Project Title: NBS Effects of Trawling Study (NETS)

1/2/2024

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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). The results will be made public.

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 be available to inform possible future management of commercial bottom-trawl fisheries and habitat conservation efforts in the region, including effects on subsistence resources and practices.

This study will help identify sensitive habitats and bottom-dwelling communities. These communities provide a rich array of food for a number of whale species, walrus, and ice-associated seals, which are cultural, spiritual and subsistence resources for Alaska Native villages throughout the region. The project would also afford opportunities for Tribal Governments and village residents to help target the research to gather information on species of interest to them. Funding has been secured to engage directly with communities in these discussions. We can also assist with a Tribal proposal to support involvement of a student or community member from the region in the project. This research and supporting food-web modelling work that the Alaska Fisheries Science Center hopes to conduct will inform understanding of higher-level ecological impacts of the observed effects on bottom-dwelling species and potentially the effects on the subsistence marine mammal species that eat them.

An important aspect of this project is community engagement. In accordance, with the Alaska Fisheries Science Center Alaska Native Community Engagement Protocol, the project team would ensure that the research does not interfere with any subsistence hunting activities occurring in the region through early engagement, mitigation planning and near-real time communications with subsistence hunters. AFSC staff initially reached out to Kawerak staff in March 2023 to discuss the best ways to engage with Bering Strait villages about the project. With guidance from Kawerak staff, the intent is to speak directly with villages during the design phase of the project to answer questions, address concerns, and identify opportunities for localized information about the effects of bottom trawling and, with guidance, to focus on species of concern and avoid sensitive or culturally important areas.

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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).

Approach

Objectives

The National Marine Fisheries Service and North Pacific Fishery Management Council (NPFMC) require a better understanding of the potential impacts of trawling on the benthic and epibenthic fauna of the NBS before any commercial trawling is authorized by the National Marine Fisheries Service.[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 predominant 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, such as marine mammals, groundfish, and crabs.

The BACI experimental design will be scalable, with modular funding to accommodate yet to be determined and potentially diverse priorities of the Alaska Native communities and 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.

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). Standard Alaska Fisheries Science Center (AFSC) procedures will be used to measure area-swept by the trawl, process the catches, and calculate catch per unit effort (CPUEs, biomass/unit area; 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.

Commentary on the approach

Precise positioning of sampling gear is a mission-critical capability for executing the BACI experimental design. Failure to sample at predetermined sites within the designated corridors (treatments) confounds statistical isolation of the bottom-trawling effects. Successful readiness testing for the ultra-short baseline (USBL) subsea positioning system on the F/V platform must be completed prior to fieldwork mobilization.

Preliminary sonar surveys to assess potential trawling hazards in the corridors prior to sampling would be prudent. The ship's echosounder would have limited coverage and resolution compared with a sidescan sonar. A sidescan system would also enable (overnight) surveys in EXP corridors to characterize effects of trawling on seabed microhabitats (morphology) and recovery, with supplemental funding for installation of an auxiliary tow winch and labor to support 24-hour operations at sea.

The modified 83-112 trawl effectively samples major infauna (7, 8, 10). More comprehensive infauna sampling with the benthic grab sampler used for sediments can be readily incorporated into field operations, but significant supplemental funding would be required for sample processing.

The effects of trawling on sediment chemistry could be accomplished at modest cost with secondary processing of sediment samples collected for granulometric analysis, enabling an assessment of trawling as a significant contributor of CO_2 release to the atmosphere (18; but see 19).

Similarly, sampling to address as yet unspecified ecological components can be considered as an integrated NETS module to support, for example, ACLIM-2 modeling efforts to characterize the trophic relationships in the NBS and predict higher-level responses to trawling impacts on the benthos.

<u>*Alternate experimental design*</u>*. A telescoping work plan is required as a fallback if full funding of the BACI-design fieldwork is not obtained or if field operations are curtailed by weather, equipment, or personnel issues at sea. Whereas the BACI design provides both depletion and recovery rates as inputs to the Alaska Fishing Effects Model being used by the NPFMC (20), a* ***depletion study*** *provides only depletion rates but at considerably lower cost and without the need for new design work. In this case, the BACI-design corridor(s) are repeatedly trawled in a single event and the catches are processed to determine the species-specific average rate of depletion (21; Fig. 2). A depletion study is readily scaled to the level of available resources, with replication up to the maximum number of corridors in the original BACI design.*

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 $\mathbf{y_{ijkm}}$ denotes a CPUE observation for time (event) *i*, treatment *j*, corridor pair *k*, and station *m*; $\boldsymbol{\mu}$ 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).

Commentary on the analysis

Sampling to detect potential environmental impact in a heterogeneous environment requires a complicated sampling design to simultaneously account for singularity, variance in space, variance in time, and interactions between space and time. These confounding effects are addressed with multiple paired corridors (replication), randomization of treatments, and repeated measures in the BACI experimental design used here. These measures will be optimized for the range of taxa represented in the study area during the NETS planning phase, with prioritization for tribal/stakeholder concerns about particular species/habitats.

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[d], and (*iii*) a Geographic Information System (GIS) for the region, with base layers of bathymetry, seafloor sediments, benthic invertebrate abundances, critical habitats, and previous commercial-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. Preliminary methodology will be similar to that used for the Bering Sea (10) and guidance obtained during community/subsistence (2010) and science (2011) workshops. Advice from Alaska Natives and stakeholders is especially important for developing an experimental design that is best suited for issues of particular concern.

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. 3, Fig. 5). This approach supports application of research findings to the larger region, not just the specific study location.
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[e]), possible anthropogenic disturbance of the seabed during the study period, 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.

[d] https://www.fisheries.noaa.gov/resource/data/mobile-fishing-gear-effects-bibliography-database
[e] https://www.npfmc.org/wp-content/PDFdocuments/rural_outreach/NBSRA_DiscPap_912.pdf

4. Conduct a statistical power-and-sample-size analysis to determine the number of corridor pairs needed to accommodate the preferred sampling effort and minimum detectable effect 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.

Proposals for funding essential and optional project elements to execute the experiment in FY24+ (Fig. 4):

1. Essential: F/V charter and associated needs for core field operations.
2. Optional: (1) Direct participation of tribal member(s) in scientific activities (assist tribal proposals), (2) Supplemental (benthic grab) infauna assessments, (3) Sediment chemistry assessments, (4) Microhabitat (sonar) sampling, (5) Undergraduate intern support, and (6) Ecological-impacts modeling.

FY24 activities (planning, fieldwork, analysis, reporting)

Refine experimental-design work to determine placement and specifications of a randomized, spatially replicated BACI experiment in a specific biogeographic stratum. Incorporate advice from Alaska Natives and stakeholders.

Charter vessel mobilization and readiness sea trials in Puget Sound.

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. Tribal and 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 ecological significance of the observed effects on select species at higher-trophic levels, such as marine mammals, groundfish, and crabs.

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. Tribal and 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 ecological significance of the observed effects on select species at higher-trophic levels, such as marine mammals, groundfish, and crabs.

Commentary on planning and implementation

The maximum number of sampling events (A_n) is determined by the experimental design, where the total number of sampling sites represents a trade-off between project cost and project duration. In general, the annual decision to continue or delay fieldwork will be guided by the magnitude of observed effects and the likelihood of determining final recovery rates for the different taxa. From a resource management perspective, it is preferable to overestimate the times required for recovery by delaying sampling than it is to prematurely deplete the full complement of sampling sites and risk underestimates.

The Bering Sea Elders have generated maps of the extensive areas where Alaska Native hunters and local fishermen harvest ocean resources, and the marine waters important to those resources (5). It would be helpful to incorporate this knowledge into the regional GIS being used for NETS planning.

A rapid turnaround of results after completion of annual fieldwork is important so that there is ample opportunity to receive external feedback and complete preparations for the next period of fieldwork. This will be facilitated by development of the core analytical software and consideration of alternative analytical methods prior to commencement of field operations.

Conventional analyses of trawling effects examine changes in the abundances and sizes of individual taxa, as well as various community metrics (28), to develop fisheries-, conservation-, and ecosystem-based management strategies. This approach requires a variety of assumptions about transferences through to higher trophic levels. There is an opportunity to assess these higher-order impacts by incorporating NETS results into an Ecopath-with-Ecosim model of NBS food-web dynamics, similar to the modeling framework developed to evaluate the bottom-up impacts of climate change on biomass trajectories in the eastern Bering Sea and the outcomes of fisheries management scenarios (29). The NBS version is expected to be available about the same time as NETS fieldwork begins in FY24.[f] *In addition to better information for NPFMC purposes, this approach may attract external funding from agencies concerned with vulnerabilities to other forms of anthropogenic disturbance (e.g. BOEM, USACOE, and USFWS)*.

Project organization

The NETS is composed of three distinct phases. Substantial stakeholder outreach to identify priorities, multiple statistical analyses to define the corresponding experimental design, and readiness trials for mission-critical equipment will occur during the **Planning phase** in FY23-24 with funding from the AFSC Regional Work Plan.

Partnering will be pursued and multiple, multi-year proposals will be developed to fund the costly **Fieldwork, and Analysis and Reporting phases** in FY24-25, including substantial outreach to keep stakeholders informed of progress and preliminary findings. Since a single comprehensive source of funding is unlikely, multiple partners, administrative processes, timelines, and obligations will be necessary during the Fieldwork, Analysis, and Reporting phases in FY24+ (Fig. 4; see *Supplemental funding* section).

[f] A. Whitehouse telcon, 6/29/22

Key roles

Bob McConnaughey (project leader): primary responsibility for scientific/technical direction and protocols during planning, execution, analysis, interpretation, and outreach/reporting; administration of budgets, contracts, and personnel; supplemental funding requests; chief scientist for at-sea team.

Steve Intelmann (physical scientist): geospatial data precision, integration, and management; readiness of technical equipment, especially mission-critical USBL system for subsea positioning; vessel configuration and testing; at-sea team; data processing; scientific products.

Sarah Rollings (OMAO hydrographer): readiness of sampling gear; navigation planning; operations scenarios; safety officer; at-sea team; coordinate outreach with AFSC Communications group; data processing and analysis; intern supervision; scientific products.

Lewis Barnett or TBD (biologist): supervise at-sea deck operations; manage retained samples; oversee catch data recording and archiving; data processing and analysis; scientific products.

Arny Blanchard (biostatistician, PSMFC contract analyst): NBS benthic-invertebrate community analysis; *a priori* power and sample size analysis; advance preparation of analysis tools; process documentation and reporting (FY23). Experimental design and sampling refinements; impacts analysis (B:A1); recovery/delayed impacts analysis ($B:A_n$); *a posteriori* statistical power analyses; experimental endpoint assessments; scientific products (FY24+).

Roger Clark (biologist, Insignis Biological Consulting): at-sea team; invertebrate-taxonomy specialist.

Marjorie Mooney-Seus (Communications Program Manager) / Mabel Baldwin-Schaeffer (AFSC Tribal Research Coordinator): support PI in advancing productive 2-way communication with Alaska Native communities about project planning, execution, interpretation. Facilitate listening sessions. Assist with development of project related materials and web pages.

TBD intern(s): protocol documentation; general logistical support; at-sea team; outreach/scientific products.

Partners and outreach

Partners: Core members of the global Trawling Best Practices Committee; fishing industry representatives; Bering Sea Tribal Elders, representatives of Bering Strait Tribal Governments, and ocean advocates (AMCC, Greenpeace, Oceana, etc.)

Outreach: Tribal and stakeholder listening sessions; NPFMC briefings; a publicly accessible web site with bibliographies of information about the NBS and bottom-trawling effects, plus specific information about the rationale, design, execution, and interpretation of the NBS effects of trawling study.

Commentary on partners and outreach

An important element of Alaska Native engagement will be placement of a community member with the project team. If there is interest, this will be pursued through a Bureau of Indian Affairs grant program by supporting a community proposal for an intern to be fully engaged in planning and execution of the study with direct reporting to the community itself. Timing of the BIA program (proposals due in April, awards in October) is such that a bridge grant would be needed for FY24 activities.

Intent

Implementation Program	Applicable
Regional Action Plans (RAP)	√ Will produce actionable management information to address climate-related redistribution of Bering Sea fisheries and possible interactions with subsistence activities.
Ecosystem-based Fisheries Management Roadmap (EBFM)	√ Objectives conform to Guiding Principles #1 (engagement for planning), #2 (ecosystem science), #3 (vulnerabilities/risks), #4 (commercial vs. subsistence harvesting trade-offs).
Integrated Ecosystem Assessment (IEA)	√ Project assesses risk and supports management strategy assessment for future trawl fisheries.
Stock Assessment Improvement Plan (SAIP)	√ Optional analysis of ecological impacts enables partitioning of habitat-related effects of trawling on conventional fishery-stock dynamics.
Northern Bering Sea Climate Resilience Area (Executive Orders 13754 (2016), 13990 (2021)	√ Project addresses Sec. 2 (policy) directives for conservation of the NBS ecosystem with Alaska Native participation.

Deliverables

Planning phase

1. Narrative report summarizing tribal and stakeholder input from listening sessions on research priorities and concerns. . Note: tribal and stakeholder engagement to date is summarized below (under Accomplishments); listening sessions are planned for spring 2024.
2. Detailed BACI experimental-design package, including layout and dimensions of paired research corridors; sample-size requirements for key response variables; written sampling protocols; and a detailed field-operations plan.
3. Multiple proposals to support unfunded field operations, optional project elements, and enhanced tribal/stakeholder participation.

Fieldwork, Analysis, and Reporting phases

1. Annual cruise reports for field operations, describing methods, data collected
2. Analysis of short-term trawling effects (events B:A1)
3. Analysis of lagged trawling effects (events B:A2) and/or recoveries 1 year after trawling (events B:A1:A2)
4. Oral presentations and a draft peer-reviewed manuscript on the scientific results.

Progress

12/27/23

Status

Technical, administrative, and logistical planning is underway and on schedule for sea trials in early FY24 and the first research cruise to the NBS in summer 2024.

Accomplishments

1. Leveraged funding. Multiple coordinated proposals to support unfunded field operations, optional project elements, and enhanced stakeholder participation resulted in funding from independent programs.

2. Experimental design. Multi-year grant awarded to the Pacific States Marine Fisheries Commission to provide an analyst responsible for experimental design details and analytical software to assess impacts from a Before-After Control-Impact (BACI) study of bottom-trawl effects on benthic invertebrates. Analytical options and a priori statistical power assessments are using 2017-2023 NBS trawl-survey data and results from a previous BACI study in the eastern Bering Sea (10). Statistical analysis identified 4 distinct communities of NBS benthic invertebrates to serve as the basis for generalizing study results (Fig. 3, Fig. 5). Preliminary taxon-specific power and sample-size analyses within each community are being refined to evaluate the effects of taxonomic level and the number of distinct communities (the k-means specification) on the probability of concluding there is no effect of trawling when there actually is one (Type II statistical error to be minimized as a primary design consideration), to better understand the detectable effect size, and to maximize operational efficiency in the field. The current analysis favors a study layout similar to the six paired corridors (total 7.3 sq. nmi) used in the previous BACI study (10), overall representing 0.01% of the 85,000 sq. nmi NBSRA.

3. Vessel charter. A firm fixed-price contract for a trawler active in Alaska groundfisheries and experienced crew was awarded for up to 83 sea days in 2024-2026. Precise positioning and navigation of the vessel (and sampling gear) is a mission-critical capability for executing the BACI experimental design. Successful proof of function and readiness for the Government's USBL subsea positioning system on the chartered vessel must be demonstrated during sea trials prior to mobilization for research cruises. Mobilization is underway for Puget Sound sea trials in January 2024. The 2024 summer research cruise commences immediately after completion of the RACE Aleutian Islands bottom-trawl survey.

4. Equipment readiness testing. Essential equipment has been mobilized and is undergoing proof of function, with field-engineer support. Updated navigation systems have been procured to ensure optimum and reliable subsea positioning.

5. Stakeholder engagements. Preliminary contacts have been made with Alaska Native communities in the Bering Strait region. Invitational travel for a face-to-face listening session with the Kawerak director of the Subsistence Resources program (Mr. Charles Menadelook) to explain research objective and methods, discuss tribal concerns and priorities, and identify opportunities for direct participation in the project. Experimental-design inputs on priority species and locations were requested, and final experimental-design work is on hold. An offer was made to help prepare a Community proposal to the Bureau of Indian Affairs Tribal Climate Resilience Program (TCRP) for embedding a Community member with the NETS project team. A follow-up virtual meeting with Dr. Julie Raymond-Yakoubian (Kawerak director of Social Science Program) briefly discussed the same opportunities. In one case, the benefit of having specific information on-hand for possible future discussions of bottom-trawling in the region was recognized and supported, as was the opportunity for participation with direct reporting to the Community receiving the BIA grant. Trawl-industry representatives are providing technical guidance for commercial trawl gear

and practices consistent with potential groundfishery interests in the region (J. Gauvin, A80 fleet; D. Carney, Bering Sea groundfish). NGO input requested (J. Warrenchuk, Oceana).

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Figures

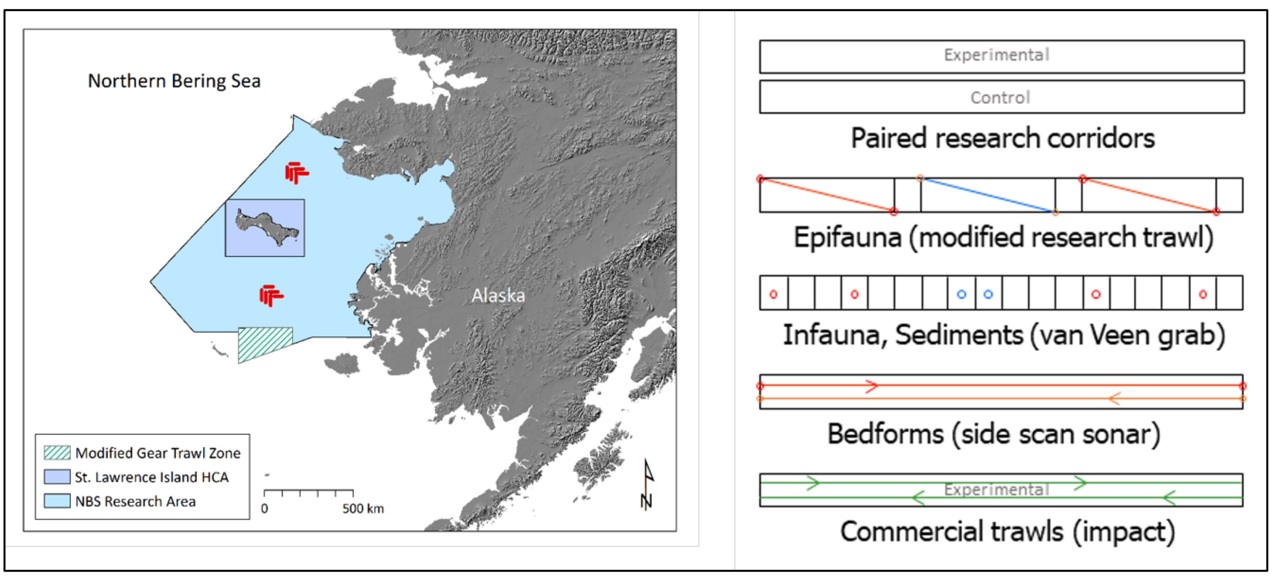


Figure 1. *The northern Bering Sea study area. Each of the clustered line segments (left panel, not to scale) represent a pair of experimental and control corridors for studying the effects of bottom trawling. Placement, size, and number of corridors will be determined during the experimental-design 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.*

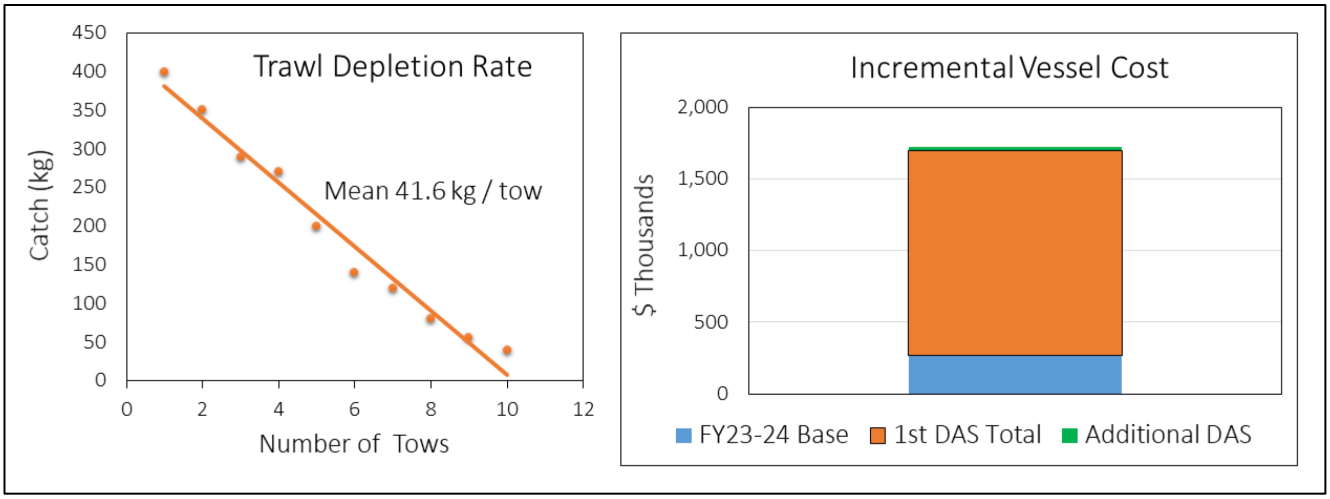


Figure 2. *The rate of depletion of benthic invertebrates by a bottom trawl can be experimentally determined with repeated towing over the same area of seabed (left panel; 21). An estimate of the recovery rate requires the more sophisticated (and costly) Before-After Control-Impact experimental design, which controls for temporal variability. Incremental costs for days at sea (right panel; DAS) are relatively low after base costs, transits and the first working DAS, providing for adaptability of field operations to match available funding.* 10/30/23

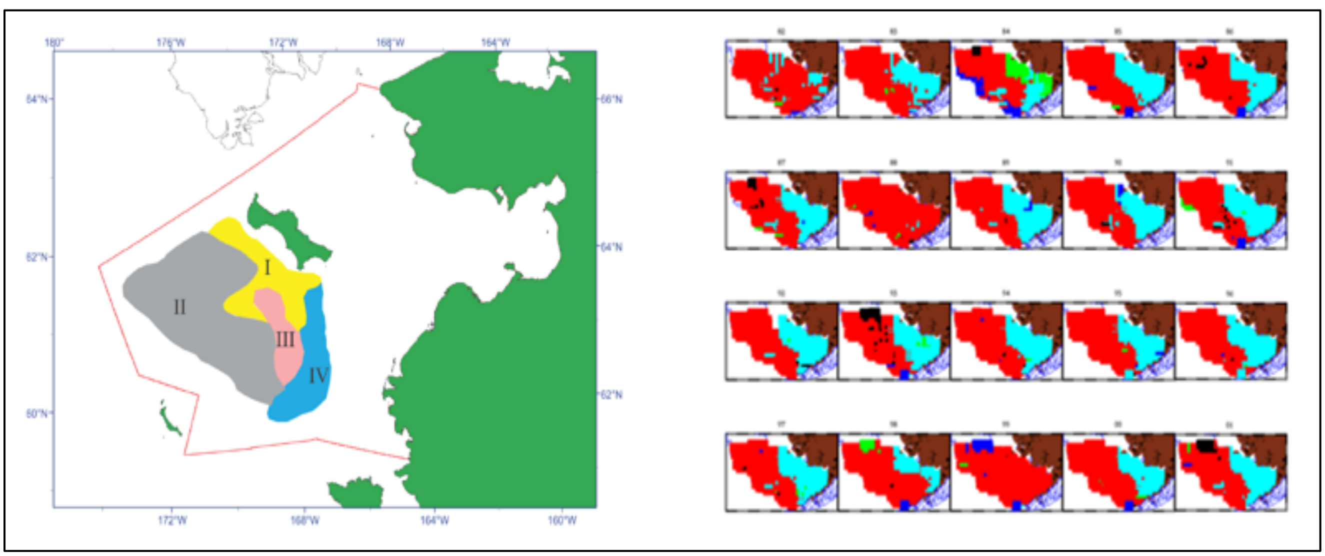


Figure 3. *Benthic invertebrates are the de facto measure of bottom trawl impacts. Prior analyses of NBS infauna (left panel; 25) and EBS benthic invertebrates (right panel; 26) illustrate well-defined and persistent assemblages that can be used as strata within which to randomly place replicated experiments and then legitimately generalize findings about trawling impacts to the larger geographical area. (Also see Fig. 5.)*

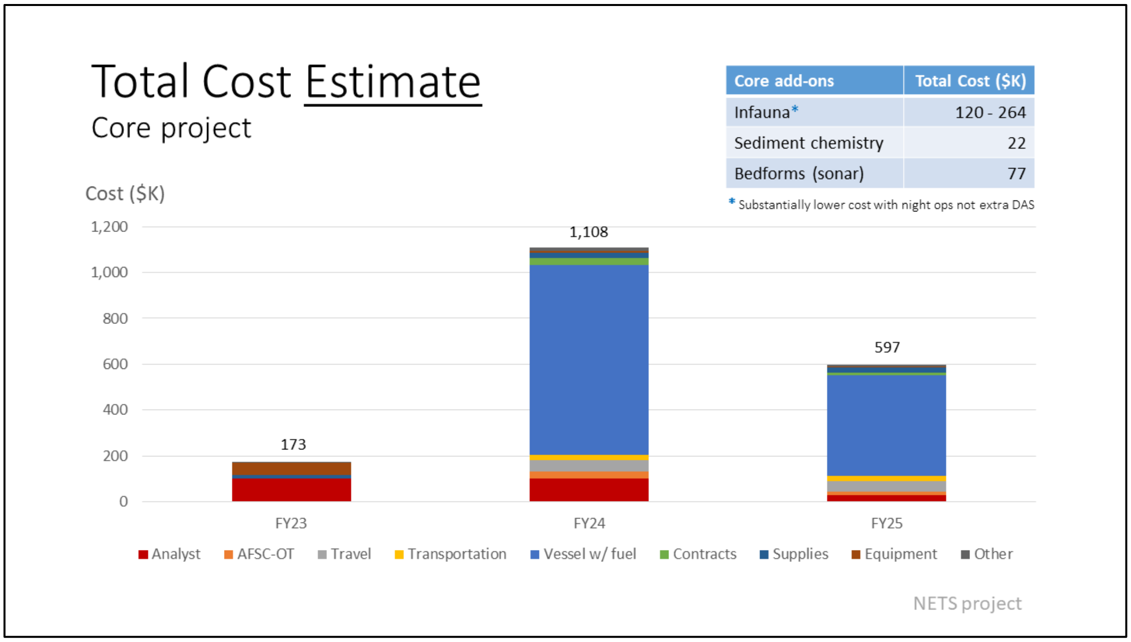
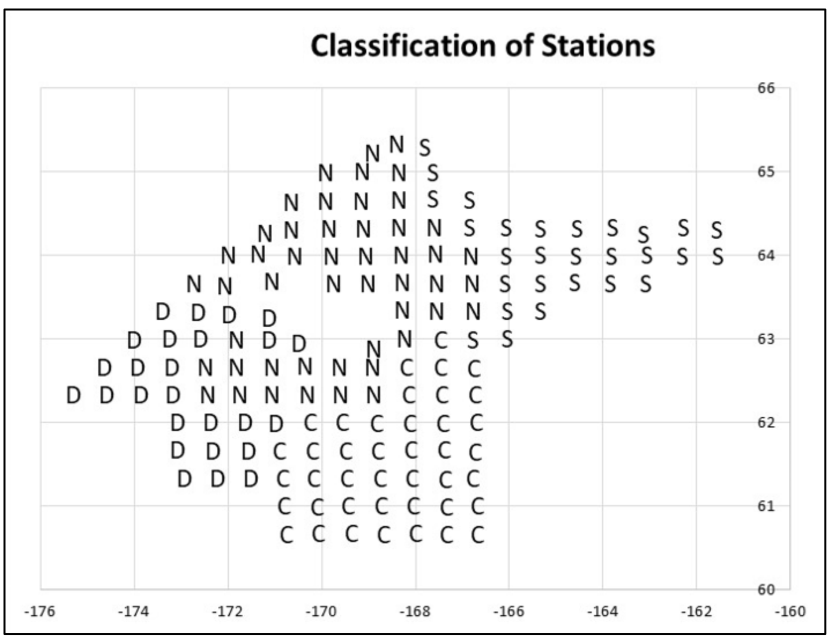


Figure 4. *Approximate total annual costs to complete the core NETS project, defined as research-trawl sampling of benthic invertebrates and grab sampling to characterize physical characteristics of the sediments. The modular design of the project can accommodate additional scientific, tribal, and stakeholder priorities with additional funding. Potential add-ons to the core project include grab sampling to characterize changes in infauna and sediment chemistry (carbon, nitrogen, stable isotopes), and nighttime sonar surveys of effects on benthic microhabitats. Estimates are based on the 2001-2002 TRAWLEX experiment – actual costs will be known after the NETS experimental design is defined during year 1 of the project.* 11/14/23



11/8/23

Figure 5. *Modal summary of hierarchical k-means clustering of 2017-2023 AFSC/GAP bottom-trawl survey stations in the NBS, based on CPUEs of benthic-invertebrate biomass at the species level. Plotted letters represent different species assemblages (communities) determined with ongoing statistical analyses.*