Economic, social and environmental impact assessment of MSP for UK marine-related industries

Alberto Roca, University of York, alberto.rocaflorido@york.ac.uk
Simon Mair, University of York, simon.mair@york.ac.uk

Marine spatial planning (MSP) is a process of coordinating the use of marine resources in an attempt to achieve economic, social, and environmental objectives. This is an extremely challenging goal, and the benefits of MSPs are contested. In this paper, we develop a marine input-output model for the United Kingdom. We use this model to explore relationships between greenhouse emissions, employment and gross value added in marine-related sectors and other industries. Based on our results, we identify three clusters of marine-related sectors, each characterised by a different relationship between environmental and socio-economic goals. Analysing the clusters could allow marine spatial planners to understand better how their policies will impact communities and the broader environment and prioritise accordingly.

1. Introduction

The marine environment is intrinsically linked to UK society and the broader economy; as such, the impacts of climate change on the marine sector (MS) will have wide-ranging consequences. Recent work identifies climate signals in a number of fishing sites in UK waters and suggests the loss of marine conditions supporting a range of species fished by UK fleets (Queirós et al., 2021). On top of the loss of the intrinsic value of the species (Sandler, 2012), this will impact the people and communities that depend on these species for their livelihoods (Stebbings et al., 2020). But the connection between climate change and marine-related economic activity is not one-way: the UK marine-related industries also contribute to climate change.

Globally, marine-related industries are an important source of carbon emissions. Greer et al. (2019) estimate that burning fuel in the industrial fishing sector emitted~159 million tonnes of CO2 in 2016, a figure 4 times greater than in 1950. The international shipping industry consumes around 289 million metric tons of fuel annually (Corbett and Koehler, 2003) and emits 3% of annual global carbon emissions (Bouman et al., 2017). The UK maritime transport sector is considered an important source of total emissions in the EU, being ships responsible for releasing 13.5% of total emissions in the EU transport industry (EMSA and EEA, 2021). Consequently, governments around the world have committed to protecting the marine environment. For example, a global commitment establishes 2030 as a deadline to protect 30% of water areas worldwide (IUCN, 2016). Similarly, at the national level, the UK government has set out a Clean Maritime Plan to cut carbon emissions and other pollutants from the sector (Department for Transport, 2019).

Interactions between economic activities and the environment require properly designed marine plans to manage them, as links between the environment and economic activities are often characterised by conflict (Martinez-Alier et al., 2016). Minimising conflict may facilitate the long-term sustainability of marine activities that support livelihoods (Department for Environment, Food and Rural Affairs, 2009). In the Marine environment, Marine Spatial Plans (MSPs) are a prominent tool that aims to minimise these conflicts (Queirós et al., 2021). However, research on MSPs has tended to be conceptual rather than empirical.

This study contributes to filling the empirical gap in the literature by developing a new marine-focussed input-output table for the UK and presenting a framework that can be used to rapidly assess possible economic, environmental and social impacts related to MSP implementation in the UK. Section 2 reviews the Marine Spatial Plan literature, noting that much work in this space is conceptual. Section 3 outlines the development of a UK input-output table with 20 marine-specific sectors. Using this table, in Section 4, we present an empirical analysis of the tensions between an environmental indicator (greenhouse gas emissions), an economic indicator (gross value added) and a livelihoods indicator (employment). Next, in section 5, we identify MS that may be suitable to address MSPs in which policymakers prioritise environmental objectives. Finally, section 6 concludes.

2. Marine Spatial Planning

Marine spatial planning is an evaluation process used by national authorities to spatially and temporally coordinate human activities within marine areas There are around 140 MSPs designed and ready to put into action in over 70 countries worldwide, though only a small number have been fully implemented (Calado et al., 2010; Pinarbaçi et al., 2017; Ansong et al., 2019).

2.1 Can MSPs overcome environment-economy tensions?

Much of the controversy around MSPs comes from their attempts to accomplish economic and environmental targets simultaneously. In theory, Marine spatial plans should consider environmental, social and economic political targets (Ehler and Douvere, 2009). But a frequent critique of MSPs has been that economic objectives are prioritised over environmental ones (Jones et al., 2016; Trouillet, 2020). Gilbert et al. (2015) argue that the prioritisation of the economy over the marine environment in MSPs has been seen after economic downturns when countries have placed financial recovery before environmental well-being. More recently, studies have argued that MSPs are driven by a 'blue-growth' worldview, which allows environmentally harmful activities such as seabed mining and industrial fishing to present themselves as sustainable without enacting meaningful changes (Schutter et al., 2021). Here we see a contradiction between what MSPs should be in theory (plans that balance environmental, economic and social concerns) and what they are in reality (plans that often prioritise the economy) (Jones et al., 2016).

Nonetheless, it has been argued that if MSPs are correctly implemented, they can overcome tensions between the environment and the economy, increasing the gross value added and output of industrial sectors, reducing costs and protecting the marine environment (EC, 2011a; Queirós et al., 2021). For instance, Hammar et al. (2020) use a Cumulative Impact Assessment approach to argue that MSPs could reduce environmental impacts in the Swedish case. Although work in this area is growing, the relationships between the environment and the economy in MSPs remain relatively understudied.

2.2 The Empirical Gaps in the Marine Spatial Planning Literature

Research into the environmental and economic impacts of MSP' has been limited due to long-running uncertainties around marine plans and a need for more data on the marine economy (EC, 2020). There is a need for more reliable economic data to forecast changes that MSPs may experience due to revisions or amendments during their long (in some cases, 20 years) lifespan (Marine Management Organization-MMO, 2014). Another difficulty is isolating the MSPs' impacts from those that would have occurred in the counterfactual case without the marine plan (EC 2020). Ideally, this would need an ex-post analysis, but as MSPs are either being developed or are in their early iterations, it is impossible to compare current MSPs' outcomes with previous ones (MMO, 2014). In response, most academic research on MSPs has focused on the conceptual side.

Extensive literature focuses on defining and detailing principal concepts that marine spatial planning should accomplish for successful implementation (Gilliland and Laffoley, 2008; Breen et al., 2010; Stelzenmuller et al., 2013; Ehler, 2014). For example, Ehler and Douvere's (2009) work set out a step-by-step process that MSPs should follow.

Quantitative investigations into MSPs implementation and economic development are still rare in the academic literature (EC, 2020). An EC (2020) report reviewing several MSPs concluded that they have generally had favourable economic impacts in Belgium and Germany. Regarding Scotland and the Island of Rhodes, the EC (2020) argue that MSPs contribute significantly to the blue economy. In contrast, in the Norwegian case, MSPs' are highlighted as having adverse economic results because of the oil and gas sector downturn. In a rare academic example, Coccoli et al. (2018) used a spatially explicit Bayesian belief network (BBN) to analyse conflicts arising from the reallocation of fishing opportunities from fishermen to settle an aquaculture site in the Basque country offshore. Their results revealed that the reserve of area displaced the net and longline sectors' effort by 10% and 7%, respectively, while 50% of the effort by traps was found in the marine reserve area.

There is relatively little research to estimate UK marine-related sectors' economic contributions. This is partly due to a lack of data availability on the Marine economy. ABPmer's (2019) report gets around this by utilising a different methodology for each sector according to the data availability. It assesses the economic influence of the maritime industry on the UK, measuring its endowment in terms of social and economic impacts. Several researchers use input-output analysis as a framework for integrating varying data sources to study the UK Marine Economy. Cerb (2017) assesses the economic contribution of the marine leisure sectors within the UK using an I-O model. Their findings are that the Uk marine leisure industry directly generates approximately £3.4 billion in turnover, £1.2 billion in GVA and around 33,000 positions. Likewise, Pug (2008) uses an IO model to break the marine industry into 18 sectors, concluding that MS involve 4.2% of the total gross domestic product of the UK, accounting for £46 billion value, and employing 890,000 workers, between 2005-2006. More recently, Stebbings et al. (2020), through an IO analysis using data from 2014, estimated that UK marine-related sectors contribute 8.1% to the total national GVA and 6.1% to output. These studies add valuable data and context to the economic aspects of the marine environment. However, they do not consider the environmental impacts of the marine economy.

Outside of marine economy studies, input-output models have been widely used to explore the environmental impacts of economic activities (e.g. Albino et al., 2002; Minx et al., 2009). As China is a major global producer and a large emitter of carbon, many studies explore the Chinese supply chain implications for the environment (Liu et al., 2017; Xu et al., 2017). Other studies have focussed on sector-level environmental impacts. Acquaye and Duffy (2010) estimated the direct GHG for the Irish construction sector and its indirect environmental consequences on their national and foreign downstream suppliers. Bagoulla and Guillotreau (2020) are a rare example of using input-output models to analyse the environmental impacts of the marine economy. They identify that the freight and passenger marine transport sectors release the highest NOx and SO2 emissions among all French industries.

There are two advantages of input-output analysis for exploring the impacts of MSPs. Firstly they provide a framework for compiling and synthesising economic data on the marine economy (e.g. Stebbings et al., 2020). Secondly, they allow economic and environmental analyses to be brought together. For instance, Mair et al. (2016) examine the distribution of carbon emissions, employment, income and GVA through Western European Clothing supply chains. Likewise, Jackson (2017, p.220) uses an input-output model to analyse the 'sweet spot of good work'. Here he plots hours of work against greenhouse gas emissions, arguing that policy should aim to support those sectors that have low emissions and high employment. Finally, input-output models can provide relatively rapid estimates of impacts based on clear and relatively simple mathematical assumptions (Miller and Blair, 2009). This is important because the ability of empirical assessments to guide the implementation of MSPs is of particular concern (EC, 2020; Blau and Green, 2015).

In this vein, applying methods to estimate impacts before the MSP implementation (ex-ante methods) are desirable for maximising potential benefits and reducing unnecessary costs (OECD, 2017).

Therefore this study, we develop the most up to date marine focussed input-output table for the UK date. We maximise the benefits of the input-output framework by empirically analysing the relationships between environmental and economic impacts in marine sectors. To do this, we plot measures of economic benefit (employment per unit of output and gross value added) against an indicator of environmental impact (greenhouse gas emissions).

3. Methodology: A Marine-Specific UK Input-Output Model

Since it was created by Leontief (1936), input-output models have been widely applied in social, environmental and economic impact assessment (for example, Mair et al., 2016; Wang et al., 2020), being developed for other research purposes (Ghosh, 1958; Miyazawa, 1966, 1971; Sonis et al., 1997; Sonis and Hewings, 1999). In this section, we outline the core elements of the IO Model, multipliers (a key analytic statistic derived from the model) and our addition of information to develop a marine-specific IO table for the UK.

3.1 An introduction to Input-Output Models

An IO model is a linear representation of all intersectoral flows given in an economy, usually within a temporal frame of 1 year. The information is recorded in squared matrix-form (IO) tables which capture, by columns, intermediate and primary inputs demanded by sectors to produce their output. Likewise, rows depict the supply of each sector's production to other industries and on final demand.

The following expression depicts all transactions between industries:

$$x = y + Ax \qquad (1)$$

Where x is a vector that represents all industry outputs in the economy, y is the final demand vector, A matrix embeds inputs coefficients that are represented by a_{ij}. These coefficients are estimated by dividing each element of A, represented z, by the total output x. They represent how much input the industry needs from other supplier industries to produce one output unit.

Rearranging (1), we obtain total industry output in terms of the final demand, such as;

$$x = (I - A)^{-1}y \qquad (2)$$

Form the above expression (2), the new elements as I is the identity matrix and $(I - A)^{-1}$ is the Leontief Inverse Matrix. This matrix allows analysts to assess all direct and indirect economic impacts due to an exogenous demand shock through multipliers estimation.

3.2 Multipliers

This study aims to present input-output multipliers that can give insight into potential consequences in the UK economy given a policy implementation. This information is valuable for policymakers to simulate their policies and advance likely outcomes. Following Miller and Blair (2009), we can describe input-output multipliers as;

$$m(\mathcal{Z}) = z'_c \, \mathrm{L} \tag{3}$$

Expression (3) is a general formula for the multipliers algebra representation, which z'_c stands for the vector of coefficient as a result of combining data between industries' flows (z) and total industries' output (x) when z is interchanged by v' or value added or employment multipliers are estimated. Likewise, when the carbon emission vector satellite is divided by x, we obtain the factor intensity e that depicts the amount (i.e. in tonnes) of emissions by a unit of industry output called the environmental multiplier.

For the purpose of this study and to facilitate the reader in the interpretation of results, we briefly define the concept and measure units behind each multiplier. The greenhouse emission (GHG) multipliers are estimated using data provided by the Office for National Statistics (ONS, 2022a), constructed according to the System of Environmental Economic Accounting (SEEA) standards. Results are given in thousand tonnes of carbon dioxide equivalent per year. They include all greenhouse gases under the Kyoto Protocol: carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, perfluorocarbons, nitrogen trifluoride, and sulphur hexafluoride (ONS, 2022a).

Gross value added (GVA) is an economic indicator of a sector's contribution to an economy's gross domestic product (GDP). This metric is calculated as the difference between the market value of an industry's total output and the market value of its intermediate inputs used in the production process (ONS, 2018a). For this study, units are given in £ million.

The employment multiplier is the total number of workers per unit of output. Employment data collected for fishing fleet segments from the Seafish website was provided in full-time employment (FTE) equivalent. The FTE is the unit of measurement used, where a person who works full-time counts as one FTE, while part-time workers/students are counted proportionally to the worked hours. However, the employment data collected for fishing fleet segments from the Seafish (2020a) website was provided in FTE, while the data for other sectors, found on the NOMIS (2021) website, was given in the number of workers.

To harmonise both databases, we estimated each fleet segment's share of full-time and part-time employees based on figures in the Seafish (2022) report. Assuming that a full-time employee works

40 hours a week and a part-time employee works 20 hours (Seafish, 2019, P.37), a part-time worker accounts for 0.5 (20 hours) of full-time employment. As a result, the total workers per fleet segment equals the FTE minus the share of part-time workers times 0.5 employment factor.

3.2 Data and sector disaggregation

The standard UK IO table (ONS, 2022) only contains high-level information on Marine sectors. For instance, Fishing and Aquaculture appear as one sector. Consequently, we collect data from several sources to disaggregate these high-level sectors (SIC code). Table 1 summarises marine-related sectors in the original table, our disaggregation, and the data sources used.

Original Sector	Marine Specific Sectors After Disaggregation	Data sources used
Fishing and aquaculture (3.1 and 3.2)	*Demersal trawlers and seiners (3.1.1); Nephrons(3.1.2); Beam trawlers (3.1.3); Scallop dredges (3.1.4); Passive gears (3.1.5); Boats under 10 m (3.1.6); Low activity (3.1.7); Pelagic Trawlers (3.1.8); Aquaculture (3.2)	Seafish (2019) STECF (2019) Seafish (2020a) Seafish (2022) Turrell (2020)
The processing and preserving of fish, crustaceans, and molluscs (10.2) and fruit and vegetables (10.3)	The processing and preserving of fish, crustaceans, and molluscs (10.2)	ONS (2016, 2018b; 2022a) NOMIS (2022)
The building of ships and boats (30.1)	The building of ships and floating structures (30.11)	ONS (2016, 2018b; 2022a) NOMIS (2022)

	The building of pleasure and sporting boats (30.12)	
Repair of fabricated metal products, machinery and equipment (33.1)	Repair and maintenance of ships and boats (33.15)**	ONS (2016, 2018b; 2022a) NOMIS (2022)
Construction industries (41 to 43)	Construction of water projects (42.91)	ONS (2016, 2018b; 2022a) NOMIS (2022)
Wholesale trade, except motor vehicles and motorcycles (46)	Wholesale of other food, including fish, crustaceans and molluscs sector (46.38)	ONS (2016, 2018b; 2022a) NOMIS (2022)
Retail trade, except for motor vehicles and motorcycles (47)	Retail sale of fish crustaceans and molluscs in specialised stores (47.23)	ONS (2016, 2018b; 2022a) NOMIS (2022)
Water transport sector (50)	Sea and coastal passenger water transport (50.10) Sea and coastal freight water transport (50.20)	ONS (2016, 2018b; 2022a) NOMIS (2022)
Warehousing and support activities for transportation (52)	Service activities incidental to water transportation (52.22)	ONS (2016, 2018b; 2022a) NOMIS (2022)
Rental and leasing activities sector (77)	Renting and leasing of water transport equipment (77.34)	ONS (2016, 2018b; 2022a) NOMIS (2022)

Table 1. Marine-related sectors before and after disaggregation.

[1] Disaggregation of these factors results in both marine-related and non-marine sectors. For simplicity, only the marine-related sector is included in this table. But the full model includes both marine-related and non-marine sectors.

*SIC codes assigned to fishing disaggregated fleets are used merely as a reference for this research.

** This sector is included as a relevant marine-related sector but was not disaggregated as it was already disaggregated in the original UK IOT.

To disaggregate the fishing (3.1) and aquaculture (3.2) sectors (both are presented as a single sector in the original IOT), we collected information from the not-for-profit organisation Seafish (2022). Seafish provided information on turnover, gross value added (GVA), and employment for fishing

(3.1) and aquaculture (3.2) separately. We use this information to estimate the share of each sub-sector in the output of the original sector as follows:

$$w_{ij} = \frac{x_i}{x_i + x_j} \tag{4}$$

Where x_j is given by:

$$x_j = v_j + z_j \tag{5}$$

and v_j is gross value added at basic prices provide by Seafish (2019) and z_j is total purchases of goods, materials and services.

3.3 Marine sector disaggregation

To create the maritime sectors (Table A.1, Annexe), we based our preselection on the Scottish Marine (Scottish Government, 2022), then narrowed down the sectors based on data availability. The marine gas and oil sector was discarded due to confidential information (ABS, 2018b), and the Miscellaneous fleet segment was ruled out due to difficulty in collecting information (more details, see Seafish, 2020b, p.6). We also had to exclude the marine tourism industry as it was difficult to isolate tourist activities linked to the maritime industry.

In order to perform an accurate analysis of the fishing (3.1) and aquaculture (3.2) sectors, it was necessary to differentiate between the two distinct industries from the initial UK IOT (ONS, 2022b). This was accomplished by utilising expression (4) to determine weightings for gross value added, total purchases of goods, materials, and services, and total output data, as sourced from the ABS in 2018 (ONS, 2018b). The fishing sector was then further subdivided into eight segments based on the fleet types (Table 1), using the same expression (4) and various sources of information for detailed data (Seafish, 2019; STECF, 2019; Turrell, 2020; Seafish, 2020a; Seafish 2022). However, the Pelagic Trawler sector presented a unique challenge due to the information required.

Total intermediate consumption can be estimated as the difference between total turnover and GVA (ONS, 2012; Central Statistics Office, 2022). We followed this approach to calculate this economic indicator for almost all fleet segments (Table A.1, Annexe). However, for the Pelagic Trawler sector, we had to rely on the GVA information reported by the STECF (2019) as a reference. They point out that the total GVA for the UK Pelagic Trawler was €111 million in 2017. First, we converted it to British Pounds, and we deflected it to 2018 by applying the UK Consumer Price Index (CPI) 2005 index (ONS, 2018c)

GHG emission data for the fishing subsectors was obtained from the Marine Scotland database (Turrell, 2020), assuming that fuel consumption and engine efficiency remained consistent between 2017 and 2018. GHG data for the non-marine sectors was collected from ONS (2022a).

To break down the marine sectors, we use the weight-estimation approach outlined in expression (4). We applied this approach using data from the 2014 ABS (ONS, 2016) until the 4-digit SIC level. Using this approach, we could estimate the weights on output, GVA, and intermediate consumption and then apply them to the 2018 ABS (ONS, 2018b) data (Table 1). We gathered employment estimates from a detailed database of the Business Register and Employment Survey (BRES) available on the Nomis website (NOMIS, 2021). We also used this employment data for non-marine sectors.

3.3 Marine sector estimations

Our research findings reveal that the marine-related sectors in the United Kingdom generate a combined output of approximately £32.6 billion, as depicted in Table 3. It is noteworthy that this figure may differ significantly from the £192 billion estimated by Sterbbing et al. (2020) in their recent and extensive IO analysis of UK marine industries. However, upon closer examination, we found that Sterbbing's approach yields a total output value of £37.8 billion when comparing only the "common sectors." Notably, among the sectors we analysed, the sea transport-related industries and the Building of ships and floating structures sector have the highest GVA, contributing to 51.7% of the total MS GVA.

Our study also indicates that MS produces 15,721 tonnes of greenhouse gas (GHG) emissions, representing 2.8% of the UK's total GHG emissions of over 560,295.10. It is worth noting that the two marine transport sectors are responsible for 89.1% of the emissions, with passenger transport accounting for 49.9% of the total. Furthermore, our research reveals that marine-related industries employed 126,570 individuals in 2018, representing 0.83% of the total employment in the UK (15,274,500). Interestingly, the top three MSs with higher employment share are Service activities incidental to water transportation (20.5%), Building of ships and floating structures (17%), and Wholesale of other food, including fish, crustaceans, and molluscs (15.4%).

3.4 Study limitations

It should be noted that the IO model presents certain technical limitations that need to be mentioned. One such limitation is that the production process exhibits linear proportionality to the input level employed, thereby giving rise to constant returns of scale. Furthermore, the production process cannot be improved from a technical standpoint, as evidenced by the assumption of no input substitution. Lastly, the inputs required for the production process are always fully available, without any restrictions, and can be furnished to fulfil production requisites. Despite these limitations, we have ascertained that IO models are an exceptional analytical tool for conducting MSP impact analysis.

4. Results

4.1 Multiplier Results

In this section, we present multipliers for GVA (Figure 1), employment (Figure 2), and GHGs (Figure 3) for our 20 marine-related sectors. Each multiplier represents the additional impact of a £1 million increase in final demand for the respective sector [1].

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[1] Final demand is made up of final consumption expenditure by government, households, and non-profits serving households, gross fixed capital formation, changes in inventories, exports of goods.

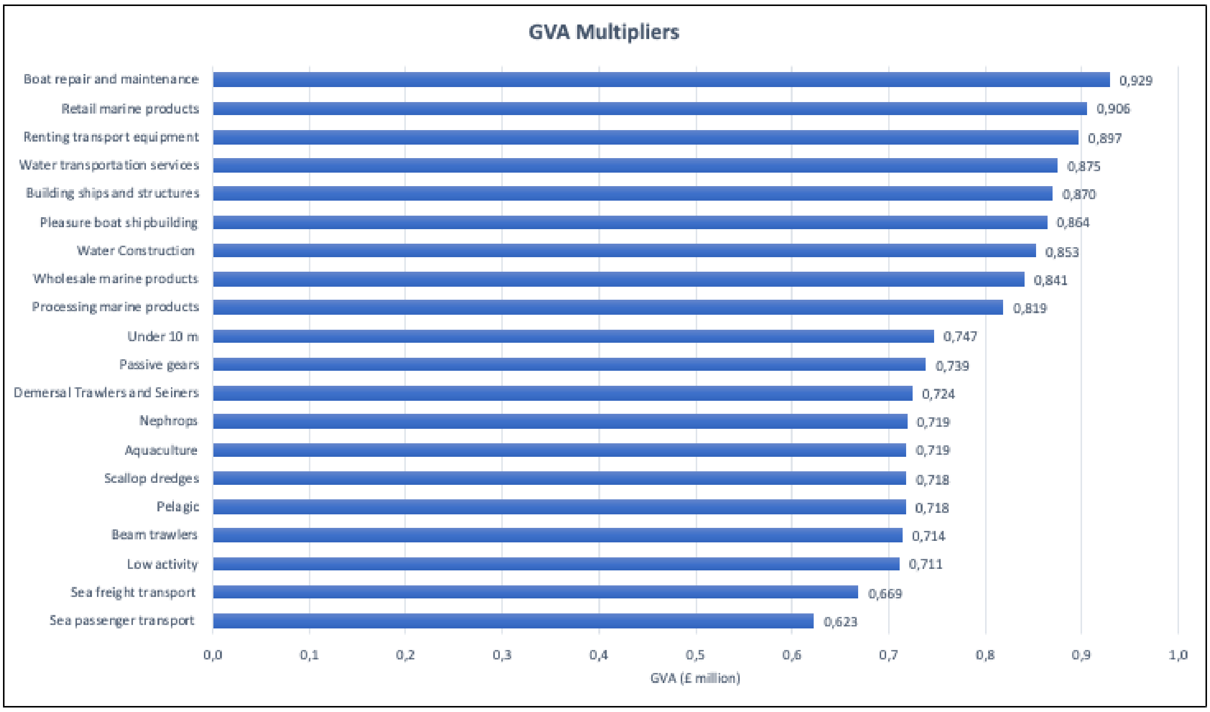

Figure 1: GVA multipliers of marine-related sectors. Each sector's name appears on the y-axis, while GVA multipliers are shown from the lowest to the highest on the x-axis, measured in £ million.

Based on Figure 1, we can see that the range of GVA generated per £1M of additional final demand varies greatly between sectors, with a difference of around three hundred thousand pounds. Boat Repair and Maintenance is the most GVA-intensive sector, producing £0.92 million for every £1 million invested. Following closely is the Processing and Preserving sector, generating £0.81 million for each £1 million invested. The shipping subsector cluster shows over £0.7 million. On the other hand, the transport-related sectors are the least GVA-intensive sectors, with multipliers rounding £0.66 and £0.62 million for the freight and passenger sectors, respectively.

From analysing Figure 2, it is clear that the employment multipliers paint a different picture than the GVA multipliers. One sector that stands out is the Low activity sector, which creates 30.45 workers per £1 million increase in demand. The Neprhop sector follows closely with 27.10

workers, while the Passive gears sector ranks third with 22 workers. In contrast, Sea passenger and freight transport have the lowest multipliers, generating less than four workers per £1 million of investment, with both sectors creating only four employees.

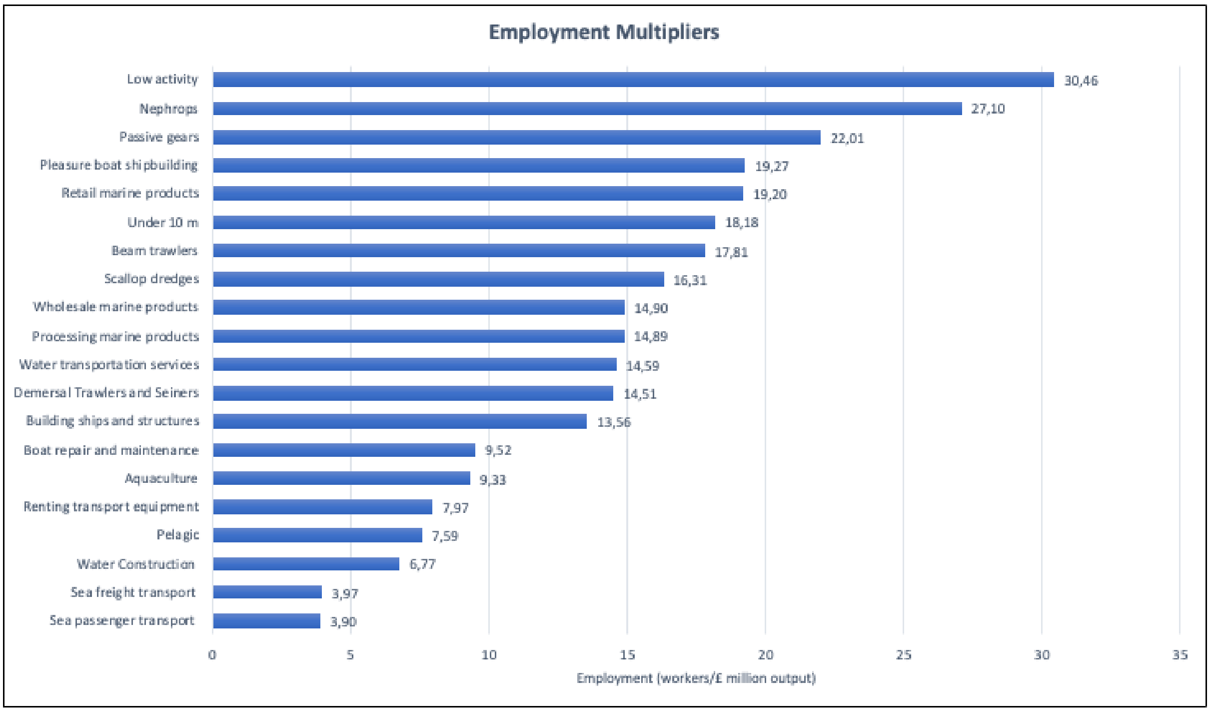

Figure 2: employment multipliers of marine-related sectors. Each sector's name appears on the y-axis, while employment multipliers are shown from the lowest to the highest on the x-axis, measured in the number of workers.

Looking at the GHG multipliers in Figure 3, we can identify three differentiated groups according to the carbon emission intensities (CO2 tonne released by £ million increase in final sector demand). The highest multipliers are found in the fishing fleet sectors, with the Beam trawlers sector having the highest multiplier of 1.45 tonnes, followed closely by Nephrops at 1.38 tonnes. Transport-sea-related sectors have multipliers of 1.16 and 1.15 tonne per £1 million output increased. The second group includes the demersal trawlers and seiners sector (0.64 tonnes) and aquaculture (0.34 tonnes). The third group consists of sectors with multipliers under 1.2, with the service of accidental assistance to water transportation having a multiplier of 0.157 tonnes and the renting and leasing of water transportation equipment ranking last with 0.07 tonnes.

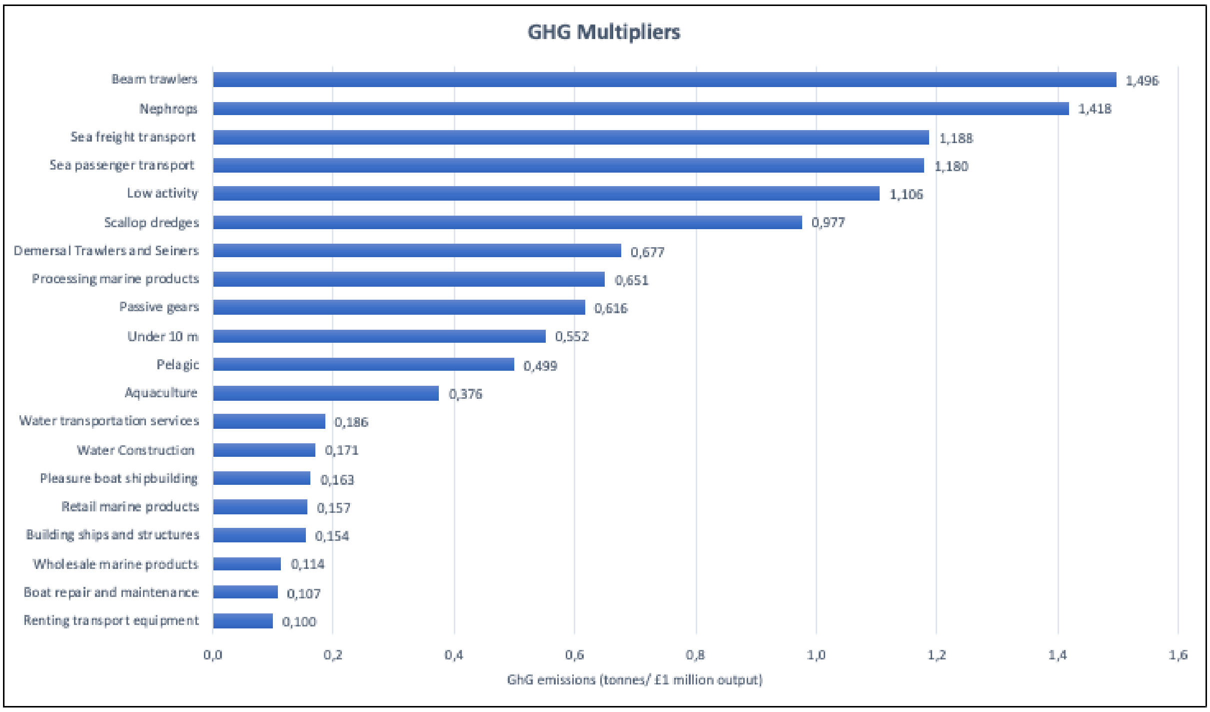

Figure 3: GHG multipliers of marine-related sectors. Each sector's name appears on the y-axis, while GHG multipliers are shown from the lowest to the highest on the x-axis, measured in tons.

4.2 Managing Tensions: is there a Sweet Spot in Marine-Related Sectors?

To better understand the conflict sources between the sector’s interest and political and environmental objectives, we plot multipliers on GHG emissions and other economic indicators of interest in several graphs.

Based on the information presented in Figure 4, we can observe that there are three distinct categories of industries depending on their GHG and GVA intensities. The first group has high GHG intensities but low GVA intensities and is located in the top left of the chart. The second group, located in the middle, has low GHG and GVA intensities. Finally, the third group, located in the bottom right, has low GHG intensities but high GVA intensities. When considering these sectors, it's worth noting that the Beam Trawlers and Nephrops industries have the potential to significantly decrease GHG emissions, reducing over 1.4 tonnes per approximately £0.7 million GVA for each declined £million in their final demand. On the other hand, freight and passenger sea transport industries offer lower GHG reduction, under 1.2 tonnes. Still, they have less impact on their GVA for each £million increase in their final production, ranging between £0.66 million and £0.62 million.

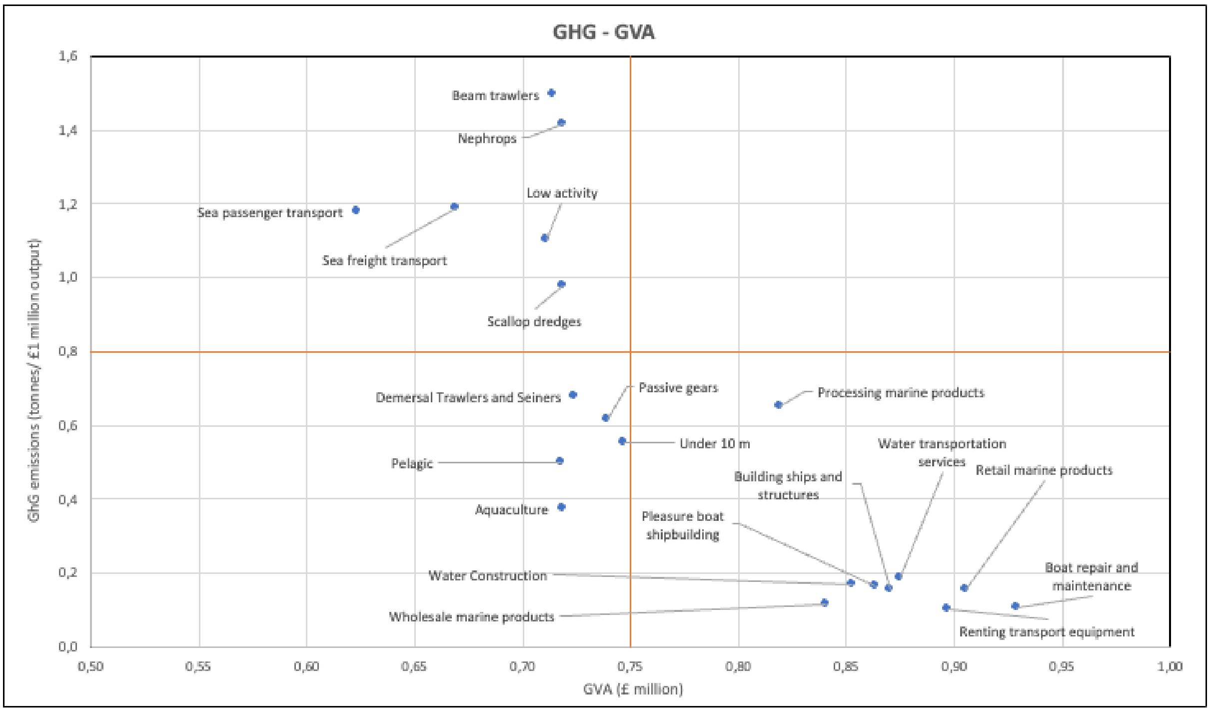

Figure 4: deploys GVA and GHG multipliers of marine-related sectors. GVA multipliers are represented by values on the x-axis and are given in £ million. GHG multipliers are shown on the y-axis and are measured in tones.

It is worth noting that the fish processing and preserving industry has the potential to significantly reduce greenhouse gas emissions, with a comparable impact of 0.65 tonnes, when compared to a cluster of fishing-related sectors located in the lower left quadrant with GHG impacts ranging between 0.46 and 0.64 tonnes. However, the processing sector appears to be of higher significance in generating gross value added (GVA), with over £0.8 million for each £million of the final output.

Lastly, the lower group demonstrates the least GHG intensities, below 0.2 tonnes, yet they have a significant impact on GVA, affecting over £0.84 million.

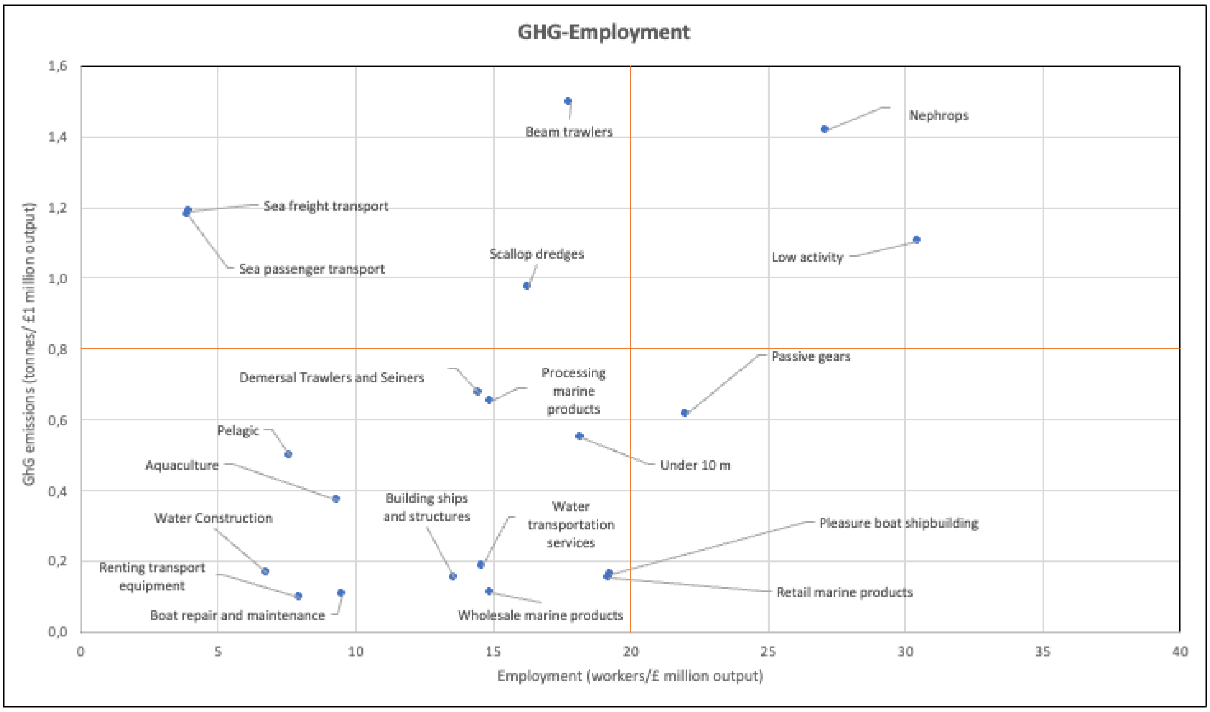

Figure 5: deploys employment and GHG multipliers of marine-related sectors. Employment multipliers are represented by values on the x-axis and are given in number of workers. GHG multipliers are shown on the y-axis and are measured in tones.

Figure 5 shows that there are three clusters based on the intensities of GHG and employment across different sectors. The top left quadrant indicates sectors with high GHG intensity and low employment intensity. The top right quadrant represents sectors with high employment intensity and high GHG intensity, while the bottom left quadrant includes sectors with low GHG intensity and low employment intensity. In the upper-left quadrant, sea transport-related sectors have a high potential impact on GHG, with almost 1.2 tonnes, but employ relatively few people, under 4, for each £million in its final demand. The Low activity sector has a slightly lower impact on GHG, around 1 tonne, but a significant impact on employment, with nearly 31 workers. The Beam trawlers and Nephrop sectors, although having more significant impacts on GHG, around 1.5 and

1.4 tonnes, respectively, they impact employment differently, with close to 18 and 28 workers, respectively.

5. Discussion and policy recommendations

This analysis does not fully cover all marine sectors in the UK but includes 20 marine-related sectors and eight fleet segments of the fishing industry. Despite this, these sectors have a significant impact on the UK's economy, contributing £13,945.36 million and providing employment for 126,570 workers. It is worth noting that these sectors also have notable environmental implications, with GHG emissions totalling 15,721.85 tonnes. While the marine sectors are essential for the country's economic development and livelihoods, it is crucial to reduce their carbon emissions, which currently account for 2.8% of the UK's total carbon emissions. Achieving sustainable development in marine areas requires finding ways to reduce these emissions to zero by 2050, according to the Department for Transport (2019).

It is of utmost importance to recognise that each marine sector in the UK holds a unique impact on both the economy and the environment. As a result, their attitudes towards environmental objectives and conflict resolution can markedly vary, thereby leading to potential trade-offs between economic growth and environmental sustainability (Castro and Nielsen, 2003; Redpath et al., 2013). As such, it is crucial to possess a comprehensive understanding of the larger implications of any policy reform aimed at addressing environmental concerns. This understanding must be an integral component of the marine planning process in order to ensure the appropriate balance between economic development and environmental sustainability.

To effectively tackle environmental concerns, it is crucial to carefully consider how different sectors impact both the economy and the environment. Balancing economic growth and reducing carbon emissions can be challenging, as the two are positively correlated (Du et al., 2019). However, sustainable degrowth has been proposed as a potential solution by several authors (Martínez-Alier et al., 2010; Schneider et al., 2010; D'Alisa et al., 2015). Certain sectors, such as Beam Trawlers, Scallop Dredges, and transportation, have high greenhouse gas intensities and low gross value added and employment intensities, making them good candidates for demand-side policies that reduce emissions without negatively impacting the economy and employment. Proposals such as altering consumer behaviour (Xue, 2014) or levying taxes on customers (Kallis and March, 2014) may indirectly contribute to reducing environmental impact, while measures like capping GHG emissions (Kallis and MartÌnez-Alier, 2010) or taxing environmental externalities (Van Griethuysen, 2012) may also prove to be viable recommendations. Ultimately, it is crucial to fully understand the spillover effects of any policy reform aimed at addressing environmental issues in order to foster economic growth while simultaneously reducing carbon emissions.

The transition to a net zero industry is expected to have a significant impact on various sectors, including employment (Broome et al., 2022). Sectors with high greenhouse gas emissions and employment rates but low gross value added - such as Nephrops and low-activity industries - are particularly susceptible to these effects. However, these sectors can be transformed to positively impact the economy by implementing policies that support job creation and wealth generation for workers. Encouraging workers to transition between related sectors can be an effective strategy, allowing them to reuse their skills and knowledge (Neffke and Henning, 2013). Such policies can be especially effective in regions where related sectors exist (Eriksson et al., 2016). Additionally, these sectors can reduce their carbon footprint through technological advancements, such as adopting low-carbon fuels and less carbon-intensive technologies (The Secretary of State for Business, Energy & Industrial Strategy, 2021). It is essential to consider the spillover effects of these policy reforms to promote economic growth while simultaneously addressing environmental concerns.

This comprehensive report provides an in-depth examination of the possible conflicts that may arise when balancing environmental and economic objectives in the UK's national marine spatial planning. The investigation offers a thorough overview of the potential tensions that must be considered when developing regional marine plans. It is important to note that marine areas with high activity levels may require a specific space allocation to meet their particular needs. The South East MSP document (Department for Environment, Food and Rural Affairs, 2018, p.4) provides an excellent example of this phenomenon. By conducting simulations of various scenarios, it is possible to assess the impact of reducing greenhouse gas emissions on employment and gross value added in the region. Evaluating a range of scenarios would be highly informative to assess the effects of GHG reduction on employment and GVA in this regional context.

6. Conclusions

The article explores the importance of MSPs in resolving conflicts arising from marine activities that share marine areas. MSPs aim to promote economic and social development while caring for the environment. However, there may be conflicts when the economic and environmental targets of MSPs conflict, with economic priorities taking precedence over environmental protection (Jones et al., 2016; Trouillet, 2020).

This article delves into the potential impact of prioritising carbon emission mitigation targets on marine-related sectors in the UK and their socioeconomic implications. The study utilised an Input-Output model to analyse 20 marine sectors, including eight fleet segments in the fishing industry. The results underscored the significant socioeconomic and environmental implications of marine sectors on the UK economy. Policymakers must consider each sector's unique characteristics when creating Marine Spatial Plans (MSPs) to address GHG emissions.

It is noteworthy that some sectors offer the potential to reduce GHG emissions while also generating employment opportunities. This may help policymakers reconcile conflicting interests and align marine plans with the UK's objective of achieving zero emissions by 2050 (Department for Transport, 2019). However, the transition towards decarbonisation will inevitably result in job displacement, particularly in sectors with high pollution levels or those that require skilled workers in low-carbon technologies. As such, policymakers must consider the impact of decarbonisation policies on workers as they implement these measures.

Certain sectors may not provide similar opportunities for expansion without causing significant environmental harm or providing minimal economic benefits in terms of employment or Gross Value Added (GVA). In such cases, demand-side policies or taxes linked to production or emissions may be viable alternatives to reduce GHG emissions. The results of this study can also serve as a benchmark to evaluate how specific sectors adapt to MSPs within a regional context.t.

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APPENDIX

Table A.1: Fleet segment data

Groups Defined	Fleet segment	Vessels	Average fishing income (£M)	Turnover proxy (nvss * income) (£M)	Turnover %	Turnover % (No Miscellaneous sector)*	GVA total (£M)	Intermediate consumption (Turnover-GVA) (£M)	Employment **
Area VIIA demersal trawl	Demersal Trawlers and seiners	10	328	3.28	0.34%	0.35%	1.81	1.47	29.7
Area VIIA nephrops over 250kW	Nephrops	31	268	8.308	0.85%	0.89%	5.09	3.218	224.3
Area VIIA nephrops under 250kW	Nephrops	33	173	5.709	0.58%	0.61%	3.54	2.169	186.04
Area VIIBCDEFGHK 24-40m	Demersal Trawlers and seiners	13	1523	19.799	2.03%	2.13%	5.96	13.839	176.36
Area VIIBCDEFGHK trawlers 10-24m	Demersal Trawlers and seiners	58	194	11.252	1.15%	1.21%	6.47	4.782	183.53
Gill netters	Passive gears	26	527	13.702	1.40%	1.47%	6.56	7.142	219.53
Longliners	Passive gears	30	472	14.16	1.45%	1.52%	6.11	8.05	198.46

Low activity over 10m	Low activity	42	5	0.21	0.02%	0.02%	-0.07	0.28	11.96
Low activity under 10m	Low activity	1552	3	4.656	0.48%	0.50%	1.93	2.726	127.8
North Sea beam trawl over 300kW	Beam trawlers	7	1660	11.62	1.19%	1.25%	2.21	9.41	173.92
North Sea beam trawl under 300kW	Beam trawlers	21	105	2.205	0.23%	0.24%	0.68	1.525	39.04
North Sea nephrops over 300kW	Nephrops	42	610	25.62	2.62%	2.75%	6.98	18.64	327.85
North Sea nephrops under 300kW	Nephrops	62	180	11.16	1.14%	1.20%	4.41	6.75	167.53
NSWOS demersal over 24m	Demersal Trawlers and seiners	44	2187	96.228	9.85%	10.34%	44.93	51.298	527.8
NSWOS demersal pair trawl seine	Demersal Trawlers and seiners	25	1913	47.825	4.89%	5.14%	22.13	25.695	279.76
NSWOS demersal seiners	Demersal Trawlers and seiners	15	1395	20.925	2.14%	2.25%	12.99	7.935	113.04
NSWOS demersal under 24m over 300kW	Demersal Trawlers and seiners	45	1038	46.71	4.78%	5.02%	21.27	25.44	476.83
NSWOS demersal under 24m under 300kW	Demersal Trawlers and seiners	19	311	5.909	0.60%	0.64%	2.47	3.439	62.18
Pots and traps 10-12m	Passive gears	184	158	29.072	2.97%	3.12%	21.66	7.412	423.69
Pots and traps over 12m	Passive gears	98	546	53.508	5.48%	5.75%	33.02	20.488	835.76
South West beamers over 250kW	Beam trawlers	26	943	24.518	2.51%	2.63%	10.15	14.368	152.92
South West beamers under 250kW	Beam trawlers	25	648	16.2	1.66%	1.74%	7.45	8.75	174.04
UK scallop dredge over 15m	Scallop dredges	81	497	40.257	4.12%	4.33%	14.52	25.737	333.37

UK scallop dredge under 15m	Scallop dredges	204	141	28.764	2.94%	3.09%	14.7	14.064	305.5
Under 10m demersal trawl/seine	Under 10 m	153	75	11.475	1.17%	1.23%	6.02	5.455	198.74
Under 10m drift and/or fixed nets	Under 10 m	209	44	9.196	0.94%	0.99%	6.56	2.636	113.99
Under 10m pots and traps	Under 10 m	1113	63	70.119	7.17%	7.54%	53.39	16.729	870.17
Under 10m using hooks	Under 10 m	204	39	7.956	0.81%	0.86%	5.53	2.426	109.06
WOS nephrops over 250kW	Nephrops	30	290	8.7	0.89%	0.93%	3.32	5.38	177.89
WOS nephrops under 250kW	Nephrops	62	173	10.726	1.10%	1.15%	5.22	5.506	285.81
Pelagic over 40m	Pelagic Trawlers	25	10829	270.725	27.70%	29.09%	96.96	173.765	87 ***
Miscellaneous	---	23	2034	46.782	4.79%	---	---	---	---
TOTAL		977	977.28	977.276	100	930.49	433.97	496.524	7706.57

Table A.1. Full description of data collected on the fishing fleet segment in the UK (Seafish, 2022). Due to the lack of output data regarding the Pelagic sector, we estimated its turnover by multiplying the number of vessels times income. Despite having the output information for the rest of the sectors, we applied the same approach to harmonise this indicator. Turnover values in Table 2 are similar to the official output data (Seafish, 2019).

*Turnover share estimated after discarding the miscellaneous sector

**Full-Time Employment (FTE) units

***Pelagic employment is found in the STEFC (2019) report