MASTS Scotia-Canada Ocean Research Exchange Outcome report

How fisheries release carbon and how fisheries management can help the climate change agenda whilst protecting marine biodiversity

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1 Background

The world's fishing fleets interact directly with carbon cycles in three distinct ways, through emissions originating from the burning of fossil fuels (Parker et al., 2018), by the removal of carbon in the form of fish (Mariani et al., 2020) and other seafood product biomass and by the impacts that bottom fishing gears have on marine sea floors (Epstein et al., 2022). With an increasing drive for many industrial sectors to reach carbon neutrality and reduce environmental impacts, all industries need to play their part by better understanding their impacts. However, research on carbon emissions and cycling in fisheries is sparse compared to many terrestrial industries. This provides an opportunity for important research to build a comprehensive, robust knowledge base on how fisheries interact with global carbon cycles.

This PhD will be the first important step in developing the evidence base to support a 'climate-smart' UK fishing industry, understanding the industry's pathway to net zero. The triple-bottom-line importance covering: economics (the costs associated with fuel emissions and changes in management); ecology (the marine and atmospheric 2 impacts of changes in fisheries behaviours); and social well-being (the ramifications of new management approaches based on the integration of carbon accounting into traditional management), means this work is primed to inform global drives for blue economic futures and the UN's 2030 Agenda for Sustainable Development Goals (SDG) (12, Responsible Consumption and Production; 13, Climate Action and; 14, Life Below Water). This project and the wider PhD have the potential to feed into other SDGs and will be of interest to COP26, and similar conferences.

The primary research aims that structure this PhD thesis focus on the Green House Gas (GHG) emissions of the UK fishing fleet and the disturbance of benthic carbon stores. There are four chapters, with each chapter addressing a specific aim. The aims are further broken down into achievable objectives, that collectively work together to address the overall aim of the chapter, and ultimately the PhD.

- Chapter 1: Accounting for Green House Gas emissions in UK wild capture bottom contacting fisheries
- Chapter 2: What is the current benthic habitat condition across the UK Economic Exclusion Zone
- Chapter 3: Understand the risks that bottom fishing gears pose on habitat organic carbon
- Chapter 4: Using knowledge gained on benthic carbon disturbance and GHG emissions identify trends in GHG performance

The scope of this research is focused on vessels operating in the UK Economic Exclusion Zone (EEZ) using Mobile bottom-contacting gears (MBCGs), analysis of these vessels makes comparisons between the fleet segments as defined by Seafish. Fishing vessels deploying MBCGs are the focus of this work because MBCGs are considered to have the greatest benthic disturbance (Sciberras et al., 2016); marine habitats are known to store significant quantities of organic carbon (OC) for geological periods relevant to climate mitigation strategies (Nellemann et al., 2009); and MBCGs produce more GHG emissions per kg of landed seafood produce (Parker et al., 2018). The Seafish reporting MBCG fleet segments were selected as the focus of this research because Seafish is the primary investigating body in the UK for understanding GHG in the UK fishing fleet and release other relevant management reporting metrics such as quota and landings. Where data is used across multiple chapters, the same data source is used to facilitate comparisons.

2 How has SCORE helped?

Chapters 1 and 4 are partially funded by the MASTS Scotia-Canadian Ocean Research Exchanges (SCORE) and therefore the focus of this outcome report. A research trip was undertaken and hosted by Peter Tyedmers at Dalhousie University, Halifax, Nova Scotia in August of 2022. Peter is leading research in the field of food systems Life Cycle Assessments (LCA) and is a co-author of the key peer-reviewed literature focusing on the GHG emissions of fishing fleets globally (Gephart et al., 2021; Hallström et al., 2019; Parker et al., 2018; Sandison et al., 2021). Dalhousie University also has exclusive access to the Fisheries Energy Use Database (FEUD), a database containing published estimates for GHG emissions of different food systems, including fishing per gear type, fishing area and vessel size. FUED was built by Peter and colleagues and is currently maintained by Peter. While at Dalhousie, Peter helped me narrow the research aims and scope of the PhD, advise on the methodological approaches used to infer GHG emissions and share key literature, data, and contacts in the field. Chapters 1 and 4 will be standalone published peer-review literature, co-authored by Peter, increasing international institutional collaboration. The SCORE program was a great success, and I would be happy to support future applicants.

3 Chapter 1: Accounting for GHG emissions in UK wild capture bottom contacting fisheries

Aim: An accounting of Green House Gas emissions in UK wild capture bottom contacting fisheries

Objectives:

1) Present an accounting of GHG emissions per bottom contacting gear fleet segment (expressed as GHG per catch weight (tonnes), catch value (£) and sea days) for UK Mobile bottom contacting vessels (2008-2021).
2) Present an account of GHG emissions for the top 10 key commercial species, by value and weight, caught by UK Mobile bottom contacting vessels (2019-2021)

Energy intensity and fuel efficiency are well studied (Greer et al., 2019; Muir, 2015), primarily driven by the oil price crisis in the 1970s and the need to reduce production costs (Tyedmers, 2001). This early work indicates that: fuel consumption can account for 75 - 90% of the total GHG emissions; fuel consumption is much higher for vessels deploying bottom contacting gears than pelagic gears; and, fuel use increases proportionally to engine size (Figure 1, (Tyedmers, 2001)). More recently, however, all food systems have come under increasing pressure to reduce their contribution to climate change and biodiversity loss, which has renewed the research focus on fuel consumption with a priority on reducing GHG emissions. While GHG emissions can be influenced by fleet structure (Parker et al., 2018), gear adaptations (Caslake, 2021), fishing behaviour and management (Bastardie et al., 2022), how changes in these areas can work collectively to reduce the GHG emissions of the UK fleet are still largely unknown. To address this, a present account of GHG emissions across the UK commercial fishing fleet is needed to identify factors that lead to lower GHG emissions and inform which fleet segments should be targeted for early implementation of GHG reduction strategies. Two approaches are used to estimate the GHG of the bottom contacting fishing gears in the UK MBCG fleet (Annex: **Error! Reference source not found.**):

A) Use Tyedmers, 2001 existing correlation analysis of fishing effort (days at sea) and engine power (kW) to infer fuel consumption and estimate GHG emissions. A wealth of publicly available data can be used to help infer GHG emissions for the UK fishing fleet (available from the Seafish UK fleet enquiry tool for 2008-2021). Following UK advice, litres of fuel burned can be converted to GHG emissions (CO_2, CH_4, N_2O).
B) Collecting new data on fuel use, vessel specifications, and fishing behaviour directly from fishing companies and port authorities via interviews to update Tyedmers, 2001 work and estimate GHG emissions.

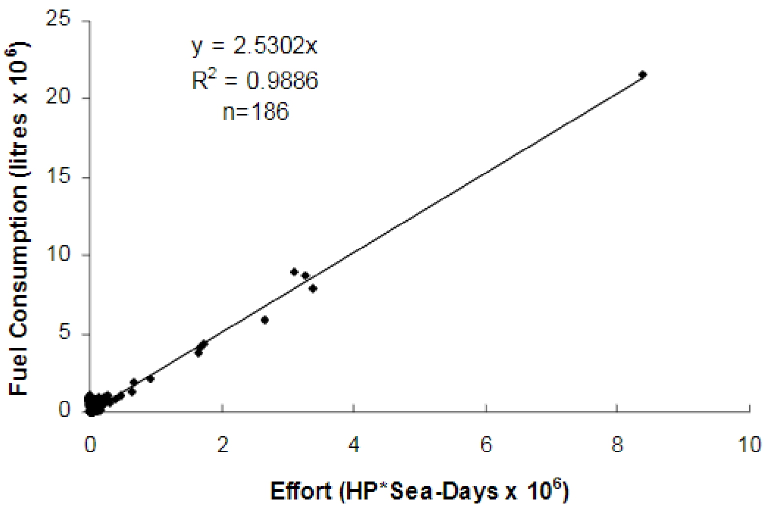

Figure 1: *Energy consumption relationship for all gear types combined (from Tyedmers, 2001).*

Catch data, relating to landing weight (kg) and species composition, per fleet segment can also be extracted from the fleet enquiry tool which can be used to calculate the GHG emissions emitted per annual total catch weight (tonnes) (2008-2021); the annual catch value (2008-2021) and the total number of days at sea annually (2008-2021) **(OBJECTIVE 1)**. Furthermore, catch data per MBCG fleet segment is available down to the species level, therefore, it would be possible to look at GHG efficiency for the top ten commercial species in terms of landing value and landing weight from 2019-2021. For example , to varying extents, all species will be caught by multiple gears and fleet segments. We will therefore calculate the overall GHG emissions for a species and compare it to the other commercially important species **(OBJECTIVE 2)**. Three years is selected for this analysis because the calculations will take longer and only three years are needed to account for any economic and environmental variability.

The GHG emissions inferred through Method (A) could be validated from information contained in the FEUD (Wayne & Parker, 2016) and Method (B). FEUD is a database, maintained by Dalhousie University, containing published estimates for GHG emissions per gear type, fishing area and vessel size.

Methods A and B work synergistically with one another. The results of Method (A) set the groundwork for Method (B), providing a way to fill any data gaps in the primary data collection. Equally, Method (B) builds on (A) by providing a way to re-analyse the relationship between effort and fuel consumption; estimate the GHG emission of non-fuel substances (Table 1) and gather anecdotal information on vessel specifications and fishing behaviour.

Table 1: Sources of GHG emission considered in this analysis

To include	To exclude
Fuel*	Fuel for trucks
Electricity onboard	Onboard or land processing
Ice	Packaging
Refrigeration**	Fishing gear maintenance & renewal
Other fluids/lubricants	Ship maintenance & renewal
Antifouling paints	Waste
Onboard processing - ask what they land, whole fish, gutted fish, or fully processed fish (and approx. proportions of each if it is mixed)	-

*May need to ask for fuel type as well. Do vessels in the UK use different types of fuel?

** refrigerant you will need type, how much annually, type of refrigerator, maximum refrigerant capacity (how much R it can hold), use of refrigerator (days at sea only?), fuel use or electricity to run R. See if vessel owners have receipts from annual servicing of refrigerant

Approach (B) involves gathering primary data on fuel use, vessel specifications, and fishing behaviour directly from vessel owners, skippers, fishing companies and/or port authorities. Anecdotal information will be collected via interviews, either in person or over the phone, and where needed, additional detail needed to reliably estimate GHG sources (Table 1) will be gathered from managers and third parties. Third parties could be, for example, port authorities which refuel vessels and issue invoices to POs/vessels. Interview questions are to be directed at skippers and/or vessel owners, depending on availability. Interviews will be organised and information by: (i) contacting Producer Organisation (PO) managers, both via UKAFPO and by individually ringing and emailing them; (ii) investigating further who the key players are in each county, where is the data and whom it is shared with; (iii) far-reaching searches on LinkedIn and contacting people directly; (iv) port visits around the UK.

4 Chapter 4: Using knowledge gained on benthic carbon disturbance and GHG emissions identify trends in GHG performance

Aim: Using knowledge gained on benthic carbon disturbance risks and GHG emission accounting work (Chapters 1-3) to identify trends in GHG performance.

Objectives:

1) For key commercial species identified examine the relationship between, fishing behaviour (days at sea), seasonality, stock size and GHG emissions (Chapter 1) (e.g., see Byrne et al., 2021)
2) Make comparisons of the total annual average GHG emissions to other food production sectors and the overall UK GHG emissions budget

In Chapter 1 we identify the top ten landed species (by value and weight), the scope of Chapter 1 will be further reduced in Chapter 4 to focus on the top four GHG-emitting species. For these four key GHG emitting species, in this chapter, we will examine the relationship between, seasonality, stock size and GHG emission per unit catch **OBJECTIVE 1**. Studying the effects of seasonality is important to understand if GHG savings can be made by changing when you fish. Adapted from Byrne et al., 2021 and Chapter 1, the GHG emission per unit of catch is calculated from two components, total GHG emissions and average landing weight (tonnes) or value (£). Catch data (weight and value) is available per fleet segment down to the species level, however, the analysis also requires a good understanding of the predicted stock size per month which may not be available for all the selected species from Chapter 1. If estimates are not available for monthly stock sizes, the seasonality component could be dropped and the objective focus on understanding the relationship between GHG emission per unit of catch and stock size instead. This is equally as important because the GHG emissions per unit catch decreases with increased stock size (Bastardie et al., 2022) and can be analysed by reviewing the GHG emissions per unit of catch and stock size over longer timescales (2008-2021). Studying this relationship could help identify which depleted stocks may be rebuilt to reduce GHG emissions (Byrne et al., 2021).

Objective 1 outcomes can be reviewed alongside work undertaken in Chapter 3 to provide an overall carbon footprint for selected MBCG Seafish segments.

The final objective (**OBJECTIVE 2**) of this chapter takes the total GHG emissions estimated in Chapter 1 for the Seafish MBCG and first evaluates how MBCG perform compared to other food products, such as beef and pork, drawing on information contained within FEUD. The second approach presents the total MBCG fishing GHG emissions as a fraction of the overall UK GHG budget, alongside other food products and industrial sectors. GHG emissions reporting in the UK groups GHG emissions into broader categories termed National Communication (NC) sectors. However, it's unclear where the fishing industry sits within the NCs.

5 Expenditure

Name of grant		**Amount Awarded**
MASTS Scotia-Canada Ocean Exchange		£3,964
Expenditure	**Spent to date**	**Remaining to date**
Return flights to Canada	£728.55 25/03/22	£3235.45 25/03/22
Accommodation in Halifax	£2149.38 30/03/22	£1,086.06 30/03/22
Transfers and travel in Halifax	£395.32 August	£690.68 August
Food subsistence	£671.77 August	£18.91 August
The remaining covers Bank transaction fees. Other subsistence costs were paid for out of my savings.		
In-kind contributions	**Spent to date**	**(£)**
Johnson (support time) – approx.	5 days	2,500
Tyedmers (support time) - approx.	5 days	2,500

6 References

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