Project Title: NBS Effects of Trawling Study (NETS)

10/1/2023

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Summary

Commercial bottom (i.e. non-pelagic) trawling is prohibited in the northern part of the Bering Sea (NBS) until there is "a better understanding of the potential impacts of trawling on the benthic and epibenthic fauna".[a] The Northern Bering Sea Research Area (NBSRA) was established in 2008 and a conceptual research plan was developed (but not implemented) to support decision-making. Since that time, periodic assessment surveys have documented poleward shifts of commercially important groundfish, due in part to warming conditions that may continue (1, 2, 3, 4).[b] The impending confluence of commercial fishing interests and longstanding traditional lifestyles has increased the urgency for completing the requisite scientific studies (5, 6).[c] In particular, there is concern about disturbing sensitive benthic habitats and cascading food-chain effects that could disrupt subsistence fishing. There has been considerable research on the effects of bottom trawling, including field studies in the eastern Bering Sea (7, 8, 9, 10) and recent global syntheses (11). However, localized studies are advisable since the biological effects of trawling will vary according to trawl configuration, seabed characteristics, and the specific composition of the benthic fauna (12, 13). Regional sensitivities can be determined with randomly placed, replicated experiments in selected habitat types (14). Such biological information in concert with social values, priorities, and available resources can then be used to choose best practices for managing impacts (15).

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[a] https://www.npfmc.org/nbsra/

[b] https://arctic.noaa.gov/Report-Card/Report-Card-2019/ArtMID/7916/ArticleID/845/Comparison-of-Near-bottom-Fish-Densities-Show-Rapid-Community-and-Population-Shifts-in-Bering-and-Barents-Seas

[c] Conducting studies to assess the impact of bottom-trawl fisheries on benthic habitat and trophic interactions is an urgent 2022-2024 research priority for the NPFMC (#217; https://www.npfmc.org/wp-content/PDFdocuments/resources/NPFMC_Research_Priorities_2022-2024.pdf).

The NBS Effects of Trawling Study (NETS) is a multi-year, phased, and modular effort to design and execute experimental studies of trawling impacts in the NBSRA. The results will inform possible future management of commercial bottom-trawl fisheries in the region.

Approach

Objectives

The North Pacific Fishery Management Council (NPFMC) requires a better understanding of the potential impacts of trawling on the benthic and epibenthic fauna of the NBS before any commercial trawling is authorized.[a] The primary research questions for the NETS are: Do bottom trawls have measurable and ecologically significant effects on NBS biota and, if impacts are identified, does the affected area recover to its original state in the absence of fishing (if so, how quickly), or does it become functionally different?

Experimental design

A Before–After Control–Impact (BACI) experiment (14, 16) will investigate the effects of a commercial bottom trawl on benthic invertebrates and other habitat characteristics in the NBS, by comparing conditions in multiple experimental (EXP) corridors before and after repeated passes of an otter trawl rigged and deployed in a manner consistent with commercial practices (Fig. 1). Concurrent sampling in paired untrawled control (CON) corridors will account for natural variability during the study period. Sampling in subsequent years will examine possible lagged effects and the recovery process. A focus on benthic invertebrates is typical for trawling-impact studies because of their key ecological roles as both structural habitat and prey, and because as a group they demonstrate rather narrow affinities for particular seafloor properties (7). These taxa are the predominate biomass in the NBS and are also important as subsistence seafood for Alaska Native communities in the region (5). There is also a clear need to better understand these effects at higher trophic levels.

The BACI experimental design will be scalable, with modular funding to accommodate yet to be determined and potentially diverse priorities of the stakeholder groups, the high cost of multi-year field operations, and the unpredictable duration of the experiment should there be significant impacts and a need to characterize the recovery process for disparate taxa. A simple depletion study that does not monitor the recovery process will also be developed as a contingency project.

Methodology

Field-tested protocols (10) will be used during all sampling events, including before (B), during, immediately after (A1), and one year after (A2) the commercial-trawl impact (I), and continue periodically thereafter until the end of the experiment (A_n). Epifauna will be sampled with a standard Bering Sea survey trawl, which has been modified to improve catchability and retention of benthos (GAP gear-accessories code 122[d]). Standard AFSC procedures will be used to measure area-swept by the trawl, process the catches, and calculate CPUEs (17). A framed and imaging-equipped van Veen grab will collect sediment samples at nested sites prior to epifauna sampling. An ultra-short baseline (USBL) acoustic system will monitor the subsea position of trawls and benthic samplers with a real-time wheelhouse display, to ensure proper placement in the corridors.

Optional sampling modules include (depending on need and funding): (*i*) overnight sonar surveys to characterize effects on seabed microhabitats (morphology) and to assess potential trawling hazards in the corridors prior to sampling; (*ii*) replicated infauna sampling at the sediment-sampling sites; (*iii*) sediment chemistry assessments; and (*iv*) ACLIM-2 modeling needs to assess food-habitat responses at higher trophic levels.

[d] https://repository.library.noaa.gov/view/noaa/31570

Analysis

The analysis will isolate the effect of trawling by comparing invertebrate densities, community indices, and sediment characteristics before and after trawling (i.e. B *vs.* A1) in the EXP corridors, while adjusting for temporal variability observed in the paired CON corridors (Fig. 1). The statistical model for the BACI analysis is:

$$y_{ijkm} = \mu + \Theta_i + \beta_j + \gamma_{ij} + \delta_k + \varepsilon_{ijkm}$$

where y_{ijkm} denotes a CPUE observation for time (event) *i*, treatment *j*, corridor pair *k*, and station *m*; μ denotes the base mean expected value; Θ_i denotes the expected time effect (Before vs. After); β_j denotes the expected treatment effect (Control vs. Impact); γ_{ij} denotes the expected time × treatment interaction (the trawling effect); δ_k denotes the expected block effect (corridor pairs); and ε_{ijkm} is the random component of the observation from each of the selected sampling stations within the corridor during the given sampling event. Both the immediate effects of the impact (i.e. B *vs*. A1) and possible delayed responses to the impact (i.e. B *vs*. A2) will be examined with significance tests based on Type III sums of squares and appropriate statistical contrasts. Physical and perhaps other covariates for each station will be added to the basic model to see if they will reduce unexplained variability in the CPUE data and thus improve the ability to detect effects of the experimental disturbance. The *a posteriori* statistical power of non-significant results will be evaluated with a method based on the non-central F distribution and the observed random variation in the CPUE data (10), as will possible main effects in the BACI model when the interaction term is not statistically significant. For management purposes, it is particularly important to know the probability of concluding there is no effect of trawling when there actually is one, and to better understand the detectable effect size (22).

Planning and implementation

FY22 activities (advance preparations)

Preliminary activities to create technical and popular outreach materials that support the design, execution, and interpretation of the study have thus far included: (*i*) a bibliographic database of scientific and cultural information about the NBS (23), (*ii*) an updated bibliographic database on mobile fishing gear effects[e], and (*iii*) a Geographic Information System (GIS) for the region, with base layers of bathymetry, seafloor sediments, benthic invertebrate abundances, critical habitats, and historical fishing activity.

FY23 activities (planning)

Coalition building to identify and prioritize regional issues of concern affecting the objectives, experimental design, and execution of the study, to include a facilitated proactive engagement of potential collaborators with commercial, environmental, subsistence, and technical interests in the region (24).

Experimental-design work to determine placement and specifications of a randomized, spatially replicated BACI experiment in a specific biogeographic stratum. The NBS design will generally conform to the Research Plan submitted to the NPFMC in 2011, which was based on field-tested methodology for the Bering Sea (10) and guidance obtained during community/subsistence (2010) and science (2011) workshops. Major activities include:

1. Perform an invertebrate-community analysis (25, 26, 27) to define the sampling frame(s) within which to randomly place the research corridors (Fig. 2). This approach supports application of research findings to the larger region, not just the specific study location.

[e] https://www.fisheries.noaa.gov/resource/data/mobile-fishing-gear-effects-bibliography-database

2. Identify geographic areas to exclude based on a review of regulations, prior fishing disturbances (particularly fixed gears and scientific activity since the NBS has no history of commercial bottom trawling), and special cultural/environmental/scientific significance.
3. Determine corridor dimensions (length, width) and the intensity of the experimental disturbance (number of overlaid trawl passes), based on industry predictions about likely tow length and total gear width for NBS trawling, pertinent observations from the eastern Bering Sea, anticipated changes in fishery practices, and other technical considerations.
4. Conduct a statistical power-and-sample-size analysis to determine the number of corridor pairs needed to accommodate the preferred sampling effort for epifauna, sediments, and other potential monitoring activities.
5. Randomly select without replacement the (nested) sampling locations within corridor pairs for the full multi-year study period (i.e. events B to A_n; Fig. 1). The experimental design will include supernumerary sampling locations(s) held in reserve for contingencies.
6. Produce an operations manual detailing the gears and methodologies for conducting the fieldwork.
7. Prepare analytical software in advance, for immediate use upon completion of annual fieldwork.

Prepare for FY24+ fieldwork, including equipment readiness review, dockside charter-vessel configuration, and Puget Sound sea trails to confirm USBL performance.

FY24 activities (fieldwork, analysis, reporting)

The first year of fieldwork will consist of: (1) sampling in EXP and CON corridors before the commercial-trawl impact (event B); (2) repetitive trawling with commercial gear in EXP corridors (event I); and (3) sampling in EXP and CON corridors after the experimental impact (event A1).

Statistical analysis will investigate the short-term effects of trawling using data from the B and A1 sampling events. The results present a decision point about whether to continue fieldwork to investigate possible lagged responses for cases with non-significant results and/or to monitor recovery if significant effects are detected. Stakeholder advice, the number of remaining sample sites, and the level of funding will influence fieldwork scheduling.

Optional analyses (depending on need and funding): effects on sediment chemistry and physical bedforms; trophodynamic/food web modeling to assess the higher-level ecological significance of the observed effects on benthic invertebrates.

FY25 activities (fieldwork, analysis, reporting)

The second year of fieldwork will consist of sampling in the EXP and CON corridors one year after the commercial-trawl impact (event A2).

Statistical analysis will investigate possible lagged effects/recovery after 1 year, using data for events B, A1, and A2. The results present a decision point about whether and when to continue fieldwork to monitor recovery. Stakeholder advice, the number of remaining sample sites, and the level of funding will influence fieldwork scheduling.

Optional analyses (depending on need and funding): effects on sediment chemistry and physical bedforms; trophodynamic/food web modeling to assess the higher-level ecological significance of the observed effects on benthic invertebrates.

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Figures

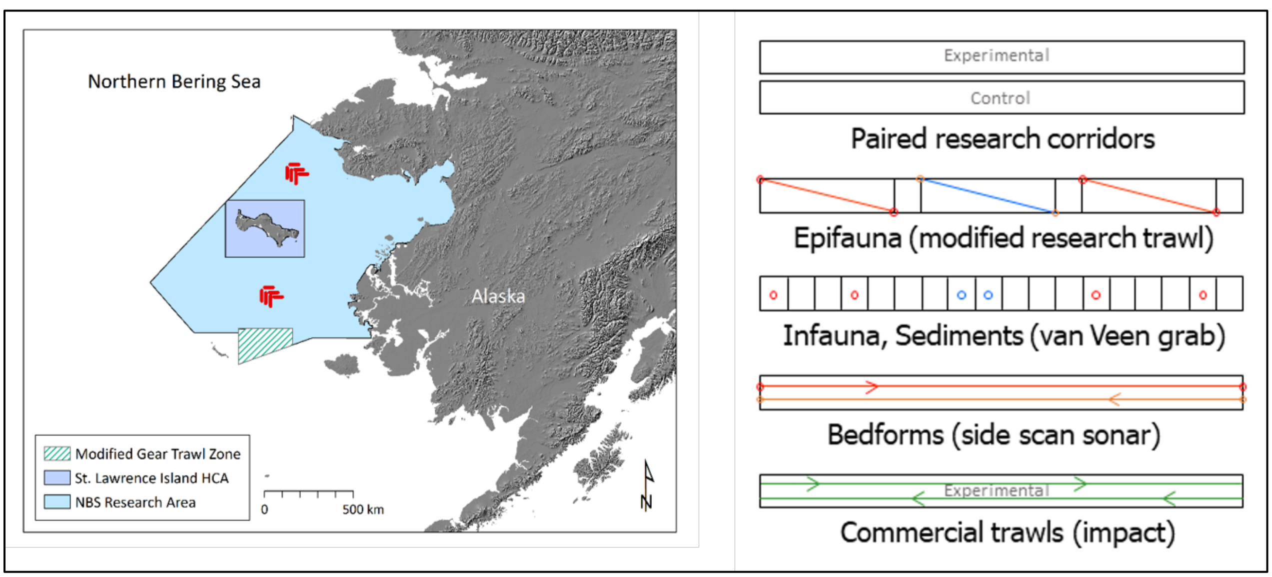

Figure 1. *The northern Bering Sea study area. Each of the clustered line segments (left panel, not to scale) represent pairs of experimental and control corridors for studying the effects of bottom trawling. Placement, size, and number of corridors will be determined during the experimental-design phase of the project. Sampling grids are superimposed in each corridor (right panel). Sampling locations are randomly chosen for all sampling events before the experiment begins and are sampled only once.*

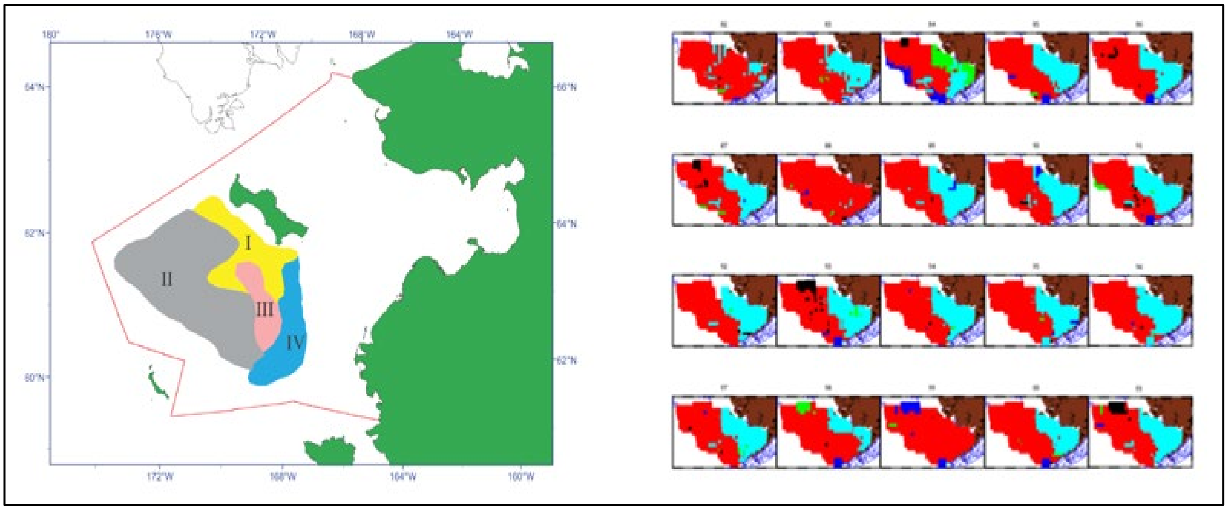

Figure 2. *Benthic invertebrates are the de facto measure of bottom trawl impacts. Prior analyses of NBS infauna (left panel; 25) and EBS benthic invertebrates (right panel; 26) illustrate well-defined and persistent assemblages that can be used as strata within which to randomly place replicated experiments and then legitimately generalize findings about trawling impacts to the larger geographical area.*