as it moves through different stages of a supply chain.

Mock recalls – a planned event practiced by processors, distributors, retailers and others in the supply chain to test the responsiveness and effectiveness of their individual recall plans, traceability systems, and recall procedures.

One-up one-down – record-keeping to track purchases (one up) and sales (one down) of products that move through a particular entity in a supply chain.

Supply Chain Actors – key trading partners and stakeholders involved in moving wild and farmed seafood from harvest to consumer.

Territorial Sea – 12 nautical miles adjacent to the coast of a state that is considered part of the state's territory. Activity in this area is subject to its sovereignty.

Tracebacks – activities to test and document the effectiveness of traceability systems in a supply-chain, often in preparation for audits or certifications.

Transhipment – the unloading of goods from one ship and its loading into another to complete a journey to a further destination.

Transparency – the ability to demonstrate product information to stakeholders, regulators, trading parties, and consumers across a supply chain. As opposed to traceability, which involves information at the lot-level, transparency is information related to business practices, manufacturing processes, locations, licenses, certifications, and other factors that may be used for compliance or risk management purposes.

UK commercial designations of fish – the list of fish names accepted at the point of retail in the UK, including the scientific name of each species, its common name and any local or regional names.

Value Chain – the series of stages involved in producing a product or service that is sold to consumers, with each stage adding to the value to the product or service.

Vertically integrated supply-chains – a company's full or partial ownership of complimentary actors in a supply chain, including suppliers, distributors, and retailers, leading to greater control of its supply chain. In the fishing industry, this often related to vessel ownership by processors.

Annex B. Project Brief

Traceability in the UK Seafood supply chain

Context

Improving traceability, the extent to which fish can be verifiably tracked as it moves through the supply chain, is a key priority for Defra's Control & Enforcement policy team and the Marine Management Organisation.

This project is the second of three traceability projects commissioned by Defra and the MMO in Q3-Q4 of 2022-23:

1. Benefits of traceability (Poseidon Ltd)
2. Traceability in the UK supply-chain (SRUC and University of Hull)
3. Use of technology in traceability (Poseidon Ltd)

Key Aims and Objectives

Through investigation into 3 case studies of UK fisheries, the project will:

- Identify the different kinds of supply chain in operation in the UK.
- Produce system maps of UK seafood supply chains.
- Identify examples of best practice.
- Identify the main challenges in the UK seafood supply chains.
- Produce suggestions of how to address challenges improve processes into UK seafood supply chains.

This project therefore aims to improve the MMO's understanding of the following questions within the context of different types of UK seafood supply-chains and business operations:

1. Where does traceability potentially break-down and where is key information lost?
2. What information is currently captured, and how it is typically transferred at various stages of the supply-chain to help organisations manage inventory and day-to-day activities?
3. How do unique identifiers for the final consumed product link back to key product information?
4. Where do organisation's interests lay in relation to the need for improved traceability?
5. What are the potential barriers and opportunities of using technology and/or modifying systems to move away from paper-based records, spreadsheets and/or incompatible software?

Stakeholder engagement

Stakeholder workshops, interviews and questionnaires will be carried out to validate and build upon desk-based findings.

This request: 30 mins – 1 hr interview

Case study locations and produce of interest

- Peterhead, Scotland – Mackerel
- Bridlington, England – European lobster and brown crab
- South-west England – Dover sole

Annex C. Stakeholder Questionnaire

(i) Recipient – Port Authorities & Fishing Authorities

Regulations & Governance

- Where do organisations typically fail to meet regulatory requirements? (e.g., data gaps/delays in reporting)
- Is regulatory data submitted in consistent formats?
- Where do you believe critical tracking events (high risk of traceability data being lost) typically occur?
- How are instances of fraud identified? What are common examples?
- How are audit/cross-checks of submitted documentation undertaken? What would prompt an audit?
- Have you ever had to implement targeted recalls and was the required data available to perform it effectively?

General attitudes

- What are the positive elements of the existing traceability systems? Are you aware of any examples of good practise?
- Do you believe fishers and other actors within the seafood supply chain have a good understanding of the need to traceability?
- How effective do you believe the current traceability system is and what changes should be made?
- What do you believe would be the main blockers to adopting technological traceability solutions with improved interoperability?

Supply chain mapping

- Please provide some fishers (of mixed business size/type) that may be interested in being interviewed
- Please provide some buyers (of mixed business size/type) that may be interested in being interviewed

(ii) Recipient – Fishers

Systems and Technologies

- How is internal traceability managed?
- Are the designated methods for capturing catch data (electronic logbook/paper/catch app) appropriate for use?
- Are any other technical solutions used for the capture/storing/reporting/transferring traceability data?
- Where do you believe critical tracking events (high risk of traceability data being lost) typically occur?
- How is catch data from multiple vessels retained when seafood is split or merged into lots during post-landing?
- Are there any variations in traceability processes according to product type? (e.g., premium vs bulk)
- How do you pass traceability data onto buyers?

Regulations

- What are the challenges/pain points in meeting regulatory requirements?
- Are there particular scenarios when regulatory requirements often cannot be met? (e.g., deadlines missed)
- What are the positive elements of the existing traceability systems? Are you aware of any examples of good practise?

Market Drivers

- Do you capture additional catch data beyond the regulatory requirements? If so, what, and why?
- Are there any requests/pressures from retailers/end market to provide additional data?
- Do you ever receive any monetary benefits from providing high levels of product data?
- Is your business certified by any traceability/supply chain/food safety certifications schemes? (BRCGS / RFVS /BAP / MSC) If so, what activities/processes are in place to ensure that your organisation meets requirements and remains certified?

General attitudes

- What do you believe are the benefits of traceability to your business and to the to the wider supply chain?
- What do you believe are the negative implications of improved traceability?
- How effective do you believe the current traceability system is and what improvements would you like to see?
- What do you believe would be the main blockers to adopting technological traceability solutions with improved interoperability?

Supply chain mapping

- Which organisations do you typically sell to?

(iii) Recipient – Supply chain actors (Processors/ auctioneers/ wholesalers/ exporters/ distributers etc.)

Systems and Technologies

- How is internal traceability managed?
- Are any technical solutions used for the capture/storing/reporting of traceability data?
- What seafood product data is supplied to you from the previous step in the supply chain, and by what mechanism?
- What seafood product data do you supply to the next step in the supply chain, and by what mechanism?
- How is data from lots retained when seafood is split or merged during processing/ distribution/ selling?
- Where do you believe critical tracking events (high risk of traceability data being lost) typically occur?
- Are there any variations in traceability processes according to product type? (e.g., premium vs bulk)

Regulations

- What are the challenges/pain points in meeting regulatory requirements?
- Are there particular scenarios when regulatory requirements often cannot be met? (e.g., deadlines missed)
- What are the positive elements of the existing traceability systems? Are you aware of any examples of good practise?

Market Drivers

- Do you capture any additional catch data beyond the regulatory requirements? If so, what, and why?
- Are there any requests/pressures from retailers/end market to provide additional data?
- Do you ever receive any monetary benefits from providing high levels of product data?
- Is your business certified by any traceability/supply chain/food safety certifications schemes? (BRCGS / RFVS /BAP / MSC) If so, what activities/processes are in place to ensure that your organisation meets requirements and remains certified?

General attitudes

- What do you believe are the benefits of traceability to your business and to the to the wider supply chain?
- What do you believe are the negative implications of improved traceability?
- How effective do you believe the current traceability system is and what improvements would you like to see?
- What do you believe would be the main blockers to adopting technological traceability solutions with improved interoperability?

Supply chain mapping

- Which organisations do you typically buy from?
- Which organisations do you typically sell to?

(iv) Recipient – End market actors (Fishmongers/ retailers/ food services etc.)

Systems and Technologies

- How is internal traceability managed?
- Are any technical solutions used for the capture/storing/reporting of traceability data?
- What seafood product data is supplied to you from the previous step in the supply chain, and by what mechanism?
- Where do you believe critical tracking events (high risk of traceability data being lost) typically occur?
- Are there any variations in traceability processes according to product type? (e.g., premium vs bulk)

Regulations

- What are the challenges/pain points in meeting regulatory requirements?
- Are any regulatory labelling data points often missed due to lack of traceability within the supply chain?
- What are the positive elements of the existing traceability systems? Are you aware of any examples of good practise?

Market Drivers

- Are consumers typically interested in product data? (e.g., source location, method of capture, sustainability metrics etc.)
- Are consumers typically willing to pay premium for products with traceability data provided?
- Is your business certified by any traceability/supply chain/food safety certifications schemes? (BRCGS / RFVS /BAP / MSC) If so, what activities/processes are in place to ensure that your organisation meets requirements and remains certified?

Supply chain mapping

- Which organisations do you typically buy from?
- Who are your typical end consumers?

General attitudes

- What do you believe are the benefits of traceability to your business and to the to the wider supply chain?
- What do you believe are the negative implications of improved traceability?
- How effective do you believe the current traceability system is and what improvements would you like to see?
- What do you believe would be the main blockers to adopting technological traceability solutions with improved interoperability?