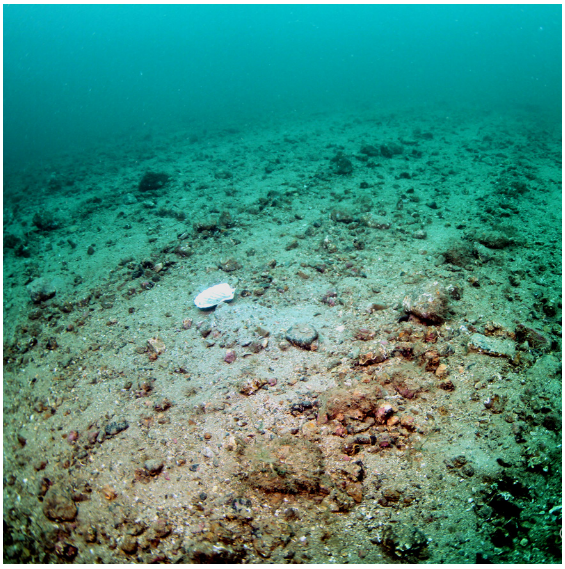
REPORT 2021

New perspectives on an old fishing practice: Scale, context and impacts of bottom trawling



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DS, JT, VRV, and FL conceptualized the report and coordinated its writing, editing, and review. DP, MLDP, and NB provided the reconstructed catch data and provided thought partnership for the report, as well as long-term investments into the SAU platform. ML provided expertise on bottom trawling in China and edited the report. JV contributed original content through the West Africa case study, guidance on methods for the social impacts section, and substantial comments on the report draft. SR and TC provided additional comments on the report draft. The authors would also like to thank Celeste Leroux of Virgil Group for her thought partnership, Mark Michelin of CEA Consulting for his review of materials, and Comms Inc. for its copy editing, report design, translation, and other communications support. Funding for this report was provided by Oceans 5, Oak Foundation, and Oceankind.

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Bottom trawling is a globally widespread fishing practice responsible for 26 percent of the total marine fisheries catch.[1] Bottom trawling is a method for catching aquatic animals that involves dragging a weighted net or rigid structure from a vessel along the seafloor. It is fundamental to the supply of a multitude of food (shrimp, whitefish, flatfish) and non-food (fishmeal and fish oil) commodities. It has played an outsized role in the industrialization and globalization of the fishing sector, becoming a mainstay of fishery economies in Europe, North America, South and Southeast Asia, East Asia, and West Africa. The vast majority of the fish caught by bottom trawlers (99 percent) is caught under the jurisdiction of coastal countries, in their exclusive economic zones (EEZs).

Bottom trawling has always attracted opposition and controversy. From 14th century "proto-trawling" to modern shrimp trawling, these fisheries have been consistently associated with social conflict (particularly in displacing traditional fishing practices), environmental degradation (in terms of contact with and penetration of the seabed as well as impacts on sensitive species) and lack of selectivity (in terms of indiscriminately catching a range of species). As a result, those involved with the practice have at times sought to minimize or obfuscate some of these impacts, while those seeking to limit it have sometimes been hyperbolic and unrealistic in their criticisms and solutions. Yet there is a surprising level of consensus among the fishing industry, researchers, governments, civil society, and NGOs that bottom trawling presents unique and critical challenges to environmental, social, and climate goals for fisheries.

This report seeks to provide new perspectives on this historical controversy by presenting the most up-to-date synthesis of available data and evidence on bottom trawling's extent, impacts, and solutions in order to inform constructive policy-making. Specifically, it uses novel data analysis from Sea Around Us to map the global extent of bottom trawling; a synthesis of peer-reviewed literature to elucidate environmental, social, and climate impacts; and insights from more than 40 global experts on what a constructive future might look like that manages or severely

[1] This statistic includes catch caught both in the exclusive economic zones of countries (EEZs) as well as on the high seas. Bottom trawling is also responsible on average for 26 percent of the catch within EEZs globally. There is also some bottom trawling in freshwater fisheries (e.g., Lake Victoria) but that practice is not included in this report.

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limits the worst impacts of this practice, while also ensuring a just and equitable society and a healthy food system.

Key findings of the report include:

- **Bottom trawlers catch 26 percent of the total global marine fisheries catch.** In the most recent decade for which there is data (2007-2016[2]), more than 99 percent of all bottom trawling occurs in the EEZs of coastal countries, and less than 1 percent on the high seas. The total amount of seafood caught by bottom trawling annually in EEZs is roughly equivalent to all of the seafood caught by the world's artisanal fishers.
- **Bottom trawling is most intense (as measured by catch per unit area) within the territorial seas of coastal states.** Approximately 20 percent of bottom trawling within EEZs occurs less than 12 nautical miles from shore (areas defined as territorial seas), despite territorial seas making up less than 10 percent of total EEZ area. The average trawling intensity in territorial seas is on average double the average trawling intensity within EEZs overall. Areas close to shore also tend to be fished by artisanal and small-scale fishers, which may contribute to conflict between artisanal fishers and industrial bottom trawlers.
- **Asia is the locus of fish caught by bottom trawls; 50 percent of all bottom trawled fish is caught in the EEZs of Asia or by the foreign fleets of Asian countries.** China, Vietnam, Indonesia, India, and Morocco are the top five bottom trawling countries, as measured by average catch over the most recent decade for which there is complete data (2007-2016). China alone catches 15 percent of the total bottom trawled catch. Whereas bottom trawling is growing rapidly in Asia, it is declining or staying constant in most other parts of the world.
- **Distant water fishing fleets catch 22 percent of all the fish caught by bottom trawlers in EEZs.** These fleets are predominantly of Asian or European origin, and fish in the EEZs of Africa and Oceania. In 34 countries – mostly in Africa – over 90 percent of the catch caught by bottom trawlers is caught by foreign-flagged vessels. These figures could be even higher, given the significant amount of distant water fishing that is thought to be illegal, unreported, or unregulated.
- **There is general agreement that the environmental impacts of bottom trawling represent unique challenges when compared to other fishing gears.** The practice stands alone among fishing gears in that it can be conclusively linked to all three of the major impacts of fishing on marine biodiversity: overfishing, bycatch, and seabed contact. It is the only gear type that requires sustained contact with and often penetration of the seafloor in a manner that can degrade and destroy marine habitats. Despite this agreement between academia, NGOs, the fishing industry, and fisheries managers, major areas of contention remain. These include bottom trawling's spatial footprint, the local character of its impacts (historic and present-day), and which solutions are viable or desired given competing goals for fisheries.
- **Bottom trawling contributes to greenhouse gas emissions through its high fuel use and the disturbance of carbon-containing sediments on the seafloor.** Of the major gear types used in global fisheries, bottom trawling has the highest emissions from fuel use. Seafood caught by bottom trawling has equivalent or higher associated greenhouse gas emissions than most meat, except lamb and beef. Novel, early-stage research on the disturbance of sediments caused by bottom trawling suggests it could contribute up to 1.46 Gt CO_2-eq in annual emissions, a level of emissions that would put it on par with the aviation sector.
- **Bottom trawling is also associated – positively and negatively – with social impacts including economic impacts, violence and conflict, food security, human rights abuses, and occupational health and safety.** While these impacts are not well studied and can vary by context, bottom trawling presents a unique threat to the livelihoods, cultural practices, and well-being of small-scale fishers, especially those in the tropics.
- **Solutions to address environmental impacts of bottom trawling typically fall into two categories: efforts to manage impacts, and efforts to limit the practice.** Fisheries management measures have been demonstrated to be effective in reducing (but not eliminating) many negative environmental impacts from bottom trawling, at relatively minimal social or economic cost. However, the effectiveness of these measures is largely a result of good governance – which tends to be absent in the regions of West Africa and Asia where most bottom-trawled seafood is currently caught. Efforts to limit the practice can more comprehensively address the full range of bottom trawling's environmental impacts, but they can be highly contentious and often do not include viable social or economic solutions for those who are displaced by the changes.
- **More work is needed to identify solutions that can avoid, minimize, or mitigate the social and economic outcomes associated with bottom trawling.** Although an increasing number of frameworks and tools exist to address the pervasive social challenges associated with fisheries more broadly, these frameworks are far from being widely adopted and are not specific to the

[2] Since the bulk of the work on this report was completed, the Sea Around Us data have been updated to 2018; the update did not alter any of the patterns and trends reported here.

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challenges associated with bottom trawling. Human rights due diligence, exclusive access for small-scale fishers in nearshore waters, and just transition economic packages are just some examples of solutions that may help to guard against negative social or economic outcomes for fishers, fishworkers, and others involved in the sector.

- **The marine conservation and fisheries management communities need to look beyond purely technical measures for solving the challenges inherent to bottom trawling.** Bottom trawling is an entrenched global practice, and solutions that fail to adequately consider or address the key political, social, or economic dynamics at play in the sector are unlikely to succeed and will make it harder to achieve Sustainable Development Goals associated with fisheries.

Building on these insights, the report concludes with a set of recommendations for constructive action, to transform the status quo around bottom trawling (under the acronym "TRANSFORM"). These recommendations for fisheries decision-makers, managers, fishing industry leaders, and advocates include:

- **Transition the system:** Bottom trawling supports a set of complex, distinct food and non-food commodity systems that are globally interconnected. Solutions must consider broader dynamics – such as broad social changes in fishing culture, the rise of the global seafood trade, and food consumption patterns – in order to avoid unintended consequences, such as effort displacement. Solutions to manage or limit bottom trawling should not be viewed in isolation by policymakers, fishery managers, NGOs, or communities.
- **Respect human rights: To catalyze meaningful improvement in bottom trawl fisheries requires a human-centered approach.** This means respecting both the civil and political rights, as well as the economic, social and cultural rights of those working in and affected by such fisheries. Bottom trawl fisheries – and policy changes relating to them – must abide by a minimum standard of "do no harm." More baseline research into socio-economic impacts and possible solutions (especially distributional impacts) should accompany these efforts.
- **Accelerate the transition to best practices:** Modern management practices – from gear innovation to enhanced observer coverage – have dramatically improved the performance of some bottom trawl fisheries, particularly in stabilizing overexploited stocks, increasing selectivity, and reducing seabed pressure especially in Vulnerable Marine Ecosystems (VMEs). Urgent efforts are needed to export these practices to regions that require them most, particularly in low and middle-income countries in the tropics.
- **Negotiate political action:** Decision-makers must recognize the unique biodiversity, climate and social conflict challenges associated with bottom trawling and legislate for it as a special case – both through national policies and international standards and agreements. As well as making bold, gear-specific policy decisions, this should also include acknowledging the significant investments and trade-offs needed to adequately resource any transition away from bottom trawling.
- **Stop harmful subsidies:** Definitions of "harmful" subsidies must include those accessed by specific fisheries using the highest impact practices, including bottom trawl fisheries. Conversely, subsidies supporting transition out of (or to improve) practices such as bottom trawling should be considered "beneficial."
- **Freeze the footprint:** Given the multitude of unresolved challenges around bottom trawling – at global and local levels – any new or expanded fisheries should be regarded as politically, socially, environmentally, and economically inappropriate.
- **Open up dialogue:** Discourses around bottom trawling from the fisheries and conservation sectors do not tend to emphasize common ground. Bold alliances and painful but necessary compromise are needed to meet the twin climate and biodiversity crises, including between sectors with different material interests.
- **Restrict appropriately:** Ecologically and culturally sensitive areas must be protected from bottom trawling through a coherent area-based approach to such fisheries, encompassing inshore and offshore exclusion zones as well as all classifications of marine protected areas (MPAs).
- **Monitor impact to support adaptive management:** While all best-practice fisheries require significant volumes of real-time information, bottom trawling management (with its reliance on expensive and complex seabed sensitivity data) necessitates robust, collaboratively funded research. As well as near-term management-focused monitoring, special attention should be directed to emerging areas of trawling research, especially life cycle analysis and carbon emissions arising from seabed disturbance.

1 Introduction

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1. Introduction

This section provides context for why bottom trawling as a fishing gear is both important and controversial, as a foundation for why this report is needed at this time.

Marine fisheries are a major component of global food production, contributing 14 percent of edible food derived from animals and forming a vital part of the aquatic production system that supports the sustenance of 3.3 billion people.[i,ii] These catches are the products of the ocean's huge and diverse ecosystems. Marine fish and crustaceans alone make up nearly two-thirds of the biomass of all animal life on Earth (nearly 190 times the biomass of all wild mammals and birds).[iii]

Ensuring that fisheries are environmentally sustainable, socially equitable and have a minimal climate footprint is central to creating a healthy, just society and a livable, flourishing planet. Environmental, social, and climate goals for fisheries are enshrined in the United Nations' Sustainable Development Goals, particularly Goal 14 "Life below water", but also more socio-economically oriented SDGs including Goal 1 "No poverty", Goal 2 "Zero hunger", Goal 10 "Reduced inequalities", and Goal 12 "Responsible consumption and production". Fisheries are also deeply connected to other environmental goals such as those relating to climate change and biodiversity, including Goals 13 and 15, "Climate action" and "Life on land".[iv]

Bottom trawling is one of the world's dominant fishing methods and is responsible for 26 percent of the marine fish catch in Exclusive Economic Zones (EEZs). Bottom trawling has played an outsized role in the industrialization and globalization of fisheries, particularly the rapid transition from sail to steam to diesel-powered trawling between the late 19th and early 20th centuries, and the commensurate increases in marine fish catch over the past century.[v] As a catching practice, it has become a mainstay of fishery economies in Europe, North America and East Asia and has experienced a post-1950s boom in emerging coastal economies in South and Southeast Asia and West Africa. It is used to catch a multitude of food commodities (shrimp, whitefish, flatfish) and provides the raw fish required for several important non-food commodities (fish meal and fish oil).

Over the course of this historical development, bottom trawling has always attracted opposition and controversy. From 14th century "proto-trawling" to modern shrimp trawling, these fisheries have been consistently associated with social conflict (particularly in displacing traditional fishing practices), environmental degradation (in terms of seabed pressure and impacts on sensitive species) and lack of selection (in terms of indiscriminately catching a range of species). Arguments in support of or against trawling have frequently been reactive, hyperbolic, and obfuscatory – pitting environmental groups and small-scale fishing communities against fisheries managers and the seafood industry, each group holding on fiercely to its own self-interest in lieu of compromise or common sense (See Table 1).

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Table 1 Common arguments for and against bottom trawling

Common anti-trawling arguments	Common pro-trawling counterpoints
"Bottom trawling is an unselective fishing gear that catches seafood indiscriminately."	*"There is no other way to catch these fish at a scale demanded by the seafood market."* *"Bottom trawl fisheries can be managed to reduce environmental impacts."*
"Bottom trawling displaces the livelihoods, cultural practices, and food security of small-scale fishers."	*"Bottom trawling is an efficient way to catch seafood in order to meet market demand"*
"Bottom trawling causes widespread and often irreversible harm to marine seabed ecosystems."	*"Bottom trawling does cause damage, but the impacts are often not as bad or as widespread as is claimed."* *"Certain areas that are already heavily trawled cannot be recovered and are viable locations for continued bottom trawling."*

While the issues associated with bottom trawling are fiercely contested, there is relative consensus (across academia, civil society, fisheries managers, and the fishing industry) that it is unique among fishing practices in terms of its environmental impacts. Bottom trawling is the most widespread anthropogenic source of physical disturbance to the seabed.[vi] In surveys of the fishing industry, NGOs, academia, and fisheries managers, bottom trawl gears rank highest among all fishing gears in terms of their environmental impacts (see Section 3: *State of the evidence: environmental impacts* for a more in-depth discussion of this point).[vii] Yet everything from its spatial footprint to the specific, local character of its historical and current impacts has created entrenched polarization. While fisheries managers generally focus on aligning bottom trawling with the standards applied to all fisheries, civil society organizations tend to advocate for a more "gear-specific" approach of measures that apply solely to bottom trawling, driven by its cumulative environmental, social and climate impacts. Reconciling such fundamental divisions is key to ensuring global progress in securing sustainable and equitable fisheries.

Bottom trawling presents unique and critical global challenges to the environmental, social, and climate goals for fisheries. All fishing gear types should be considered subject to the SDGs, especially Target 14.4 relating to ending "overfishing" and "illegal, unreported and unregulated fishing." However, bottom trawl fisheries represent unique additional challenges for the global goals and other international frameworks and standards, particularly in ensuring international progress in tackling "destructive fishing practices" (also enshrined in SDG14, leveraging off the UN Food & Agriculture Organization's Code of Conduct for Responsible Fisheries and other related frameworks such as UN General Assembly resolution 59/25 on high seas fisheries).

This report assesses the current state of global evidence around the status, extent and impacts of bottom trawling. The authors believe that the acceleration of environmental and social justice concerns in fisheries in recent years makes it a ripe time to revisit our understanding of the role of bottom trawl fisheries in achieving a sustainable planet and a thriving society.[vii] Finding lasting solutions to the unique challenges posed by bottom trawling is fundamental to the growing international focus on the role of a healthy seabed in maintaining a livable planet, which includes concerns about deep-sea mining and the emerging evidence of seabed carbon loss.[ix,x] Other topical political commitments include preserving seafloor integrity (e.g., in the new EU Biodiversity Strategy), a proposed moratorium on deep-sea mining, and more broadly for industries to go beyond "do no harm" principles and be active "contributors to an overall nature positive future" (e.g., in the UN Convention on Biological Diversity's Post-2020 Draft Global Biodiversity Framework).[xi,xii] Equally, increasing recognition that there are deep, regionally-specific social inequalities in how fisheries are managed requires a particularly precautionary approach to bottom trawl fisheries in areas of minimal marine governance, transboundary exploitation and contested fishery access.[xiii]

To conclude the report, the authors propose a broad framework of high-level recommendations to "TRANSFORM" the status quo around bottom trawl fisheries. The authors hope to inspire constructive, inclusive, and meaningful action to reduce the well-evidenced negative impacts of these fisheries and accelerate progress towards a healthy and just society, a thriving ocean, and a livable planet.

2 Definitions and historical context

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2. Definitions and historical context

This section defines what bottom trawling is and discusses its various forms. It also provides historical context for the development and extent of bottom trawl fisheries. It concludes by considering key debates about whether bottom trawling is an "inherently destructive" practice and definitionally "industrial" as a fishing gear.

Definitions and key terms

Bottom trawling is a widespread fishing practice that involves dragging a weighted net or rigid structure from a fishing vessel along the seafloor. The practice is used to catch bottom-dwelling fish (cod-like fish and flatfish), mollusks, swimming crustaceans (shrimp/prawn), or non-specific (mixed) demersal species. The term "bottom trawling" is often conflated with the word "trawling" which refers to both bottom trawling and pelagic trawling (the towing of a net through the water column).[3] This report focuses on the practice of bottom trawling, but calls out some instances where evidence or impacts are conflated.

The ecology of target species, especially their habitat preferences, drives patterns of bottom trawling exploitation. The extent to which target species are benthic (i.e., flatfish and shellfish that live and feed only on the seabed substrate), benthopelagic (i.e., groundfish that live and feed close to, but not always on, the seabed substrate) or infaunal (i.e., some shrimp species that form burrows in the seabed) influences the design and physical properties of the gears and vessels needed to catch them. The nature of these species' preferential substrate (i.e., from hard to soft substrate; from complex, multi-dimensional seabed structures to simple, high-energy plains; from shallow to deep waters) also determines how, where and what forms of bottom trawling take place on the global seabed.

A diverse array of distinct fishing gears can be used in bottom trawling. The UN Food and Agriculture Organization (FAO) defines a bottom trawl as "a cone-shaped net towed on the seabed and designed to catch fish living on or near the seabed."[xiv] FAO lists six specific gears under this category in its global classification of fishing gears, principally separated by the technology used to keep the trawl net open (either "beams" or "otter boards") or the number of trawl nets deployed (single, twin/pair or multiple).[xv] An additional two "towed demersal gears" (gears that are also intended for use on the seafloor and are towed from a vessel but have different properties to bottom trawl gear e.g., dredges) are also relevant to this report (see Table 2).

[3] Midwater (or pelagic) trawling – a practice that involves towing a trawl net through the water column to target pelagic species – is not within the scope of, and should not be confused with, bottom trawling.

Distinguishing between gears is important as their typical configuration, use, and deployment are highly distinctive – and this influences their potential environmental impacts. Some towed demersal gears are designed to penetrate the seabed (e.g., the row of metal "teeth" on a scallop dredge) while others are designed only to transit along it. In some cases, the entirety of the catching device contacts the seabed whereas in others it is only the main, lower part of the net (e.g., the footrope of a flatfish pair trawl). While all towed demersal gears should be considered to exert some inherent level of pressure on the seabed, impacts associated with bottom trawling fisheries are not uniform in their character, scale, or consequences. Bottom trawls (beam and otter trawls) involve less penetration of the seabed than the use of dredges, and therefore cause less overall depletion of biomass per single trawl pass (6-14 percent for bottom trawls vs. 20-41 percent for dredges).[xvi] Although bottom trawls have less impact at a local level, their use and spatial footprint is far more widespread than dredges, and they are responsible for 26 percent of all seafood catch as compared to <1 percent for dredges.[4] For the remainder of this report the term "bottom trawl" applies only to bottom trawl gears, and not dredges.

The range of bottom trawl gear types and target species have led to such fisheries emerging in diverse national and international jurisdictions (which in turn influences their potential social impacts). Where bottom trawl fisheries take place (i.e., inshore or offshore waters; temperate or tropical zones) influences the scale of the fleets and the sizes of the vessels needed to effectively deploy these gears. These parameters in turn influence the magnitude of investment needed to undertake extraction of specific bottom-trawled commodities. Fisheries closer to shore tend to be operated by more numerous, smaller vessels and fisheries offshore by fewer, larger vessels, although this distinction is not consistent. A bottom trawl fishery can be anything from the six to seven vessels of various countries targeting orange roughy on the high seas off southwest Africa (all vessels 80 m or longer), to the more than 1,000 "baby" inshore shrimp/finfish trawlers in Cambodia, all below 12 m, working in a very small shelf area.[xvii,xviii]

Fundamentally, the most common property of all bottom trawling practices is the requirement to make sustained contact with the seabed. Differences of scale, impact, controversy, and level of management arise when considering target species and where they live, the specific technologies most appropriate to catch those species, and the social and economic conditions surrounding the location where trawling is taking place.

[4] This number includes catch in EEZs and catch on the high seas. Source: Pauly D., Zeller D., Palomares M.L.D. (editors). 2020. Sea Around Us Concepts, Design and Data, seaaroundus.org.

2. Definitions and historical context

Historical context: the emergence and growth of bottom trawling

Towing or dragging demersal gears along the seabed has happened, and been controversial, for at least 600 years of human history. The earliest known references to the fishing practice of bottom trawling come from the 13th and 14th century United Kingdom, the 16th century Netherlands, 17th century Japan and 18th century France.[xxi,xxii] In most of these cases, the references are from petitions to decision-makers to restrict the use of these proto-trawl fisheries – known variously in northwest Europe as “wondyrchroum” and “wonderkuil,” terms roughly translating as “marvelous fishing trawl” – citing as their rationale the loss of juvenile fish, the destruction of benthic habitat, and the outcompeting of existing methods.[xxiii]

Temperate water bottom trawl fisheries became industrialized first, prior to the 20th century. From the 1850s onwards, driven by the industrial revolution in Europe and North America, bottom trawling vessels were designed for industrial operation. In the Northeast Atlantic the introduction of steam-powered hauling aboard bottom trawl vessels in the 1870s, and then steam-powered engines and otter boards in the 1880s, began a 140-year process of rapidly increasing the power to catch more fish per unit of effort.[xxiv] Steam-powered trawling reached the USA by 1906 and began appearing throughout the early 1900s in, for example, New Zealand, Chile, and South Africa.[xxv, xxvi] As with all fishing activity, the two World Wars affected this growth, but 1950s post-war innovations such as double-beam trawls and diesel-powered engines – as well as the development of export markets for key trawled commodities such as flatfish – cemented this new global industry.[xxvii] These innovations contributed to exponential growth in global catch across all fishing methods from 1950 to 1970.[xxviii]

Tropical water bottom trawl fisheries emerged later, as the technology was introduced in these regions in the early 20th century. With some exceptions, bottom trawling fisheries in the tropics were more recently developed than

Table 2 Bottom trawling gears and related towed demersal fishing gears

Bottom trawling gears[xix, xx]					
FAO gear category	**FAO gear name**	**FAO description**	**Example areas/ species of use**	**Penetration depth (cm)**	**Depletion of seabed biomass (%)**
Trawls (3)*	Beam trawls	“A trawl whose horizontal spread is maintained by a rigid beam across the net mouth”	North Sea flatfish; Gulf of Mexico US shrimp	2.72 (± 1.24)	6
	Single boat bottom otter trawls	“One cone-shaped trawl towed on the seabed by one boat, with its horizontal spread maintained by a pair of otter boards”	Australian river prawn; North Atlantic deep-water shrimp; New Zealand orange roughy	2.44 (± 1.14)	14
	Twin bottom otter trawls	“Two *[otter]* trawl nets towed over the seabed by one boat”	UK (Scotland) nephrops (shrimp)		
	Multiple bottom otter trawls	“More than two *[otter]* trawl nets towed over the seabed by one boat”			
	Bottom pair trawls	“A trawl towed over the seabed by two boats, which maintain the horizontal spread of the net during fishing”	Vietnam multi-species demersal	n/a	n/a
Other towed demersal gears					
Dredges (4)**	Towed dredges	“A cage-like structure made of a robust metal frame that is towed behind a boat”	Japan Yesso scallop; US giant scallop	5.47 (± 2.19)	20
	Mechanized dredges	“A large metal cage equipped with a cutting blade, which uses high-pressure hydraulic jet pumps to fluidize the substrate and wash out animals from the sediment and into the cage”	Ireland razor clam; Canada surf clam	16.11 (± 5.80)	41

*Excluded: Single boat midwater otter trawls, Midwater pair trawls
**Excluded: Hand dredges

A range of other towed demersal gears are also described by FAO, including anchor seines, boat seines, and semi-pelagic trawls. These gears are not included in our analysis because relatively little information on their specific use exists at a global level.

“FAO gear category”; “FAO gear name”; “FAO description”; and “Example areas/species of use” are taken from He, P., Chopin, F., Suuronen, P., Ferro, R.S.T and Lansley, J. 2021. *Classification and illustrated definition of fishing gears*. FAO Fisheries and Aquaculture Technical Paper No. 672. Rome, FAO. https://doi.org/10.4060/cb4966en

“Penetration depth” and “Depletion of seabed biomass” are taken from Hiddink, J. G., Jennings, S., Sciberras, M., Szostek, C.L., Hughes, K.M., Ellis, N., ... & Kaiser, M.J. 2017. Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. *Proceedings of the National Academy of Sciences*, 114(31), 8301-8306.

2. Definitions and historical context

those in temperate waters.[xxix, xxx] The development of "double-rig" trawlers (specifically to target shrimp) in 1930s North America helped to create the trawl fisheries of the tropics, including in Africa, Central America, and Asia. For example, in Southeast Asia, after unsuccessful attempts by British colonial entrepreneurs to introduce steam-powered trawling to Malaysian waters in the 1890s, Japanese diesel-powered trawlers reached the Philippines in the 1920s and German aid introduced the fishing method domestically in Thailand and Vietnam in the 1960s, with other countries in the region quickly following suit.[xxxi,xxxii]

Today, bottom trawling makes up about a quarter (26 percent) of the total marine fisheries catch in exclusive economic zones (EEZs) and the high seas. Bottom-trawled seafood is now a cornerstone of the global food commodity market. Of the species groups with the highest catch for human consumption – such as whitefish, crustaceans, and mollusks – several are targeted at least partly through bottom trawling or related towed demersal gears. Bycatch (catch of non-target species) products from tropical bottom trawling are a major contributor to the fishmeal and fish oil industry, making up an estimated 24 percent of the raw material in this $6 billion global trade.[xxxiii,xxxiv]

Defining bottom trawling in a policy context

Given its variety of impacts, scales and characteristics, bottom trawling presents a complex challenge to policymakers nationally and internationally. This challenge particularly extends to whether it should be defined as an "inherently destructive" and/or an "industrial" practice.

Is bottom trawling "inherently destructive"?

According to global standards of fisheries governance (FAO's 1995 Code of Conduct for Responsible Fisheries, or CCRF), fishing practices defined as "destructive" should be subject to complete, state-level prohibition.[xxxv] A 2009 FAO/UNEP expert meeting explored the scope of this term, concluding "only a very small number of fishing gears…[the primary examples being explosives and synthetic toxins]…should be considered inherently 'destructive' wherever and however they are used." In contrast, a 2003 paper established a broad consensus among fisheries stakeholders in the US as to the destructiveness of bottom trawls.[xxxvi] In addition, a 2009 review of the CCRF (in referring to global progress on article 8.4.2 "Prohibiting destructive fishing methods and practices") referred to bottom trawls as "implicitly covered by the measure" but noted that very few countries have interpreted it this way and implemented full prohibitions.[xxxvii] Such policy discussions have, in recent years, become dominated by the unsettled debate over appropriate measurements of its environmental impacts (see **Section 3: *State of the evidence: environmental impacts*** for more detail), particularly the level at which such impacts can be considered "significant" and "adverse."[xxxviii]

Is bottom trawling "industrial"?

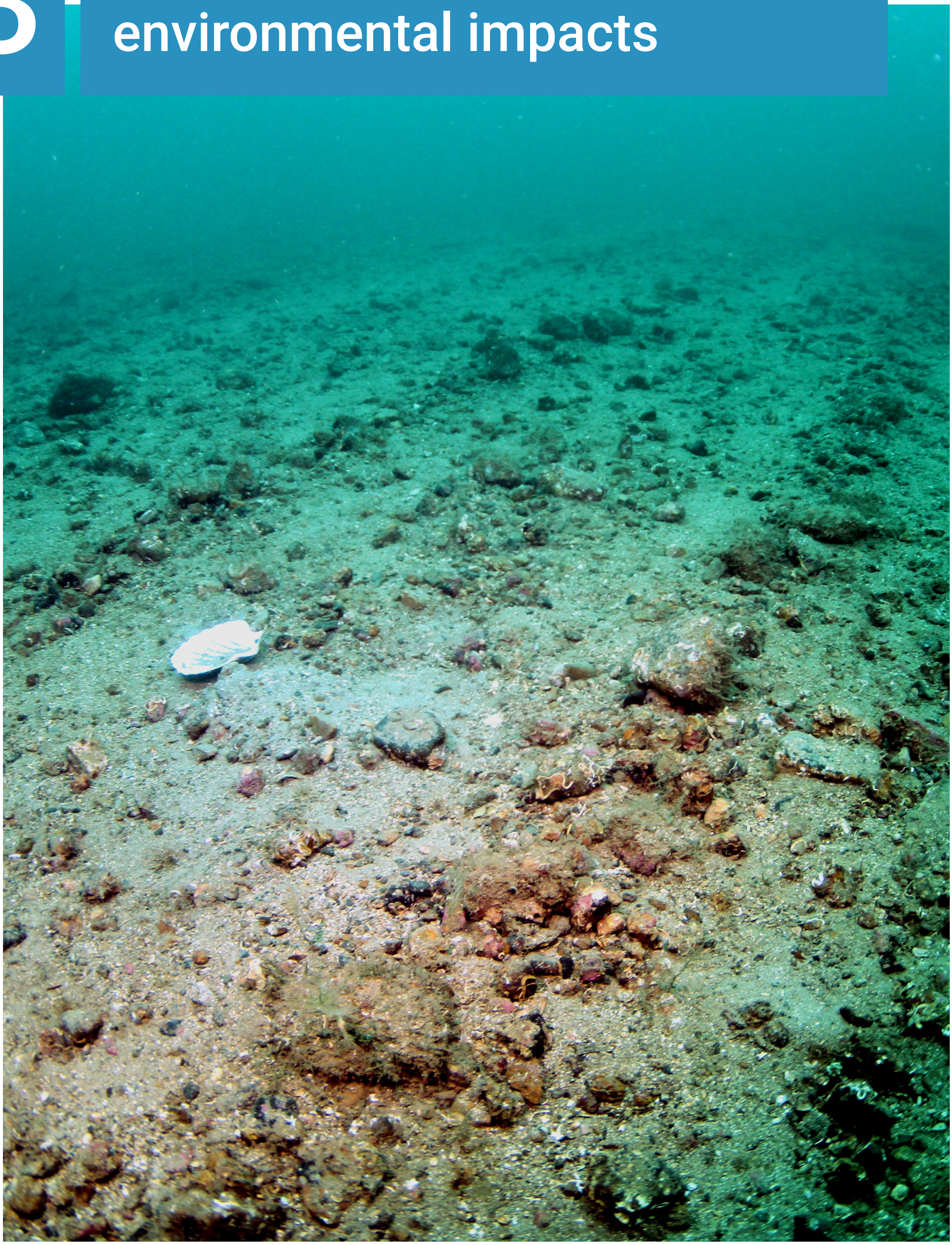
Although there are several proto-trawling methods that involve the use of dragged catching devices without fuel, all forms of modern bottom trawling display common characteristics of being "industrial" (i.e., an engine, multiple crew, and relatively heavy and at least partly, mechanized net, frame and rope configurations). In a 2019 review of "small-scale" fisheries definitions in academic literature, fishing gear was identified as the primary means of differentiation from "industrial" fisheries, with gear that is "labor-intensive" and "passive" denoting the two most common "small-scale" sub-characteristics.[xxxix] Bottom trawling is never a passive gear and is not frequently deployed or hauled by hand (i.e., it is not "labor-intensive"), so it could not therefore be considered "small-scale" within the scope of this review.[5]

An influential 2012 report to the EU parliament stated that all towed gears are inherently industrial, regardless of the size of the towing vessel. Additionally, a 2021 IUCN Motion that sought to define "industrial fishing" in the context of activities not compatible with marine protected areas (MPAs) defined "all fishing using trawling gears that are dragged or towed across the seafloor" as industrial.[xli]

While these terminological precedents exist, the fact that bottom trawl vessel sizes, fleet sizes and fleet ranges are so variable means that not all trawl operators are treated as "industrial", leading to conflicts and inconsistencies over acceptable scales of commercial activity permissible in different zones/regions, especially with regards to inshore access (e.g., in African coastal states).[xli]

[5] Sail, hand, and horse-powered bottom trawls still exist in some parts of the world to this day.

3 State of the evidence: environmental impacts



3. State of the evidence: environmental impacts

This section reviews the evidence on the environmental impacts of bottom trawling. It begins by introducing a framework for understanding how fishing has impacts on marine biodiversity and is followed by a section showing how bottom trawling impacts all three dimensions of that framework. Next, it discusses the implications of bottom trawling being the only fishing gear that registers on all three measures of biodiversity impact. It concludes with a consideration of a key debate around how to assess environmental impacts under different contexts of historical use.

A framework for understanding bottom trawling's environmental impacts

Fisheries are one of the most significant stressors to marine biodiversity – spatially, ecologically, and cumulatively.[xliii] As a sector it takes place over 55 percent of the world's ocean area and has been exerting pressure on marine biodiversity for hundreds of years, in some cases fundamentally reshaping ocean ecosystems.[xliv,xlv]

Fishing's impacts on biodiversity come from three broad mechanisms: (1) overfishing of the target species; (2) bycatch of non-target species; and (3) contact with the seabed resulting in habitat impacts. Within these categories, specific impacts include the extinction of a species (e.g., the smooth handfish *Sympterichthys unipennis*, declared extinct in 2020) to the likely local extinction of other species (e.g., several species of sawfishes throughout the Tropics) or the near wholesale removal of a likely non-recoverable seabed habitat (e.g., seamount cold-water coral communities in New Zealand). A wider and more complex set of collateral impacts range from disruption to trophic food webs to less diverse species communities as well as phenomena that are only just being characterized, such as environmental carbon storage disruption and acoustic habitat degradation (See Table 3).

Table 3 Observed biodiversity impacts from fishing

Fishing impact type[6]	Evidence
Overfishing: Depletion of the target species. Overfishing can result from multiple factors (e.g., weak fisheries governance, ecological changes, excess fishing effort, specific gear types).	• Local extinction (target species)[xlvii] • Population-level genetic disturbance [xlviii] • Trophic imbalance[xlix] • Simplified species community[l] (reduced species biodiversity) • Removal of ecosystem function (target species)[li]
Bycatch: Interaction, injury, depletion, and mortality of the non-target species. Non-selective gear types typically have higher levels of bycatch, particularly of species of concern: marine mammals, sea turtles, sharks and rays.	• Global extinction (non-target species)[lii, liii] • Local extinction (non-target species)[liv]
Seabed contact: Fishing methods that contact or penetrate the seabed can result in habitat modification and destruction.	• Habitat removal[lv] • Habitat degradation (physical)[lvi] • Habitat degradation (acoustic) [lvii] • Sediment dispersal leading to smothering[lviii] • Seabed organism removal[lix] • Disturbance of stored carbon in marine sediments (not observed)[lx] • Removal of ecosystem function (e.g., pollution reduction) for seabed species[lxi]

The environmental impacts of bottom trawling[6]

Bottom trawls and other towed gears that contact or penetrate the seabed are the only gear group that can be conclusively linked to all three major biodiversity impacts of fishing. In other words, while all fishing gears can lead to target species declines and almost all fishing gears can lead to some form of bycatch, bottom trawl gears can lead to both of these impacts in addition to that of seabed habitat decline (See Table 4). The most definitive evidence connects bottom trawling to bycatch impacts and harm to seafloor ecosystems. Bycatch impacts are due to its highly non-selective nature in comparison to almost every other gear except gillnets (See Table 5). Seabed habitat impacts are largely unique to bottom contact gears, with bottom trawls and dredges ranking highest among fishing gears in terms of these impacts. It is commonly

[6] Abandoned, lost, or discarded fishing gear (ALDFG) can result in impacts on biodiversity via each of these three mechanisms. ALDFG can result in continued catch of target species and non-target species, cause interactions with threatened or endangered species, and cause seabed habitat degradation and destruction.

3. State of the evidence: environmental impacts

acknowledged that bottom trawling is "the most widespread source of anthropogenic physical disturbance to global seabed habitats."[lxii]

Table 4 The biodiversity impacts of bottom trawling

Fishing impact type	Evidence
Overfishing	• Changes community production, trophic structure, and function in some cases enhancing productivity of target species (such as shrimp), but generally reducing carrying capacity.[lxiii,lxiv,lxv]
Bycatch	• Results in high levels of small-bodied species (i.e., non-target demersal fish, invertebrate) bycatch (80-90% in some shrimp trawl fisheries) as compared to other gear types.[lxvi] Some of these species are of conservation concern e.g., seahorses.[lxvii] • Interacts (frequently fatally) with large-bodied species of conservation concern including regionally-specific impacts on sea turtles, sharks, and rays.[lxviii,lxix]
Seabed contact	• Remove or permanently degrade highly sensitive seabed habitats, for example cold-water coral communities and seagrass beds.[lxx,lxxi] • Affects the physical properties of marine sediments through resuspension, erosion, near-bottom turbidity, and changes to seabed morphology (which also results in localized pollution and toxicity).[lxxii,lxxiii,lxxiv] Resuspension of biogenic carbon may also have major greenhouse gas implications.[lxxv] • Reduces topographic complexity in biogenic, habitat-forming seabed structures such as sponge communities, shallow water corals, infaunal worm reefs and mollusk beds.[lxxvi,lxxvii,lxviii,lxvix,lxxx] • Reduces faunal biomass, numbers, and diversity.[lxxxi,lxxxii] • Selects for communities dominated by fauna with faster life histories.[lxxxiii]

Demonstrating that specific gear types cause overfishing is a complex area of study that requires further inquiry. In general, demonstrating the connection between specific gear types and overfishing is not an area that has been widely studied because there are many variables that affect fish stock sustainability. This does not mean that bottom trawling cannot be linked to overfishing, particularly when viewed in the broader context of the historical development of fisheries. Bottom trawling emerged during a broader industrialization of fishing effort that has been widely linked to our understanding of the phenomenon of overfishing.[lxxxiv,lxxxv] Longitudinal studies of specific bottom trawl fisheries in diverse geographies (i.e., Australia, the Adriatic, the Gulf of Thailand, North Sea, the Philippines, Scotland, South Africa, and United Kingdom) show that bottom trawling results in marked changes in demersal fish assemblages, including reductions in the abundance of target species.[lxxxvi,lxxxvii,lxxxviii,lxxxix,xc,xci,xcii,xciii] However, these same studies also make it clear that bottom trawl fishing is only one of several likely drivers behind these changes, which makes this claim difficult to assess conclusively.[xciv,xcv]

The stock status of the various species caught by bottom trawl fleets offer mixed insights. On the one hand, a recent study of global groundfish stocks that are targeted by bottom trawls shows that in many parts of the world, groundfish stocks – on average – appear to be above or near sustainable biomass levels (Europe, Alaska, New Zealand, South Africa, and Namibia), while in several parts of the world groundfish stocks continue to be below sustainable biomass levels (Japan, Russia, Chile, and Argentina) or are still recovering (Canada and the USA).[xcvi] Many bottom trawl fisheries are in parts of the world where stocks are unassessed or where fisheries governance is weak, such as West Africa, Southeast Asia, India, and China (for more see Section 7: *Global extent*).[xcvii,xcviii] More gear-disaggregated studies of stock status would help provide greater clarity on this issue.

When ranked against other fishing gears, bottom trawling comes at or near the top of two of the three metrics relevant to fishing's impact on biodiversity: habitat impact and bycatch. The report authors conducted a literature review of papers that compared the impacts of different fishing gear types on specific ecological features (See Table 5). Papers used similar methods at the national level in the US, UK and Canada – a method called "paired comparisons" where survey respondents from the fishing industry, academics, government agencies and NGOs were asked to compare the impacts related to interactions between fishing gears and ecological features.[xcix]

When habitat and bycatch impact scores are aggregated, towed demersal gears such as bottom trawls and dredges rank at or near the top in national-level studies. Global meta-analyses focused on specific impacts relating to habitat and bycatch (of sharks, sea turtles, and marine mammals) show similar results, with bottom trawl gears showing the highest habitat and bycatch impacts of all gear types. Bottom trawling also is notable for its impacts in terms of fuel use: it is one of the most fuel-intensive methods of seafood capture (for more see Section 4: *State of the evidence: climate impacts*).

3. State of the evidence: environmental impacts

Not all bottom trawling is the same in terms of its environmental impacts. Impacts will vary depending on the design of the gear and its operation, the frequency and intensity of bottom trawling, the susceptibilities of the affected ecosystem and species to trawling (mortality) and their ability to recover (life history).[c] For example, hydraulic dredges cause the greatest depletion of seabed biomass (sponges, soft corals, macrofauna) from a single trawl pass (the duration and distance covered by a trawl, also called "area swept"), followed by towed dredges, beam trawls, and otter trawls.[ci]

The ability of bottom trawling and other towed demersal gears to affect all three variables of interest to marine biodiversity suggests that it is unique among fishing gears. However, singling out particular fishing gears and their inherent environmental properties can risk obscuring the importance of context and the distinction between responsible and irresponsible use. Critics of these kinds of gear comparisons promote the implicit notion of "fishing gear neutrality," perhaps best typified by the Marine Stewardship Council's assertion that "any fishing will have an impact on the environment, but its relative impact depends on a range of factors."[cii] Bottom trawling is often the implied focus of this concept. However, the findings presented in Table 5 above suggest that bottom trawling is in fact different from other gear types, in that its aggregate impact – as assessed by academics, the seafood industry, fisheries managers, and NGOs in paired comparison studies – is highest across nearly every factor of concern for marine biodiversity, and these trends become only more apparent in global meta-analyses.

Table 5 National and global-level comparisons of environmental impacts of different fishing gears

Gear/gear category	National-scale environmental impact rankings by gear type[1]		Global-scale environmental impact rankings by gear type[2]		
	Habitat impact	Bycatch	Fuel use intensity	Habitat impact	Bycatch
Trawl - bottom	High	High	High	High	High
Gillnet - bottom	High	High	Medium	Medium	High
Dredge	High	Medium	Medium	High	Low
Pots & traps	High	Medium	Medium	Medium	Medium
Gillnet - midwater	Medium	High	Medium	N/A	Medium
Longline - bottom	High	Medium	Low	Medium	Medium
Longline - pelagic	Medium	Medium	Low	Medium	Medium
Trawl - midwater	Medium	Medium	Medium	Low	Medium
Purse seine	Medium	Medium	Low	Low	Low
Hook and line	Medium	Low	High	Low	Low
References	U.S.: Chuenpagdee *et al.*, 2003 Canada: Fuller *et al.*, 2008 United Kingdom: MMO, 2014		Parker and Tyedmers, 2015	Grieve *et al.*, 2014	Wallace *et al.*, 2013; Lewison *et al.*, 2014; Oliver *et al.*, 2015; Gilman *et al.*, 2020

Legend: High | Medium | Low | N/A

Methods:

1. Authors identified three studies in the U.S., Canada, and the U.K. that used a paired comparison analysis to directly compare fishing gear types against each other. Authors summed impact scores from each of the papers for all habitat feature interactions and bycatch species interactions by gear type, resulting in mean habitat and bycatch impact scores across the three papers. Gear types that were not comparable across studies were removed. Absolute scores were then converted into relative rankings for the remaining gear types. Relative rankings were converted into High, Medium, and Low terciles.
2. For each study, the authors ranked all cited gears based on their study-specific score. Gear types that were not comparable across studies were removed. Study-specific ranks were then converted to relative ranks. Bycatch rank references studies across multiple species type (marine mammals, sharks, sea, turtles, and non-specific discards). Ranks were averaged across the four studies, and then an overall relative rank was created. Impact scores were then converted into High, Medium, and Low terciles. Where one of the gear/gear categories was represented by multiple gears in a detailed study, the authors took the highest applicable rank.

3. State of the evidence: environmental impacts

How do we measure and manage seabed habitats that have different characteristics and different histories of bottom trawling?

The emergence of bottom trawling in different parts of the world at different times means that some bottom trawl fisheries are relatively recent (i.e., multi-decadal) and some are extremely well established (i.e., multi-century) and that a wide variety of seabed types are impacted by the practice. Meaningful baseline data on the ecological characteristics of seabed habitats and demersal communities pre-bottom trawling are rare, which makes the process of defining impacts (and appropriate parameters for recovery) both complex and contentious, particularly given that the "first pass" of a towed demersal gear may cause the most change.[ciii,civ]

Certain seabed habitats are of greater concern than others in relation to bottom trawl impacts. Slow-growing, coralline communities in remote, deep areas are demonstrably less resilient to disturbance than high-energy areas of naturally mobile sediment, with instances in which the former show no signs of recovery 15 years after initial trawl disturbance and in which the latter can return to pre-trawl impact state within a year.[cv] A weakness of some bottom trawl seabed impact studies showing relatively short recovery timeframes is their failure to account for the serial, sometimes multi-century level of seabed contact that may have preceded the baseline year of such studies.[cvi]

The question of what it means for a seabed habitat to be "pristine," "recovered" or in "favorable condition" is vital to bottom trawling policy formulation, standard-setting and management. The most relevant policy concepts are those of "avoiding significant adverse impact" or "serious irreversible harm," that are respectively applied to bottom trawl fisheries taking place in international waters or seeking Marine Stewardship Council certification. In order to be compliant with either of these frameworks, fisheries managers and bottom trawl operators must demonstrate that their activities fall within the limits of acceptable impact (i.e., how much of a given habitat can be trawled) and acceptable recovery timeframes. It is notable that i) neither of these two concepts are applied consistently in national or nearshore waters (although some MSC-certified bottom trawl fisheries operate in these waters); and ii) both concepts are based on "do no harm" principles rather than aligning with emerging calls for any use of the environment to make an active contribution to planetary health.[cvii,cviii]

4 State of the evidence: climate impacts

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4. State of the evidence: climate impacts

This section discusses the contributions of bottom trawling to climate change. It examines the well-established evidence base on the fuel intensity of the practice as well as emerging research on the role of bottom trawling in disturbing marine sediments that store carbon.

Bottom trawling is attracting increasing attention for its global impact on greenhouse gas emissions. The impact of bottom trawling on climate change can be broken down into two primary mechanisms: the relatively high fuel use of trawling vessels and the disturbance of carbon-containing sediments on the seafloor.

Fuel use

Fisheries consume about 40 billion liters of fuel annually, generating 179 million tonnes of CO^2-eq GHG emissions (about 4 percent of global food production emissions).[cix] Of the major gear types used in global fisheries, bottom trawling has the highest emissions from fuel use. Seafood is often credited for being a “more sustainable” dietary choice with regards to climate change because the average GHG emissions per gram of protein consumed are less than 1/10 those of beef.[cx] However, GHG emissions vary significantly by gear type, and fish caught by bottom trawling can rank among the most GHG-intensive foods due to the fuel use requirements of dragging a heavy net across the seafloor.

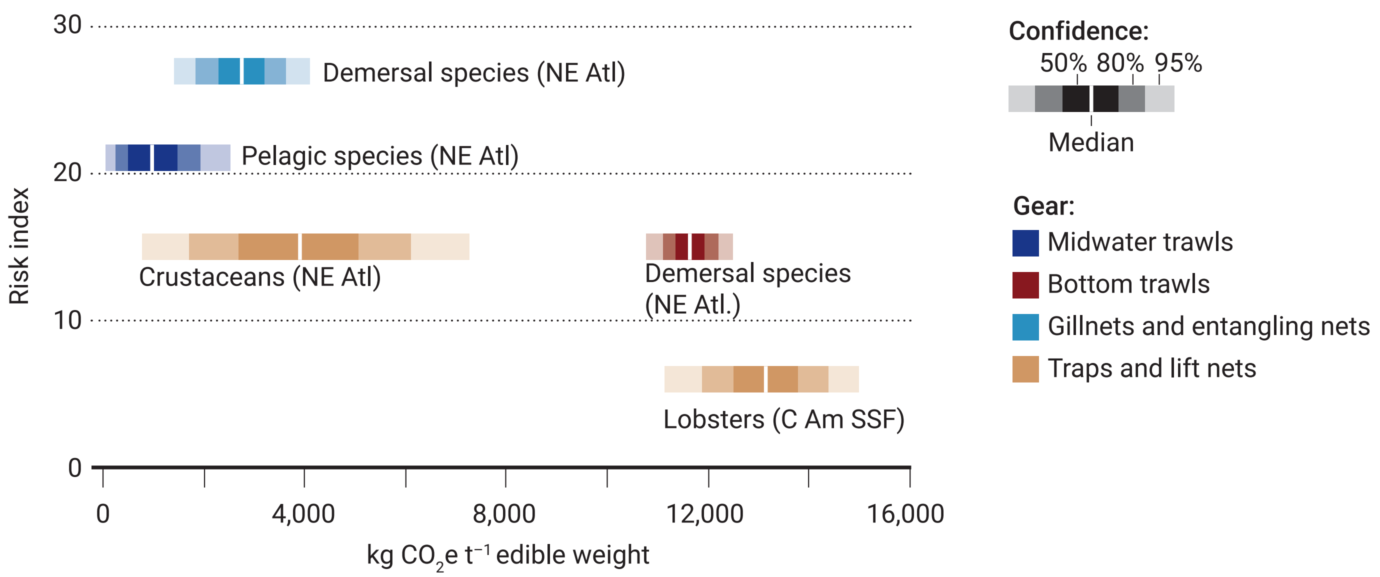
A 2017 study showed that bottom-trawl fisheries emit almost three (2.8) times more greenhouse gases than non-trawling fisheries.[cxi] This estimate gives fish caught by bottom trawling a higher GHG footprint than most meat, except for lamb and beef. While the carbon footprint of land-based protein sources includes land-use change and feed emissions, bottom-trawled fish account for more emissions than pork and poultry through associated fuel use alone – without including broader life-cycle considerations (see Figure 1). Within bottom trawl fisheries, the catch of small crustaceans (shrimp) and non-schooling fish (flatfish) have comparatively high carbon emissions compared to catching species that form schools (e.g., cod and cod-like species).

Trawling emissions from fuel use can be mitigated by switching to different gear types. Studies have shown that fuel use can be decreased by 4x per kilo of Norway lobster, 15x per kilo of Danish flatfish, and 4x per kilo of Swedish cod when switching to creel, Danish seine, and gillnet gears, respectively.[cxiii, cxiv, cxv]

Sediment disturbance

Bottom trawling may also generate up to 1.47 Gt CO_2-eq annually by disturbing seabed sediments, according to emerging research. Sala *et al.* (2021) attempted for the first time to quantify the disturbance of carbon-containing sediments from bottom trawling and the subsequent release of that carbon back into the water column and atmosphere.[cxvi]

Figure 1 GHG emissions from seafood, by gear type, compared to marine mammal risk



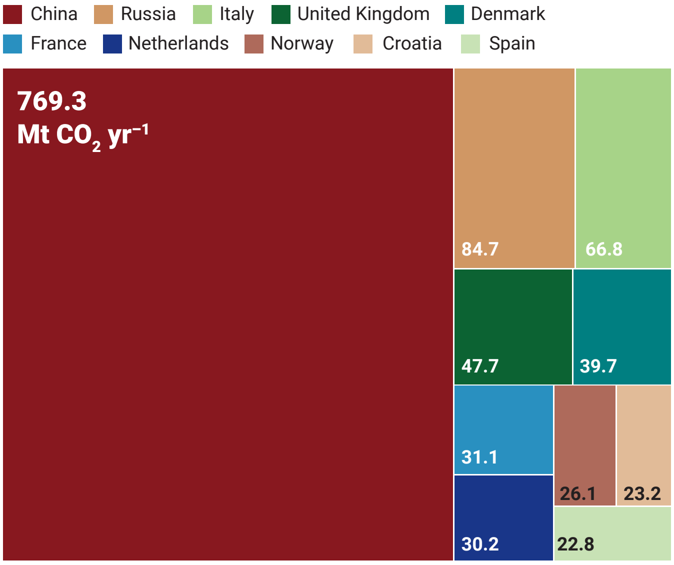
Seafood caught by bottom trawls generates among the highest carbon emissions per tonne of edible weight, along with crustaceans caught through traps and lift nets. Data represent fisheries in Europe (NE Atlantic) and Central America (C Am SSF) by gear type. The risk index is the sum of the number of marine mammals at risk from bycatch.[cxi]

4. State of the evidence: climate impacts

Using a global average of carbon accumulation and sedimentation rates combined with automatic identification system (AIS) data from bottom trawling vessels, the authors estimated that bottom trawling could release between 0.6 and 1.5 Gt CO_2e a year, roughly equivalent to the entire global aviation industry. Though these estimates are an emerging area of research, countries with high estimated emissions from bottom trawling are predominantly in Western Europe, due to the intensity of trawling in those regions as recorded by Global Fishing Watch data (see **Figure 2**). China appears to be the leading emitter of CO_2 into the atmosphere through bottom trawling activities, due to both high trawling intensity and total trawling effort. Since AIS data to track vessel traffic is limited in Southeast Asia, South Asia, and West Africa, GHG emissions from bottom trawling in those regions may be underestimated. This study builds on previous work to produce 1-km resolution estimates of marine sedimentary carbon stocks globally.[cxvii]

Additional research is needed to refine these estimates. Future work should focus on building a spatially explicit map of global carbon accumulation and sedimentation (especially in heavily bottom-trawled areas) and attempting to reduce the large uncertainty over the proportion of carbon that is released back into the atmosphere. Initial research mapping organic carbon densities and accumulation rates in the Norwegian Trough and Skagerrak found that sediment stocks vary spatially in those regions, indicating that restricting bottom trawling may have different effects on carbon emissions depending on locality.[cxviii] Refining carbon stock estimates and resuspension rates in areas where bottom trawling is occurring will be important to ensure that ocean areas are being managed both to protect biodiversity and to minimize GHG emissions.

Figure 2 Estimated GHG emissions from bottom trawling (Gephart *et al.*, 2021)



Preliminary estimates suggest that the emissions from bottom trawling in China are over an order of magnitude greater than any other country. Emissions are otherwise concentrated in Europe, where trawling intensity is high.[cxix]

5 State of the evidence: socio-economic impacts

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5. State of the evidence: socio-economic impacts

This section shares the findings of a global academic literature review conducted by the report authors to identify and categorize the kinds of social impacts associated with bottom trawling. It also presents an in-depth case study of bottom trawling in West Africa, and the socio-economic implications of the practice there.

Documented socio-economic impacts associated with bottom trawling

Conceptualizing the socio-economic impacts of bottom trawling is more nuanced and complex than documenting its environmental impacts. Conservation practitioners and scientists have historically failed to value and study both the natural and social dimensions of environmental problems.[cxx] The lack of understanding about the social dimensions of conservation hinders the ability to design solutions that can improve environmental and social outcomes.[cxxi] This shortcoming manifests through the poor conceptualization of bottom trawling's socio-economic impacts in the academic literature.

Formal documentation of bottom trawling's socio-economic impacts is limited. The authors conducted a global literature review and found 31 papers that explicitly discuss trawling's socio-economic impacts, compared to the many more papers that explore its environmental impacts.[7] For example, a recent meta-analysis on bottom trawling's footprint cited almost double the number of academic papers.[cxxii] Interpretation and understanding of socio-economic impacts across non-English speaking regions may be rudimentary since this review only considered English language literature. Regions in data-poor and under-researched parts of the world (such as low- and middle-income countries) are likely inadequately represented. Other socio-economic dynamics, including inequitable benefit-sharing between seafood corporations and coastal communities, might be uncovered if additional sources of information were included in this analysis.[8]

The tendency to conflate bottom trawling with midwater trawling, or more generally industrial fishing, makes it difficult to determine the unique socio-economic impacts of each fishing gear. The available socio-economic literature rarely disaggregates by gear type, in contrast to environmental impact studies. While many of the impacts found through this analysis are not unique to bottom trawling, they have all been documented with respect to bottom trawling and therefore merit consideration. The limitations of the current evidence base for socio-economic impacts requires a nuanced discussion of bottom trawling's outcomes.

Five broad themes for the socio-economic impacts of bottom trawling emerged from the authors' literature review: economic impacts, violence and conflict, food security, labor and human rights, and occupational health and safety.[cxxiii] Documented socio-economic impacts apply to those affected by bottom trawling, often small-scale fishers, as well as to those within the bottom trawling sector.

1. **Economic impacts include impacts on jobs, landings and food supply, public revenues from access agreements and license fees, and subsidies.** Impacts documented can be both positive and negative, which may help to explain why bottom trawling is both widespread and controversial.
   - **Jobs and economic opportunities.** Bottom trawling may increase labor productivity in the sector if it replaces more economically inefficient forms of fishing. If workers can move to higher quality jobs, then the total effect could be positive. However, workers cannot always transition to other jobs, particularly in coastal countries with fewer alternatives, which may result ultimately in job losses overall.[9] For example, in the case of Colombia bottom trawling has been documented to offer fishers with limited income opportunities the chance to increase their incomes due to the low investment and maintenance costs, low operational risks, high value of target species, and high profitability of the sector, when compared to alternatives.[cxxiv]
   - **Foreign fishing access agreements.** Coastal countries often trade fishing access agreements with foreign countries to profit from their fish resources.[cxxv] Foreign access agreements with distant water bottom trawl fleets often result in sub-optimal economic outcomes for host countries, including lost economic rents, high opportunity costs, and proportionally little value remaining in-country. West Africa is a prime example of the economic impact that foreign bottom trawlers have on local fishing communities. In Sierra Leone these agreements add up to 2-3 percent of estimated total resource rents from fishing, or about $2 million annually.[cxxvi] Many countries with large fishery resources are trading off cash in hand today to allow bottom trawling. The economic benefit from this trade often stays within central governments and is not reinvested into the long-term livelihoods and economic growth of the coastal communities directly affected by the agreements.

[7] In April 2021 CEA Consulting conducted a review of scientific literature focused on the social impacts associated specifically with bottom trawl fisheries. The scope included both bottom and midwater trawling since most of the literature described trawling in generalized terms. A total of 31 papers, published since 2000, were reviewed for content describing the socio-economic implications of trawling on coastal and fishing communities. Most of the literature focused on South Asia followed by East and West Africa, Latin America, and the Mediterranean, with less coverage on Western Europe, Southeast Asia, and South Africa.

[8] In addition to the findings from the literature review, expert interviews highlighted anecdotal observations and eyewitness testimony of socio-economic impacts related to bottom trawling. Experts suggest that bottom trawling is often a taboo topic given the nuanced role it plays in shaping coastal communities. For example, in India trawlers (bottom, pelagic, and midwater) are often owned and operated by poor fishers, resulting in a general social opposition to complete bottom trawling bans.

[9] Personal communication with John Virdin.

5. State of the evidence: socio-economic impacts

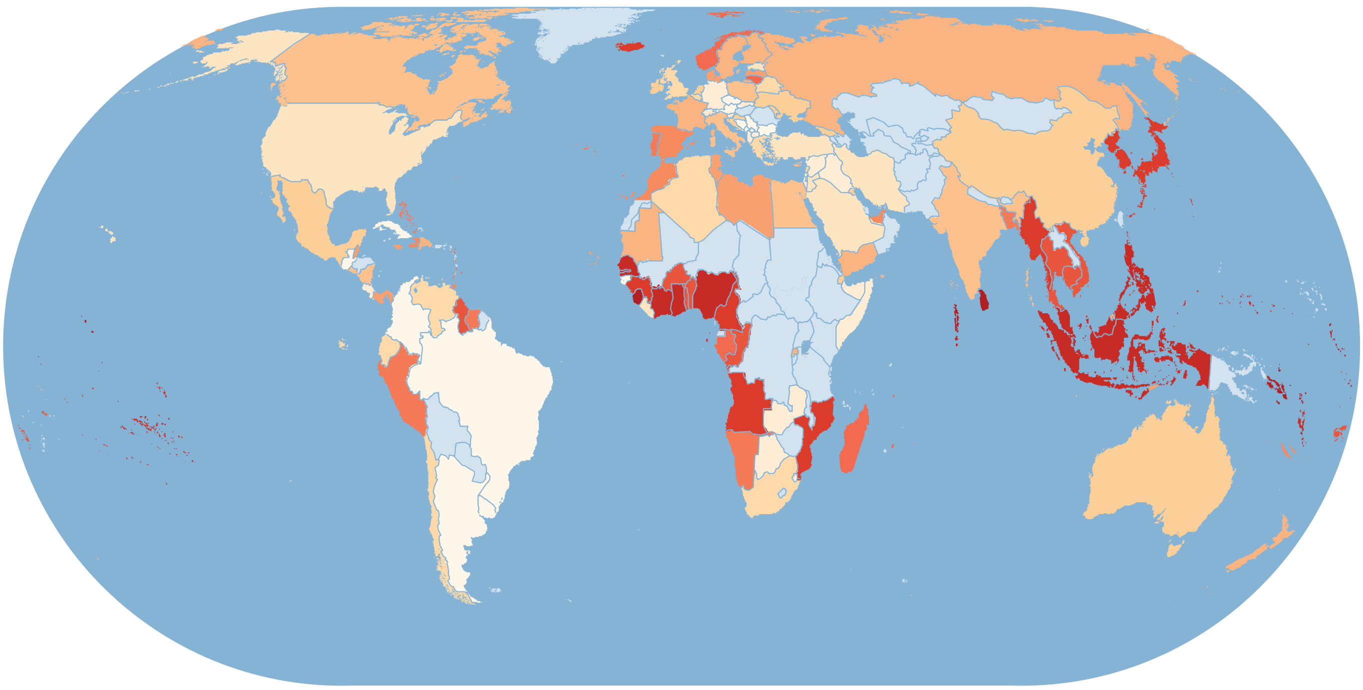
- **Subsidies.** Government subsidies exist across multiple gear types, but deep-sea bottom trawl fisheries are major beneficiaries.[cxxvii] Bottom trawling remains profitable across the high seas, even though it is a fuel-intensive fishing method, because of subsidies. Without government subsidies, high-seas bottom trawling would be largely unprofitable.[cxxviii] Experts suggest that bottom trawlers fishing in the high seas receive $152 million per year in the form of subsidies, representing 25 percent of the fleet's total landed value.[cxxix]

2. **Violence and conflict** often characterize the relationship between small-scale fishers and industrial bottom trawlers, involving physical conflict, fishing gear loss and damage, and political confrontation. The long history of violence and conflict between Sri Lankan and Indian fishers and bottom trawlers is particularly well documented, demonstrating entrenched animosity between bottom trawlers and artisanal fishers of both countries.[cxxx,cxxxi,cxxxii,cxxxiii,cxxxiv,cxxxv] Illegal cross-border bottom trawling has often resulted in artisanal fishers facing irreparable damage to their nets.[cxxxvi] The heightened tension has led to increased patrolling and arrests of fishers of both countries.[cxxxvii]

3. **Food security implications from bottom trawlers depend on what is caught and who can consume that catch.**

- **Negative outcomes.** In many coastal fisheries throughout the tropics, bottom trawlers often out-compete local small-scale fishers and deplete local resources historically caught by small-scale fishers or consumed by local communities.[cxxxviii,cxxxix] These impacts have resulted in reduced food, lower incomes, and forced migration in countries such as India, where 90 percent of small-scale fishers live below the poverty line and fish catches have decreased at alarming rates in recent years.[cxl]
- **Positive outcomes.** Bottom trawling can provide cheap fish for human consumption. The bottom trawl fisheries in Southeast Asia provide food for millions of people in coastal communities as well as feed for the region's growing aquaculture sector, which is largely consumed by low and middle income consumers in Asia.[cxli,cxlii] Some experts suggest that global demand for fish will double by 2050, with urbanization as an important driver.[cxliii] While current fish consumption per capita in Asia, Europe and Oceania surpasses the global average, consumption across Africa and South America is well below it.[cxliv] Demersal species are most in demand in Europe, North America and Oceania.[cxlv]
- **Overall outcomes.** Bottom trawling is occurring in countries that are highly dependent on marine resources for food security, particularly in West Africa and Southeast Asia (see **Figure 3**).[cxlvi] Given the complicated interplay between these social, environmental, and economic systems, efforts to constrain bottom trawling

Figure 3 **Degree of human dependence on marine ecosystems for nutrition (Selig *et al.*, 2019)**



Countries with the highest nutritional dependence on seafood, in order, include the Maldives, Kiribati, the Solomon Islands, Sierra Leone, Sri Lanka, Palau, Ghana, Tavalu, Nauru, Cote D'Ivoire, Indonesia, and Senegal.[cxlvii]

5. State of the evidence: socio-economic impacts

in these places may give rise to concerns about unintended consequences for human well-being.

4. **Human rights abuses** such as unlawful arrest, torture, and even murder connected to bottom trawling have been documented, particularly in South Asia. Human rights violations affecting Indian and Sri Lankan fishers have been documented and debated in domestic and international media.[cxlviii] The use of social media platforms has facilitated the swift sharing of videos and cases depicting abuses, and this has increased public attention on the conflict over resources and the right to fish.[cxlix]

5. **Occupational health and safety** may be an underappreciated problem for trawling fleets, although evidence of impacts by gear type is very limited. Documented occupational health and safety impacts were associated with trawling more generally and did not explicitly refer to bottom trawling.[cl] However, these impacts merit discussion given the similarities between the fishing methods.The International Labour Organization (ILO) identified fishing as among the most dangerous occupations.[cli] In Norway, commercial fishing is recognized as the occupation with the most fatal and nonfatal accidents, with the trawler fleet holding the highest injury rates in the fishing sector.[clii] Trawling-related injuries accounted for an estimated 37 percent of all reported injuries across the entire Norwegian fishing fleet.[cliii] More research is needed to differentiate risks specifically associated with bottom trawling.

The socio-economic impacts of bottom trawling may vary based on ecological conditions, with a distinct difference between temperate and tropical fisheries. Fish that live in temperate waters have life histories that involve the open ocean and deep waters, which generally allows for deep-water bottom trawl fisheries. As a result, there can be a natural spatial separation between bottom trawlers targeting deep-water species, such as orange roughy, grenadiers, and toothfishes, and other fishing vessels that target shallower or inshore waters. Tropical waters tend to be more productive inshore than offshore, so more of the fishing occurs closer to shore. As a result, there is a higher likelihood of spatial overlap and conflict between fisheries, especially with small-scale fishers. Most of the world's marine small-scale fishers fish in tropical waters near the shore, where the majority of bottom trawling is taking place.[cliv] Small-scale fishers are particularly vulnerable and often marginalized, forced to endure the consequences of ineffective fishing regulations, market inequity, and environmental shocks.[clv] For these reasons, some governments, particularly in Africa, have pursued the creation of inshore exclusion zones (IEZs) to restrict bottom trawling in coastal waters.[clvi] This human-centered approach is designed to protect artisanal fisheries from the socio-economic impacts of bottom trawling and other industrial forms of fishing – enforcement, however, is critical.[clvii]

Inshore exclusion zones as a tool to support small-scale fisheries

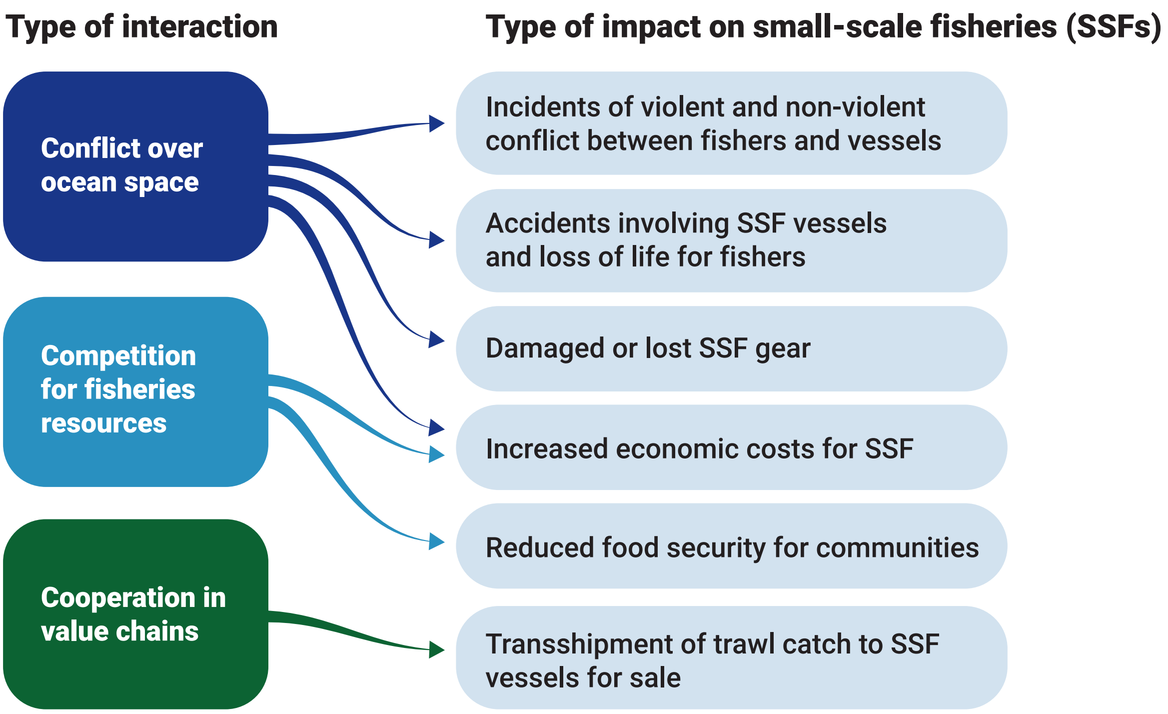
Inshore exclusion zones (IEZs) are a spatial management tool used by governments to address the socio-economic impacts of industrial fishing. IEZs are found within a country's jurisdiction, typically within territorial waters (12 nautical miles from shore), and are usually areas reserved for small-scale fishing craft where industrial fishing may be prohibited. Because bottom trawling is nearly always categorized as industrial fishing, an industrial ban also serves as an implicit ban on bottom trawling. However, some IEZs, such as Cambodia's, explicitly target bottom trawling in their fisheries laws.[clviii] African governments in particular have implemented IEZs as a result of the conflicts between foreign trawlers and small-scale fishers in the region. Industrial fleets have been documented within African inshore areas reserved for small-scale fisheries, resulting in fatal collisions, increased competition, and conflict over fishing access.[clix] In some cases, IEZs have demonstrated progress toward combating illegal fishing and protecting local fishers. In 2010 the Liberian government introduced a six-nautical mile IEZ protecting the inshore artisanal fishery, which supports the livelihoods of an estimated 33,000 people.[clx] The decrease in illegal fishing and increase in artisanal catch in Liberia is attributed to the implementation of the IEZ.[clxi] This in turn has also led to a reduction in conflict with industrial fishing vessels and an overall improvement in artisanal livelihoods.[clxii] Similar to other spatial management measures, IEZs are often a result of technocratic processes and in some cases receive technical assistance from FAO. The success of IEZs may depend on proper enforcement. Illegal trawler encroachment of IEZs in Sierra Leone has resulted in conflict and violence, suggesting discrepancies in the effectiveness of IEZs.[clxiii] The *Illuminating Hidden Harvests* report, an upcoming FAO, WorldFish, and Duke University study, will include an analysis on the extent of IEZ coverage in 58 country case studies across the world, with insights relevant for the connection of small-scale fisheries to bottom trawling.

5. State of the evidence: socio-economic impacts

Case study examples highlight the connections between bottom trawling and food security, erosion of cultural practices, and loss of local livelihoods. Case studies from Myanmar, Scotland and Peru demonstrate how bottom trawling is part of a broader trend towards the capitalization and commoditization of fisheries that often favor corporate, foreign, and urban interests at the expense of traditional fishers and local communities. These trends can play out relatively quickly or over generations, and have not been widely studied.

- In **Myanmar**, the increased global demand for fishmeal and fish oil has encouraged the development of a bottom trawl "trash fish" fishery.[10] This dynamic is shifting seafood out of the mouths of local consumers (who historically consumed bycatch from the bottom trawl fishery) and into export-oriented supply chains for animal feed – all while decimating local fishery resources.[clxiv]
- In **Scotland**, an IEZ established in 1889 prohibited bottom trawling within three miles from shore in order to protect small-scale fisher livelihoods. Nearly 100 years later, the 1984 repeal of that IEZ resulted in the collapse of inshore fisheries, conflict between artisanal and industrial fishers, loss of economic opportunities for coastal communities, and the loss of historical cultural practices such as fisherman's dances.[clxv,clxvi,clxvii,clxviii]
- In **Peru**, the economic opportunities presented by bottom trawling displaced traditional small-scale fishing, with some small-scale fishers adopting bottom trawling to take advantage of the greater economic stability and opportunity it provided in comparison to traditional practices. A recent study documented how small-scale fishers that used trawl nets and purse seines were the only small-scale fishers who did not experience a decline in annual income for the past seven decades, with most other artisanal fishers living in relative poverty.[clxix]

Figure 4 Interactions and impacts between bottom trawlers and SSFs in West Africa.



[10] Trash fish is a misleading but widespread term used to describe unwanted species with usually little to no market value for human consumption that are typically caught when fishing for more valuable, targeted species.

5. State of the evidence: socio-economic impacts

Deep dive into West Africa, a region profoundly influenced by trawling.[10]

Trawl vessels have dominated the large-scale fisheries in West Africa, a region where persistent and largely foreign trawling has been relatively well documented.[clxx] The analysis of socio-economic impacts across West Africa includes both bottom trawl and midwater trawl fisheries, since most of the literature describes small-scale fisheries interactions with trawl fisheries more generally. The conflict between trawlers and small-scale fisheries is a key and defining feature of West African fisheries. Since the 1950s the region's coastal waters have been fished by foreign industrial trawl vessels, from Europe, Russia and more recently China.[clxxi] There is a reinforcing feedback loop with the ecosystem, where declining fish stocks are both an outcome and a driver of the interaction between trawlers and small-scale fishers.[clxxii] Formal governance systems and the capacity, or willingness, of governments to monitor and enforce compliance with fishing laws and regulations are also often cited as drivers of this interaction.[clxxiii]

Three broad and mutually exclusive categories of interaction between trawl fisheries and small-scale fisheries were identified, with the first two interactions described as key characteristics of West African fisheries.[clxxiv]
These three interactions are categorized as conflicts over ocean space, competition for fisheries resources, and cooperation in value chains.

1. **One of the main interactions between trawl and SSF vessels is conflict over ocean space.**[clxxv] Spatial overlap is not necessarily static, which can heighten the risk of conflict as trawlers or SSF vessels follow each other to fishing grounds or shift fishing areas due to environmental and seasonal variations.
   a. **Incidents of violent and non-violent conflict** between fishers and vessels overlapping in operating space is quite common. In Senegal, for example, SSF and trawl vessels often fish alongside one another, resulting in physical violence such as throwing bottles, rocks or ignited objects from boat decks, spraying water at high pressure to damage or tip a vessel, and threats and attacks involving weapons.[clxxvi] There are also documented accidents involving vessels and loss of life as a result of collisions with trawlers. More than 250 small-scale fishers die every year in West Africa as a result of collisions with trawlers, although this number may be higher as accidents often go unreported.[clxxvii] In Senegal alone, collisions with trawl vessels were the most common cause, an estimated 30 percent, of SSF vessel accidents between 2001 and 2006.[clxxviii]
   b. **Damaged or lost gear** from interactions with trawl vessels was frequently reported by small-scale fishers, particularly closer to shore or at night. In Sierra Leone, small-scale fishers in major landing sites reported damage to their nets that in some cases was financially crippling, claiming that "every fisherman in the community is now a debtor…if they do not borrow, they cannot survive."[clxxix]
   c. **Increased economic costs** for small-scale fishers have also been documented. A recent study suggests that the majority of fishers in Sierra Leone believe that the competition has reduced the availability of resources in closer waters, forcing them to travel farther and incur higher fishing costs, such as for fuel.[clxxx]
2. **While not perfectly interchangeable, the higher efficiency of trawl vessels can outcompete small-scale fishers for the same resources – and they often do in West Africa, resulting in intense competition for fisheries resources.** There are increased economic costs for small-scale fishers, similar to the impact from conflict over ocean space as previously stated. Additionally, there are negative implications for community food security because of reduced catches due to competition for fisheries resources with trawl vessels, though with relatively little analysis of the magnitude of the impact. It is known that trawl operations within nearshore waters legally reserved for small-scale fisheries have continuously "put a strain on food security."[clxxxi]
3. **Lastly, in some instances trawl vessels cooperate across value chains with transshipment of trawl catch being sold to small-scale fishers.** The *saiko* fishery in Ghana is a clear example of this cooperation, where trawling vessels sell back trawled fish caught in the inshore zone to small-scale fishers who have legal rights to catch that fish. Ghana's small-scale fishing sector, which employs about 80 percent of the country's fishers and ensures livelihoods for more than 2 million people, continues to decline and risks a possible collapse.[clxxxii] An estimated 200 coastal villages in Ghana depend on fisheries as their primary source of income.[clxxxiii] In 2017 around 80 *saiko* canoes landed over 55 percent of the total artisanal sector catch.[clxxxiv] This cooperation is likely in response, at least partially, to the effects of conflict over ocean space and competition, and can be seen as an adaptation by local fishers to maintain access to resources.

[11] John Virdin and Dana Grieco from Duke University conducted a review of the scientific literature for the period from January 1, 2000 to January 1, 2020. Search strings were developed from a review of key recent papers on West Africa's fisheries as well as a review of their references. These search strings were used on March 17, 2021 in the following databases: Web of Science, Scopus and the Earth Atmospheric and Aquatic Sciences (EAAS) database, returning 38 papers for review. The papers retained were reviewed for content describing interactions between the trawl fisheries and small-scale fisheries in West Africa. Following an inductive approach, the interactions between trawl and small-scale fisheries were identified and categorized based on open coding, together with the types of impacts on small-scale fisheries from each category. Finally, with categories of interactions identified, and their associated impacts on small-scale fisheries, the information relevant to each was synthesized.

6 Global extent

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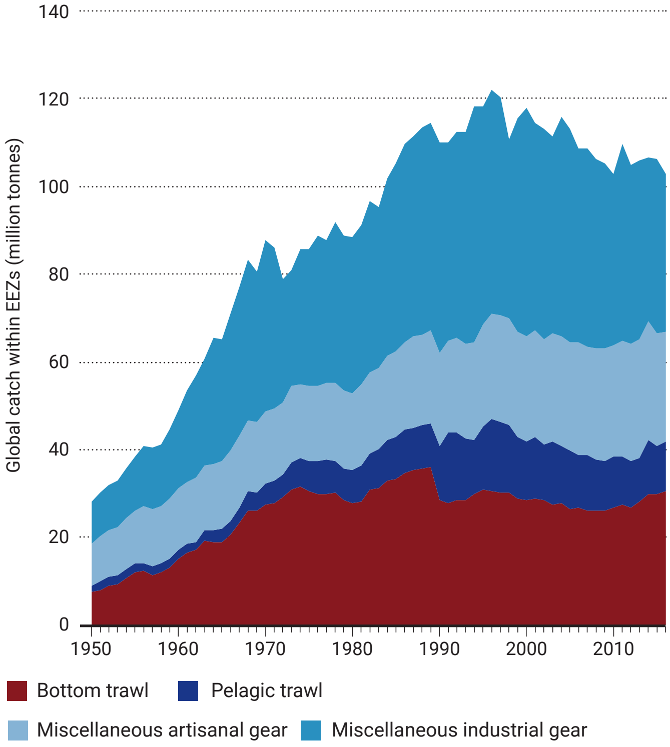
6. Global extent

This section uses novel analysis of global catch reconstructions provided by Sea Around Us, a research initiative at the University of British Columbia, to estimate the global extent of bottom trawling. It presents historical trends by geography and gear type and discusses limitations with these estimates. It offers a discussion on the global distribution of environmental impacts from bottom trawling and concludes with a separate discussion of foreign fishing fleets and their contribution to bottom trawling catches.

Contribution of bottom trawling to global catch

According to reconstruction estimates from Sea Around Us (SAU), bottom trawling represents 26 percent of the global fisheries catch within exclusive economic zones (EEZs) but varies significantly by country and region (see Figure 5).[12] In 2016, the last year for which data is fully available, this equated to 30.5 million tonnes of seafood caught by bottom trawls within EEZs.[13] Less than 1 percent of bottom trawling occurs outside EEZs, amounting to about 0.2 million tonnes of catch in 2016. Bottom trawling catches saw a steep growth beginning in the 1950s from less than 8 million tonnes/year to a peak of 36.5 million tonnes in 1989, followed by a period of decline and stabilization. In recent years, bottom trawling has pulled in approximately the equivalent quantity of fish to all artisanal gears combined, and nearly three times that of pelagic trawling gears.

Figure 5 Global marine fisheries catch within EEZs from 1950-2016, by gear type. Source: Sea Around Us (SAU)



Bottom trawling saw a steep growth beginning in the 1950s from less than 8 million tonnes/year to a peak of 36.5 million tonnes in 1989, followed by a period of decline and stabilization.[clxxxv]

Patterns showing stability in bottom trawl catch at the global level obscure trends and impacts at the regional, national, and sub-national level. Some areas have significantly higher or lower amounts of catch from bottom trawling than others, and total catch is an imperfect proxy for environmental impact because an overexploited fishery can have low catch amounts but involve a high effort (i.e., repeated bottom trawling of the seabed) due to depleted local stocks.

The percentage of total catch from bottom trawling gears varies significantly by region. Oceania[14] has the highest proportion of its total catch from bottom trawling with 44 percent – almost twice the global average. Within this region, New Zealand has a similar quantity of bottom trawl catch to Australia despite only having some 20 percent of its population size, pulling approximately 53 percent of its total catch through bottom trawling. In contrast, only 4 percent of the total catch in South America comes from bottom trawling due to the region's focus on small pelagic fish like anchoveta. In Africa, Asia, and North America, approximately 21-29 percent of the total catch is caught via bottom trawling – this is consistent with global averages and represents almost 24 million tonnes of catch per year.

[12] Sea Around Us (SAU), a research initiative at the University of British Columbia, uses "reconstructed" global catch data to combine officially reported landings with comprehensive estimates of unreported landings and discards. While the catch reconstructions have some uncertainty, this methodology led to the most comprehensive database of global catch estimates in the world. The catches therein can be disaggregated by gear type and locality to estimate trends in bottom trawl catch. The report's authors used SAU data for this study because catch can serve as a proxy for fishing effort. Additionally, no other dataset exists that allows comparisons at the global level. Efforts to describe bottom trawling effort in greater detail have mostly focused on specific seabed areas, such as Amoroso et al. (2018). Other datasets, such as those provided by Global Fishing Watch, are currently constrained to where automatic identification system (AIS) data is available. The period used for this analysis, 2007-2016, represents the most recent decade for which full catch reconstruction data was available while this report was being written; since the analyses reported herein were performed, the SAU data were updated to 2018. These new data do not modify the trends and comparisons reported.

[13] SAU data disaggregates catch by gear type. In the database "bottom trawl" refers to beam and otter trawls. Seafood caught via dredge is not included in these estimates, as it accounts for only 0.91 percent of all seafood caught in EEZs and the high seas in the latest year for which there is complete data (2016).

[14] The authors assigned bottom trawling catch at the continent level based on EEZs. Countries with EEZs spanning multiple continents were split proportionally so that catch occurring in the EEZs of particular continents was properly attributed to that continent. For example, bottom trawl catch in Russia's six EEZs was assigned to either Arctic, Asian, or European catch based on the location of each EEZ.

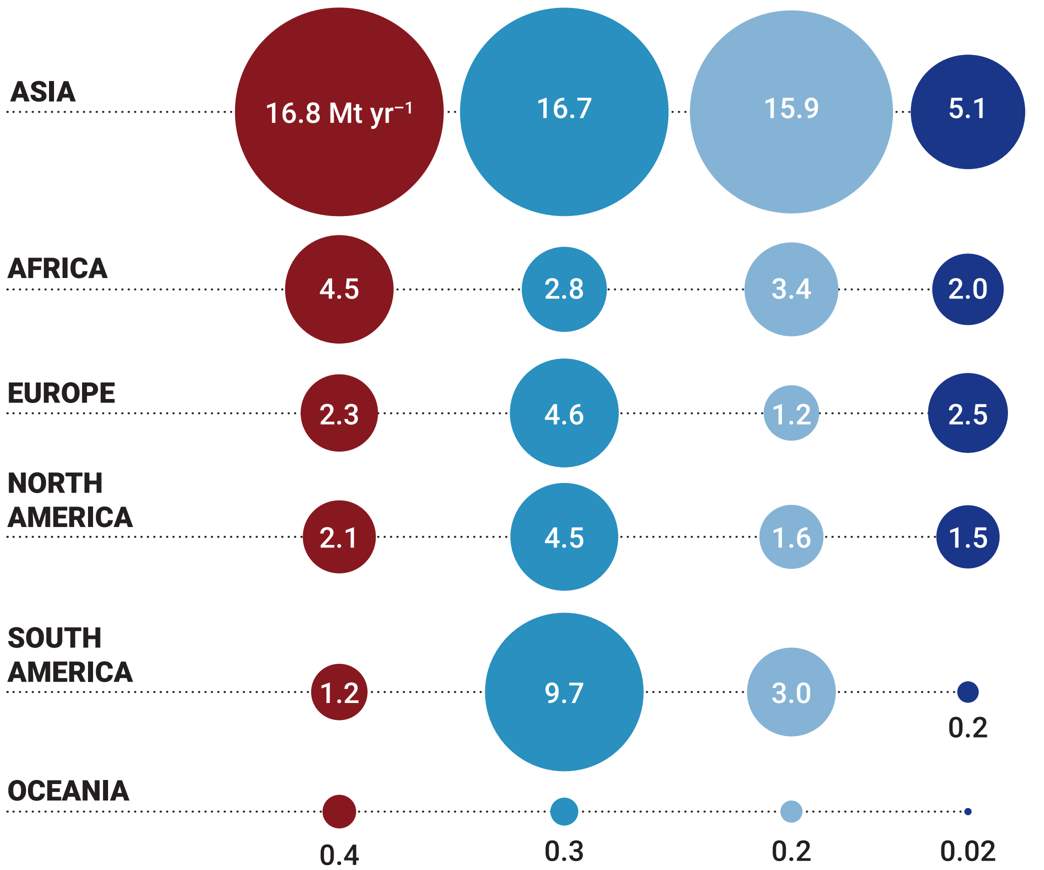
6. Global extent

From 2007-2016, more than half of all bottom trawling catch was caught in the EEZs of Asian countries (see Figure 6**).** Bottom trawling peaked in Asia before the fall of the Soviet Union at around 18 million tonnes/year in 1989, when a large-scale switch from bottom trawl to pelagic trawl for Alaska pollock in the Russian Far East and fleet diversification in the Barents Sea precipitated a global decrease in bottom trawl catch.[clxxxvi] Since the gear transition, Russia's total bottom trawl catch has amounted to less than 1 million tonnes/year, while dramatic increases in China and Vietnam have driven the rise in bottom trawl catch in Asia back to 1989 levels. In most other regions, bottom trawling is slightly declining or staying constant (although individual countries may vary).

In Europe, bottom trawling as a percentage of overall catch has decreased relative to pelagic trawling, which began taking over a more significant portion of the catch in the late 1990s.

Major bottom trawling regions overlap with areas of the world where the majority of small-scale fishing occurs. According to the *Hidden Harvest* report, 97 percent of workers in commercial capture fisheries value chains are in developing countries, predominantly Asia and Sub-Saharan Africa, of whom more than 90 percent work in the small-scale fisheries subsector.[clxxxvii] These two regions also have the highest absolute amounts of bottom trawling, which can create conflict between industrial and small-scale fishers.

Figure 6 **Global catch by gear type (within EEZs)**



Bottom trawl · Miscellaneous artisanal gear · Miscellaneous industrial gear · Pelagic trawl

Asia contributes 60 percent of global bottom trawl catch, totaling approximately 14 million tonnes/year over the last decade of available data (2007-2016).[clxxxviii]

6. Global extent

Major bottom trawling countries

At the sub-continent level, bottom trawling is concentrated in East Asia, Southeast Asia, and West Africa. The top 10 bottom trawling countries contribute 64 percent of the global bottom trawling catch. Of these 10 countries, seven are in Asia: China, Vietnam, Indonesia, India, Japan, South Korea, and Malaysia (see Table 6). Given the outsize role of these countries, they may be promising focal areas for efforts to minimize the ecological and socio-economic impacts of bottom trawling.

Table 6 Top 10 bottom trawling countries by total catch and percentage of global catch.[clxxxix]

Country	Average annual bottom trawl catch (2007-2016) in million tonnes	Percentage of global bottom trawl catch
China	4.1	14.9
Vietnam*	2.3	8.3
Indonesia	2.2	8.1
India*	1.9	6.8
Morocco*	1.8	6.5
Japan	1.8	6.4
South Korea	1.1	4.1
United States	1.1	4.0
Argentina*	0.7	2.5
Malaysia	0.7	2.4

*Vietnam, India, Morocco, and Argentina have high uncertainty in the disaggregation of reconstructed catch estimates by gear type from SAU due to large amounts of unreported data and unidentified species in their catch reports.

Bottom trawling is growing rapidly in many Asian countries. In the last two decades China has become the country with the highest bottom trawl catch, accounting for 15 percent of global catch from bottom trawling over the past decade. The country has also seen explosive growth in its bottom trawling catch of nearly 400 percent in the last four decades, from 1.4 million tonnes in 1985 to 5.2 million tonnes in 2015. Vietnam has the second highest bottom trawl catch and shares a border with China, putting extra pressure on fish stocks in the region. Vietnam also has the largest bottom trawl fleet in Southeast Asia – approximately 20,000 vessels (both bottom trawling and pelagic trawling) and about twice the size of Indonesia's fleet.[cxc] Vietnam has seen over 7,000 percent growth in bottom trawling since the 1970s, while India and Myanmar have both seen more than 400 percent growth.

Bottom trawling levels might be even higher than SAU data suggests in countries such as Indonesia, North Korea, and the Philippines. Unpublished Global Fishing Watch (GFW)[15] near-shore radar detections indicate that levels of bottom trawling may be even higher than those estimated by SAU in many Asian countries, including Indonesia, North Korea, and the Philippines where automatic identification system (AIS) coverage is limited. Additionally, through SAU data and expert interviews, the authors are aware of several regions where there are "mini-trawlers" or "small trawlers" that might not get picked up by radar, including Cambodia, Indonesia, the Philippines, the US Gulf of Mexico, the North Sea, and the Mediterranean.

In many African and European countries more than half of the total catch comes from bottom trawling, suggesting very high reliance on the practice (see Table 7)**.** Given the importance of this fishing method to the seafood sector in these regions, any efforts to reduce bottom trawling would require significant investment, capacity building, and provisioning for a successful transition to support fleet diversification or a just transition.

Table 7 Top 10 countries ranked by the percentage of their total EEZ catch from bottom trawling gears.

Country	Average bottom trawl catch (2007-2016) in millions of tonnes	Percentage of sea-food catch from bottom trawling
The Netherlands	0.09	65
Morocco*	1.8	65
Somalia*	0.1	64
Vietnam*	2.3	59
Guinea*	0.5	59
Côte d'Ivoire	0.1	56
Germany	0.9	55
Republic of the Congo	0.05	54
Guyana	0.03	53
New Zealand	0.4	53

Average bottom trawl catch represents average values for the most recent decade for which data is available (2007-2016). Only countries with at least 10,000 tonnes/year are included.[cxci]

*Morocco, Somalia, Vietnam, and Guinea have high uncertainty in the disaggregation of reconstructed catch estimates by gear type due to large amounts of unreported data and unidentified species in its catch reports.

Approximately half of all coastal countries have little or no bottom trawling. Of 156 coastal countries, 73 have less than 10,000 tonnes per year caught in their EEZs through bottom trawling. This includes several South and Central American countries and territories such as Colombia, Venezuela, French Guiana, Honduras, and Belize (which banned the practice in 2010). While bottom trawling may not be a major presence in these waters, from a global perspective, even low levels of catch or short durations of bottom trawling can have relatively large impacts on marine habitats. Furthermore, global trends and lessons from Asia show that growth in use of the gear can occur rapidly and foreign bottom trawl fleets often push into underexploited EEZs if demersal fish stocks in their home waters show decline.

[15] Global Fishing Watch (GFW) is an international non-profit that uses vessel GPS data, including AIS and synthetic aperture radar (SAR), to track vessel locations globally. These data sources can be used to identify undetected near-shore vessels that can serve as a proxy for estimating bottom trawling effort in the EEZs of countries which supply their data to GFW.

6. Global extent

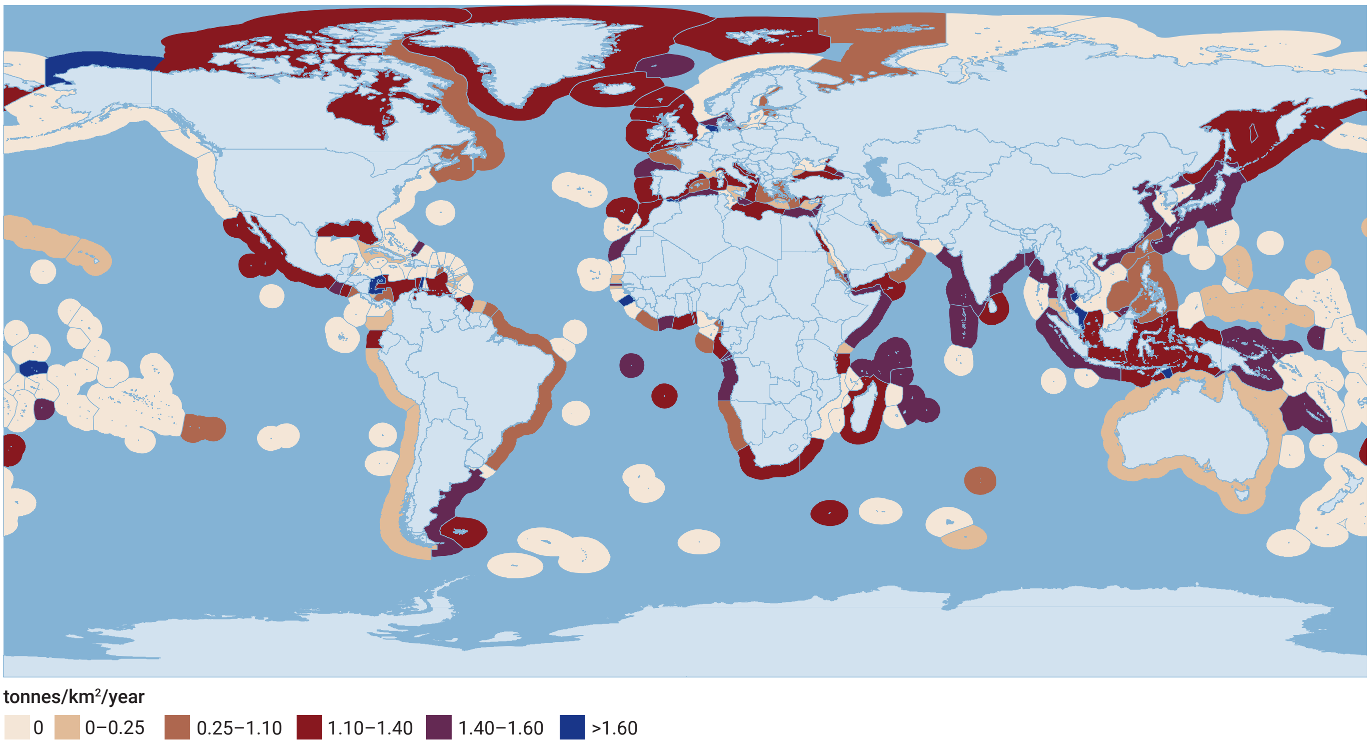
Global extent of environmental impact

Mirroring catch, the ecological impact of bottom trawling is not evenly distributed. Bottom trawling's effects on overfishing, bycatch, and habitat can be more a function of the intensity of effort rather than the overall catch amounts throughout an EEZ. An individual bottom trawl fishery can occur along an entire coastline, or target one seabed area for repeated exploitation, meaning that the ecological impacts are dependent on the characteristics of the specific bottom trawl fisheries. Bottom trawling intensity, a measure of how often a region is fished with bottom trawling gears, determines the environmental impact on specific seabed areas. Where specific vessel location data is unavailable, bottom trawling intensity can be estimated by dividing the total catch in an area by the size of that area.

Average bottom trawl intensity is highest in nearshore territorial seas and the EEZs of a few West African and Southeast Asian countries (see Figure 7)**.** Intensity estimates (as measured by catch per unit area) for territorial seas are on average more than twice the rate of intensity estimates within EEZs – approximately 0.4 tonnes/km^2/year in territorial seas versus 0.2 tonnes/km^2/year in EEZs. Areas close to shore tend to be fished by artisanal and small-scale fishers, which may contribute to conflict between artisanal fishers and industrial bottom trawlers. At the EEZ level, bottom trawling intensity is highest in Guinea, Guinea-Bissau, Morocco, South Korea, Cambodia, Thailand, and Cameroon, which suggests that the seabed of these nations is strongly impacted by bottom trawling. Of this group, Guinea stands alone with more than 5 tonnes of bottom trawl catch/km^2/year, over 1.5 times the intensity of neighboring Guinea-Bissau. However, low average intensities as measured by catch/area may indicate that an area that has been historically trawled is already depleted, rather than reflecting less activity from bottom trawling vessels. For example, the Mediterranean appears to have a lower catch/area from bottom trawling which may be reflective of the low levels of catch due to depleted stocks, rather than lack of bottom trawl activity, as there are several thousand bottom trawl vessels active in the region.[cxcii]

Another measure of trawling intensity is swept area ratio (SAR), the sum of the area swept by bottom trawls divided by the area of the region. The Mediterranean and Northern Atlantic regions appear to have the highest trawling intensity as measured by SAR. Amoroso *et al.* (2018) used high-resolution satellite vessel monitoring system (VMS) and logbook data on 24 continental shelves to find that the highest SAR bottom trawling intensity occurred in the Adriatic

Figure 7 **Bottom trawling intensity estimates in EEZs between 2007 and 2016.**[cxciii]



6. Global extent

Sea and the region west of Iberia.[cxciv] The study found that trawling footprints are mostly localized and take up less than 10 percent of the area in almost half of the regions studied. However, when scaled to the entire area of continental shelves globally, bottom trawling is still the single largest anthropogenic physical disturbance of global seabed habitats. The estimated global bottom-trawled area of 1.1 million km^2/year is at least 10 times larger than the 100,000 km^2/year of forest lost to deforestation.[cxcv,cxcvi]

Furthermore, climate change may contribute to shifting fish stock ranges, which could widen the existing footprint of bottom trawling as fishers seek to adjust their fishing effort in response. Fish have been observed to shift into new territory at a rate of 70 km per decade as a result of climate change, with shifts expected to accelerate going forward.[cxcvii,cxciii]

Distant water fishing and bottom trawling

The reach of several countries' bottom trawling fleets extends well beyond their own EEZs and into the waters of other countries. Understanding the global extent of bottom trawling and its environmental and social impacts requires looking at not just where the fishing is happening, but who is doing it. Around the world, 22 percent of all bottom trawl during the most recent decade of available data occurred on foreign-flagged ships in other countries' EEZs (see Figure 8). This figure could be even higher, given that a significant amount of distant-water fishing is thought to be illegal, unreported, and unregulated, and is thus difficult to track. In 34 countries, predominantly in Africa, over 90 percent of the catch caught by bottom trawlers in the EEZ is caught by foreign-flagged vessels. With few exceptions, the countries with the highest overall catch from bottom trawling – such as China, Vietnam, Indonesia, and India – also have the highest overall catch from bottom trawling by their fleets fishing in foreign waters.

Foreign-flagged bottom trawling vessels are predominantly of Asian and European origin and operate primarily in Africa and Oceania. Over half of the bottom-trawl catch landed in Africa and Oceania is caught by vessels with Asian or European flags. In contrast, almost all the bottom trawl catch in Asia, Europe, and the Americas is caught by trawlers flagged to the country in which they fish. China deploys bottom trawlers in the EEZ of nearly every country in West Africa and is the primary fishing entity in Côte d'Ivoire, Ghana, Guinea-Bissau, Liberia, and Togo.

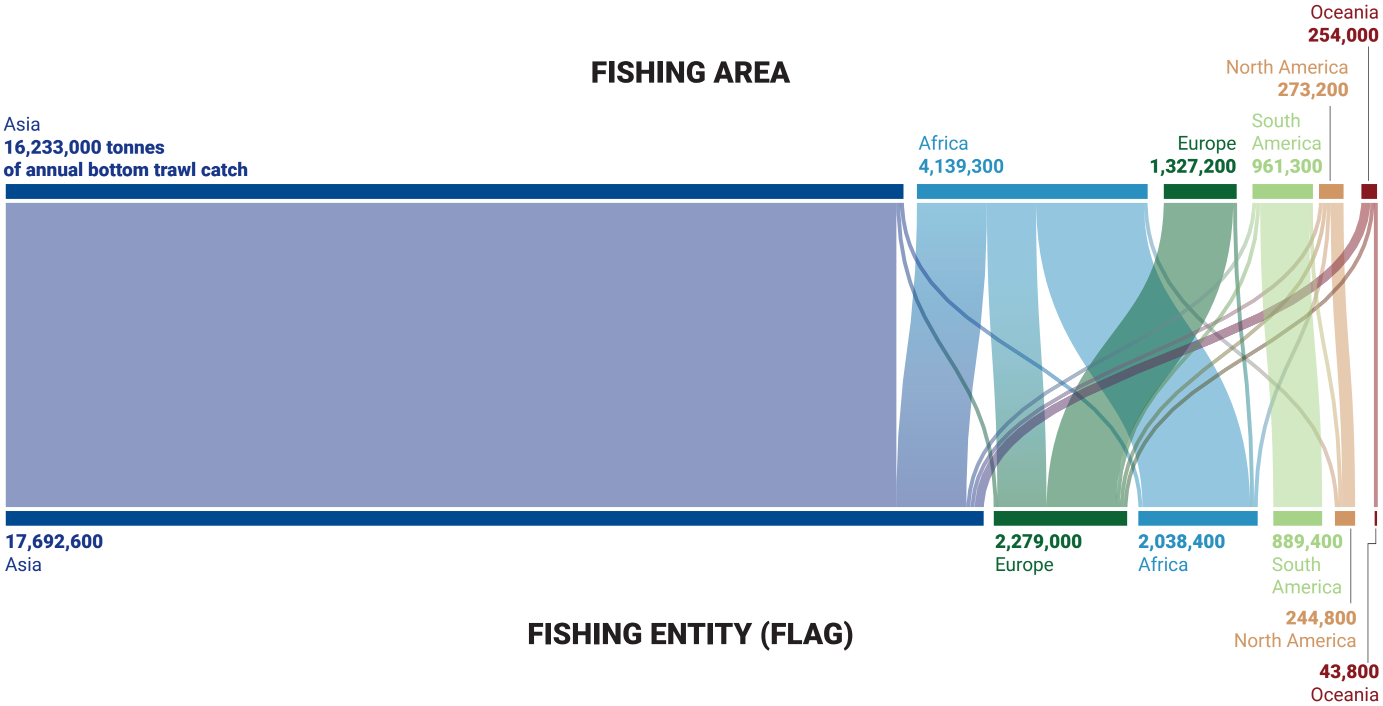
The presence of foreign bottom trawling has implications for local livelihoods, economies, and politics. Though the social implications of foreign bottom trawling are not well documented at the global level, various regions have long histories of associated conflict. In West Africa, foreign bottom trawlers have played a critical role in shaping local dynamics (See Section 5: *State of the evidence: socio-economic impacts*).[cciii] Social unrest, violence and food insecurity in Mauritania and The Gambia are connected to the foreign fishmeal factories that are primarily sustained by foreign trawlers, with many trawlers actively fishing in areas reserved for artisanal fishers.[cciv,ccv,ccvi] Although trawlers mostly target pelagic species, pelagic or midwater trawling in some cases takes place in shallow waters and can effectively act as a bottom trawl. Bottom trawling is illegal in Somalia, yet bottom trawlers are responsible for 6 percent of total foreign catch in the country.[ccvii] While this may be a relatively small amount, bottom trawlers have disproportionately influenced the overall Somali perception of foreign fishing and have come to symbolize the conflict between foreign and domestic fishers.[ccviii] In South Asia, increasing animosity between Indian and Sri Lankan bottom trawlers has resulted in violent and even deadly conflict over fishing access.[ccix]

Foreign access agreements for bottom trawlers often come at the expense of local fishers and coastal communities. Governments establish agreements with foreign bottom trawlers under the pretense of increasing economic benefit domestically. However, many of these agreements result in local fishing communities losing access to valuable resources. This in turn threatens coastal livelihoods and economic growth in the long term. A recent study found that the foreign fishing access agreements for bottom trawl fisheries in West Africa generated revenues between 2-8 percent of the estimated landed value of the harvest.[ccx] In other words, West African governments are agreeing to significant trade of critical resources without getting much in return.

6. Global extent

The overall effect of bottom trawling on stock status and recovery post-trawling in non-target benthic species is not well documented, but there are indications of regional concern. Hilborn *et al.* (2021) recently published a review of 349 individual stocks constituting 90 percent of the global groundfish catch (which are traditionally caught via bottom trawl) and found that, on average, stock abundance is increasing and is currently above the level that would produce maximum sustainable yield.[cxcix] However, the study showed that in several parts of the world with high levels of bottom trawling including Japan, Russia, Chile, and Argentina, groundfish stocks continue to be below sustainable biomass levels. Mazor *et al.* (2020) found that most species are depleted by only a few percent where bottom trawling occurs, though this figure can be up to 14 percent in Europe where trawl intensity is high and has persisted for decades. However, these studies failed to consider the impact on structure-forming species, harm to which is viewed by many marine ecologists as a potential ecological threat of bottom trawling. For example, ecological damage to non-fish species such as sponge and corals from bottom trawling has been identified in the Aleutian Islands, and the disturbance could take over three decades to recover.[cc] Additionally many bottom trawl fisheries are in parts of the world where stocks are unassessed or where fisheries governance is weak, such as West Africa, Southeast Asia, India, and China.[cci, ccii]

Figure 8 Flow of annual bottom trawl catch (in tonnes) from foreign-flagged vessels



About half of the total bottom trawl catch within African EEZs is from vessels with Asian or European flags.[ccxi]

7 Paths forward

7. Paths forward

This section seeks to build on the common understanding of the extent and impacts of bottom trawling discussed in previous chapters by presenting possible paths forward that acknowledge the broader context and importance of the sector. It concludes with recommendations for constructive action.

Avoiding, minimizing, or mitigating environmental impacts

There are generally two broad categories of approach when it comes to addressing the environmental impacts of bottom trawling: manage its worst impacts or fundamentally limit the practice.

1. **Measures to manage impacts.** This set of interventions uses the conventional tools of fisheries management (monitoring, enforcement, input and output controls) to manage fishing effort for bottom trawls in the same way that other fishing methods might be managed. Many of these approaches are not unique to bottom trawls and operate under the fundamental assumption that the environmental impacts of all fishing methods can be managed. These interventions can be categorized into four types:
   - **Technical, gear, and vessel measures** that change operations in order to improve efficiency, increase yield, or achieve legal compliance (e.g., increased mesh sizes to allow less retention of juveniles, electronic monitoring, bycatch reduction devices). These could also include measures that apply only to bottom trawling to reduce bottom trawl-specific impacts (e.g., devices that reduce bottom contact, penetration depth, or fuel consumption; modifications that affect weight and durability of gear; "move-on" rules when sensitive species are identified in trawl catch; use of pre-catch image identification software to increase selectivity).
   - **Spatial and temporal controls (non-gear-specific and gear-specific)** to protect target species at vulnerable life stages or VMEs (e.g., the protection of nursery grounds and spawning areas, seasonal closures, marine protected areas that ban industrial uses, no-take zones).
   - **Output controls** to limit the amount of seafood that can be caught in a given fishery, which may or may not include bycatch or habitat impact quotas.
   - **Effort controls** that affect the number and types of vessels that can exert bottom trawling effort.[ccxii]

Fisheries management interventions require relatively good governance and coastal community buy-in to be successful and effective. Given that most bottom trawl fisheries occur in parts of the world with relatively weak fisheries governance (see Section 6: *Global extent*) the tools of fisheries management have often been criticized as not appropriate or ineffective in these contexts.[ccxiii,ccxiv,ccxv] These tools are unlikely to make sense in parts of the world which lack the ability to monitor or enforce these kinds of solutions.

2. **Measures to limit the practice.** This set of interventions refers to efforts to severely limit the footprint of bottom trawl fleets under the assumption that bottom trawling has unique environmental impacts that are socially, politically or otherwise unacceptable, and for which the tools of fisheries management are unlikely to be effective. These often include measures beyond the fisheries management toolkit (e.g., bans, campaigns, artificial reefs, subsidy reform, ecosystem-based management). These interventions can include:

- **More aggressive gear-specific spatial measures** to restrict bottom trawling (e.g., "no trawling" standards in MPAs, IEZs, VME closures, MPA "minimum standard" laws to protect essential habitats; "freezing the footprint" approaches)
- **Complete prohibitions** such as national-level gear-specific bans
- **Deterrents** such as anti-trawling devices (e.g., artificial reefs built of large concrete blocks)
- **International laws, standards, and agreements** that seek to constrain the practice (e.g., subsidy reform at the World Trade Organization, prohibitions within international waters, regional ecosystem-based management approaches).

Minimal evidence exists to systematically evaluate and compare the effectiveness of different approaches to manage or limit bottom trawling. Conventional fisheries management approaches –particularly those addressing capacity (i.e., effort and output controls) – have seen declines in bottom-trawled target species reversed in some temperate trawl fisheries.[ccxvi] However, whether changes in trawl fishing effort drive improvements at an ecosystem level has not been conclusively demonstrated and many advocates remain unconvinced that stable catches of trawled species offer a sufficiently robust indication of a healthy marine environment. While more comprehensively addressing impacts unique to these fisheries, bottom trawl-specific measures – particularly the more stringent approaches such as national bans or large inshore exclusion zones – can be highly contentious and lead to significant additional social conflict (e.g., the Costa Rica and Indonesia bottom trawl bans), especially in cases where the costs of retiring licences, scrapping trawl vessels and redeploying trawl workforces have not been adequately identified or covered by the state. [ccxvii,ccxviii] Such dramatic measures may yield straightforward benefits, such as increases in non-trawl catches (particularly where trawlers and non-trawlers are targeting similar species groups)[ccxix], higher biomass of high trophic level species, increases in extent of sensitive seabed habitats, and increased diversity in seabed ecological communities.[ccxx, ccxxi,ccxxii]

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Through expert consultation the report authors identified several real-world examples that demonstrate the success of both measures to manage and limit bottom trawling's environmental impacts. There are examples of NGOs, the fishing industry, academia, fishing communities, and civil society successfully working together globally to try to minimize the harmful impacts of the practice, and in cases where those impacts are deemed unacceptable, to severely constrain it (see Table 8). Efforts that align with existing political will and collaboration with the seafood industry appear to have been more effective in minimizing the bottom trawling sector's impact while not fundamentally changing the status quo. However, many advocates argue that these efforts do not go far enough in protecting vulnerable ecosystems and that more aggressive measures are needed.

Table 8 **Examples of measures to manage or limit bottom trawling's environmental impacts**

Examples of measures to manage	Examples of measures to limit
• **China**'s central government passed a mandate to reduce fishing capacity that resulted in a 10 percent decrease in bottom trawling vessels.[ccxxiv] • WWF-Russia has worked with the MSC-certified pollock fisheries in the **Barents Sea** to model and transition to "gentle trawl" gears that significantly reduce environmental impacts.[ccxxv] • In **South Africa**, the hake bottom trawl fishery voluntarily gave up 5 percent of the EEZ to trawling in response to pressure from the MSC and NGO objections	• The **United Kingdom** banned bottom trawling in four MPAs as part of an effort to show improved support for marine conservation.[ccxxv] • In **Costa Rica**, the tourism industry, sport fishing sector, small-scale sector, and longline sector joined forces to advocate against the domestic bottom trawling sector, resulting in a constitutional ban.[ccxxvi] • In **Madagascar**, small-scale fishers successfully got permits for foreign bottom trawlers revoked by the government after incursions into their fishing area. • The Deep Sea Conservation Coalition engaged in a successful 17-year effort to work with the UN to acknowledge and formally recommend limits to bottom trawling in VMEs on the high seas.

All of these interventions imply tradeoffs; therefore, which solutions make sense will depend on what fisheries managers, communities, governments, and NGOs deem to be priorities, and the resources available for implementation. While minimal habitat impacts especially for sensitive species or areas may be desirable from an environmental perspective, or a reduced overall carbon footprint to stay within planetary boundaries, competing objectives might include maintaining employment in the bottom trawl sector, or supporting the aquaculture feed sector and the food it provides to urban consumers. Awareness and management of the inherent tradeoffs in these complex systems is critical.

Avoiding, minimizing, or mitigating social impacts

More work is needed to identify solutions that can avoid, minimize, or mitigate negative social and economic outcomes of bottom trawl fleets – especially for structurally vulnerable or marginalized groups.[ccxxvii] The pervasive social challenges (and in some cases human rights abuses) associated with seafood production have only recently received attention from the marine conservation community and the seafood industry. Although tools like the Monterey Framework for Social Responsibility outline a set of goals for social responsibility in the seafood industry, the framework is far from being widely adopted by the seafood sector and faces significant resistance from both the conservation community and the seafood industry.[ccxxviii] The Transform Bottom Trawling Coalition explicitly calls for four actions to reduce both environmental and social impacts: 1) strengthening national IEZs for small-scale fishers, 2) prohibiting bottom trawling in all MPAs, 3) ending harmful subsidies to bottom trawlers while supporting a fair and just transition for all those affected, and 4) prohibiting the expansion of bottom trawling to new, untrawled areas. Sharing best practices for managing the social and economic impacts of bottom trawl fisheries as well as examples of successful transitions could help fishing communities, the seafood industry, and NGOs envision a future whereby at a minimum, bottom trawl fisheries do no further social or economic harm.

Possible solutions to support positive and just social outcomes could follow the outline presented by the High Level Panel for a Sustainable Ocean Economy: safeguards, mainstreaming equity, and transformative approaches.[ccxxix] The association between bottom trawl fisheries and human rights abuses suggests that basic human rights are not being protected in this subset of the fishing sector and that stronger safeguards are required. Human rights due diligence is one such approach that is increasingly being piloted in the seafood sector – which is arguably long overdue in comparison to other food and commodity sectors. An additional safeguard should be the protection of exclusive access for small-scale fishers, especially in the nearshore zone or territorial seas. This is consistent with the FAO Guidelines for Small-Scale Fisheries that, as of yet, are purely voluntary. IEZs are one promising tool (see Section 5: *State of the evidence: socio-economic impacts*) that would benefit from greater enforcement and institutional support. Other transformative approaches

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could include economic transition packages that go beyond pure vessel buybacks, which are rife with challenges, and towards approaches to help actually transition fishers and fishworkers out of bottom trawling and into retraining in equally compensated or similar sectors, or retirement. Similar programs are being considered under the moniker of a "just transition" away from fossil fuels, recognizing that these transitions will hit fossil fuel workers first and worst. Given that global bottom trawling fleets are highly uneconomical even with subsidies, the time may be ripe to reconsider more beneficial redirection of those resources.[ccxxx]

Just transitions in the bottom trawl fishery

Just transitions represent strategies to move away from extractive economies.[ccxxxi] They are rooted in labor unions and the environmental justice movement and are meant to ensure that workers impacted by economic shifts can equitably access pathways to new opportunities. Although just transitions can look very different depending on the context they are considered in, they ultimately share a set of core principles including 1) guaranteed pathways to quality jobs, 2) training and retraining support, and 3) worker transition funds.

There have been no well documented just transitions in the bottom trawling fleet. However, Hong Kong's 2012 trawl ban and associated buyout scheme serves as an example of a type of economic package that can support the transition away from bottom trawling.The buyout scheme included 1) compensation to trawl vessel owners who stopped fishing in inshore waters, 2) introduction of the voluntary buyout scheme with a one-year transitional period, and 3) payment to crew members affected by the trawl ban.[ccxxxii] Training and technical support were offered to fishers who wanted to transition to other fishing operations.[ccxxxiii] The buyout scheme amounted to $219 million, which included payment for affected fishing crew members.[ccxxxiv] Part of the buyout scheme included plans to sink some of the fishing vessels so they could be used as artificial reefs to improve the local marine environment. Hong Kong's buyout scheme gives insight into what countries with similar resources and contexts could potentially achieve. However, more work is needed to ensure a true just transition.

Further consideration of the social and political dimensions of a transition either towards more limited bottom trawling, or away from the practice entirely, may create new opportunities to achieve more positive outcomes for people and nature. Efforts to limit bottom trawling have historically been contentious, due to significant political, cultural, financial, and even environmental obstacles. Yet in many parts of the world governments, communities, civil society, and the seafood industry itself are looking for solutions to the impacts of this method of seafood production that is often highly subsidized, economically inefficient, with an aging workforce, and which has environmental, climate, and social impacts that are increasingly challenging to justify. It is important for any transition away from bottom trawling to avoid demonizing those who currently work in the sector – especially in cases where those working in the sector may support economically fair and socially just transitions.

Strategies and solutions need to address the dependence that many across the world have on this fishing practice and include viable alternatives to prevent undue harm to already vulnerable communities. More creativity and experimentation is needed from both the conservation community and seafood sector to identify viable ways forward that do not further marginalize fishers, workers, and those already marginalized by this sector. Thus, in 2010 in Belize, the environmental NGO Oceana, working with local allies and the government of Belize, after a public information campaign emphasizing the need for sustainable fisheries, was able to achieve a legislated ban on all trawling in the EEZ by arranging the purchase and decommissioning of a pair of aging trawlers.[ccxxxv]

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Recommendations for constructive action

The authors recommend that fisheries decision-makers, managers, fishing industry leaders and advocates prioritize the following nine high-level actions to transform bottom trawling for better environmental and socio-economic outcomes (under the acronym **"TRANSFORM"**):

- **Transition the system:** Bottom trawling supports a set of complex, distinct food and non-food commodity systems that are globally interconnected. Solutions must take into account broader dynamics – such as broad social changes in fishing culture, the rise of the global seafood trade, and food consumption patterns – in order to avoid unintended consequences, such as effort displacement. Solutions to manage or limit bottom trawling should not be viewed in isolation by policymakers, fishery managers, NGOs, or communities.

- **Respect human rights:** To catalyze meaningful improvement in bottom trawl fisheries requires a human-centered approach. This means respecting both the civil and political rights, as well as the economic, social and cultural rights of those working in and affected by such fisheries. Bottom trawl fisheries – and policy changes relating to them – must abide by a minimum standard of "do no harm." More baseline research into socio-economic impacts and possible solutions (especially distributional impacts) should accompany these efforts.

- **Accelerate the transition to best practices:** Modern management practices – from gear innovation to enhanced observer coverage – have dramatically improved the performance of some bottom trawl fisheries, particularly in stabilizing overexploited stocks, increasing selectivity, and reducing seabed pressure especially in VMEs. Urgent effort is needed to export these practices to regions that need them most, particularly in low- and middle-income countries in the tropics.

- **Negotiate political action:** Decision-makers must recognize the unique biodiversity, climate and social conflict challenges associated with bottom trawling and legislate for it as a special case – both through national policies and international standards and agreements. As well as making bold, gear-specific policy decisions, this should also include acknowledging the significant investments and trade-offs needed to adequately resource any transition away from bottom trawling.

- **Stop harmful subsidies:** Definitions of "harmful" subsidies must include those accessed by specific fisheries using the highest impact practices, including bottom trawl fisheries. Conversely, subsidies supporting transition out of (or to improve) practices such as bottom trawling should be considered "beneficial."

- **Freeze the footprint:** Given the multitude of unresolved challenges around bottom trawling – at global and local levels – any new or expanded fisheries should be regarded as politically, socially, environmentally, and economically inappropriate.

- **Open up dialogue:** Discourses around bottom trawling from the fisheries and conservation sectors do not tend to emphasize common ground. Bold alliances and painful but necessary compromise are needed to meet the twin climate and biodiversity crises, including between sectors with different material interests.

- **Restrict appropriately:** Ecologically and culturally sensitive areas must be protected from bottom trawling through a coherent area-based approach, encompassing inshore and offshore exclusion zones as well as all classifications of marine protected areas.

- **Monitor impact to support adaptive management:** While all best-practice fisheries require significant volumes of real-time information, bottom trawling management (with its reliance on expensive and complex seabed sensitivity data) necessitates robust, collaboratively funded research. As well as near-term management-focused monitoring, special attention should be directed to emerging areas of trawling research, especially life cycle analysis and carbon emissions arising from seabed disturbance.

This report has made the case that bottom trawling is an important and unique subset of the global fishing industry. Bottom trawling as a fishing practice has its own specific impacts and requires a combination of conventional and transformative solutions to manage them. With this synthesis of evidence, the report authors believe the time is right to reconsider some of the stale perspectives that have plagued discussion of this sector and contributed to its ongoing environmental, social, and climatic challenges. There is a possible future that is both just and sustainable, through the best that science, advocacy, and industry action have to offer.

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