INdIGO

INnovative fishing Gear for Ocean

T1.3.2 Market Analysis

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Executive Summary

In EU sea basins, the contribution of fishing gear to marine litter is estimated to be 27% (EU, 2018). Abandoned, lost or otherwise discarded fishing gear (ALDFG) is created by the fishing industry and directly impacts fishermen's livelihoods through ghost fishing, entanglements and presents navigational hazards. In addition, ALDFG creates a myriad of environmental (FAO, 2016) and socioeconomic (Beaumont et al., 2019) impacts that affects fisheries and other commercial sectors operating in the marine environment, as well as recreational users and land based sectors e.g. tourism.

One of the main causes of ALDFG is the lack of facilities for end of life disposal. There are only three fishing gear recycling facilities in Europe – all of which have limited capacity when compared to the sheer volume of ALDFG estimated to enter the world's oceans each year. The complex nature of materials used in fishing gear renders recycling difficult, often resulting in a value gap (i.e. the value of the recycled material is less than the cost of producing it). There is growing interest in improving recycling channels to integrate fishing gear into a circular economy - particularly through extended producer responsibility schemes. However, even with adequate recycling facilities, there is no guarantee that there would be more gear to recycle (without the provision of measures and incentives to improve the rate at which lost gear is brought back to shore and end of life gear made available for recycling). While gear may be marked etc., so that it can be located and brought ashore, such measures cannot locate the vast amount of ALDFG currently in the world's oceans. Gear retrieval programmes have been the main response to ALDFG, although they have been (mostly) undertaken in the absence of information on the costs and benefits (Brown et al., 2005). Further, dedicated gear retrieval programmes are costly and require the development of efficient recycling facilities.

Given the inefficiencies of current approaches to deal with ALDFG, urgent solutions are required. Various options are being explored. For example, integrating fishing gear into extended producer responsibility schemes and mandatory deposits for new fishing gear. Biodegradability, as a design feature of fishing gear, is not a new idea, but it is one that requires further research to fully understand the potential role of biodegradable fishing gear (BFG) to mitigate (various) environmental and economic impacts of ALDFG. While there is a paucity of information on BFG, it is currently in use in some commercial fisheries.

The objectives of this market analysis report are 1. To understand the potential market (fleets, gear types, target species etc. for BFG) in the Channel fishery (currently there is no market for BFG); 2. Demonstrate the benefits of BFG over the status quo (and against the alternative mitigation measures to ALDFG) and; 3. Consider the management framework and incentives required to facilitate the uptake of BFG in the Channel fishery.

We conclude that during the developmental phase of biodegradable gear, the market that offers the most potential for integration into commercial fishing activity is represented by static gear vessels (those using fixed nets and trap type gear). Of the 1,170 vessels registered in UK Channel Ports, 1,004 are <10m in length and mostly

utilise static type gears. These gear types are estimated to represent the highest risk of becoming ALDFG, as well as having greater environmental and socioeconomic impacts (Gilman et al., 2021). Further, the available literature suggests that biodegradability has potential in static type gears.

Extrapolate these findings to EU fisheries (using the latest STECF data) and the potential market size for biodegradable gear in small scale static gear vessels grows to 47,999.

1. Introduction

This report has been prepared for Work Package 1 - Task 1.3.2. The purpose of the market analysis is to understand the "potential market" for biodegradable fishing gear (BFG) in the programme area. The potential market is disaggregated to three levels – the total addressable market, the serviceable available market and the serviceable obtainable market. The distinction is important, as currently there is no market for BFG in the project programme area, the UK, France and the EU (although experimental work is Norwegian fisheries i ongoing). On a commercial scale, BFG is only available in gillnet fisheries in China, Japan and South Korea and in some trap fisheries (mainly) in the USA[1].

Biodegradability, as a design feature of fishing gear, is not a new idea. Before the mass production of fishing nets made largely of synthetic based materials, fishing gear was made from materials that naturally degraded in water overtime (Radhalekshmy & Nayar, 1973). However, given the favourable characteristics of plastic (particularly from an economic viewpoint), such as its durability, affordability and versatility, it has become the main material used to produce fishing gear around the world (Fjelstad, 1988). Plastic is an input into countless production processes in the global economy, resulting in the production of plastic growing nearly 200 fold from 2 million tonnes in 1950 to 381 million tonnes in 2015 (Ritchie and Rosser, 2018). While most plastics in theory are recyclable, in practice, plastic products are often constructed and used in ways that make recycling difficult and costly. As a result, the recycling of fishing gear is almost non-existent around the world. For example, there are no facilities to recycle fishing gear in the UK and only three recycling facilities in Europe (one in Denmark, one in Italy and one in Norway). The largest facility can recycle around 30,000 tonnes of fishing gear a year, yet there are more than 81,000 fishing vessels (STECF, 2020) using a variety of fishing gears in the EU alone, with the FAO (2016) estimating the annual global loss of fishing gear at more than 640,000 tonnes per year. Therefore, developing fishing gear recycling chains will remain important, but at present, it is largely not economically viable. The cost of dismantling end of life gear and producing the recycled raw material is often higher than the value of the raw material produced (generating a "value gap").

However, as the fishing industry represents a significant contributor to marine litter (estimated at 27% in EU waters by the European Commission[2]) continuing with a "business as usual" scenario is not appropriate. Given increasing public knowledge and concern about the environmental damage caused by marine litter, urgent solutions are needed. BFG, or gear that consists of biodegradable components, (e.g. escape hatches fitted to trap type gear) represents a potential solution (Gilman, 2015; Wilcox and Hardesty, 2016). Importantly, a solution that focuses on the reduce and reuse elements of developing a circular economy for fishing gear is preferable to a sole focus on end of life recycling.

Research into the development and use of BFG is limited (Gilman, 2015). From the initial research of testing the applicability of biodegradability as a design feature of nets, which in most cases identified issues around strength, durability, flexibility and cost (Macfadyen, Huntington and Cappell, 2009; Grimaldo et al., 2018a; Wilcox and Hardesty, 2016), the research agenda has shifted to focus on developing biodegradable

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[1] Largely biodegradable escapee mechanisms of various designs fitted to lobster and crab pots.

[2] See: https://ec.europa.eu/fisheries/new-proposal-will-tackle-marine-litter-and-%E2%80%9Cghost-fishing%E2%80%9D_en

gear that addresses these challenges (e.g. the causes of reduced catch efficiency and how it may be overcome). Acceptance from the fishing industry will be a key driver in the potential success of BFG. However, the fishing industry have reservations about biodegradability as a solution to the marine litter problem (Brown et al., 2005; MRAG, 2020). Rather, other aspects of integrating fishing gear into a circular economy e.g. modification, reusability, efficient dismantling for recycling are seen as the key circularity aspects (Brown et al., 2005; MRAG, 2020), although few studies have engaged fishermen on this issue. Most experimental research (Bae et al., 2013; Grimaldo et al., 2018a; Grimaldo et al., 2018b; Grimaldo et al., 2019; Grimaldo et al., 2020; Kim et al., 2016) continues to focus on issues around strength and flexibility and its relationship to fishing efficiency. As such, it is important to engage the fishing industry in the market analysis[3] to better understand their views and experiences of ALDFG, as well as their views on BFG (strengths, weaknesses, what would persuade them to use BFG etc.), so that the INdIGO project develops BFG that meets their needs.

While demand for BFG from the fishing industry is not fully known, their concerns around functionality issues need to be addressed to facilitate the uptake of BFG on a commercial scale (across various fleets and fishing gears). An important step in this process is to understand the market segments of the fishing industry where BFG is most likely to be accepted in the developmental phase. One important aspect in this regard is the impact of consumer acceptance regarding sustainability. As consumers become more demanding that the fish they consume is caught/produced sustainably (e.g. Marine Stewardship Council for fisheries[4] and the Aquaculture Stewardship Council for aquaculture[5]) fishermen that are willing and able to adopt new and sustainable fishing practices can be rewarded with higher market prices. This has been demonstrated in fisheries in the programme area e.g. lobster from sustainable Lyme Bay fisheries[6]. Therefore, as noted by MRAG (2020), consumer (dis)acceptance of the environmental impacts of ALDFG – notably entanglement of marine life and ghost fishing - may offer opportunities for further research regarding the implementation of BFG.

The fishing industry have regularly engaged with projects and initiatives to address sustainability. For example, to improve selectivity and fishing efficiency to reduce bycatch. Partly, this has been to improve economic efficiency (costs of fishing and profitability), partly in response to regulations (e.g. the landing obligation) and partly in response to developing sustainable low impact fishing practices. Since public awareness (and disapproval) of the global marine litter problem is growing, the main opportunity for BFG may be in improving sustainability (through integrating fishing gear into a circular economy, which may be perceived as positive by consumers). This report will contribute to other research efforts e.g. the Glaukos[7] project (in addition to the research conducted in INdIGO) that considers the opportunities and challenges of integrating BFG into the fishing industry.

Although BFG is not viewed as a "silver bullet" solution to marine litter, ALDFG and the various environmental impacts (e.g. ghost fishing), it is increasingly put forward as a potential solution (Gilman 2015; Kim et al., 2016; Wilcox and Hardesty, 2016).

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[3] This is achieved through the two surveys conducted in Work Package 1.
[4] See: https://www.msc.org/
[5] See: https://www.asc-aqua.org/
[6] See: https://www.bluemarinefoundation.com/wp-content/uploads/2018/05/Lyme-Bay-ecology-and-fisheries-data-2016-.pdf
[7] https://www.b4plastics.com/projects/glaukos/

Conducting a market analysis to understand the market segments where BFG could be introduced (in the developmental phase) is an important step in demonstrating the potential role of BFG to address ALDFG – a problem that currently does not have a well-defined solution.

1.1 Objective

The objective of conducting the market analysis is threefold. **1**. To demonstrate the size and current conditions (e.g. fleet segments, profitability, management framework, competition from alternative mitigation measures etc.) of the potential market for BFG in the programme area. The 'potential' market size (**the total addressable market**) is relatively straightforward to derive (as such data are available). However, the potential market size does not necessarily capture the market segment(s) where BFG may be adopted. This is an important consideration given there is no regulation mandating BFG use. This, coupled with an apparent lack of demand from the fishing industry in the programme area (see Brown et al., 2005), necessitates progression to the next level of market disaggregation. Therefore, we progress to define a 'realistic' market (**the serviceable achievable market**), defined as fleet segments and gear types that represent a viable option for the developmental phase of BFG. **2**. To demonstrate the benefits of BFG over the status quo (i.e. traditional gear use) and against alternative measures (e.g. gear retrieval). **3**. To review the management measures (i.e. incentives) required to integrate BFG into the **serviceable obtainable market** in the programme area.

1.2 Report structure

The report is organised as follows. Section 2 presents an overview of the UK fishing industry followed by a detailed overview of the Channel fisheries. We also present a brief overview of aquaculture activity and the potential role of biodegradability in aquaculture. Finally, Section 2 provides a brief overview of the management framework in the Channel fisheries and its role in BFG implementation. Section 3 reviews the competition in the market for BFG that may impact on BFG implementation. Section4 discusses the barriers and opportunities for BFG use, including outputs from the stakeholder engagement work on fishermen's views on BFG. Section 5 considers incentives and management measures for BFG integration. Finally, Section 6 presents the target market for BFG in the programme area (Channel fisheries) disaggregated from the total addressable market to the serviceable achievable market and finally the serviceable obtainable market.

2. Industry overview[8]

2.1 Introduction

In this section of the report, we present an overview of the fishing industry. We begin at the UK level and then disaggregate to the fishing industry at the programme area level (i.e. the Channel fisheries) – the total achievable market. At this point, we suggest the markets segments for BFG. However, we only disaggregate to the final level - the serviceable obtainable market, when all aspects e.g. management framework, the opportunities and barriers for BFG, environmental impacts mitigated by BFG, incentives required etc. are considered.

The industry analysis will focus largely on the current situation within the industry (recent data for most variables are available for 2019 in ICES, MMO, Seafish and STECF databases), against a backdrop of the last 5-10 years to allow for comparison)[9]. Forecasting for future years is not undertaken is this report[10].

Important factors to assess include the growth rate of the industry in recent years, changes in industry composition, catches (volume) and the evolution of market prices (value), operating costs and profits, employment and other socioeconomic factors. A brief overview of the impact of the EU exit fisheries deal is considered. All further sections in this report link directly to this industry overview. For instance, the current position of the industry may influence the barriers to implementation and the subsequent incentives that may be required to facilitate uptake.

Finally, for completeness, the UK commercial fisheries industry comprises three sectors – the fishing industry, the aquaculture industry and the fish processing industry. This report will focus primarily on the fishing industry, which represents the vast majority of fish production in the UK. The report will also consider (to a lesser extent reflecting the relative importance of the sector) aquaculture in England (which is representative of type aquaculture that may be developed in the programme area), as this may represent an important market for biodegradable gear in the future[11]. The report will not consider the fish processing industry.

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[8] All of the tables produced in this section are the authors own creation based on MMO data – see Section 8 References (numbers: 52-55)

[9] Data analysis is constrained by the data available/accessible. For example, the characteristics of the data collected by ICES are not the same as data collected by the MMO. This is explained in the text where relevant – and is not considered problematic, as the requirement for ‘perfect’ data is not needed for the market analysis.

[10] Brexit complexities, coupled with the ongoing pandemic, would make such forecasts only rough estimates at best.

[11] See section on Biodegradability and Aquaculture.

2.2 UK fleet landings into UK and abroad

Figure 1 - All Vessels 2019 - Value (£): £986,839,884. Volume (Live weight tonnes): 621,886

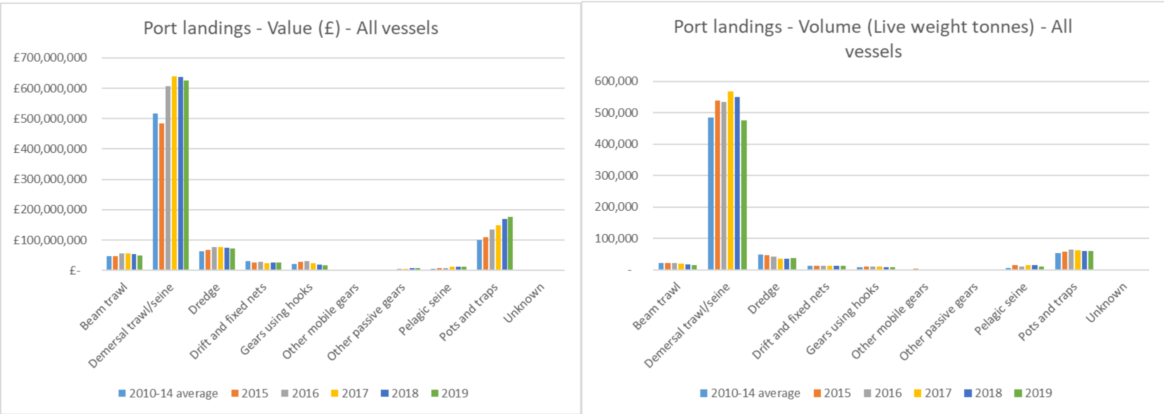


Figure 2 – Over 10m: 2019 - Value (£): £854,230,442. Volume (Live weight tonnes): 580,623

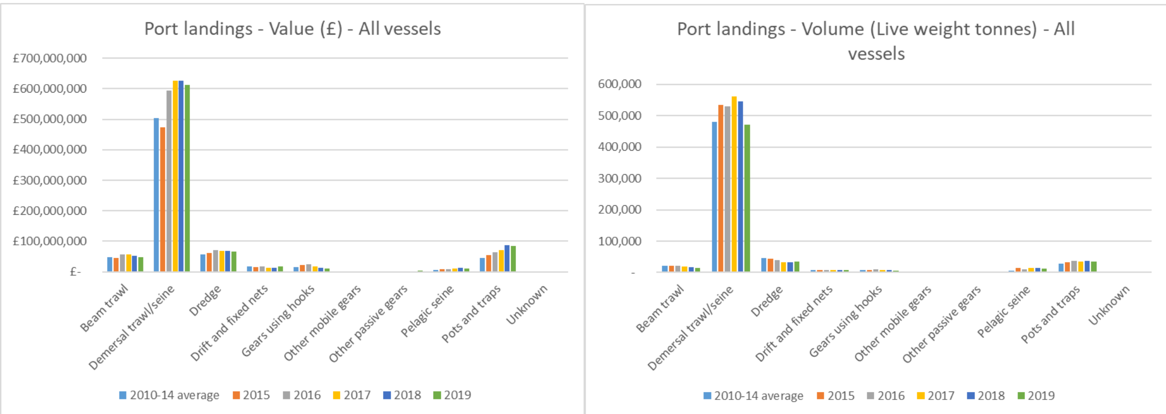
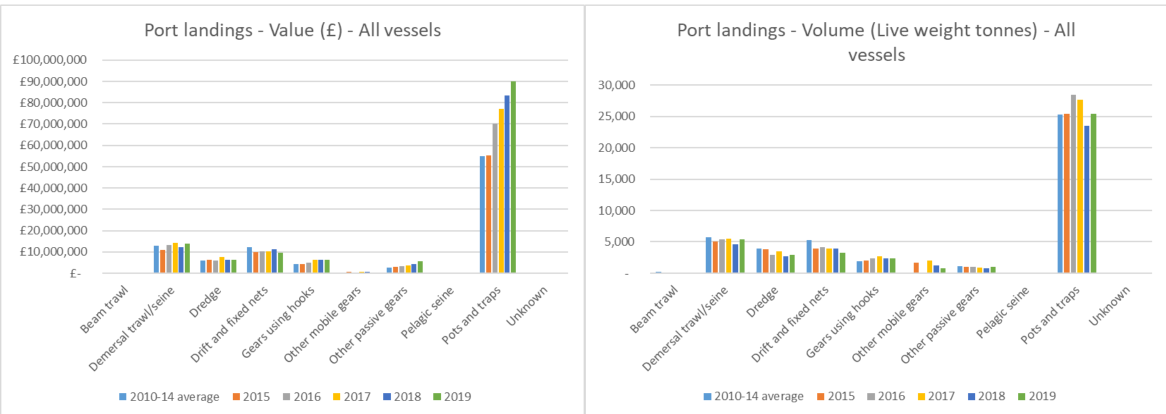


Figure 3 - Under 10m - 2019 Value (£): £132,609,442. Volume (Live weight tonnes): 41,263



2.2.1 Species by gear type for UK fleet landings

The following tables show the top five species by value for each of the nine gear types recorded by the MMO landed into the UK or abroad by the UK fleet in 2019. NB. Pelagic midwater trawls (excluding purse seine) are captured under demersal trawl/ seine by the MMO.

Table 1 - All vessels:

Beam trawl	
Sole	£ 14,055,839
Cuttlefish	£ 8,521,382
Plaice	£ 7,792,267
Monks or Anglers	£ 4,847,462
Turbot	£ 3,084,932

Drift and fixed nets	
Monks or Anglers	£ 8,038,728
Hake	£ 6,201,415
Sole	£ 3,150,445
Pollack	£ 1,545,448
Turbot	£ 1,316,620

Other passive gears	
Razor Clam	£ 6,013,769
Scallops	£ 2,133,273
Manilla Clam	£ 186,345
Periwinkles	£ 28,880
Whelks	£ 8,618

Demersal trawl/seine	
Mackerel	£ 169,927,140
Nephrops (Norway Lobster)	£ 99,101,954
Cod	£ 72,871,671
Haddock	£ 50,452,813
Monks or Anglers	£ 40,687,713

Gears using hooks	
Hake	£ 7,305,037
Bass	£ 2,813,031
Ling	£ 2,340,273
Mackerel	£ 2,280,918
Swordfish	£ 662,534

Pelagic seine	
Mackerel	£ 9,526,181
Pilchards	£ 1,486,234
Anchovy	£ 65,651
Horse Mackerel	£ 16,946
John Dory	£ 246

Dredge	
Scallops	£ 54,947,605
Cockles	£ 9,590,106
Queen Scallops	£ 3,028,691
Mussels	£ 860,420
Manilla Clam	£ 694,885

Other mobile gears	
Scallops	£ 337,424
Cockles	£ 305,922
Manilla Clam	£ 44,224
Mixed Clams	£ 25,679
Sand Eels	£ 12,241

Pots and traps	
Crabs (C.P.Mixed Sexes)	£ 73,318,291
Lobsters	£ 45,992,124
Whelks	£ 25,409,755
Nephrops (Norway Lobster)	£ 16,592,873
Crabs - Velvet (Swim)	£ 5,289,881

Table 2 - Over10m:

Beam trawl	
Sole	£ 13,924,646
Cuttlefish	£ 8,480,772
Plaice	£ 7,696,699
Monks or Anglers	£ 4,824,950
Turbot	£ 3,053,167

Drift and fixed nets	
Monks or Anglers	£ 7,659,265
Hake	£ 6,189,883
Turbot	£ 752,972
Pollack	£ 678,999
Pilchards	£ 561,996

Other passive gears	
Razor Clam	£ 2,221,424
Scallops	£ 625,987
Nephrops (Norway Lobster)	£ 3,661
Lobsters	£ 34

Demersal trawl/seine	
Mackerel	£ 169,911,835
Nephrops (Norway Lobster)	£ 92,111,786
Cod	£ 72,809,979
Haddock	£ 50,358,859
Monks or Anglers	£ 40,396,675

Gears using hooks	
Hake	£ 7,305,001
Ling	£ 2,332,844
Swordfish	£ 662,534
Blue Shark	£ 313,996
Pollack	£ 86,528

Pelagic seine	
Mackerel	£ 9,526,181
Pilchards	£ 1,486,234
Anchovy	£ 65,651
Horse Mackerel	£ 16,946
John Dory	£ 246

Dredge	
Scallops	£ 51,493,170
Cockles	£ 8,882,725
Queen Scallops	£ 3,020,818
Mussels	£ 833,700
Sole	£ 614,817

Other mobile gears	
Scallops	£ 228,449
Nephrops (Norway Lobster)	£ 3,538
Monks or Anglers	£ 15
Brill	£ 12
Sole	£ 6

Pots and traps	
Crabs (C.P.Mixed Sexes)	£ 50,531,413
Lobsters	£ 15,085,069
Whelks	£ 12,960,969
Nephrops (Norway Lobster)	£ 5,685,996
Crabs - Velvet (Swim)	£ 701,695

Table 3 – Under 10m:

Beam trawl	
Sole	£ 131,193
Plaice	£ 95,568
Cuttlefish	£ 40,610
Turbot	£ 31,766
Lemon Sole	£ 27,360

Drift and fixed nets	
Sole	£ 3,044,083
Bass	£ 1,063,469
Pollack	£ 866,449
Turbot	£ 563,648
Whelks	£ 561,893

Other passive gears	
Razor Clam	£ 3,792,345
Scallops	£ 1,507,286
Manilla Clam	£ 186,345
Periwinkles	£ 28,880
Whelks	£ 8,618

Demersal trawl/seine	
Nephrops (Norway Lobster)	£ 6,990,168
Sole	£ 1,380,715
Squid	£ 1,089,225
Cuttlefish	£ 632,348
Plaice	£ 623,856

Gears using hooks	
Bass	£ 2,755,284
Mackerel	£ 2,277,189
Pollack	£ 503,060
Cod	£ 350,159
Lobsters	£ 74,544

Pelagic seine	

Dredge	
Scallops	£ 3,454,436
Cockles	£ 707,381
Manilla Clam	£ 661,646
Razor Clam	£ 431,588
Mixed Clams	£ 303,092

Other mobile gears	
Cockles	£ 305,922
Scallops	£ 108,974
Manilla Clam	£ 44,224
Mixed Clams	£ 25,679
Sand Eels	£ 12,241

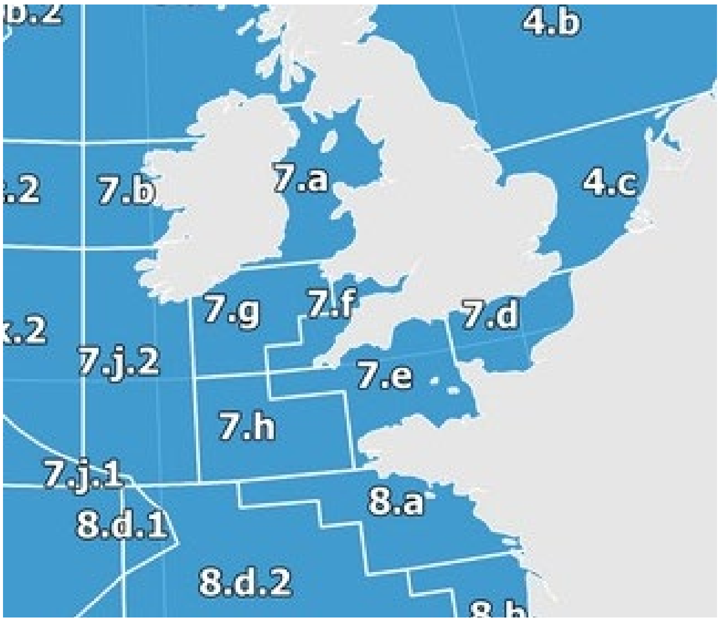
Pots and traps	
Lobsters	£ 30,907,055
Crabs (C.P.Mixed Sexes)	£ 22,786,879
Whelks	£ 12,448,786
Nephrops (Norway Lobster)	£ 10,906,877
Crabs - Velvet (Swim)	£ 4,588,187

The UK's fishing industry is dominated by active gears, with trawls accounting for the majority of volume and value with Mackerel and Nephrops the most important species. While this is the case for the over 10m fleet, for the 10m and under fleet the majority of the volume and value comes from static and passive gears, such as pots and traps with crabs and lobsters the most important species.

2.3 Channel fishery

The FCE programme area coastline directly borders five ICES divisions within Major Fishing Area 27. These are 4.c, 7.d, 7.e, 7.f and 8.a. Due to their proximity it is likely that the bordering divisions (4.b, 7.g, 7.h and 8.d.2) contain fishing activity related to the programme area. As fishing vessels are not all constrained by these divisions and do not solely fish in the closest division to their home port it is necessary to define a 'Channel fishery' in order to perform an analysis. Areas 7.d and 7.e (fully titled 27.7.d and 27.7.e) were selected as they are the only ICES divisions wholly bounded by the programme area and therefore will allow for fishing activity from UK fleet operations to be more closely linked to the coastline. Therefore, references to the Channel fishery or Channel ports in this analysis refer to this area.

Figure 4 – FCE programme area



Source: FAO, (2021).

There are two ways of measuring UK fleet operations in the Channel from the MMO sea fisheries statistics. Two data sets are available by the MMO - Port landings and ICES landings. The first shows landings by UK vessels into UK and foreign ports and by foreign vessels into UK ports. The second shows landings by UK vessels by the location of the fishing activity. The data sets do not provide any way to track fishing activity in a given area to the port of landing.

Therefore, there are two options for examining the data:

1. Port landings - By identifying the UK and French ports present in ICES division 27.7.d (Eastern channel) and 27.7.e (Western channel) the landings by port from UK Vessels in the Channel fishery can be investigated; and
2. ICES activity - Fishing activity by UK fishing vessels in ICES divisions 27.7.d and 27.7.e with no link to the port of landing can be investigated

Both sets of data are presented below.

Figure 5 - All vessels: Port landings - 2019 - Value (£): £116,037,286. Volume (Live weight tonnes): 51,053. ICES activity - 2019 - Value (£): £130,711,493. Volume (Live weight tonnes): 60,130

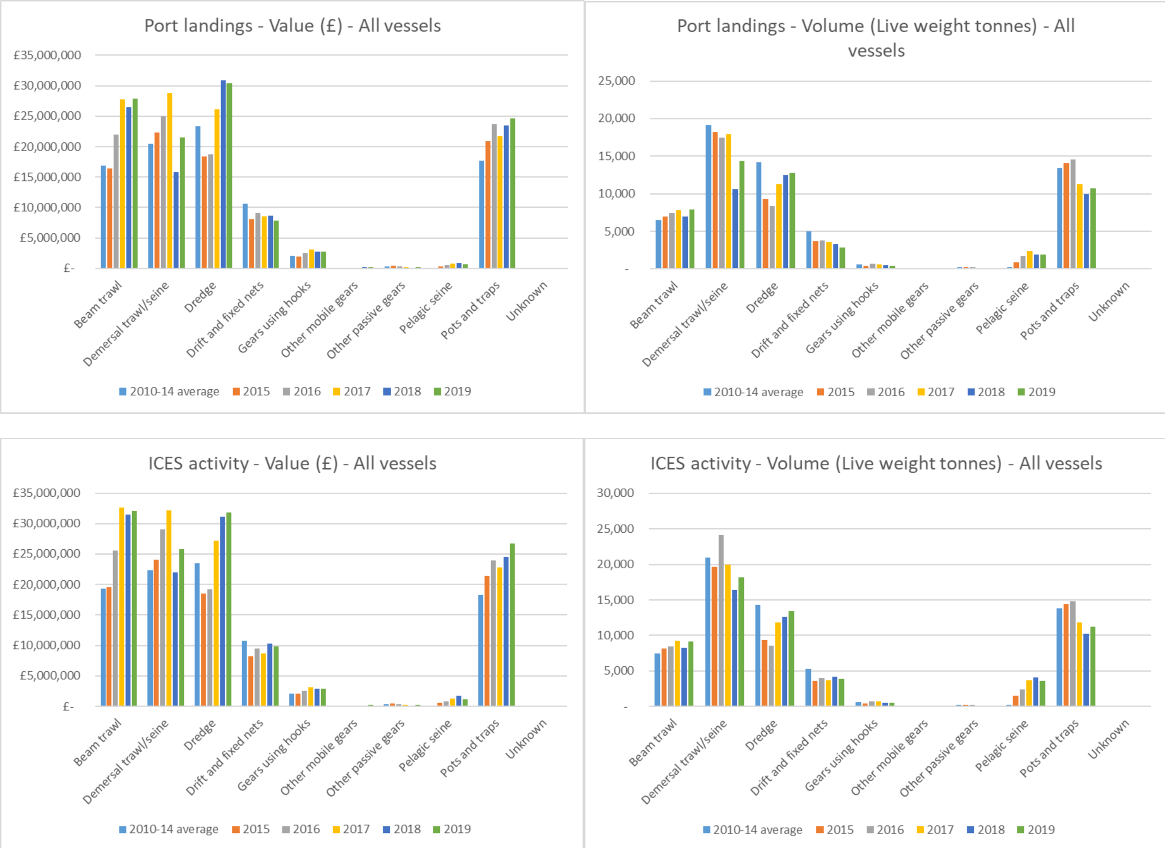


Figure 6 - Over 10m: Port landings - 2019 - Value (£): £88,867,614. Volume (Live weight tonnes): 41,008. ICES activity - 2019 - Value (£): £102,762,923. Volume (Live weight tonnes): 49,652

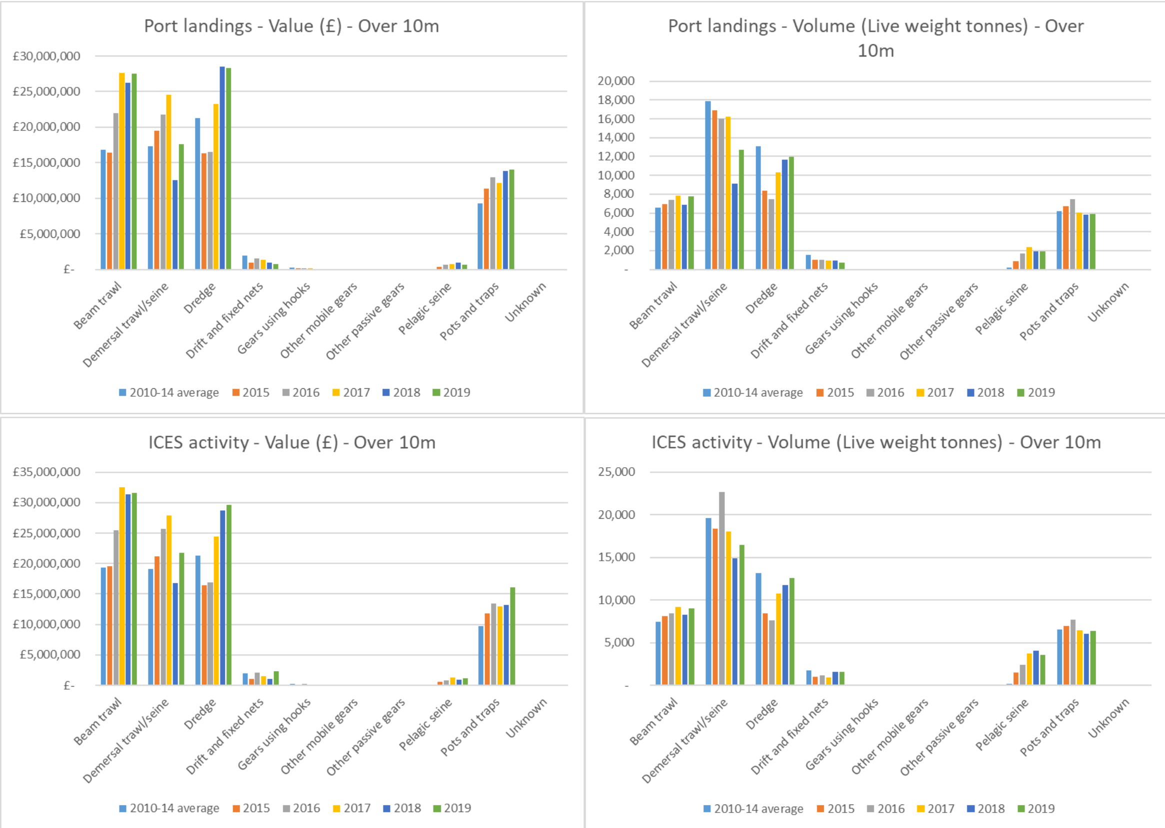
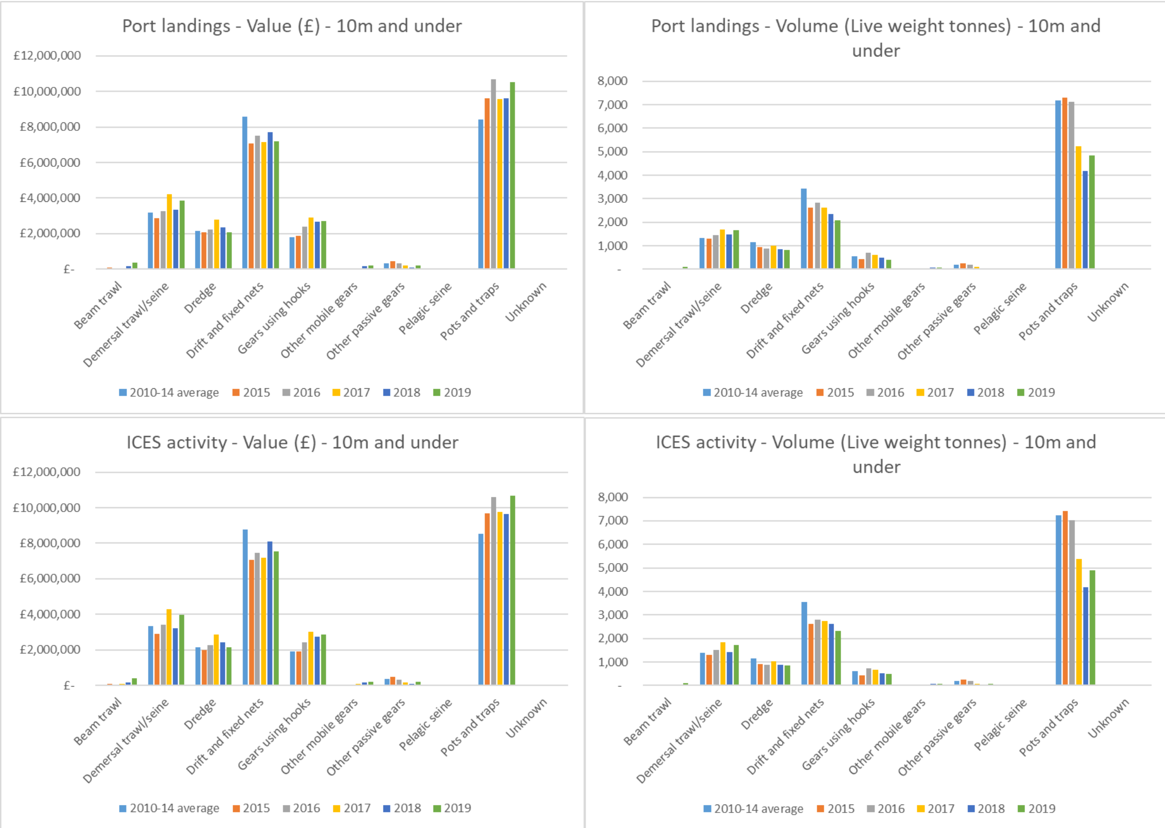


Figure 7 - 10m and under: Port landings - 2019 - Value (£): £27,169,672. Volume (Live weight tonnes): 10,045. ICES activity - 2019 - Value (£): £27,948,569. Volume (Live weight tonnes): 10,478



The value of port landings in the Channel ports is 88.8% of the ICES fishing activity in the Channel. For the over 10m fleet the figure is 86.5% whereas the figure is 97.2% for the 10m and under fleet. Although it is not possible to track where a given catch is landed, the disparity between the over 10m fleet and the under 10m fleet suggests that the Under 10m fleet catch and land within the Channel whereas the over 10m activity includes vessels that fish in the Channel but land to ports in other areas (see Newlyn section). As a result, both sets of landing statistics give an incomplete picture. The Port landings show where the catch was landed but not where it was caught with the ICES landings showing the opposite.

Despite these differences, the pattern of activity and landings over the last ten years is broadly the same between the two methods of capturing the data.

Looking at all vessels, four gear types dominate the value (beam trawl, demersal trawl/seine, dredge and pots and traps) with only Demersal trawl/seine not growing over the period, although it increased from 2018 to 2019. Pots and traps have seen an increase in value while the tonnage has reduced demonstrating an increase in the value per tonne, which has been seen in Beam trawl and Dredge in recent years. Of the other gear types, only drift and fixed nets contribute significantly to the fishery with the value of landings holding steady in recent years against a slight decline in the volume of port landings. This decline is not seen in the ICES activity, with value rising slightly in the last 5 years against a steady volume.

The over 10m vessels, representing 76.6% of the value/ 80.3% volume by port landing and 78.6% of the value/ 82.6% volume by ICES activity, broadly mirror the trends for all vessels however the importance of pots and traps is reduced as are drift and fixed nets.

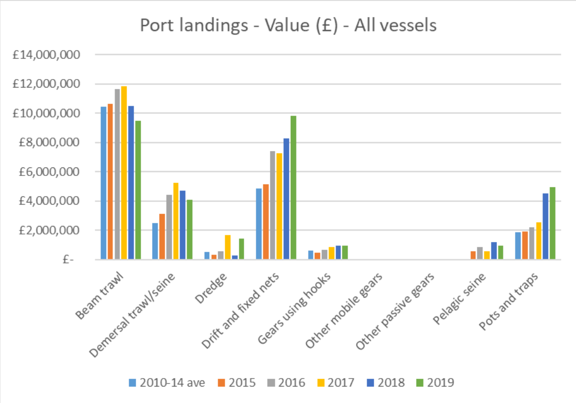
The 10m and under vessels show a different split of gear type with two gear types (pots and traps and drift and fixed nets) contributing 65.2% of the value/ 69.0% volume by Port landing and 65.1% of the value/ 68.8% volume by ICES activity. Both gear types catch by volume have declined over the last decade (although pots and traps showed an increase in 2019 over 2018 it was still lower than 2017) although this has not been reflected in the value as the higher price per tonne has been offsetting the volume declines. Of the other three gear types that are of importance to the 10m and under fleet, dredge and gear using hooks have been declining in volume but again an increase in value per tonne has led to dredge offsetting some of this decline and gear using hooks value increasing over the decade. Demersal trawl/ seine has grown in value and volume over the decade, although large increases in 2017 were matched by declines in 2018 before rising again in 2019.

These figures illustrate the differences between the two fisheries with mobile gears of highest importance for the over 10m fleet and passive gears dominating the 10m and under fleet activity.

2.3.1 Newlyn

Newlyn, located on the southern coast of Cornwall in the southwest of England, was the largest English port by volume landed (13,900 tonnes) and the second largest by value (£31.7m) in 2019 (Brixham was the largest in England by value £36.6m in 2019). The port itself, while situated on England's Channel coast, is in ICES division 27.7.f (an area that covers South Wales, the Bristol Channel and the north coast of Cornwall and Devon with only a very small portion of the Channel itself) and is therefore outside of this report's defined 'Channel fishery'. Given the size of the port it is important to the programme area and it is likely, although not demonstrated with the available statistics, that some vessels landing into Newlyn are fishing in 27.7.e and/or 27.7.d.

Figure 8 - All vessels: Port landings - 2019 - Value (£): £31,709,611. Volume (Live weight tonnes): 13,862



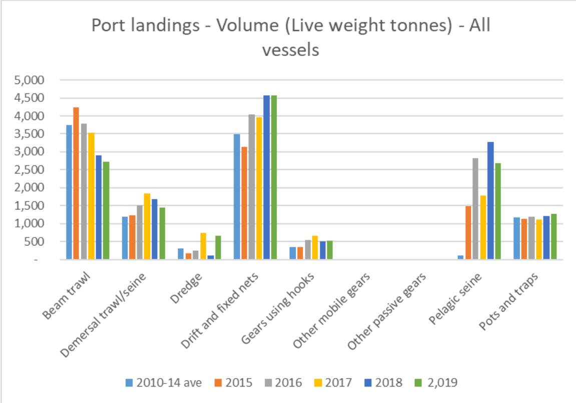
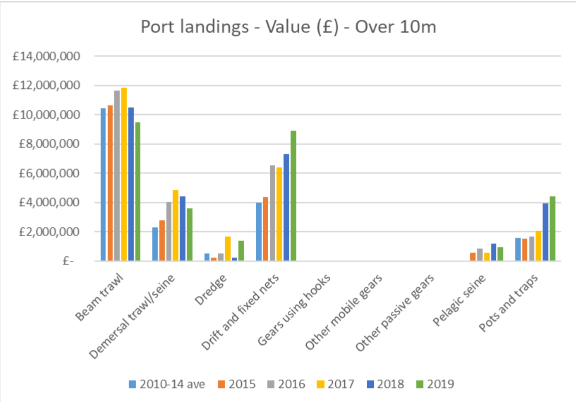


Figure 9 - Over 10m: Port landings - 2019 - Value (£): £28,849,841. Volume (Live weight tonnes): 12,550



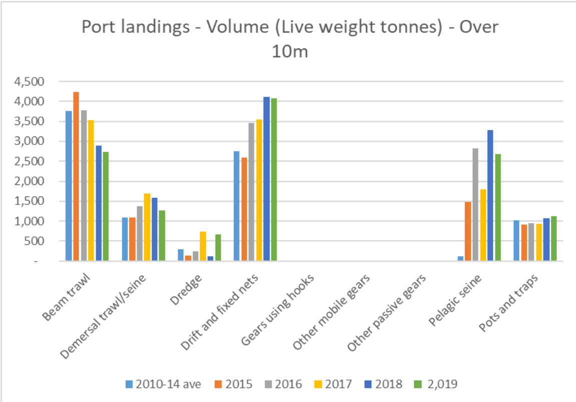
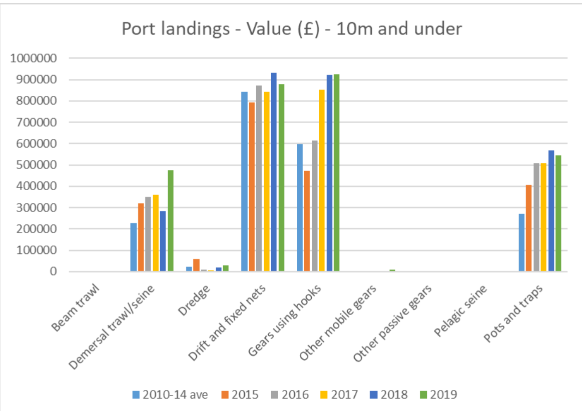
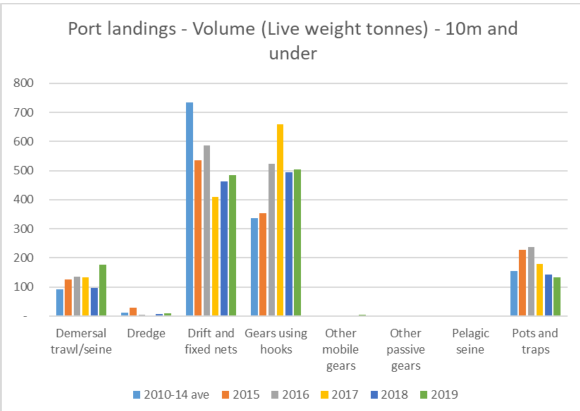


Figure 10 - 10m and under: Port landings - 2019 - Value (£): £2,859,770. Volume (Live weight tonnes): 1,312





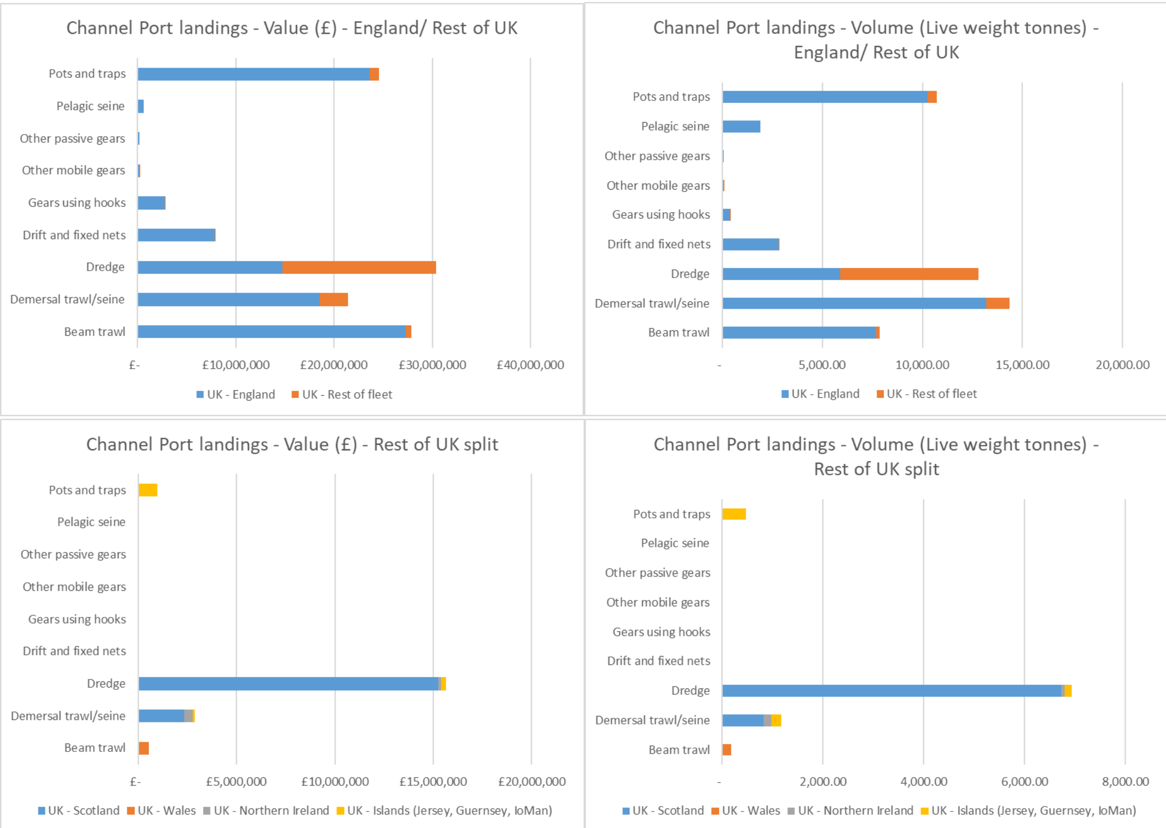
2.4 Activity of the UK fleet in the Channel fishery

By Port Landings:

The English fleet have the largest share of landings to ports in the Channel fishery with 82.7% of the value and 82.9% of the volume. Scottish registered vessels make up the next largest fleet landing into Channel ports with 15.2% of the value and 14.8% of the volume. The remainder of the landings are relatively small as a proportion with Islands (Jersey, Guernsey, and Isle of Man) registered vessels landing 1.2% value, 1.6% volume, Welsh vessels 0.5% value, 0.3% volume and Northern Irish vessels 0.5% value, 0.4% volume.

The bulk of the landings from UK vessels not registered in England are from dredging and demersal trawl/seine (Scottish and Northern Irish vessels) with some beam trawling by Welsh vessels. Of the Islands registered vessels, 99.9% of landings by value and volume are from Jersey and Guernsey registered vessels who are active in most gear types with 71.9% of value and 57.3% of volume derived from pots and traps.

Figure 11 – Activity of the UK fleet in the Channel area by port landings

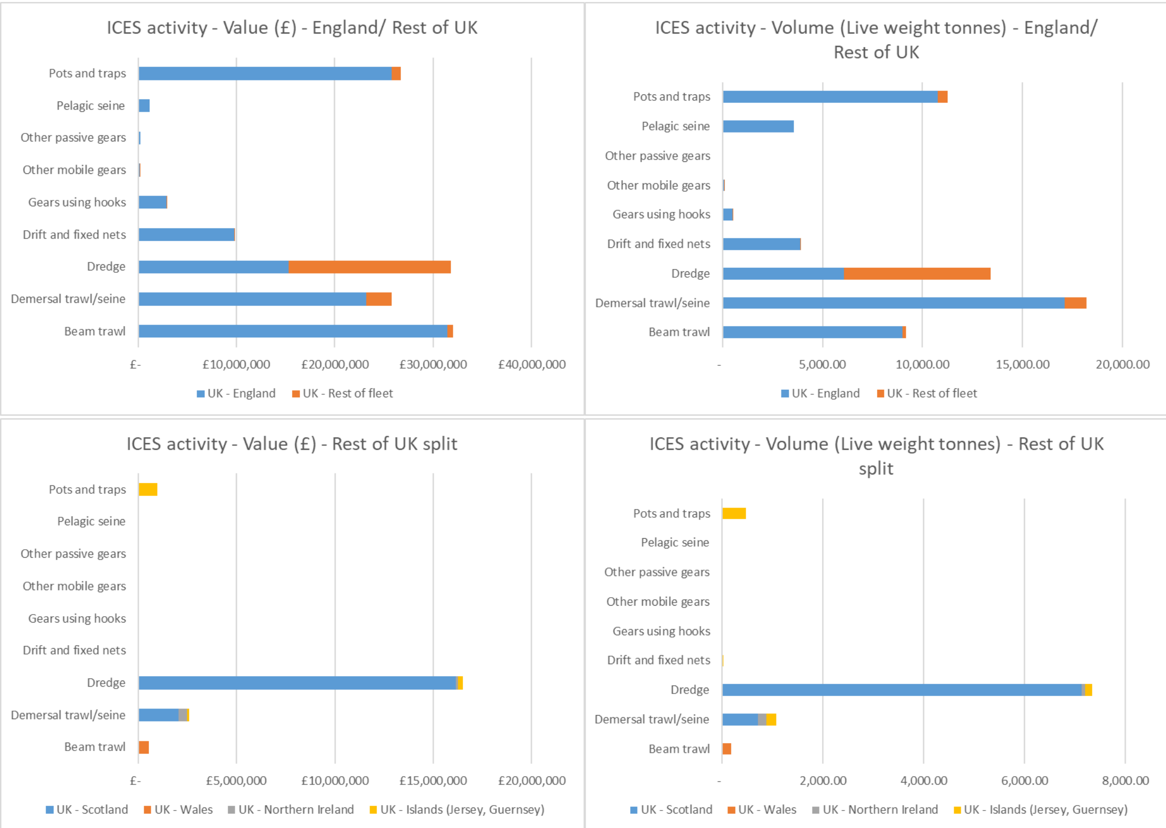


By ICES activity:

The English fleet have the largest share of catching activity in the two ICES divisions of the Channel fishery with 84.2% of the value and 85.4% of the volume. Scottish registered vessels make up the next largest fleet landing into Channel ports with 13.9% of the value and 13.0% of the volume. The remainder of the landings are relatively small as a proportion with Islands (Jersey and Guernsey with no activity captured for Isle of Man vessels) registered vessels landing 1.0% value, 1.4% volume, Welsh vessels 0.4% value, 0.3% volume and Northern Irish vessels 0.4% value, 0.4% volume.

The bulk of the landings from UK vessels not registered in England are from dredging and demersal trawl/seine (Scottish and Northern Irish vessels) with some beam trawling by Welsh vessels. Of the Islands registered vessels, all of the activity by value and volume are from Jersey and Guernsey registered vessels who are active in most gear types with 71.9% of value and 57.3% of volume derived from pots and traps.

Figure 12 - Activity of the UK fleet in the Channel area by ICES activity



Channel fleet:

The MMO vessel lists for March 2021 give a figure for total registered fishing vessels in the UK of 5,264. This is broken down into 1123 vessels over 10m and 4141 10m and under in length.

The Channel ports have 1170 registered vessels with 166 over 10m vessels and 1004 vessels belonging to the 10m and under fleet. Of the larger vessels, 45 have a shellfish licence, 78 a scallop licence with 7 vessels having both. Of the 1004 10m and under vessels, 466 have a shellfish licence while only 1 holds a scallop licence. This does not mean that the 10m and under fleet are not active in targeting scallops as the Inshore Fisheries and Conservation Authorities (IFCAs), who manage fisheries up to the 6NM limit from the English coastline, license scallop fishing for these vessels in this area through a variety of local byelaws, permits and zoning.

The Channel ports are home to 14.8% of the over 10m UK fleet and 24.2% of the 10m and under fleet and altogether hold 17.0% of the UK's shellfish licences.

Table 4 – Vessels with shellfish and scallop licences

	Channel ports	Newlyn	Rest of UK	UK total
Total vessels	**1170**	**194**	**3900**	**5264**
Over10	**166**	**51**	**906**	**1123**
Shellfish licence	45	16	226	287
Scallop licence	78	17	141	236
Both licences	7	3	41	51
10-12m	**68**	**11**	**255**	**334**
Shellfish licence	25	5	149	179
Scallop licence	19	1	16	36
Both licences	5	2	22	29
12-15m	**56**	**11**	**185**	**252**
Shellfish licence	13	5	47	65
Scallop licence	33	2	44	79
Both licences	2	0	14	16
15-18m	**3**	**4**	**120**	**127**
Shellfish licence	2	3	14	19
Scallop licence	1	0	35	36
Both licences	0	0	4	4
18-24m	**20**	**11**	**177**	**208**
Shellfish licence	3	3	11	17
Scallop licence	11	2	29	42
Both licences	0	1	0	1
Over24m	**19**	**14**	**169**	**202**
Shellfish licence	2	0	5	7
Scallop licence	14	12	17	43
Both licences	0	0	1	1
Under10	**1004**	**143**	**2994**	**4141**
Shellfish licence	466	55	2186	2707
Scallop licence	1	0	0	1
7-10m	**405**	**33**	**1455**	**1893**
Shellfish licence	244	21	1121	1386
Scallop licence	1	0	0	1
Under7	**599**	**110**	**1539**	**2248**
Shellfish licence	222	34	1065	1321
Scallop licence	0	0	0	0

The tables below show species by gear type for UK fleet landings and catching activity in the Channel fishery:

Top five species by value for each of the nine gear types recorded by the MMO in 2019.

Table 5 - All vessels by Port landings:

Beam trawl		Drift and fixed nets		Other passive gears	
Sole	£ 8,928,668	Sole	£ 2,871,693	Manilla Clam	£ 186,345
Cuttlefish	£ 7,251,650	Pollack	£ 722,119	Periwinkles	£ 17,077
Plaice	£ 2,416,113	Bass	£ 705,747	Clams (M.Mercenaria)	£ 8,334
Monks or Anglers	£ 2,173,506	Plaice	£ 468,950	Cockles	£ 4,446
Turbot	£ 1,946,189	Turbot	£ 441,653	Scallops	£ 1,337
Demersal trawl/seine		**Gears using hooks**		**Pelagic seine**	
Cuttlefish	£ 3,224,646	Bass	£ 2,253,798	Pilchards	£ 585,307
Squid	£ 2,173,728	Mackerel	£ 215,405	Anchovy	£ 31,337
Mixed Squid and Octopi	£ 1,974,770	Pollack	£ 206,963	Mackerel	£ 10,911
Lemon Sole	£ 1,831,968	Sole	£ 13,227	John Dory	£ 216
Horse Mackerel	£ 1,575,215	Lobsters	£ 12,976	Horse Mackerel	£ 62
Dredge		**Other mobile gears**		**Pots and traps**	
Scallops	£ 26,576,937	Scallops	£ 107,192	Crabs (C.P.Mixed Sexes)	£ 11,584,373
Mussels	£ 833,700	Manilla Clam	£ 44,224	Whelks	£ 8,321,494
Manilla Clam	£ 693,589	Mixed Clams	£ 25,679	Lobsters	£ 3,654,488
Sole	£ 648,329	Sole	£ 6,798	Cuttlefish	£ 537,282
Turbot	£ 449,704	Native Oysters	£ 3,291	Spider Crabs	£ 171,873

Table 6 - All vessels by ICES activity:

Beam trawl		Drift and fixed nets		Other passive gears	
Sole	£ 9,882,724	Sole	£ 2,876,417	Manilla Clam	£ 186,345
Cuttlefish	£ 8,400,763	Hake	£ 1,112,563	Periwinkles	£ 18,295
Monks or Anglers	£ 2,919,042	Pollack	£ 1,028,627	Clams (M.Mercenaria)	£ 8,334
Plaice	£ 2,685,179	Bass	£ 740,750	Cockles	£ 4,446
Turbot	£ 2,027,628	Turbot	£ 539,720	Scallops	£ 1,337
Demersal trawl/seine		**Gears using hooks**		**Pelagic seine**	
Horse Mackerel	£ 3,526,696	Bass	£ 2,265,108	Pilchards	£ 1,112,831
Cuttlefish	£ 3,302,800	Mackerel	£ 326,564	Anchovy	£ 62,090
Squid	£ 2,266,824	Pollack	£ 241,890	Mackerel	£ 17,669
Herring	£ 2,266,718	Lobsters	£ 14,113	Horse Mackerel	£ 62
Lemon Sole	£ 2,035,632	Sole	£ 13,227	Cuttlefish	£ 12
Dredge		**Other mobile gears**		**Pots and traps**	
Scallops	£ 27,858,257	Scallops	£ 107,192	Crabs (C.P.Mixed Sexes)	£ 13,399,086
Mussels	£ 833,700	Manilla Clam	£ 44,224	Whelks	£ 8,369,451
Manilla Clam	£ 694,709	Mixed Clams	£ 25,679	Lobsters	£ 3,901,702
Sole	£ 673,775	Sole	£ 6,798	Cuttlefish	£ 537,282
Turbot	£ 452,830	Native Oysters	£ 3,291	Spider Crabs	£ 175,618

Table 7 - Over 10m by Port landings:

Beam trawl	
Sole	£ 8,798,040
Cuttlefish	£ 7,211,040
Plaice	£ 2,324,378
Monks or Anglers	£ 2,155,183
Turbot	£ 1,914,519

Drift and fixed nets	
Pollack	£ 221,125
Pilchards	£ 124,651
Monks or Anglers	£ 112,684
Turbot	£ 85,590
Sole	£ 79,786

Other passive gears	
None	

Demersal trawl/seine	
Cuttlefish	£ 2,602,915
Mixed Squid and Octopi	£ 1,972,441
Squid	£ 1,921,508
Horse Mackerel	£ 1,574,963
Lemon Sole	£ 1,493,393

Gears using hooks	
Bass	£ 55,402
Mixed Clams	£ 1,272
Conger Eels	£ 523
Mackerel	£ 374
Pollack	£ 360

Pelagic seine	
Pilchards	£ 585,307
Anchovy	£ 31,337
Mackerel	£ 10,911
John Dory	£ 216
Horse Mackerel	£ 62

Dredge	
Scallops	£ 25,758,848
Mussels	£ 833,700
Sole	£ 573,332
Turbot	£ 437,462
Monks or Anglers	£ 335,929

Other mobile gears	
None	

Pots and traps	
Crabs (C.P.Mixed Sexes)	£ 8,664,063
Whelks	£ 3,719,689
Lobsters	£ 1,533,580
Cuttlefish	£ 57,348
Scallops	£ 35,841

Table 8 - Over 10m by ICES activity:

Beam trawl	
Sole	£ 9,752,095
Cuttlefish	£ 8,360,153
Monks or Anglers	£ 2,900,719
Plaice	£ 2,593,444
Turbot	£ 1,995,959

Drift and fixed nets	
Hake	£ 1,109,375
Pollack	£ 443,202
Pilchards	£ 238,234
Turbot	£ 112,710
Sole	£ 93,881

Other passive gears	
None	

Demersal trawl/seine	
Horse Mackerel	£ 3,526,445
Cuttlefish	£ 2,681,275
Herring	£ 2,266,679
Squid	£ 2,014,924
Lemon Sole	£ 1,670,088

Gears using hooks	
Bass	£ 55,402
Pollack	£ 28,502
Mixed Clams	£ 1,272
Mackerel	£ 882
Conger Eels	£ 528

Pelagic seine	
Pilchards	£ 1,112,831
Anchovy	£ 62,090
Mackerel	£ 17,669
Horse Mackerel	£ 62
Cuttlefish	£ 12

Dredge	
Scallops	£ 27,016,620
Mussels	£ 833,700
Sole	£ 595,961
Turbot	£ 439,809
Monks or Anglers	£ 368,018

Other mobile gears	
None	

Pots and traps	
Crabs (C.P.Mixed Sexes)	£ 10,457,693
Whelks	£ 3,723,989
Lobsters	£ 1,750,064
Cuttlefish	£ 57,348
Scallops	£ 35,223

Table 9 - 10m and under by Port landings:

Beam trawl	
Sole	£ 130,628
Plaice	£ 91,735
Cuttlefish	£ 40,610
Turbot	£ 31,669
Lemon Sole	£ 23,931

Drift and fixed nets	
Sole	£ 2,791,908
Bass	£ 704,586
Pollack	£ 500,995
Plaice	£ 466,567
Whelks	£ 370,324

Other passive gears	
Manilla Clam	£ 186,345
Periwinkles	£ 17,077
Clams (M.Mercenaria)	£ 8,334
Cockles	£ 4,446
Scallops	£ 1,337

Demersal trawl/seine	
Sole	£ 756,730
Cuttlefish	£ 621,731
Plaice	£ 579,624
Lemon Sole	£ 338,575
Squid	£ 252,220

Gears using hooks	
Bass	£ 2,198,396
Mackerel	£ 215,030
Pollack	£ 206,603
Sole	£ 13,227
Lobsters	£ 12,976

Pelagic seine	
None	

Dredge	
Scallops	£ 818,089
Manilla Clam	£ 660,350
Mixed Clams	£ 156,881
Whelks	£ 88,987
Sole	£ 74,997

Other mobile gears	
Scallops	£ 107,192
Manilla Clam	£ 44,224
Mixed Clams	£ 25,679
Sole	£ 6,798
Native Oysters	£ 3,291

Pots and traps	
Whelks	£ 4,601,805
Crabs (C.P.Mixed Sexes)	£ 2,920,310
Lobsters	£ 2,120,908
Cuttlefish	£ 479,934
Spider Crabs	£ 148,335

Table 10 - 10m and under by ICES activity:

Beam trawl	
Sole	£ 130,628
Plaice	£ 91,735
Cuttlefish	£ 40,610
Turbot	£ 31,669
Lemon Sole	£ 23,931

Drift and fixed nets	
Sole	£ 2,782,536
Bass	£ 718,985
Pollack	£ 585,425
Plaice	£ 463,942
Turbot	£ 427,010

Other passive gears	
Manilla Clam	£ 186,345
Periwinkles	£ 18,295
Clams (M.Mercenaria)	£ 8,334
Cockles	£ 4,446
Scallops	£ 1,337

Demersal trawl/seine	
Sole	£ 757,638
Cuttlefish	£ 621,525
Plaice	£ 576,090
Lemon Sole	£ 365,544
Squid	£ 251,900

Gears using hooks	
Bass	£ 2,209,706
Mackerel	£ 325,682
Pollack	£ 213,388
Lobsters	£ 14,113
Sole	£ 13,227

Pelagic seine	
None	

Dredge	
Scallops	£ 841,637
Manilla Clam	£ 661,470
Mixed Clams	£ 160,174
Whelks	£ 88,987
Sole	£ 77,815

Other mobile gears	
Scallops	£ 107,192
Manilla Clam	£ 44,224
Mixed Clams	£ 25,679
Sole	£ 6,798
Native Oysters	£ 3,291

Pots and traps	
Whelks	£ 4,645,462
Crabs (C.P.Mixed Sexes)	£ 2,941,393
Lobsters	£ 2,151,638
Cuttlefish	£ 479,934
Spider Crabs	£ 149,007

Scallops, crabs, sole and cuttlefish are the most important species in the Channel fishery across all vessels. However, for the 10m and under fleet whelks are the most important species followed by crabs, sole, bass and lobsters, all caught with static and passive gear.

2.5 Economics of the UK fishing fleet[12]

The Seafish analysis of the UK fleet adds the results of interviews with stakeholders to the MMO statistics. The UK fishing industry generated a little over £1 billion in 2019 - representing a slight decrease on the previous year. Seafish estimate that the UK fleet had 4,491 active vessels in 2019 with 74% of these under 10m in length. Of these active vessels, 1,524 had income of less than £10,000 and are classified as 'low activity'.

51% of the active fleet (excluding low activity and inactive) mainly used static or passive gear with three of the top five fleet segments by FTE (full time equivalents) dedicated to static or passive gears. Employment in the sector has remained stable for the last decade or so at 8,000 FTE jobs, estimated to cover almost 12,000 fishermen in 2019. From 2009 to 2019 the number of vessels in the active fleet remained steady (2009: 2,869, 2019: 2,916), but there was a significant change in focus with those vessels mainly involved in static or passive gears growing by 16% whereas those using active gear (trawls and dredges) decreased by 19%. Over the same period, the number of FTEs increased by 9% for static and passive gears and decreased by 25% for those using active gear but FTEs remained much higher for this gear at 4,649 FTEs, in 2019, against 2,829 for static or passive gears. Pelagic species, mainly mackerel, represent the highest catch in both terms of volume (152,000 tonnes) and value (£182m) in 2019. Nephrops was the second highest value species in 2019. Scotland accounts for the largest share of both volume and value landed by the UK fleet into the UK. The Scottish fleet landed 384,000 tonnes (of the 616,000 tonnes landed by UK vessels into UK ports) with a value of £570 million (of the £972 million total value in 2019). However, in all four countries, the volume landed by vessels is dominated by the few >24m vessels, ranging from 46% for Wales to more than 80% for Scotland.

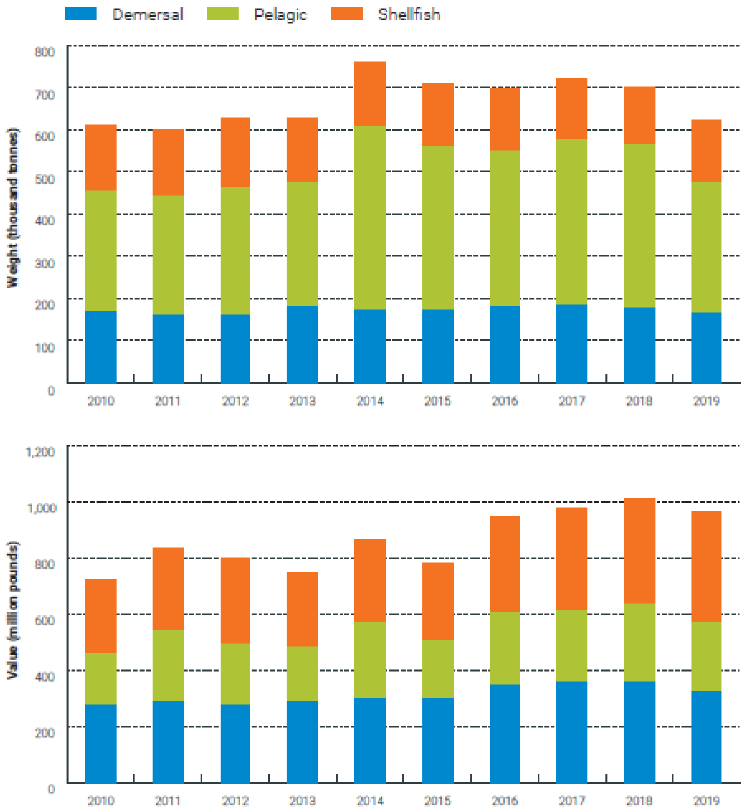
Operating profits for both gear categories, adjusted for inflation, grew over the period with active gear generating an operating profit of £1,937,100 against £285,200 for the static and passive gears in 2019. This was a growth of 28% on 2009 for active gears and 97% for static and passive gears. At the same time, total costs grew 44% and 53%, respectively. Operating margin declined from 15.3% to 13.7% for active gears but grew from 17.2% to 22.2% for static and passive gears.

This improvement in the commercial performance of those with passive and static gears can be explained by looking at the relative value of species groups. Although active gears target commercially important shellfish species such as scallops, the bulk of the catch is in demersal and pelagic species whereas static and passive gears, while targeting some demersal and pelagic species, are most heavily involved in placing pots and traps to catch shellfish. Over the period of 2010 to 2019, the catches by volume of shellfish and demersal species remained relatively consistent while the pelagic catch

[12] This section is largely based on the Seafish report - Economics of the UK fishing fleet 2019 with data taken from the Multi annual UK fishing fleet estimates 2009-2019.

fluctuated. This does not translate directly into the value of the catch as the value of both demersal and shellfish landings have grown over the period.

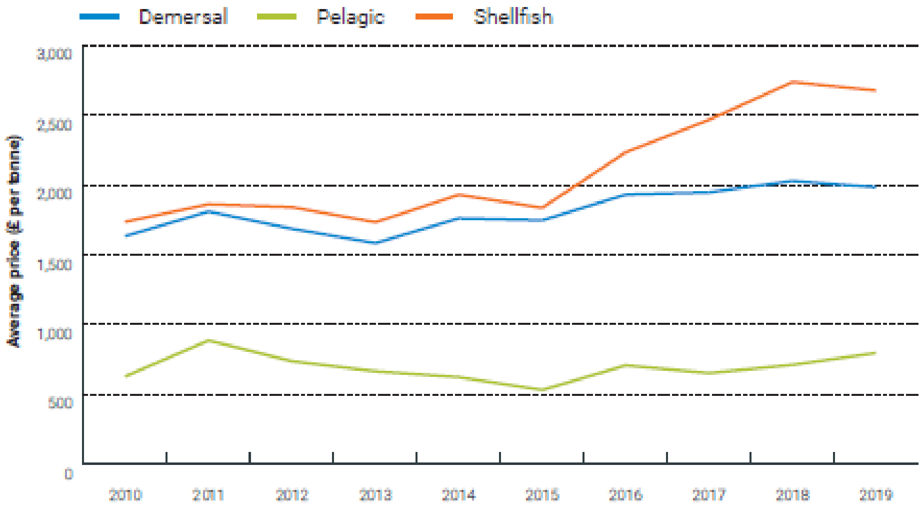
Figure 13 – Weight and value of landings by the UK fishing fleet in the UK and abroad by species type, 2010-2019



Source: Seafish (2020).

Figure 14 shows that the average prices per tonne for landing shellfish and demersal species have risen over the period with shellfish increasing from c. £1,750 per tonne to over £2,500 per tonne.

Figure 14 – Average price of landings in the UK and abroad by species type, 2009-2010



Source: Seafish (2020).

The Seafish report does not give a geographic breakdown of this activity for the fleet segments. However, the MMO statistics show that the Channel fishery represents a higher proportion of the UK fishing industry for static and passive gears than active gears. However, active gear remains the larger share of the catch (£91.0m for active gear against £39.7m for static and passive gear in 2019)

Measured by Port landings, the Channel fishery accounts for 13.2% of the UK landings by value and 9.7% by volume (ICES activity 11.8% value, 8.2% volume) but 17.4% of the value and 19.4% of the volume caught by static and passive gears (ICES activity 15.5% value, 17.3% volume).

2.6 Fisheries management framework

The UK fishing industry is diverse with large inshore and offshore fleets, utilising a variety of fishing techniques and gears to catch a wide range of demersal, pelagic and shellfish species. Both quota and non-quota species are of varying levels of importance to different fleet segments (Uberoi et al., 2020). Despite the UK fleet comprising mostly <10m vessels (accounting for 78% of total vessels), the <10m fleet collectively land less than 10% (volume) of fish caught. The >10m fleet (those managed by a PO) received almost 98% of UK quotas in 2018 (MMO, 2019) reflecting the majority of landings.

Since the implementation of the EU's Common Fisheries Policy (CFP), the sustainable exploitation of fisheries resources were governed under the following policy areas: fisheries management, international policy and market and trade policy. However, different management systems are in place for inshore vessels and offshore vessels, as well as those targeting quota and non-quota species in England and the devolved administrations. Vessels targeting quota-managed species tend to be subject to greater regulation and monitoring. For example, there are regulations that apply to fishermen targeting quota species that do not apply to vessels targeting non-quota species e.g. the landing obligation. However, small scale vessels fishing inshore coastal waters are subject to fishery specific bylaws and regulations for the sustainable management of habitats and fish stocks. The extent to which smaller vessels fish inshore waters, the gear types they use (predominantly static – nets and pots), the adaptiveness and flexibility to fisheries management (e.g. IFCA bylaws to prevent overfishing and environmental damage) are important considerations for BFG implementation. In England, while the MMO are responsible for implementing national policies, they work closely with the industry to understand the opportunities and challenges for implementing policy.

Since exiting the EU, most CFP regulations have been maintained[13]. The Fisheries Act 2020[14] introduced new objectives and amended parts of the CFP around vessel licencing, quota allocation and funding. Underpinned in the Fisheries Act is a commitment to sustainability and the ability of the UK to develop fisheries management plans to the benefit of the fishing industry and the marine environment. Our brief assessment of the management framework within which different fleet segments operate, coupled with our industry overview presented here, favours BFG implementation in small scale static gear fleets (over active gear vessels).

In short, we did not identify anything within the current national or EU framework that would either help or hinder the adoption of BFG. The lack of commercial use of BFG is not a governance or management issue (rather it is a technical issues e.g. fishing efficiency that create economic issues e.g. cost impact on profitability).

2.7 Biodegradability in aquaculture

Aquaculture has already demonstrated its crucial role in global food security, with production growing at 7.5% per year since 1970 (FAO, 2020). The latest data shows that in 2018 aquaculture was responsible for 52% of fish produced for human consumption, which equates to 82 million tonnes, valued at USD 250 billion, with China alone contributing more farmed aquatic food than the rest of the world combined since 1991 (FAO, 2020). While the main opportunity for aquaculture development is its capacity for further growth, the main challenge is the enormity of the environmental challenges to achieve sustainable growth. Therefore, new sustainable aquaculture development strategies are required (FAO, 2020).

The UK's contribution to global aquaculture output is less than 1% (by volume), although Scotland is the third largest producer of Atlantic Salmon, accounting for 166,000 tonnes of the UK's total aquaculture output (OECD, 2020), which stood at 197,168 tonnes in 2018 (World Bank, 2020). The farming of Atlantic salmon is concentrated to the west coast of Scotland and the Scottish Islands. A typical net pen structure is one with nets suspended either from a floating metal framework, or from plastic floating structures, both of which are anchored to the seabed (Cardia and Lovatelli, 2015). One of the environmental concerns of open farming systems is fish escape. The main impact of escapees is on natural populations, resulting from cages breaking in poor weather and by other means (e.g. fish biting nets creating holes).

[13] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1054476/fisheries-management-provisional-common-framework.pdf

[14] Available at: https://commonslibrary.parliament.uk/research-briefings/cbp-8994/

Furthermore, seals biting through cages in order to enter them represents a large concern for salmon farmers, who have invested in anti-predator nets, although these do not provide 100% protection. Given the current constraints on BFG development (e.g. strength), the use of biodegradability as a design feature of salmon cages is not, therefore, currently assessed to be feasible.

Salmon farming in Scotland aside, the production of farmed finfish is currently very small-scale in England, although there is some growth in shellfish farming in the programme area e.g. Lyme Bay. However, excluding Scotland, total aquaculture production amounted to 21,342 tonnes in 2014 (Hambrey and Evans, 2016), down from 34,394 tonnes in 2010, generating a modest £55 million in 2014. Taking into account fluctuations, the aquaculture industry in England has been relatively stagnant over the last three decades (Hambrey and Evans, 2016). However, there are signs that shellfish farming may be entering a growth phase – particularly mussels.

The potential for developing mussel farming is also highlighted in the recently published English Aquaculture Strategy[15], with mussels being the main species expected to contribute to a ten-fold increase in production volume by 2040 (Huntington and Cappell, 2020). In fact, growth in rope grown mussel farming is highlighted as the main driving force, growing almost 40-fold from 1,000 tonnes to 38,000 tonnes by 2040. This represents an opportunity for biodegradability. An EU funded project – BIOGEARS[16] – is currently developing biobased (biodegradable) ropes for aquaculture, attempting to extend use beyond the rope culture of mussel. The Spanish company Intermas, has developed a biodegradable and compostable rope – the biorope[17] – for mussel farming. Mussel ropes have a limited lifespan, as they are often too dirty to clean and reuse. Therefore, mussel farmers face similar issues to fishermen regarding end of life disposal issues i.e. lack of recycling. While mussel ropes are not thought to be a major contributor to ALDFG, other studies – see e.g. Tamburini et al, (2020) also point to the role of biodegradability as a solution to improve the sustainability of mussel farming. This study identified the main environmental impacts of mussel farming in order to identify the "hotspots" of different impact categories, highlighting biodegradability of farming systems as an option to reduce potential environmental impacts should nets and ropes used in mussel culture become ALDFG.

2.8 Section summary

The volume of gear used by the fishing industry dwarfs the aquaculture industry in England (noting that most aquaculture activity in England takes place in the programme area) and hence the contribution to ALDFG. Mussel farming offers perhaps the most potential for biodegradability given the short lifespan of mussel gear[18]. Furthermore, issues of strength and flexibility (a major weakness for certain gear types

[15] Prepared within the Seafood 2040 Strategic Framework for England.

[16] See: https://cordis.europa.eu/article/id/413319-new-emff-project-biogears-launched-to-develop-biobased-ropes-for-aquaculture

[17] See: https://www.intermas.com/news/intermas-biorope-as-an-alternative-to-synthetic-mooring-lines.html

[18] Mussel ropes become quickly bio fouled. Gear is frequently replaced, as it is not economically viable to clean and reuse gear.

used by the fishing industry) would be less problematic in mussel farming (than net cages for salmon farming, for example).

The main advantage of BFG over conventional fishing gear is the reduced lifespan in the marine environment, and the reduction of related environmental impacts of ALDFG, such as ghost fishing. In view of the volume of gear used in the fishing sector compared to aquaculture, we consider that biodegradability has a bigger role to play in the fishing industry. Having said that, as the English Aquaculture Strategy calls for a large sustainable increase in output, with mussel singled out as the main contributing species, further research into biodegradable production systems for aquaculture would be beneficial at a time where the industry may be set to expand.

3. Competition in the market for BFG

3.1 Introduction

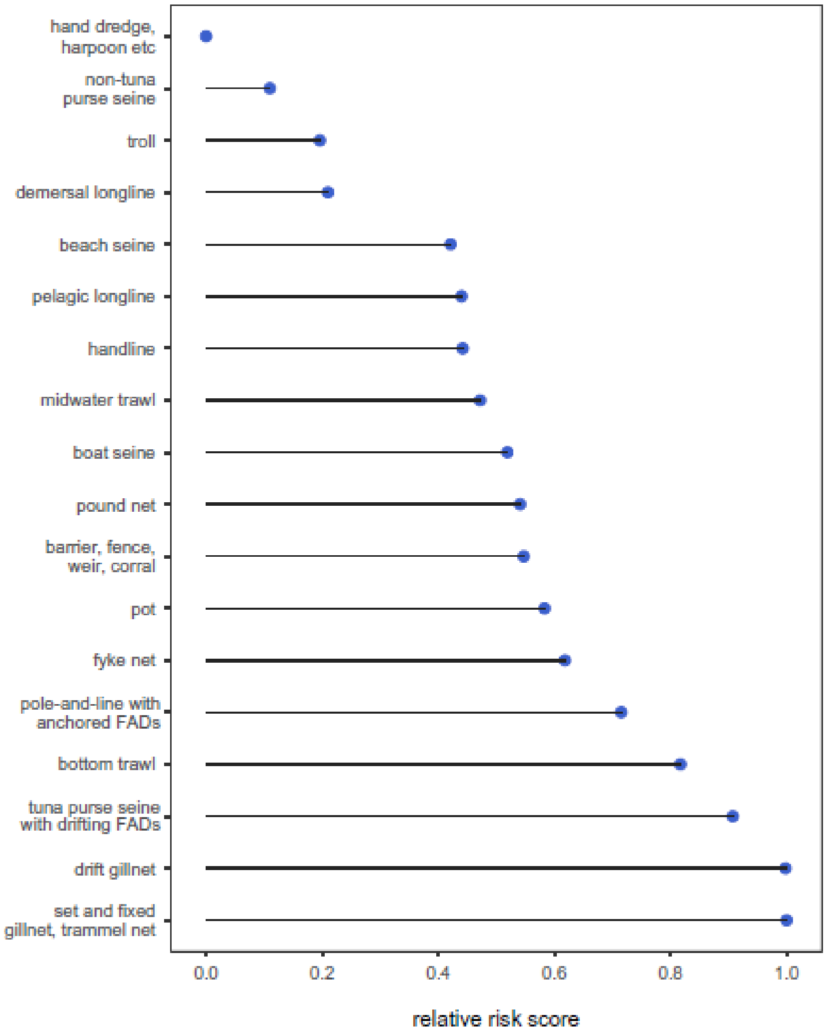
Given the lack of options (port facilities) for fishermen to deposit damaged/end of life fishing gear, coupled with a lack of commercial recycling options, urgent solutions are needed to integrate fishing gear into a circular economy. Gear retrieval programmes have been the main mitigation measure adopted (e.g. in the Norwegian gillnet fishery) although they have largely been undertaken in the absence of information on the costs/benefits (Brown et al., 2005). In addition, gear retrieved through gear retrieval programmes suffers the same fate as gear returned by fishermen (i.e. the lack of commercial recycling options). In short, the stock of ALDFG continues to grow in the world's oceans with no clearly defined solution.

In this section, we consider the competition in the market for BFG. We focus on gear retrieval programmes and gear recycling, which represent the two main responses to the growing levels of ALDFG.

3.2 ALDFG

In a recent study of the relative risk posed by ALDFG (Gilman et al., 2021) static and passive gears scored the highest for risk based on the rate that the fishery produces ALDFG, the amount of global fishing effort and the potential for ecosystem and socioeconomic impacts. Two gear types using FADs (Fish aggregating devices) score highly for risk but these are not present in the Channel fishery, primarily being used in Tuna fisheries. Therefore, excluding these, the top five fishing gears by risk were: set and fixed gillnets, drift gillnets, bottom trawl, fyke net and pots. With the exception of bottom trawls, these are static and passive gears. The authors do note, however, that the leakage rates of ALDFG are based on a five-decade old estimate and that more robust data for each gear type is required.

Figure 15 – Relative risk posed by ALDFG



Source: Gilman et al., (2021)

Macfadyen, Huntington and Cappell, (2009) summarised research into ALDFG in table 11 and found that the gear loss varies between fisheries using similar gear. In the English Channel gillnets were lost at a rate of 0.2% to 2.11%, whereas pots and traps can be lost at a rate of up to 30%. The report notes that there is little data available on trawl nets in Europe but notes that anecdotal evidence suggests that trawl fisheries seek to recover lost nets immediately (but there is likely to be a large quantity that remain lost). A study of fishing debris in the Northern Territory in Australia indicated that three-quarters of it was trawl nets.

Table 11 - Summary of gear loss/abandonment/ discard indicators from around the world

Region	Fishery/gear type	Indicator of gear loss (data source)
North Sea & NE Atlantic	Bottom-set gillnets	0.02–0.09% nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
English Channel & North Sea (France)	Gillnets	0.2% (sole & plaice) to 2.11% (sea bass) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
Mediterranean	Gillnets	0.05% (inshore hake) to 3.2% (sea bream) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003)
Gulf of Aden	Traps	c. 20% lost per boat per year (Al-Masroori, 2002)
ROPME Sea Area (UAE)	Traps	260 000 lost per year in 2002 (Gary Morgan, personal communication, 2007)
Indian Ocean	Maldives tuna longline	3% loss of hooks/set (Anderson & Waheed, 1998)
Australia (Queensland)	Blue swimmer crab trap fishery	35 traps lost per boat per year (McKauge, undated)
NE Pacific	Bristol Bay king crab trap fishery	7 000 to 31 000 traps lost in the fishery per year (Stevens, 1996; Paul *et al.*; 1994; Kruse and Kimker, 1993)
NW Atlantic	Newfoundland cod gillnet fishery	5 000 nets per year (Breen, 1990)
	Canadian Atlantic gillnet fisheries	2% nets lost per boat per year (Chopin *et al.*, 1995)
	Gulf of St Lawrence snow crab	792 traps per year
	New England lobster fishery	20–30% traps lost per boat per year (Smolowitz, 1978)
	Chesapeake Bay	Up to 30% traps lost per boat per year (NOAA Chesapeake Bay Office, 2007)
Caribbean	Guadeloupe trap fishery	20 000 traps lost per year, mainly in the hurricane season (Burke and Maidens, 2004)

Source: Macfadyen, Huntington and Cappell, (2009)

Gear loss from crab and lobster fisheries examined in Scheld et al., (2016) (table 12) showed that the loss of pots was highly variable and ranged between 10 and 70% of the pots deployed each year.

Table 12 – Gear loss from crab and lobster fisheries

Species	Annual Gear Loss (% Deployed)[*]	Landings (MT)	Revenues (US$)	Major Producers
Blue swimmer crab *Portunus pelagicus*	70	173,647	$199M[†]	China, Philippines, Indonesia, Thailand, Vietnam
American lobster *Homarus americanus*	20–25	100,837	$948M	Canada, USA
Blue crab *Callinectes sapidus*	10–50	98,418	$152M	USA
Queen crab/snow crab *Chionoecetes opilio*	NA	113,709	$401M	Canada, St. Pierre and Miquelon (France), USA
Edible crab *Cancer pagurus*	NA	45,783	$49M[‡]	United Kingdom, Ireland, Norway, France
Dungeness crab *Metacarcinus magister*	11	35,659	$169M	USA, Canada
Spiny lobster *Panulirus argus*	10–28	34,868	$500M[§]	Bahamas, Brazil, Cuba, Nicaragua, Honduras, USA
King crab *Paralithodes camtschaticus*	10	10,137	$99M	USA
Stone crab *Menippe mercenaria*[‖]	NA	2,502	$24M	USA
TOTAL		615,560	$2.5B	

Source: Scheld et al., (2016).

What these reports show is that ALDFG is a global issue within fisheries, although the information held across fisheries is low with no routine monitoring. An MRAG report from 2019 highlights this by noting that global estimates are based on figures that are decades old and that there is a general lack of data available to assess the volume of ALDFG and its impacts on the environment, especially with regards to the UK.

The INdIGO technical questionnaire has had 39 responses (at the time of writing this report). 21 of these listed a secondary fishing activity alongside their primary activity. This gave 60 total responses by gear category. The data collected on gear type, units used and gear cost are presented below. The data is taken from some numerical responses and some free text responses, with some respondents not providing data in some areas and some providing incomplete data (although not precise, it allowed estimates to be made).

Table 13 – Gear type, units used and gear cost

Respondents	Gear category	Gear category sub-type and target species	Number of units: Respondents	Number of units: Range	Number of units: Average	Unit cost: Respondents	Unit cost: Range	Unit cost: Average	Total gear cost: Respondents	Total gear cost: Range	Total gear cost: Average
7	Pots and traps	Crab and Lobster	7	10 to 1,500	602	6	£30 to £100	£79	6	£300 to £150,000	£45,686
1	Pots and traps	Whelk	1	600	600	1	£5	£5	1	£3,000	£3,000
1	Beam trawl	Shrimp	1	4	4	1	£3,500	£3,500	1	£14,000	£14,000
15	Otter trawl or unspecified trawl	Mix of fish species	15	2 to 22	9	14	£2,000 to £12,000	£4,553	11	£6,000 to £85,000	£27,673
2	Dredge	Scallops	2	10 to 40	25	2	£550 to £900	£725	2	£5,500 to £36,000	£20,750
27	Gill, trammel, tangle and wreck nets	Mix of fish species	19	1 to 450	141	25	£7 to £600	£119	18	£60 to £36,000	£13,679
4	Hand line	Pollock, bass and mackerel	2	1 to 2	1.5	1	£5	£5	1	£5	£5
1	Long line	Skate and bass	1	35	35	1	£100	£100	1	£3,500	£3,500
2	Ring netting	Sardines and anchovies	2	1	1	2	£81,000 to £90,000	£85,500	2	£81,000 to £90,000	£85,500

Source: Authors own creation[19]

Table 13 shows that hand line and whelk pots are the cheapest gear type by unit but whereas multiple whelk pots are used to assemble one gear, hand lines are used alone. Towed gear of all types (beam trawl, otter trawl or unspecified, dredge and ring netting) has the highest unit cost of the gear types. This ranges from an average of £725 per scallop dredge to £85,500 for a ring net. These high unit prices ensure that towed gear, despite their relatively low unit volumes are the highest value gear type overall with the exception of crab and lobster pots. Pots and traps for crab and lobster are the second highest total gear cost on average (£45,686) despite the low unit cost (average £79) as they are used in large numbers by the respondents with an average of 602 deployed, with a large range from 10 to 1,500 used. Static or passive nets have a relatively low average unit cost (£119) and the second highest number of units deployed with an average of 141. The range is large from a single net deployed up to 450 arranged in fleets.

These figures are consistent with the results of a survey conducted by MRAG in 2019 for their "Rapid assessment of evidence on ALDFG" report, showing a figure of between £3,000 to £40,000 to supply a vessel with gear and costs of £100 for each unit in a gillnet.

[19] Based on preliminary outputs from the INdIGO technical survey.

Table 14 - Anonymised list of UK companies supplying fishing gear to UK vessels

Company[24]	Product	Volume nylon manufactured (metric tonnes per year)	Cost	Client/s	Source of raw materials	Number of employees
Company 1	Bottom trawls	500	£40,000 (per vessel)	UK	EU (France, Spain, Portugal), India.	-
Company 2	Fishing gear	-	£3,000 to £15,000	UK	EU (Spain, Portugal[25], Belgium)	4
Company 3	Buy in both net and rope	-	-	-	EU (Spain, Portugal), India.	50
Company 4	Pelagic nets	150-160	-	Irish, UK	EU (Portugal, Netherlands), South Africa.	12
Company 5	Netting and trawl gear	< 10 (Purchase 40,000 metric tonnes of rope per year)	-	Only South west England	EU (Portugal), India.	8
Company 6	Netting	12	-	UK	EU (Portugal[26], Spain), India	3
Company 7	Wire mesh creels and accessories to creels.	10	-	UK, International	EU (Italy, UK)	-
Company 8	Trammel, gillnets	40 units per year (Trawl nets); 500 units per year (Gill nets)	£200-2000 (Trawl); £100 per standard 100-yard mesh panel (Gillnet).		China, India	13

Source: MRAG (2019)

The technical questionnaire also captures the total annual cost of renewal, repair and replacement of gear (including that lost at sea) but is held by respondent and not gear type, so it is presented as such in the table 15 (below) where the respondents have provided the necessary detail. While this shows the annual gear cost per respondent, it does not show the amount that can be attributed to the primary and secondary fishing activity. The figures demonstrate that across the fishing gears a significant sum is spent on gear annually in order to continue fishing activity, indicating that, whether it is disposed of on land or lost at sea, a large amount of waste fishing gear is produced in the Channel fishery. Although some data is provided by respondents that indicates that repair and renewal are the biggest areas of annual cost with low amounts spent on replacing lost gear, the data is inconsistently supplied with some respondents supplying a figure for each and others providing a total figure for the cost of gear.

Table 15 – Gear loss and replacement cost in the programme area

Respondents	Primary gear category	Gear category sub-type and target species	Secondary gear category (if applicable)	Gear category sub-type and target species	Total annual gear cost: Respondents	Range	Average
3	Pots and traps	Crab and Lobster	Drift and fixed nets	Gill netting (Turbot, monkfish, ray, pollock and sole)	3	£2,700 to £5,500	£6,067
1	Pots and traps	Crab and Lobster	Gears using hooks	Hand line (Bass, pollock and mackerel)	1	£50	£50
1	Beam trawl	Shrimp			1	£10,000	£10,000
11	Otter trawl or unspecified trawl	Mix of fish species			9	£300 to £20,100	£6,589
1	Otter trawl or unspecified trawl	Mix of fish species	Dredge	Scallops	1	£7,600	£7,600
1	Dredge	Scallops	Demersal trawl/seine	Otter trawl or unspecified trawl (Mix of fish species)	1	£40,000	£40,000
10	Gill, trammel, tangle and wreck nets	Mix of fish species			8	£950 to £12,000	£5,681
1	Gill, trammel, tangle and wreck nets	Mix of fish species	Otter trawl or unspecified trawl	Mix of fish species	1	£4,000	£4,000
2	Gill, trammel, tangle and wreck nets	Mix of fish species	Hand line	Bass, pollock and mackerel	1	£30,000	£30,000
3	Gill, trammel, tangle and wreck nets	Mix of fish species	Pots and traps	Crab and Lobster	3	£15,300 to £18,000	£16,767
1	Gill, trammel, tangle and wreck nets	Mix of fish species	Pots and traps	Whelk	1	£25,000	£25,000
1	Gill, trammel, tangle and wreck nets	Mix of fish species	Ring netting	Sardines and anchovies	1	£5,400	£5,400
1	Hand line	Pollock			-	-	-
1	Long line	Skate and bass	Gill, trammel, tangle and wreck nets	Mix of fish species	1	£2,000	£2,000
1	Ring netting	Sardines	Gill, trammel, tangle and wreck nets	Mix of fish species	1	£10,000	£10,000

Source: Authors own creation[20]

3.3 Competition - Gear recycling to integrate fishing gear into a circular economy

A Google search, "fishing gear recycling UK" yields the usual millions of results. The first results reveal several small-scale initiatives and projects that are developing to tackle end of life fishing gear, with one of the industry partners in the INdIGO projects – Odyssey Innovation[21] – appearing at the top of the list. Odyssey Innovation has made available free net recycling to fishing harbours in the south west of England, which previously represented a financial cost to the fishermen and the harbour. Rather than being disposed in landfill, they are recycled and re-purposed into a range of products. This recycling system involves collected nets being transported to Denmark, where they are recycled into plastic pellets that are used as an input into various production processes (such as kayaks, sunglasses, roof tiles). Other small scale initiatives and examples of gear recycling include:

[20] Based on preliminary outputs from the technical survey conducted in INdIGO.
[21] https://www.odysseyinnovation.com/

Netcycle[22] – an Innovate UK funded project led by Impact Solutions is developing innovative solutions to the marine litter problem. The project aims to create value from fishing net waste by developing a technology to recover and recycle the high value plastic fibres from fishing nets for use in high-end applications. The technique developed in this project is currently being trialled.

Circular Ocean[23] – an EU funded project – led by the Centre for Sustainable Design at the University of Surrey, aims to develop innovative and sustainable solutions to marine litter by inspiring enterprises and entrepreneurs to realise the hidden opportunities of discarded fishing nets and ropes. Developing net recycling and reuse opportunities will enhance income generation and retention in local regions (coastal communities) that are impacted directly by marine litter.

Fishy Filaments,[24] is a small company that has developed a technique for repurposing end of life fishing nets into high quality 3D printer filament, supported by industry through the Cornish Fish Producers Organisation.

Fil & Fab[25], based in the project programme area, is tackling the issue of marine litter by developing the first French recycling network for old fishing nets.

The ports of Ullapool and Peterhead have been involved in a free at the point of deposit net recycling scheme[26]. The scheme is simply a container that is transported to Denmark for recycling old fishing gear in to plastic pellets that can then be used in other production processes. A current issue with this scheme is that the value of the recycled material is less than the cost of transport and recycling, especially for demersal nets.

There are examples from other parts of the world. For instance, Fourth Element[27], an Australian based company, who in collaboration with Italian firm Aquafil[28], have developed a process for recycling nylon waste from fishing nets (sourced from gear retrieval programmes) into high quality nylon yarn, which is then used to produce swimwear.

As well as complete fishing nets, net and rope cuttings also contribute to marine litter. These mostly originate on board fishing vessels and on the quayside when fishermen are repairing nets. If at the quayside, and there are no recycling facilities, the cuttings will most likely end up in landfill. At worst, they are blown into the harbour and taken out to sea by currents. On board fishing vessels, they may be blown overboard (either by design or accident). Given the significant contribution of net and rope cuttings to marine waste generated by the fishing industry, a best practice guide has recently been developed (see Metcalfe and Bentley, 2020).

[22] https://www.impact-solutions.co.uk/netcycle-the-solution-to-ghost-nets/
[23] http://www.circularocean.eu/
[24] https://fishyfilaments.com/
[25] https://www.fil-et-fab.fr/
[26] https://www.kimointernational.org/news/net-recycling-in-scotland/
[27] https://fourthelement.com/recycled-from-the-sea/
[28] https://www.aquafil.com/sustainability/econyl/

Beyond the first page of results from the initial search (and modifying the search terms), very few examples of fishing gear recycling are available. Further searching only identified other small-scale initiatives.

The 'value gap' identified in the fishing gear recycling chain would point to the main problem being an economic one. However, the complex nature of the variety of materials used in some fishing gears, and the difficulty in separating these materials prior to recycling, may indicate that the fishing gear recycling is a technical problem as well as an economic problem. Given the low price of virgin plastic, it has not been economically viable to develop efficient fishing gear recycling (i.e. the low cost of plastic has meant that investing in developing technical solutions for recycling have not been viable).

There remain limited commercial recycling channels for end of life fishing gear – with only three commercial operations in Europe – Plastix[29] in Denmark, NoFir in Norway[30] and Aquafil[31] in Italy. However, the amount of fishing gear recycled is small in comparison to the estimated level of ALDFG. Plasix, a Danish company (engaged with some of the small-scale recycling initiatives discussed previously e.g. Ullapool and Peterhead harbours, Odyssey Innovation), is a clean-tech manufacturer of green plastics. They are engaged with recycling plastic from around the world and have developed the capacity to clean, separate and recycle a variety of plastics used in fishing nets into a material known as OceanIX HDPE. In total, Plastix aim to develop their capacity to recycle 30,000 tonnes per year (no timescale given), yet it is estimated that over 640,000 tonnes of fishing gear enters the world's oceans every year (FAO, 2016).

The lack of recycling options is not a problem unique to fishing gear. It is estimated that the majority of plastic, particularly plastic food packaging is lost to the economy after a short first-use cycle, with only 14% of plastic that could be recycled entering the recycling system (New Plastics Economy, 2017). The New Plastics Economy (2017), a report produced by the Ellen MacArthur Foundation, estimated that 95% of plastic packaging material (USD 80-120 billion annually) that could exist within a circular economy is lost from the economy.

Research has shown that there is substantial value-creation potential in recycling plastic waste to make new plastics and other chemicals (Gao, 2020). However, recycling of plastic remains small-scale. While adopting the reuse, reduce and recycle model to plastics production seems relatively straightforward (as most plastic is marketed and sold as recyclable e.g. packaging), relatively few plastics are recycled (estimates tend to suggest less than 15% of recyclable plastic is recycled). Investments in addressing plastic recycling have yet to emerge, even though recent research has demonstrated the substantial value creation in plastic recycling for reuse (see e.g. Gao, 2020).

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[29] https://plastixglobal.com/
[30] http://nofir.no/
[31] https://www.econyl.com/

3.4 Competition - Gear retrieval programmes to integrate fishing gear into a circular economy

Gear retrieval represents the main response to address the impacts of ALDFG in the marine environment. In terms of cost, Deloitte (2019) report gear retrieval- along with beach cleans (land based) – account for the main (curative) mitigation efforts. In terms of action, preventative measures are always preferable to curative ones, especially in the case of ALDFG, because it can persist for a long time in the marine environment. Prevention of ALDFG would eliminate[32] the environmental, economic and social costs e.g. the impacts of ghost fishing, entanglement of other marine life, entanglement with vessels, reduced commercial fish catches, damage to corals etc. Given the sheer volumes of ALDFG estimated to be present (see FAO, 2016) gear retrieval will remain important. However, countries around the world have embarked on these programmes in the absence of information on their economic viability, including assessments of alternative measures to mitigate or prevent ALDFG (Brown et al., 2005). While forms of legislation exist in some fisheries, such as gear marking, reporting of gear loss and voluntary measures including communication to prevent gear conflict[33], there is a lack of policy or assistance in place to change the behaviour of fishermen to adequately prevent ALDFG. For instance, gear recycling facilities were largely absent from fishing ports until recently, with recent pilots in fishing ports around the UK demonstrating that there is a value gap in the current fishing gear recycling value chain (i.e. the cost of recycling is not met with value addition activities). Similarly, while small-scale recycling collection points are available across ports in the programme area, in other ports visited as part of our stakeholder engagement (e.g. Bridlington and Cromer) no such recycling facilities are available. Further, discussions with fishermen and their representatives (e.g. the Holderness Fishing Industry Group) demonstrated that fishermen are unaware of what happens to end of life fishing gear generated in their fishery.

As noted by Brown et al., (2005), there are a lack of studies that focus on the economic feasibility of gear retrieval programmes. What has been done is largely restricted to estimations of the costs of ghost fishing (and hence the cost of having no retrieval programme) in terms of the volume and value of ghost catch, (e.g. Al-Masroori, 2002; Al-Masroori et al; 2004; Mathews et al, 1987) and, separately, the cost of gear retrieval programmes (e.g. Brown et al., 2005; Drinkwin, 2022; Tschernij et al, unpublished). There is also a lack of literature on the relative costs/benefits of different management measures as a basis for prioritisation. There is also limited research to understand how measures may also change the behaviour of consumers (e.g. WTP studies to reveal preferences for sustainable fisheries). UK consumers, for example, have been accepting of policy to address the reduced use of plastic carrier bags through the disposable carrier bag charge. The EU[34] estimate that the carrier bag charge, since the 2015 Plastic Bags Directive, brought about a rapid change in consumer behaviour that will lead to a reduction in 3.4 million tonnes of CO_2 emissions, avoid environmental

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[32] Some level of ALDFG would be generated in fisheries. As such, the removal of all ALDFG would not be the economic optimum, as the costs would outweigh the benefits (at a given point).
[33] https://www.gov.uk/guidance/marking-of-fishing-gear-retrieval-and-notification-of-lost-gear
[34] https://ec.europa.eu/commission/presscorner/detail/de/STATEMENT_19_1873

damage, which could cost the equivalent of €22 billion by 2030 and save consumers an estimated €6.5 billion.

As espoused by Brown et al., (2005), there is little or no evidence to support the economic viability of gear retrieval. They find the benefits of gear retrieval do not outweigh the costs in their hypothetical gillnet study in the Channel. Even so, countries invest millions in gear retrieval. For example, the Canadian Department of Fisheries have allocated more than US$ 8.3 million to reduce the amount of ALDFG, as well as implementing a sustainable fisheries solutions and retrieval support contribution fund (Walker, Goodman and Brown, 2020). Gear retrieval has been undertaken annually since the 1980s in the Norwegian gill net fishery. Sundt et al., (2018) and the NDF, (2019) report on the removal of 20,450 (gill type) nets, although estimate gear loss at 35,000 (Sundt et al., 2018) and 490,000 (NDF, 2019). Furthermore, no information regarding the costs and benefits of the programmes is available[35]. Large et al., (2009) conducted several gear retrieval exercises as part of EU DEEPCLEAN project in 2005 and 2006 in deepwater gillnet fisheries in the Northeast Atlantic. The purpose was to estimate the extent of ALDFG and the level of ghost fishing. One exercise towed creeper type retrieval gear for 228km and retrieved no lost or abandoned fleets (or whole/complete gillnet panels), but did recover parts of equipment such as fragments of gillnet. As such, no ghost catch was identified. Another exercise completed 54 tows at depths of 400-1300m for a total distance of 320km. In this exercise, 648 gillnet panels were recovered with an estimated length of 35-40km. Considerable ghost catch of a mixture of fish and crustaceans weighing 14.3 tonnes (approx. 50% were commercial species) was recorded. A further exercise recovered fragments of gillnets (no whole panels or fleets) totalling almost 34km in length with low levels of ghost catch. As noted by the authors, part of the cause of retrieving mostly fragments of gear (rather than whole panels/fleets) may have been due to the stresses of towing and hauling. For example, gillnet panels may have been located but the panels may have disintegrated by the time they were hauled. Overall, the exercises demonstrated that gear retrieval success is highly dependent on gear type and understanding of where lost gear may be located. The study reported nothing on the cost of the retrieval exercises.

Locating lost gear is especially problematic in countries where the reporting of lost gear is not mandatory. As noted by Drinkwin (2022) even basic preventative measures (e.g. gear marking) are not required in some fisheries (noted in 2/3 of 25 countries reported in Drinkwin, 2022) with no mandatory retrieval efforts for lost gear. In addition, more than 80% of the countries studied were found to have waste reception facilities that were not adequate.

Drinkwin (2022) represents an important contribution to knowledge providing a synthesis reports of various gear retrieval programmes, including information on costs.

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[35] The cost saving from the resultant reduction in ghost fishing. Furthermore, there may be environmental issues with retrieving lost nets e.g. damage to the benthic environment if gear becomes embedded on the ocean floor. Ghost nets and pots may act as food sources for scavengers. Generally, studies focus solely on the economic cost of ghost fishing as a starting point.

For example[36], the fishing for litter programme operates 16 projects in 11 EU countries (60 ports and 670 vessels) where fishermen are provided with bags or bins in order to keep ALDFG they encounter, which has led to the removal of 600 tonnes of ALDFG since 2013. Regarding costs, Drinkwin (2022) reports an average cost of around €150,000 per 12 participating ports (equates to €2,500 per port with an estimated removal cost of €1,250[37] per tonne of ALDFG). Some modest income is generated through the selling of recyclable materials, although no information is given. The Enaleia Mediterranean Cleanup Programme works with 23 ports in Greece and Italy (around 250 vessels) and collects around 1 tonne of ALDFG per year and around 20-30 tonnes of end of life fishing gear. Most of the costs associated with the programme are met through sponsorship and grants, although fishermen are paid around €100 per month to retrieve ALDFG, which resulted in a seven-fold increase in participation. This demonstrates the role of positive incentives (discussed in Section 5) on behavioural change. Fishermen benefit by way of an improved public image and intrinsic satisfaction from removing waste from their fishing grounds (such satisfaction received as resource custodians came through strongly in the INdIGO surveys conducted earlier in the project).

The "Fishing Net Gains Africa" project operates an ALDFG retrieval programme in the coastal areas of Nigeria. A relatively small-scale programme, 700kg of ALDFG has been removed by 523 fishermen. An incentive is paid to fishermen for nets brought ashore, which benefits the fishing community through the reduction of ghost fishing. NGOs and the Canadian Government currently fund the programme.

The Washington Coast crab tag programme is a voluntary programme operated in a high intensity fishery. Around 90,000 pots are set annually with approx. 9,000 lost each year. Retrieval rates of between 1 and 10% occur each year. As recovered gear is expensive, fishermen are allowed to keep the gear they recover (representing a form of financial incentive for retrieving lost gear encountered).

A gear retrieval programme operates in the Canadian Dungeness crab fishery. In 2020, 119 traps were recovered at a cost of US$ 13,500 (equates to US$ 113 per trap) leading to a reduction in gear conflict (with the lost gear) and ghost fishing.

[36] This section is largely taken from Drinkwin (2022).

[37] Estimate based on €12,500 per 12 ports, which equates to €750,000 for all 60 ports that engage in the programme. Removal of 600 tonnes equates to €1,250 per tonne of ALDFG removed.

Textbox 1: Ghost fishing efficiency

Locating lost gear represents a significant barrier to the success of gear retrieval. In the absence of GPS tracking of all fishing equipment, fisheries authorities have largely relied on fishermen reporting gear loss[38] (which is a requirement in all UK fisheries). Gear loss in inshore fisheries tends to be less problematic, as it is easier to locate and recover. In addition, gear loss is thought to be less problematic in inshore fisheries (in terms of ghost fishing) as fishing efficiency declines through tidal action, fouling etc. (Brown et al., 2005). However, in offshore, deep-water fisheries, ghost fishing can represent more of a problem as nets can keep fishing for many years – with catch rates of 6-20% (see e.g. Szulc and Kasperek, 2015).

Therefore, the benefits (from an economic perspective regarding ghost fishing) may be minimal if gear is not retrieved quickly in inshore fisheries. Finally, if annual gear retrieval resulted in the removal of the majority of ALDFG – say 80% - the stock of ALDFG would continue to increase each year.

On the one hand, the literature suggests that gear retrieval programmes can be efficient under certain circumstances. They are possibly most successful and economically efficient (although there remains limited information to support this) in high intensity fixed gear fisheries (mainly inshore). Lobster and crab fishing in Chesapeake Bay are one such example where it is reported to be economically viable to retrieve lost gear (Bilkovic et al., 2012). In these fisheries, economic benefits accrue through retrieval to fishermen themselves. For instance, the cost of lost gear, the cost of ghost catch, reduced gear conflict between active and lost gear (resulting in further lost gear) and lost fishing time. The role of biodegradability in these fisheries requires further attention, as it can address the economic costs to fishermen – especially ghost fishing as fishing efficiency in these fisheries is thought to be of concern.

On the other hand, there is little evidence to demonstrate the economic viability of gear retrieval in other fisheries from the viewpoint of economic benefit to fishermen. However, the environmental impact of lost gear on the marine environment (and other sectors like shipping and tourism) is not factored into this assertion[39]. Furthermore, there may be environmental issues with retrieving lost nets e.g. damage to the benthic environment if gear is deeply embedded on the ocean floor. Ghost nets and pots may act as food sources for scavengers. Bio fouled gear may act as a Fish aggregating devices (FADS) rather than actively catch fish.

3.5 Section summary

Overall, management responses to ALDFG have not been widely studied. As recycling channels for end of life fishing gear are poorly developed, and currently not economically viable, the reduction of plastic use is preferable. The technical survey in

[38] However, as lost gear is not stationary, if not done quickly gear retrieval success may be limited. In addition, as fishing gear is expensive, fishermen will tend to exert significant effort in retrieving it themselves.
[39] However, this report is about creating a resource base to support the uptake of BFG by fishermen, hence the consideration of the costs and benefits to fishermen from this perspective.

INdIGO referred to gaps in gear collection chains and recycling facilities. It also noted that some fishermen were not aware of regulations for end of life fishing gear.

Gear retrieval efforts, the main response to ALDFG in some fisheries, can be effective, but are only cost effective under certain conditions (e.g. high intensity fisheries that suffer high levels of gear loss). In any case, preventative measures are preferable to curative ones.

BFG is regularly considered a potential solution for the fishing gear in the literature (see e.g. Gilman, 2016; Kim et al., 2016; Wilcox and Hardesty, 2016; Standal, Grimaldo and Larsen, 2020). While biodegradable plastics may be more difficult to recycle than conventional plastic, when conventional plastics break down in the sea they become microplastics, which is argued to be more problematic (Napper and Thompson, 2020). Thus, the real benefit of biodegradability, as a design feature of fishing gear, may be the reduction of potentially deadly microplastic in the marine environment. While BFG may not be the panacea to marine litter caused by fishing gear, its potential to reduce microplastic pollution, as well as other benefits e.g. damage to the benthic environment caused by ALDFG, have been somewhat overlooked in the literature on biodegradability. In short, further research is required to understand the role of biodegradability for fishing gear. However, several studies have focussed on elements of biodegradability for fishing gear and tend to reach consensus on the potential role of BFG in reducing the harmful ghost fishing (Gilman, 2016; Kim et al., 2016; Standal, Grimaldo and Larsen, 2020; Wilcox and Hardesty, 2016).

4. Barriers and opportunities for BFG implementation

4.1 Introduction

Improvements in the efficiency and selectivity of fishing gear have led to reductions in environmental impacts e.g. bycatch and undersized fish. One of the main advantages of conventional gear – its durability and strength – is now its major weaknesses. Irrespective of how gear becomes ALDFG, the environmental impacts are strongly linked to the durability and persistence of synthetic materials in the marine environment. Apart from the effects of ghost fishing of target and non-target species (including other marine life), fishing gear that becomes unmanaged in the marine environment causes a variety of harmful impacts to coral reefs and benthic fauna, and introduces plastic materials into the marine food chain. This causes significant economic impacts e.g. replacement of lost gear, species mortality, ecosystem costs, costs of retrieving lost gear and so on (Brown and Macfadyen, 2007; Gilman, 2015; Gilman et al., 2016; Grimaldo et al., 2018; Large et al., 2009; Lusher et al., 2017; Macfadyen, Huntington and Cappell, 2009). The global problem of ALDFG is reflected in the growing number of international organisations (e.g. WWF) and agreements that focus on the global reduction of ALDFG to mitigate the ecosystem impacts (as discussed by Gilman et al. 2016).

This section of the report reviews the experimental research[40] on the development and use of BFG, either as a substitute (i.e. replacement to traditional gear) or complement (e.g. partial replacement to traditional gear – for instance, biodegradable escape hatches on trap gear) to conventional fishing gear. The objective is to synthesise the research to develop understanding of the potential barriers and opportunities for BFG to address impacts of ALDFG.

4.2 What are the barriers and opportunities?

The development of fishing gears made of biodegradable plastic materials e.g. PBSTAT resin, is a potential solution to reduce the environmental impacts of ALDFG with a particular focus on ghost fishing and plastic pollution (see e.g. Brown and Macfadyen, 2007; Gilman, 2015; Gilman et al, 2016; Large et al, 2009; Macfadyen, Huntington and Cappell, 2009). As noted by Grimaldo et al., (2018) it is important to evidence the environmentally safe application of such biodegradable plastics e.g. ecotoxicological effects on the ecosystem during degradation (currently undertaken for the BFG produced in INdIGO). In addition, BFG should be at least as efficient (cost, lifespan etc.) as conventional fishing gear to not impact profitability. We will focus largely on studies that consider the impacts of BFG on fishing efficiency[41] (also known as catchability) as well as studies that have engaged the fishing sector. The latter mostly focus on the wider issue of integrating fishing gear into a circular economy (to determine the key circularity aspects and the relevant barriers and opportunities for BFG).

[40] This will include outputs published in academic journal articles and research organisation reports.
[41] A full cost-benefit analysis is being developed in T 2.3.1.

The majority of experimental work on developing and testing BFG has focussed on fixed gear - mainly gillnets[42] and traps/pots. Around the world, gillnets are commonly used to catch a variety of demersal and pelagic species, as well as some shellfish species (FAO, 2016). The size of gillnet operations can vary greatly, from small single crewed vessels (in developed and developing countries) to large-scale industrial vessels (Grimaldo et al., 2020). While data are not available to estimate the number of gillnetters in the Channel fisheries, 50% of respondents in the technical survey conducted in INdIGO reported gillnetting as a primary or secondary fishing activity. In the last decade or so, the recognition of the harmful impacts of ALDFG has been noted by international organisations (FAO, 2016; GGGI, 2020[43], MSC[44] 2020), with the development of BFG, particularly for gillnet fisheries, increasing around the world (FAO, 2016). Biodegradability serves two main functions. Firstly, as the gear degrades completely in the marine environment, lost gear would have limited capacity to ghost fish (and for a significantly reduced time). Secondly, the vast reduction of plastics degrading to microplastic, compared with the loss of non-BFG.

Biodegradable gillnets are currently used in commercial fisheries in China, Norway, Japan and South Korea and trap type gear in the USA and South Korea. The majority of research (as represented in the academic literature) has been (and is currently) conducted in Norway, South Korea and the USA. There is nothing available in the literature that documents the development of biodegradability in active gear types e.g. trawls and seines. However, as revealed in the stakeholder engagement work conducted for our task, there is growing interest in the use of BFG for sacrificial parts of trawl nets e.g. the dolly ropes that are designed to protect trawl nets. Biodegradable versions of dolly rope are currently being produced and tested in EU fisheries[45]. Further, biodegradable ropes have been tested for use with Fish Aggregating Devices (FADs) in tuna fisheries showing similar aggregative patterns of fish for conventional and biodegradable FADs (Moreno, Orue and Restrepo, 2017).

In South Korea, BFG has been studied across 13 different fisheries focussing on gillnetting and potting targeting a variety of species. A type of trap gear that is used to catch Octopus minor in South Korea was compared against a biodegradable trap, as both a direct substitute (complete replacement of conventional material) and as a complement (e.g. partial replacement) in a study by Kim, Park and Lee (2014). The trap gear used to catch Octopus minor comprises two parts – a funnel and a body. Kim, Park and Lee (2014) produced three experimental designs. First, a trap made 100% of biodegradable plastic. Second, a trap with a funnel made of biodegradable plastic and a body made of conventional material. Third, a trap with a funnel made of conventional material and a body made of biodegradable plastic. The study concluded that biodegradability is not a suitable substitute for gear made of conventional materials, as the 100% BFG has a reduced fishing efficiency of 60%, having a great impact on profitability. However, the authors note that biodegradability offers considerable

[42] Including entangling nets, drift nets, trammel nets and encircling gillnets.
[43] See: https://www.ghostgear.org/resources
[44] See: https://www.msc.org/what-we-are-doing/preventing-lost-gear-and-ghost-fishing
[45] https://www.senbis.com/products/marine-degradable-fishing-net-protection-dolly-rope/

potential as a partial design feature of the trap gear studied to catch Octopus minor. The gear with a biodegradable funnel and conventional body performed slightly better than the 100% BFG (with a 50% lower fishing efficiency over the conventional gear). However, the gear designed with a conventional funnel and biodegradable body returned almost the same catch efficiency as the conventional gear (Kim, Park and Lee, 2014).

Biodegradability is used as a design feature of gear in the Maine lobster fishery in the USA. Pots in this fishery must be designed in such a way to allow undersize lobsters to escape. Pots must also be fitted with a biodegradable panel[46] to reduce ghost fishing should they become lost. However, as noted by Bilkovic et al., (2012), escape mechanisms on pots often rely on hinges or degradable attachment points that can fail due to encrustation of bio-fouling organisms, which can prevent the escape mechanism operating. Bilkovic et al., (2012) developed a mechanism that is fully biodegradable and dissolves, thus not relying on hinges or detachable components. In Chesapeake Bay (USA), the authors tested their biodegradable panel with a cull (escape ring). The cull is placed on the side of crab pots and completely degrades after one year. The study notes that the escape panel and cull are relatively inexpensive and easy to install (including retrospectively). The authors found no statistical difference in catch rates of the target catch (or any increase in bycatch). The developmental phase of the panel and cull was supported by fishermen, who were paid to fish with the gear for a season. Chesapeake Bay is an intensively fished area, where it is estimated that 10-30% of the millions of pots set annually are lost, resulting in the ghost catch of as many as 1.9 million blue crab (alone) in some fisheries (Boilermaker, 2015).

Of the options to address ALDFG in trap fisheries in the USA e.g. improved port reception facilities, behaviour changing, gear retrieval and the use of biodegradable escape panels have grown in popularity. The use of biodegradable escape panels (and its acceptance) is mainly attributed to the panels not causing a decline in catchability (Boilermaker, 2015). In other fisheries, particularly the Alaskan Dungeness crab fishery, the use of BFG is common, with biodegradable escape cords used on all pots. However, studies have shown (Boutson et al, 2009) that the position of escape devices is dependent on target species and likely bycatch, as the latter may prevent escape from ghost gear. For example, escape hatches at the top of a pot are less likely to allow the easy release of crabs, who are more likely to crawl out of a pot than swim upwards to escape from the top. The utilisation of biodegradable escape panels means that should pots become lost they can act as valuable habitats for other marine life (e.g. nursery area), rather than be damaging to them. While some studies report that implementing biodegradability as a design feature of trap-type gear is relatively inexpensive, others (see e.g. Kim et al. 2014) suggest that in fact the main disadvantage is that the biodegradable pots are more expensive, so it is unlikely they will be widely used by the fishing industry without financial incentives. Further, as noted by Bilkovic et al., (2012) and Boilermaker (2015), many fisheries in the USA claim to use BFG, when in fact it is only degradable, meaning it can degrade into microplastic.

[46] This was a requirement for MSC certification.

Rather than having a sole focus on the relative catch efficiency of different BFGs, most studies have now evolved to address the outputs of earlier studies on BFG that documented such shortcomings – most related to strength, flexibility and durability. For example, a study by Bae et al., (2012) found that biodegradable gillnets in the South Korean Flounder fishery were 45% less effective (in terms of catching efficiency), but this was not correlated to soak time (issues relating to reduced strength) - rather it was correlated to wave height. A further study by Bae et al., (2013) compared flexibility with soak time, finding a positive correlation between soak time and catch efficiency. Overtime the BFG becomes relatively less efficient for all of the 15 species targeted ranging from 10-45%. A study by Kim et al., (2016) demonstrated the dry breaking strength of a nylon gillnet exhibited a greater breaking strength than a biodegradable monofilament of the same diameter, which when wet revealed a stiffness of around 1.5 times the nylon net. As demonstrated by other studies (some reported here), these characteristics (less flexibility and strength) should correlate to lower catching efficiency. However, as demonstrated by Kim et al., (2016), similar catch efficiency was noted for the experimental BFG in the Yellow Croaker fishery in South Korea.

Demonstrating both the technical and economic feasibility remains one of the main challenges for BFG implementation. A study by Park, Park and Kwon (2010), estimated the economic benefits to the fishing industry adopting BFG using a contingent valuation technique. The study looked at the role of consumer willingness to pay for BFG to address marine litter. While the average willingness to pay (household level) was less than £5 (currency equivalent), extrapolating to the national level gives a willingness to pay of around £52 million for biodegradable fishing net development and supply. This could be translated as consumers' willingness to pay higher prices for sustainable low impact fisheries – and thus has relevance for BFG implementation. Brown et al., (2005) also addressed the role of consumers in BFG implementation. While BFG ranked low as a management response to reduce the impact of lost fishing gear, the role of consumer awareness and acceptance was suggested as a potential benefit of using BFG. Other studies (Whitmarsh and Wattage, 2006) also demonstrate the role of consumer awareness, acceptance and willingness to pay for sustainably produced fish. Drinkwin (2022) reports on the improvement in public image as a driving force for fishermen recovering ALDFG.

Taking into consideration the current challenges around developing BFG (e.g. strength, durability), the role of consumer awareness and consumer acceptance is perhaps one of the greatest opportunities for BFG implementation. A number of studies (Kershaw, 2015; Tsai, Lin and Chang, 2019) have shown that a variety of factors are responsible for differing attitudes towards the marine environment (age, education, gender, cultural background). While very few studies have been conducted on attitudes towards marine litter (Kershaw, 2015), a study on attitudes of European populations found that Governments and policy were considered responsible for the reduction of marine litter. There is also some evidence to suggest that human perceptions influence behaviour and that some people are attracted to technological solutions as an alternative to changing behaviour (Klockner, 2013). While this could be seen as positive for BFG – e.g. a new technology that reduces the need for behavioural change to correct an environmental externality caused by ALDFG, it may also be seen as negative, as a perceived lower responsibility could result in a reluctance to take action e.g. BFG that become ALDFG also has environmental impacts.

Norway dominates BFG research for fixed nets. Gillnet fisheries are particularly popular in Norway with more than 5,500 vessels using them (Grimaldo et al., 2020). While some studies in South Korea have shown comparable fishing efficiency between conventional and experimental BFG, most studies in Norway have shown a consistently lower catch efficiency, which has been attributed to the weaker monofilaments used (11-16% weaker monofilaments than nylon monofilaments of the same diameter (Grimaldo et al., 2020)). However, increasing the diameter of the monofilament did not have a significant impact in Grimaldo et al., (2020), who tested larger diameter monofilaments in the north Norwegian cod and saithe fishery. Therefore, Grimaldo et al., (2020) conclude that strength does not explain the difference in catch efficiency, but the elasticity and stiffness (that relate to monofilament strength) may be responsible for reduced catch efficiency. Further, larger diameters of monofilaments cause a decrease in fishing efficiency, as gear becomes more visible (and thus available) to fish.

Grimaldo et al., (2019) compared biodegradable gillnets to nylon gillnets and found the traditional gear caught 21% more of the target catch (cod), with better catch rates for most size classes. The number of deployments resulted in lower catch rates. Although less efficient, the biodegradable nets offer considerable potential for the reduction of ghost fishing and plastic pollution caused at sea by the fishery.

A study by Cerbule et al., (2022) found a similar decline in catch rate (25%) in the Norwegian cod gillnet fishery, declining with each deployment. Grimaldo et al., (2020) noted that the long term use of biodegradable gillnets negatively affects catch performance, with an aging test showing signs of deterioration after just 200 hours of exposure. Cerbule et al (2022a) also conducted a study on the use of biodegradable materials in longline comparing nylon vs. biodegradable snoods finding no difference in either the loss of snoods (nylon vs. biodegradable) or catch efficiency.

Profitability is the main drawback to reduced fishing efficiency. However, there are other factors that may also reduce profitability e.g. strength – as gear will more likely break during the active fishing phase (Wilcox and Hardesty, 2016). Further, less strength and flexibility may increase the time (and expense) of gear repair and maintenance. As strength is correlated with soak time (Wang et al., 2020), then further trails in commercial conditions to test gear characteristics. For example, breaking strength during degradation, which may highlight a shorter commercial lifespan increasing costs and reducing profitability. Moreover, the impact of BFG on ghost fishing could also be limited, with some studies suggesting that the degradation time of BFG far exceeds the (likely) ghost fishing time. Other studies also demonstrate that fishing efficiency of lost gear is a function of time since becoming lost in the marine environment, with sharp declines in fishing efficiency. For example, Brown et al., (2005) found a negative exponential function with rapidly declining ghost catches, so that after 90 days, a ghost gillnet would fish at less than 5% the capacity of the same net under the control of a fisherman. However, given the time that conventional non-biodegradable nets can persist in the marine environment (before breaking down into the arguably more harmful microplastic), catches at only 5% of a managed net will likely be significant.

Evidence from the FANTARED 2 project[47] (which is extensively reported on in Brown et al., 2005) suggested (based on interviews with fishermen) that net loss in the Channel fisheries is not extensive and is mainly a result of gear conflict, with trawlers often cited as the culprit. The FANTARED 2 project concluded that in the Channel it was unlikely that lost gillnets had any great impact on fishing mortality. This is (somewhat) supported by the technical questionnaire conducted in INdIGO, which reports low levels of gear loss with some apparent cause/effect relationship with gear conflict. We found similar from the stakeholder engagement undertaken with fixed net and trap fishermen, suggesting better communication between fishermen (often facilitated by POs for cross Channel communication) has resulted in less gear loss compared to a decade ago. In deep water offshore fisheries, the impact of lost nets on fishing mortality may be significantly higher with long soak times and greater environmental pressures.

Ghost fishing, however, is only one negative impact of ALDFG. Reducing ALDFG may deliver significant reductions in the environmental damage to benthic fauna and corals (Clare Eno et al., 2001; Meurer, 2020) that could benefit from BFG implementation. In any case, a major barrier would likely be the increased cost of investing in new BFG. This investment cost would likely need supporting with incentives (Wilcox and Hardesty, 2016).

Overall, there are a number of challenges that need to be addressed and overcome for the use of BFG to become commonplace in fisheries in the programme area, the EU and global fisheries. While the idea of biodegradation to tackle the environmental impacts of ALDFG is by no means a new idea, there is a paucity of literature on the role of biodegradability in the circular design of fishing gear. Combining BFG with an EPR programme could lead to better outcomes than developing EPR for traditional gear (and deserves further attention). However, research that has engaged stakeholders on the better management of fishing gear has tended to rank BFG low against alternatives to address ALDFG. Brown et al, (2005) note that several alternatives e.g. gear marking, communication, recycling supply chain development were ranked higher as key circularity aspects to address ALDFG and ghost fishing. Brown et al., (2005) report on a lack of faith in the concept of biodegradability in the Channel as well as Baltic and Mediterranean fisheries. MRAG (2020) report little interest from stakeholders in the use of biodegradable materials. OSPAR (2020) report on mixed responses to biodegradable materials for fishing gear with responses ranging from “promising” to “concerns raised about the functionality” and “time to degradation concerns”. Therefore, there is a real need for research into the economic impacts as conducted here (and linking with technical shortcomings) – otherwise the uptake of BFG by industry is unlikely to become commonplace.

While most of what is available in the literature points to negative aspects, such as strength and flexibility resulting in reduced fishing efficiency (and the knock-on

[47] https://cordis.europa.eu/project/id/FAIR984338

effects e.g. increased costs), further research is required to address the challenges. Importantly, there has been a shift in this direction in recent research (e.g. Grimaldo et al., 2020). While INdIGO is addressing some of the challenges around biodegradability, other EU funded projects also focus on biodegradability and the circular economy for fishing gear. For example, the Glaukos[48] project focuses on developing eco-friendly fishing gear, the BIO gillnets project is attempting to address fishing efficiency reductions in BFG[49], the Dsolve project[50] and the Clean Nordic Oceans Project[51] are addressing some of the common challenges of developing BFG that is comparable to traditional fishing gear to meet fishermen's expectations. Projects are also developing bio-based solutions for aquaculture, such as the recently funded BIOGEARS project[52].

The use of BFG in commercial fisheries is confined largely to South Korea (gillnets) and the USA (crab and lobster pots) – with experimental work growing in Norway. Most research refers to the common challenges outlined here – and the need for further research to address these challenges (noting that fishermen are unlikely to adopt gear that is perceived to be less effective than current standards). One major link is often made between BFG and the elimination of ghost fishing. Several studies though have shown that the impact of ghost fishing is reduced significantly overtime, resulting from a large decline in fishing efficiency (compared with managed gear) (see e.g. Pawson, 2003; Brown et al., 2005). However, this is dependent on the type of gear and environmental conditions (e.g. water depth, tides). For example, in some gillnet fisheries, catch rates at 5% of commercial catch rates have been noted more than two years after net loss (MRAG, 2020). Trap fisheries may be even more problematic in terms of ghost catch, as traps can be self-bait (thus retaining a higher fishing efficiency for a longer period). Taking into account that there are wide variations in the estimation of ALDFG (and ghost fishing) local level studies are important to provide an indication of the scale of the problem to prioritise mitigation measures (at the fishery level).

Perhaps one of the greatest opportunities for BFG– as there is little research that refers to BFG as a technically feasible and economically viable alternative – is to link BFG with consumer awareness and willingness to pay more for fish caught from sustainable low impact fisheries (see e.g. Jaffry et al, 2016; Vitale et al. 2020).

4.3 Fishermen's views on BFG (research and INdIGO surveys)

In 2005, a report funded by DG FISH authored by Brown et al., focussed on ghost fishing by lost fishing gear in EU fisheries and considered the potential management responses to prevent and mitigate lost gear. Fishermen and fishing representatives (e.g. associations) were engaged in the project to discuss issues on the extent and causes of ALDFG and the impact and feasibility of a range of management responses. One of the management measures proposed in Brown et al., (2005) was the use of biodegradable gear to reduce ghost fishing once nets are lost. Overall, biodegradability was not supported by fishermen. Specifically, in the Western Channel, the appropriateness of

[48] See: https://www.b4plastics.com/projects/glaukos/
[49] See: https://www.sintef.no/en/projects/2016/bio-gillnets/
[50] See: https://uit.no/research/dsolve-en?p_document_id=704783
[51] See: https://pub.norden.org/temanord2020-509/temanord2020-509.pdf
[52] See: https://biogears.eu/

biodegradability as a management measure to reduce ghost fishing was considered low. Primarily, the concerns were centred on a lack of confidence in the strength of the gear, especially mixing panels and poor calibration of degradability (that would reduce performance and fishing efficiency overtime). Other measures, including retrieval programmes, reporting losses, zoning schemes, gear use limits and soak time limits all ranked above biodegradability. This suggests a clear preference for retaining the use of conventional gear (favouring management measures to prevent and mitigate losses). However, these options may be seen as closer to retaining the status quo (and preferred on that basis – as fishermen are happy with the performance of their current gear). Aside from strength, the main technical issue that is reported in Brown et al., (2005) is the technology to time degradability of gear, which should be the same as conventional gear (e.g. fishing efficiency during gear life). In short, Brown et al., (2005) report acceptability is likely to remain low, unless the same lifespan, price and fishing efficiency as conventional gear could be guaranteed. Research almost two decades later has not been able to address these issues, particularly fishing efficiency, which is consistently reported to be lower than traditional gear (see e.g. Cerbule et al., 2022).

The behavioural survey[53] conducted as part of INdIGO to a large degree supports these views. A preliminary analysis of the summary results (i.e. while the survey was in progress) revealed that 86% of fishermen agreed that financial incentives would be essential to start using BFG. Further, 70% revealed that the guarantees of a BFG fishing the same as gear currently used would encourage them to use BFG. In addition, only 43% agreed that they would trust BFG, with 37% thinking the maintenance time/repair would be greater for BFG and 54% assuming that the frequency of BFG replacement would be higher than conventional gear.[54] In addition, the most important features of BFG, as reported by the survey respondents, were lifespan, cost and strength. This is supported by a stakeholder workshop held as part of the 2020 report produced by MRAG, which focussed on the circular design of fishing gear for the reduction of environmental impacts. However, many positive features are drawn from the survey. For instance, 90% of fishermen revealed it is important to them to contribute to a fishery that protects the environment. 80% agreed that BFG could help to protect marine resources, with 66% agreeing that BFG would make their fishery more sustainable (with 80% agreeing that BFG could help to reduce ghost fishing).

The early survey results from INdIGO reported here, suggest that fishermen link the role of consumer awareness and acceptance with sustainable fisheries. For instance, 80% agreed that using BFG could enhance the image of fishermen among the general public, with 71% agreeing that the use of BFG could help them promote their catch. Further supporting the role of consumers as a positive for implementing BFG, more than 50% of fishermen reported they would accept a shorter lifespan, with the majority revealing that would be between 10-20%. Although around 50% revealed they would

[53] See appendix 1 for more details on the behavioural survey.

[54] A complete analysis of the survey results will be undertaken by CEFAS and UBS, which may reveal complexities beyond what is reported here. For example, it may be the case that of the 54% who thought gear replacement frequency would increase, many are gillnetters who already replace gear more frequently than e.g. a trawler fishermen (thus even more frequent replacement may represent a cost concern for gillnet fishermen).

not be willing to pay more for BFG, 37% revealed they would pay between 1-10% more. This demonstrates the important role of consumer awareness and acceptance - supported by studies that show that consumers are willing to pay a price premium for sustainable fish (Jaffry et al., 2016).

However, the overall headline message (from this preliminary analysis of survey results) is that financial incentives and fishing efficiency are the two most important influencing factors to invest in BFG.

4.3.1 Fishermen's views on BFG (interviews with fishermen)

Section 5 of the report "T1.1.3 - The Economic Impacts of ALDFG and Ghost Fishing: the Role of Biodegradable Fishing Gear as a Mitigation Measure" contains the results of fieldwork undertaken with those fishing in the Channel area. In total there were 29 respondents representing 48 vessels of which 31 fished using static gear. These came from the following ports from West to East: Newlyn, Helford, Newquay, Padstow, Mevagissey, Clovelly, Plymouth, Bideford, Portsmouth and Shoreham. Respondents were interviewed for 15-20 minutes on their fishing activity, interaction with ALDFG and experience of BFG. Alongside the data collected that was used for the economic impacts model in report T1.1.3, qualitative data was collected from the respondents which is supplemented with qualitative data from some of the organisations contacted during the data gathering.

This provides a rich data source, from static gear fishers, towed gear fishers and administrators, for views on problems encountered with ALDFG, opinions on the impact of ghost fishing, how often ALDFG is encountered. And their awareness of BFG, how they view it as a potential solution to any issues, what they regarded as potential positives and negatives of using BFG and whether they would be interested in trialling BFG either with or without any incentive.

A further piece of research[55] will be undertaken to analyse the responses in depth but it is possible at this point to draw out some of the key findings.

In general, respondents are not aware of BFG and are sceptical that it would provide a solution, either because they do not believe ALDFG to be major problem or because they have concerns over its performance relative to traditional plastic gear. That being said they are broadly in favour of trialling it (some with and some without incentives) and finding out for themselves whether it works.

The belief from many that ghost fishing from ALDFG is not a major problem in the fishery comes from the shallow seas and strong tides as well as vastly improved communication between the static gear fishers and the towed gear fleet both domestic and foreign. The tides are seen to roll lost nets up and smash lost pots to pieces which leads to plastic in the environment but not ghost fishing. Some of those that fish with pots also point to crab's ability to 'chew' their way out of pots if left for any length of time, reducing any ghost catch. That being said those who fish with towed gear do regularly bring up ALDFG in their nets but at volumes in the low single figures per week or month. An interesting additional note is that land based plastic litter is encountered

[55] A publication is being finalised for submission (as part of this deliverable) to Marine Policy.

frequently and one fisher highlighted that the amount of litter they catch in their nets and bring ashore with his catch would make them a significant net reducer of plastic in the marine environment.

Concerns over the performance relative to traditional fishing gear range from the broader (replicating current performance and lifespan, robustness in rough conditions with the strain of shooting and hauling through mechanical haulers, strength and it's cost effectiveness) to the very specific. For example, one fisher chooses 'ice white' mesh from their supplier as it fishes best for the whitefish species that they target and is aware that those targeting hake use a green tinted mesh for the same reason. Another talked about the shine on the mesh. Once the shine starts to go off the mesh and it starts to dull, their experience is that the fishing efficiency declines. There were also more general points raised about the specificity of BFG to the various target species within the channel and whether this would replicate the variety of choice available currently from traditional plastic gear.

A memorable point from one respondent, which sums up a broad range of concerns from respondents, was that whatever the solution is it has to at least leave the industry in the same position it is now or move them forward. They previously used BFG in the form of natural materials and moved to plastic as it lasts in the marine environment and the current materials have been perfected for durability and fishing efficiency. They suggested that asking them to accept any reduction in performance or increased cost would be akin to asking the authors of this report, for sound environmental reasons, to conduct this piece of research with a pencil and paper or typewriter and to correspond by post rather than email.

4.4. Section summary

Overall, there are a number of challenges that need to be addressed and overcome for the use of BFG to become commonplace in fisheries in the programme area, the UK, France and the wider EU. While the idea of biodegradation to tackle the environmental impacts of ALDFG is by no means a new idea, there is a paucity of literature on the role of biodegradability in the circular design of fishing gear.

While most of what is available in the literature points to negative aspects, such as strength and flexibility resulting in reduced fishing efficiency (and the knock-on effects e.g. increased costs), further research is required to address the challenges. Importantly, there has been a shift in this direction (see e.g. Grimaldo et al., 2020). While INdIGO is addressing some of the challenges around biodegradability, other EU funded projects also focus on biodegradability and the circular economy development for fishing gear. For example, the Glaukos[56] project focuses on developing eco-friendly fishing gear, the BIO gillnets project is attempting to address fishing efficiency reductions in BFG[57], the Dsolve project[58] and the Clean Nordic Oceans Project[59] are addressing some of the common challenges of developing BFG that is comparable to

[56] See: https://www.b4plastics.com/projects/glaukos/
[57] See: https://www.sintef.no/en/projects/2016/bio-gillnets/
[58] See: https://uit.no/research/dsolve-en?p_document_id=704783
[59] See: https://pub.norden.org/temanord2020-509/temanord2020-509.pdf

traditional fishing gear to meet fishermen's expectations. Projects are also developing bio-based solutions for aquaculture, such as the recently funded BIOGEARS project[60].

One major link is often made between BFG and the elimination of ghost fishing. However, several studies have shown that the impact of ghost fishing is reduced significantly overtime, resulting from a large decline in fishing efficiency (compared with managed gear) (see e.g. Pawson, 2003; Brown et al., 2005). However, this is dependent on the type of gear and environmental conditions (e.g. water depth, tides). For example, in some gillnet fisheries, catch rates at 5% of commercial catch rates have been noted more than two years after net loss (MRAG, 2020). Trap fisheries may be even more problematic in terms of ghost catch, as traps can be self-bait (thus retaining a higher fishing efficiency for a longer period).

The use of biodegradable fishing gear in commercial fisheries is confined largely to South Korea (gillnets) and the USA (crab and lobster pots) – with experimental work growing in Norway. Most research refers to the common challenges outlined here – and the need for further research to address these challenges (noting that fishermen are unlikely to adopt gear that is perceived to be less effective than current standards).

Perhaps the greatest opportunity in this respect – as there is little research that refers to BFG as an economically viable alternative – is to link BFG with issues of growing consumer awareness and consumer willingness to pay more for fish caught from sustainable low impact fisheries (Jaffry et al, 2016; Vitale et al. 2020).

[60] See: https://biogears.eu/

5. Overview of the role of incentives and management measures for BFG integration

5.1 Introduction

According to Chen (2015), there are four types of management approaches that can be implemented to address marine litter. The approaches broadly intersect some form of regulation and some form of incentive (or market based) measure. Regulation and incentive based measures are not binary choices or mutually exclusive categories – usually there is some overlap in policy.

Firstly, preventative measures - essentially legislation and regulations that ultimately aim to prevent marine litter from entering oceans. By integrating elements of marine litter (e.g. fishing gear) into a circular economy by reusing before recycling (and preventing land-based waste entering oceans), the level of marine litter would naturally decrease. With regards to waste fishing gear, two key improvements can be made. One is the upgrading of port reception facilities (which are almost non-existent at most ports in the EU) for dealing with end of life fishing gear (Chen, 2015). The other option is to make producer responsibility mandatory. This is commonplace in the EU for environmentally damaging production processes e.g. car batteries, where the producer has responsibility for financing the collection, recycling and responsible end of life disposal. In the EU, extended producer responsibility is considered a cornerstone of waste policy (Pouikli, 2020). For example, the EU Single-Use Plastics Directive covers fishing gear as well as tackling the 10 single use plastics most commonly found washed up on beaches. From the end of 2024, an extended producer responsibility will be applied to fishing gear, bringing fishing gear in line with other damaging sources of environmental pollution in the EU[61].

Secondly, mitigation measures - essentially attempting to dilute the impact of marine litter (Chen, 2015), given some type/amount of marine litter is unavoidable. There is a close link with preventative measures, where command and control regulations are attempting to prevent the pollution in the first instance. Mitigation measures, that link to port reception facilities, for instance, are relevant to fishing gear waste.

Thirdly, removal measures - essentially activities that take place to remove marine litter. For example, beach clean-ups and gear retrieval programmes. There is some link to preventative measures e.g. extended producer responsibility.

Fourthly, behaviour changing – essentially the use of educational tools to change behaviours and reduce marine litter. A significant element here is the use of economic incentive tools to bring about the required behavioural changes to address the problem (in the hope that once the behaviour has changed the incentive can be withdrawn).

Given the global scale of the marine litter problem, new international instruments delivered at the national level are required.[62] Nations are faced with two broad (although not mutually exclusive) options to manage fishery resources –

[61] Extended Producer Responsibility is considered in more detail in T1.1.3.

[62] In fisheries, Regional Fisheries Bodies (RFBs) could play a significant role, supporting management standards to minimise the impacts of gear loss (Gold et al., 2013).

command and control regulations or incentive based approaches (so called market based mechanisms[63]). Historically, the effectiveness of the command and control approach is strongly linked with a nation's ability to enforce the regulation set – significantly more difficult for ocean based activities compared with land based activities. While significant improvements in the way fisheries management regulations are enforced have been made (e.g. technological advances such as GPS vessel monitoring), the task remains challenging. For example, Illegal, Unreported and Unregulated (IUU) fishing is considered to be "one of the greatest threats to marine ecosystems for its potent ability to undermine national and regional efforts to manage fisheries sustainably as well as endeavours to conserve marine biodiversity" (FAO, 2021[64]).

However, the use of incentive based approaches is by no means a 'silver bullet' solution. For example, subsidies, a commonly used incentive measure, can lead to perverse outcomes that contribute to resource depletion (i.e. contributing to the problem addressed). In 2016, 90 countries signed up to an UNCTAD-FAO-UNEP roadmap towards ending harmful fishing subsidies. UNCTAD estimate the use of subsidies in fisheries reached USD 35 billion in 2017, of which USD 20 billion actually contributes to overfishing, with the amount of stocks fished at unsustainable levels increasing from 10% in 1974 to 34.2% in 2017.[65] However, as noted by UNCTAD, some subsidies are beneficial for sustainable fisheries management; for instance, by helping the industry switch to environmentally friendly fishing gear.

Below, we consider the role of command and control regulation and incentive based measures in relation to their role in integrating BFG in to fisheries.

5.2 Command and control measures

Command and control relies on regulation, defined as permission, prohibition, standard setting and enforcement. This involves government regulators issuing a command, typically a maximum level of impact/pollution that is allowable (i.e. the negative externality that is causing the environmental impact). Industry performance against the set standard is then monitored and (where necessary) enforced (Aranda, Murillas and Motos, 2006). Command and control approaches can be very successful for certain types of environmental impact, although they are also often referred to as a disappointing approach to resource management (Aranda, Murillas and Motos, 2006). For example, it is relatively straightforward to monitor effluent discharge into rivers from a manufacturing plant. It is also straightforward to implement penalties for non-compliance with the standard. However, a potential shortcoming of command and control regulations is setting the command at the optimal level. A further problem is the lack of incentive/reward (which is essentially zero) for producers to go beyond the standard set e.g. make further improvements in the reduction of the environmental

[63] In addition, there are other systems, like community based management or voluntary measures (such as no take zones, or voluntary agreements on gear type use) and other initiatives like the Blue Marine Foundation Lyme Bay fisheries.

[64] The FAO (2021) estimate that up to 26 million tonnes of fish caught annually, valued at USD 10 to USD 23 billion, is attributed to IUU fishing.

[65] See: https://unctad.org/project/regulating-fisheries-subsidies

impact (Harrington and Morgenstern, 2007). This is an important consideration for the marine litter problem – as the economically optimal solution is not the complete removal of marine litter from the marine environment (simply because the financial burden would be too high i.e. the marginal benefits will diminish (rapidly) beyond a given point). However, the economic optimum is clearly not the status quo.

For marine litter, the problem is further complicated by virtue of the amount of sources of litter that end up in the ocean (land based) and the different types and sources of litter that originate from users of the marine environment e.g. shipping and fishing. Therefore, setting the command level (i.e. max level) is more complex than the example provided above (manufacturing plant polluting a river). While estimates exist for the amount of fishing gear entering the ocean (as ALDFG), they are only estimates (Richardson et al., 2021). The same is true for the impacts (environmental and economic) – few estimates exist but they tend to be large (e.g. Beaumont et al, 2019). Fishing gear can become lost in the ocean for several reasons (under ALDFG conditions) and there is a lack of knowledge regarding what gear is lost, if it is subsequently recovered etc. Further, rope (e.g. cuttings from repairing fishing gear) is a significant and growing contribution to marine litter from the fishing industry (that may be underrepresented in the estimates available). In addition, it is likely that a command and control approach would be difficult to implement for fishing gear, as it could incentivise gear being abandoned at sea e.g. if costs of recycling are high and borne by fishermen. If the A of ALDFG is set at zero, the command and control approach can have little more impact, as one would assume that fishermen are not losing 'good' gear on purpose. To complicate the matter further, even if gear abandonment is commonplace, it is inherently more difficult to monitor compliance and enforce regulations in the marine environment (compared with land-based industries e.g. the manufacturing plant example provided above). Therefore, measures like the polluter pays principle are difficult to assess. Fishermen have a responsibility to dispose of used gear (and prevent it becoming ALDFG in the marine environment) yet abandonment is expected to be significant in some fisheries (contributing to the 5.7% of nets, 8.6% of traps and pots and 29% of fishing lines lost annually (WWF, 2020)).

Further, while command and control approaches tend to be unpopular with producers as well as consumers in some circumstances. However, regarding consumers it may only be short lived. For example, applying corrective taxes is normally met with opposition. However, the opposition can decrease overtime if the corrective action leads to positive results, e.g. the plastic carrier bag charge[66] in the UK has led to a reduction in use by around 86%.

In the case of marine litter pollution, demographics may be an important indicator for the acceptance of marine litter from the fishing industry. For example, those that witness the impact of marine litter on a daily basis e.g. coastal communities, might be more accepting of (and willing to pay) a tax/charge to decrease the level of marine litter compared with communities that live 100 miles from the ocean. The same applies to users of the marine environment – either those that derive their livelihood

[66] Although the tax element in the plastic bag charge only relates to VAT portion of the carrier bag fee.

from the marine environment e.g. fishermen, tourism operators, or those that derive recreation from the marine environment, such as boating, diving or walking, over someone who never visits (and never wishes) to visit a beach. The engagement of stakeholders, particularly industry stakeholders directly impacted by the imposition of a new regulation, is critical to designing and implementing any regulation. However, engaging all stakeholders that might be (if only indirectly) affected by the implementation of a new regulation is also needed. The importance of engaging stakeholders (and the right stakeholders at the right level) cannot be overstated, not least to avoid implementing an inflexible (e.g. one-size fits all) approach. As noted earlier, this is particularly important given that compliance is preferable to enforcement, especially in the marine environment.

5.3 Incentive based measures

Governments may implement incentive based (also known as market based) approaches. From a theoretical viewpoint, incentives refer to economic instruments of cost internalisation. The incentive-based approach is preferable providing it delivers what it promises - that being, it incentivises/rewards greater reduction in the level of environmental impact. Connecting environmental objectives with financial incentives effectively incentivises producers to find alternatives to reduce pollution and invest in such technology if it is cost effective (the incentive can be implemented to ensure the short term cost effectiveness, or to facilitate engaging in fishing gear trials, for example). As a result, (although there are caveats – as outlined below), the social cost of incentive-based approaches tends to be less, as society as a whole benefit from better environmental performance of firms. It is clear that society will benefit from reductions in marine litter.

The traditional economic viewpoint of incentive-based approaches is that they will achieve at the least the same outcome as the command and control regulation, as well as (incentivising) reduction beyond the “command” level – leading to lower levels of environmental impact (the externality that the incentive based approach is targeting). However, in some cases, a mixed policy framework (command and control with incentives) may lead to a better outcome – especially in cases where monitoring compliance and enforcement is difficult.

Incentive based approaches also have drawbacks. Subsidies, a commonly used market based measure to correct market failure, are often considered particularly damaging to the environment (Arthur et al., 2019; Cisneros-Montemayor and Sumaila, 2019; Skerritt and Sumaila; 2021; Sumaila et al., 2016). This is (in part) because they may create perverse incentives that lead to unintended outcomes. The worst-case scenario is that a subsidy to decrease the level of a negative environmental impact can actually result in an increase in the negative environmental impact. While subsidies should incentivise improvements in reducing pollution overtime they may (if poorly implemented) in practice, create inefficient production processes and have the opposite effect. For example, most fisheries subsidies are estimated to be harmful to the environment, particularly fuel subsidies that make it affordable for vessels to spend longer at sea and catch more fish from already depleted stocks. Added to that, it is estimated that the use of subsidies in developed countries are far greater than developing countries (accounting for 65% of total subsidies transferred by governments to the fishing industry), with EU fisheries (including the UK) accounting for 25% of global subsidies alone (Sumalia et al., 2013).

Further, certain incentive-based (also known as quasi-incentive based) measures are tradeable, like marketable permit systems or tradeable programmes. While attempting to address an environmental impact (like pollution) they can actually lead to an increase in the level of environmental impact, if (in some way) they are coupled with economic growth. These so-called pollution reduction credits do not set a maximum level of pollution, rather a maximum level of pollution per production unit – with producers receiving credits for achieving production per unit below the maximum permitted. Of course, if the market allows growth through new entrants this will actually increase the overall level of pollution (for instance, while no licences have been granted in UK fisheries since 2004, there are no catch limits on some shellfish species and production has grown significantly since 2004). There may be economic and environmental benefits of tradeable pollution permit programmes, where either an initial (tradeable) allocation of pollution unit is distributed among producers. From a theoretical viewpoint, this should lead to efficient allocation of resources, and incentivise reductions in the environmental impact (in this case pollution). However, in practice, by virtue of the tradeable element, they may generate social costs, such as employment, as the permits to pollute may end up in the hands of larger firms (e.g. quota allocation in UK fisheries which has created a system of "the have and have nots"). Therefore, the cost of complying with command and control approaches, and the cost if investing in some incentive based systems (like tradeable permits) should take into consideration that the costs may be dependent on firm size (as well as other factors). This is an important consideration for the target market for BFG.

A further drawback is that market based instruments may be negatively received by society (Fullerton, Leicester and Smith, 2007), as part of their transaction cost is to incentivise producers to reduce their environmental impact e.g. consumers may consider that the responsibility of the producer (and/or government). As such, there may be a higher moral value assigned to command and control approaches, or extended producer responsibility schemes.

5.3.1 Examples of incentives for BFG

There are limited examples in the literature of the type/amount of incentive that would be required for fishermen to engage with BFG. There are several references to the use of government financial incentives to mitigate impacts of ALDFG (including the role of BFG to address ghost fishing). For example, Cho (2009) discusses incentive schemes for ALDFG removal with different rates paid for the type and volume of gear retrieved. Kim, Lee and Moon (2014) discuss the need for financial incentives to stimulate BFG use (and the importance of public education to emphasise the need to address gear discarding at sea). Kim et al., (2015) report on the use of government financial incentives for biodegradable gillnet use as compensation for lower catch efficiency and higher gear costs.

A study by Standal, Grimaldo and Larsen (2020) discussed the options for type and level of incentives required for BFG use in the Norwegian cod gillnet fishery. Standal, Grimaldo and Larsen (2020) report on a 10.9M gillnetter working a fleet of six nets (120 panels in total). Replacing all gear with biodegradable gillnets would result in a 21% decline in catch (approx. 20 tonnes) resulting in almost £40,000[67] of lost revenue. Given biodegradable gillnets are twice as expensive in Norway as traditional gear the investment would be almost £3,000. Therefore, a total cost (lost catch and gear investment) of £43,000. In the lack of government assistance e.g. financial incentive, the gillnetter would either have to set more gear (higher investment cost) or spend more time fishing (higher variable costs e.g. fuel). Therefore, everything else remaining constant, the gillnetter would need to be compensated for the reduced catch and extra gear investment cost. This study does not factor in higher market prices from BFG use (as we do in our analysis). However, what this study does show is that the use of BFG is a technical challenge and not an economic one. The majority of incentive (more than 90%) is to compensate for fishing efficiency and less than 10% for the cost of gear. Our analysis of the level of incentives required is being undertaken in Task 1.1.3 – results are presented in that report.

Along with the use of incentives for BFG, fishermen will continue to play an important role in retrieving lost gear. Perhaps more so if fishermen were using BFG. Drinkwin (2022) notes that "requiring" fishermen to retrieve gear if it is lost as a critical measure to avoid impacts from ALDFG. Most fishermen make a great deal of effort to retrieve gear (even illegal fishing activity) as the purchase and maintenance of fishing gear is a major expense and investment for fishermen. Incentivising fishermen to do so will be important, otherwise retrieval attempts that divert attention from lucrative fishing, costing time and fuel, fishermen may abandon lost gear in order to carry on fishing. An incentive to ensure that vessels carry the necessary equipment to recover gear would be useful in this respect (Drinkwin, 2022). Finally, coupling this with policy to establish new regulations would likely yield the best chance of success.

5.4 Section summary

There is little to suggest in the short to medium term a regulation (either direct or indirect) mandating the use of BFG (excluding the use of non-biodegradable type gears). Biodegradability is not (yet), a proven solution for reducing ALDFG and subsequent environmental impacts like ghost fishing. Mandatory EPR schemes for fishing will be developed in the EU by the end of 2024. This should facilitate the development of economic fishing gear recycling. It is likely that similar will follow in the UK reflecting the trade in fish between the UK and the EU. However, the development of a circular economy will not eradicate ALDFG and the various environmental impacts ALDFG creates. This is perhaps the main opportunity for BFG.

To facilitate the developmental process of BFG, engaging industry will require the use of incentives. This will be particularly important to understand the 'functionality' issues in static gears in the Channel fisheries. Two important themes

[67] Figures adjusted to GBP at 2022 values.

emerged in the INdIGO 'behavioural' survey[68]. 1. The majority of fishermen accept that BFG would be viewed positively by consumers (as a step taken by industry to improve the sustainability of fisheries). 2. Financial assistance is "essential" for fishermen to start using BFG. While some fishermen note that BFG could contribute to the protection of the marine environment through the reduced loss of fishing gear (as lost BFG would have a controlled lifespan), they (generally) were not able to respond to questions in the behavioural survey about fishing efficiency, strength etc. as they have no experience of fishing with BFG. This further supports the role of financial incentives to stimulate interest from fishermen to engage in the developmental phase of BFG (with some fishermen suggesting that being able to try BFG would encourage them to use it). The necessity for incentives was also reflected by the lack of willingness from fishermen to pay more for BFG gear. Assuming the same characteristics (e.g. lifespan, fishing efficiency), some suggested a modest increase of 5-10% for BFG. However, the initial investment cost could be substantial. Standal, Grimaldo and Larsen (2020) report on a doubling in cost for biodegradable gillnets in the Norwegian cod gillnet fishery.

[68] Here, we present a rough overview of the outputs – not a detailed analysis. In light of the detailed analysis becoming available, some changes to the rough summary data that we present may be required.

6. Target market

6.1 Introduction

This section briefly outlines the total addressable market and the serviceable achievable market before detailing the serviceable obtainable market for the developmental phase BFG in the programme area.

6.2 Total addressable market

The total addressable market is relatively straightforward to determine, as the MMO and ICES hold the relevant data (in terms of vessel numbers, characteristics, catches and prices and so on). Further, Seafish hold the relevant economic data (e.g. cost and earnings, profitability, employment etc.). At the UK level, the total addressable market comprises 5,264 vessels. Of the total vessels, 4,141 are vessels <10m and 1,123 are vessels >10m. 1,524 vessels are considered 'low activity' with an annual income of less than £10,000. In total, roughly 50% use primarily active gear and 50% static gear, with static gear representing three of the top five fleet segments by employment. A noticeable shift in the last decade is the increase in vessels using static gear (16% increase) and a decrease in active gear (trawls and dredges) by 19%. While operating profits have grown for both gear types, the growth has been more pronounced for static gears, although as noted by NEF (2018) there is variability among fleet segments. The increase in operating profit and margin for static gears (pots) correlates with an increasing price trend for shellfish (the main target species). While prices for demersal species have also grown, some of the volume is caught by static gear, although price growth is not as prominent as shellfish (but both show an upward trend). For comparison, pelagic prices, while fluctuating, have grown only slightly in the past decade.

In terms of the current operating environment, we differentiate fleets that are operating mainly under the CFP or national fisheries management. The main distinction is those vessels fishing for quota species are managed under the CFP (covering most pelagic and demersal trawling activity), with static gears (traps covering shellfish with the exception of nephrops[69]) and fixed nets (e.g. gillnets, although some species like cod and hake are quota managed) are managed under national management. Larger trawling vessels represent the majority of quota fishing activity. In the UK, the allocation of quota has been a contentious issue for decades, with fishermen revelling in the opportunity of becoming an independent coastal state operating outside of the CFP. However, Brexit has not delivered what the fishing industry (or large parts of it) anticipated, with the status quo largely remaining. In the absence of a regulation (command and control approach), we consider that the incentives to trial biodegradability for towed gear would be prohibitively large, given the challenges of BFG development noted in this report (strength, flexibility, degradation time etc.). Further, the competition in the market that BFG would enter for active gear is growing. Integrating fishing gear into a circular economy by incentivising the recycling of end of life gear e.g. improved port reception facilities, financial rewards for returning lost gear to shore, means there is little to demonstrate that targeting larger vessels that use active gears represents a realistic (at this point) serviceable obtainable market. Part of the

[69] However, nephrops are mainly caught by trawling (active gear type).

response towards gear retrieval programmes and recycling reflects the sheer volume of ALDFG estimated to be present in the world's ocean. While BFG likely represents a long-term solution to ALDFG mitigation (and the associated impacts), it cannot retrieve and recycle gear that is already lost in the world's oceans.

The market for biodegradability in aquaculture is not considered given the limited aquaculture activity in the programme area. While the English Aquaculture Strategy details potential for growth, most aquaculture activity remains centred on Scottish salmon farming, which is not considered to represent a market for biodegradability (even if it could be undertaken in the programme area), as the functionality concerns (particularly strength and durability) represent similar problems to those noted for large scale active gear vessels.

Therefore, we progress to the next level of the market analysis focussing on static gear vessels.

6.2.1 Serviceable achievable market

The use of static gears is commonplace in fisheries around the world. The use of gillnets (and other types of entangling nets e.g. trammel nets) are widespread in global fisheries to catch a wide variety of demersal, pelagic and shellfish species (FAO, 2016). The size of static gear fishing operations ranges from single crewed vessels to large-scale industrial vessels (Grimaldo et al., 2020). Static gear activity has grown in the last decade in the programme area, with vessel numbers, employment and profitability over-represented in the Channel fishery.

As the world becomes more aware of the marine litter problem, including the role of ALDFG, the Channel fishery is well placed to engage in studies relating to mitigation measures e.g. BFG. Data on gear loss and the risk factors associated, point to static gear[70] as being higher risk than active gear (Gilman et al., 2021), based on the rate the fishery produces ALDFG, the amount of global fishing effort and the potential ecosystem and socioeconomic impacts. Further, while data for ALDFG are sparse, Macfadyen, Huntington and Cappell (2009) summarised research into ALDFG and found that gear loss varies between fisheries using similar gear. In the Channel gillnet fishery, loss was estimated at a rate of 0.2 to 2.11%, whereas pots and traps can be lost at a rate of up to 30%. In addition, Scheld et al., (2016) showed that the loss of pots was highly variable and ranged between 10 and 70% of the pots deployed each year.

In terms of fleet segments, the vast majority of landings by volume and value for >10m vessels is represented by active gear types, mainly trawl gear. The opposite is seen in <10m vessels, where the vast majority of landings by volume and value is represented by pots and traps, with static net use more widespread in smaller vessels. There are a number of positives to take from this with respect to BFG implementation. For example, these vessels are not subject to management under the CFP, smaller vessels tend to target inshore fisheries (with some important role for IFCAs in terms of national management) and catch high value shellfish (as well as some high value

[70] Set and fixed gillnets, drift gillnets, bottom trawl, fyke net and pots (5 out of the 7 worst offending gears for ALDFG).

demersal/pelagic fish using gillnets). Further, while there is a paucity of research on the development of BFG, most has focussed on static gears given the challenges of strength, flexibility and durability that would impact more on active gears (particularly during the hauling of nets). While profitability is variable in different segments of the UK fishing fleet, the data for Channel fisheries shows two important things that are positive for BFG implementation. 1. Static gear fishermen are over-represented in the UK fleet, 2. Profitability of static gear vessels has increased more than other gear types in the Channel fishery since 2009. This suggests, given the absence of a direct regulation, that while incentives will be required to facilitate the developmental phase of BFG implementation (a view largely supported in the surveys conducted in INdIGO), they will be less than those required for other fleet segments.

6.2.2 Serviceable obtainable market

This report has considered the current conditions within the fishing industry (at the UK and Channel fishery level), including activity, management structures, the contribution of different gear types to ALDFG and its relative effects. We have also considered the competition for BFG in the market place (e.g. current gear, net recycling, net retrieval programmes with respect to integrating fishing gear into a circular economy). The barriers and opportunities (technical and economic) to BFG implementation, including the views and role of industry stakeholders (including those on consumer acceptance and awareness) and the incentives and management measures to facilitate BFG implementation in the Channel fisheries have also been considered. Outputs from the stakeholder engagement work (the two INdIGO surveys) is also included.

Based on the above, we arrive at the serviceable obtainable market for the developmental phase of BFG in the Channel fishery as <10m vessels using the static gears of gill (type) nets and traps and pots. Overall, we consider the serviceable obtainable market as realistic in these fisheries. While BFG is not a 'silver bullet solution' to ALDFG and the myriad of environmental and socioeconomic impacts, it is a potential solution to the problem (particularly ghost fishing). As a potential solution, that is currently in its development phase, we consider that targeting markets beyond small scale static gear vessels, is both unrealistic and unviable (and may hinder the potential of BFG to progress through a developmental phase).

Serviceable Obtainable Market = Small Scale Static Gear Fishermen.

For static gear, while the data does not offer the granularity needed to provide exact (robust) figures in the Channel fisheries in terms of gear types[71], the data[72] shows that 1,170 vessels are registered in Channel ports with 166 >10m and 1,004 <10m vessels. Of the larger vessels, 45 have a shellfish licence, although the extent to which they utilise the entitlement is unknown (as there is significant beam trawl effort among the larger vessels, particularly in area 7d). For the <10m fleet, 466 vessels have a shellfish licence. Therefore, the Channel ports are home to 14.8% of the >10m UK fleet and 24.2% of the <10m fleet – totalling 17% of the UK's active shellfish licences. Given

[71] Data to estimate the number of fishing vessels by gear type is not currently available.
[72] Data publicly available and held by the MMO.

that smaller vessels fish static gear more so than active gear, the size of the serviceable obtainable market may be as high as 1,170 for fixed nets and traps. Extrapolating this based on STECF (2020) data, the EU serviceable obtainable market may be as many as 47,999 vessels (classified as the small-scale coastal fleet, comprising vessels <12m using static gear, representing 75% of total active vessels in the EU).

7. References

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8. Appendices

Appendix 1: Relevant responses from behavioural questionnaire

In general the respondents were in favour of BFG and preserving the environment but believed that financial assistance was essential for it to be adopted (Q9).

They believed that it would enhance the public's view of fishermen and be personally rewarding as well as it being an aspect that could be used to promote the catch and fulfil customer's expectations (Q11 response 3 and 6, Q16 response 1, Q14 r4)

Many responses related to BFG product knowledge received a response of 'Neither agree nor disagree' (Q12 r1 &4, Q13 r3, Q18 r1-4) while those related to enthusiasm for adoption received a positive response (Q12 r2,3&5, Q13 r2, Q15 1,3&4, Q16 r3,4,5&6). This suggests that while not much is known about BFG this is not a barrier to its adoption with the majority of respondents wanting to adopt it.

The impact of adoption on profitability was central to many responses with lifespan and cost as the most pressing concerns (Q19). Over 50% of respondents would accept between a 5 and 20% decrease in lifespan with two thirds accepting some decrease (Q20). 50% would also accept some increase in cost although only four of the 34 respondents would accept an increase above 10% (Q21).

Top five factors that would influence the uptake of BFG are (Q22):

1. Financial incentives to purchase BFG

2. Efficiency and catchability

=3. Cost

=3. Consumer's willingness to pay more for fish caught by BFG

5. Lifespan

Appendix 2: The Economic performance of UK fleet segments

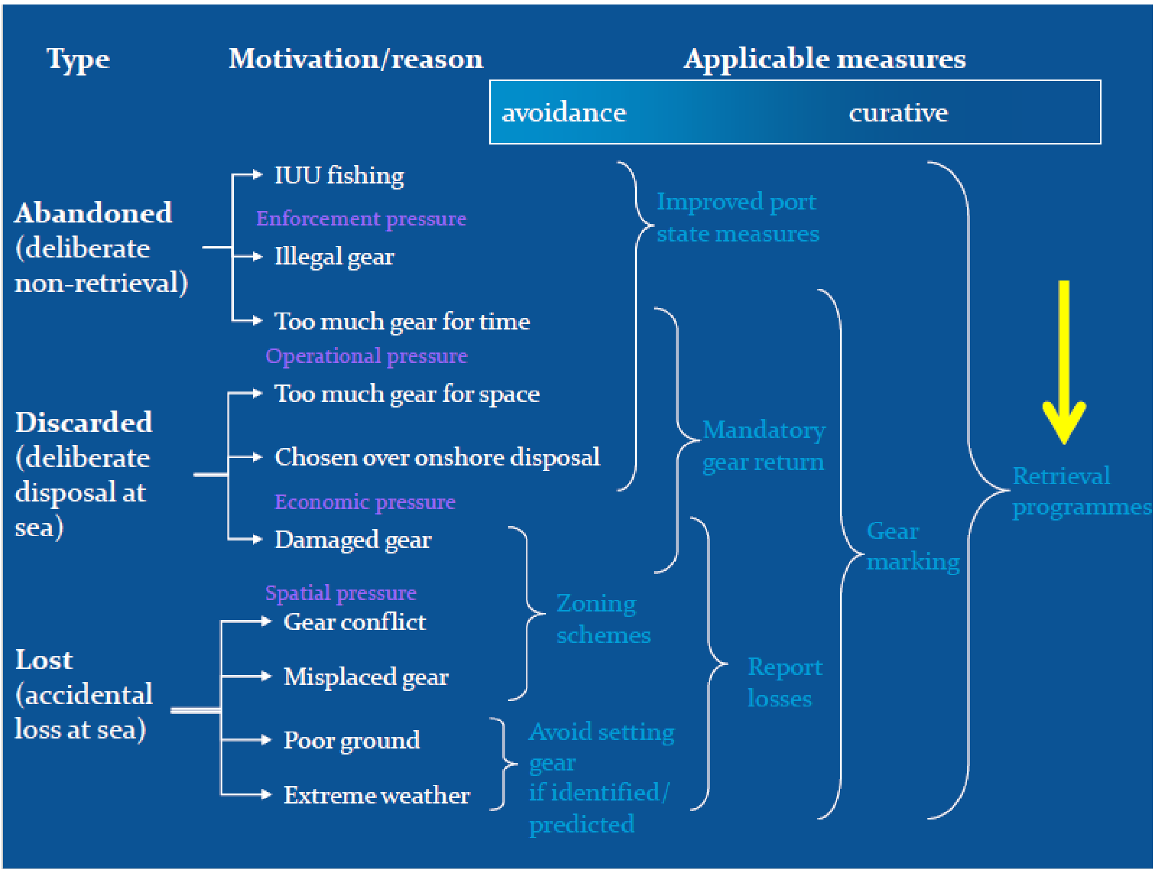
Fleet segment	Number of vessels	Number of FTE fishers	Landings (tonnes)	Earnings (£)	Net profit (£)	Net profit margin
Drift/fixed net 0–10m	622	175	4,015,932	9,544,148	-583,684	-6%
Drift/fixed net 10–12m	15	75	2,348,757	4,134,734	820,645	20%
Drift/fixed net 24–40m	16	272	5,323,974	13,991,700	2,958,938	21%
Dredgers 0–10m	105	76	3,298,674	5,821,918	417,473	7%
Dredgers 10–12m	32	52	2,627,702	5,121,013	879,118	17%
Dredgers 12–18m	114	312	17,153,080	24,023,378	3,460,799	14%
Dredgers 18–24m	25	160	10,644,565	12,900,206	1,523,518	12%
Dredgers 24–40m	31	307	13,265,569	21,225,543	2,844,251	13%
Demersal trawl/seine 0–10m	257	290	4,794,036	11,206,112	405,166	4%
Demersal trawl/seine 10–12m	89	164	3,386,989	8,049,016	1,067,898	13%
Demersal	208	818		40,852,055	5,027,754	12%

trawl/seine 12–18m			17,590,155			
Demersal trawl/seine 18–24m	171	1,087	42,426,070	83,194,670	12,185,905	15%
Demersal trawl/seine 24–40m	86	909	72,135,080	126,636,917	28,800,954	23%
Demersal trawl/seine 40m+	10	137	26,513,163	39,262,660	5,131,041	13%
Pots & traps 0–10m	1,739	1,190	25,452,792	57,905,610	-50,858	0%
Pots & traps 10–12m	166	378	9,573,686	20,047,772	5,174,123	26%
Pots & traps 12–18m	81	358	15,245,745	25,341,827	3,721,884	15%
Pots & traps 18–24m	14	155	7,823,939	12,029,787	2,084,487	17%
Hook & line 0–10m	527	216	2,274,052	6,224,460	-524,932	-8%
Hook & line 10–12m	17	34	305,567	1,139,538	-220,083	-19%
Hook & line 24–40m	13	263	8,301,350	22,722,546	2,068,231	9%
Polyvalent active	30	27	2,272,339	1,606,735	52,181	3%

gear 0–10m						
Polyvalent active gear 12–18m	37	58	8,262,978	3,981,629	498,926	13%
Polyvalent passive gear 0–10m	70	22	361,899	921,199	-53,711	-6%
Beam trawl 0–10m	12	10	163,265	345,280	-2,292	-1%
Beam trawl 12–18m	10	38	815,895	1,793,639	159,571	9%
Beam trawl 18–24m	18	132	4,758,097	12,530,091	2,030,584	16%
Beam trawl 24–40m	33	365	16,782,785	36,923,838	2,102,258	6%
Pelagic trawl 40m+	28	55	380,912,449	203,487,658	55,774,390	27%
Total	4,576	8,135	708,830,584	812,965,679	137,754,533	17%

Source: NEF (2018) – calculations of GBP based on STECF (2017). Figures in 2015 constant GBP.

Appendix 3: ALDFG causes and management measures



Source: Macfadyen, Huntington and Cappell (2009).

ALDFG causes a myriad of environmental impacts. These include: continued catching of target and non-target species (including turtles, seabirds and marine mammals), alterations to the benthic environment, navigational hazards, beach debris/litter, introduction of synthetic materials into the marine food web, introduction of alien species transported by ALDFG (Macfadyen, Huntington and Cappell, 2009).