The UK and Selected Regions Marine Focused Input-Output Tables

Report for the Marine Spatial Planning Addressing Climate Effects Project

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MSPACE
Marine Spatial Planning Addressing Climate Effects

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DESIGN BY LANDS

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1 Introduction

The marine environment is intrinsically linked to UK society and the broader economy; as such, the impacts of climate change on UK marine sectors will have wide-ranging economic consequences. This is acknowledged in the UK government's commitment to quantifying and measuring natural capital (ONS 2024). 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 (Townhill et al., 2023; Queirós et al. 2024). On top of the loss of the intrinsic value of species and habitats (Sandler, 2012), these impacts have the potential to impact the people and communities that depend on them for their livelihoods (Stebbings et al., 2020). But the connection between climate change and marine-related economic activity is not one-way: 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 fossil fuels in the industrial fishing sector emitted~159 million tonnes of CO_2 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 maritime transport sector is considered an important source of total emissions in the EU, ships being 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 making changes to reduce marine industry carbon emissions. For instance, an objective of the International Maritime Organization (IMO) is to reduce the sulphur levels in ship fuel to minimise SO2 emissions, which are considered to be highly damaging health pollutants (Corbett et al., 2007). To meet these challenges governments are taking action to reduce pollutants. For example, the UK government has set out a Clean Maritime Plan that aims to cut carbon emissions and other pollutants from the sector (Department for Transport, 2019), and Emissions Control Areas (UK Gov, 2024) have been established across all UK waters to limit e.g. sulphur dioxide pollution from ships, another climate active gas.

That marine sectors both depend upon the marine environment to provide livelihoods and support local economies and threaten the marine environment by contributing to climate change is typical of environmental management issues. Environmental issues are commonly characterised in terms of multiple objectives and interests cutting across economic, social and environmental domains (Clift et al., 2022). The relationships between these domains are often characterised by conflict (Martinez-Alier et al., 2016). Minimising conflict between different interests may facilitate the long-term sustainability of marine activities that support livelihoods (Department for Environment, Food and Rural Affairs, 2009). This perspective has led to the development of several policy tools to try to minimise conflicts between the marine-environment and the marine economy, notably Marine Spatial Planning (Ehler and Douvere 2009). However, research on such policy tools has tended to be conceptual rather than empirical.

This report describes our efforts to fill the empirical gap in the scientific literature and facilitate economic impact assessment in support of climate-smart Marine Planning, that is, marine planning that addresses the sources and impact of climate change, through climate change mitigation and adaptation actions (Frazão-Santos et al. 2020, Queirós et al. 2021). This report is part of the Marine Spatial Planning Addressing Climate Effects (MSPACE) Project[1], funded through the Sustainable Management of UK Marine Resources (SMMR) programme.[2]

1 https://www.smmr.org.uk/funded-projects/marine-spatial-planning-addressing-climate-effects/

2 https://www.smmr.org.uk/

The main objective of MSPACE is to enhance the capability of UK nations in developing and implementing marine plans that are both climate-smart and economically and socially acceptable. As part of this effort, we aimed to translate the spatial interventions recommended by marine resource modelling in the project to help improve climate change adaptation potential of marine nature and activity sectors (based on Queirós et al. 2024) into economic indicators for the adjacent economies that may be more tangible to stakeholders (employment, labour compensation, gross value added, carbon emissions). These indicators are intended to support consultations that form part of the development and review of four case-study marine plans explored in the MSPACE. The four case-study areas explored in MSPACE are the Welsh Marine Plan, the Marine Plan for Northern Ireland, the Orkney Islands Marine Plan (Scotland), and the East Marine Plan (England). Our framework for this is input-output modelling. This report describes the construction of input-output tables and a framework that will be combined with a set of scenarios of possible changes in marine plan areas. The scenarios will be co-developed with the project's case-study specific stakeholder groups, including key planning team members and industry representatives (Reinhardt et al., 2023a; 2023b; 2023c; 2024). The scenarios will capture both changes driven by climate change (Queirós et al. 2024) and spatial management policies, including changes to the limits and distribution of conservation areas in each planning area and the promotion of sustainable use of climate change refuges climate-resilient sites (Queirós et al. 2024).

This report focuses on the construction of the UK and Selected Regions Marine Focused Input-Output Tables (UK+SRMFIOT v.1), the first stage of the input-output modelling carried out for MSPACE. Specifically, the UK+SRMFIOT v.1 consists of 6 novel marine focused input-output tables:

1. **UK marine focused input output table. 122 sectors, of which 20 marine focused sectors.**
2. **Northern Ireland marine focused input output table. 77 sectors, of which 15 marine focused sectors.**
3. **Scotland marine focused input output table. 108 sectors, of which 12 marine focused sectors.**
4. **East of England marine focused input output table. 120 sectors, of which 19 marine focused sectors.**
5. **Orkney marine focused input output table. 65 sectors, of which 8 marine focused sectors.**
6. **Wales marine focused input output table. 80 sectors, of which 17 marine focused sectors.**

Tables 1-5 are made freely available for non-commercial use at the University of York repository: ***https://doi.org/10.15124/a76f2b2c-3dd6-435c-abae-a82b5413cafa***. Table 6, the Wales marine focused input output table is based on the proprietary table prepared by the Welsh Economy Research Unit at Cardiff University (Jones, 2022). This table cannot be shared without prior permission at this time.

The rest of this report is structured as follows. Section 2 reviews the literature on economic impacts of marine planning; section 3 outlines the potential contributions of Input-Output Analysis. Section 4 then provides a detailed description of the construction of marine-focused Input-Output Tables for the whole of the United Kingdom and for selected nations and regions within this. By developing these new marine-focused input-output tables for different regions in the UK, we present multiplier analysis as a framework that can be used to rapidly assess possible economic, environmental and social impacts related to marine economy development in the UK (section 5). This has been developed in more detail using the UK table in Roca Florido and Mair (In Press).

2 Economic Assessment of Marine Spatial Plans

Marine Spatial Planning (MSP) is the public process of analysing, recording and allocating marine space uses to achieve ecological, economic and social objectives overarched by political processes, and has emerged as a key tool to deliver Ecosystem-Based Management (Eheler and Douvere 2009). Around 140 MSPs have been designed in over 70 countries worldwide, though only a small number have been through the complete MSP cycle (Calado et al., 2010; Pinarbaçi et al., 2017; Ansong et al., 2019, UNESCO-IOC/European Commission 2021).

2.1 Can MSPs overcome environment-economy tensions?

Much of the controversy around MSPs derives from an inherent aim to simultaneously accomplish economic, social and environmental targets. In theory, marine spatial plans should consider environmental, social *and* economic targets (Ehler and Douvere, 2009). But in practice, MSPs have often been found to prioritise economic objectives over environmental and social ones (Jones et al., 2016; Trouillet, 2020). For instance, 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 for environmentally harmful activities such as seabed mining and industrial fishing to present themselves as sustainable without enacting meaningful change (Schutter et al., 2021). Hadjimichael (2018) proposes 'blue degrowth' as an alternative approach.

Nonetheless, it has been argued that if MSPs are correctly implemented, they can overcome conflict 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. The concept of Sustainable Ocean Planning has therefore emerged more recently as a competing approach intending to describe MSP that deliver on sustainability goals, including environmental sustainability (Hanson et al., 2021). Although work in this area is growing, attempts to quantify environment-economy tensions in sectors covered by MSPs remain relatively understudied.

2.2 The Empirical Gaps in the Marine Spatial Planning Literature

Research into the environmental and economic impacts of MSPs has been limited due to a lack of data focused on the marine economy (EC, 2020). There is a need for more reliable marine-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 in most cases in their early stages of the MSP cycle or in their early iterations, it is difficult to assess MSPs' outcomes at present (MMO, 2014). In response, most academic research on MSP has focused on conceptual studies.

Extensive literature has focused on defining and detailing principal concepts or components that marine spatial planning should include for successful implementation (Gilliland and Laffoley, 2008; Breen et al., 2010; Stelzenmuller et al., 2013; Ehler, 2014); and Ehler and Douvere (2009) and UNESCO-IOC/European Commission (2021) MSP guides include guidelines for monitoring, evaluation and adaptation stages. However, quantitative assessments into the effects of MSPs implementation on economic development are still rare.

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, the EC highlight that MSPs have 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 to inform on MSP development.

In a time when MSP's need to be climate-smart, entailing implications for a potential re-distribution of marine activities to promote climate change mitigation and adaptation, such studies may become essential to: 1) help governments and others make decisions that are informed by quantitative estimates of the potential economic repercussions of spatial interventions; and 2) to support the stakeholder consultations that are inherent to the MSP cycle.

2.3 Input-Output Analysis and the Marine Economy

While there is relatively little research to estimate UK marine-related sectors' economic contributions, existing efforts have used Input-Output (IO) analysis as a framework for integrating varying data sources to study the UK Marine Economy. Cerb (2017) used an IO model to assess the economic contribution of the marine leisure sectors within the UK. They found that the UK marine leisure industry directly generates approximately £3.4 billion in turnover, £1.2 billion in gross-value added ("GVA") and around 33,000 jobs. In alignment with these estimates, the CatcH And Release Tagging (CHART) project reported on the economic impact of the UK sea angler industry based on surveys of sea anglers. According to Edwards et al. (2023), the direct economic impact of angling within CHART in 2021 was £410,000, with a total economic impact of £889,000, a GVA of £189,000, and support for 11 full-time equivalent (FTE) jobs. Likewise, Pug (2008) used an IO model to disaggregate the "marine industry" into 18 activity sectors, concluding that Marine Sectors (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 and 2006. More recently, Stebbings et al. (2020), through an IO analysis using data from 2014, estimated that UK marine-related activity contributes ~10% to the total national GVA and ~5% to output. Outside of a UK context, input-output analyses have been used to study marine economies. For instance, Roca Florido and Padilla Rosa (2023, 2024) analyse the implications of removing fishing subsidies in Spain. These studies add valuable data and context to the economic aspects of the marine environment. However, these studies did not consider the environmental impacts of the marine economy.

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; Mair et al., 2019). As China is a major global producer and a large emitter of carbon, many studies explore Chinese supply chain implications for the environment (Liu et al., 2017; Xu et al., 2017). Other studies have focused on sector-level environmental impacts. For instance, Acquaye and Duffy (2010) estimated the direct greenhouse gas emissions ("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 SO_2 emissions (climate active gases) among all French industries.

3 Input-Output Tables and Input-Output Analysis: A Primer

In this section we briefly outline core concepts of input-output analysis sufficient to aid interpretation of the published data and multiplier analysis. For interested readers, a comprehensive account of input-output tables and input-output analysis is available in Miller and Blair (2009), an introductory guide is available in Mair and Druckman (2023).

3.1 Input-Output Tables

Input-output tables collect data on transactions for all sectors in an economy. This is shown schematically in Figure 1. In an input-output table, rows represent outputs from production. In other words, elements of a row represent sales from one sector to the others. Columns represent inputs to production: elements of the columns represent purchases by one sector from the others.

Figure 1 Schematic Representation of an Input-Output Table

The core of an input-output table is the **Z** matrix, which records intermediate transactions – purchases and sales made as part of the production cycle of the market economy. These are purchases made by one sector from others in order to produce something they will sell. The **Z** matrix emphasizes the nature of interconnectedness in modern market economies: one sectors input becomes another sectors output.

Below the transactions matrix comes value added. Gross Value Added (**GVA**) is difference between the value of output and the value of all intermediate purchases. GVA can be represented as a single vector. However, it is equivalent to the sum of labour compensation, taxes minus subsidies, and gross operating surplus (though in practice the latter component is typically estimated as a residual, European Commission et al., 2009). For our purposes it is useful to represent each of these components separately in a matrix format.

To the side of the transactions matrix is Final Demand (the **Y** matrix). Final demand is any purchase made by an entity outside the production cycle of the domestic market. This includes households, governments and exports.

Finally, input-output tables commonly have satellite accounts (**e′**) which display additional variables of interest. These are often non-monetary. Of particular relevance to the MSPACE project are carbon accounts, which display carbon emissions by sector, and employment accounts which display direct labour inputs by sector.

3.2 Input-Output Models

Using the data in the input-output tables, it is possible to introduce some basic assumptions to construct input-output models such as those used in the analyses reviewed in 2.3. By definition, the sum of a row in the input-output table gives an estimate of the total output from that sector. Writing the vector of output by sector as **x** we can represent this as:

$$\mathbf{x} = \mathbf{Zi} + \mathbf{Yi} \qquad (1)$$

Where **i** is a summation vector. Here and throughout the paper we use matrix notation such that bold capital letters are matrices, bold lower case letters are vectors, and non-bold letters are scalar values.

$$\mathbf{x} = \mathbf{Zi} + \mathbf{Yi} \qquad (2)$$

We can then define the technical coefficients matrix (**A**), such that each of its elements a_{ij} represents the intermediate input from sector j required to produce a single unit of output from sector:

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1} \qquad (3)$$

The columns of the **A** matrix can be interpreted as the market production structure of an economy. Entering (3) into (2) we get:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{Yi} \qquad (4)$$

Rearranging for **x**:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Yi} \qquad (5)$$

This is the basic input-output model equation. It is interpreted as showing how a change in final demand drives a network of intermediate purchases and sales generates output in a wide range of sectors. The term $(\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief Inverse, after Wassily Leontief, and represents the supply chain map capturing all intermediate linkages between different sectors of the market economy.

To extend this analysis from output to carbon, labour compensation, employment, and GVA, we use the value added matrix and the satellite accounts writing a vector of impacts per unit of output:

$$\mathbf{u}' = \mathbf{e}'\,\mathbf{x}^{-1} \qquad (6)$$

Where **e′** is a general vector of the variable of interest derived from either the GVA matrix or the satellite accounts, and represents the total impact from each sector. This is entered into (4) to give:

$$\mathbf{u}'\mathbf{x} = \mathbf{u}'(\mathbf{I} - \mathbf{A})^{-1}\,\mathbf{Yi} \qquad (7)$$

Removing the final demand component from the right hand side then gives us the multipliers that form the basis of our analysis in section 5:

$$\mathbf{m} = \mathbf{u}'\,\mathbf{x}\,(\mathbf{Yi})^{-1} = \mathbf{u}'\,(\mathbf{I} - \mathbf{A})^{-1}\mathbf{1} \qquad (8)$$

These multipliers[3] represent the total impact (carbon, labour income, employment, or gross value added), per unit of final demand. They capture impacts along the full supply chain, both direct and indirect effects.

3.3 Advantages and Limitations of Input-Output Modelling for Marine Planning

There are two advantages of input-output analysis for exploring sectors relevant to marine planning. Firstly, it provides a framework for compiling and synthesising economic data on the marine economy (e.g. Stebbings et al., 2020). Secondly, it allows for economic and environmental analyses to be brought together. For instance, Mair et al. (2016) examined the distribution of carbon emissions, employment, income, and gross operating surplus through Western European clothing supply chains. Likewise, Jackson (2017) used an input-output model to analyse the 'sweet spot of good work'.

3 Formally we are using 'type 1' multipliers, because we keep household spending as an exogenous variable. It is possible to close the input-output model with respect to household consumption by integrating this vector into the Z matrix, this allows a user to derive 'type 2' multipliers. We do not do this.

Here, he plots hours of work against greenhouse gas emissions, arguing that policy should aim to support sectors with 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 context, applying methods to estimate impacts before MSP implementation through scenario exploration (ex-ante methods) is desirable for maximising potential benefits and reducing unnecessary costs (OECD, 2017). Ensuring that work is co-delivered as part of trustful and diverse research-stakeholder partnerships may also ensure that this is a more conducive path toward sustainability and climate-resilience (Iwaniec et al. 2020, Nostrom 2020), a key aim of the marine plans.

The limitations of input-output models are the other side of their strengths: the simplicity of the mathematics, which is what enables the transparency and relative speed of the method, requires strong economic assumptions. Specifically, the linearity of the model means we must interpret all results as being about the average outputs/impacts from a sector. This is most problematic where sectors have highly diverse products. As we will discuss, the marine sectors are represented in very aggregated ways in standard input-output tables: fishing and aquaculture may be just one sector for example. Where these sectors have different production structures and social/environmental impacts assuming an average output from the sector is problematic, and it has been shown that for most environmental analysis applications results are more robust when tables add additional detail, even where this requires making additional assumptions (Lenzen 2011). This is the principle motivator behind our decision to disaggregate existing tables, adding detail to marine-focused sectors. However, it is inevitable that our sectors will still hide differences between different activities within them.

The aggregation issue also arises at geographic scale. There may be major differences between a sector operating in different regions. This is especially likely to be the case in our fishing sectors, where different parts of the UK operate different fleets with different characteristics. For this reason we set out to develop tables as close to the geographic scale of the MSPACE case study areas as possible. We follow established methods to do this (see section 4) and draw on a wide range of data sources. However, without the resources to construct new tables with a primary survey of businesses in each region, we have had to rely on statistical methods to integrate data sources. These require assumptions, and each table can only be taken as a best guess of the structure of the economy. In general we would expect national tables to be the most reliable, and regional tables to be less reliable. For the marine focused sectors we compiled data from a variety of sources (see section 4), the non-marine focused sectors in the sub-national tables are derived from statistical processes and therefore are likely to be less reliable.

4 Construction of the UK and Select Nations and Regions Marine Focused Input-Output Tables (UK+SRMFIOTs) Version 1.0

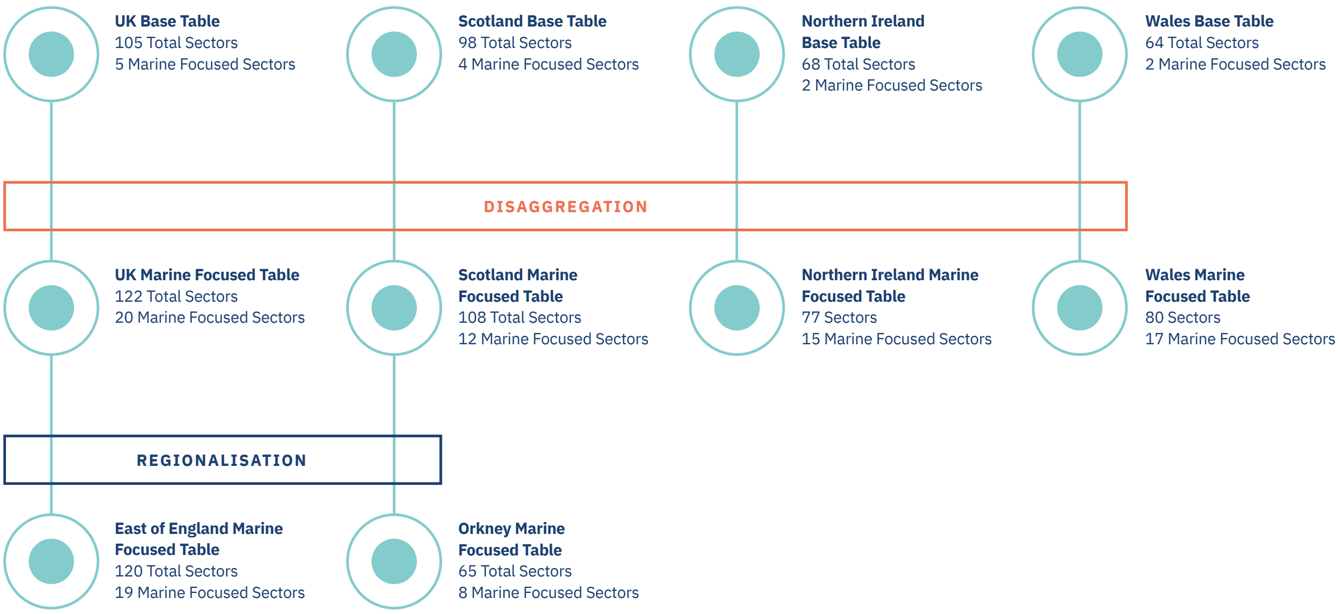

Figure 2
Relationship between base tables and final tables

The construction of the input-output tables for the MSPACE project broadly followed a two-step process of adjustment to a series of base tables published by national statistical offices of the UK, Scotland and Northern Ireland, and a Welsh research team (Jones, 2022). First we added additional detail on marine focused sectors to national base tables through a process of disaggregation. This was followed by regionalisation, to add geographical specificity for the East of England and Orkney tables. Figure 2 shows the relationship between the base tables and the final tables.

As can be seen in Figure 1, base input-output tables available for the UK, Scotland, Northern Ireland and Wales represent the marine economy in very aggregated ways. In principle, the tables capture all the information we need to conduct analysis of the marine economy – but it is combined with data on non-marine activities (for example, the UK table represents fish processing and fruit processing in a single sector). Or the marine data combines multiple marine activities, which would more usefully be analysed a greater level of granularity (for example all four tables represent fisheries and aquaculture in a single sector which leaves limited opportunity to analyse impacts on different fish species). Consequently, the decision was made to add detail to these tables by disaggregating the existing sectors.

4.1 Disaggregation Methodology

The initial choice of marine-focused sectors to disaggregate from the national base tables (UK, Scotland, Wales and Northern Ireland), was based on the Marine Scotland Directorate classification of marine sectors (The Scottish Government, 2022), In addition we added Wholesale of other food, including fish, crustaceans and molluscs (46.38) and the Retail sale of fish crustaceans and molluscs in specialised stores (47.23). These sectors were chosen to enable us to broadly analyse the role of marine sectors in UK supply chains as they relate to changes in fish species and interventions on fishing activity around the UK. Some sectors were excluded based on a lack of data availability. Support activities for petroleum and natural gas extraction were discarded, as information for these sectors was unavailable due to the suppression of information to avoid disclosure (ONS, 2018b). The Miscellaneous fleet segment was ruled out due to difficulty in collecting information (for more details, see Seafish, 2020b, p.6).

The basic challenge of disaggregation is that without doing detailed survey work, the information required to split one sector into two is very hard to come by. The standard approach since Wolsky (1984) has been to split sectors based on relative output weights, assuming identical production technologies. Applying this to the transactions matrix,a **Z**, gives a new **Z*** matrix which contains a set of sectors shared with the base transactions matrix (common sectors) and a set of 'new' sectors disaggregated using the output weights. The **Z*** matrix can then be amended using either statistical techniques or the addition of superior information (Wolsky 1984; Lindner, 2012; García-de-la-Fuente et al., 2016, Raffray 2022).
We gathered data to facilitate a three step approach to disaggregating sectors by columns. First we estimate (i) Intermediate Consumption (IC) weights, then (ii) imports and net taxes on products, and finally (iii) Gross Value Added (GVA). Relevant data sources are described in section 4.3, what follows is the broad outline applied in each disaggregation process.

We follow Raffray et al., (2022) in disaggregating the intermediate consumption of newly added marine sectors using an intermediate consumption ratio. We estimate this using data on intermediate consumption of the marine sub-sector and data on intermediate consumption for the more aggregated sector. We then disaggregated imports and net taxes on products, we estimated the weight of the import and tax share of the aggregated sector over its total output. To estimate the imports and net taxes on products of the newly added sectors, we used the new sector output weight over the total sector group. For instance, we calculated the output weight of the fish processing sector (10.2) over the output of the group sector (10), which is the manufacture of food products. We then multiplied the output weights by the aggregated total output and the import or tax share of the aggregated sector estimated initially.

Additionally, like García-de-la-Fuente et al., (2016), we construct new Gross Value Added (GVA) estimates for each disaggregated sector. First, we estimated the share of each GVA component (such as wages, operating surplus, and taxes on production) over the total GVA of the aggregated sector. Subsequently, the GVA share of the disaggregated sector was estimated over the GVA of the higher SIC code sector group. For example, the GVA of the three-digit code sector, Repair of fabricated metal products, machinery, and equipment (33.1), was calculated over the GVA of the two-digit code sector 33, Repair and installation of machinery and equipment. Then, we estimated the GVA share of the Repair and maintenance of ships and boats (33.15) over the GVA of Repair of fabricated metal products, machinery, and equipment (33.1). Finally, to compute the GVA components (Compensation of employees, Gross operating surplus and mixed-income, and taxes less subsidies on production) of the newly added marine sectors, we multiplied the GVA share for each component of the aggregated sector computed earlier. In this manner, the GVA and the corresponding elements of the newly added marine sectors were computed accurately.

When all columns were disaggregated and the total column sums were obtained, weights based on those totals were used to disaggregate the rows. This approach ensured that the total values in both columns and rows remained equal, thereby fulfilling one of the fundamental requirements of IOT construction: the total input of a sector must equal its total output. This comprehensive and balanced disaggregation provided a detailed and precise breakdown of each sector, maintaining consistency and allowing for the inclusion of new sectors, such as the marine sector, without disrupting the overall structure of the IOTs.

4.2 Regionalisation Method

To obtain the East of England and the Orkney Islands tables we regionalised the UK table and Scottish tables respectively. This process broadly follows the processes set out by Aydoğuş et al. (2015) and Anagnostou and Gajewski (2021). We used Flegg's location quotient (FLQ) (Flegg et al., 1995; Miller and Blair, 2009) to construct regional transactions matrices from the UK and Scottish tables, before using detailed data to construct gross value added matrices, and final demand vectors separately. The tables were then balanced using the RAS algorithm (Miller and Blair, 2009).

The FLQ formula is expressed as:

$$FLQ_{ij} = CILQ_{ij} \cdot \lambda \qquad (9)$$

where

$$\lambda = [\log_2 (E._r/E..)]^{\delta} \qquad (10)$$

In expression (9), $CILQ_{ij}$ is a coefficient that contrasts the employment amount of the selling industry (i) at the regional level with the national to the workers employed in the purchasing sector (j) at the regional level to the national. $E._r$ stands for the total regional employment and $E..$ for the total national employment. On the other hand, the λ parameter specifies the magnitude of a region, and its value increases progressively with the region size, which allows for adjusting regional imports more accurately. It means that trade within a region lowers when regional imports rise. Finally, the δ bounded parameter ($0 \le \lambda \le 1$) determines the degree of convexity of the λ function due to variations in its value, contributing adjustment of regional imports (Kowalewski, 2012). The selection of this value is the primary concern among researchers. Several papers focus on finding out the optimal value of this unknown parameter (Kowalewksi 2015; Flegg and Tohmo 2016; Lamonica and Chelli 2018). We selected the δ value of 0.2 from one of the few studies for the regionalisation of input-output tables for Scotland (Flegg and Webber 2000) that showed improved accuracy on estimations. The estimation of the FLQ follows the following criterion (Kowalewski, 2012):

$$a_{ij}^R=\{a_{ij}^N \text{ if } FLQ_{ij} \ge 1;\ FLQ_{ij} \cdot a_{ij}^N \text{ if } FLQ_{ij}<1\} \qquad (11)$$

If FLQ_{ij} is greater than 1, it means that the region is self-sufficient to supply its regional demand with its industries; hence, the regional coefficient (a_{ij}^R) is equal to the national coefficient (a_{ij}^N), it is assumed the same when FLQ_{ij} = 1. Nevertheless, when FLQ_{ij} is less than 1, it is considered that the regional production is incapable of covering the regional demand requirements; hence it is necessary to import from other regions the rest of the production, which is computed as $a_{ij}^R=FLQ_{ij} \cdot a_{ij}^N$.

The available data on industry output was provided by the ONS (2023d) and the Scottish Government (2023) statistics office at a higher level of aggregation than the disaggregation required for the input-output tables. To address this, region-specific data for sectors was directly assigned where available. In cases lacking regional data, the national weight of each industry within the broader sector group was used to disaggregate the sectors regionally, applying national distribution proportions to estimate regional values. For final adjustments, total GDP data for the East of England (EoE) and the Orkney Islands regions were used as reference points, ensuring that the sum of industry outputs aligned with the official GDP figures (ONS, 2016; ONS, 2020a; and The Scottish Government, 2019) for these regions. This methodology facilitated a more accurate regional disaggregation of industry output data, ensuring consistency with official economic statistics.

A similar approach was followed to construct the GVA vector for the industries. Total gross value-added figures for industries in both regions were used. For imports, total import information for the two regions was split among sectors according to their national-level weights. After obtaining the total output values, imports, and GVA for each industry, the intermediate consumption (IC) of sectors was elicited by difference, as total output equals IC plus GVA (including imports) (ONS, 2012). The Y matrix is divided into final demand categories: households and government spending, investment, and exports. As outlined in the technical report, each component of the Y matrix was individually calculated. Subsequently, the total output for each sector in the Y matrix was computed. The total values determined for the industries' output were then used to calculate the supply sectors' IC.

Estimating the gross domestic product (GDP) can be approached from three perspectives: output, income, and expenditure (ONS, 2022b). Each approach provides a different angle on economic activity: the output approach reflects the supply side, highlighting production capabilities and industrial structure; the income approach focuses on how income is generated and distributed across the economy; and the expenditure approach captures the demand side, showing how different sectors spend and invest. All three approaches lead to the circular flow of money, which implies that each total must be equal, creating a closed-loop flow in the economy. Based on this economic premise, we used the total output estimated from the production side (production approach) as the total output of the supply side (expenditure approach). The total sum of final consumption (households and government), investment, and exports by row and sector was subtracted from the total values (calculated from the production approach) by row and sector. The final value obtained by difference is the supply sectors' IC.

In the last step, to balance the regional input-output table (total output equals total inputs), the IC values from the total column sum and the IC values from the total row sum, estimated by difference, were used to adjust the input coefficients of the intermediate consumption matrix (Z matrix) using the RAS method, also known as the biproportional adjustment method. This widely used mathematical technique adjusts and updates input-output tables while preserving the consistency of row and column sums. The RAS method involves adjusting a given input-output table using three scaling factors: row multipliers (R), the original matrix (A), and column multipliers (S). The goal is to adjust the initial matrix so that the resulting matrix's row and column sums match specified control totals.

4.3 Data Sources and Method Detail by Table

4.3.1 The UK Marine Input-Output Table (UKMIOT18)

For UKMIOT18, the primary source was the 2014 Annual Business Survey (ONS, 2016), which allowed initial disaggregation to the 4-digit SIC level for output, GVA, and intermediate consumption. We then gathered employment estimates for marine (excluding fishing fleet segments, explained in the next paragraph) and non-marine sectors from a detailed database of the Business Register and Employment Survey (BRES) available on the Nomis website (NOMIS, 2021). We also collected the GHG data for the marine (excluding fishing fleet segments, explained in the last paragraph) and non-marine sectors was collected from ONS (2022c). The election of the input-output table target year (2018) was based on the latest updated input-output table.

To perform a deeper analysis of the fishing sector (3.1), we further disaggregated it into different fleet segments, following the same approach set out in 4.1 and using detailed data from various sources (Seafish, 2019; STECF, 2019; Turrell, 2020; Seafish, 2020a; Seafish 2022). Total intermediate consumption can be estimated as the difference between total turnover and GVA (ONS, 2012). 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 fleet was €111 million in 2017. We converted this to British Pounds and used the UK Consumer Price Index (CPI) 2005 index (ONS, 2018c) to adjust it to 2018 prices. It should be noted that the Pelagic fleet segment could only be disaggregated at the UK level.

The greenhouse gas emission data for the fishing subsectors utilised in the input-output tables case studies was sourced from the Marine Scotland database (Turrell, 2020). This particular data set was selected due to its comprehensive nature at the fleet segment level. It is assumed that the fuel consumption and engine efficiency stayed constant for each year of input-output table construction

4.3.2 The Wales Marine Input-Output Table (WMIOT19)

The latest available Official Welsh data dates back to 2007 (Jones et al., 2010). We are grateful to the Welsh Economy Research Unit from Cardiff University who provided an updated input-output table for Wales in 2019 (Jones, 2022). We take this as our base table. In this Wales input-output table, the fishing and aquaculture sectors are depicted as one singular sector, so they needed to be disaggregated. Moreover, the input-output table for Wales initially had GVA split into various categories, including disposable income for the workforce, gross operating surplus (excluding mixed income), income and self-employment tax, pension contributions, and taxes less subsidies on production. However, to make all constructed input-output tables harmonious and comparable, we aggregate the second and third indicators into one when building the WMIOT19, now referred to as gross operating surplus and mixed-income.

In total, 80 sectors are included in the WMIOT19, with 17 being marine sectors. These maritime sectors include 8 fishing fleet segments, aquaculture, processing marine products, building ships and structures, pleasure boat shipbuilding, boat repair and maintenance, wholesale marine products, retail marine products, water transport (as a single sector, no data available to disaggregate into passenger and freight sectors), water transportation services, and renting transport equipment. It is worth noting that the WIOT19 does not include the water project construction sector. All disaggregation was done using data from the Annual Business Survey by ONS (2016; 2020a). We further disaggregate the fishing sector into eight fleet segments in the WMIOT19: including under 10m drift and/or fixed nets, under 10m pots and traps, under 10m using hooks, pots and traps 10-12m, other static gears using vessels, UK scallop dredge, demersal beamers and trawlers, and low activity vessels. Finally, it is worth noting that employment data is included in the base Welsh input-output table, this was updated for the fishing fleet segments using data from Seafish (Arina Motova-Surmava, 2024a).

4.3.3 The Northern Ireland Marine Input-Output Table (NIMIOT17)

In 2017, the Northern Ireland Statistics and Research Agency (NISRA) released the latest version of the input-output table for Northern Ireland (NI), which features 77 sectors in total (NISRA, 2023). There are 15 marine sectors in the finished NIMIOT17 including eight fishing fleet segments, aquaculture, processing marine products, building ships and structures, pleasure boat shipbuilding, boat repair and maintenance, wholesale marine products, and retail marine products. Due to a lack of data, the water transport sector is represented as a single sector. Additionally, the water transportation services and renting transport equipment sectors were included. However, no activity was recorded for the water project construction sector. The eight fishing fleet segments are: Area VIIA Nephrops over 250kW, Area VIIA Nephrops under 250kW, under 10m demersal trawl/seine, under 10m pots and traps, pots and traps over 10m, UK scallop dredge, demersal beamers and trawlers, and low activity vessels.

The main data source for the NIMIOT17 was employment data from the Business Register and Employment Survey, which is available on the NISRA (2022). Fishing fleet segment data, which provides employment, landing value (output), and GVA, was obtained from Seafish (Arina Motova-Surmava, 2024b). Note that the information on fishing income and GVA for Pelagic and miscellaneous fleets is confidential, and no data is available due to confidentiality. Employment in Aquaculture was obtained by subtracting the employment data for fishing from the aggregated data for fisheries personally requested from Seafish (Arina Motova-Surmava, 2024b).

Information was collected from the ABS (ONS, 2016; ONS 2020a) regarding total purchases of goods, materials, and services, total turnover (excluding VAT), GVA, and total output at basic prices. Regarding GHG emissions data for the NIMIOT17, there is an available Northern Ireland greenhouse gas inventory 1990-2018 statistical bulletin data available on the Department of Agriculture, Environment and Rural Affairs (DAERA, 2023) However, the information is given at a high sectoral aggregation level (Agriculture, Business, Energy Supply, Industrial Process, Land Use Change, Public, Residential, Transport, and Waste Management). Therefore, GHG emissions data for the UKMIOT, obtained from ONS (2022c), was used instead. Fleet segment GHG data was obtained using an emission factor estimated from Marine Scotland data (Turrell, 2020).

4.3.4 The Scottish Marine Input-Output Table (SMIOT18)

The Scottish Statistics Office offers a comprehensive, up-to-date table for 2018 (The Scottish Government, 2022). The table is structured to present Fishing and Aquaculture as a single sector. The Fish processing and Fruit processing sectors are presented as a single sector and were disaggregated. After the addition of the marine sectors, the Scottish Input-Output Table (SMIOT18) expanded to a total of 108 industries, with 12 of them being marine-related activities. Unlike the other national tables, the fishing sector was not divided further into fleet segments. This action is unnecessary for MSPACE as this differentiation must only be done for the Orkney IOT. Likewise, the construction of water projects sector (42.91) could not be disaggregated due to data confidentiality issues (The Scottish Government, 2020).

Information from the Scottish Annual Business Survey for 2018 (The Scottish Government, 2020) was utilised to disaggregate the data. This included data on total purchases of goods, materials, and services, total turnover (excluding VAT), gross value added (GVA), and total output at basic prices. Additionally, data from the ABS for 2014 (ONS, 2016) was required to disaggregate major industries into their specific sectors. It is worth mentioning that the construction of the SMIOT18 formed part of the MSPACE project since it is the national table from which the regional table for the Orkney Islands departs.

4.3.5 The Orkney Marine Input-Output Table 2018 (OMIOT18)

After completing the SMIOT18 marine-oriented analysis, the Orkney Islands marine-focused regional table for 2018 (OMIOT18) was constructed utilising a regionalisation method (Aydogus et al., 2015; Anagnostou and Gajewski, 2021). This process entails three steps: the creation of the intermediate consumption matrix (Z), the derivation of the GVA matrix (V), and the final demand matrix (Y).

However, before delving into the details of each step, it is crucial to ensure that the national and regional tables are equal regarding industrial sector numbers. To achieve this, it is necessary to determine which sectors are operating in the Orkney Islands compared to the Scottish economy at the national level. The pre-selection of sectors between both levels was based on employment data for 2018 (The Scottish Government, 2020). In this case, a sector is assumed to exist in the regional area if it has employment. The final adjustment between both tables resulted in 65 total sectors, eight of which are marine-focused. Unfortunately, the following sectors had to be discarded due to data confidentiality or because no data was collected by the survey, division (SIC 07) codes within parentheses: - Manufacture of Textiles, Wearing apparel and Leather products (13,14,15) - Manufacture of Coke, Chemicals, Pharmaceutical, Rubber and Mineral products (19,20,21,22,23) - Manufacture of Computer, electronic and Electrical equipment (26,27).

Once the number of industrial sectors is defined, the next step is to determine the transaction value between industries. However, since information on intermediate consumption of goods and services sales and acquisitions between industries, embedded information in the intermediate transaction matrix (Z) is unavailable for the Orkney Islands region. The Location Quotient (LQ) approach described in 4.2 was applied to address this issue (Flegg and Webber, 2000).

To gather accurate information on the economy of the Orkney Islands, we first selected 65 sectors based on sector preselection, including newly added marine sectors. Unfortunately, no data was available for these sectors regarding imports, gross value added, or output. To overcome this challenge, we obtained information from the Office for National Statistics (The Scottish Government, 2019) on the total GDP value of the Orkney Islands. Using this data, we assumed that the output for any given sector in the Orkney Islands is a share of the output of the same industry in Scotland, with these shares being based on output figures from the Scottish Input-Output Table (SCOIOT18). By applying these weights over the GDP for the Orkney region, we were able to estimate the total outputs of different industries. Finally, after obtaining the LQs' technical coefficients, we multiplied the estimated total output for each industry by its corresponding column of LQs' technical coefficient in the intermediate matrix. This helped us calculate the intermediate consumption coefficients.

Regarding gross value added (GVA), we could only obtain the most detailed regional information, which provided us with a 38-industry aggregation level (NACE Rev.2 industrial classifications, A38) collected from the ONS. To allocate this information among the sectors within the same sector group, we assumed that those more disaggregated would have the same GVA share to total output as they have at the national level.

Regarding the imports vector, we collected information on the total value of imports from the HM Revenue and Customs (2023) broken down into imports from the rest of the UK and imports from the rest of the world. Using the national import share to output by sector as a reference, we could allocate these figures among all sectors.

We must consider several elements to construct the final demand matrix (Y). Firstly, the final consumption expenditure should be taken into account. This refers to the purchases made by the end consumer, such as household spending on goods and services. Secondly, gross capital formation should be included, which refers to the investment made by businesses in machinery, equipment, and buildings.

In addition to these elements, we also need to consider consumption for Orkney based on Highland's data share. This means the consumption patterns of the Orkney and Highlands regions are assumed to be similar. Lastly, we need to consider the change in inventories. This can be obtained using the regional gross value added (balanced) database by industry at all International Territorial Levels (ITLs) provided by (ONS, 2023c).

It is worth noting that changes in inventories and valuables are estimated using the regional gross value added as a proxy, following expression (21) in Anagnostou and Gajewski (2021). This approach allows us to estimate the changes in inventories and valuables more accurately and ensures that the final demand matrix is constructed in a detailed and precise manner.

In relation to the export vector, the necessary information was sourced from the HM Revenue and Customs (2023). The export data was then categorized based on whether it was exported from the EU or non-EU trade partners. The export share of the total exports from the Scottish Input-Output Table was used to allocate the Orkney Islands export data accordingly.

4.3.6 The East of England Marine Input-Output Table (EEMIOT18)

The regional East of England (EoE) input-output table (EEMIOT18) departs from the national UKIOT18. The EEMIOT18 followed an equal construction procedure as the OMIOT18, given that it is a regional area (classified as ITL2). Sectors were selected based on the Business Register and Employment Survey data from the NOMIS database (BRES, n.d.) sourced by ONS. This database contains detailed information on industry employment up to the 5-SIC code level at national and regional levels in the UK economy.

The level of detail of the information allowed us to select the industries present in the EoE region according to the premise that if there is employment for a given sector, it is assumed that this industry exists in the region. This assumption helped identify 120 sectors with 19 marine-related industries including 7 fishing fleet segments constructed using Seafish socio-economic data (employment, GVA, and output) upon request (Arina Motova-Surmava, 2024a).

Data on production on total turnover, approximate gross value added at basic prices, and total purchases of goods, materials, and services were collected from the 2018 Annual Business Survey (ONS, 2020a). As the 2018 ABS only provides information on sectors classified up to a 2-digit SIC code, shares compiled from the ABS (ONS, 2016) from 2014 were used. The latter database is the most disaggregated information provided by ONS at the sectoral level., reaching up to 4-digit SIC codes.

Information on the GVA elements (compensation of employees, gross operating surplus (GOS), and taxes less subsidies on production) was gathered from ONS (2023a) originally given at an aggregated level for 31 sectors in the region of EoE. Therefore, to conform to the UK table, this information had to be disaggregated into 114 sectors (fishing sector accounting as a single sector) included in the EEMIOT18 by applying a weighing approach based on the national GVA components shares in each sector at the UK level over the total national value of each component.

Information on imports and trade with EU and non-EU countries was picked from the Customs Office (HM Revenue and Customs (2023). Weights for both trade fluxes were calculated and allocated according to industry import share over the total import at the national level.

To estimate the intermediate matrix for the EoE, we followed the same approach as in regionalising the OIOT18 (see section 4.3.5 for detail).

The final demand (Y) comprises several accounts, including the government's final consumption expenditure, households' final consumption expenditure, and non-profit organisations serving households' final consumption expenditure (NPISH). Additionally, it includes gross fixed capital formation, changes in inventories, acquisitions less disposals of valuables, and exports split by EU countries, the rest of the world, and service products. To estimate government spending, a weight over the total UK was calculated. Data on public sector expenditure for each country and region of the UK can be found on the ONS website (ONS, 2023b). Regarding households' final demand data, it is also available on the ONS website (ONS, 2020b). The weight of EoE regional families' final demand over the national one was assessed. The NPISH final expenditure was approached using weights from gross disposable household income (Anagnostou and Gajewski, 2021) at the regional level over the UK. Regional gross disposable household income for all ITL regions is available at the ONS website (ONS, 2023c).

The gross capital formation vectors are divided into gross fixed capital formation, changes in inventories and acquisitions less disposals of valuables. Two steps were followed to construct them. Firstly, to achieve a more accurate estimate, data on GFCF by industry level was collected on ONS websites (ONS, 2019a) . This data is available at an aggregated level (differentiating only 11 sectors), at least allowing us to find out the weight of each industrial group in terms of GFCF. Once weights were calculated, it was necessary to identify each of the 114 sectors (the fishing sector stands for a unique sector) in one of those 11 groups. The industry sector distinction was based on the SIC industry classification(ONS, 2023d). Finally, weights for each industry within each sector group were estimated and then applied to the UK GFCF vector to be regionalised.

Next, the changes in inventories and acquisitions, resulting in fewer disposals of valuables vectors, were combined into a single sector. Then, the new aggregated vector is computed using the regional GVA as a proxy (Anagnostou and Gajewski, 2021). The vector was estimated at the regional level by weighting the national and regional GVA on the total sum of single changes in inventories and acquisitions less disposals of valuables vector. All data on GVA displayed at ITL regions and by sectors was gathered from ONS (2023c).

As mentioned earlier, exports are divided into those traded to EU nations, non-EU, and services. For the two former vectors, HM Revenue and Customs (2023) provides information on imports and exports trade at a regional level and broken down by EU and non-EU commercial partners. Estimations on service exports were done according to information collected from ONS (2019b) for 2016. According to total export service values, weight in this product category for the EoE was calculated and applied to the total sum of the service export vector in the UKIOT18. Finally, the total service export estimate was divided into 114 sectors according to each industry's share of the total export service at the UK level.

4.3.7 Use of expert knowledge

Engagement with expert stakeholders formed a core part of our table development process. As part of the broader MSPACE project, a series of workshops with stakeholders were held. From June to November 2023, we hosted stakeholder workshops for the case study regions of East of England, Northern Ireland, Orkney Islands (Scotland), and Wales. Participants were invited from the stakeholder groups in each location and included key marine planning teams, other regulators, as well as representatives of the conservation sector and of crucial industries in each case-study region (Reinhardt et al., 2023a; 2023b; 2023c; 2024).

For Wales, the workshop was broken into two separate online sessions; all other workshops were held in person, with some participants also online (i.e. hybrid). The first in-person workshop was hosted in Stromness, Orkney (June 2023), followed by Belfast, Northern Ireland (September 2023), and finally York, England (September 2023). Each in-person workshop lasted one day, with presentations in the morning and interactive sessions in the afternoon. In the morning sessions, the MSPACE team presented their research work and findings, with the objective of sharing project outputs and soliciting feedback regarding its usefulness. Participants asked questions and contributed their reactions to the information, including advice on how to make it as useful as possible to stakeholders. In the afternoons, participants were broken into groups to discuss issues such as the trade-offs involved in marine planning and plan implementation, opportunities and fears associated with the planning process, and priorities of the different sectors with respect to marine planning.

These workshops allowed us to delve deeper into different aspects of the maritime industry, sense-checking multipliers, identifying operational and non-operational marine sectors, identifying any missing marine industries, and double-checking GHG emissions data by the marine sector. We also used handouts in each workshop to gather individual data about different aspects that may improve the model's applications. Furthermore, we used these workshops as an opportunity to reach out to industry representatives to collect valuable data and feedback, which will help us establish better connections with stakeholders in the marine sector.

Table 1 Marine sectors included in the input-output tables for the MSPACE project

	UKMIOT18	SCMIOT18	NIMIOT2017	WMIOT19	EEMIOT18	OMIOT18
1	Demersal Trawlers and seiners	Fishing	Area VIIA Nephrops over 250kW	Under 10m drift and/or fixed nets	Under 10m drift and/or fixed nets	Fishing
2	Nephrops	Aquaculture	Area VIIA Nephrops under 250kW	Under 10m pots and traps	Under 10m pots and traps	Aquaculture
3	Beam trawlers	Fish processing	Under 10m demersal trawl/seine	Under 10m using hooks	North Sea beam trawl under 300kW	Building of ships and floating structures
4	Scallop dredges	Building of ships and floating structures	Under 10m pots and traps	Pots and traps 10-12m	UK scallop dredge under 15m	Wholesale of other food, including fish, crustaceans and molluscs
5	Passive gears	Building of pleasure and sporting boats	Pots and traps over 10m	Other static gears using vessels	Demersal trawlers	Retail sale of fish crustaceans and molluscs in specialised stores
6	Under 10 m	Repair and maintenance of ships and boats	Scallop dredge	UK scallop dredge	Other static gears using vessels	Sea and coastal passenger water transport
7	Low activity	Wholesale of other food, including fish, crustaceans and molluscs	Demersal beamers and trawlers	Demersal beamers and trawlers	Low activity vessels	Service activities incidental to water transportation
8	Pelagic	Retail sale of fish crustaceans and molluscs in specialised stores	Low activity vessels	Low activity vessels	Aquaculture	Renting and leasing of water transport equipment
9	Aquaculture	Sea and coastal passenger water transport	Aquaculture	Aquaculture	Processing and preserving of fish, crustaceans and molluscs	
10	Processing and preserving of fish, crustaceans and molluscs	Sea and coastal freight water transport	Processing and preserving of fish crustaceans and molluscs	Fish processing sector	Building of ships and floating structures	
11	Building of ships and floating structures	Service activities incidental to water transportation	Repair and maintenance of ships and boats	Building ships and structures	Building of pleasure and sporting boats	
12	Building of pleasure and sporting boats	Renting and leasing of water transport equipment	Wholesale of other food including fish crustaceans and molluscs	Pleasure boat shipbuilding	Repair and maintenance of ships and boats	
13	Repair and maintenance of ships and boats		Retail sale of fish crustaceans and molluscs in specialised stores	Boat repair and maintenance	Construction of water projects	
14	Construction of water projects		Water transport	Wholesale marine products	Wholesale of other food, including fish, crustaceans and molluscs	
15	Wholesale of other food, including fish, crustaceans and molluscs		Service activities incidental to water transportation	Retail marine products	Retail sale of fish crustaceans and molluscs in specialised stores	
16	Retail sale of fish crustaceans and molluscs in specialised stores			Water transportation services	Sea and coastal passenger water transport	
17	Sea and coastal passenger water transport			Renting transport equipment	Sea and coastal freight water transport	
18	Sea and coastal freight water transport				Service activities incidental to water transportation	
19	Service activities incidental to water transportation				Renting and leasing of water transport equipment	
20	Renting and leasing of water transport equipment					

5 Quantifying Direct and Indirect Impacts in Regional UK Marine Economies

In this section we present multipliers for each of the regional economies. We do this for carbon emissions, employment, income, and gross value added. With these variables we aim to get a broad representation of 3 domains of sustainability: environment, society, economy (e.g. Clift et al., 2022). The impact of changes in final use on various indicators within an industry and across the broader economy can be understood using the concept of multiplier effects. When there is an increase in final use for a specific industry output, it sets off a chain reaction of effects. This reaction includes an increase in demand, which leads to increased output in the industry to meet that demand, known as the direct effect. As a result, suppliers and other businesses within the industry's supply chain also experience increased demand, leading to indirect effects (The Scottish Government, 2023).

5.1 Regional Multiplier Estimates

In this section we present the Marine-Focused IO multipliers for each of the case study regions: Northern Ireland, Wales, East of England, and the Orkney Islands. When we compare multipliers between different regions, we can conduct two different types of analysis. The first type of analysis helps us identify which sectors are important in each region. The second type of analysis allows us to compare the relevance of these sectors with other case studies. However, it is important to remember that not all sectors are present in each region. As a result, only sectors that are commonly present can be compared. Multipliers for the Orkney Islands should be taken with particular caution. Due to its small regional scale, these data are the most uncertain and may be subject to further revision.

Table 2 Northern Ireland Multipliers

	DIRECT				INDIRECT				TOTAL			
	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG
Area VIIA Nephrops over 250kW	0.22	0.57	2.90	11.34	0.12	0.20	3.80	0.11	0.34	0.78	6.70	11.46
Area VIIA Nephrops under 250kW	0.23	0.60	3.29	1.36	0.11	0.19	3.51	0.11	0.34	0.78	6.81	1.46
Under 10m demersal trawl/seine	0.22	0.58	1.74	1.72	0.12	0.20	3.67	0.11	0.34	0.78	5.41	1.83
Under 10m pots and traps	0.19	0.50	2.12	2.56	0.15	0.25	4.65	0.14	0.34	0.75	6.77	2.70
Pots and traps over 10m	0.25	0.65	1.93	3.40	0.09	0.15	2.82	0.08	0.34	0.80	4.75	3.48
Scallop dredge	0.18	0.46	1.23	9.40	0.17	0.28	5.23	0.16	0.35	0.74	6.47	9.56
Demersal beamers and trawlers	0.18	0.46	2.37	0.16	0.17	0.28	5.23	0.16	0.35	0.74	7.60	0.32
Low activity vessels	0.16	0.41	1.98	7.08	0.19	0.31	5.76	0.17	0.35	0.72	7.73	7.25
Aquaculture	0.20	0.52	11.75	0.17	0.14	0.24	4.43	0.13	0.34	0.75	16.18	0.30
Processing and preserving of fish crustaceans and molluscs	0.17	0.21	6.17	0.11	0.15	0.32	4.28	0.58	0.33	0.53	10.45	0.69
Repair and maintenance of ships and boats	0.10	0.16	8.90	0.01	0.01	0.02	0.38	0.01	0.11	0.18	9.28	0.02
Wholesale of other food including fish crustaceans and molluscs	0.32	0.60	6.92	0.05	0.07	0.12	2.10	0.03	0.39	0.73	9.02	0.09
Retail sale of fish crustaceans and molluscs in specialised stores	0.41	0.78	22.06	0.04	0.06	0.11	1.95	0.03	0.47	0.90	24.00	0.07
Water transport	0.31	0.35	2.18	1.07	0.14	0.22	4.76	0.12	0.45	0.57	6.94	1.19
Service activities incidental to water transportation	0.41	0.62	8.43	0.04	0.13	0.22	4.18	0.09	0.54	0.84	12.60	0.13

Table 3 Wales Multipliers

	DIRECT				INDIRECT				TOTAL			
	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG
Under 10m drift and/or fixed nets	0.16	0.46	4.95	0.41	0.24	0.15	3.04	0.15	0.40	0.61	7.99	0.56
Under 10m pots and traps	0.15	0.42	3.48	0.41	0.24	0.17	3.43	0.17	0.39	0.60	6.91	0.58
Under 10m using hooks	0.13	0.39	5.11	0.41	0.24	0.20	3.86	0.19	0.37	0.58	8.97	0.60
Pots and traps 10-12m	0.15	0.42	5.52	0.46	0.24	0.17	3.41	0.19	0.39	0.60	8.93	0.65
Other static gears using vessels	0.12	0.34	1.32	0.46	0.23	0.22	4.36	0.24	0.35	0.56	5.68	0.70
UK scallop dredge	0.08	0.23	2.10	0.77	0.22	0.29	5.63	0.53	0.30	0.52	7.73	1.30
Demersal beamers and trawlers	0.08	0.22	6.21	0.48	0.22	0.29	5.80	0.34	0.30	0.51	12.01	0.83
Low activity vessels	0.09	0.25	6.46	0.88	0.22	0.28	5.47	0.59	0.31	0.53	11.93	1.47
Aquaculture	0.13	0.37	5.52	0.17	0.24	0.21	4.21	0.09	0.37	0.58	9.73	0.26
Fish processing sector	0.08	0.45	29.28	0.11	0.17	0.18	4.24	0.04	0.25	0.63	33.52	0.15
Building ships and structures	0.09	0.13	7.46	0.05	0.08	0.22	6.29	0.03	0.17	0.35	13.75	0.08
Pleasure boat shipbuilding	0.08	0.11	10.37	0.05	0.07	0.20	5.63	0.02	0.15	0.30	16.00	0.08
Boat repair and maintenance	0.03	0.24	1.12	0.01	0.24	0.23	4.52	0.01	0.27	0.47	5.64	0.02
Wholesale marine products	0.04	0.24	2.94	0.05	0.29	0.45	7.56	0.06	0.33	0.69	10.49	0.11
Retail marine products	0.17	0.80	6.12	0.04	0.25	0.07	1.23	0.01	0.42	0.86	7.35	0.05
Water transportation services	0.16	0.65	7.36	0.04	0.21	0.08	1.44	0.01	0.37	0.72	8.80	0.04
Renting transport equipment	0.06	0.67	14.39	0.03	0.13	0.10	2.08	0.01	0.19	0.78	16.47	0.04

Table 4 East of England Multipliers

	DIRECT				INDIRECT				TOTAL			
	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG
Under 10m drift and/or fixed nets	0.29	0.53	1.28	0.409	0.10	0.18	4.35	0.13	0.39	0.71	5.63	0.54
Under 10m pots and traps	0.28	0.52	1.31	0.409	0.11	0.18	4.50	0.14	0.39	0.71	5.81	0.55
North Sea beam trawl under 300kW	0.13	0.25	2.38	1.282	0.21	0.37	9.14	0.88	0.35	0.62	11.52	2.16
UK scallop dredge under 15m	0.24	0.45	0.51	0.885	0.13	0.23	5.63	0.38	0.38	0.69	6.15	1.26
Demersal trawlers	0.12	0.23	3.97	0.485	0.22	0.39	9.39	0.34	0.34	0.62	13.36	0.83
Other static gears using vessels	0.27	0.50	0.89	0.456	0.11	0.20	4.83	0.17	0.38	0.70	5.72	0.62
Low activity vessels	0.14	0.25	1.99	0.885	0.21	0.37	9.00	0.60	0.35	0.62	10.99	1.48
Aquaculture	0.19	0.35	0.97	0.169	0.16	0.27	6.63	0.08	0.34	0.62	7.60	0.25
Processing and preserving of fish, crustaceans and molluscs	0.19	0.29	0.51	0.109	0.30	0.55	12.28	0.09	0.49	0.84	12.79	0.20
Building of ships and floating structures	0.28	0.48	0.42	0.054	0.19	0.30	8.32	0.03	0.46	0.78	8.74	0.08
Building of pleasure and sporting boats	0.27	0.46	8.37	0.054	0.19	0.31	8.96	0.03	0.46	0.77	17.33	0.08
Repair and maintenance of ships and boats	0.39	0.75	6.72	0.009	0.11	0.17	4.16	0.00	0.49	0.92	10.88	0.01
Construction of water projects	0.19	0.44	0.90	0.042	0.20	0.38	6.47	0.02	0.39	0.82	7.37	0.07
Wholesale of other food, including fish, crustaceans and molluscs	0.42	0.60	24.62	0.054	0.05	0.08	2.20	0.01	0.47	0.68	26.81	0.06
Retail sale of fish crustaceans and molluscs in specialised stores	0.48	0.77	30.23	0.042	0.07	0.12	3.28	0.01	0.55	0.89	33.51	0.05
Sea and coastal passenger water transport	0.34	0.65	0.74	1.069	0.09	0.15	2.91	0.26	0.43	0.79	3.65	1.33
Sea and coastal freight water transport	0.40	0.76	1.38	1.069	0.05	0.08	1.83	0.15	0.46	0.85	3.21	1.22
Service activities incidental to water transportation	0.53	0.70	39.04	0.036	0.09	0.13	4.18	0.01	0.62	0.83	43.22	0.04
Renting and leasing of water transport equipment	0.37	0.81	4.70	0.033	0.08	0.12	3.65	0.01	0.45	0.93	8.35	0.04

Table 5 Orkney Island Multipliers

	DIRECT				INDIRECT				TOTAL			
	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG	Income	GVA	Jobs	GHG
Retail sale of fish crustaceans and molluscs in specialised stores	0.35	0.53	26.01	0.04	0.27	0.43	10.92	0.03	0.62	0.96	36.93	0.07
Sea and coastal passenger water transport	0.15	0.17	43.51	1.07	0.45	0.72	27.06	1.30	0.60	0.90	70.57	2.37
Aquaculture	0.41	0.64	78.48	0.17	0.19	0.31	22.71	0.08	0.60	0.95	101.19	0.25
Service activities incidental to water transportation	0.09	0.15	57.17	0.04	0.49	0.76	35.61	0.05	0.58	0.91	92.79	0.09
Wholesale of other food, including fish, crustaceans and molluscs	0.04	0.08	70.76	0.05	0.50	0.84	27.16	0.07	0.54	0.91	97.93	0.13
Building of ships and floating structures	0.35	0.44	8.63	0.05	0.19	0.30	9.26	0.03	0.54	0.75	17.89	0.08
Fishing	0.29	0.54	26.44	0.94	0.22	0.36	10.58	0.52	0.51	0.90	37.02	1.46
Renting and leasing of water transport equipment	0.11	0.43	29.96	0.03	0.28	0.54	20.82	0.03	0.39	0.97	50.78	0.06

5.2 Overview of the Multipliers

5.2.1 Income Multipliers

The income multipliers across various sectors in different regions provide valuable insights into the economic impact of these industries. In Northern Ireland, for example the income generated by the Water transport sector has substantial indirect effects. For every £million of final demand spent in the sector £0.45 million of income is generated. Of this, £0.14 million is indirect effects – i.e. in sectors other than water transport itself. On the other hand, the fish retail sector mainly generates income for workers employed within the sector itself. For every £million spent in the sector, £0.47 in income is generated, with £0.41 million of this in the fish retail sector itself. Similarly, the Water transport service sector generates £0.54 million per £million final demand of which three-quarters (£0.41 million) is direct.

In Wales, indirect income carries more significance overall. Wholesale marine products and Boat repair and maintenance industries showcase that their indirect impacts are 87% and 88% of their overall income impacts, respectively. This means that out of a total income multiplier of £0.33 million wages per £ million final demand, £0.29 million is indirect for Wholesale marine products, while for Boat repair and maintenance, indirect effects amount to £0.24 million out of a total income multiplier of £0.27 million. The Building ships and structures sector has the highest direct income effect, contributing £0.09 million or of the total income multiplier of £0.17 million. The two sectors with the highest income multipliers are the retail marine products and the vessels fleet segment under 10m using drift and/or fixed nets.

In the East of England area, the wholesale of seafood products is the sector with the largest relative direct income multiplier (£0.42 million, 90% of the total income multiplier of £0.47million). Sea freight water transport comes in second with an overall income effect of £0.46 million per £million of final demand, of which £0.40 million is created directly. The water transport service and the retail of seafood products are ranked first and second, respectively, in terms of total income generated per £million of final demand. The former generates £0.53 million of direct income over a total of £0.62 million, while the latter directly generates £0.48 million over a total of £0.55 million. The seafood processing sector generates a total of £0.49 million in wages per £ million of final demand, out of which £0.3 million is an indirect impact. The Low activity, North Sea beam trawl under 300kW, and Demersal trawlers fleet segments also have greater indirect than direct implications, although their total income multipliers are relatively low.

The Orkney economy has several sectors with significant income multipliers. The top-performing sector is the retail of fish products, which contributes a total effect of £0.62 million per £million of final demand spend. The sea and coastal passenger water transport and aquaculture sectors also perform well. Both have total income multipliers of £0.6million, with different direct effects (£0.15 million and £0.41 million respectively). The service activities incidental to the water transportation sector indirectly generates £0.49 million of indirect income out of a total income multiplier of £0.58 million. Similarly, for the wholesale of seafood products sector 90% (£0.5 million) of its total income multiplier (£0.54 million) is indirect.

5.2.2 GVA multipliers

The GVA multipliers are useful in determining the economic impact of various industries in different regions. In Northern Ireland, the fish retail, water transport services, and pots and traps over 10m industries have the highest total GVA multipliers, contributing £0.9 million, £0.84 million, and £0.8 million of GVA per £million of final demand respectively. In the fish retail, and pots and traps industries direct effects dominate GVA, with more than 80% of the total income effects (£0.78 million and £0.65 million) being direct. In water transport services, indirect effects dominate (£0.62 million, 75%) The repair and maintenance ship sector has the lowest total GVA effects of £0.18 million, with more than 85% of these (£0.16 million) being direct.

In Wales, the retail marine products sector has a total impact of £0.86 million, with £0.80 million (92%) being direct impacts. The renting transport equipment sector takes the second spot in terms of total impacts, with a total multiplier of £0.78 million in GVA per £ million final demand, out of which £0.67 million (87%) comes as direct effects. The water transport services sector has a total impact of £0.72 million, out of which direct impacts represent a share of 90% or £0.65 million. The wholesale marine products industry has the fourth-largest total impact, generating a total impact of £0.69 million, out of which £0.45 million (66%) is indirect. The building of ships and structures and pleasure boat shipbuilding have similar impacts and are the two lowest sectors in terms of total GVA multipliers at £0.35 million and £0.3 million each. Their impacts are predominantly indirect at £0.22 million (64%) and £0.20 million (65%), respectively.

In the East of England area, the top three industries in terms of total GVA multiplier are the renting and leasing of water transport equipment sector (£0.93 million), repair and maintenance of ships and boats (£0.92 million), and retail sale of fish crustaceans and molluscs in specialised stores (£0.89 million). These are all dominated by direct effects: £0.81, £0.75, and £0.77 million respectively. The seafood processing industry, the North Sea beam trawl fleet under 300kW, and the Demersal trawler fleets have the most significant indirect impacts, relative to their total effects. In the processing sector indirect effects account for

66% (£0.55 million) of total GVA effects of £0.84 million. Both the North Sea beam trawl fleet under 300kW, and the Demersal trawler fleets have total effects of around £0.62 million each with indirect effects contributing about 60% (£0.37 million and £0.39 million, respectively).

In the Orkney economy, the renting of water transport equipment sector shows the most significant GVA multiplier, £0.97 million, being 55% (£0.54 million) being indirect effects. Aquaculture contributes £0.95 million, of which 33% is indirect. Fishing contributes £0.9 million GVA for every £1million in final demand. Of this, £0.54 million is direct. The wholesale of seafood products and the service activities related to water transportation account for £0.84million (92%) and £0.76 million (84%), respectively, in terms of their indirect impact on totals of £0.91 million each

5.2.3 Employment multipliers

The following information outlines the employment multipliers for various sectors in different regions of the UK. In Northern Ireland, the fish retail industry has the highest employment multiplier, generating 24 jobs, followed by the aquaculture sector with 16 jobs and water transport services with 13 jobs created for every £million in final demand . The retail sector has a direct impact of 92%, which means that 22 workers are employed within the sector. The repair and maintenance ship sector has the highest relative direct impact (96%) employing around 9 workers, and less than 1 indirectly for directly with while only 4.1% of its impact is indirect. The Scallop dredge fleet segment has the lowest direct impact percentage in employment, but the greatest relative indirect effects of 81%, of it's total 6.5 workers employed indirectly.

In Wales, the employment multipliers for the number of jobs created for each £ million final demand are highest in the fish processing sector, with 33.5 workers, followed by renting transport equipment with 16.5 workers and pleasure boat shipbuilding with 16 workers. Of these three, the fish processing sector and the renting transpirt equipment sector have large relative direct effects, employing 29 workers (87%) and 14 workers (87%) respectively, while the shipbuilding sector directly employs only 65% (10 workers) directly. The wholesale of marine products generates 7.6 workers (72%) indirectly, with a total impact of 10.5 workers for every £ million final demand.

According to the findings on employment multipliers in the East of England area the three sectors generating the most employment per £million final demand are: water transportation services (43 jobs), retail of seafood (33.5 jobs), and wholesale of seafood products (27 jobs). In each of these sectors, over 90% of those effects are directly within the sector itself. The processing sector and the building of ships and floating structures have the most significant relative indirect employment effects. For the processing sector, 96% (12 jobs) of the total impact of 13 workers per £ million final demand were indirect. The shipbuilding industry employs 8 workers (95%) out of 9 workers directly.

In the Orkney Islands, the aquaculture industry has the highest total employment multiplier, creating jobs for 101 workers per £1 million of output. Following closely, the wholesale of fish products supports 98 workers per £1 million output, these are dominated by direct employment effects. The ship and floating structure construction sector stands out for its higher proportion of indirect employment effects. This sector generates 18 jobs per £1 million final demand, with 9 workers being indirect.

5.2.4 GHG multipliers

Regarding the GHG multipliers in the Northern Ireland, there is a group of eight marien focused sectors that have in common that more than 90% of the total effects are direct. These are all of the fishing fleet segments, with the exception of the demersal fleet, and the water transport sector. Of these, the *Nephrops* over 250kW fleet segment is the most GHG intensive in terms of multiplier. It is also the most intensive overall for Northern Ireland, with a total multiplier of 11.5 thousand tonnes of GHG per £million final demand, from which 11.3 thousand tonnes (99%) are caused directly and 0.1 (1%) indirectly. Next, is the low activity segment with a direct impact of 9.4 thousand tonnes (98%) and 0.16 thousand tonnes (2%) caused in indirectly. At the bottom of this group is the water transport service sector, creating around 1.1 thousand tonnes (90%) in a direct manner and 0.12 thousand tonnes (10%) indirectly. It is observed that service activities related to water transportation and processing and preserving fish, crustaceans, and molluscs have the most significant relative indirect impacts. In the case of incidental service activities to the water transportation sector, it contributes to 0.09 thousand tonnes (72%) of the total impact of 0.13 thousand tonnes. The processing seafood sector has indirect effects of 0.58 thousand tonnes of a total impact of 0.69 thousand tonnes, which is 84% of the total indirect impact.

Various industries in Wales are characterised by significant relative direct (GHG) emissions. For instance, the retail of marine products contributes a direct effect of 0.04 thousand tonnes per £million final demand, which makes up 89% of the total multiplier (0.05 thousand tonnes). The water transportation services industry accounts for a significant share of indirect effects, with 85% (0.04 thousand tonnes) over its total impacts (0.04 thousand tonnes). Renting transport equipment also contributes to the indirect effects of GHG, accounting for 82.5% (0.01 thousand tonnes) of a total GHG multiplier of 0.02 thousand tonnes. In most sectors, the direct effects of GHG emissions are higher than the indirect effects, except for wholesale marine products, which have greater indirect effects (0.06

thousand tonnes) over the total (0.11 thousand tonnes). Furthermore, fishing fleet segments are the top two classifieds that record the greatest total GHG impact. The low-activity fishing fleet segment generates a total of 1.47 thousand tonnes, with 0.88 thousand tonnes emitted directly and 0.59 thousand tonnes indirectly. Similarly, the UK scallop dredge segment scores a total impact of 1.30 thousand tonnes, with 0.77 thousand tonnes emitted directly and 0.53 thousand tonnes produced indirectly in the rest of the sectors.

In the East of England, the North Sea beam trawl under 300kW and the Low activity fleet segments show the largest total effect of GHG thousand tonnes per £ million final demand, with 2.16 thousand tonnes and 1.48 thousand tonnes in each case. In both cases, direct effects are the largest portion of the total (1.3 and 0.89 thousand tonnes respectively). In the sea passenger transport sector, total GHG's are 1.33 thousand tonnes per £million final demand. In sea freight transport, the total GHG multiplier is 1.22 thousand tonnes. In both cases the effects are predominantly direct. The Demersal fishing fleet segment and seafood product processing sector, both have indirect effects that represent over 40% of their total GHG effects. The Demersal fleet segment generates 0.48 out of 0.83 thousand tonnes GHG indirectly (41%), while seafood product processing generates 0.09 out of 0.20 thousand tonnes (46%) of its GHGs indirectly.

The two sectors in the Orkney economy with the most significant greenhouse gas (GHG) impacts per unit of final demand are sea passenger water transport, and fishing. Sea passenger water transport has a total GHG effect of 2.37 thousand tonnes, with 1.07 thousand tonnes (45%) generated directly. Fishing produces a total effect of 1.46 thousand tonnes, with direct effects accounting for 64% (0.94 thousand tonnes). Aquaculture ranks as the third highest total impact (0.25 thousand tonnes), with nearly 67% of effects being direct (0.17 thousand tonnes).

6 Conclusions

Overall, our analysis highlights the complex interplay between marine-focused sectors and their broader economic, environmental, and social impacts across various regions in the UK. To do this, this report has outlined the process of constructing six input-output tables, which form the UK+SRMFIOT v.1 collection. The purpose of these tables is to model economic indicators and evaluate various marine spatial plan alternatives suggested by the MSPACE project.

Each table is unique and requires different data sources to build. Therefore, the report also aims to provide insights to researchers and modellers to develop industry-focused IOTs specific to other research purposes by explaining the construction of marine-oriented IOTs at the national level for Northern Ireland (NIMIOT17) and Wales (WMIOT19) and regional levels (East of England (EEMIOT18) and the Orkney Islands (OMIOT18).

With detailed breakdowns of each marine sector, policymakers can use multipliers to assess the potential ripple effect of implementing these plans in the short, medium, and long terms. Pre-estimations of marine plan impacts can help policymakers plan ahead and mitigate any adverse effects. Likewise, by making the UK+SRMFIOT v.1 collection publicly available[4], the aim is to facilitate policymaker and academic testing of different policy alternatives and navigation of marine environment-economy tensions.

4 *https://doi.org/10.15124/a76f2b2c-3dd6-435c-abae-a82b5413cafa*

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MSPACE is a three year project designed to drive forward the capability of the four UK nations in designing and implementing climate-smart marine spatial plans.

Led by Plymouth Marine Laboratory (PML) and funded through the Natural Environment Research Council (NERC) and Economic and Social Research Council (ESRC) via the research programme Sustainable Management of UK Marine Resources (SMMR) this project involves a wide range of partners bringing unique skills and expertise together to help manage sustainably the UK's marine environment in a changing climate.

The highly integrated, multidisciplinary MSPACE project was co-developed between PML, University of York, University of Essex, Heriot-Watt University, Joint Nature Conservation Committee, Centre for Environment, Fisheries and Aquaculture Science, Agri-Food and Biosciences Institute, Marine Scotland, The Marine Biological Association, Marine Climate Change Impacts Partnership, Marine Management Organisation, Natural Resources Wales, The Seaweed Alliance, National Federation of Fishermen's Organisations, Scottish Pelagic Fishermen's Association, Ørsted and Aquamaps.

MSPACE

Marine Spatial Planning Addressing Climate Effects