EFH Component 2 Fishing Effects Model and Analysis Methods for the 2028 EFH 5-year Review

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Abstract

The objective of an essential fish habitat (EFH) 5-year review is to evaluate and synthesize new information for the ten EFH components in Fishery Management Plans (FMPs) and propose revisions or amendments to the EFH components as warranted based on available information (50 CFR 600.815(a)(10)). Under section 303(a)(7) of the Magnuson-Stevens Fishery Conservation and Management Act, every FMP must minimize, to the extent practicable, adverse effects of fishing on EFH. Fishery Management Councils must act to prevent, mitigate, or minimize any adverse effects from fishing to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is “more than minimal and not temporary in nature”. Evaluating the potential adverse impacts of commercial fishing to benthic habitat is EFH Component 2 (50 CFR 600.815(a)(2)).

In December 2025, the North Pacific Fishery Management Council (Council) and the National Marine Fisheries Service (NMFS) launched the 2028 EFH 5-year Review and advanced the workplan to update EFH information in the FMPs with new and best available science since the 2023 EFH Review. This discussion paper focuses on the Fishing Effects Model (hereafter ‘FE model’) and analysis, which supports the evaluation of adverse fishing effects (FE) on EFH (EFH Component 2) for the 2028 EFH Review. We describe the FE model framework that was developed during the 2017 EFH Review and applied in both the 2017 and 2023 EFH Reviews, and we present proposed updates to key FE model inputs using newly available data and resources. We also provide a summary for reference of the 2022 FE evaluation process, completed by stock assessment authors for the 2023 EFH Review. For the February 2026 Council meeting, staff are seeking input from the Scientific and Statistical Committee (SSC) on the proposed updates for the 2028 EFH Review FE model runs, planned advancements, and associated bridging analyses. The SSC will have the opportunity to review the proposed methods for the stock assessment author FE evaluation at a future meeting.

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Executive Summary

The objective of an essential fish habitat (EFH) 5-year review is to review the ten EFH components of Fishery Management Plans (FMPs) and revise or amend the ten EFH components as warranted based on available information (50 CFR 600.815(a)(10)). The EFH 5-year review is a mechanism to ensure the National Marine Fisheries Service (NMFS) and Fishery Management Councils incorporate the most recent and best science available into fishery management for EFH. The 2028 EFH 5-year Review will update information with the most recent and relevant habitat-related literature and research developed for the North Pacific region. In December 2025, the North Pacific Fishery Management Council (Council) reviewed and advanced the workplan for the 2028 EFH 5-year Review, including Component 2: Fishing activities that may adversely affect EFH.

The requirements for EFH Component 2 are that each FMP must contain an evaluation of the potential adverse effects of fishing on EFH and minimize, to the extent practicable, adverse effects from fishing on EFH (50 CFR 600.815(a)(2)). This discussion paper proposes the new information that we are developing and gathering to update EFH Component 2 for the 2028 EFH 5-year Review. The primary focus for this paper is the proposed updates to the Fishing Effects Model (hereafter 'FE model'), developed for the 2017 EFH Review and updated for the 2023 EFH Review (Pirtle et al. 2025a). In response to recommendations from the Council's Scientific and Statistical Committee (SSC) and Plan Teams, NMFS, Council staff, and the Fisheries, Aquatic Science & Technology Laboratory (FAST Lab) are collaborating on FE model updates (input updates supporting the 2028 EFH Review) and funded FE model advancements (enhancements to model structure and reporting). We also include, for reference, a summary of the methods and process for the stock assessment author (hereafter 'stock author') evaluation of adverse fishing effects (FE) from the 2022 FE evaluation (Zaleski et al. 2024).

The FE model estimates benthic habitat disturbance over time and space from commercial fishing activities (Smeltz et al. 2019). The primary output of the FE model is an estimate of the amount of disturbed habitat in each 5 km x 5 km grid cell for each month of the model run. The FE model was first developed and applied for the 2017 EFH 5-year Review, and then again for the 2023 EFH 5-year Review, to estimate adverse effects within the core EFH area of FMP species. For the 2028 EFH Review, this discussion paper presents the proposed updates to FE model inputs as new data becomes available since the 2023 EFH Review. The fishing data cutoff date for the 2028 EFH Review model runs is December 2026. Updates to model inputs proposed include—

- Use of updated ensemble species distribution model (SDM) maps from Component 1: Description and identification of EFH,[1]
- Updated Catch-In-Areas (CIA) database fishing event data, including six more years of data since the 2023 EFH Review, through December 2026 (the data cutoff for 2028 EFH Review model runs),

[1] D3 EFH Descriptions and Maps, February 2026 SSC meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3117

- Updated gear parameters (including nominal widths and bottom contact adjustments), incorporating FAST Lab Gear Innovation Initiative (GII) products for participating fleets and established update methods for other fleets,
- Updated benthic habitat and substrate data as warranted, and
- Updated habitat feature susceptibility and recovery rates as warranted, informed by newly synthesized literature and pilot empirical recovery estimates, where feasible, to inform recovery priors for select taxa/features.

This discussion paper also describes proposed analyses to quantify changes in FE model outputs from the updates to the FE model inputs, including bridging analyses to support interpretation and continuity across EFH review cycles.

For reference, we provide an overview of the FE evaluation process that follows the FE model run. This evaluation informs discussions on impacts from fishing activities to individual species or species complexes. For the 2028 EFH 5-year Review, the stock author evaluation for adverse FE to EFH will focus on a subset of groundfish species in the Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska Groundfish FMPs and all BSAI Crab FMP species. The methods for the stock author evaluations will be presented more fully to the SSC for review and recommendations at the February/March 2027 Council meeting (tentatively).

This document presents an introduction to EFH Component 2 (Chapter 1), description of the FE model and overlay analysis (Chapter 2), proposed changes to the inputs for each of the FE model parameters (listed as "*Proposed Updates*" for each parameter in Chapter 2) and, for reference, a summary of the FE evaluation methods (Chapter 3) used during the 2022 Evaluation of Fishing Effects on EFH (Zaleski et al. 2024). Staff are seeking guidance from the SSC on proposed updates and planned advancements to support Component 2: Fishing activities that may adversely affect EFH.

Table of Contents

List of Figures

List of Tables

1 Introduction

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) requires NMFS and regional Fishery Management Councils (Councils) to describe and identify essential fish habitat (EFH) for all fisheries (section 303(a)(7)). The Magnuson-Stevens Act (MSA) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity". Federal agencies that authorize, fund, or undertake actions that may adversely affect EFH must consult with NMFS and NMFS must provide conservation recommendations to Federal and state agencies regarding actions that would adversely affect EFH. Councils also have the authority to comment on Federal or state agency actions that would adversely affect the habitat, including EFH, of managed species.

Additionally, section 303(a)(7) of the MSA requires that every FMP must minimize, to the extent practicable, adverse effects of fishing on EFH. Councils must act to prevent, mitigate, or minimize any adverse effects from fishing to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is "more than minimal and not temporary in nature". NMFS established guidelines to implement the MSA's EFH provisions in the Federal regulations at 50 CFR 600 Subparts J and K. The evaluation of fishing effects (FE) is Component 2 of the ten EFH components of Fishery Management Plans (FMPs) (50 CFR 600.815(a)(2)).

This discussion paper presents information on EFH Component 2: Fishing activities that may adversely affect EFH and the Fishing Effects Model (hereafter 'FE model') model and analysis methods proposed for the 2028 EFH 5-year Review. **Staff are seeking input from the Scientific and Statistical Committee (SSC) on the updates to the FE model data inputs and analyses of potential changes to model outputs from the updates.** This document presents an introduction to EFH Component 2 (Chapter 1), description of the FE model and overlay analysis (Chapter 2), proposed changes to the inputs for each of the FE model parameters (listed as "*Proposed Updates*" for each parameter in Chapter 2) and, for reference, a summary of the FE evaluation methods (Chapter 3) used during the 2022 Evaluation of Fishing Effects on EFH (Zaleski et al. 2024).

1.1 Fishing Effects on Essential Fish Habitat Overview

Fishing operations may change the abundance or availability of certain habitat features used by managed fish species to accomplish spawning, breeding, feeding, and growth to maturity. These changes can reduce or alter the abundance, distribution, or productivity of that species, which in turn can affect the species' ability to "support a sustainable fishery and the managed species' contribution to a healthy ecosystem" (50 CFR 600.10). The outcome of this chain of effects depends on the characteristics of the fishing activities, the habitat, fish use of the habitat, and fish population dynamics. Conducting an analysis considering all relevant factors requires the consolidation of information from a wide range of sources and fields of study to focus on the evaluation of the effects of fishing on EFH. The EFH regulations base the evaluation of the adverse effects of fishing on EFH on a 'more than minimal and not temporary' standard (50 CFR 600.815(a)(2)). The duration and degree of FE on habitat features depend on the intensity of fishing, the distribution of fishing with different gears across habitats, and the sensitivity and recovery rates of habitat features.

The assessment of FE on EFH is guided by the EFH regulations at 50 CFR 600.815(a)(2) that state:

> *Fishing activities that may adversely affect EFH*— (i) *Evaluation*. Each FMP must contain an evaluation of the potential adverse effects of fishing on EFH designated under the FMP, including effects of each fishing activity regulated under the FMP or other Federal FMPs. This evaluation should consider the effects of each fishing activity on each type of habitat found within EFH. FMPs must describe each fishing activity, review and discuss all available relevant information (such as information regarding the intensity, extent, and frequency of any adverse effect on EFH; the type of habitat within EFH that may be affected adversely; and the habitat functions that may be disturbed), and provide conclusions regarding whether and how each fishing activity adversely affects EFH. The evaluation should also consider the cumulative effects of multiple fishing activities on EFH. The evaluation should list any past management actions that minimize potential adverse effects on EFH and describe the benefits of those actions to EFH. The evaluation should give special attention to adverse effects on habitat areas of particular concern and should identify for possible designation as habitat areas of particular concern any EFH that is particularly vulnerable to fishing activities. Additionally, the evaluation should consider the establishment of research closure areas or other measures to evaluate the impacts of fishing activities on EFH. In completing this evaluation, Councils should use the best scientific information available, as well as other appropriate information sources. Councils should consider different types of information according to its scientific rigor.
>
> (ii) *Minimizing adverse effects*. Each FMP must minimize to the extent practicable adverse effects from fishing on EFH, including EFH designated under other Federal FMPs. Councils must act to prevent, mitigate, or minimize any adverse effects from fishing, to the extent practicable, if there is evidence that a fishing activity adversely affects EFH in a manner that is more than minimal and not temporary in nature, based on the evaluation conducted pursuant to paragraph (a)(2)(i) of this section and/or the cumulative impacts analysis conducted pursuant to paragraph (a)(5) of this section. In such cases, FMPs should identify a range of potential new actions that could be taken to address adverse effects on EFH, include an analysis of the practicability of potential new actions, and adopt any new measures that are necessary and practicable. Amendments to the FMP or to its implementing regulations must ensure that the FMP continues to minimize to the extent practicable adverse effects on EFH caused by fishing. FMPs must explain the reasons for the Council's conclusions regarding the past and/or new actions that minimize to the extent practicable the adverse effects of fishing on EFH.

(iii) *Practicability*. In determining whether it is practicable to minimize an adverse effect from fishing, Councils should consider the nature and extent of the adverse effect on EFH and the long and short-term costs and benefits of potential management measures to EFH, associated fisheries, and the nation, consistent with national standard 7. In determining whether management measures are practicable, Councils are not required to perform a formal cost/benefit analysis.

(iv) *Options for managing adverse effects from fishing*. Fishery management options may include, but are not limited to:

(A) *Fishing equipment restrictions*. These options may include, but are not limited to: seasonal and areal restrictions on the use of specified equipment, equipment modifications to allow escapement of particular species or particular life stages (e.g., juveniles), prohibitions on the use of explosives and chemicals, prohibitions on anchoring or setting equipment in sensitive areas, and prohibitions on fishing activities that cause significant damage to EFH.

(B) *Time/area closures*. These actions may include, but are not limited to: closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities and designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life stages, such as those areas designated as habitat areas of particular concern.

(C) *Harvest limits*. These actions may include, but are not limited to, limits on the take of species that provide structural habitat for other species assemblages or communities and limits on the take of prey species.

1.2 History of Evaluating Adverse Fishing Effects

In 2005, NMFS and the Council completed the EIS for EFH Identification and Conservation in Alaska (“2005 EFH EIS”, NMFS 2005). The 2005 EFH EIS reviewed the effects of fishing at the then-existing rate and intensity, and reported the final analyses and adverse effects finding in Appendix B: Evaluation of Fishing Activities that May Adversely Affect Essential Fish Habitat. The 2005 EFH EIS concluded that the effects of fishing were no more than minimal for managed species in the Bering Sea (BS), Aleutian Islands (AI), and Gulf of Alaska (GOA). Since the analysis in the EIS, the Council has taken management actions that may have changed the distribution or intensity of fishing, including a suite of mitigation measures adopted by the Council to provide additional protection to EFH. Management actions, stock changes, and industry innovations and adaptations can change the scale of FE to habitat, and the subsequent EFH 5-year reviews (completed in 2012, 2017, and 2023) are used to evaluate new information. If a change to the conclusions of the evaluation of FE is indicated, this may be a higher priority action item for the Council.

Prior to the 2005 EFH EIS, scientists at the Alaska Fishery Science Center (AFSC) developed a quantitative model, the Long- term Effects Index (LEI), to organize and synthesize available information on fishing impacts (from 11 gear types) to benthic habitats (using four substrate types). As described in Fujioka (2006), the LEI framework combines information on the location (endpoint only) and intensity of fishing with assumptions about how fishing gears affect habitat features and how quickly disturbed habitat recovers. Under the assumption that fishing continues at then-current patterns long enough for disturbance and recovery to balance, the model estimates the long-term (equilibrium) reduction in habitat features relative to an unfished condition. The LEI was useful for bringing together disparate inputs (e.g., gear types used in Alaska fisheries and observer-based fishing effort information, but early applications were constrained by limited or uncertain habitat and parameter information, so results varied in quality and spatial applicability for Alaska fisheries.

For the 2010 EFH 5-year Review, NMFS examined and compared inputs to the LEI model used for the 2005 EFH EIS against new information available since 2005. Fishing intensity had decreased overall, with moderate shifts causing increases or decreases in limited areas. Therefore, there were no substantial changes to the model inputs and the 2010 EFH 5-year Review carried the same conclusion as the 2005 EFH EIS of impacts to habitats being minimal and not detrimental to fish populations (NMFS 2012)

During the 2017 EFH 5-year Review, NMFS collaborated with the Fisheries, Aquatic Science & Technology Laboratory (FAST Lab) at Alaska Pacific University to develop the FE model to support the evaluation of adverse FE on EFH. The FE model architecture and inputs draw on the Swept Area Seabed Impact (SASI) Model created by the New England Fishery Management Council (NEFMC) Habitat Plan Development Team for use in the NEFMC's 2011 Omnibus EFH process (NEFMC 2011). The FE model development was conducted with funding support from multiple sources including NMFS Alaska Region, NPFMC, NEFMC, the Atkinson Foundation (Cornell University), and the fishing industry via the Alaska Education Tax Credit Program. Following the 2017 EFH 5-year Review, model developers published a full description of the FE model (Smeltz et al. 2019).

The FE model was applied for the 2023 EFH 5-year Review. Model inputs and minor corrections to model code were implemented for the 2022 FE evaluation as part of the 2023 EFH Review (Zaleski et al. 2024), including:

- Fishing effort data was updated with five additional years using VMS data from the NMFS Catch-In-Areas (CIA) database through December 2020.
- Gear information in the gear parameter table was updated following input from fishery participants and gear experts. The gear parameter table was reviewed by NMFS Alaska Region Sustainable Fisheries in-season management personnel.
- The FE model code was corrected in 2018 after analysts discovered an error that transposed susceptibility rates for trawl and longline gears. Differences in model outputs after the correction were minor and were reported for transparency (Figure 7 in Zaleski et al. 2024).
- A comparative analysis of species-specific results from the corrected FE model was undertaken for the species with ≥ 10% estimated habitat disturbance in CEAs to identify

the reason for exceeding that threshold: FE model correction, new species distribution model (SDM) maps and species CEAs, or changes in fishing activity.

The SSC found that the EFH evaluation methodology was appropriate for the 2023 EFH 5-year Review and they offered recommendations for the next review cycle.[2] All FMP amendments to update EFH information, including the FE model results and species evaluations, were implemented as an omnibus amendment package in 2024 (89 FR 58632, July 19, 2024), accompanied with the final environmental assessment for EFH omnibus amendments (NMFS 2024), and summarized in the 2023 EFH 5-year Review Final Summary Report (Pirtle et al. 2025a).

In December 2025, the North Pacific Fishery Management Council (NPFMC/Council) and NMFS launched the 2028 EFH 5-year Review and advanced the workplan to update EFH information in the FMPs with new and best available science since the 2023 Review.[3] The workplan includes the FE model and analysis, which supports the evaluation of adverse FE on EFH (EFH Component 2) for the 2028 EFH Review. In response to SSC and Plan Team recommendations, NMFS and Council staff are working with the FAST Lab to implement FE model updates. The FAST lab is also working on funded FE model advancements (enhancements to model functionality) to better align the FE model with evolving management questions and data availability.

1.3 Documents Incorporated by Reference

This discussion paper relies heavily on the information and evaluations contained in previous EFH 5-year review reports, and these documents are incorporated by reference. The documents listed below contain information about the 2023 EFH 5-year Review and the evaluation for adverse FE to EFH during that review, as well as the workplan for the 2028 EFH 5-year Review, including a high-level plan for updating and evaluating FE analyses.

2022 Evaluation of Fishing Effects on Essential Fish Habitat: This document is the full report of the 2022 FE evaluation completed for the 2023 EFH 5-year Review. It contains the full FE model description, an explanation for updates to the model and evaluation process from the 2017 EFH Review, and the complete results from the stock assessment author evaluations (Zaleski et al. 2024). This document is available from: https://repository.library.noaa.gov/view/noaa/66042.

Essential Fish Habitat 5-year Review Final Summary Report: North Pacific 2023 Essential Fish Habitat 5-year Review: This document is the final summary report of the 2023 EFH 5-year Review including a comprehensive record of the review and updates to the EFH components (Pirtle et al. 2025a). It also includes the updates to EFH information in the five

[2] B9 SSC Report (October 2022 Final), October 2022 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/2946

[3] MOTION D2 EFH REVIEW PLAN, December 2025 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3108

applicable FMPs and a record of the FMP amendment process. This document is available from: https://repository.library.noaa.gov/view/noaa/71565.

2028 Essential Fish Habitat 5-year Review Plan: This document describes the workplan for the 2028 EFH 5-year Review with an overview of the proposed updates to NMFS prioritized EFH components for a subset of FMPs and FMP species. This was presented to the AP and the Council at the December 2025 Council meeting and informed the Council motion to support and advance the review process. This document is available in the February 2026 SSC eAgenda for under agenda item D3, linked at "D3 2028 EFH 5-year Review Plan Discussion Paper Dec 2025: https://meetings.npfmc.org/Meeting/Details/3117.

2 Fishing Effects Model and Analysis

The FE model estimates benthic habitat disturbance over time and space from commercial fishing activities. The model is implemented in two linked modules: a Fishing Module that translates CIA database fishing event data and gear parameter tables into estimates of fishing footprint and fishing gear–seabed interactions (e.g., bottom contact), and a Habitat Module that combines Fishing Module outputs with habitat maps and feature-specific susceptibility and recovery parameters to estimate cumulative benthic habitat disturbance. The FE model employs an impact/recovery dynamic that tracks habitat transitions between disturbed and undisturbed states in monthly time steps within 5 km x 5 km (25 km^2) grid cells across the North Pacific (see Smeltz et al. 2019 for a full description of the model). The primary output of the FE model is an estimate of the amount of disturbed habitat in each grid cell for each month of the model run.

The 2028 EFH 5-year Review workplan proposes to apply the FE model to support a quantitative determination of adverse effects to EFH in the same manner as the 2017 and 2023 EFH Reviews. No changes are proposed to the model dynamics or overall workflow (Figure 1). All changes in the FE model for the 2028 EFH Review will be through updates to the data inputs, described below under each section as "*Proposed Updates*".

The FE model is used by the NPFMC but is also used for the 2025 EFH 5-year Reviews for the NEFMC and Mid-Atlantic Fishery Management Council (Bachman et al. 2025) and applied in a wide variety of other Council actions. For clarity, in this discussion paper, we use "updates" to refer to planned refreshes of FE model input datasets and parameter tables needed for the 2028 EFH Review model runs, while maintaining the established FE model structure and standard 5 km × 5 km monthly outputs (as described in Zaleski et al. 2024). We use "advancements" to refer to enhancements to model functionality (e.g., empirical estimation of recovery parameters for select habitat features; more flexible reporting tools; and scenario-based simulations) that are being developed in parallel and will be implemented where feasible and upon request without disrupting the 2028 EFH Review.

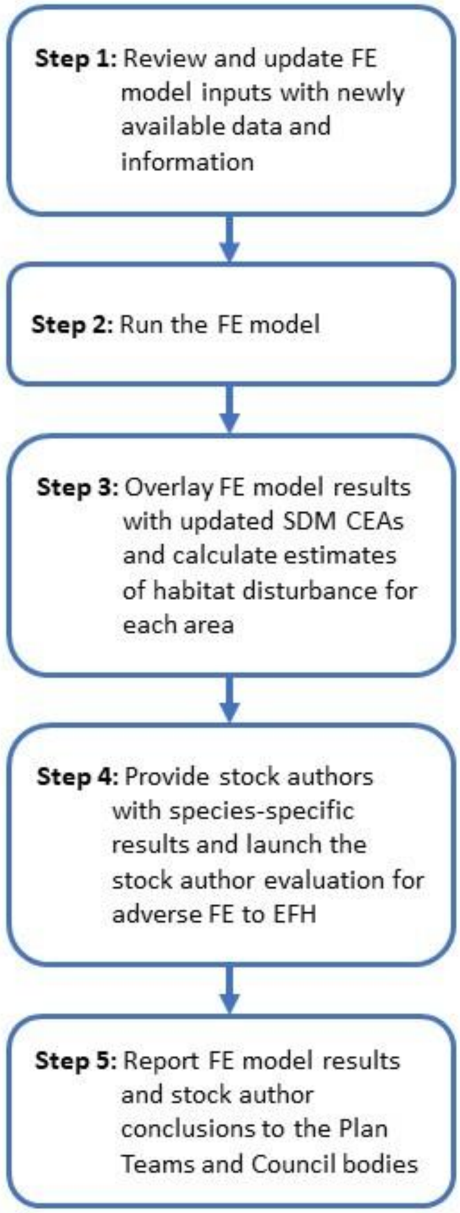

Figure 1. A workflow diagram of the steps for the essential fish habitat (EFH) fishing effect (FE) evaluation process. (SDM = species distribution model; CEA = core EFH area)

2.1 FE Model Input Parameters

The first step in the overall workflow is to review and update FE model inputs as warranted (Figure 1 step 1). The inputs to the FE model include: fishing effort, spatially-explicit surficial substrate data, gear parameters, and substrate- and gear-specific susceptibility and recovery rates of habitat features. A full description of the model and underlying equations are provided in Appendix 1 of this document and Smeltz et al. (2019).

2.1.1 Fishing Effort

Fishing effort data comes from the Catch-In-Areas (CIA) database produced by the NMFS Alaska Regional Office (AKRO).[4] The CIA database is a GIS database that contains information on the spatial extent of commercial fishing activities in the North Pacific. The application integrates catch data from AKRO's Catch Accounting System (CAS),[5] which has the spatial resolution of NMFS reporting areas, with spatial data from the VMS for each trip. The VMS data is automatically collected onboard nearly all commercial fishing vessels in the North Pacific. The database does not include vessel and trip information from state-managed fisheries. The VMS records GPS locations in 30-minute intervals while a ship is at sea providing a continuous path of where that vessel has traveled. In addition to the spatial data for each trip, the CIA database contains information about the fishing activity (e.g., total catch, target species, vessel size, etc.) such that gear types can be attributed to the spatial records, which allows for fishing lines to be converted to 'swept area', or the product of gear widths by fishing track lengths.

CIA Database System

The legacy CIA database system is complex and had limited documentation for the process of creating work products, which made long-term maintenance and reproducibility a challenge. In response to process questions and evolving data needs, NMFS rebuilt the legacy CIA system using a new and more modern architecture. The new system is deployed and has produced an initial (alpha) dataset that is undergoing quality assurance testing and preliminary internal use.

NMFS will check that the total reported catch grouped by species, processing sector, FMP sub area, and year are comparable between the legacy and new CIA datasets. While differences are expected between the two systems, a bridging analysis is included in the 2028 EFH 5-year Review workplan to evaluate any resulting differences in FE model outputs.

Proposed Updates

1) Add additional fishing data from years since the 2022 FE evaluation

For the 2028 EFH 5-year Review FE model runs, we will incorporate additional years of spatial data from individual fishing events in the CIA database beyond the 2022 FE evaluation. The fishing data cutoff date for the 2028 EFH Review model runs will be December 2026. Quality assurance protocols will be applied to all new fishing event data (e.g., removal of erroneous or duplicate events and vetting of questionable geospatial artifacts) prior to model runs. The spatial extent of the data will cover the North Pacific within the United States Exclusive Economic

[4] Alaska Regional Office Catch-In-Areas database: https://www.fisheries.noaa.gov/inport/item/27363
[5] Alaska Catch Accounting System: https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/alaska-catch-accounting-system

Zone, at depths less than 1,000 m to include areas of the continental shelf and slope, resulting in a total domain area of 1.2 million km^2. Gear types for the federal fisheries that will be included are pelagic trawl, non-pelagic trawl, hook-and-line, pot, and jig.

2) Improve the accuracy of identifying the "unobserved" fishing events

In the CIA database, the VMS paths are truncated to include only the portions of the path that correspond to fishing activity rather than activity such as steaming, searching, etc. For vessels that have onboard fisheries observers that record the time of fishing activity, the VMS paths are truncated based on the observers' records. For vessels with electronic monitoring (EM), hauls were identified based on EM records. For vessels that did not have observers or EM onboard, a filtering process was used on the VMS data that identifies likely fishing activity based on the vessel's speed and are flagged in the CIA database as "unobserved" fishing. AKRO's recent updates to the CIA database include an update to the underlying application that generates the spatial data, as mentioned above. A bridging analysis will be run to examine how updates to the CIA database may affect FE model outputs (see Section 2.2.2).

2.1.2 Gear Parameter Table

The gear parameters used as data inputs into the FE model are nominal width and contact adjustment. Nominal width represents the largest cross-sectional width of a fishing gear and contact adjustment represents the proportion of gear's nominal width that is in contact with the seafloor. These values come from the Gear Parameter Table, which is a catalog of commercial fishing gears used in the North Pacific (described below). This table includes nominal width and contact adjustment values for all these gears as well as information to link fishing events in the CIA database to specific gears. This gear table was initially developed by NMFS and the FAST Lab during the 2017 EFH 5-year Review (with minor updates in the 2023 EFH 5-year Review) and was based on industry and expert input with ongoing availability for public input.[6]

The Gear Parameter Table provides the input parameters relating to the fishing gears used in the FE model. To avoid confusion, at this time, we are incorporating by reference the gear parameter table used during the 2022 FE evaluation (Appendix 2 in Zaleski et al. 2024), and will include a list of parameters and definitions below. Input parameters are nominal width and contact adjustment. The nominal width is used to convert VMS lines to areas and represents the full door-to-door width of a trawl, or the lateral movement of a fixed line gear. The nominal gear width values in the gear parameter table provide a standard measure by which to estimate the footprint of gears. Nominal width parameters are intended for the study of habitat disturbance and do not describe the time/area collocation of these gear types.

Here we provide an explanation of the gear parameters that will be included in the gear parameter table, with a note on the data sources for those parameters:

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[6] D1 Fishing Gear Parameters AK EFH, April 2016 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/564

- Fishery: This is a simple label for each row to represent the combination of parameters provided in the table, including region, target species, gear type, and vessel type.
- Vessel Type: Vessel types are either catcher vessels or catcher-processors.
- Area: Area is divided by regions: BS, AI, and GOA. Locations are provided by trip information from the CAS.
- Gear: The main gear types are pelagic trawl, non-pelagic trawl, hook-and-line, and groundfish pot gear. Jig is also included for Pacific cod jig fisheries.
- Target Species: Target species are the dominant species caught. Each haul is assigned a Trip Target Code in the CAS, so one trip with multiple hauls may have multiple target species associated with it. The data inputs for the CAS assignments are based on observer data, production reports, and landings reports.
- Other Species: In some fisheries, as mentioned above, some fisheries may have hauls with different dominant species and different assigned Trip Target Codes, so this column accounts for the range of species that may be represented in the CAS.
- Vessel Length: Vessel metrics are reported through Federal Fisheries Permits.
- Season: Season is not always applied for certain fisheries, but includes A and B seasons.
- Depth Range: The depth range is based on the gear and bottom depths reported for each observed haul collected by the Observer Program.
- Nominal Width: The nominal width is the width of different gears as they are operating. Nominal widths of trawls are dependent on many factors, including specific gear characteristics, vessel size, sea state, and depth fished. Nominal width estimates were provided by industry representatives ahead of the 2017 EFH 5-year Review.[7]
- Contact Adjustment: Contact adjustment represents the proportion of the fishing gear's nominal width that is assumed to make contact with the seafloor during a fishing event. Contact adjustment values are unique to each type of gear and can vary based on fishing depth, vessel size, target species, location, and season.

Proposed Updates

1) Gear Innovation Initiative

The Gear Innovation Initiative (GII) is a cooperative scientific research effort developed and executed by the FAST Lab.[8] The goal of the GII is to provide scientifically robust information on fishing gear to support effective fisheries management. The GII employs an empirical workflow based on net plans, realized fishing scenario-based simulations, field validation with vessel-based gear mensuration, and flume tank trials to characterize gear geometry, forces, and seabed interactions. The GII workflow underwent external peer review by fishing gear experts (e.g., Fisheries and Marine Institute of Memorial University) as well as fishing gear design and construction firms. For the 2028 EFH 5-year Review, available GII results will be used to update gear parameter metrics applied in the FE model (e.g., nominal widths and bottom contact

[7] D1 Fishing Gear Parameters AK EFH, April 2016 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/564
[8] NPFMC Pelagic Trawl Research Summaries: https://www.npfmc.org/pelagic-trawl-gear-research-summaries/

adjustments) for the fleets participating in the GII. Current participants include all BSAI and GOA pollock fleets and the Amendment 80 fleet.

2) NMFS Alaska Region Internal Review

For the 2028 EFH 5-year Review, NMFS AKRO staff will review the gear parameters table for completeness and consistency with fishery definitions and management databases, concurrently with fishery participants and gear experts.

2.1.3 Habitat Categorization

Owing to the lack of continuous empirical habitat data for the BS, AI, and GOA regions, the FE model employs an extensive spatially explicit surficial substrate (sediment) data set derived largely from the usSEABED database. Sediment type is used as a proxy for habitat types because continuous spatially explicit data for biological and geological habitat types are not available. Until continuous empirical data or validated spatial models are available for all habitat features, sediment-based categories are the best available science. For the 2017 and 2023 EFH Reviews, sediment had been used to classify habitats into six categories: mud, sand, gravel, cobble, boulder, and deep/rocky. The deep/rocky habitat category is defined as cobble or boulder habitats deeper than 200 m and was implemented during the 2017 EFH Review to indicate habitats which were likely to have long recovering deep water corals and sponges. The NOAA Deep-Sea Coral Research and Technology Program's (DSCRTP) *Deep-Sea Coral Data Portal*[9] is a comprehensive data repository that compiles known locations of deep-sea corals and sponges in U.S. territorial waters, derived from research funded by the program with results of other studies provided voluntarily. The data portal was updated in 2025, including new data from the recently completed DSCRTP Alaska Coral and Sponge Initiative (Conrath et al. 2025), and is a resource that will be used to improve the existing information of the deep/rocky habitat category in the FE model. The sediment map used for the 2017 and 2023 EFH Reviews was based on the dbSEABED system (the parent system for the usSEABED database project), which was also recently updated (Jenkins et al. 2025).

Proposed updates

1) Include new sediment observations using recently published data

Analysts will search for additional sediment observations to add to the existing sediment record applied to the FE model. New substrate data will be incorporated from recently published studies and curated data repositories (e.g., USGS usSEABED). The dbSEABED system was recently updated (Jenkins et al. 2025) and will be reviewed to incorporate new sediment records to ensure the most recent and best available sediment data are applied to the FE model, consistent with the approach used in the 2017 and 2023 EFH Reviews.

2) Research in development: If feasible, use coral and sponge SDMs in the FE model workflow to better classify where slow recovering habitats are likely to be found.

[9] Deep-Sea Coral Portal: https://deepseacoraldata.noaa.gov/data

The methods for advancing EFH descriptions and maps (EFH Component 1) for the 2028 5-year Review, include revising the structure-forming invertebrates (SFI) covariate SDMs that are applied as habitat covariates (along with the full suite of other habitat covariates) to the ensemble SDMs to map EFH for managed species.[10] The SFI covariates are included in the EFH SDMs to ensure that the EFH maps account for the distribution of these SFI as habitat features for groundfishes and crabs in the North Pacific region. Updates to Component 1 SFI covariates include new SFI data and a new combined-gear SDM method. The SFI data are classified into three taxonomic groups of corals, sponges, and Pennatulaceans (sea pens and sea whips). The new SFI SDM method that AKRO has developed will combine new data from underwater image analysis from the Alaska Coral and Sponge Initiative[11] with AFSC Resource Assessment and Conservation Engineering Division Groundfish Assessment Program (RACE GAP) bottom-trawl survey data[12] to produce covariate raster surfaces of coral, sponge, and Pennatulacean presence-absence.

The final versions of the updated Component 1 SFI covariates, along with the updated ensemble SDM EFH maps, and relevant bridging analysis, will be presented to the SSC for review at the February/March 2027 Council meeting (tentatively scheduled). If feasible, at that time, we will also present methods advancements for incorporating the new combined gear SDM-based SFI covariates into the FE model workflow with bridging analysis to the SSC with the FE model run results.

2.1.4 Susceptibility and Recovery

Susceptibility and recovery are key input parameters that are specific to each habitat type. Susceptibility is the proportion of habitat impacted (i.e., transitions from “undisturbed” to “disturbed”) if it is contacted by fishing gear. For a single fishing activity, the proportion of habitat impacted within a grid cell and time step is the product of the swept area ratio, contact adjustment, and susceptibility. Recovery is the rate at which a habitat transitions from “disturbed” to “undisturbed”, based on both the underlying habitat and the gear type.

Susceptibility and recovery tables currently include the following metrics (refer to Appendix 3 in the 2022 FE evaluation (Zaleski et al. 2024) for more detail):

- Feature Class: The habitat features included in the FE model are either geological or biological features.
- Feature: The individual features are either of the feature classes that are associated with the habitat categories. A feature may be associated with one or all categories, and they have susceptibility and recovery rates specific to those categories.
- Habitat Categories: There are six habitat categories based on sediment type and depth.

[10] D3 EFH Descriptions and Maps, February 2026 SSC meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3117
[11] NMFS Deep Sea Coral Research and Technology Program https://deepseacoraldata.noaa.gov/
[12] Groundfish Assessment Program: https://www.fisheries.noaa.gov/contact/groundfish-assessment-program

- Susceptibility Codes: Susceptibility codes are adapted from Grabowski et al. (2014) global meta-analysis of benthic susceptibility and recovery. There are gear specific codes for hook-and-line, pot, and trawl (both pelagic and non-pelagic) fisheries.
- Recovery Codes: Recovery codes are also adapted from Grabowski et al. (2014) with recovery rates ranging from less than 1 year to 50 years.

Proposed updates

1) Review recovery and susceptibility rates using newly synthesized literature, and update as warranted.

A newly available resource, *The Fishing Gear Effects on Marine Habitats Database* (also referred to as the Fishing Effects Database), will be reviewed for any new information on recovery and susceptibility rates that can be updated for use in the FE model.[13] This database is hosted by the U.S. Regional Fishery Management Councils Habitat webpage and is designed to compile and share literature on the impacts of fishing gear on marine habitats.[14]

2) Research in development: If feasible, present advancements in estimated recovery parameters using an integrated fishing effects-species distribution modeling (FE-SDM) approach for select long-lived taxa/features (e.g., corals and sponges) to inform recovery priors and bridge to literature-based values.

This work in development by the FAST Lab will estimate recovery parameters that can be applied in the FE model. An integrated FE-SDM model is built on three processes: species/taxa distributions, fishing impacts/recovery, and observations of the seafloor (Smeltz 2023). Empirical FE–SDM recovery estimates are expected to be feasible for only a subset of habitat features due to data limitations, so literature-based values (*status quo*) will continue to be used for the remaining features. Bridging between FE–SDM-informed estimates and literature-based estimates will be important for interpretation. If feasible, we will present methods for incorporating new estimated recovery parameters into the FE model workflow with bridging analysis and the FE model run results for SSC review at the February/March 2027 Council meeting (tentatively scheduled).

2.2 Bridging Analyses

The proposed updates to FE model inputs will be used to run the FE model for the 2028 EFH 5-year Review (Figure 1 step 2). Changes to model inputs may change model outputs and we propose running bridging analyses to understand how updates impact FE model results. This will be similar to analyses performed during the 2022 FE evaluation where species-specific results from the FE model were compared for corrected model code and updated polygons of species CEAs (Section 4.3 in Zaleski et al. 2024).

[13] The Fishing Gear Effects on Marine Habitats Database: https://fishmaps.shinyapps.io/FishingEffectsDatabase/_w_20e321c691e142ae878380160604de2d/#!/
[14] U.S. Regional Fishery Management Councils: Fish Habitat: https://www.fisherycouncils.org/habitat

2.2.1 Fishing Effort

We will run a bridging analysis comparing FE model outputs from vessel track data pulled from the two CIA database systems (legacy CIA and updated CIA) and from the same time frame (a range of vessel track information predating the update) to identify potential differences in FE model outputs. Results from the bridging analysis will be used to demonstrate whether or not, and if so, those differences may affect the FE model results and evaluations.

2.2.2 Gear Parameters

Updates to gear parameters may change the scale of resulting estimates of habitat disturbance in the different regions depending on fishing effort. We propose to compare estimates of disturbance using the gear parameter table inputs from the 2022 FE model run (Appendix 2 in Zaleski et al. 2024) to estimates using the table updated for the FE model run prepared for the 2028 EFH Review. Analysis and reporting, for example, can include how estimates of habitat disturbance differ by region and by the subset of species included in the 2028 EFH 5-year Review plan.

2.3 Overlay FE Model Results with Updated Ensemble SDM EFH Maps

The next step in the FE evaluation process is to overlay FE model results with species-specific EFH areas in order to determine if potential adverse FE to any individual species' EFH are more than minimal and not temporary (Figure 1 step 3). Results from the FE model will be overlaid with updated ensemble SDM EFH maps (Component 1) in order to evaluate estimates of habitat disturbance on the species' EFH. New ensemble SDMs will be produced in the 2028 EFH 5-year Review for a subset of FMP species in light of capacity constraints for both the Council and NMFS.[15] The subset includes—

- Sablefish, pollock, Pacific cod, Pacific ocean perch, and arrowtooth flounder in the BSAI and GOA Groundfish FMPs, and
- All five species of crab in the Crab FMP.

All current Level 2 EFH descriptions and maps for the listed species will be updated using ensemble SDMs. The SDMs will include five additional years of species survey data from the RACE GAP bottom-trawl surveys. The new SDMs will also apply updated environmental covariates including bathymetry, all bathymetry-derived terrain variables (slope, aspect, curvature, and bathymetric position index), sediment grain size (*phi*), rockiness, bottom temperature, ocean currents, and SFI presence-absence that will be used in model fitting.[16]

EFH is characterized for each species' life stage as the spatial domain containing the upper 95% of occupied habitat (NMFS 2005) and a subarea of the upper 50% is referred to as the "core EFH

[15] D3 2028 EFH 5-year Review Plan Discussion Paper Dec 2025, February 2026 SSC meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3117
[16] D3 EFH Descriptions and Maps, February 2026 SSC meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3117

area" or "CEA" (Pirtle et al. 2025b). The CEAs from the updated ensemble SDM EFH maps will be applied to the FE analysis in an overlay with the FE model run results to determine the percent habitat disturbed for each species' adult life history stage.

2.4 Responses to SSC and AP/Council Recommendations on the Model

Here we list comments and recommendations the SSC, AP, and Council have provided regarding the FE evaluation moving forward from the 2023 EFH 5-year Review and in consideration of the workplan for the 2028 EFH 5-year Review.

2.4.1 Scientific and Statistical Committee Recommendations

During the October 2022 Council meeting, the SSC approved of the FE model and evaluation results presented.[17] The SSC also encouraged consideration of what products or areas of research are necessary to satisfy EFH regulatory requirements and inform management decisions for future iterations of FE evaluations. With regard to FE concerns, the SSC recommended:

Continue to consider long-lived benthic habitat features and the extent to which current definitions of depth distribution and recovery times within the FE model are appropriate, and whether they can be refined in the future given available data.

- Response: The FE model team will continue to refine representation of long-lived benthic habitat features as the best available science and available data allow. For the 2028 EFH 5-year Review, updates include improved information on corals and sponges (e.g., the Alaska Coral and Sponge Initiative that was completed in 2024 (Conrath et al. 2025)) through both habitat categorization updates and updated SFI covariates applied to the ensemble SDMs to map EFH (Section 2.1.3).

Consider whether subsequent FE evaluations should include other life stages for which EFH has been described during the next 5-year EFH review cycle.

- Response: The scope of the 2028 EFH 5-year Review workplan reflects NMFS and Council staff capacity for this review cycle. A research recommendation can include considering assessing fishing effects to the CEA of additional life history stages given the data available. The stock author FE evaluation to EFH considers potential population level effects across the life history of the species and they can request additional EFH subareas as needed to complete the evaluation (Chapter 3).

Reporting of species-specific habitat disturbance from the FE model by major gear classes.

- Response: The FE model uses a comprehensive approach to gear impacts on habitats including recovery status of habitat features from cumulative fishing events, therefore,

[17] B9 SSC Oct 2022 Report_Final, October 2022 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/2946

the full FE model disturbance output is not generally interpretable when limited to individual gear types. However, mid-model products from the Fishing Module (e.g., fishing footprint, swept area, or bottom contact area) can be summarized by major gear types to support discussions of gear-specific interactions, similar to what was done for the Mid-Atlantic Fishery Management Council 2025 EFH 5-year Review (Bachman et al. 2025). Additional summaries by major gear types, Council-defined areas, fleets, and/or time periods may be produced where feasible and upon request, consistent with ongoing FE model reporting-tool enhancements. For the 2028 EFH Review, standard FE model outputs will be produced comprehensively using all gear types combined, by management region (BS, AI, and GOA), and at the established 5 km × 5 km monthly resolution.

2.4.2 Advisory Panel and Council Recommendations

Pelagic trawl gear innovation development (e.g., the Fast Lab GII) was discussed during the June 2025 Council meeting and a connection was recognized between changes to trawl gear performance and the bottom contact adjustments used in the FE model. Updating the FE model was included as part of the final Council motion: "*Update to Fishing Effects Model. The Council requests the Fishing Effects model be updated with the refined and current information to improve bottom contact estimates. The Council affirms the Fishing Effects model is the peer-reviewed, best available tool to assess the effects of fishing on essential fish habitats in Alaska.*"[18]

- Response: We will review and update the gear parameter table (including bottom contact adjustments) as part of the FE model updates for the 2028 EFH 5-year Review. For fleets participating in the GII (currently all BSAI and GOA pollock fleets and the Amendment 80 fleet), empirically derived GII results will be incorporated as they become available within the EFH review timeline (see Appendix B in the 2028 EFH 5-year Review Plan).[19] For fleets not participating in the GII, gear parameters will be reviewed and updated following the established methods used in the 2017 and 2023 EFH Reviews.

During AP deliberations on the 2028 EFH 5-year Review Plan at the December 2025 Council meeting, there was a request for transparency with any model changes specific to gear parameters.[20]

- Response: We will include a description of which gear parameters are updated from the last model used in the 2022 FE evaluation, as well as the sources or data used to inform the updates for this review cycle. Where available, we will also summarize the review context for each source (e.g., external peer review of the GII workflow, gear expert consultations, peer-reviewed publications). The gear parameter updates incorporated into

[18] C3b Council motion, June 2025 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3087
[19] D3 2028 EFH 5-year Review Plan Discussion Paper Dec 2025, February 2026 SSC meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/3117
[20] AP meeting December 4, 2025 recording: https://www.youtube.com/watch?v=97qXc5DsPyg

the next proposed run of the FE model will be presented for review by the Council bodies and public throughout the 2028 EFH 5-year Review process.

3 Overview of Stock Assessment Author Evaluation Process

For reference, we are providing an overview of the FE evaluation process that follows the FE model run and application to species EFH (Figure 1). This evaluation informs discussions on impacts from fishing activities to individual species and/or, in the 2022 FE evaluation, species complexes. For the 2028 EFH 5-year Review, the stock assessment author (hereafter 'stock author') evaluation for adverse effects to EFH will focus on the subset of BSAI and GOA groundfish species and all BSAI crab species. The methods for the stock author evaluations for this iteration will be available for SSC review at the February/March 2027 Council meeting (tentatively).

3.1 Development of and Implementation of Adverse FE Evaluation Methods

Once the FE model is run for the full BSAI and GOA domain, the timeseries of FE model results corresponding to the CEA of each groundfish and crab species with an updated SDM is provided to the appropriate stock author for review. This launches the next stage of the FE evaluation process (Figure 1 step 4). The methods for the evaluation process were developed for the 2017 EFH 5-year Review and summarized in Section 3.1.1, and the instructions provided to stock authors for the 2022 FE evaluations are summarized in Section 3.1.2.

3.1.1 2016 SSC Subcommittee

In 2016, an SSC subcommittee developed a process for stock authors to review the FE model results and conduct an evaluation for adverse FE to EFH to meet the requirements of EFH Component 2. The SSC subcommittee's approach was approved by the SSC in December 2016 (NPFMC 2016). This process was used again for the 2022 EFH 5-year Review, with adjustments based on the February 2022 SSC review and some improvements as discussed below.[21]

3.1.1.1 Core EFH Area

The 2005 EFH EIS defines EFH as the area inhabited by 95% of a species' population (NMFS 2005). EFH is characterized for each species' life stage as the spatial domain containing the upper 95% of occupied habitat (NMFS 2005). Subarea percentiles are the upper 75% ("principal EFH area"), upper 50% ("core EFH area" or "CEA"), and upper 25% ("EFH hot spots") (Pirtle et al. 2025b).

To investigate the potential relationships between fishing effects and stock health, the stock authors examine trends in life history parameters and the amount of disturbed habitat in the CEA for each species (see Section 3.1.1.3 Correlative Analyses below). The FE subcommittee performed an investigative review of model outputs overlaid with 25%, 50%, and 95% quantiles.

[21] B9 SSC Oct 2022 Report_Final, October 2022 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/2946

The proportions of disturbed habitat in each quantile were similar, so the SSC recommended using the 50% quantile CEA for applying FE model results. This quantile was chosen to avoid the likelihood that important areas are excluded (if using the smaller EFH hot spots area) and to avoid statistically minimizing the amount of habitat reduction by using the larger, full EFH area (see page 16 in NPFMC 2016).

3.1.1.2 Impetus For Assessments

NMFS and the Council apply two threshold-based tools in the FE evaluation in order to ensure that a more in-depth FE evaluation is applied in cases when a) a species includes a stock below MSST, and b) FE analysis results indicate a species' CEA has greater than 10% habitat disturbance (NPFMC 2016). We describe these two threshold-based tools below. Meeting either of these thresholds does not preclude a stock author from completing a more in-depth evaluation. Each stock author has an opportunity to conduct a quantitative or qualitative assessment during the FE evaluation regardless of a species' stock status or scale of estimated habitat disturbance.

Minimum Stock Size Threshold

EFH is defined for species' populations managed by the Council, so the first consideration of the FE analysis is at the population level. Stock authors indicate whether the population in question is above or below Minimum Stock Size Threshold (MSST) or note if MSST is not defined. Stock authors are asked to conduct a quantitative or qualitative FE assessment for any species with a stock that is below MSST to determine if there is a possible influence of habitat degradation on the population productivity. Mitigation measures may be recommended for any species' stock that is below MSST if the stock author determines that there is a plausible connection to disturbance of EFH as the cause.

Estimated Habitat Disturbance ≥ 10%

Stock authors have the opportunity to conduct additional analyses, as described below, for any species for which the estimated proportion of habitat disturbed by fishing in the CEA is ≥ 10%. In 2016, the BSAI and GOA groundfish and BSAI crab Plan Teams, SSC, and Ecosystem Committee recommended that the SSC subcommittee investigate alternate estimates of habitat disturbance as thresholds for additional analyses. The SSC subcommittee noted that at 10% habitat disturbance, 90% of the CEA remains undisturbed, which suggests that the impacts are minimal, and lower thresholds were not considered further. The SSC subcommittee noted two important points on the 10% threshold: (1) estimated habitat disturbance at levels higher than 10% of the CEA does not necessarily indicate that impacts of fishing are more than minimal, but it triggers a closer look by stock authors, and (2) the 10% threshold does not preclude stock authors from completing an FE evaluation for levels of habitat disturbance less than 10%, if other data suggest that impacts may be affecting the population. Therefore, the subcommittee recommended the 10% habitat disturbance threshold to trigger additional analyses by the stock authors during the FE evaluations.

3.1.1.3 Correlative Analyses

Stock authors are provided with time series data of the estimates of habitat disturbance in monthly time steps. To guide a quantitative assessment, stock authors have the opportunity to examine other information, such as the indices of growth-to-maturity, spawning success, breeding success, and feeding success (e.g., time trends in size-at-age, recruitment, spawning distributions, and feeding distributions) to determine whether correlations between those parameters and the trends in the proportion of the CEA disturbed exist. If a correlation exists (negative or positive), the stock authors can determine whether the correlation was significant at a p-value of 0.1. Because multiple parameters may be examined for correlation to habitat disturbance, it is somewhat likely that spurious significant ($p < 0.1$) correlations will be found. If stock authors determine that the correlation between the impacts to the CEA and life history parameter(s) suggest a plausible population effect, using their subject matter expertise, they can raise that potential impact to the attention of the Plan Teams, SSC, and Council for additional analysis. After that review, if the impact is determined to be more than minimal and not temporary, the Plan Teams and SSC can recommend consideration of mitigation measures to the Council.

3.1.2 2022 Instructions to Stock Assessment Authors

The instructions to stock authors during the launch of the FE evaluation process followed the methods developed by the SSC subcommittee in 2016. Full instructions are provided in the 2022 FE evaluation report, including a description of the questionnaire given to stock authors and the decision tree for advancing through the assessment process (Appendix 4, Figure A4.1 in Zaleski et al. 2024).

Once the FE model runs were completed in April 2022, we requested stock authors assess the impacts of commercial fishing on EFH in Alaska. To investigate the potential relationships between FE and population productivity, the stock authors had the opportunity to examine trends in life history parameters and the amount of disturbed habitat in the CEA for each species they assess, as appropriate. Stock authors were given the choice to perform a quantitative assessment, as described above in Section 3.1.1.3, or a qualitative assessment if there were concerns of data limitations for their stock. They were guided to take a “closer look” if their species were below MSST or if the estimated habitat disturbance was ≥ 10% of the species CEA, however they were instructed that meeting those thresholds was not a requirement in order to move forward with either a quantitative or qualitative assessment.

To better understand the data limitations on the spatial representation of EFH, the SSC requested more detailed information on stock author concerns. We provided the opportunity for stock authors to express concerns with the data limitations in the SDM and FE model inputs, as well as limits in population dynamics information for performing correlation analyses with the time series of disturbance estimates for species CEAs. NMFS provided stock authors the option to request an overlay of the FE model results with the upper 75% of occupied habitat instead of the CEA for their evaluation. Only one author requested the additional analytical results but was satisfied with the original 50% CEA (see Appendix 5, Section 5.3.3 in Zaleski et al. 2024). There was also the option to perform a qualitative analysis instead of a quantitative analysis in order to complete their evaluation with concerns of data limitations.

The SSC subcommittee recommended that the stock author should consider the question of whether to elevate a species for possible mitigation. Stock authors were instructed to elevate species based on their interpretation of the results from correlative analyses, and if the author was concerned about available information, to base that determination on other sources of information. Stock authors, therefore, could elevate a species to the attention of the Plan Teams and SSC if a correlation has a p-value not otherwise considered significant (e.g., between 0.1 and 0.25) using their subject matter expertise to explain why the result may still be considered an adverse impact (a possible outcome of Figure 1 step 5).

To conclude the FE analysis review, stock authors were asked to recommend EFH research activities or priorities for the identification or evaluation of impacts to EFH. As part of the 2023 EFH 5-year Review, stock authors were also given the opportunity to raise habitat concerns that would be appropriate for the Habitat Areas of Particular Concern (HAPC) process for Council consideration.[22]

The SSC found that the EFH evaluation methodology summarized here was appropriate for the 2023 EFH 5-year Review.[23] We will seek guidance and input on the methods for the stock author evaluations for the 2028 EFH 5-year Review at the February/March 2027 Council meeting (tentatively).

4 Council Action

The proposed plan for the 2028 EFH 5-year Review is based on direction received from the Council and Council bodies during the 2023 EFH Review and was presented to the AP and Council in December 2025. Here, we present the FE model methods and the proposed data updates for SSC consideration. Staff are seeking guidance from the SSC on the advancement of information for Component 2: Fishing activities that may adversely affect EFH:

- Newly available data resources for FE model inputs;
- Bridging analyses for changes in model outputs due to CIA database updates, gear parameter table updates, and any other updates proposed; and
- Recommendations for other analyses that could inform the FE evaluation.

SSC comments from the February 2026 meeting will be taken into consideration and included in the next discussion paper and presentation (tentatively February/March 2027 Council meeting).

[22] NPFMC HAPC Process: https://www.npfmc.org/wp-content/uploads/hapc_process092010.pdf
[23] B9 SSC Oct 2022 Report_Final, October 2022 Council meeting eAgenda: https://meetings.npfmc.org/Meeting/Details/2946

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Appendix 1. Fishing Effects Model Description

The Fisheries, Aquatic Science & Technology Laboratory's (FAST Lab) Fishing Effects (FE) model is run on a combination of Python and R code. The FAST Lab's model code is available upon request.

The FE model incorporates two mutually exclusive habitat states: undisturbed habitat, H, and disturbed habitat, h (see Table A 1.1 for a list of all model parameters). Casting H and h as proportions of a spatial domain, then:

$$H + h = 1 \qquad (1),$$

where H∈[0,1] and h∈[0,1]. The FE model considers transitions between H and h in discrete time steps, t. Let $\tilde{I}_t$ represent the proportion of H that transitions to h by fishing impacts from one time step to the next, and $\tilde{\rho}_t$ as the proportion of h that recovers to H over the same time step, leading to the discrete-time habitat state equation:

$$H_{t+1} = H_t(1 - \tilde{I}_t) + h_t\tilde{\rho}_t \qquad (2),$$

where $\tilde{I}_t \in [0,1)$ and $\tilde{\rho}_t \in [0,1)$. Thus far, Eqs. 1-2 imply a single generic model spatial domain. In practice, the fishing impacts model is implemented on a spatially explicit grid, with H indexed by both time, t, and cell, i.

A given model grid cell can contain multiple types of habitat, indexed by s. As outlined below, the FE model accounts for impacts and recovery at the level of specific habitat types. Subsequently, for the purposes of calculating the aggregate proportion of disturbed habitat within a given cell at a point in time, $H_{i,t}$ is calculated as a weighted mean over k habitat types based on the proportion of each habitat type in the cell, $\phi_{i,s}$,

$$H_{i,t} = \sum_{s=1}^{k} H_{i,s}\phi_{i,s} \qquad (3),$$

where $\phi_{i,s} \in [0,1]\ \forall\ s = 1, \dots, k$ and $\sum_{s=1}^{k} \phi_{i,s} = 1$. Although habitat types may be treated as spatially explicit regions within a grid cell, in practice such fine resolution habitat information is usually not available. Thus, it is assumed that each habitat type is distributed uniformly throughout a grid cell, and habitat proportions, $\phi_{i,s}$, are not indexed on t in the model formulation. An implication of this is that the *relative* proportions of habitat types within cells remains fixed across time, regardless of where and to what extent fishing events occur within cells.

Impacts

The impacts process translates fishing activity into disturbed habitat outcomes, i.e. governing the transition of H to h. Impacts, $I_{i,t,s,j(g)}$, represent a proportionate area of a habitat type in a grid cell that could convert from undisturbed to disturbed in a time step from a single fishing event j (e.g. a single tow, deployment of a longline, etc.). For what follows, the notation "(g)" is used to emphasize dependencies on gear configuration for a given model quantity where appropriate (i.e. $j(g)$ and $s(g)$). $I_{i,t,s,j(g)}$, are decomposed as the product of $f_{i,t,s,j(g)}$, the proportionate area of a habitat in a cell contacted during a fishing event with gear, g, and susceptibility, $q_{s(g)}$, the proportion of a habitat impacted by contact with the gear, where susceptibility is unique to each habitat-gear combination:

$$I_{i,t,s,j(g)} = f_{i,t,s,j(g)} q_{s(g)} \qquad (4),$$

where $f_{i,t,s,j(g)} \in [0, \infty)$ and $q_{s(g)} \in [0,1] \; \forall \; s = 1, \dots, k$.

Generally, $f_{i,t,s,j(g)}$, represents the amount of contact with the seafloor by fishing gear and will often be less than the nominal area swept by a gear because only certain gear elements are actually in contact with the seafloor. Furthermore, explicit inclusion of a contact adjustment parameter provides functionality to model gear modifications that lift gear elements off the seafloor. To accommodate this feature, $f_{i,t,s,j(g)}$ is decomposed as the product of nominal area swept, $A_{i,t,s,j(g)}$, and gear specific contact adjustment, $c_{j(g)}$:

$$f_{i,t,s,j(g)} = A_{i,t,s,j(g)} c_{j(g)} \qquad (5),$$

Where $A_{i,t,s,j(g)} \in [0, \infty)$ and $c_{j(g)} \in [0,1] \forall g = 1, \dots, r$ for r gear types. In practice, since the distribution of habitats within a grid cell is not spatially explicit, $A_{i,t,s,j(g)}$ is distributed proportionally among all habitat types within a grid cell. Because $A_{i,t,s,j(g)}$ is measured as a proportion itself, $A_{i,t,s,j(g)}$ will simply equal the proportional swept area of the grid cell for all habitat types (i.e. $A_{i,t,s,j(g)} = A_{i,t,j(g)}$).

Note that $A_{i,t,s,j(g)}$, and the related quantities $f_{i,t,s,j(g)}$and $I_{i,t,s,j(g)}$, are unbounded in the positive direction, indicating proportions that exceed unity. This arises if a fishing event within a cell has a nominal swept area that exceeds the area of the cell. The only way this could occur at the level of a single fishing event is if the tow overlapped with itself. Furthermore, in most fishing applications, a given grid cell will experience multiple fishing events, possibly from multiple fisheries and possibly with overlapping swept area. Thus, the Fishing Effects model need account for aggregate impacts in a cell, and accommodating potentially overlapping fishing effort. To get an aggregate value of $I_{i,t,s,j(g)}$ in a cell, $I_{i,t,s,\bullet}$, we sum impacts across m fishing events that occur in a time step in a cell for a respective habitat type:

$$I_{i,t,s,\bullet} = \sum_{j=1}^{m} I_{i,t,s,j} \quad (6).$$

Because $I_{i,t,s,\bullet}$, is a sum of potentially multiple events which can overlap, it often exceeds unity in practice. We account for this aggregate impact by calculating $\tilde{I}$ from Eq. 2 as a strict proportion of impacted area as:

$$\tilde{I}_{i,t,s} = 1 - e^{-I_{i,t,s,\bullet}} \quad (7),$$

producing the constraint of $\tilde{I}_{i,t,s} \in [0,1)$. While not obvious, the relationship in Eq. 7 which accounts for potentially overlapping effort implies that fishing events are randomly distributed within a grid cell (see Smeltz et al. 2019 Supplemental Materials for derivation and test of this assumption). If fishing activity is more aggregated in space than random (within a grid cell), Eq. 7 would produce an overestimation of $\tilde{I}_{i,t,s}$ uniformly distributed fishing activity would result in an underestimation. Note, the scale of the grid cell will affect how well this assumption is met. At a seascape scale, fishing activity is clearly aggregated, but at smaller scales (e.g., an area smaller than the swept area of a single tow) fishing becomes uniformly distributed. It is also important to note that because the amount of disturbed habitat cannot exceed 100%, repeated impacts do not continue to produce an increased intensity of disturbed habitat. For example, if $\tilde{I}_{i,t,s}$ is large, but the proportion of disturbed habitat in a grid cell is already high from past impacts, there will be little additional disturbance caused by a high $\tilde{I}_{i,t,s}$.

Recovery

In the FE model, recovery $\tilde{\rho}_{i,t,s}$, is the proportion of disturbed habitat, $h_{i,t,s}$, that transitions to undisturbed habitat, $H_{i,t,s}$, from one time step to the next. Because $\tilde{\rho}_{i,t,s}$ is indexed by t, it can be time-varying and incorporate seasonality or other dynamic features. In the simpler case where $\tilde{\rho}_{i,t,s}$ is held constant through time, reflecting a fixed proportional recovery each time step, recovery occurs most rapidly when $H = 0$ and slows asymptotically as $H \to 1$. In practice, most benthic habitat empirical studies estimate the time required for disturbed habitat to recover to pre-disturbance conditions (e.g., Grabowski et al., 2014). To accommodate this form of recovery information, we cast $\tilde{\rho}_{i,t,s}$ as a discretized rate based upon a mean time to recovery parameter, τ_s:

$$\tilde{\rho}_{i,t,s} = 1 - e^{-1/\tau_s} \quad (8),$$

where τ_s is strictly positive. This model is consistent with an exponential time-to-event recovery process parameterized with a mean time to recovery, producing a concave asymptotic recovery curve.

Model implementation

Requirements to implement the FE model include: 1) a defined spatial domain with an appropriate-sized grid overlay; 2) the spatial distribution of habitats within the model domain; 3) fishing event locations, most likely derived from electronic monitoring such as vessel monitoring system (VMS) data; 4) nominal gear width and gear contact adjustments for each fishing event; and 5) habitat susceptibility and recovery parameters.

Spatial domain and habitat distribution

The FE model implemented for EFH 5-year Reviews is run for the North Pacific within the United States Exclusive Economic Zone, and depths less than 1,000 m to define the continental shelf, resulting in a total domain area of 1.2 million km^2. A 5 km x 5 km grid overlay was used for the analysis reflecting availability of fishing and habitat information within the North Pacific fishery management system. High resolution information on the spatial distribution of benthic habitat features was not domain-wide, however, observations from sediment surveys in the North Pacific were more widely available. Thus, we used sediment-based habitat categories (mud, sand, granule/pebble, cobble, and boulder) and developed a GIS workflow to map the sediment observations across the domain. Sediment observations (232,517 total points) were combined in a GIS and parsed using a text mining algorithm (Feinerer and Hornik, 2017)[24] to map over 8,861 different sediment labels onto the five primary sediment categories. Subsequently, indicator kriging interpolation (Geospatial Analyst, ArcGIS v10.4.1) was used to create a presence/absence surface for each sediment on a 2.5 km grid. This resulted in four sediment grid cells nested within each 5 km model grid. To calculate the sediment proportions for a respective 5 km model grid, $\phi_{i,s}$, we found the ratio of the sum of the four sediment cells, w, with a specific sediment present, $\pi_{i,s,w} \in \{0,1\}$, to the sum of sediment cells present for all five sediments,

$$\phi_{i,s} = \frac{\sum_{w=1}^{4} \pi_{i,s,w}}{\sum_{s=1}^{5} \sum_{w=1}^{4} \pi_{i,s,w}} \qquad (9).$$

Initial conditions

Options for initial habitat conditions for a model run, H_0, include starting from "pristine" undisturbed habitat, a case-specific set of initial conditions that match a known habitat state, or equilibrium initial conditions based upon a "burn in" period under constant fishing effort. With insufficient data available to determine the spatial distribution of impacts prior to 2003, but operating on the assumption that impacts were present, we used a "burn in" approach for the North Pacific. To calculate H_0, we first randomly selected a value for an initial H_0 from a uniform distribution (zero to unity) for all grid cells that had nonzero fishing effort from 2003 – 2020. We then ran the model using the first three years of fishing data (2003 – 2005) repeated ten times, resulting in a total burn-in of 30 years which provided ample time for the model to

[24] Feinerer, I., and Hornik, K. 2017. tm: text mining package. https://cran.r-project.org/web/packages/tm/index.html

lose dependence on the initial H_0 and reach a stable habitat state. Only the first three years were used for the burn-in as it was expected that these early years of data likely reflected the distribution of fishing prior to 2003 better than more recent data. The terminal month of the burn-in period was then used as H_0 for the actual model run.

Table A 1.1. Fishing effects model parameters and indices.

Model Parameters	**Description**
H	Undisturbed habitat
h	Disturbed habitat
$\tilde{I}$	Proportional impacts
$\tilde{\rho}$	Proportional recovery
$I_{i,t,s,j(g)}$	Impact from a fishing event
$f_{i,t,s,j(g)}$	Ground contact by a fishing event
$q_{s(g)}$	Susceptibility
$A_{i,t,s,j(g)}$	Nominal swept area by a fishing event
$c_{j(g)}$	Contact adjustment
τ_s	Mean time to recover
$\phi_{i,s}$	Proportional habitat cover
Model Indices	
i	Grid cell, for n total cells
t	Time step
s	Habitat types, for k total habitats
j	Fishing event, for m total events
g	Gear type, for r total gears