Environmental Evidence

SYSTEMATIC REVIEW PROTOCOL

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Exploring the relationship between static fishing gear, fishing effort, and benthic biodiversity: a systematic review protocol

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Abstract

Background and objectives: The environmental effects of static gear fishing include habitat-level effects such as permanent changes to the physical environment and the structure of the benthic and epibenthic communities. Ecosystems subjected to prolonged exposure to pressure from static gear may undergo permanent changes and may never regain their prior 'unfished' state even if the fishing pressure is removed entirely. These long-term changes to physical structure of benthic habitats have implications for benthic biodiversity and ecosystem functioning. Despite this, the understanding of habitat and static fishing gear interactions is limited- with most studies focusing on the impact of mobile fishing gear. The rise of ecosystem-based fisheries management (EBFM), where managers and decision-makers manage target species within their environmental context while protecting essential ecosystem services and components, has led to an increased demand for ecosystem-level reference points. A systematic review could provide clarification on the short and long-term impacts of commercial static gear fishing on benthic community diversity.

Methods: This review will examine primary studies on the relationship between static fishing gear, intensity, and benthic biodiversity to answer the primary question 'How do different types of static fishing gear affect benthic species richness and abundance?'. A structured search will be conducted in English. The search terms used to find relevant data to answer the research question were chosen specifically for this review and were generated using the R package *litsearchr*. Captured articles will be screened against pre-defined eligibility criteria. The internal and external validity of remaining studies will be classified using a pre-defined framework. Studies meeting validity will be used for data extraction. Data to be extracted includes data on study design, intervention, study results, habitat and geographical context. Outcome data (such as sample sizes, means and measures of variation such as confidence intervals, standard deviations, and standard errors) will also be extracted. Information on effect modifiers will also be collected where available as well as metadata on study methodologies and general article identifiers. Data will be used for both narrative and quantitative synthesis techniques.

Keywords: Environmental impact, Fisheries, Pots, Seabed, Seafloor, Static gear, Traps

Background

The rise of ecosystem-based fisheries management (EBFM), where managers and decision-makers manage target species within their environmental contexts while protecting essential ecosystem services and components has led to an increased demand for ecosystem-level

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reference points [1]. Understanding the impacts of commercial fishing (both short- and long-term) as well as ecosystem recovery, recruitment, and regrowth is a key component of EBFM and vital to ensure ecosystem integrity alongside sustainable socio-economic benefits [1, 2].

To date, most studies exploring the impact of fishing gear on the marine environment have been centered around the impact of mobile fishing gear (gear that is dragged across the seabed or through the water column). In their 2014 paper, Grabowski et al. conducted a meta-analysis of 97 studies on the impacts of fishing gear on benthic habitats-only one of which concentrated on static fishing gear [3]. Static fishing gear (e.g. pots, traps and longlines), which is highly selective and relatively stationary, is generally assumed to cause little damage to benthic species and has been largely overlooked in the literature. Within the literature, the effects of pots and traps are overrepresented, with studies exploring the impact of nets and setlines largely focusing on the effects on populations resulting from ghost fishing from abandoned, lost, or discarded fishing gear rather than active fishing gear [2, 4, 5]. These studies have found that static fishing gear is associated with impacts such as increased sediment suspension, changes to the benthic community, and changes to physical structures within benthic habitats [5]. Much like with mobile gear, the effects of static gear on benthic habitats depends on the magnitude and frequency of the impact, the biological community present and the type of gear being used [5, 6]. One study found that high-energy environmental conditions may increase the area of impact, with wind and wave movement causing traps to move over the seabed, damaging species such as corals and reducing benthic cover [6]. These impacts are likely to be compounded by the movement of gear during fishing and retrieval [2, 6]. In another experiment 5% of traps landed directly on live epibenthic organisms when deployed, with contact rate increasing up to 50% as traps were hauled and dragged across the seabed [7].

The effects of static fishing gear can be described as either pulse (short-term) or press (long-term) and can include increased damage or mortality of individuals, changes in their feeding, growth, or reproduction rates, as well as habitat-level effects [2, 5, 8, 9]. While the fishing of individual traps or nets represent pulse impacts and are associated with increased sedimentation and damage to organisms such as seapens, corals and starfish, it is the long-term effect of static gear which is thought to have a greater influence [2, 4]. Ecosystems subjected to prolonged exposure to pressure from static gear may undergo permanent changes to their physical and community structure ('altered state') and may never regain their prior 'unfished' state even if the fishing pressure is removed entirely [2, 10]. These long-term changes to the physical structure of benthic habitats have implications for benthic biodiversity and ecosystem functioning, however our understanding of habitat-gear interactions is still limited [2]. In their 2001 study Eno et al. observed that pots and traps had minimal impact on species that had previously been assumed to be sensitive, and that in some habitats certain sponge species increased in abundance once pots and traps had been removed [2, 4].

Using a systematic review methodology, the relationship between static fishing gear, fishing effort, and benthic biodiversity will be explored on a global scale. The interaction intensity, duration, and frequency of static gear activities will be mapped against data on benthic species richness and abundance, as well as habitat type and habitat recovery rates. The findings of this systematic review and meta-analysis will provide better insight into the relationships between benthic fauna and the different methods and intensities of static fishing. Ultimately the results from this review will be used alongside existing data on known fishing-levels and habitat types to identify areas that are particularly vulnerable to current levels of static gear fishing pressure, allowing fisheries managers to redirect their resources accordingly, and may provide comparisons to mobile fishing impacts.

The systematic review protocol has been shaped and informed by the needs of stakeholders, who were contacted by the review authors via email and asked for their input into defining the research questions and identifying potential effect modifiers. Stakeholders included were primarily individuals from non-governmental organizations focusing on conservation such as the RSPB and Nature Scot, but individuals from academia and the fishing industry were also consulted. Stakeholders helping shape the review were invited by authors of the review and were given the opportunity to provide feedback on the systematic review before submission and, as well as being involved in the literature search, will be given a further opportunity to comment on the final review.

A wider pool of stakeholders (loosely defined as anyone with an interest in the review topic) will be invited to submit primary materials they feel are relevant to the review during the literature search. These stakeholders are to be reached through an open call via the author's networks and over social media.

Objectives of the review
Primary question
How do different types of static fishing gear affect benthic species richness and abundance?

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Table 1 Operational definitions and clarification of terms

Variable	Definition	Metric(s)
Abundance	The number or proportion of the same species within an area	Counts obtained through transect or quadrant sampling
Community composition	The relative abundances of taxa within an area	Biotope classification (e.g. OSPAR)
Condition	Physical state of fauna within an area	Identification of damage, disease, injury, discoloration, etc
Diversity	The richness and abundance of an area	Diversity indices (e.g. Shannon–Weiner Index or Simpson's Index)
Mortality	Measure of individual deaths	Mortality rate (may instead be measured by proxies such as community composition, abundance, or condition)
Recovery rate	Physical and biological recovery of site to a pre-determined state	Diversity of area, abundance of area, physical condition of area
Richness	The number of different species within an area	Counts obtained through transect or quadrant sampling

Secondary question (if applicable)

1. How do different static gear fishing intensities affect benthic species richness and abundance?
2. How do the impacts of high intensities of static fishing gear compare with low intensities of mobile fishing gear on benthic communities?
3. How does the rate of recovery of benthic community habitat type impact the rate of recovery for benthic communities after fishing?
4. Are recovery rates of benthic communities and individual species affected by fishing intensity?

Primary question components

The primary and secondary review questions can be broken down into the following components: subject, exposure, control, effect modifier, and outcome- as defined in Table 2.

Subject (population): Marine benthic fauna (fish and invertebrates), subtidal benthic habitats.

Exposure: Exposure to static fishing gear.

Comparator: Areas with no static fishing, areas with low levels of fishing (both static and mobile), fishing gradient studies, areas fished with mobile gear, areas fished with static gear.

Table 2 Definitions of some of the different static gear types [10]

Gear category	Gear name	Definition	Examples
Traps and pots	Barrier traps	Traps that can be closed manually by the fisher after fish enter	Walls, dams, fences, fyke nets, gratings, watched chambers
	Habitat traps	Traps that mimic hiding places for target species	Brush traps, octopus pots
	Tubular traps	Narrow funnels or hoses that prevent the fish from escaping backwards	Eel tubes
	Mechanical traps	Traps that mechanically close once the target species enters	Gravity traps, box traps, bent-rod traps (including whipping bough traps), torsion traps, snares
	Baskets	Enclosed traps and pots	Pots made of wood, wire or plastic, conical and drum-like traps made of netting with hoops and frames (e.g. Drum nets) and box-like traps made with strong frames (e.g. creels)
	Large open traps	Large open traps or corrals with a mechanism to stop escapes. These traps can be fixed on sticks or anchors and either set or floating	Corrals
	Out of water traps	Traps set out of the water to catch fish such as flying fish	Veranda nets
Longlines	Longlines	A mainline with baited (occasionally unbaited) hooks at regular intervals. Can be used in the water column or on or near the seabed (where it can be referred to as a set longline or bottom longline)	Set longlines, bottom longlines
Nets	Gill nets	Strings of single, double, or triple-walled netting which can be fished on the surface, in the water column, or on the seafloor	Bottom set gill net, trammel net

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Effect modifier: Examples include benthic habitat type, depth of sampling site, environmental factors (e.g. fronts, reefs, mounds, nutrient cycling), fishing intensity, and gear design (e.g. pot aperture size, j vs circle hooks). See "Potential effect modifiers/reasons for heterogeneity" section for a full list of potential effect modifiers.

Outcomes: Changes in the biodiversity of benthic fauna (measured by proxies such as diversity or species richness), Changes in abundance (measured through % cover, density or biomass), Changes in body size or size at maturity of an individual.

Table 1 provides a list of operational definitions and clarification of terms.

Table 2 provides an overview of some of the different categories of static fishing gear this review will include along with definitions and examples for each gear type [11]. Table 2 is not an exhaustive list and other types of static gear will also be considered.

Methods

This review will follow the guidelines set out by the Collaboration for Environmental Evidence [12] and the ROSES reporting standards [13]. The ROSES form is available as Additional file 1.

Searching for articles

A structured search will be conducted in English using web-based search-engines ($n = 1$), organizational websites ($n = 40$), and platform databases ($n = 1$). A full list of all sources that will be used can be found in later in this section. An open call to stakeholders (loosely defined as anyone working in the fishing industry, as well as conservationists and researchers) through both formal and informal networks and over social media will also be asked to provide any sources they feel to be relevant to the review topic. Stakeholders may provide either study titles or provide links to relevant studies. Supplementary searches will be carried out based on stakeholder recommendations as well as through snowball sampling of key articles and studies (identified by stakeholders).

All efforts will be made to obtain full copies of articles identified in the search process. If an article is unobtainable through stakeholder networks, online databases, or web-based searches the authors (or their institutions) will be approached to provide a copy.

All search hits from the identified databases and specialist sources will be exported before being assessed using the inclusion criteria defined in "Eligibility criteria" section, but the hits from the identified search engines will be limited to the first 1000 results, as is standard in other systematic review protocols [14, 15].

The search terms used to find relevant data to answer the research question were chosen specifically for this review and were generated using the R package *litsearchr*, which partially automates keyword selection to generate a Boolean search string using a keyword co-occurrence network [16].

To generate the final Boolean Search string an initial naïve search (made up of broad search terms "impact static fish gear OR longline OR pot OR trap") was conducted in Web of Science and Scopus. The results were imported into R. Any duplicates were removed, after which the package systematically extracted all potential keywords from the titles and abstracts. A keyword co-occurrence network was created, and potential keywords were grouped into themes echoing the PICO structure and were used to inform the final Boolean search string. A shorter search string was also created to be used in databases where the number of searchable words is capped. The results for this shorter search in each database will be compiled and any duplicates removed.

Browsing history will be deleted before conducting any database searches.

The following search string, generated through the *litsearchr* package, will be used where there are no character limits imposed by the database or search engine:

> *Fish* AND (creel* OR dam* OR demersal OR "drum net"* OR "eel tube" OR fence OR fixed OR "fixed gear" OR gillnet OR "gill net" OR gill-net OR long-lin* OR long-lin* OR "long lin*" OR passive OR passive-* OR pot* OR static OR trammel OR trammel-* OR trap*) AND ((benth* OR bottom OR habitat+ OR seabed OR sea-bed OR "sea bed") OR (affect* OR alter* OR caus* OR chang* OR damag* OR declin* OR decreas* OR deterior* OR effect* OR impact* OR increase* OR influenc* OR reduc* OR result* OR shift* OR transform*))*

Shorter search terms will be used where character limits are in place or—as is the case for google scholar—where the database or search engine is limited in its ability to combine multiple Boolean values, for example:

> *Fish* AND (fixed OR net OR line OR passive OR pot* OR static OR trap*) AND (abundance OR "community composition" OR condition OR diversity OR mortality OR recovery rate OR richness)*

Both the longer and shorter search strings were tested against a set of fifteen articles (see Additional file 2) which had been identified by subject experts and stakeholders as being highly relevant to answer the research questions. Both search strings were tested against these articles through searches in Google Scholar, Web of Science, Scopus, JSTOR, Oxford Academic, and the British Library's e-thesis Online Service. Using a

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combination of both the long and short search strings all 15 test articles were retrieved (see Additional file 3).

The search engine Google Scholar (https://scholar.google.com/) and the platform of databases Web of Knowledge (https://apps.webofknowledge.com/WOS_GeneralSearch) will be searched.

Stakeholder consultation, combined with a web search of organizations involved in fisheries management and environmental conservation were used to identify the following organizational websites which will be searched for additional studies not available through bibliographic databases:

- American Fisheries Society https://fisheries.org/.
- Australian Society for Fish Biology https://www.asfb.org.au/.
- British Ecological Society https://www.britishecologicalsociety.org/.
- Centre for Ecology and Hydrology https://www.ceh.ac.uk/.
- Centre for Environment, Fisheries, and Aquaculture https://www.cefas.co.uk/.
- Commonwealth Scientific and Industrial Research Organisation. https://www.csiro.au/
- Department for the Environment, Food and Rural Affairs https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs.
- Department of Fisheries and Oceans Canada https://www.dfo-mpo.gc.ca/index-eng.htm.
- Esme Fairburn Association https://esmeefairbairn.org.uk/open-data.
- Food and Agriculture Organisation (FAO) http://www.fao.org/home/en/.
- French Research Institute for the Exploitation of the Sea https://tethys.pnnl.gov/organization/french-research-institute-exploitation-sea-ifremer.
- Institute of Marine Engineering, Science, and Technology https://www.imarest.org/.
- International Council for the Exploration of the Sea https://www.ices.dk/data/Pages/default.aspx.
- International Seafood Sustainability Foundation https://iss-foundation.org/who-we-are/about/.
- Japanese Society of Fisheries Science https://jsfs.jp/en/.
- Joint Nature Conservation Committee https://jncc.gov.uk/.
- Korean Society of Fisheries and Aquatic Sciences http://www.kosfas.or.kr/main_en.php.
- Marine Conservation Alliance http://marineconservationalliance.org/.
- Marine Conservation Alliance https://marineconservationalliance.org/.
- Marine Fish Conservation Network https://conservefish.org/.
- Marine Life Information Network https://www.marlin.ac.uk/.
- Marine Scotland https://www.gov.scot/marine-and-fisheries/.
- Marine Stewardship Council https://www.msc.org/home.
- National Environment Research Council https://nerc.ukri.org/.
- National Institute of Water and Atmospheric Research www.niwa.nz.
- National Oceanic and Atmospheric Administration (including regional fisheries websites: Alaska, Northwest, Pacific Islands, South east and Caribbean and west coast) https://www.noaa.gov/.
- National Oceanic Atmospheric Administration https://www.noaa.gov/.
- Natural England https://www.gov.uk/government/publications/natural-englands-publications-maps-and-data.
- North Pacific Marine Science Organization https://meetings.pices.int/.
- Northern Ireland Environmental Agency https://www.daera-ni.gov.uk/northern-ireland-environment-agency.
- Northwest Atlantic Fisheries Organisation https://www.nafo.int/.
- Oceana https://oceana.org/.
- Pew Trusts https://www.pewtrusts.org/en/.
- Scottish Association for Marine Science (SAMS) https://www.sams.ac.uk/.
- Scottish Environmental Protection Agency https://www.sepa.org.uk/.
- Scottish Natural Heritage-Nature Scot https://www.nature.scot/.
- Seafish https://www.seafish.org/article/selling-directly-to-consumers.
- Sustainable Fisheries Partnership https://www.sustainablefish.org/.
- The Nature Conservancy https://www.nature.org/en-us/.
- World Wide Fund for Nature https://www.wwf.org.uk/.

For each source the relevancy of first 50 hits will be checked (as is standard in other systematic review protocols), with all relevant papers, pages, or data being exported before being assessed using the previously defined inclusion criteria.

Other organizational sources may be consulted in addition to those listed as part of stakeholder feedback or through snowballing references from searches.

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The first 1000 results returned by Google and Google Scholar will be downloaded, as is standard practice in other systematic review protocols [14, 15].

Search results will be imported and managed using the Endnote X9 reference management software. In cases where an article or paper cannot be imported into the software a separate file will be manually created. Once the search protocol has been completed reference files will be checked for duplicates and all duplicates will be removed.

Article screening and study eligibility criteria
Screening process
After duplicate articles are removed using Endnote studies will then be screened to ensure articles that do not provide relevant data are removed.

The screening criteria is based on the eligibility criteria provided in the following section.

Screening will occur in three stages: (1) screening the title according to its relevance, (2) screening the abstract according to its relevance, and (3) full text screening. At each stage, a random subset of at least 10% of will be subjected to another round of screening by a second independent reviewer to ensure accuracy and repeatability of the process. Where the level of agreement is below 0.6 according to a kappa test, all disagreements will be discussed in detail and further consistency checking will be conducted on an additional set of articles.

A list of articles that were removed at each stage of the screening process will be provided, alongside reasons for their exclusion.

Reviewers will not screen any studies they have authored.

Eligibility criteria
Eligibility criteria will be based on the PICO model. For a study or report to be considered eligible they must provide or signpost data on the following:

- Population: Studies must perform experiments on marine benthic habitats, communities, or populations of macrofauna.
- Exposure: Exposure to any type of static fishing gear.
- Comparator: Control sites or areas with no intervention (i.e. no static fishing) will be used as a comparator (including before/after sites). However, control sites with very low levels of static fishing or even mobile fishing activity will also be included, as will fishing gradient studies that include a static fishing gear component.
- Outcome: Outcomes include positive, negative, or no changes in the biodiversity of benthic fauna (measured by proxies such as diversity or species richness),

changes in abundance (measured through % cover, density or biomass), changes in body size or size at maturity of an individual. Studies must include data on at least one benthic faunal species, specifying the name of either the taxon, genera, or species of the benthic fauna as well as values relating to numerical abundance, biomass, or diversity. Studies providing data on total faunal abundance will also be included.
- Study design types: Experimental primary studies that use control and treatment areas, 'before and after', 'control and impact', or combinations of the two (BACI) will be considered. Comparisons of at least two sites experiencing different levels of bottom fishing exposure using static fishing gear will also be considered acceptable. Studies conducted in laboratory settings will also be included.

Study validity assessment
Critical appraisal will be done on a study-by-study basis. If an article reports more than one study each of these studies will undergo an individual critical appraisal. Studies meeting the eligibility criteria will be evaluated to gauge their internal and external validity and consequently classified as with having either a *low, medium,* or *high* potential for bias using the pre-defined framework CEE Critical Appraisal Tool (CEECAT) [17] which considers selection, performance, attrition, and reporting bias.

Data will be extracted from all studies, and a sensitivity analysis will be conducted to compare the outcomes between "low", "moderate" and "high" risk papers. Results from the validity assessment will be recorded and presented with the results of the final review.

Validity assessment will be carried out independently by two reviewers. Any disagreements will be discussed, and a third reviewer will be consulted if no conclusion can be reached. Reviewers will not appraise any studies they have authored.

Data coding and extraction strategy
Data on study design, exposure, study results, habitat and geographical context will be extracted from included studies. Outcome data (such as sample sizes, means and measures of variation such as confidence intervals, standard deviations, and standard errors) will also be extracted. Information on effect modifiers will also be collected where available as well as metadata on study methodologies and general article identifiers. Summary statistics will be calculated if only raw data is provided. Where necessary, authors of the original study will be asked to provide unpublished primary data or provide

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clarification for unclear data. A list of data to be extracted can be found in Additional file 4.

Extraction will be carried out by one reviewer, however prior to full extraction of the data the extraction process will be independently tested. If the number of studies is > 50 then 10% of the studies will be tested by two reviewers. If the number of studies is < 50 then 30% of the studies will be tested. Any uncertainty will be discussed with the wider team until an agreement is reached. All extracted data will be saved in a Microsoft Excel spreadsheet which will be included in the final review as an additional file.

Potential effect modifiers/reasons for heterogeneity

All effect modifiers identified in the data extraction process will be recorded in an Excel spreadsheet. The following list identifies potential effect modifiers and was collated by the author team in consultation with stakeholders:

- Benthic habitat type.
- Depth of sampling site.
- Environmental factors (e.g. fronts, reefs, mounds, nutrient cycling).
- Fishing intensity.
- Gear design (e.g. pot aperture size, J vs Circle hooks).
- Gear type (i.e. pots, traps, longlines, or nets).
- Geographical co-ordinates.
- Hauling frequency.
- Historical fishing pressure in the area.
- Exposure duration and seasonality.
- Number of pots/traps/hooks/nets.
- Species biological traits (e.g. mobility; sessile vs mobile).
- Study duration and seasonality.
- Study sample size.
- Taxonomic or functional groupings.
- Time interval(s) between impact and sampling.

Additional effect modifiers that are identified during the review will be added to the list. All effect modifiers will be coded and included analysis.

Data synthesis and presentation

This study will employ both narrative and quantitative synthesis techniques. A narrative synthesis will be carried out on data from all studies and will describe the validity of results and tabulate study design, outcome measures, and other key descriptors. Maps of locations of all studies and of studies included in meta-analyses will be included. Heatmaps will be created by cross-tabulating different key descriptors to identify knowledge gaps.

Valid studies (as defined in "Eligibility criteria" section) which have comparable outcome effect sizes will be standardized and weighted appropriately. Where there is sufficient quantitative data, meta-analysis will be used to assess the effect of static fishing gear on benthic biodiversity. This will be conducted using the R package *metafor* which supports meta-regression analysis with both continuous and categorical moderators and fixed and random-effect models [18]. Meta-analysis will be conducted using both the estimates described by the authors as being the main results as well as all estimates from the same study. Effect sizes will be measured using the natural log-transformed response ratio [19].

The heterogeneity and the impact of effect modifiers will be explored through meta-regression analysis, which will help identify which effect modifiers have the greatest impact. Meta-regression will be conducted for all estimates.

Publication bias will be tested for using funnel plots, Egger tests, and comparisons of peer-reviewed and grey literature. A sensitivity analysis, comparing the outcomes of including and excluding papers with a "high risk" of bias, will be carried out to test the robustness of the validity assessment.

To avoid bias within the results reviewers carrying out this stage will not have published in this research area.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13750-021-00242-y.

Additional file 1. ROSES for Systematic Review Protocols. The completed ROSES form for systematic review protocols.

Additional file 2. List of benchmark studies used to test Boolean search strings.

Additional file 3. Scoping results of search string.

Additional file 4. Data to be extracted.

Declarations

Ethics approval and consent to participate
Not applicable.

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