Framework for performance analysis and benthic impact assessment in bottom-contacting trawl fisheries

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Background

Towed bottom-fishing gears, such as bottom trawls and dredges, are widely used in commercial fisheries but represent one of the most significant sources of physical disturbance to seabed habitats (Hiddink *et al.*, 2017; Amoroso *et al.*, 2018). These gears function by being dragged across the sea floor, directly interacting with the substrate and the benthic communities. This mechanical action disrupts sediment structure, reduces habitat complexity, and can lead to the mortality of a wide range of benthic organisms, including sessile invertebrates like sponges, bivalves, and cold-water corals (Rijnsdorp *et al.*, 2017).

The ecological impacts of such disturbances are not limited to the immediate removal of fauna. Towed gears can alter community composition, decrease biodiversity, and impair the recovery potential of sensitive habitats, especially those characterized by slow-growing or long-lived species (Hiddink *et al.*, 2017). The severity of these impacts depends on several factors, including the type of gear used, the intensity and frequency of trawling, and the vulnerability of the seafloor habitat.

Recent scientific advances, including spatial modelling and meta-analyses of empirical data, have provided robust estimates of how trawling intensity correlates with reductions in benthic biomass, production, and diversity (Rijnsdorp *et al.*, 2016; Rickwood *et al.*, 2025). These findings underscore the need for improved management strategies to minimize the footprint of towed gears and promote the resilience of marine ecosystems.

Recent studies suggest that bottom-trawling may play also a considerable role in disturbing carbon-rich sediments, thereby contributing to global carbon emissions. However, these estimates remain highly uncertain, primarily due to data limitations concerning gear characteristics, operational practices, and environmental variability (Rickwood *et al.*, 2025).

To address these uncertainties, there is a pressing need for a comprehensive understanding of how bottom-contacting fishing gears operate and interact with the seabed. A major uncertainty is the estimation of the area of seabed disturbed by applying European-based vessel size to gear footprint relationships (Figure 1) to the global fleet, thereby assuming these relations hold worldwide (Eigaard *et al.*, 2016a). An improved assessment of gear performance, fuel consumption, and seabed impacts is essential to develop accurate models of fishing effort and ecological footprint (Parker *et al.*, 2018; Sala *et al.*, 2022).

The recent publication by Rickwood *et al.* (2025), to which the PhD candidate contributed as a co-author, presented predictive models of fishing gear performance based on basic vessel characteristics and the type of gear employed. However, the study was limited by the insufficient availability of detailed gear-specific parameters in both the published literature and the vessel registries accessed during the model development phase. As a result, the authors were unable to conduct regionally specific analyses of gear performance, leading to necessary simplifications in the modelling approach.

This limitation will be directly addressed through the current PhD project, which aims to develop a more robust and geographical understanding of fishing gear performance, particularly focusing on parameters such as the maximum width of otterboards and nets.

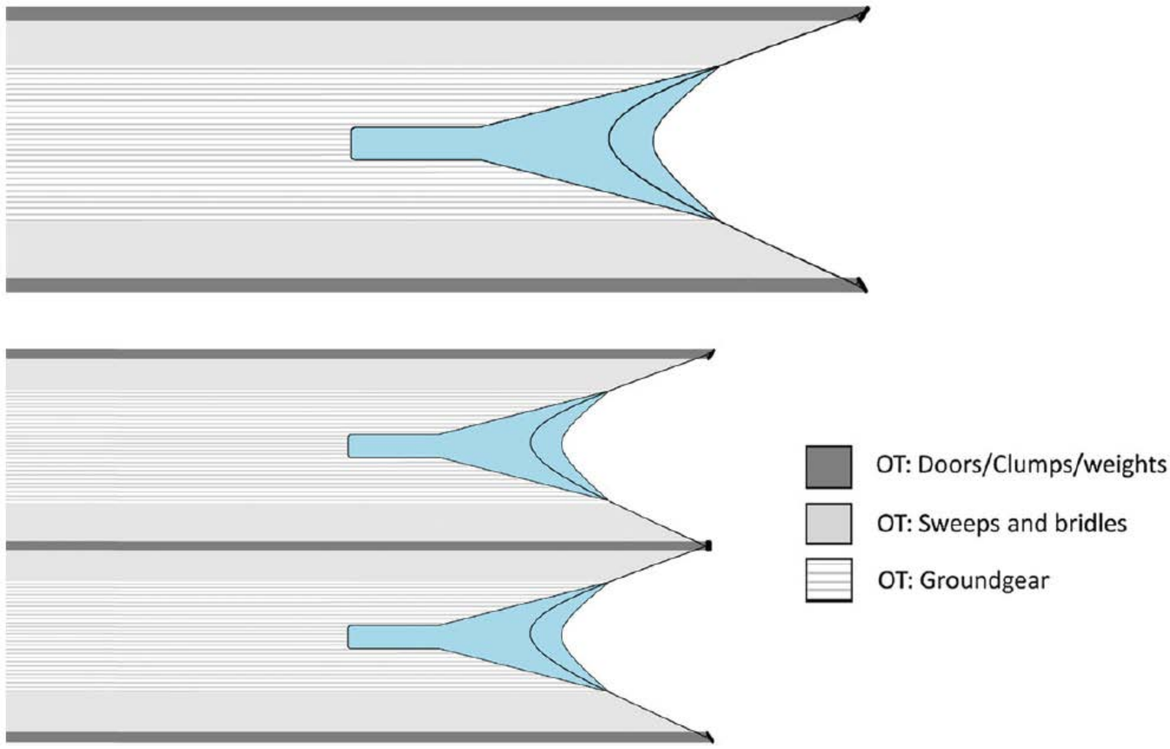

Figure 1. Conceptual gear footprints of single OTs fished by one vessel or with two vessels when pair-trawling (top) and of twin-rigged Ots fished by one vessel (bottom). The conceptual footprint consists of three types of seabed impacts: (1) the track affected by the doors/clumps/weights, (2) the track influenced by the sweeps and bridles, and (3) the track affected by the trawl/groundgear itself. *Source*: modified and adapted from Eigaard *et al.* (2016b).

The project will initially concentrate on the Mediterranean region, drawing on data collected by the PhD candidate during scientific research cruises conducted over a 35-year career at the National Research Council (CNR). These cruises involved the direct measurement of gear performance at sea using underwater instrumentation and custom-developed software tools developed by the candidate.

Following this regional focus, the project will expand to incorporate the expertise and datasets of internationally recognised fisheries organisations, including the ICES/FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB). By engaging with these networks, the project will compile a globally representative database of mobile, bottom-contacting fishing gears.

This comprehensive dataset will include detailed information on vessel characteristics, gear configurations, and key operational parameters, providing a valuable foundation for global models of fishing gear performance based on vessel characteristics and gear operational parameters. In fact, by incorporating spatial data on fishing activity, the new models will identify fishing depth and therefore include other critical operational metrics such as towing cable length into the model.

When combined with environmental context, particularly sediment type, this will allow for more precise predictions of gear penetration depth and, consequently, more accurate assessments of benthic impact.

Overall, this PhD project seeks to address a critical knowledge gap by developing an integrated framework for globally assessing the performance of trawl fishing gears and their environmental impacts on the seafloor. Building on this scientific foundation, the project will focus on formulating practical, evidence-based models and solutions that support sustainable fishing practices while minimizing damage to benthic habitats and contributing to the reduction of greenhouse gas emissions.

Justification

Reliable estimates of the ecological and fishing footprint of trawl fisheries depend on detailed knowledge of the gears employed and their operational characteristics. However, global assessments often rely on data derived from a limited number of well-monitored fleets, particularly in Europe. This limits the ability to make accurate extrapolations to other regions where such data are lacking.

While advances in vessel monitoring systems (e.g., AIS, VMS) have improved our spatial understanding of fishing activity, there remains a critical gap in knowledge regarding gear diversity, configuration, and operational patterns. These factors significantly influence fuel use and seabed disturbance.

This PhD project seeks to address these deficiencies by focusing on the interaction between vessel and gear parameters with fishing footprint and fuel consumption, aiming to develop a methodological framework for performance assessment at both regional and global scales. By improving the accessibility of gear-related data, this work will support more accurate assessments of carbon emissions and benthic impacts and promote the sustainable management of bottom-trawl fisheries.

Objectives of the project and origin of the data

The overarching goal of this PhD project is to develop a globally applicable framework that supports the evaluation of fishing gear performance and the environmental footprint of bottom-contacting trawl fisheries. The specific objectives of the study include:

1. To review and synthesize existing literature on vessel and gear performance in bottom-trawl fisheries;
2. To develop novel tools for assessing gear performance, energy intensity, and emission profiles;
3. To investigate how gear performance varies with operational practices and environmental contexts;
4. To model the relationships between vessel/gear parameters and fuel consumption, gear geometry (e.g., door spread, horizontal net opening), and seabed contact;
5. To identify and address key sources of uncertainty in estimating the ecological footprint of trawl fisheries;
6. To propose standardized methods for reporting vessel and gear characteristics to support future innovation and policy development;
7. To explore innovative approaches to assess the seabed impacts and spatial footprint of bottom-contacting gear.

Data will be sourced from a combination of personal field experiments, existing scientific literature, fisheries monitoring systems, and collaborative datasets from partner institutions (e.g, ICES/FAO Working Group on Fishing Technology and Fish Behaviour, WGFTFB).

Project workplan and timeline

Phase	Task	Lead institutions	Deliverables
1. December 2025	Data collection on vessel and gear performance	CNR, Ancona	Comprehensive database integrating experimental and literature-based data
2. June 2026	Preliminary modelling of vessel/gear parameters with respect to fuel consumption and gear geometry (Mediterranean case study)	CNR, Ancona; University of Tor Vergata	Operative models and tools for analysing gear performance, fuel use, and carbon emissions by fleet and area
3. December 2026	Development of a global framework for vessel and gear parameter collection	CNR, Ancona; University of Tor Vergata; University of Exeter	Online tool for standardized data collection
4. June 2027	Final modelling of vessel/gear parameters related to fuel use, gear geometry, and seabed interaction	CNR, Ancona; University of Tor Vergata; University of Exeter	Refined models and analytical tools for assessing gear performance and emissions
5. December 2027	Final thesis and scientific dissemination	CNR, Ancona; University of Tor Vergata; University of Exeter	PhD thesis and peer-reviewed publications summarizing data analyses and final models

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