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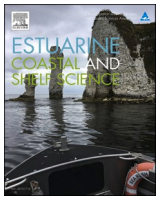

# Short-term effects of Danish seining on seabed fauna in a shallow coastal ecosystem

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ABSTRACT

Danish seining is a fishing method in which long ropes are hauled over the seabed from an anchored vessel. In Denmark, it has been used widely for catching plaice (*Pleuronectes platessa*). Despite its commercial use, empirical evidence on its effects on seabed communities remains limited compared with other bottom towed gears. This short communication presents results from a field experiment designed to assess the short-term effects of a Danish seine haul on benthic macrofauna in the southern Skagerrak. Benthic samples were collected immediately before and after fishing to detect potential changes in community characteristics. Minor declines in total abundance, biomass, and species richness were observed following seining, but none of these responses were statistically significant. Overall community composition also showed no significant changes. However, several species specific responses were observed. The annelids *Owenia fusiformis* and *Magelona mirabilis* increased in abundance, whereas the phoronid worm *Phoronis muelleri*, the bivalve *Chamelea gallina*, and brittle star *Ophiura ophiura* declined. The sensitivity of *Phoronis muelleri*, a soft bodied tube-builder, has been noted in other trawling impact studies and likely relates to its protruding position above the sediment surface, making it potentially vulnerable to the large seabed footprint of the seine ropes. Overall, our findings show that a Danish seine haul in shallow coastal habitats causes relatively minor short-term disturbances to the benthic fauna, and thus, exhibit reduced ecological impacts on the seabed than other commercial bottom trawling gears, such as otter and beam trawls.

## 1. Introduction

Demersal mobile fishing gears encompass a range of fishing gears such as otter and beam trawls, dredges, and demersal seines, all of which are actively trawled across the seabed to capture fish and invertebrates. These gears physically modify the seabed and alter the benthic communities that inhabit it (Jones, 1992; Collie et al., 2000; Thrush and Dayton, 2002). The severity of disturbance from trawling depends largely on factors such as gear size, weight, engine power, and the resulting area swept and penetration depth of the gear into the sediment (Eigaard et al., 2016; Hiddink et al., 2017). However, characterising and quantifying trawling impacts is often challenging, particularly in environments subject to natural or other anthropogenic disturbances (Van Denderen et al., 2015; Gislason et al., 2017; McLaverty et al., 2024). Experimental trawling studies, in which the seabed is trawled under controlled conditions, therefore remain a key approach for assessing the immediate and localised effects of bottom fishing on benthic fauna (Sciberras et al., 2018).

Compared with dredges, beam trawls, and otter trawls, the Danish seine is a relatively lesser known demersal gear. Empirical evidence on its effects on seabed biota is limited despite its importance in Danish waters (Noack et al., 2017; Dinesen et al., 2018; McLaverty et al., 2023; Bromhall et al., 2026) and other regions globally (Wijayanto et al., 2020). In the absence of direct data, Danish seines have generally been assumed to exert comparatively low ecological impacts (Suuronen et al., 2012; Eigaard et al., 2016; Rijnsdorp et al., 2020), owing to their design and relatively lightweight components (O'Neill and Noack, 2021; Huda et al., 2025).

In this study, we describe an experiment designed to evaluate the effects of a Danish seine on benthic fauna within a low fishing intensity area of established coastal fishing grounds. Benthic samples were collected immediately before and after fishing, and changes in the

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benthic fauna were assessed using community composition, ecological indicators, and species specific responses. This study represents the first fishing impact trail of the Danish seine in the southern Skagerrak where this method is prevalent among local coastal flatfish fisheries.

## 2. Materials and methods

### 2.1. Danish seine fishery in Jammer Bay

In Denmark, Danish seine fisheries operate predominantly in Jammer Bay (or Jammerbugt, in Danish), a large bay located between in the southern Skagerrak adjacent to the northern North Sea (Fig. 1A). Fishing takes place mainly on sandy and gravelly sediments and primarily targets European plaice *Pleuronectes platessa*, with Atlantic cod *Gadus morhua*, common dab *Limanda limanda*, and other flatfish also contributing to commercial catches (Hoffmann, 2016).

Although categorised as a demersal trawl under Council Regulation (EC) 850/98, the operation and configuration of Danish seines differ markedly from conventional bottom trawls. A typical haul begins with the vessel setting an anchor and deploying two long, lead filled seine ropes (up to ~3 km in length) arranged in a pyriform or roughly triangular footprint (Fig. 1 B&C). A seine net, attached to a ground gear, is positioned between the ropes, which herd the fish toward it. The net then captures the fish as they are hauled back to the anchor point during winching. Hauls are usually repeated several times in a petal shaped spread around the anchor position, meaning that a given area of seabed is swept once during a fishing event (O'Neill and Noack, 2021).

Only a small fraction of the footprint is contacted by the ground gear, which is estimated to sweep ~1% of the total area and to penetrate only the upper few centimetres of sediment. The remaining ~99% of the footprint consists of the ropes, which are believed to skim across or lightly contact the sediment surface (Noack et al., 2019; O'Neill and Noack, 2021).

### 2.2. Study site, experimental design, and sample collection

The fishing trial was conducted within a roughly 2 × 1 km area at ~7 m depth in Jammer Bay (57.2°N, 9.4°E; Fig. 1 A&B). The site represents nationally appointed military shooting range and was selected based on Vessel Monitoring System (VMS) data showing low impact from vessels in the 12-36 months prior to the trial. In addition, the commercial Danish Fisheries Production Organisation (DFPO) issued a voluntary closure of the area for all its members in the period prior to the trail.

A Before–After Control–Impact (BACI) study was initially planned for 26–27 June 2018. The area was divided into control and impact zones, and 'before' sampling was completed accordingly in each area. However, prior to the arrival of the vessel designated to conduct the experimental trawling, an unrelated commercial Danish seiner entered the area and fished across both the planned control and impact zones. Although this unplanned event compromised the intended BACI design, we were able to accurately verify the footprint of the vessels haul using a combination of AIS data, the coordinates of the fishing vessels anchor point, and a theoretical model of gear footprint based on Noack et al. (2019). This allowed us to identify 24 sampling positions that were fished by the intruding vessel. These sites were subsequently resampled, enabling a simplified Before–After design that focused specifically on areas of seabed verified as impacted. The position of the Danish seine haul relative to the sampling stations was further corroborated by side-scan sonar surveys conducted before and after fishing, which revealed new trawl marks in areas corresponding to the modelled pyriform ground gear path.

A total of 48 benthic samples were collected (24 before and 24 after fishing). Samples were taken using a 0.1 $m^2$ Van Veen grab, sieved using 1 mm and 4 mm mesh sizes, and preserved in a 4% formalin–seawater solution buffered with borax (sodium borate). In the laboratory, fauna were identified to the lowest possible taxonomic level and biomass was quantified as ash-free dry weight. Taxonomic nomenclature was validated and standardised using the World Register of Marine Species

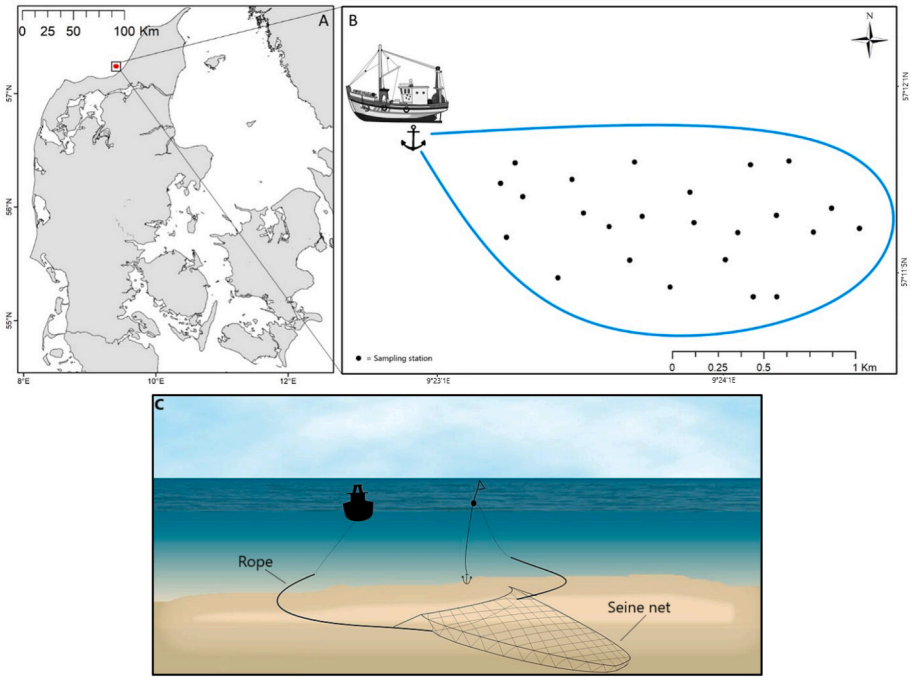


**Fig. 1.** (A) Location of experimental fishing site in Jammer Bay off the northwest Danish coast, (B) Location of sampling stations (black points) that were sampled before and after fishing. The estimated footprint of the Danish seine ropes is shown in blue, in relation to the anchor point of the seine. (C) Schematic illustration of a Danish seine deployment, showing the vessel, anchor, ropes, and seine net positioned on the seabed during fishing (adapted from Bos, 2016). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

(WoRMS Editorial Board, 2020).

### 2.3. Data analysis

Potential changes in the benthic faunal community were assessed using community indicators (abundance, species richness, and biomass), multivariate analysis of community composition, and species-level responses before and after fishing. Generalised Linear Models (GLMs) were used to analyse community indicators. Community biomass was log transformed, and models were fitted with negative binomial (abundance), Poisson (species richness), or Gaussian (biomass) distribution. All GLM analyses were conducted in R 4.0.5 (R Core Team, 2021). Differences in community composition were examined using a one-way permutational multivariate analysis of variance (PERMANOVA), based on Bray–Curtis dissimilarities and 999 permutations. Multivariate analyses were performed in PRIMER v.7 with PERMANOVA+ (Anderson et al., 2008). Species level responses were described as the percent change in abundance and biomass between the before and after samples.

## 3. Results

A total of 66 species and 3702 individuals were recorded across the 48 samples. Generalised linear models indicated no significant changes in mean abundance ($\beta = -0.04$, SE = 0.06, $p = 0.493$), species richness ($\beta = 0.04$, SE = 0.07, $p = 0.580$), or biomass ($\beta = -0.18$, SE = 0.18, $p = 0.327$) following fishing. However, all three indicators showed slight declines in their post-fishing values (Fig. 2).

The composition of the benthic faunal community did not change significantly over the course of the experiment. PERMANOVA analyses indicated that both abundance- (pseudo-F = 1.28, $p = 0.201$) and biomassbased (pseudo-F = 1.56, $p = 0.146$) community composition were similar before and after fishing (Table S1).

Table 1 summarises changes in the 10 species recorded with the highest abundance and biomass. In terms of abundance, six species declined after fishing, while four increased. However, only two of these changes were statistically significant - the phoronid worm *Phoronis muelleri* decreased by 42%, while the annelid *Owenia fusiformis* increased by 69%. Biomass responses were broadly similar, with six species declining and four increasing after fishing. Three of these changes were statistically significant - the bivalve *Chamelea gallina* and brittlestar *Ophiura ophiura* declined by 82% and 85%, respectively, whereas the annelid *Magelona mirabilis* increased in biomass by 30%.

**Table 1**
Differences in species abundance and biomass before and after fishing. Statistically significant changes ($\alpha = 0.05$) are highlighted with an asterisk (*).

| **Abundance** | | | | | | |
|---|---|---|---|---|---|---|
| Class | Species | Before | After | | % Change | Total |
| Bivalvia | *Fabulina fabula* | 786 | 708 | ↓ | 9.9 | 1494 |
| Bivalvia | *Mactra stultorum* | 765 | 661 | ↓ | 13.5 | 1426 |
| Annelida | *Magelona mirabilis* | 315 | 392 | ↑ | 24.4 | 707 |
| Annelida | *Chaetozone setosa* | 104 | 89 | ↓ | 14.4 | 193 |
| Annelida | *Owenia fusiformis* | 62 | 105 | ↑ | 69.3* | 167 |
| Phoronida | *Phoronis muelleri* | 86 | 50 | ↓ | 41.8* | 144 |
| Bivalvia | *Phaxas pellucidus* | 66 | 57 | ↓ | 13.6 | 123 |
| Annelida | *Sigalion mathildae* | 54 | 59 | ↑ | 9.2 | 113 |
| Annelida | *Spiophanes bombyx* | 49 | 61 | ↑ | 24.4 | 110 |
| Annelida | *Nephtys hombergii* | 44 | 33 | ↓ | 25 | 77 |
| **Biomass (g AFDW)** | | | | | | |
| Class | Species | Before | After | | % Change | Total |
| Echinodermata | *Echinocardium cordatum* | 3.031 | 2.772 | ↓ | 8.5 | 5.803 |
| Bivalvia | *Fabulina fabula* | 1.476 | 1.304 | ↓ | 11.6 | 2.780 |
| Bivalvia | *Chamelea gallina* | 1.522 | 0.275 | ↓ | 81.8* | 1.797 |
| Bivalvia | *Mactra stultorum* | 0.208 | 0.641 | ↑ | 207.9 | 0.849 |
| Echinodermata | *Ophiura ophiura* | 0.488 | 0.072 | ↓ | 85.1* | 0.560 |
| Annelida | *Magelona mirabilis* | 0.214 | 0.279 | ↑ | 30.1* | 0.494 |
| Annelida | *Sigalion mathildae* | 0.238 | 0.211 | ↓ | 11.2 | 0.449 |
| Annelida | *Nephtys hombergii* | 0.277 | 0.125 | ↓ | 54.7 | 0.403 |
| Bivalvia | *Ensis ensis* | 0.009 | 0.235 | ↑ | 2511 | 0.244 |
| Gastropoda | *Euspira nitida* | 0.11 | 0.112 | ↑ | 2.6 | 0.244 |

## 4. Discussion

This study provides one of the first experimental assessments of the benthic faunal effects of Danish seining, offering empirical evidence from a gear type that is lacking in data and evidence. Overall, our findings indicate a pass of a commercial Danish seine resulted in minor and statistically non-significant reductions in benthic abundance, biomass, and species richness. Multivariate analyses similarity did not detect shifts in community composition. Conversely, we observed changes in the abundance and biomass of specific species. These results are thus consistent with previous assumptions that Danish seines exert relatively low ecological impact on the seabed and are likely to result in less benthic mortality than conventional otter and beam trawls due to their lighter ground gear and limited penetration depth (Eigaard et al., 2016; Rijnsdorp et al., 2020; O'Neill and Noack, 2021).

Despite the absence of detectable community level effects, several taxa exhibited measurable species-specific responses. Declines in *Phoronis muelleri*, *Chamelea gallina*, and *Ophiura ophiura* indicate that vulnerability to Danish seining varies among species. The pronounced reduction in *P. muelleri*, a widespread and functionally important tube-building phoronid worm (Emig, 1982), is consistent with observations from other Danish seine studies (McLaverty et al., 2024; Bromhall et al., 2026) and from broader assessments of trawl impacts (Hinz et al., 2009; Gislason et al., 2017; McLaverty et al., 2020). Experimental trials conducted in the northern Kattegat have shown that *P. muelleri* abundance can be reduced by approximately 35% following a single pass of Danish seine ropes, and by up to 90% under repeated trawling (Bromhall et al., 2026). Additionally, these trials also did not find changes to community level indicators. The sensitivity of species such as *P. muelleri* is likely attributable to its tube-dwelling life habit, as emergent and structure forming benthic fauna are often disproportionately affected by bottom contact fishing gears (Kenchington et al., 2006; Sciberras et al., 2018). Given that Danish seine ropes disturb the sediment surface across a large footprint, soft-bodied taxa extending above the seabed are particularly susceptible to mechanical disturbance.

In contrast, the observed increases in the annelids *Owenia fusiformis*

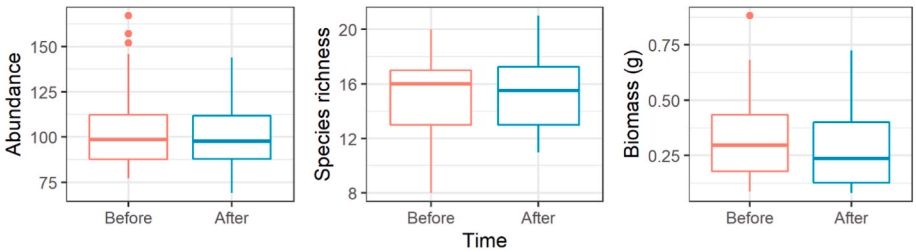


**Fig. 2.** Comparison of benthic (A) abundance (B) species richness and (C) biomass before and after fishing.

and *Magelona mirabilis* likely reflect a combination of disturbance tolerance and opportunistic life history traits (Tillin et al., 2006). This is supported by reports of high densities of *O. fusiformis* in intensively fished areas of the North Sea (Reiss et al., 2009) and Irish Sea grounds (Kaiser et al., 1998), as well as elevated biomass of *M. mirabilis* recorded under high Danish seining intensity in Jammer Bay (McLaverty et al., 2024).

Importantly, the small effect sizes observed in this study must be interpreted in light of study design constraints. An unplanned fishing event prior to sampling necessitated a shift from a Before-After-Control-Impact (BACI) framework to a simplified Before-After design, limiting our ability to account for natural spatial variability. Nevertheless, sampling stations were verified to lie within the fishing footprint, ensuring that comparisons reflected true impact locations. In addition, the experiment assessed only a single haul, whereas observed fishing pressure in the southern Skagerrak suggests that the seabed may be repeatedly disturbed by Danish seines over annual or monthly scales (McLaverty et al., 2024). Furthermore, there is evidence that repeated hauls increase the degree of benthic impact from Danish seines (Bromhall et al., 2026). Our study therefore is limited in its ability to interpret potential cumulative or longer-term effects under higher fishing intensities. Finally, the shallow sandy seabed at the study site is subject to regular natural disturbance and is generally less sensitive to bottom towed gears than more stable, structure forming habitats, which may partly explain the limited community level responses observed. Despite these constraints, the study area is representative of extensive inshore Danish seine grounds, and our findings support the conclusion that Danish seining on mobile sandy sediments generates relatively minor short-term disturbance.

Given the spatial overlap between Danish seine core fishing grounds and areas fished by international beam trawlers and fly-shooters, the ecological sustainability of these fisheries has been widely debated (Dinesen et al., 2025). The ground gears of otter trawls are estimated to penetrate sediments to ~2.5 cm and remove ~6% of benthic biota per pass, while heavier beam trawls penetrate ~2.7 cm with depletion rates of ~14% (Hiddink et al., 2017; Sciberras et al., 2018; Rijnsdorp et al., 2020). These estimates include a range of sediment types, including mud, which is generally more sensitive to trawling than sand. In our study, all sampling stations were located on sandy sediments, which are inherently less affected by bottom contacting gears due to shallow penetration. Our results thus support the assumption that Danish seines primarily disturb surface sediments, as reflected by the limited changes observed in the benthic community. Therefore, the minor short-term impacts observed in our study likely reflect a combination of the lower sensitivity of sandy sediments and less forceful seabed contact of the Danish seine itself. These findings suggest that Danish seines likely impose lower impacts on seabed fauna than conventional otter or beam trawls and may represent a comparatively lower impact option for coastal fisheries. However, the species specific sensitivity observed, particularly for *Phoronis muelleri*, indicates that Danish seining can still affect functionally important taxa, with potential implications for sediment dynamics and local biodiversity. Overall, this study provides empirical evidence that short-term disturbances from Danish seining are limited in shallow coastal environments, while underscoring the need for further research in deeper habitats and across a broader range of sediment types to assess cumulative effects and inform gear specific ecosystem-based management strategies.

## CRediT authorship contribution statement

**Ciarán McLaverty:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Writing – original draft, Writing – review & editing. **Ole R. Eigaard:** Funding acquisition, Investigation, Project administration, Writing – review & editing. **Thomas Noack:** Formal analysis, Investigation, Methodology, Writing – review & editing. **Grete E. Dinesen:** Conceptualization, Formal analysis, Funding acquisition, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecss.2026.109764.

## Data availability

Data will be made available on request.

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