2022 Evaluation of Fishing Effects on Essential Fish Habitat
September 2022

M. Zaleski[1], T. S. Smeltz[2], S. Rheinsmith[3], J. L. Pirtle[1], and G. A. Harrington[1]

Abstract: Evaluating the potential impacts of commercial fishing to benthic habitat is an important component of the Essential Fish Habitat (EFH) 5-year Review. The Magnuson-Stevens Fishery Conservation and Management (MSA) requires regional Fishery Management Councils to describe and identify EFH for all fishes managed under a Fishery Management Plan (FMP). Under Section 303(a)(7) of the MSA and 50 CFR 600.815(a)(2), 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".

The North Pacific Fishery Management Council and NMFS are currently evaluating updates to ten EFH components in the FMPs in the 2022 EFH 5-year Review, including revisions to the component 1 species distribution model based EFH maps for species of groundfish and crabs in the eastern Bering Sea (EBS), Aleutian Islands (AI), and Gulf of Alaska (GOA), and an updated evaluation of the fishing effects (FE) on EFH for component 2. **This discussion paper focuses on the evaluation of fishing effects on EFH**. We used the methods and process for evaluating FE developed for the 2017 EFH 5-year Review for the 2022 Review, with the addition of questions for stock authors (SA) from the SSC February, 2022 meeting.

This discussion paper reports the methods and results of the FE model and the assessment of fishing effects on EFH for species of groundfish and crabs, including 27 AI species, 34 EBS species, and 42 GOA species. Fishing effects on EFH were determined using the FE model and the core EFH area (CEA) based on the new EFH component 1 SDM ensemble EFH maps. Those results were assessed by stock authors and stock experts, and if ≥ 10% of the CEA was disturbed by fishing gear, an additional analysis was run to determine if the fishing effects to EFH were more than minimal and not temporary. **No SA recommended their species for elevation for possible mitigation to reduce fishing effects to EFH.** Stock authors and experts also provided future research recommendations in their FE assessments, which are reported here.

[1] Habitat Conservation Division, NMFS Alaska Region, Juneau, AK
[2] Fisheries, Aquatic Science, and Technology Lab, Alaska Pacific University, Anchorage, AK
[3] North Pacific Fishery Management Council, Anchorage, AK

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 10 EFH components as warranted based on available information (50 CFR 600.815(a)(10)). The EFH 5-year Review is a mechanism to ensure NOAA Fisheries and Fishery Management Councils incorporate the most recent and best science available into fishery management for EFH. The review is to evaluate newly: 1) published scientific literature, 2) unpublished scientific reports, 3) information solicited from interested parties, and 4) previously unavailable or inaccessible data. The current 2022 EFH 5-year Review encapsulates the recent habitat related literature and research developed in the North Pacific. **This Discussion Paper present the new information that NMFS is developing under EFH component 2 (1 of 10), the fishing effects (FE) analysis, for the 2022 EFH 5-Year Review.** The methods and process for evaluating fishing effects were developed for the 2017 EFH 5-Year Review with the guidance from a Scientific and Statistical Committee (SSC) subcommittee. The methods and process for evaluating fishing effects were developed for the 2017 EFH 5-year Review with the guidance from an SSC subcommittee. We used the methods and process developed for the 2017 EFH 5-year review for this review cycle, with the addition of questions for stock authors (SA) from the SSC February 2022 meeting. Additionally, this discussion paper provides the details of the iterative review process that this body of work has undergone to date in the 2022 5-year Review.

In February 2022, the SSC reviewed the updated Fishing Effects (FE) model available for the 2022 EFH 5-year Review[4]. SSC supported the updated version of the model and the 2016 SSC subcommittee's process for the analysis to evaluate fishing impacts, after addressing SSC recommendations as practicable. This document provides the results of the FE model and the SA's FE assessment to describe the duration and degree of fishing effects on habitat features based on the intensity of fishing, the distribution of fishing with different gears across habitats, and the sensitivity and recovery rates of habitat features for North Pacific groundfishes and crabs. In the 2022 FE assessment, the percentage of habitat disturbed by fishing was assessed for a species' core EFH area (CEA), which is the upper 50% of the total EFH area from an SDM ensemble EFH map developed for the 2022 EFH 5-year Review.

The FE model resulted in robust information on fishing impacts, susceptibility, and recovery time for 27 Aleutian Island species, 34 Eastern Bering Sea species, and 42 Gulf of Alaska species. All the species assessed using the 2022 FE model were EFH Level 2, whereby there exists data on habitat-related densities or relative abundances for all species involved in the FE analysis. Of the 103 species, 16 exhibited ≥10% CEA disturbed (Table 7). In the 2017 EFH Review, no species were found to exceed this threshold. Given substantive changes to the SDMs as well as corrections to the FE model since the 2017 EFH Review, we sought to identify what changes led to these species exceeding the 10% threshold this review. A comparison of estimates of habitat disturbance in the 2017 EFH 5-year Review and in 2022 EFH 5-year Review can be found in Chapter 4.3.

[4] Discussion Paper on the Assessment of the Effect of Fishing on Essential Fish Habitat in Alaska for the 2022 5-year Review January, 2022 https://meetings.npfmc.org/CommentReview/EFHFishingEffectsDiscussionPaper.pdf

In April 2022, the results of the FE model and analysis of the percent CEA disturbed were delivered to SAs for each species in the Fishery Management Plan for Groundfish of the Gulf of Alaska (GOA FMP, NPFMC 2020b), Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area (BSAI FMP, NPFMC 2020a), and the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs (Crab FMP, NPFMC 2021), where a 2022 SDM ensemble EFH map was available.

The SAs were asked to conduct an FE assessment to evaluate whether the current impacts of fishing on EFH presented the potential for impacts that were more than minimal or not temporary. **None of the SAs concluded that fishing effects on their species were more than minimal and not temporary, and therefore no SAs recommended to elevate their species to the Plan Teams and the SSC for possible mitigation to reduce fishing effects to EFH. None of the authors recommended any change in management with regards to fishing within EFH at this time.** However, some SAs reported data limitation concerns with respect to conducting the FE assessment for their species.

At this meeting, we are seeking feedback from the Plan Teams and SSC. The big picture questions for the Plans Teams and SSC in context of the 2022 EFH 5 year review are**—**

(1) Does the 2022 FE evaluation incorporate newly available information to provide an appropriate evaluation of the potential adverse effects of fishing on EFH designated under the FMPs and meet the requirements in the EFH regulations at 50 CFR 600.815(a)(2) for the 2022 EFH 5 year review? See section 1.1 for the EFH regulations.

(2) Does the 2022 FE evaluation support the continued conclusion that adverse effects of fishing activity on EFH are minimal and temporary in nature?

(3) For the 9 species for which the stock author identified that data limitations prevent making the conclusion that adverse effects of fishing activity on EFH are minimal and temporary, does the Plan Team or SSC have guidance on evaluating FE beyond what is provided in this document? Note that of these 9 species, 1 species (Tanner crab) is above the ≥10% threshold for habitat disturbance.

Detailed below are areas in which improvements have been made to the FE review process since the February 2022 review and responses to the SSC comments from February 2022.

Responses to SSC Recommendations and Comments Specific to the FE Model

- Consideration of stock author comments on the reliability of SDM-derived EFH designations should be used to determine whether the current EFH definition of Core Habitat Area is sufficient for use within the FE model. In cases where SDM-derived EFH definitions are deemed inadequate, the question of whether to elevate a species for possible mitigation should be based on other sources of information.
    - *Considerations based on stock author comments on the reliability of SDM-derived EFH designations based on the criteria outlined above (survey reliability, seasonal representativeness, spatial representativeness) were used to determine whether the current EFH definition of Core Habitat Area is sufficient for use within the FE model. SA response surrounding the use of SDM-derived EFH*

maps can be found in Chapter 4, Appendix 5 for a more detailed response, and addressing specific SDM EFH map concerns in the companion EFH Component 1 SDM EFH Discussion Paper[5]*. SAs chose a qualitative FE assessment using other sources of information for some of the data limited species. No SAs recommended elevating a species to the plan teams for mitigation based on their current Core Habitat Area (Chapter 4). However, there were 9 species in which SA stated there was insufficient information to make a decision to elevate to plan teams for mitigation.*

- *AI Golden King Crab (GKC)*
- *EBS Red king crab (RKC)*
- *EBS Tanner crab*
- *EBS Snow crab*
- *GOA Greenstriped rockfish*
- *GOA Pygmy rockfish*
- *GOA Redbanded rockfish*
- *GOA Silvergray rockfish*
- *GOA Spiny dogfish*

For more information regarding stock author response, see chapter 4, or Appendix 5 for detailed response.

- The SSC recommends that the inclusion of unobserved fishing events, or the development of a multiplier for observed fishing events to expand the cumulative impact to account for unobserved fishing events including non-VMS fleets, is a top priority for future model development. The authors should provide a qualitative discussion about how gaps in observer coverage may influence FE outputs.
  - *Unobserved and observed fishing events data were included, per SSC recommendation. A brief explanation of the origin of unobserved fishing events data can be found in Chapter 2.1.1. Additionally, a comparison of unobserved and observed fishing events data is compiled in Table 1 by gear type and region, coupled with a qualitative discussion detailing the effects of inclusion of unobserved fishing events data and gaps in observer coverage (Chapter 2.1.1).*
- Groundfish species in Tier 4 and below there is no available definition for MSST and suggests that for these species analysis of disturbance to core habitat areas with the FE model should not depend on biomass relative to reference points.
  - *Concerns for groundfish species in Tier 4 and below were addressed by allowing stock authors the opportunity to select and perform a qualitative assessment of the effects of fishing on their species where a quantitative assessment would not have been possible or preferred (Chapter 4 and Appendix 5).*
- The SSC recommends adding a map and/or table showing the extent of unobserved groundfish and halibut fishing relative to observed fishing for recent years and, to the

[5] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

extent possible, the authors should provide a qualitative discussion about how gaps in coverage may influence FE outputs.

  - *To satisfy the SSC recommendation of adding a map and/or table to visualize differences between observed and unobserved coverage, authors compiled Figure 5 and Table 1 in Chapter 2.1.1 detailing the extent of unobserved and observed fishing data by gear type and region from 2016-2020. Additionally, a brief description of the effects of including unobserved fishing events data into the FE model is found in Chapter 2.1.1.*

- The SSC further recommends, prior to finalizing the 2022 FE model, that the authors work with Alaska Regional Office in-season management personnel to determine if fishery definitions are complete (e.g., Appendix 2).
  - *Authors included an expanded description of origin of nominal width, bottom contact adjustment, and detailed information surrounding the origin of gear table updates (Appendix 2) for the 2022 model based on industry knowledge and peer reviewed literature. Additionally, Alaska Regional Office in-season managers reviewed the fishery definitions in the Gear Parameter Table and their edits were incorporated (see Appendix 2).*
- The SSC feels it is important to include data specific to the North Pacific to the extent practicable, given potential differences in the growth and recovery of habitat features at northern latitudes, and encourages the authors to incorporate results from the 2020-2024 Alaska Deep-Sea Coral and Sponge Initiative, when available, as well as any additional information on the distribution of habitat features across sediment types from NMFS survey products.
  - *When applicable, analysts included data specific to the North Pacific.*
  - *Due to the current timeline for the 2024 Deep-Sea Coral and Sponge initiative and the current 2022 EFH review, analysts were not able to incorporate any new habitat feature data from the NMFS surveys that occurred in summer 2022.*
- The SSC requests expanded descriptions of, and justifications for, the assumed recovery times detailed in the document. In addition, the SSC recommends that the authors be explicit in indicating whether recovery times for a feature and substrate type are unknown versus not present (e.g., filling in blank cells in Appendix 3 of the document)
  - *Appendix 3 depicts explicit visualization of the presence/absence of recovery times for features and substrate types.*
- SSC requests expanded descriptions of, and justifications for, the assumed recovery times detailed in the document.
  - *Additional information surrounding the origin of recovery times has been provided in section 2.1.4.*
- Given that unobserved fishing events are not currently included in the FE model and that the proportion of observed fishing events varies across regions, the SSC recommends that impact metrics not be aggregated to the North Pacific scale.

- *Given that authors incorporated unobserved fishing in the FE model, we continued to aggregate impact metrics to the North Pacific scale, but also added regional (AI, EBS< and GOA) estimates where applicable.*

TABLE OF CONTENTS

TABLES

FIGURES

1 INTRODUCTION

The Magnuson-Stevens Fishery Conservation and Management (MSA) requires regional Fishery Management Councils to describe and identify Essential Fish Habitat (EFH) for all fishes managed under a Fishery Management Plan (FMP). Under Section 303(a)(7) of the MSA and 50 CFR 600.815(a)(2), 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". The North Pacific Fishery Management Council (Council) and NMFS are currently evaluating updates to EFH in the FMPs, including revisions to the model-based maps of EFH for Bering Sea (BS), Aleutian Islands (AI), and Gulf of Alaska (GOA) groundfish and BSAI crab species, and updated output from the Fishing Effects (FE) model developed to assess the effects of fishing activities on EFH. This discussion paper focuses on the evaluation of fishing effects, component 2 of 10 to be presented in the full EFH 5-year Review.

This Discussion Paper presents the 2022 FE evaluation for species and species complexes in the BSAI, GOA, and Crab FMPs, including 27 Aleutian Island species, 34 eastern Bering Sea species, and 42 Gulf of Alaska species. Stock assessment authors and species experts were provided the opportunity to review the results of the FE analysis and provide an FE assessment for their stocks.

None of the stock assessment authors concluded that habitat disturbance within the CEA for their species was affecting their stocks in ways that were more than minimal or not temporary. None of the authors recommended any change in management with regards to fishing within EFH at this time. However, a number of stock authors raised issues with data limitations, affecting their ability to assess the effects of fishing on EFH for their species even with a qualitative assessment. Data limitations were regarding data sources used to map EFH for their species, life history stages, and ongoing data issues for stocks that are data limited in general affecting the EFH maps and the FE analysis. Other stock authors raised issues on the FE analysis approach, requesting future considerations for life history, timing, spatial extent, and spatial scale, in particular for crabs.

This FE evaluation contributes updated information concerning FMP species, many of which are data limited stocks, for the purposes of the 2022 EFH 5-year Review. Following SSC review and recommendations, analysts are hopeful to incorporate the 2022 EFH component 2 FE assessment into the full EFH 5-year Review, which is tentatively scheduled for Council review in February 2023.

1.1 Fishing Effects on Essential Fish Habitat Overview

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). Fishing operations may change the abundance or availability of certain habitat features (e.g., prey availability or the presence of living or non-living habitat structures) 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 required 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. Quantifying the effects of fishing on benthic habitats often requires best professional judgment due to the number of unknowns. The duration and degree of fishing effects 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 fishing effects 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.

The National Research Council (NRC 2002) stated a complete assessment of the ecosystem effects of trawling and dredging requires three types of information: gear-specific effects on different habitat types (obtained experimentally); frequency and geographic distribution of bottom tows (trawl and dredge fishing effort data); and physical and biological characteristics of seafloor habitats in the fishing grounds (seafloor mapping). A complete assessment would synthesize available data and technical studies to describe the nature, severity, and distribution of risk to habitat features relevant to the marine fish population of Alaska. While some qualitative or quantitative information was available for each of these factors, it varied in quality, spatial coverage, and applicability.

1.2 History of Evaluating Fishing Effects

In 2002, scientists at the Alaska Fishery Science Center (AFSC) developed a numeric model, the Long- term Effects Index (LEI) as a tool to structure the relationships between available sources of information on the gear, habitat recovery, and percent coverage factors. The Long-term Effects Index model, described in Fujioka (2006), estimated the proportional reductions in habitat features relative to an unfished state, assuming that fishing would continue at the current intensity and distribution until the alterations to habitat and the recovery of disturbed habitat reached equilibrium. The model provided a tool for bringing together all available information on the effects of fishing on habitats, such as fishing gear types used in Alaska fisheries (trawl, pot, hook-and-line), fishing intensity information from observer data, and gear impacts and recovery rates for different habitat types. While some information was available for all these factors during the EFH EIS analysis (NMFS 2005), it varied in quality, spatial coverage, and applicability to Alaska fisheries.

Following the 2005 EFH review, the Council designed a suite of precautionary management measures to reduce adverse effects of fishing to habitat, including expanded closures for bottom contact fishing gear in the Bering Sea, Aleutian Islands, and Gulf of Alaska. NMFS reconsidered the effects of fishing on EFH in the 2010 EFH 5-year review (NPFMC 2010). 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. The 2005 EFH EIS and 2010 EFH review both concluded that fisheries do have long-term effects on habitat, and these impacts were determined to be minimal and not detrimental to fish populations or their habitats (NMFS 2005, NPFMC 2010). While the 2010 EFH 5-year review provided incremental improvements to our understanding of habitat types as well as the sensitivity and recovery of seafloor habitat features, these new results were consistent with the sensitivity and recovery parameters and distributions of habitat types used in the prior analysis of fishing effects for the 2005 EFH EIS.

During the 2017 EFH 5-year review, NMFS contracted with the Alaska Pacific University (APU) to develop the FE model to make input parameters more intuitive and to draw on the best available data. The FE model estimates benthic habitat disturbance from commercial fishing activities, especially as it occurs within EFH. Similar to the LEI model, the FE model uses a $25km^2$ grid cells throughout the BS, AI, and GOA. It is based on the interaction between the amount and spatial extent of fishing effort, types of fishing gear, habitat susceptibility to fishing gear, the rate at which habitat recovers, and information about the spatial extent of habitat types. The FE model updated the LEI model in the following ways—

- The FE model is cast in a discrete-time framework. Rates such as impact or recovery are defined over a specific time interval, compared to the LEI model that used continuous time. Using discrete time makes fishing impacts and habitat recovery more intuitive to interpret compared to continuous time.
- The FE model implements sub-annual (monthly) tracking of fishing impacts and habitat disturbance. This allows for queries of habitat disturbance for any month from the start of the model run (January 2003). While this was possible in the LEI model, the LEI model was developed primarily to estimate long-term equilibrium habitat disturbance given a constant rate of fishing and recovery. The FE model also allows for queries of habitat disturbance for any month in the time series. This aids in assessing the implications of variable fishing effort within a season and over years.
- The FE model draws on spatially explicit vessel monitoring system (VMS) data to determine fishing locations as line segments representing the locations of individual tows or other bottom contact fishing activities. This provides a more accurate allocation of

fishing effort among grid cells. In comparison, the LEI model used haul-back locations summarized to the 25 km^2 grids to represent fishing activity. The description of fishing gears that may contact benthic habitat was also greatly improved with significant input from fishing industry representatives; the LEI model listed 4 gear types, whereas the FE model contains over 60 region/gear/target-specific categories.

- The FE model incorporates an extensive, global literature review and vulnerability assessment from Grabowski et al. (2014) to estimate habitat susceptibility and recovery dynamics. The FE model identifies 26 unique categories of habitat features and incorporates impact and recovery rates to predict habitat reduction and recovery over time.

Following the 2017 EFH review, APU reviewed and updated the FE model with additional modifications that are explained in Chapter 2 of this document and Appendix 1. This revised FE model was used for the 2022 FE assessment.

2 2022 FE MODEL DESCRIPTION

Since the 2017 EFH review, model developers published a full description of the FE model (Smeltz et al. 2019) and explored several advancements to model parameters. Model parameters involving fishing effort, habitat categorization, and susceptibility and recovery are updated regularly, and the base code of the FE model continues to be refined. A sensitivity analysis is now available as a standard FE model output, and updated gear descriptions are available for several gear types. Analysts continue to look at options regarding categories of biological and geological habitat, as well as issues with feature averaging. The FE model was developed to estimate spatiotemporal benthic habitat disturbance from commercial fishing activities. The FE model follows an impact/recovery framework, tracking 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. Recovery is the rate at which disturbed habitat converts to an undisturbed state and impacts measure the amount of habitat that converts from undisturbed to disturbed. Recovery is based on the underlying habitat and the habitat features associated with it. Impacts are based on the intensity of fishing activity, the types of gears used, and the susceptibility of the underlying habitat. A full description of the model and underlying equations is in Appendix 1.

The primary output of the FE model is an estimate of the proportion of disturbed habitat in each grid cell for each month of the model run. Static maps (Figs. 1 - 3) and point estimates given in this document show the terminal year of the model run (Dec 2020). Time series plots show a mean habitat disturbance aggregated for defined regions. Time series of habitat disturbance are shown in this document for AI, EBS, GOA, and the North Pacific at large (Figure 4). SAs were provided time series clipped to the CEA of their stock to assess stock-specific impacts.

Figure 1. Aleutian Islands cumulative percentage habitat disturbed. All gears combined.

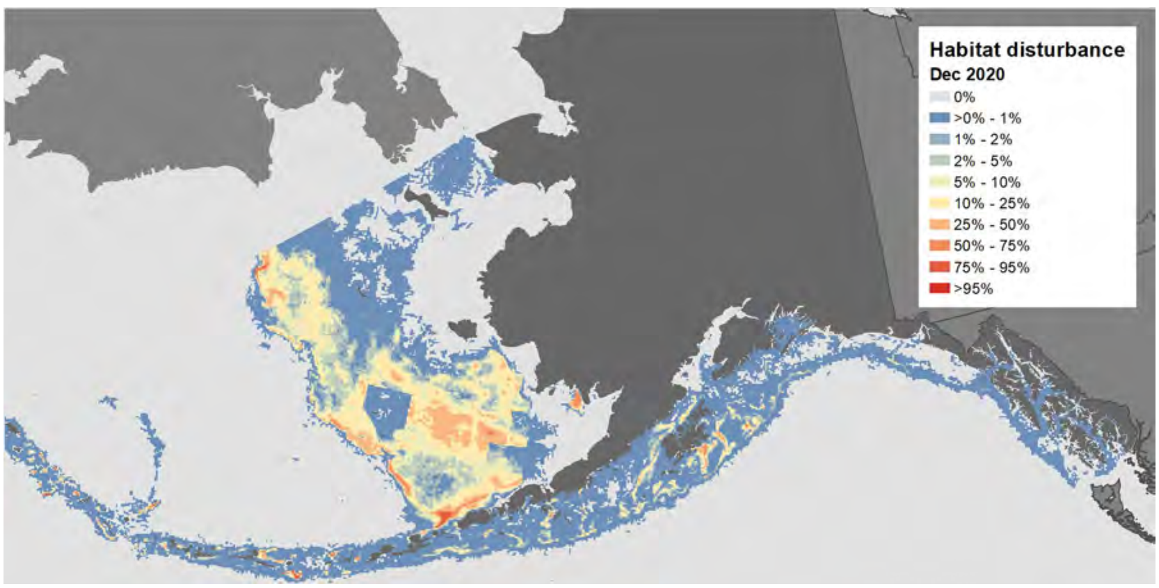


Figure 2. Eastern Bering Sea (EBS) cumulative percentage habitat disturbed. All gears combined.

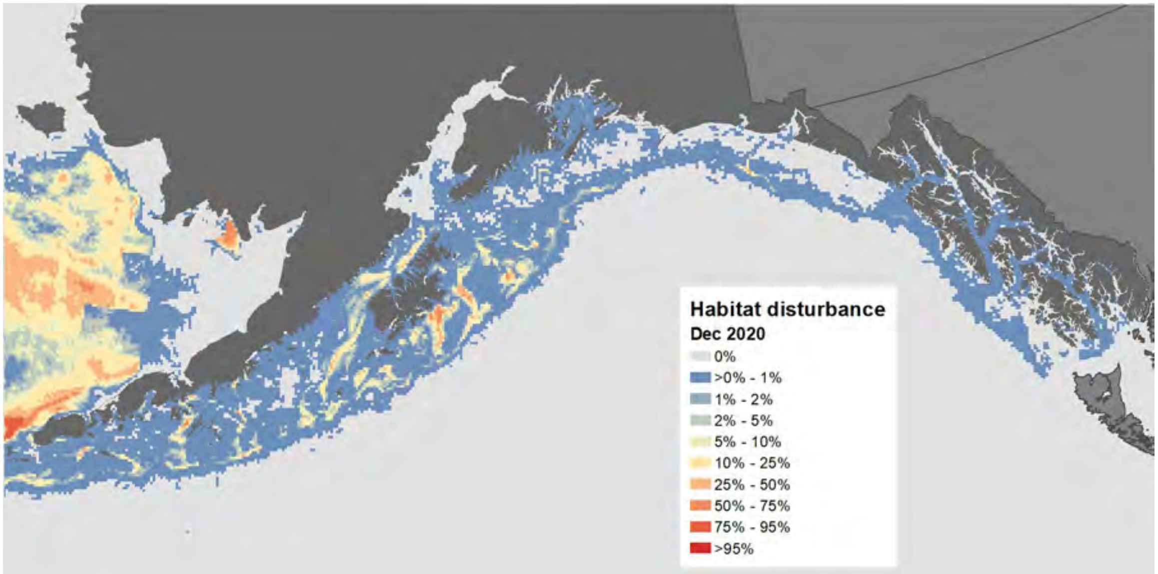


Figure 3. Gulf of Alaska (GOA) cumulative percentage habitat disturbed. All gears combined.

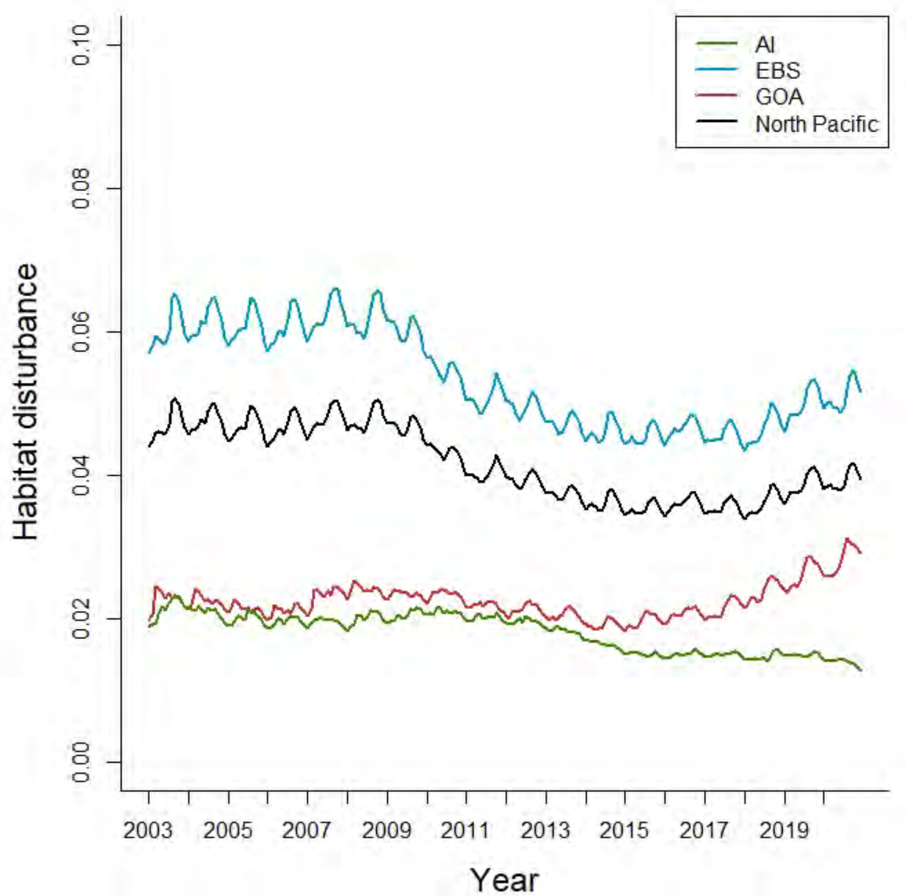


Figure 4. A time-series output of the Fishing Effects Model showing habitat disturbance aggregated for all areas less than 1000 m depth for the Aleutian Islands, Eastern Bering Sea, Gulf of Alaska, and the North Pacific at large.

2.1 FE Model Input Parameters

The inputs to the FE model include: fishing effort, habitat maps, gear parameters, and susceptibility and recovery of habitat features. Updates to the FE model were made in 2022, and are discussed in depth in Appendix 1 as well as in the document Fishing Effects on EFH[6] presented at the February 2022 Council meeting (NMFS 2022).

2.1.1 Fishing effort

Fishing effort is based on the Catch-In-Areas (CIA) database produced by the NMFS Alaska Regional Office. The CIA database is a GIS database that contains information on the spatial extent of all fishing activities in the North Pacific. It is derived from VMS data automatically collected onboard nearly all commercial fishing vessels in the North Pacific. The VMS continually records GPS locations while a ship is at sea providing a continuous path of where that vessel has traveled. 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 that did not have observers onboard, a filtering process was used on the VMS data that identifies likely fishing activity based on the vessel's speed and location and are flagged in the CIA database as "unobserved" fishing. From 2016 – 2020, observed fishing accounted for 94%, 95%, and 45% of the total contact adjusted fishing area for AI, EBS, and GOA, respectively (Table 1, Figure 5). In addition to the spatial data, the CIA database also 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 area swept (see section 2.1.3 for more detail).

During the 2017 EFH review, both observed and unobserved fishing effort data were included in the analysis. Since then, visual examination of the unobserved fishing activity in the CIA database revealed that the VMS filtering was likely overestimating fishing activity. For example, it was clear in many cases that movement between fishing grounds was identified as fishing activity. As a consequence, including unobserved data likely leads to an overestimation of fishing impacts, however excluding it results in an underestimation. Per the SSC's request, and as a conservative estimate, all analyses presented in this document use both observed and unobserved fishing data. Stock-specific analyses provided to SAs contained model runs with and without the unobserved data included in order to show the magnitude of uncertainty associated with the unobserved data.

[6] Discussion Paper on the Assessment of the Effect of Fishing on Essential Fish Habitat in Alaska for the 2022 5-year Review January, 2022 https://meetings.npfmc.org/CommentReview/EFHFishingEffectsDiscussionPaper.pdf

Table 1. Fishing area contact adjusted footprint (CAF) by region and sector.

Region	**Sector**	**CAF (km^2) Observed fishing (2016 – 2020)**	**CAF (km^2) Unobserved fishing (2016 – 2020)**	**CAF (km^2) All fishing (2016 – 2020)**	**% CAF Observed vessels**	**% CAF Unobserved vessels**
AI	HAL	156.3	608.9	765.2	20%	80%
	JIG	0	0.055	0.055	0%	100%
	NPT	32731.2	1173.7	33904.9	97%	3%
	POT	35.9	305.2	341.1	11%	89%
	PTR	13.3	2.7	16.0	83%	17%
	All gears	32936.6	2090.6	35027.2	94%	6%
EBS	HAL	2904.4	374.7	3279.1	89%	11%
	NPT	200895.1	11209.3	212104.4	95%	5%
	POT	254.0	2052.3	2306.3	11%	89%
	PTR	137986.8	2522.9	140509.6	98%	2%
	All gears	342040.2	16159.2	358199.5	95%	5%
GOA	HAL	331.0	2564.0	2895.0	11%	89%
	JIG	0.00	0.25	0.25	0%	100%
	NPT	18185.2	14601.6	32786.8	55%	45%
	POT	35.1	1990.8	2025.9	2%	98%
	PTR	2309.3	5917.5	8226.9	28%	72%
	All gears	20860.6	25074.1	45934.7	45%	55%

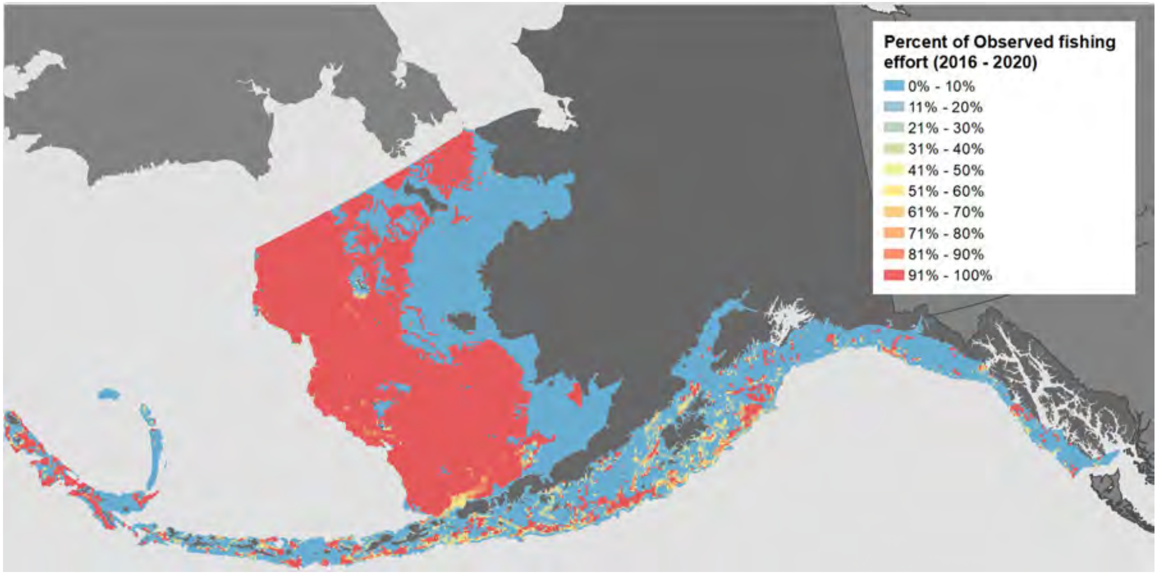


Figure 5. Map of the percentage of contact adjusted fishing effort attributed to observed fishing activity.

2.1.2 Habitat Categorization

For the 2022 EFH 5-year review, analysts identified few additional data to add to the sediment record. Other sources of sediment data are available, such as dbSEABED (http://instaar.colorado.edu/~jenkinsc/dbseabed/), but this dataset does not represent a significant new source of information over the current sediment records used by the FE model.

Sediment type continues to be used as a proxy for habitat types because spatially explicit data for biological and geological habitat types are not available. While an area like the Bering Sea may be well-sampled by the trawl survey, the Aleutian Islands and Gulf of Alaska are not nearly as well sampled (Baker et al 2019). Until validated spatial models are available for all habitat features, sediment-based categories are the best available science.

2.1.3 Gear Parameter Table

The Gear Parameter Table in Appendix 2 provides the input parameters relating to the fishing gears used in the FE model. 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 provides 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 tell the reader anything about the time/area collocation of these gear types.

The nominal gear widths for trawls in the BSAI and GOA range from 50 m to 259 m. BSAI pelagic trawls ranged from 50 m to 175 m and BSAI non-pelagic trawls ranged from 90 m to 259 m. GOA pelagic trawls ranged from 50 m to 100m and GOA non-pelagic trawls ranged from 55 m to 193 m. Certain categories of non-pelagic trawling have bottom contact adjustments of 1.0 (assumed bottom contact) but others, where trawl sweeps are raised and fishing gear is elevated by bobbins, have contact adjustments as low as 0.27 (27% of nominal area swept being contacted). Contact adjustment represents the proportion of the fished area in which the gear interacted with the seabed. In practice, the nominal widths are used to spatially buffer the VMS paths which are then intersected with a 5 km grid. The ratio of the area of each of these resulting polygons to the grid cell area (25 sq. km, unless on the edge) is the "swept area ratio" and represents the total footprint within a grid cell of a fishing event.

During the 2017 EFH review, a database of gears used in the North Pacific was developed with input from industry that provided nominal width and contact adjustment for 73 types of fishing gear. Each of these gears was attributed with information such as target stock, vessel size, fishing depth, etc. that allowed each record in the CIA database to be attributed with a gear type. For the 2022 EFH 5-year Review, a few minor changes were made to the gear database. Updates included a cited hook-and-line longline study from Australia (Welsford et al. 2014) and a sablefish longline-pot study from British Columbia, Canada (Doherty et al. 2017). The average lateral line movement in Welsford et al. was 6.2 meters, and virtually all lateral movement occurred during deployment or retrieval. The documentation behind the FE gear parameter table noted that lateral line movement can result from currents or from captured fish. Bycatch of sessile benthos (e.g., sponges, corals) are sometimes observed in the Alaska longline fishery so it is known that seafloor interactions do occur. The longline-pot study (Doherty) noted that hauling speed and direction, combined with environmental factors like depth, slope, and current affects a pot's footprint. The British Columbia pot study was assessing conical pots that are significantly smaller than most Bering Sea crab pots but similar to smaller groundfish pots (e.g., sablefish). Doherty estimated the mean bottom-contact area for a 54-inch pot at $53m^2$, or roughly 36 times its static footprint of 1.47 x 1.47 meters. The longline-pots were observed to drag for between 0.4 and 5.9 minutes when hauling. The analysts note that the effect of pot dragging would greatly depend on hauling conditions and also note that less dragging would be expected for pots that are not connected to one another by a groundline. For the 2022 EFH 5-year Review, authors collaborated with NMFS Alaska Region Sustainable Fisheries in-season management personnel to ensure all fishery definitions were complete (Appendix 2).

2.1.4 Susceptibility

Susceptibility is the proportion of habitat disturbed if contacted by fishing gear. It is based on both the underlying habitat and the gear type. 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. Note that when multiple fishing activities occur within a grid cell and time step, possible overlap of fishing activity also needs to be accounted for (see Appendix 3).

The susceptibilities used here are drawn from the Grabowski et al. (2014) global meta-analysis of benthic susceptibility and recovery. Susceptibility is parameterized for 26 habitat features (e.g., sponges, macroalgae, boulder piles) for each gear-habitat combination (Appendix 3). It is measured with a four-interval scale: 0 - 10%; 10% - 25%; 25 - 50%; and >50%. Because the underlying habitat map is resolved to sediment type, and not the distribution of individual habitat features, the mean susceptibility of all habitat features associated with a habitat (i.e. a sediment type) is calculated and used for that habitat. At each monthly time step, the susceptibility score for a habitat feature is randomly drawn from its corresponding susceptibility interval.

2.1.5 Recovery

Recovery, ρ, is the proportion of disturbed habitat that returns to an undisturbed state each time step and is the property of a habitat type. When ρ is held constant across time, it creates an asymptotic recovery trajectory that is equivalent to an exponential time-to-failure distribution, where a "failure" is the recovery of habitat features (i.e. failure to remain disturbed habitat). Using this framework, ρ can be calculated from the mean recovery time, τ as:

$$\rho = 1 - exp(-1/\tau) \qquad (1)$$

This provides an easier way to parameterize recovery as previous studies generally report how long it takes habitats to recover rather than the incremental change each year. One challenge, however, when interpreting τ is that the mean of an exponential time-to-failure model corresponds to when ~63% of all failures have happened. Within the context of the FE model, this means that in a completely disturbed grid cell (100% disturbed), with no further impacts, we would estimate the disturbance to be ~27% (63% undisturbed) after τ years. To avoid misinterpreting τ as the time required to fully recover, we also report alongside τ the equivalent time required for a nearly full recovery, τ^*, defined as the time required for habitats to recover from 95% disturbed to 5% disturbed. The two parameterizations can be converted between each other as:

$$\begin{aligned} \tau^* &= \tau[ln(0.95) \ - \ ln(0.05)] \\ &= 2.94\tau \qquad (2) \end{aligned}$$

The recovery values used here are drawn from the Grabowski et *al.* (2014) global meta-analysis of benthic susceptibility and recovery. Like susceptibility, it is defined for 26 habitat features for each habitat type (Appendix 3). Grabowski et *al.* (2014) reported mean recovery time (τ) on a four-interval scale representing: < 1 year; 1 – 2 years; 2 – 5 years; and 5 – 10 years equivalent to τ^*values of < 2.9 years; 2.9 – 5.8 years; 5.8 – 14.5 years; and 14.5 – 29 years. During the 2017 EFH review it was noted that recent studies had estimated recovery of some corals on rocky habitat > 200 m depth to be in excess 10 years. To include these long-lived/slow recovering corals, the SSC suggested adding an additional habitat category for rocky and cobble habitats >200 m depth where these long-lived corals were likely to be found and were assigned a mean recovery times of 10 - 50 years (τ^* :29 - 145 years) and identified as "deep/rocky" habitats (see Section 2.1.4.1 below).

Like susceptibility, a recovery time is randomly selected for each habitat feature from its associated recovery interval. Recovery for a given sediment type is averaged over all habitat features associated with that sediment, and recovery times are converted to the proportion of disturbed habitat recovered each month via Eq 1.

2.1.6 Incorporation of longer recovery times into FE model

In 2016, a deep/rocky habitat category was added with a habitat feature to represent long-lived corals (resulting in 27 habitat features). Three Aleutian Island cruises conducted by NMFS in 2003-2004 resulted in 71 submersible and ROV transects (Stone 2006, 2014). Video analysis of those transects indicated that corals have the highest density at depths of 400 to 700 m with bedrock or cobbles substrates, moderate to very high roughness, and slopes greater than 10 percent. To be precautionary, the new habitat feature was defined as cobble or boulder habitats deeper than 300 m. Cobble and boulder substrate was defined using the original sediment map for the FE model; depth was determined from a domain-wide 100 m (hectare) resolution bathymetric model. All cobble and boulder sediments categories in grid cells with an average depth deeper than 300 m were converted to the deep/rocky category. Habitat features originally in the cobble or boulder categories were mapped to the deep/rocky category with their original recovery scores. To account for the long-lived species expected in these habitats, a new "long-lived species" recovery interval (10 – 50 years) was added with a new recovery score of 4. The 50-year upper limit of recovery time was calculated with the expectation that 5% of these long-lived species would require 150 years to recover.

2.2 Sensitivity analysis

During initial development of the model, the contact adjustment, susceptibility, and recovery parameters were chosen to include random variables from uniform distributions with the intent that running multiple iterations of the model would allow for estimation of uncertainty. While this approach does produce reasonable estimates of uncertainty at the grid cell level, when aggregating results across large spatial domains this measure of uncertainty was less useful due to aggregation of many grid cells. The key sources of uncertainty unaccounted for in this stochastic approach is either 1) potential bias in the parameter estimates, or 2) misspecification of model parameters. To evaluate these potential uncertainties, we ran several versions of the model to bound the estimate of habitat disturbance.

To evaluate potential uncertainty due to bias in the parameters, we ran the FE model with each of the stochastic parameters fixed to their upper and lower bounds, producing a range of habitat disturbance estimates that bounds habitat disturbance within the parameter space. In other words, estimates of habitat disturbance will always be in this range assuming that the model is well specified and that no parameters exceed their defined bound. Generally, this produces a conservative band of uncertainty (i.e., much wider than reasonably expected) as it is unlikely that all parameters are biased consistently high or low with similar magnitude.

To evaluate potential misspecification of the model, we ran three alternate models with restricted parameters in a hierarchical manner to demonstrate the effect of each parameter on model estimates. Each restricted model provides a hard upper boundary of potential habitat disturbance for each of the more complex models. Notably, each of the restrictive models has a relevant physical interpretation that can be used to better understand habitat disturbance dynamics.

The first restricted model fixed contact adjustment and susceptibility to unity and did not include recovery. This model is equivalent to the spatial footprint fishing activity (including pelagic fishing activity) and will be referred to as the "fishing footprint". This model provides a hard upper limit of habitat disturbance if we assume fishing activities do not disturb habitat features outside of their spatial footprint. The second restricted model fixed susceptibility at unity with no recovery but included the standard contact adjustment parameters. This model provides an estimate of how much of the seafloor has ever been contacted by fishing gear and referred to here as the "benthic footprint". This will always be less than the fishing footprint, with the difference representing the area that has only ever had pelagic (or at least off-bottom) fishing activity and represents an upper bound of habitat disturbance if contact adjustment is well defined. A third restricted model was run that also did not include recovery but included the standard contact adjustment and susceptibility parameters. This model is a measure of the proportion of benthic features that have ever been impacted by fishing activity and is referred to as the “impacted footprint”. This model provides an upper bound of habitat disturbance assuming contact adjustment and susceptibility are well specified in the model. Results for each of these models are given below in Table 2 and displayed in Figure 6.

Table 2. Model outputs for December 2020 for low/high habitat disturbance scenarios and restricted models.

Model version	**AI**	**EBS**	**GOA**	**North Pacific**
Habitat disturbance (lower – upper bound)	2.9% (1.5% - 4.1%)	5.2% (1.3% - 9.2%)	1.3% (0.3% - 2.7%)	3.9% (1.1% - 7.1%)
Fishing footprint	16.9%	37.9%	18.9%	31.2%
Benthic footprint	15.8%	35.0%	16.0%	28.4%
Impact footprint	8.7%	23.0%	8.1%	17.9%

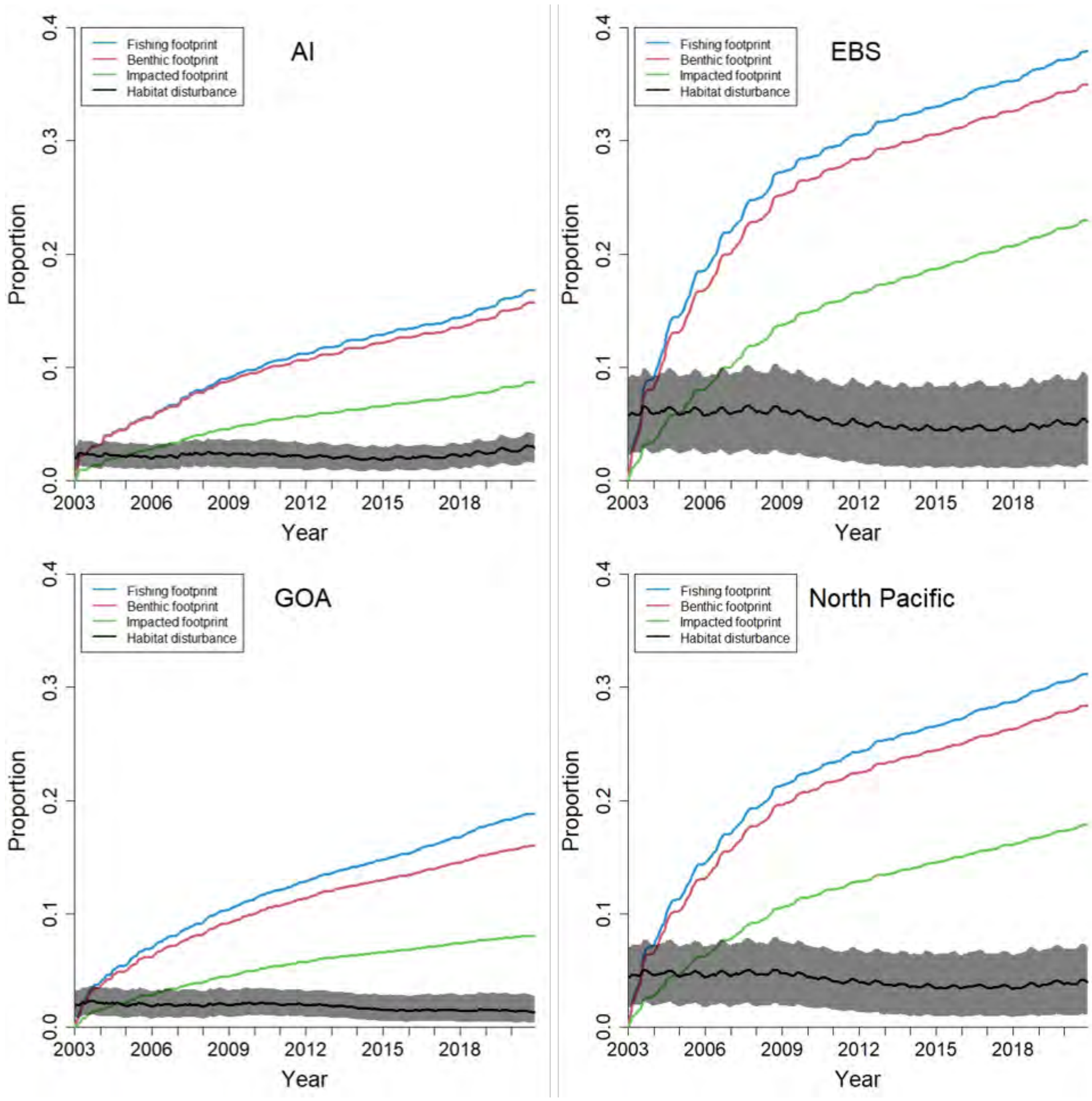


Figure 6. Model outputs for habitat disturbance and each of the restricted models. The gray band shows the bounds of habitat disturbance with all parameters fixed to their highest or lower values.

2.3 2022 FE Model Code Correction

The FE model is run on a combination of Python and R code. APU's FE model code is now available upon request. The 2017 EFH 5-year Review was the initial implementation of the model, and the code was constructed in such a way that did not provide for great flexibility when porting the model to other applications. Since 2017, APU has made various updates and improvements to the model code with an aim toward flexibility and efficiency. In 2018, an error was discovered in the 2017 model code that transposed the susceptibility for trawl and longline gears. Because susceptibility is generally higher for trawls than longlines, the effect was an underestimation of impacts from trawls and an overestimation of impacts from longlines. Because the total footprint of trawling throughout the North Pacific is much greater than the footprint of longlines, the net effect of this error resulted in an underestimate of habitat disturbance (Figure 7), with the largest difference evident in the Bering Sea. The differences between the outputs in Figure 6 are due to the correction made to properly attribute susceptibility to trawl and longline, as well as updates to the Gear Parameter Table (Appendix 2).

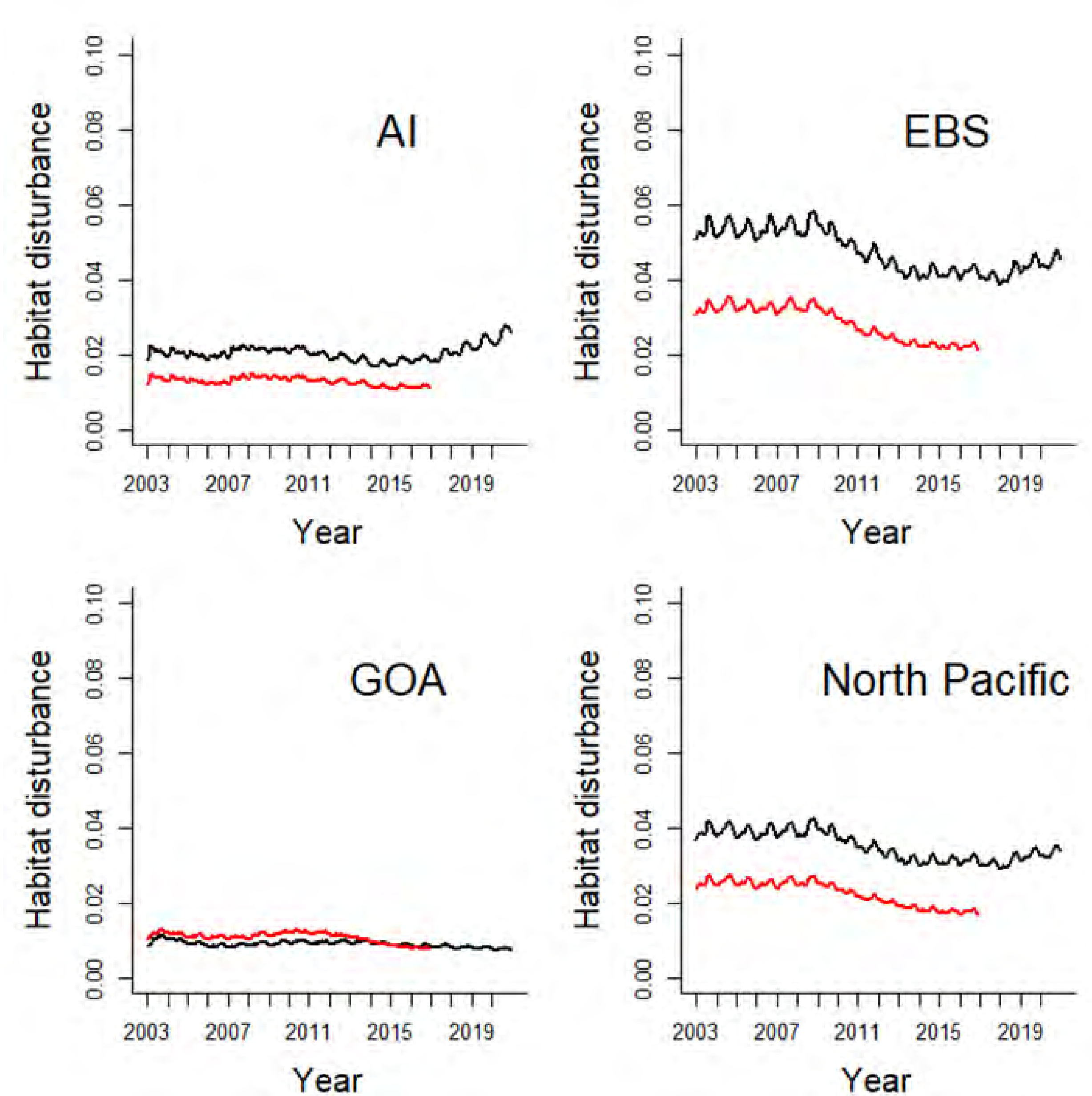


Figure 7: Comparison of 2017 FE output (red lines) and corrected 2022 FE model output (black lines) among subregions and the North Pacific at large.

3 STOCK AUTHOR FISHING EFFECTS ASSESSMENT PROCESS

In 2016, an SSC subcommittee developed a process for SAs to review the FE model results and conduct an FE assessment to meet the requirements of EFH component 2. 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.

In February 2022, the SSC supported the use of the new species distribution model (SDM) ensemble EFH component 1 maps. The SDM ensemble EFH mapping approach for the 2022 EFH 5-year Review provides several advantages over the single SDM approach of the 2017 Review (Chapter 2, EFH Component 1 Discussion Paper September, 2022[7]).

Once the FE model runs were completed in April 2022, we requested SAs assess the impacts of commercial fishing on EFH in Alaska following the process established in 2016 and used for 2017 EFH 5-year Review. To investigate the potential relationships between fishing effects and stock production, the SAs had the opportunity to examine trends in life history parameters and the amount of disturbed habitat in the core EFH area (CEA) for each species they assess, as appropriate.

The 2022 FE model was run using the upper 50th percentile CEA from the summer distribution SDM ensemble EFH maps for adults or combined life stages, representing EFH Level 2 information of habitat-related abundance. The Final Environmental Impact Statement for EFH Identification and Conservation in Alaska defines EFH as the area inhabited by 95% of a species' population (NMFS 2005[8]). EFH is characterized for each species' life stage as the spatial domain containing the upper 95% of occupied habitat[9]. As in the 2017 EFH 5-year Review, the 2022 SDM-based EFH maps included additional area percentiles, representing the upper 75%, 50%, and 25% of occupied habitat. For 2022, NMFS requested SAs consider a 75% CEA as well as 50% as a way to address SSC concerns for data limited stocks.

To better understand the data limitations on the spatial representation of EFH, the SSC requested more detailed information on SA concerns reported for a subset of species during the SA draft SDM EFH review in 2021. The first set of questions for SA aimed to better understand SAs concerns with the SDM EFH maps. SAs first had the opportunity to qualitatively score their concern that the EFH map does not encompass the summer distribution of adults of their species in the fishery management unit as High (3), Medium (2), or Low (1). Then SAs were asked to explain their concern and qualitative score. A summary of SDM concerns and discussion can be found in the EFH Component 1 SDM EFH Discussion Paper prepared for the SSC October, 2022 meeting[10].

---

[7] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

[8] FEIS for EFH in Alaska https://repository.library.noaa.gov/view/noaa/17391

[9] See section 3.2.8 for EFH mapping methods in the EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

[10] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

The approach for the SA's FE assessment was developed by the SSC subcommittee and approved by SSC in December 2016[11] (NPFMC 2016). Because EFH is defined for populations managed by the Council, the first consideration of the FE analysis is at the population level. SAs indicated whether the population in question is above or below Minimum Stock Size Threshold (MSST) or note if MSST is not defined for the stock. SAs were asked to provide a written FE assessment for any stock that is below MSST if the stock assessment author determines that there is a plausible connection to disturbance of EFH as the cause. Additionally, in February 2022, the SSC noted it "encourages the use of habitat modeling outputs and methods, data inputs, and stock author input to help inform specific rebuilding plans and monitor progress towards rebuilding, as appropriate."

SAs had the opportunity to conduct additional analyses, as described below, for any stocks for which the proportion of habitat disturbed by fishing in the CEA was ≥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 (≥10%) 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 that habitat disturbance at levels higher than 10% does not indicate that impacts of fishing are more than minimal but would result in additional review by the SA, as described below**. The SSC subcommittee also noted that the 10% threshold does not preclude stock assessment authors from completing the evaluation for levels of habitat disturbance less than 10%, if other data suggest that impacts may be affecting the population.** Therefore, in 2016, the SSC subcommittee continued to recommend the ≥10% habitat disturbance threshold to trigger additional analyses by the SAs.

If ≥10% of the CEA was estimated to be disturbed by fishing, SAs had 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 existed (negative or positive), the SAs determined whether the correlation was significant at a p-value of 0.1. This criterion provides an objective threshold to ensure that a "hard look" has been taken for each species, as appropriate. Because multiple parameters were examined for correlation to habitat disturbance, it is somewhat likely that spurious significant ($p < 0.1$) correlations will be found. If the SA found a significant correlation ($p < 0.1$), the SA would elevate the potential impact to the Plan Teams and SSC for review or provide rationale for why it is not necessary. SAs were not precluded from elevating a potential impact if they felt it was necessary for species below the ≥10% threshold. If SAs determined that the correlation between the impacts to the CEA and life history parameter(s) suggest a plausible stock effect, they could 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 would recommend mitigation measures to the Council.

[11] Methods to evaluate the effects of fishing on EFH proposal from the SSC subcommittee December, 2016 https://meetings.npfmc.org/CommentReview/EFHFishingEffectsProposedMethods.pdf

In February 2022, the SSC raised issues with data limitations for the FE model, including habitat feature susceptibility and that it did not initially include unobserved fishing events for which VMS data was available. Both the observed and observed + unobserved model runs were included for the 2022 FE model results. We provide the opportunity for SAs to express concerns with the data limitations in the FE model as well as the SDM EFH component 1 maps, as requested by the SSC. The SSC recommended that the SA should consider the question of whether to elevate a species for possible mitigation based on other sources of information if the SA was concerned about the information available for the FE assessment from the SDM EFH map, FE model, or other reasons. The Google Form (2022 FE Assessment Questionnaire) included questions seeking the SA's input on their concerns and recommendations.

Information from stock authors was collected using a Google Form. Detailed instructions and a decision tree (Appendix 4) were provided to aid in SA review and provide guidance on the questionnaire to assist in SA feedback provided on the Google Form. Information detailing the stock author questionnaire and instructions can be found in Appendix 4. Feedback from stock authors was compiled for the EFH component 2 FE assessment for each species or species complex by region and provided in Appendix 5.

To conclude the FE analysis review, SA were asked to recommend EFH research activities or priorities for the identification or evaluation of impacts to EFH. As part of the 2022 EFH 5-year Review, SAs were given the opportunity to raise habitat concerns that would be appropriate for the Habitat Areas of Particular Concern (HAPC) process for Council consideration[12].

4 RESULTS

Given the intricacy of the FE model, results, and the SA assessments the authors chose to present the results in the following order:

- FE model results for the percent habitat disturbance and a summary of SA concerns with the SDM maps and FE model reported in the 2022 FE Assessment Questionnaire (**Section 4.1**),
- Species with SA reported data limitations and requests for SSC recommendations (**Section 4.2**),
- Species with ≥10% CEA disturbed (**Section 4.3**), and
- FE assessment results for species with ≥10% CEA disturbed (**Section 4.4**). Section 4.4 includes FE model maps of habitat disturbance, time series graphs for observed and unobserved fishing, CEA comparisons between 2017 and 2022, and the SA FE assessments for species with ≥10% CEA disturbed.

The FE model resulted in an estimate of the percentage of habitat disturbed using robust information on fishing impacts, susceptibility, and recovery time for 103 species, including 27 Aleutian Island (AI) species, 34 Eastern Bering Sea species (EBS), and 42 Gulf of Alaska (GOA). FE model results were also calculated for 10 species complexes overall, where an EFH

[12] NPFMC HAPC Process https://www.npfmc.org/wp-content/PDFdocuments/conservation_issues/HAPC/hapc_process092010.pdf

map representing all species in the complex was provided as an option for the SA to assess the effects of fishing on EFH (i.e., rather than by individual species)[13]. SAs used the FE model results to conduct the FE assessment for their species or species complex.

Twenty-two SAs participated in EFH component 2 FE assessment for the 2022 EFH 5-year Review. We received 86 responses in the Google Form and via email for individual species and/or stock complexes. Most SAs chose a quantitative FE assessment with the FE model and 50% CEA as the most appropriate approach to assess the effects of fishing on EFH for their species (85% of responses). SAs chose a qualitative FE assessment using other sources of information for species with data limitations (15% of responses). We received a more detailed written FE assessment for 17 species. The complete SA FE assessments are provided in Appendix 5. **No SA recommended to elevate their species to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH.** However, SAs raised issues with data limitations for some species (section 4.2).

At this meeting, we are seeking feedback from the Plan Teams and SSC. The big picture questions for the Plans Teams and SSC in context of the 2022 EFH 5 year review are—

(1) Does the 2022 FE evaluation incorporate newly available information to provide an appropriate evaluation of the potential adverse effects of fishing on EFH designated under the FMPs and meet the requirements in the EFH regulations at 50 CFR 600.815(a)(2) for the 2022 EFH 5 year review? See section 1.1 for the EFH regulations.

(2) Does the 2022 FE evaluation support the continued conclusion that adverse effects of fishing activity on EFH are minimal and temporary in nature?

(3) For the 9 species for which the stock author identified that data limitations prevent making the conclusion that adverse effects of fishing activity on EFH are minimal and temporary, does the Plan Team or SSC have guidance on evaluating FE beyond what is provided in this document? Note that of these 9 species, 1 species (Tanner crab) is above the ≥10% threshold for habitat disturbance. Specific options are provided in Section 4.2.

4.1 FE Analysis Results and Summary of Stock Author Concerns

In response to the SSC request in February 2022, during this FE assessment we requested that SAs provide additional information on their concerns about the spatial representativeness of the summer distribution 2022 SDM ensemble EFH maps for their species and the FE model. We collected information from SAs on their concerns with the SDM EFH maps and/or FE model, including a qualitative ranking of *low (1), medium (2), or high (3) concern*, and additional explanation of concerns with research recommendations. There were 51 responses with *no concern* for the SDM EFH maps and 52 responses with *no concern* for the FE model. SDM EFH map concerns were reported for 34 species or species complexes and ranked *low* (n = 20), *medium* (n = 10), and *high* (n = 4) (one species had multiple entries of low concern from the team of reviewing SAs and was counted once) (Figure 8)[14]. FE model concerns were reported for 18 species or species complexes and ranked *low* (n = 7), *medium* (n = 7), and *high* (n = 4) (one

[13] EFH Component 1 SDM EFH Discussion Paper February, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[14] A summary of SDM concerns and discussion can be found in the EFH Component 1 SDM EFH Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

species had multiple entries of medium concern from the team of reviewing SAs and was counted once). No response was received on 14 forms for the optional question ranking concerns for the FE model.

FE model results of percent CEA disturbed are presented for all species or species complex, where the SA responded to the FE assessment questionnaire, including any reported FE model concerns (Tables 3-6). A summary of concerns reported for the FE model and/or SDM EFH maps is also provided (Figure 8). For more details on the concerns reported and the SA FE assessments, see Appendix 5. Fishing Effects documents, FE model results, and SA FE Assessments have been provided for the SSC October, 2022 meeting[15]. For each species, a map of the percent habitat disturbed, a time series graph of their percent habitat disturbed from 2003 - 2020, and an overlay of 50% CEA comparing 2017 and 2022 EFH maps are provided.

Concerns listed for the FE model were communicated with the SAs. In all cases, the SAs did not elevate their species for mitigation measures, though SAs noted insufficient information to make the decision for nine species. Most FE concerns that were communicated focused on data needs and cited lack of data to assess fishing impacts, with concerns under the themes of SDM EFH map data, life history stages, differences in habitat ranges and the FE model extent, season over which FE are assessed, and the spatial scale of FE calculated by region (e.g., smaller scale subregions or larger scale North Pacific-wide). Incorporating new data sources into the FE model is a future recommendation for the next EFH 5-year Review. Concerns with the FE model were under the following themes:

- the SDM EFH maps used for the FE results,
- life history considerations,
- differences between the FE analysis regions and stock management areas,
- regional FE results undervaluing fishing impacts in smaller areas and/or time spans,
- using stock complexes undervaluing fishing impacts to individual species, and
- different measures of FE on not only habitat but fisheries bycatch.

A summary of SDM concerns and discussion can be found in the EFH Component 1 SDM EFH Discussion Paper prepared for the SSC October, 2022 meeting[16]. The EFH Component 1 Discussion Paper provides a summary of the 2022 SDM ensemble EFH mapping approach and results and supporting EFH component 1 documents provide the complete set of methods, results, and future recommendations[15]. Opportunity for continued improvements of EFH component 1 is possible through research leading up to a future EFH 5-year Review, which are by design an iterative process and occurring at least every five years (50 CFR 600.815(a)(10)).

Concerns listed for the EFH maps were previously discussed during the SA's draft SDM EFH review and reported in the EFH Stock Author Review Report (NMFS 2021)[17]. EFH analysts and SAs worked through concerns at that time, reaching agreement on proceeding with the new SDM

[15] EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[16] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[17] Attachment 1: Report of Stock Assessment Author Review of Essential Fish Habitat (EFH) Components 1 and 7 for the 2022 EFH 5-year Review

ensemble EFH maps, while also identifying areas for future research and mapping development that could positively inform the next iteration of EFH maps for their species. In some cases, the SDM ensembles were revised where an improvement was possible at that time.

Many of the EFH map concerns reported by the SAs in their FE assessment questionnaire and their 2021 review of the draft SDMs were about adding additional data sources if possible. Following the first SDM review, EFH analysts and SAs worked together to develop data caveat statements that were included in the applicable species results chapters of the three EFH NOAA Technical Memoranda to inform where an SA identified that additional data sources and/or other research may add value to the EFH map for that species life stage in future EFH mapping efforts. This approach to recognizing data concerns in the NOAA Technical Memoranda can accompany additional EFH map reporting for this 5-year Review, such as in the EFH 5-Review Summary Report and any EFH FMP Amendments that the Council chooses to implement. Additional information on the SDMs for data limited species and how reviewer concerns have been addressed to the extent possible at this time is provided in the companion EFH Component 1 Discussion Paper prepared for the SSC October 2022 meeting, with additional supporting documents.

Table 3. FE model results of percent (%) habitat disturbed for Aleutian Island (AI) groundfish species and species complexes estimated for December 2020. FE model concerns reported by the SA as a qualitative score are listed (low, medium, high) with concern theme. Full concerns and explanations are in Appendix 5.

AI Groundfish Species	% Habitat disturbed	FE model concern
AI adult Arrowtooth flounder	3.8%	No concern
AI adult Atka mackerel	4.0%	No concern
AI adult Blackspotted/rougheye rockfish complex	5.1%	No concern
AI adult English sole	1.0%	No concern
AI adult Flathead sole	3.0%	*No response*
AI adult Giant octopus	4.0%	No concern
AI adult Greenland turbot	5.2%	*No response*
AI adult Kamchatka flounder	5.3%	No concern
AI adult Northern rockfish	4.0%	*No response*
AI adult Northern rock sole	2.5%	*No response*
AI adult Other flatfish complex	3.0%	No concern
AI adult Dover sole	3.9%	No concern

AI Groundfish Species	**% Habitat disturbed**	**FE model concern**
AI adult Rex sole	4.0%	No concern
AI adult Southern rock sole	1.2%	No concern
AI all Other rockfish complex	4.4%	*No response*
AI adult Dusky rockfish	4.0%	*No response*
AI adult Harlequin rockfish	4.5%	*No response*
AI adult Shortspine thornyhead	4.6%	No concern
AI adult Pacific cod	3.6%	No concern
AI adult Pacific ocean perch	5.0%	*No response*
AI adult Sablefish	4.8%	Low (1) SDM data/Analysis region/Life history
AI adult Shortraker rockfish	4.2%	No concern
AI adult Skate complex	4.1%	No concern
AI adult Alaska skate	3.5%	No concern
AI adult Aleutian skate	4.9%	No concern
AI adult Mud skate	4.6%	No concern
AI adult Whiteblotched skate	4.9%	No concern
AI adult Walleye pollock	4.3%	No concern

Table 4. FE model results of percent (%) habitat disturbed for eastern Bering Sea (EBS) groundfish species and species complexes estimated for December 2020. FE model concerns

reported by the SA as a qualitative score are listed (low, medium, high) with concern theme. Full concerns and explanations are in Appendix 5.

EBS Groundfish Species	**% Habitat disturbed**	**FE model concern**
EBS adult Alaska plaice	4.6%	No concern
EBS adult Arrowtooth flounder	10.3%	No concern
EBS adult Atka mackerel	24.8%	High (3) SDM data
EBS adult Blackspotted/Rougheye rockfish complex	19.9%	No concern
EBS adult Flathead sole-Bering flounder complex	8.9%	*No response*
EBS adult Bering flounder	1.9%	*No response*
EBS adult Flathead sole	10.0%	*No response*
EBS all Giant octopus	13.5%	Medium (2) SDM data
EBS adult Greenland turbot	7.7%	No concern
EBS adult Kamchatka flounder	9.1%	No concern
EBS adult Northern rockfish	14.9%	No concern
EBS adult Northern rock sole	6.3%	No concern
EBS Other flatfish complex	4.1%	No concern
EBS adult Butter sole	6.9%	No concern
EBS all Deep sea sole	2.6%	No concern
EBS adult Dover sole	18.8%	No concern
EBS all Longhead dab	2.2%	No concern
EBS adult Rex sole	12.0%	No concern
EBS adult Sakhalin sole	0.0%	No concern
EBS adult Starry flounder	2.1%	No concern
EBS adult Pacific cod	6.3%	No concern
EBS adult Pacific ocean perch	12.8%	No concern

EBS Groundfish Species	% Habitat disturbed	FE model concern
EBS adult Sablefish	12.4%	Medium (2) SDM data/Analysis region/Life history
EBS adult Shortraker rockfish	11.5%	No concern
EBS adult Shortspine thornyhead	11.4%	No concern
EBS adult Skate complex	7.7%	No concern
EBS adult Alaska skate	7.1%	No concern
EBS adult Aleutian skate	20.3%	No concern
EBS adult Bering skate	11.1%	No concern
EBS adult Mud skate	19.0%	No concern
EBS adult Whiteblotched skate	20.8%	No concern
EBS adult Walleye pollock	8.2%	No concern
EBS adult Yellowfin sole	5.7%	No concern

Table 5. FE model results of percent (%) habitat disturbed for Gulf of Alaska (GOA) groundfish species and species complexes estimated for December 2020. FE model concerns reported by the SA as a qualitative score are listed (low, medium, high) with concern theme. Full concerns and explanations are in Appendix 5.

GOA Groundfish species	% Habitat Disturbed	FE model concern
GOA adult Arrowtooth flounder	2.0%	No Concern
GOA adult Atka mackerel	2.1%	No Concern
GOA adult Blackspotted/Rougheye rockfish complex	1.8%	No Concern
GOA adult Dover sole	1.5%	No Concern
GOA adult Dusky rockfish	1.5%	No Concern
GOA adult Flathead sole	1.9%	No Concern
GOA all Giant octopus	1.7%	No Concern

GOA Groundfish species	**% Habitat Disturbed**	**FE model concern**
GOA adult Northern rockfish	1.8%	*No Response*
GOA all Other rockfish complex demersal subgroup	0.7%	No Concern
GOA all Other rockfish complex slope subgroup	1.1%	Low (1) FE assessment with CEA of complex map would hide fishing effects for individual species
GOA adult Greenstriped rockfish	0.0%	Medium (2) SDM data
GOA adult Harlequin rockfish	1.1%	Low (1) SDM data
GOA all Pygmy rockfish	0.3%	High (3) SDM data
GOA adult Redbanded rockfish	1.3%	Medium (2) SDM data
GOA adult Redstripe rockfish	1.2%	Low (1) SDM data
GOA adult Sharpchin rockfish	1.2%	Low (1) SDM data
GOA adult Silvergray rockfish	0.7%	Low (1) SDM data
GOA adult Pacific Cod	1.8%	No Concern
GOA adult Pacific ocean perch	1.6%	No Concern
GOA adult Rex sole	2.0%	No Concern
GOA adult Sablefish	1.8%	Low (1) SDM data/Analysis region/Life history
Shallow water flatfish complex	1.1%	No Concern
GOA adult Shortraker rockfish	1.5%	*No Response*
GOA adult Shortspine thornyhead rockfish	1.5%	*No Response*
GOA adult Skate complex	2.0%	No Concern
GOA adult Spiny dogfish	0.03%	Medium (2) SDM data
GOA adult Walleye pollock	2.0%	No Concern

Table 6. FE model results of percent (%) habitat disturbed for Bering Sea-Aleutian Island (BSAI) crab species estimated for December 2020. FE model concerns reported by the SA as a qualitative score are listed (low, medium, high) with concern theme. Full concerns and explanations are in Appendix 5.

BSAI Crab species	% Habitat disturbed	FE model concern
EBS all Blue king crab	2.3%	No concern
AI all Golden king crab	4.7%	High (3) SDM data
EBS all Red king crab	4.9%	Medium (2) Life history stages/Timing
AI all Red king crab	2.3%	Medium (2) Life history stages/Timing
EBS all Snow crab	3.8%	High (3) Life history stages/Timing
EBS all Tanner crab	10.9%	No concern

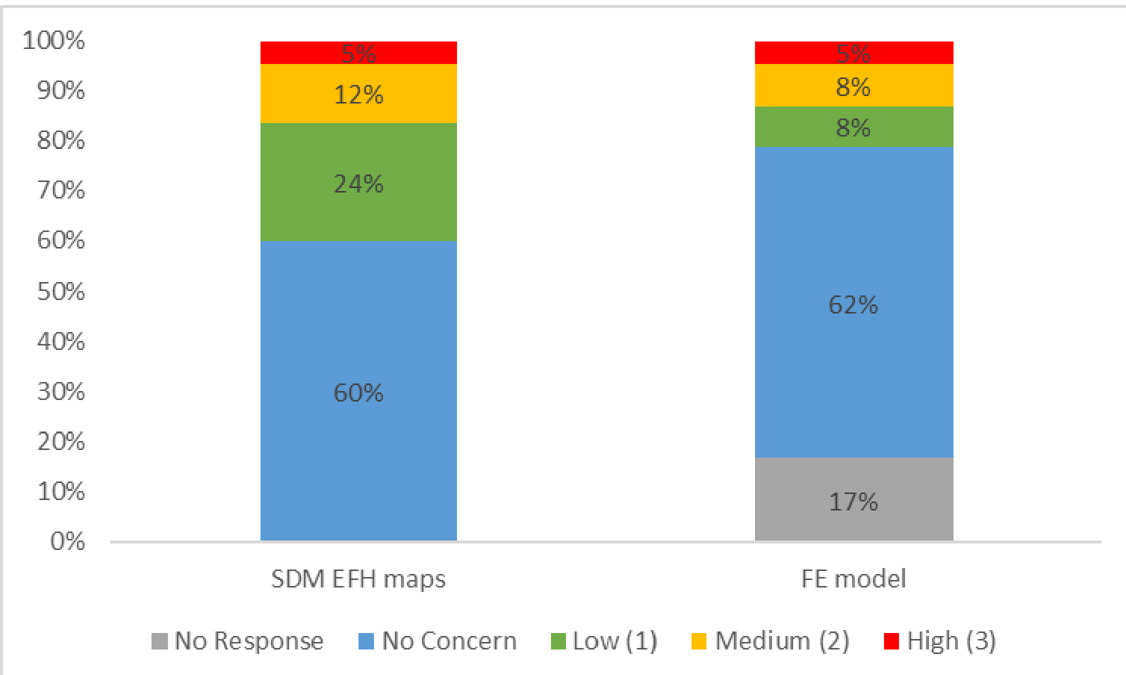


Figure 8: Ranked concerns by qualitative score (low (1), medium (2), high (3)) reported by stock authors for the SDM ensemble EFH maps representing the summer distribution of adults (or all life stages combined) for their species (or species complexes) (left), and the FE model results representing the effects of fishing on their species' habitat (core EFH area (CEA)) (right).

4.2 Species with Reported Data Limitations

SAs reported concerns with the SDM EFH maps and/or FE model due to data limitations and chose either a quantitative or qualitative FE assessment. SAs chose a qualitative FE assessment using other sources of information for 12 species or species complexes. For seven of those species, based on their qualitative assessments, they reported insufficient information to make the decision to elevate their species for possible mitigation to reduce fishing effects to EFH (Table 7). Those species were data limited GOA rockfishes, EBS red king crab, and GOA spiny dogfish. SAs chose a quantitative FE assessment for AI golden king crab, EBS snow crab, and Tanner crab and also reported insufficient information to make the decision to elevate or not elevate those species. EBS Atka mackerel, EBS giant octopus, and Tanner crab are the data limited species above the ≥10% threshold. EBS Tanner crab was the only species that reached the ≥ 10% threshold of habitat disturbance where the SA reported insufficient information to make the decision to elevate. EBS Atka mackerel and EBS giant octopus, the SA concluded that no further action was necessary to elevate the species for consideration of mitigation.

The SAs and experts assessing EBS red king crab indicated interest in both quantitative and qualitative assessments and requested more FE model output for further analyses. Those analyses for EBS red king crab are in progress and they noted, since the estimated CEA disturbance was less than the ≥10% threshold, they would continue evaluating correlations for future comparisons.

FE assessments and responses collected for the FE Assessment Questionnaire via the Google Form are reported these data limited species in Appendix 5. **Of the SAs that reported insufficient information to make the decision to elevate their species, none reported concerns that fishing effects on the EFH were likely more than minimal and not temporary.**

Does the SSC have guidance on evaluating the effects of fishing on EFH for the species beyond what was provided by the SAs for the species where the SA reported insufficient information to make the decision to elevate their species for possible mitigation to reduce fishing effects to EFH (Table 7)? We provide more information for these species in sections 4.2.1 – 4.2.3.

Table 7. Species where the SA reported concerns with the SDM EFH map and/or FE model due to data limitations and chose either a quantitative or qualitative FE assessment. SA response is indicated for Q7 of the 2022 FE Assessment Questionnaire, including the nine species where the SA reported *insufficient information* to make the decision. EBS Atka mackerel, EBS giant octopus, and Tanner crab are the data limited species above the ≥10% threshold (**bold**).

Species where the SA reported concerns due to data limitations	Quantitative FE assessment	Qualitative FE assessment	Q7. Based on your FE assessment, do you recommend this species be elevated to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH?		
			a. No further action	b. Elevate for possible mitigation of habitat impacts	c. Insufficient information to make this decision
EBS Atka mackerel		X	X		

Species where the SA reported concerns due to data limitations	Quantitative FE assessment	Qualitative FE assessment	Q7. Based on your FE assessment, do you recommend this species be elevated to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH?		
			a. No further action	b. Elevate for possible mitigation of habitat impacts	c. Insufficient information to make this decision
GOA Atka mackerel		X	X		
AI Giant octopus		X	X		
EBS Giant octopus		**X**	**X**		
EBS Walleye pollock		X	X		
AI Golden king crab	X				X
EBS Red king crab	X	X			X
EBS Snow crab	X				X
EBS Tanner crab	**X**				**X**
GOA Other rockfish complex demersal subgroup		X	X		
GOA Other rockfish complex slope subgroup	X		X		
Harlequin rockfish	X		X		
Redstripe rockfish	X		X		
Sharpchin rockfish	X		X		
Greenstriped rockfish		X			X
Pygmy rockfish		X			X
Redbanded rockfish		X			X
Silvergray rockfish		X			X
GOA Spiny dogfish		X			X

4.2.1 GOA Other rockfish slope subgroup

EFH component 1 requires individual species maps for the fishery management unit (FMU) corresponding to the FMP (50 CFR 600.805(b)). However, where appropriate, EFH may be designated for assemblages of species or life stages that have similar habitat needs and requirements (50 CFR 600.815(a)(1)(iv)(E)). As a new approach in 2022, NMFS provided maps for species complexes, including the other rockfish (OR) complex slope subgroup, to represent the EFH of member species where an SDM was not possible (e.g., due to low sample size and/or other reasons). These **complex EFH maps** are an additive map of the area of occupied habitat from the combined individual species 2022 SDM ensemble EFH maps for this subgroup[18]. The complex EFH maps will be reported with the other new SDM ensemble EFH maps for member species of those complexes in the 2022 EFH 5-year Review, and were provided to the SAs as an option for completing their 2022 FE assessments.

For the GOA OR complex slope subgroup, the SA chose a quantitative assessment with the FE model and 50% CEA from the **complex EFH map** as the most appropriate approach to assess the effects of fishing on EFH for the slope subgroup and **recommended no further action** with respect to elevating the slope subgroup to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH (Table 7 and A5.6). However, the SA reported concerns over only using the complex map rather than maps for individual species to assess fishing effects on EFH (i.e., "Lumping the species has the risk of hiding critical changes within the complex. Assessing SDMs or FE at this level runs the risk of being too low of a resolution to detect significant results.").

For certain species in the slope subgroup, the SA also chose a quantitative assessment with the FE model and 50% CEA from the **species EFH maps** and **recommended no further action** (Table 7 and Table A5.6). The SA preferred a qualitative assessment for the remaining species with an EFH map due to data limitation concerns and reported **insufficient information** to make the decision to elevate for possible mitigation regarding fishing effects to EFH. For species where the SA reported insufficient information, **NMFS recommends that the complex map be used as a proxy for the individual species EFH maps for the FE assessment, however those individual species EFH maps should be retained for EFH component 1 requirements.**

Due to SA concerns for assessing the effects of fishing on EFH for the GOA OR complex slope subgroup, regarding a) only using the complex EFH map rather than the EFH maps for individual species, and b) concerns of data limitations for some of the species with an EFH map, **we are seeking SSC recommendations to assess fishing effects on EFH for the GOA OR complex slope subgroup species. We identified the following approaches:**

(1) As a subgroup, using only the CEA from the GOA OR complex slope subgroup map;

(2) As individual species with an EFH map and using the subgroup map for or data limited species with an EFH map where the SA is concerned about insufficient information, and using the subgroup map for individual species without an EFH map; or

(3) As individual species only, where an EFH map is available.

NMFS recommends the following approach for (2):

- Use the individual species EFH maps for Harlequin rockfish, Redstripe rockfish, and Sharpchin rockfish (i.e., SA chose a quantitative FE assessment and no further action (Table 7));

[18] For more information on mapping EFH for species complexes, refer to section 3.2.8.3 of the EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised, March 2022) https://meetings.npfmc.org/Meeting/Details/2947

- Use the subgroup map for Greenstriped rockfish, Pygmy rockfish, Redbanded rockfish, and Silvergray rockfish (i.e., SA chose a qualitative FE assessment and insufficient information to make the decision to elevate or not elevate (Table 7)); and
- Use the subgroup map for Darkblotched rockfish and Yellowtail rockfish (i.e., species without an EFH map (Table A5.6).

4.2.2 BSAI Crabs

SAs provided quantitative and qualitative assessments for BSAI crabs. For all species except EBS blue king crab and AI red king crab, SAs indicated that there was **insufficient information** to make the decision to elevate these species to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH (Table 7). SAs reported concerns with the BSAI crab SDM EFH maps, including that EFH mapping should be more specific to certain life stages and times of year (e.g., early juveniles, spawning females) and to include other species data sources if possible. SA FE model concerns reported for BSAI crabs were with respect to the overall approach to the FE assessment, including the timing, spatial scale, locations, and the life stages over which fishing effects on EFH was assessed for crabs. See Appendix 5 for more information on the SA concerns reported for BSAI crabs, including those reported in detail in the SA's written FE assessments.

HAPC considerations were reported by SAs for two species in the FE assessment, blue king crab EFH around St. Matthew Island and the Pribilof Islands and red king crab EFH in the western Aleutian Islands.

Current data limitations and/or the current approach to the FE assessment may prevent using the assessment to meet the evaluation requirements for 4 crab species. Of the SAs reporting insufficient information, none reported concerns that fishing effects on EFH were likely more than minimal and not temporary. **We are seeking SSC recommendations on assessing fishing effects on EFH for BSAI crabs beyond what was provided by the SAs for the following species:**

- AI golden king crab
- EBS red king crab
- EBS snow crab
- EBS Tanner crab (the crab species above the ≥10% threshold).

4.2.3 GOA Spiny dogfish

The SDM ensemble EFH maps for spiny dogfish are new in the 2022 EFH 5-year Review and represent the only EFH maps for a species in the GOA shark complex. Analysts developed SDM ensemble EFH maps for subadult and adult spiny dogfish. The adult spiny dogfish CEA was used with the FE model in the FE analysis that was provided for the SA's FE assessment. The SA noted concerns with the SDM EFH map due to data limitations for this species, suggested additional data sources (e.g., longline survey data) that may improve the EFH maps for this species in a future EFH 5-year Review. Due to data limitations, the SA chose a qualitative FE assessment and reported **insufficient information** to make the decision to elevate this species to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH (Table 7).

EFH component 1 requires individual species maps for the FMU corresponding to the FMP (50 CFR 600.805(b)). However, where appropriate, EFH may be designated for assemblages of species or life stages that have similar habitat needs and requirements (50 CFR 600.815(a)(1)(iv)(E)). Due to data limitation concerns for the adult life stage of spiny dogfish, analysts combined the subadult life stages for this species into a revised SDM ensemble EFH map and recommend that this replace the separate draft subadult and adult SDM ensemble EFH maps that the SSC reviewed in February, 2022[19]. The revised spiny dogfish SDM EFH map combining the subadult and adult life stages provides a more complete representation of the summer EFH for this species until additional data sources can be added. The revised spiny dogfish SDM ensemble EFH map is now available for the 2022 FE assessment. **We recommend assessing fishing effects to GOA spiny dogfish EFH using the FE model and the 50% CEA from the new SDM ensemble EFH map that combined the subadult and adult life stages and are seeking SSC's input.**

4.3 Species with ≥ 10% CEA Disturbed

The threshold of ≥10% CEA disturbed was reached for 16 out of 103 species where fishing impacts to EFH were assessed for EFH component 2 in the 2022 EFH 5-year Review (Table 8). All species reaching the CEA disturbance threshold in 2022 were in the EBS and none were in the AI or GOA. SAs provided both quantitative and qualitative assessments for these species and none were elevated for possible mitigation (Table 7). However, for EBS Tanner crab the SA reported following their quantitative assessment that there was insufficient information to make the decision to elevate or not elevate for this stock (as reported in section 4.2).

In the 2017 EFH 5-year Review, no species were found to reach or exceed this ≥10% threshold. Given the changes to the SDM EFH maps and corrections to the FE model since the 2017 Review, we sought to identify what changes led to those species exceeding the ≥10% threshold in the 2022 Review but not in 2017. This was accomplished by comparing estimates of 50% CEA disturbance at November 2016 (the terminal month of the 2017 FE model run) to estimates of 50% CEA disturbance at December 2020, using the 2017 and 2022 CEAs and the corrected 2022 FE model (Table 9).

Of the 16 species that exceeded the ≥10% CEA disturbed (Table 9)**—**

- Nine species exceeded ≥10% in 2022 but not in 2017 due to **FE model correction and updates** because the 2017 SDM would have led to exceeding ≥10% CEA disturbed in November 2016 using the corrected 2022 FE model.
- Two species exceeded ≥10% in 2022 but not in 2017 due to **SDM EFH map changes** because the 2017 SDM EFH map would not have led to exceeding ≥10% CEA disturbed, but the 2022 SDM EFH map would have.

[19] See Chapter 5 for more information on how SDM EFH map concerns for spiny dogfish and other species were addressed in the EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- Three species exceeded ≥10% in 2022 but not in 2017 due to an increase in **fishing effort** within the CEAs because neither the SDM EFH map nor the FE model would not have led to exceeding ≥10% CEA disturbed in 2017. **The three EBS species with increased habitat disturbance attributed to fishing were sablefish, shortraker rockfish, and shortspine thornyhead rockfish.**
- Two species had no 2017 SDM maps on which to make the comparison:
  - EBS Whiteblotched skate did not have a comparative framework because the sample size was < 50 hauls with positive catches in the EBS, which was the SSC's threshold for sample size inclusion in an SDM for the 2017 5-year Review.
  - EBS blackspotted/rougheye rockfish complex did not have a comparative framework because the species were mapped individually in 2017 and combined as a complex in 2022 by request of the SA.

Additionally, some SAs highlighted that stocks exceeding ≥10% habitat disturbance in the EBS are assessed at the BSAI level (Atka mackerel, blackspotted and rougheye rockfish complex, northern rockfish, and Pacific ocean perch). It may be more appropriate to map EFH and assess fishing effects to EFH for these species at the BSAI level, rather than as separate EBS and AI regions, in future EFH 5-year Reviews. This will require research to develop methods to combine different regional sources of species data and habitat covariates in the SDM ensemble EFH maps, which is not computationally straightforward at this time. Developing BSAI SDMs and FE evaluation could be a research topic and future recommendation.

Table 8. Species list with an estimated percent CEA disturbance ≥ 10%. For each species, the change to 50% CEA is the increase (+) or decrease (-) in the 50% CEA between 2017 and 2022, percent (%) CEA disturbed is the calculated disturbance by fishing gear, using the 50% CEA footprint. Whether or not the SA completed an FE assessment and elevated the species for mitigation in indicated (Yes/No). Atka mackerel, giant octopus, and Tanner crab (**bold**) were the species also identified as data limited (see section 4.2).

Species (All EBS)	**Change to 50% CEA (2017 to 2022)**	**% CEA disturbed (2022)**	**SA completed FE assessment?**	**Elevated for mitigation?**
Arrowtooth flounder	-15.5%	10.3%	Yes	No
Atka mackerel	**-91.1%**	**24.8%**	**Yes (Qualitative)**	**No**
Blackspotted/Rougheye rockfish complex	N/A	19.9%	Yes	No
Giant octopus	**-38.0%**	**13.5%**	**Yes (Qualitative)**	**No**
Dover sole	-56.8%	18.8%	Yes	No
Rex sole	+89.1%	12.0%	Yes	No
Northern rockfish	-21.8%	14.9%	Yes	No
Pacific ocean perch	+145.2%	12.8%	Yes	No
Sablefish	-14.6%	12.4%	Yes	No
Shortraker rockfish	-40.8%	11.5%	Yes	No
Shortspine thornyhead rockfish [a]	+54.5%	11.4%	Yes	No
Aleutian skate	-5.4%	20.3%	Yes	No
Bering skate	+96.0%	11.1%	Yes	No
Mud skate	-60.7%	19.0%	Yes	No
Whiteblotched skate	N/A	20.8%	Yes	No
Tanner crab	**+13.3%**	**10.9%**	**Yes**	**Insufficient Information**

[a] Shortspine thornyhead rockfish represent the Other rockfish complex but are the only representative species for the EBS region.

Table 9. Habitat disturbance estimates within CEAs for the 16 species estimated to have ≥10% in this EFH 5-year Review. The FE model analyst compared outputs with 2017 and 2022 CEAs and the corrected FE model iterations to interpret why the listed species surpassed the disturbance threshold in 2022 but not in 2017. Habitat disturbance estimates are given for November 2016 and December 2020 using both the 2017 and 2022 SDMs. Red cells highlight estimates >10%.

Species (All EBS) and **change to 50% CEA (2017 to 2022)**	**Nov 2016 (2022 SDM)**	**Nov 2016 (2017 SDM)**	**Dec 2020 (2022 SDM)**	**Dec 2020 (2017 SDM)**	**Cause of species exceeding 10% in 2022 but not 2017**
Arrowtooth flounder, 15.5% smaller	13.0%	9.1%	10.3%	9.6%	SDM EFH map
Dover sole, 56.8% smaller	13.3%	13.0%	18.8%	20.1%	FE model
Rex sole, 89.1% larger	10.4%	12.5%	10.2%	14.6%	FE model
Atka mackerel, 91.1% smaller	23.3%	10.7%	24.8%	10.6%	FE model
Sablefish, 14.6% smaller	8.8%	8.9%	12.4%	11.5%	Increased fishing
Northern rockfish, 21.8% smaller	12.1%	12.4%	14.9%	13.9%	FE model
Pacific ocean perch, 145.2% larger	11.6%	12.7%	12.8%	17.6%	FE model
Rougheye/blackspotted rockfish complex	11.0%		19.9%		*No 2017 SDM*
Shortspine thornyhead, 54.5% larger	7.0%	4.4%	11.4%	7.3%	Increased fishing
Shortraker rockfish, 40.8% smaller	5.2%	9.4%	11.5%	16.1%	Increased fishing
Aleutian skate, 5.4% smaller	13.5%	13.3%	20.3%	19.8%	FE model
Bering skate, 96.0% larger	11.0%	12.6%	11.1%	14.0%	FE model
Mud skate, 60.7% smaller	12.0%	12.7%	19.0%	18.9%	FE model
Whiteblotched skate	12.7%		20.8%		*No 2017 SDM*
Giant octopus, 38.0% smaller	10.4%	8.8%	13.5%	10.1%	SDM EFH map
Tanner crab, 13.3% larger	10.6%	11.1%	10.9%	11.4%	FE model

4.4 FE Assessments for Species with ≥ 10% CEA Disturbed

This section provides the FE analysis figures and SA FE assessments for the 16 species where ≥10% of the CEA is estimated to be disturbed by fishing (Table 8).

FE analysis figures from the FE model include—

- a map of the percent habitat disturbed,
- a time series graph of the percent habitat disturbed estimated from observed and unobserved fishing from 2003–2020, and
- an overlay map of 50% CEA comparing 2017 and 2022 SDM EFH maps.

The SA FE assessments are provided for these 16 species, including a quantitative or qualitative assessment depending on SA preference. SAs were prompted to examine 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 there are correlations between those parameters and the trends in the proportion of the CEA disturbed.

The full SA assessment of fishing effects on EFH for all species and species complexes assessed and SA input provided are in Appendix 5.

4.4.1 Arrowtooth Flounder

This section provides the FE analysis figures from the FE model and SA's FE assessments for Arrowtooth flounder.

FE analysis figures:

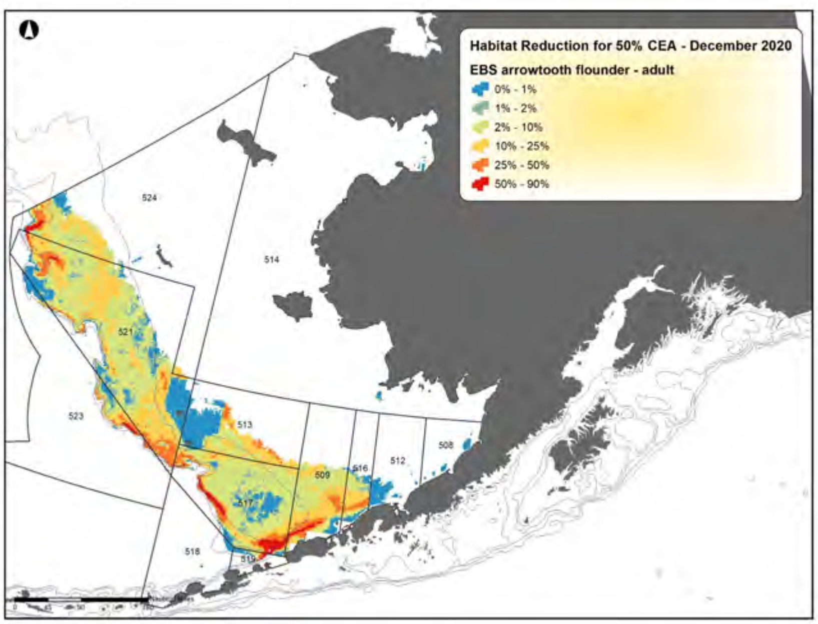


Figure 9. Proportion of habitat disturbance, December 2020 - EBS adult arrowtooth flounder.

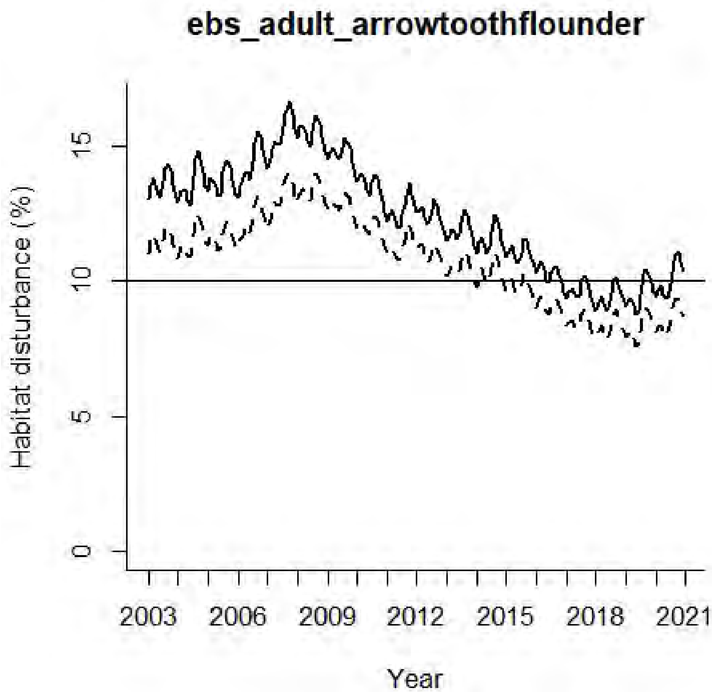


Figure 10. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS adult arrowtooth flounder.

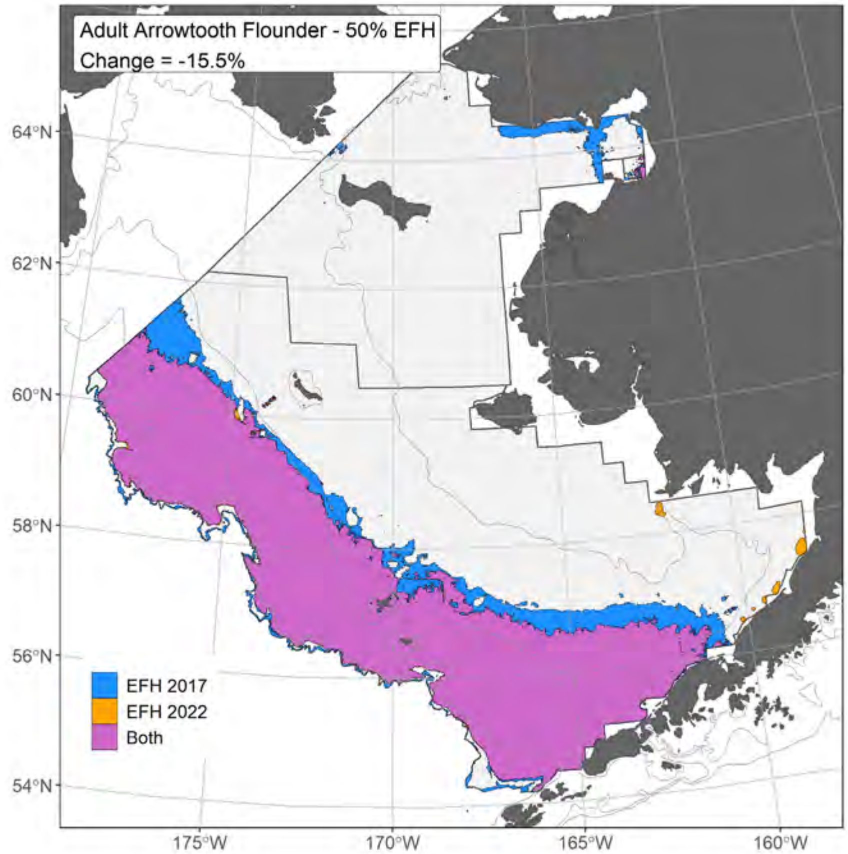


Figure 11. Change in 50% CEA, 2017 compared to 2022 - EBS adult arrowtooth flounder.

SA FE assessment for arrowtooth flounder:

The impacts of commercial fishing on EFH are of interest as part of the EFH 5-year review. Similar to 2017, the 2022 FE model is run using the upper 50th percentile CEA from summer species distribution maps for adults or combined life stages for a given fish stock. Data to support this model are from the RACE GAP bottom trawl survey and various environmental covariates (SDM EFH Discussion Paper). Maps and habitat disturbance output provided from the FE model were used to assess the effects of fishing on Bering Sea arrowtooth flounder.

A three-tiered approach is used for evaluating effects of fishing as suggested by the SSC EFH subcommittee. The first step of the evaluation was to determine whether Bering Sea arrowtooth flounder are above their MSST. The MSY level is defined as B35% for Tier 3 stocks. Please note that arrowtooth flounder are assessed and managed as a unit across the Bering Sea and Aleutian Islands (BSAI). The BSAI arrowtooth flounder female spawning biomass is above B35%; therefore, BSAI arrowtooth flounder are above their MSST (Shotwell et al., 2020a).

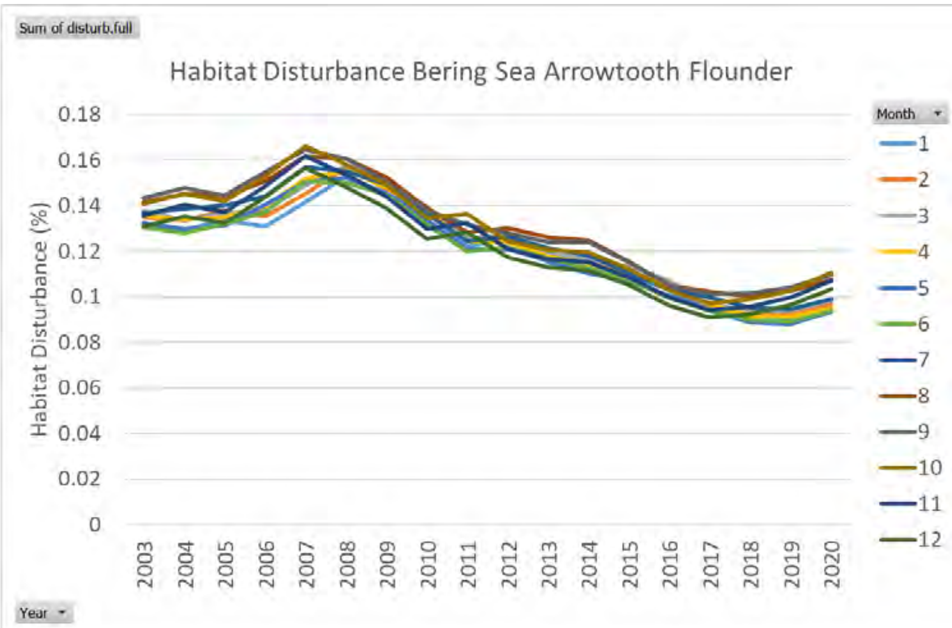
The next step was to determine whether fishing in the CEA resulted in a disturbance in habitat of 10% or greater. Arrowtooth flounder in the Bering Sea were evaluated to have greater than 10% disturbance in habitat in 2020 for the FE model using observed plus unobserved fishing events but not for the observed only model. If the ≥10% threshold of habitat impact is exceeded, correlation analyses are requested between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success. Similar annual trends were observed for the monthly time series of the habitat disturbance percentages for the observed plus unobserved model (Figure 12, top graph). These trends are similar for the observed only model (Figure 12, bottom graph). Therefore, the average habitat disturbance within each year was used for the correlation analyses. Habitat impact was compared with total (feeding) biomass, female spawning stock biomass, and age-1 recruitment estimated over the BSAI based on the stock assessment for those regions (Shotwell et al., 2020a). There is no data to examine growth-to-maturity. We conducted correlation analyses for both the observed plus unobserved model and the observed model. A visual representation of the correlation matrix from this analysis does not indicate any strong relationships between the habitat disturbance models and the stock assessment model output (Figure 13). Additionally, none of the correlation tests were significant (Table 10). The only close to significant relationship was between the observed plus unobserved model and the spawning stock biomass. However, arrowtooth flounder spawning takes place in deep water greater than 400m so the documented habitat impact would be unlikely to affect the areas that arrowtooth flounder select for spawning (DeForest et al. 2014, Blood et al. 2007).

The final step is to consider if any mitigation measures are needed at this time for arrowtooth flounder in the Bering Sea. Fishing effects appear to overall spatially have a low effect on habitat; the majority of fishing effects reduced 2-10% of habitat in the main areas where Bering Sea for arrowtooth flounder are observed on the bottom trawl survey (Shotwell et al., 2020a). The proportion of habitat reduction in the Bering Sea CEA has been less than 10% for much of the recent time series since the 2017 analysis and is below 10% for the observed FE model. Habitat impacts on the available data for Bering Sea arrowtooth flounder growth-to-maturity, spawning success, breeding success and feeding success are not detectable, and mitigation measures are not needed at this time.

Table 10. Results of correlation analysis between annual Bering Sea habitat impact and total biomass, female spawning biomass, and age 3 recruitment from the BSAI stock assessment (Shotwell et al., 2020a).

Correlation Compared with Habitat Disturbance (observed plus unobserved)	**Correlation Coefficient (r)**	**P-value**
Total Biomass	0.136	0.592
Spawning Stock Biomass	-0.447	0.063
Recruitment	-0.081	0.748

Correlation Compared with Habitat Disturbance (observed only)	**Correlation Coefficient (r)**	**P-value**
Total Biomass	0.193	0.444
Spawning Stock Biomass	-0.344	0.162
Recruitment	-0.104	0.681



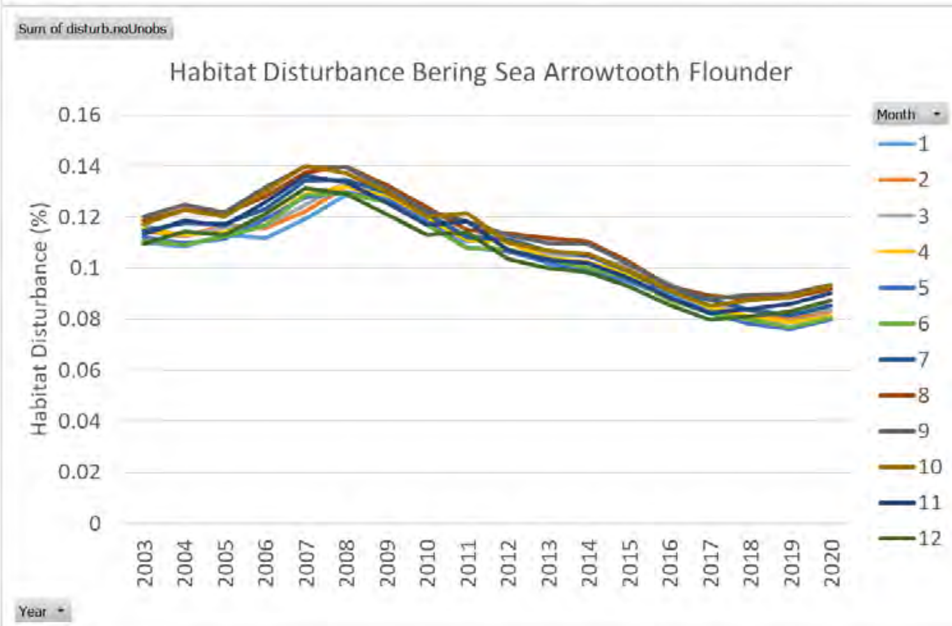


Figure 12. Habitat disturbance by month and year for arrowtooth flounder in the Bering Sea for the observed plus unobserved model (top graph, sum of disturb.full) and observed only model (bottom graph, sum of disturb.noUnobs).

Figure 13. Correlation matrix visual for observed plus unobserved (hd_full) habitat disturbance, observed only (hd_nouob) habitat disturbance, total biomass (tot_biom), spawning stock biomass (ssb), and recruitment (rec) for BSAI arrowtooth flounder.

4.4.2 Atka mackerel

This section provides the FE analysis figures from the FE model and SA's FE assessments for Atka mackerel.

FE analysis figures:

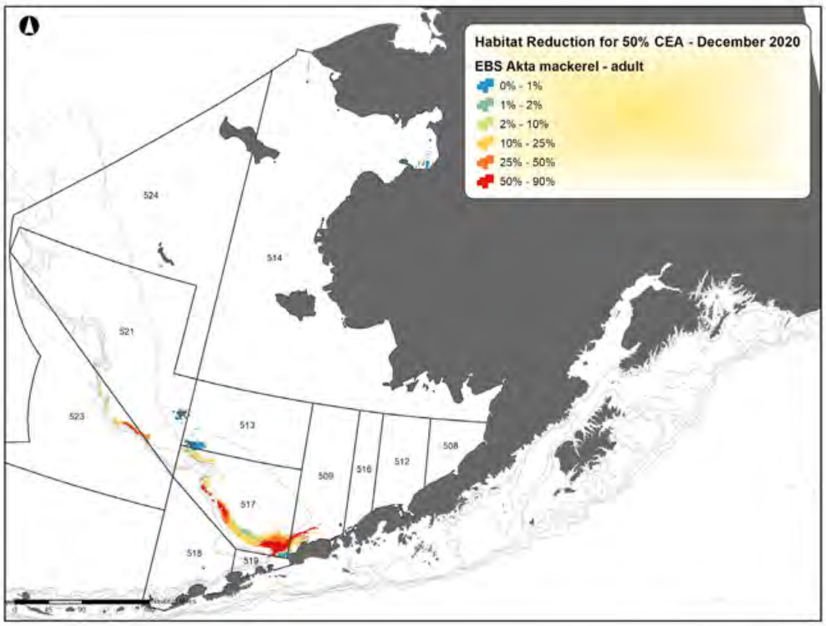


Figure 14. Proportion of habitat disturbance, December 2020 - EBS Atka mackerel.

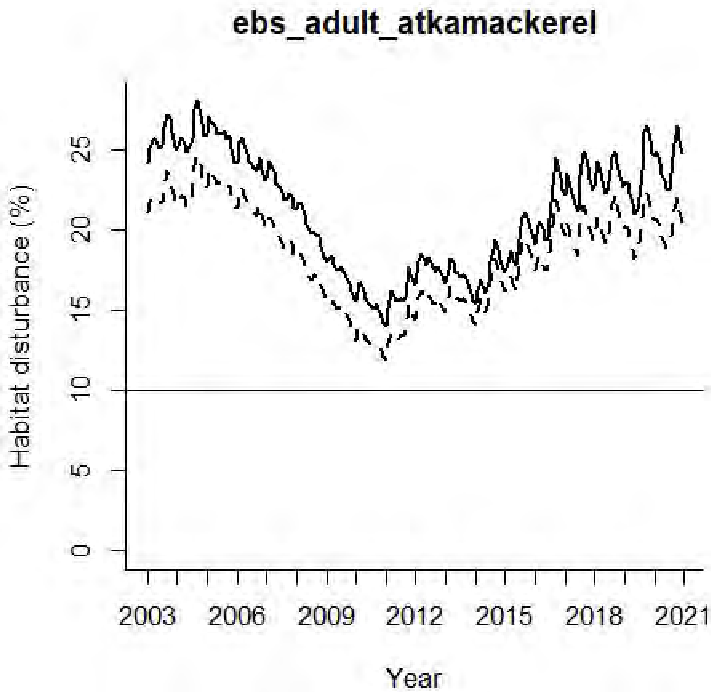


Figure 15. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Atka mackerel.

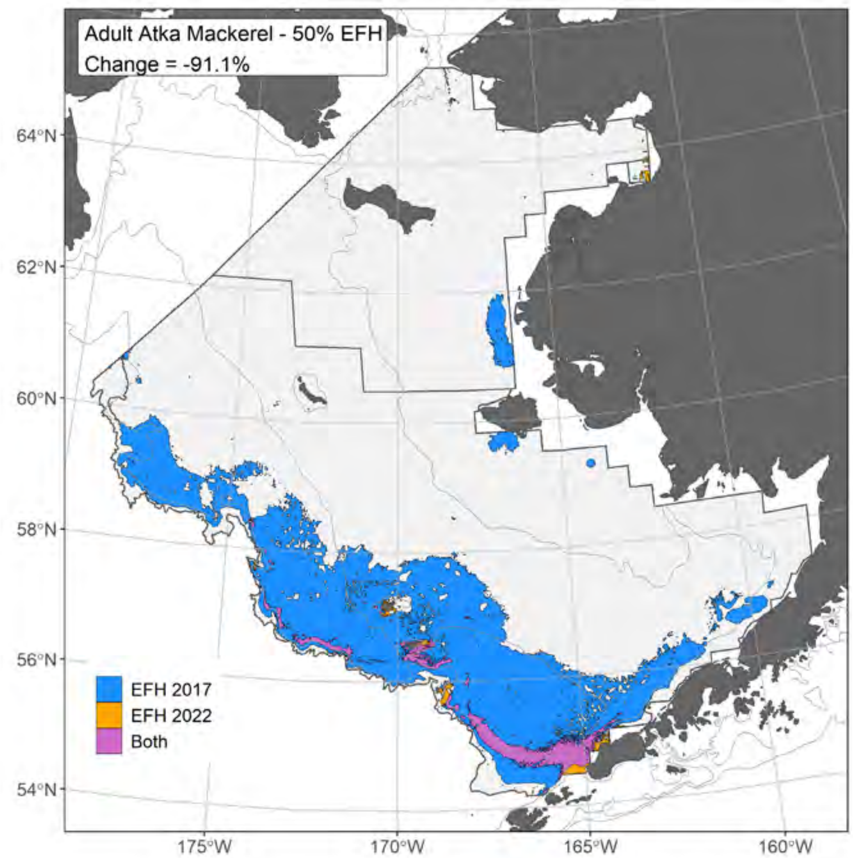


Figure 16. Change in 50% CEA, 2017 compared to 2022 - EBS Atka mackerel.

SA qualitative FE assessment for Atka mackerel:

The EBS represents the margin of Atka mackerel distributions. Their center of abundance is the Aleutian Islands. Observations in the EBS of Atka mackerel are very sparse, and there is no directed fishery for Atka mackerel in the EBS. However, there is a lot of fishing activity in the EBS. Due to the very low occurrences of Atka mackerel in the EBS, it is unlikely that CEA disturbance is >10% as determined by the FE analysis; it is an artifact of the data.

4.4.3 Blackspotted/Rougheye rockfish complex

This section provides the FE analysis figures from the FE model and SA's FE assessments for the blackspotted/rougheye rockfish complex. *Please note that no 2017 EFH map exists for the Blackspotted/Rougheye rockfish complex. Therefore, no Change in 50% EFH CEA comparison of 2017/2022 figure exists for this species.*

FE analysis figures:

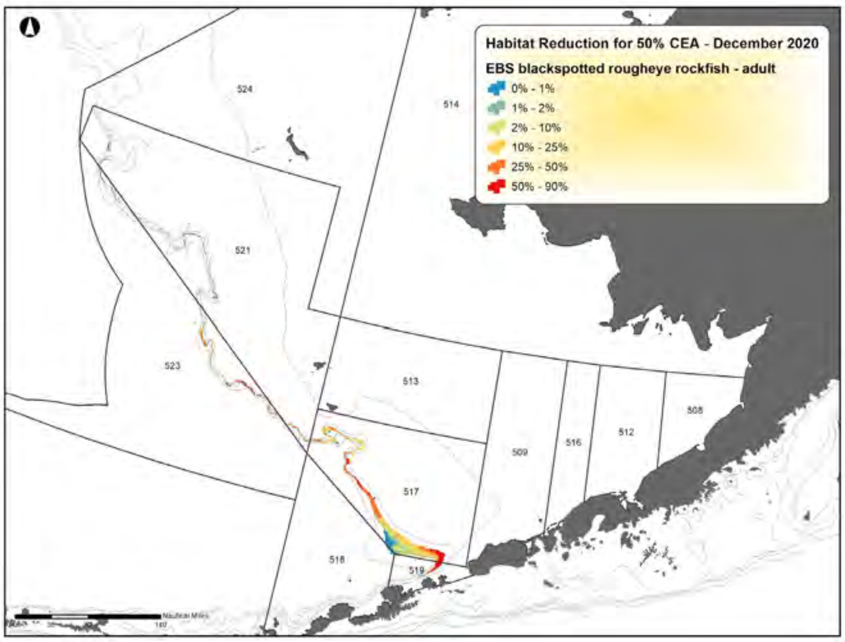


Figure 17. Proportion of habitat disturbance, December 2020 - EBS Blackspotted/Rougheye rockfish complex.

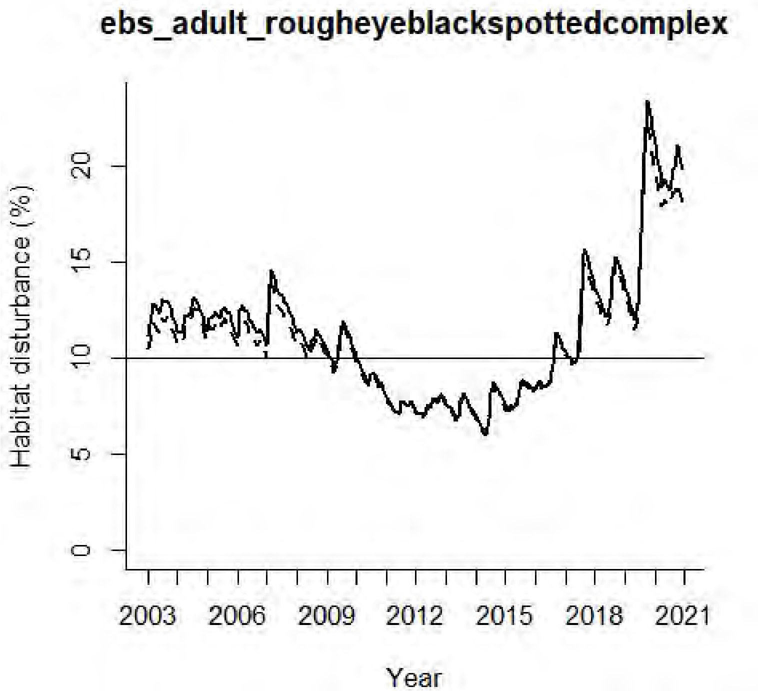


Figure 18. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Blackspotted/Rougheye rockfish complex

SA FE assessment for the blackspotted and rougheye rockfish stock complex:

The FE model was applied to the blackspotted and rougheye rockfish stock complex in the EBS. However, blackspotted/rougheye rockfish are assessed and managed as unit across the BSAI. The BSAI POP stock is above the MSST, as indicted from the estimated 2020 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer et al. 2020).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed and used for analysis. The cumulative effects analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 12.4% in 2004 to 7.5% in 2014, then increased to 20.0% in 2020 (Figure 19).

Limited information is available to estimate trends in life history characteristics for blackspotted/rougheye rockfish along the EBS slope, and time series of age at 50% maturity, recruitment, and spawning distributions are not available for this region. Estimated size at age is available from otoliths sampled in the 2004, 2008, 2010, 2012, and 2016 EBS slope surveys. The correlation between size at age 8 in these survey years and the proportional habitat reduction was estimated; this age was chosen because rapid increases in size at this age may allow detection of the influence of habitat reduction. The estimated correlation coefficient was 0.34 (p-value = 0.58).

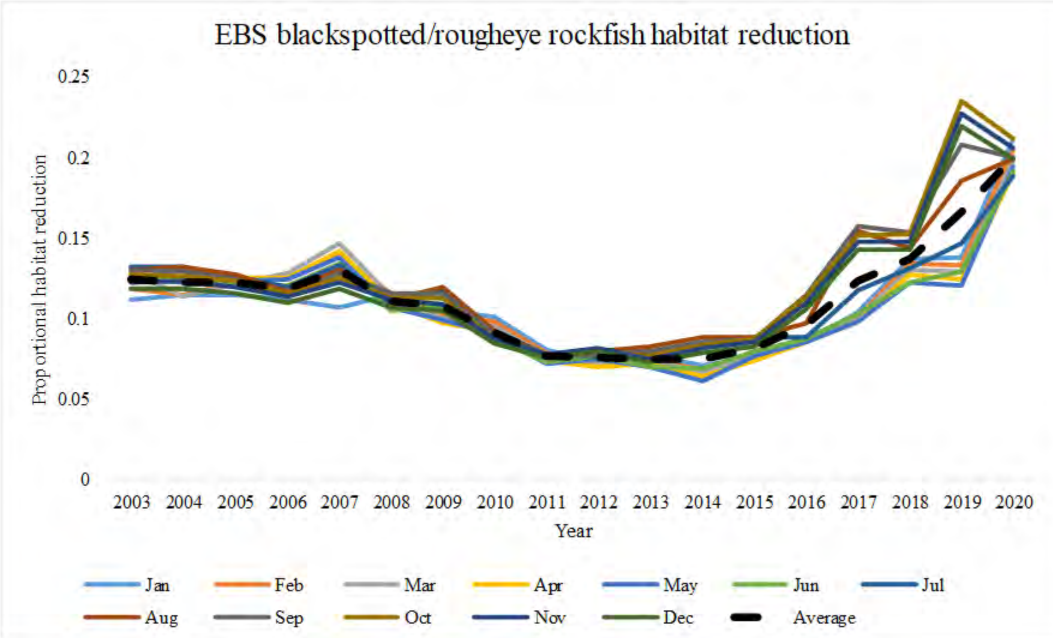


Figure 19. Proportional habitat reduction estimations for the EBS blackspotted/rougheye rockfish complex by month.

4.4.4 Giant octopus

This section provides the FE analysis figures from the FE model and SA's FE assessments for giant octopus.

FE analysis figures:

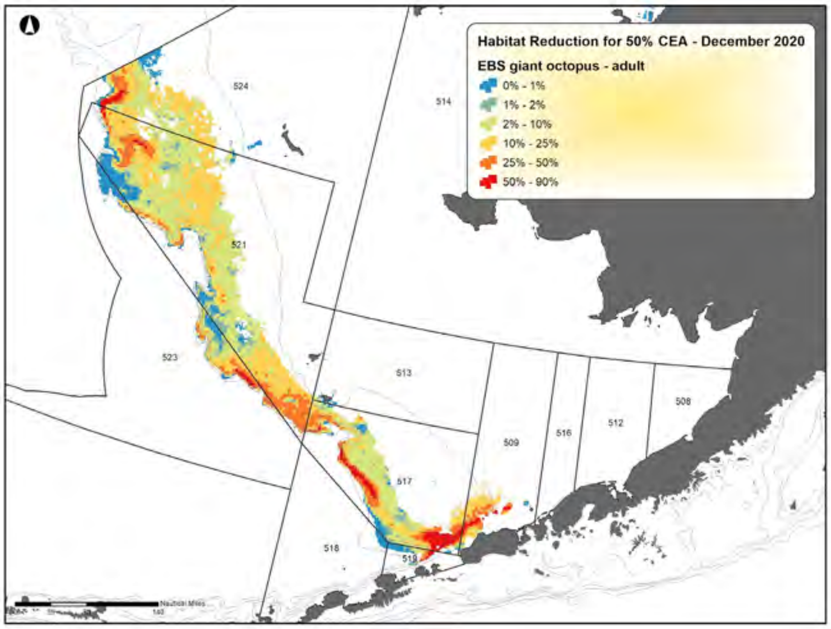


Figure 20. Proportion of habitat disturbance, December 2020 - EBS Giant octopus.

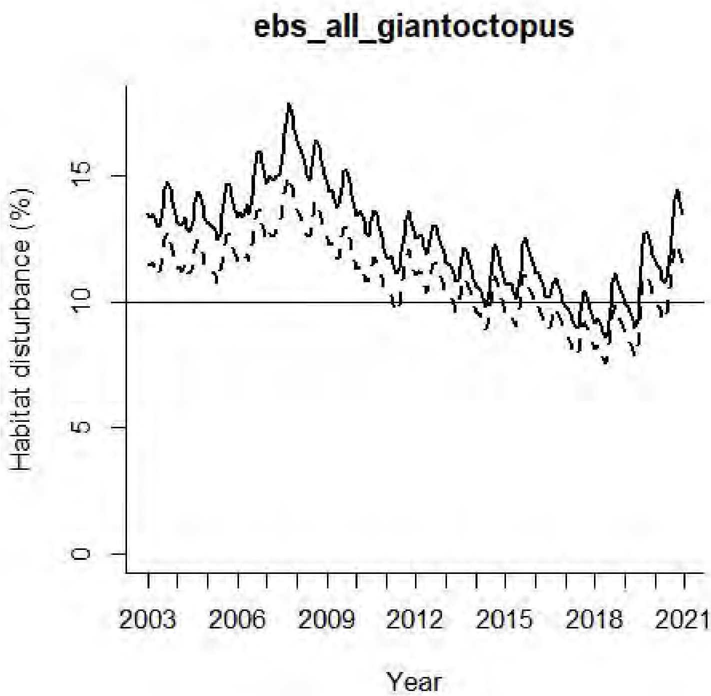


Figure 21. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Giant octopus.

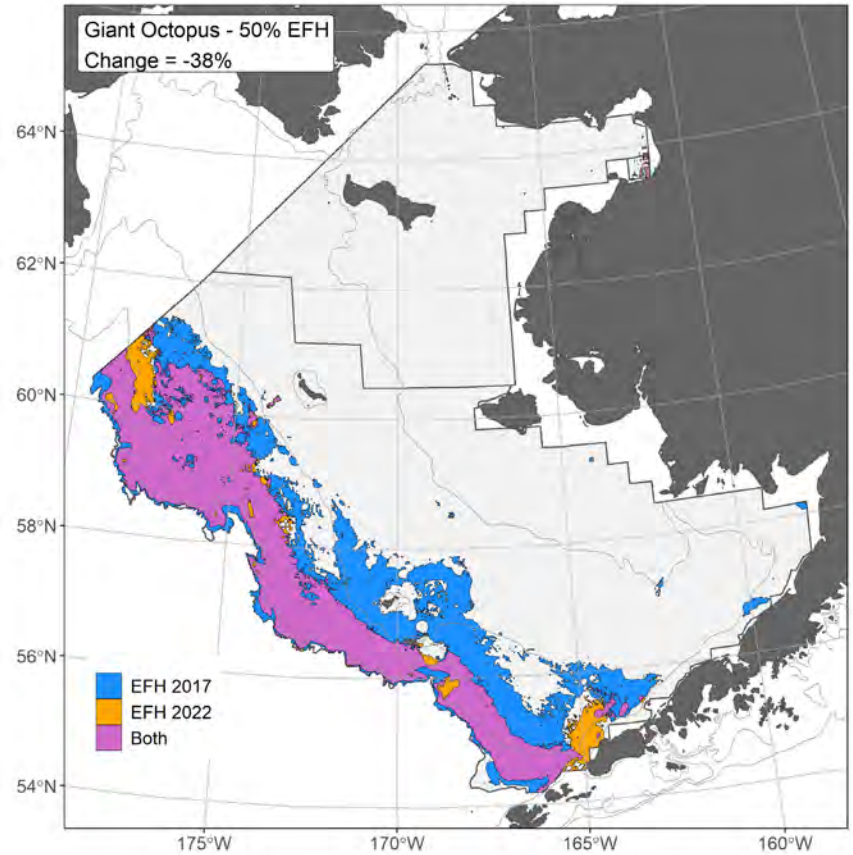


Figure 22. Change in 50% CEA, 2017 compared to 2022 - EBS Giant octopus.

SA qualitative FE assessment for giant octopus:

Observations in the EBS of giant octopus are very sparse, and they are not well sampled by the bottom trawl survey. There is no directed fishery for giant octopus in the EBS. However, there is a lot of fishing activity in the EBS. Due to the very low occurrences of giant octopus in the EBS, the CEA disturbance is likely very low as determined by the FE analysis. It is noted that the data is not sufficient to appropriately conduct a quantitative analysis, but a qualitative assessment supports the <10% CEA disturbance determined by the FE analysis.

4.4.5 Other flatfish complex

This section provides the FE analysis figures from the FE model and SA's FE assessments for dover sole and rex sole.

FE analysis figures for dover sole:

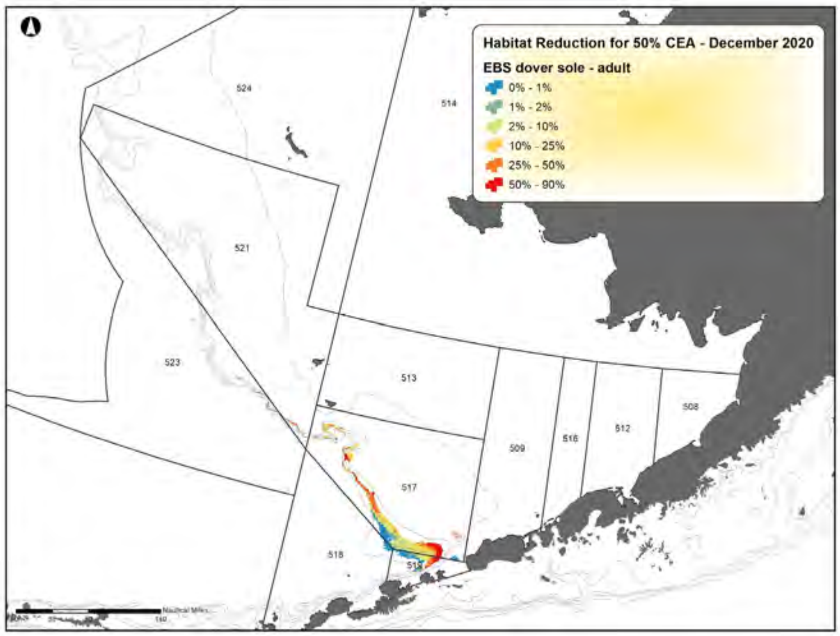


Figure 23. Proportion of habitat disturbance, December 2020 - EBS Dover sole.

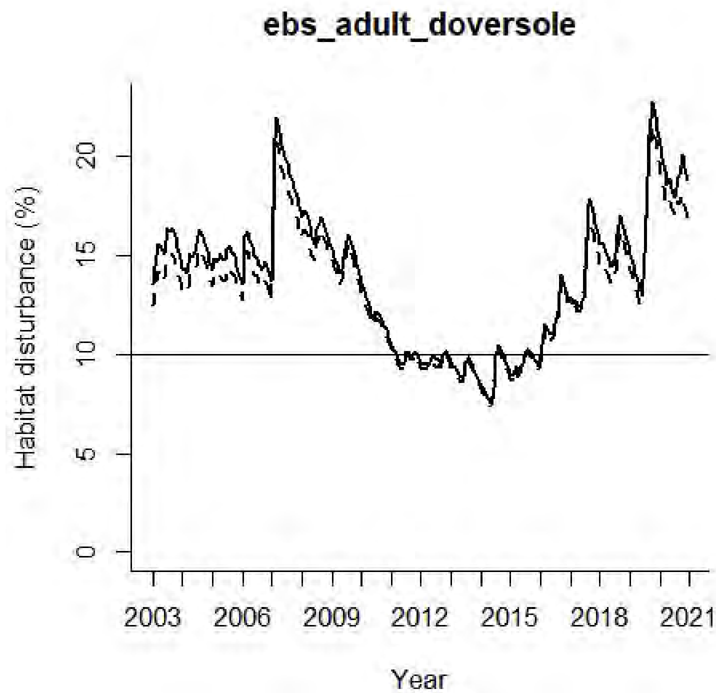


Figure 24. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Dover sole.

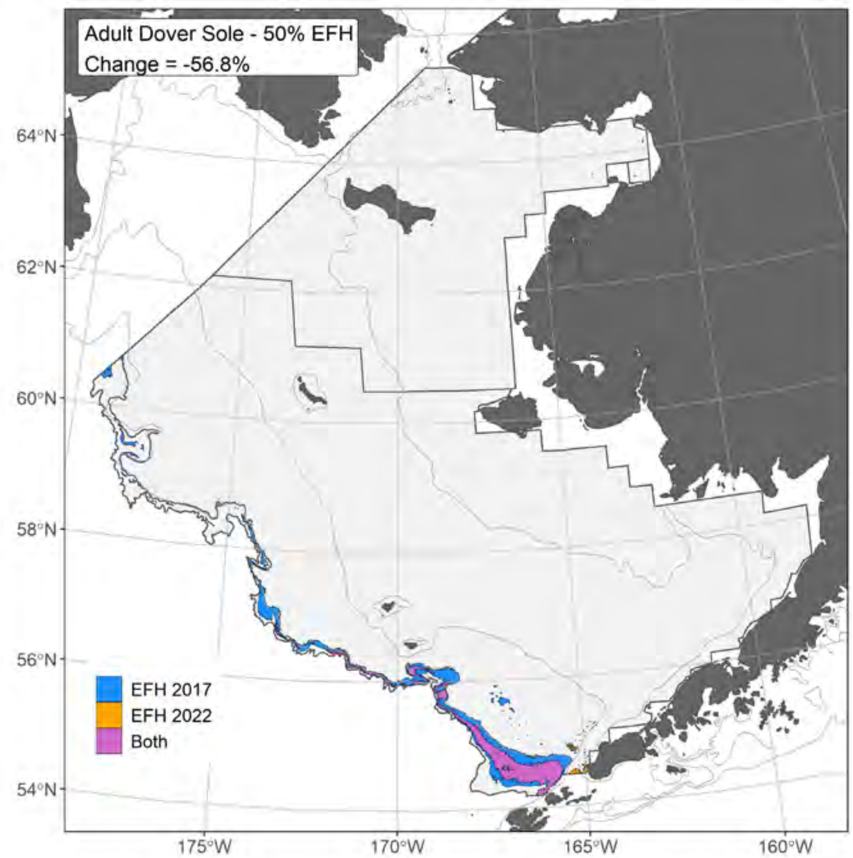


Figure 25. Change in 50% CEA, 2017 compared to 2022 - EBS Dover sole.

FE analysis figures for rex sole:

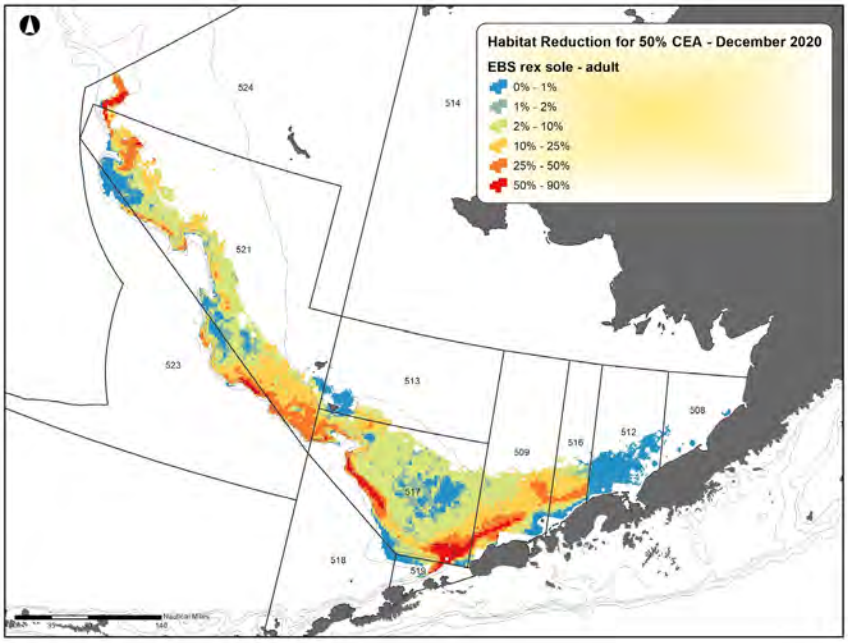


Figure 26. Proportion of habitat disturbance, December 2020 - EBS Rex sole.

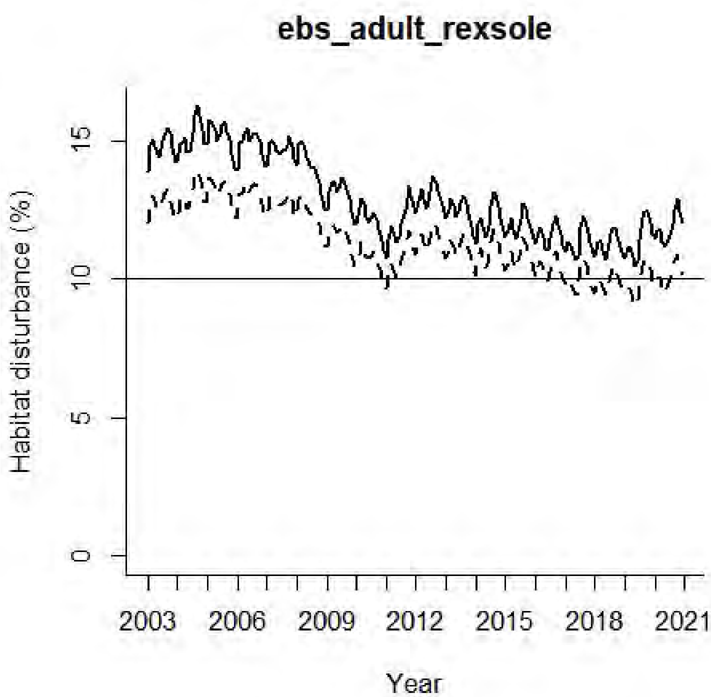


Figure 27. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Rex sole.

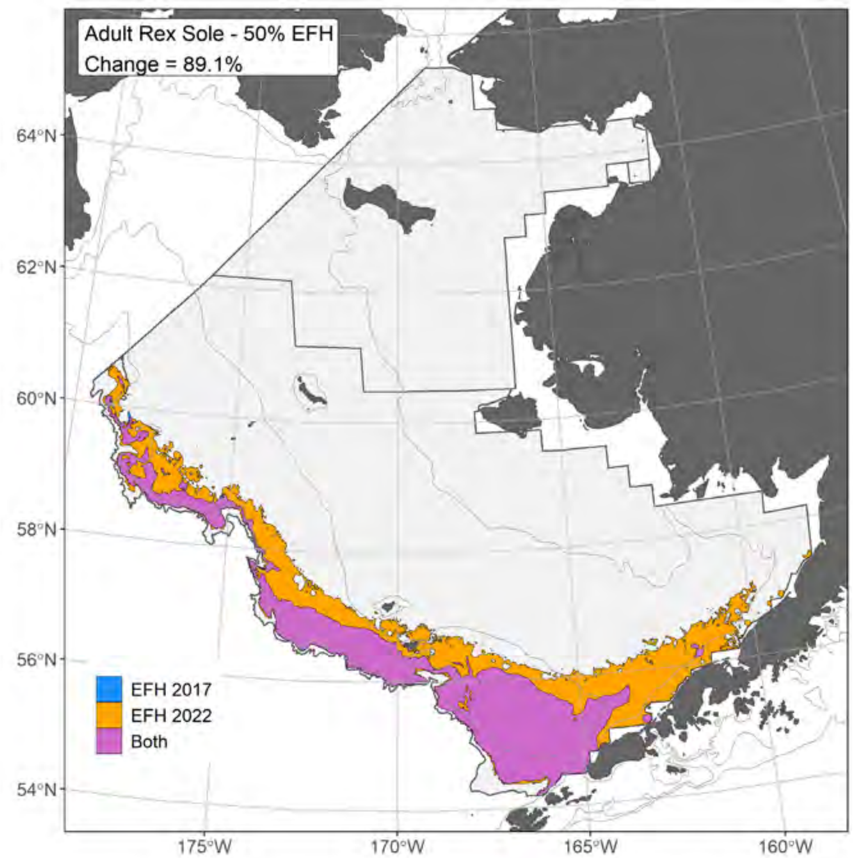


Figure 28. Change in 50% CEA, 2017 compared to 2022 - EBS Rex sole.

SA FE assessment for dover sole and rex sole:

EBS Rex and Dover sole are both component stocks within the Other Flatfish Complex in the EBS. Both species exhibited greater than 10% habitat disturbance within the CEA in recent years, while other stocks within the complex did not. Pearson’s correlation coefficient and p-values from a t-distribution to evaluate significance of correlations were used to assess the relationship between EBS shelf survey biomass (as estimated in the Tier 5 stock assessment) and habitat disturbance in the previous year (averaged over months for each year) for EBS rex and Dover sole (Table 11). The biomass estimates for the EBS slope were excluded, as only 7 data points existed over the period for which habitat disturbance was calculated and the most recent slope survey occurred in 2016 (Figure 29). Pearson’s correlation coefficient was positive for both species, indicating that biomass increased with increased habitat disturbance. The correlation was significant (< 0.05) for EBS Dover sole. However, concern is low for this species because biomass did not decline with increased habitat disturbance.

Table 11. Pearson’s correlation coefficient and the p-value from a test of significance of the correlation based on a t-distribution, comparing estimated survey biomass of EBS rex and Dover sole to habitat disturbance in the previous year, averaged over months within each year, for each species. The years 2003-2021 were included in the analysis. Additional figures are included below.

Species	Pearson's correlation coefficient	p-value
EBS rex sole	0.261	0.311
EBS Dover sole	0.493	0.044

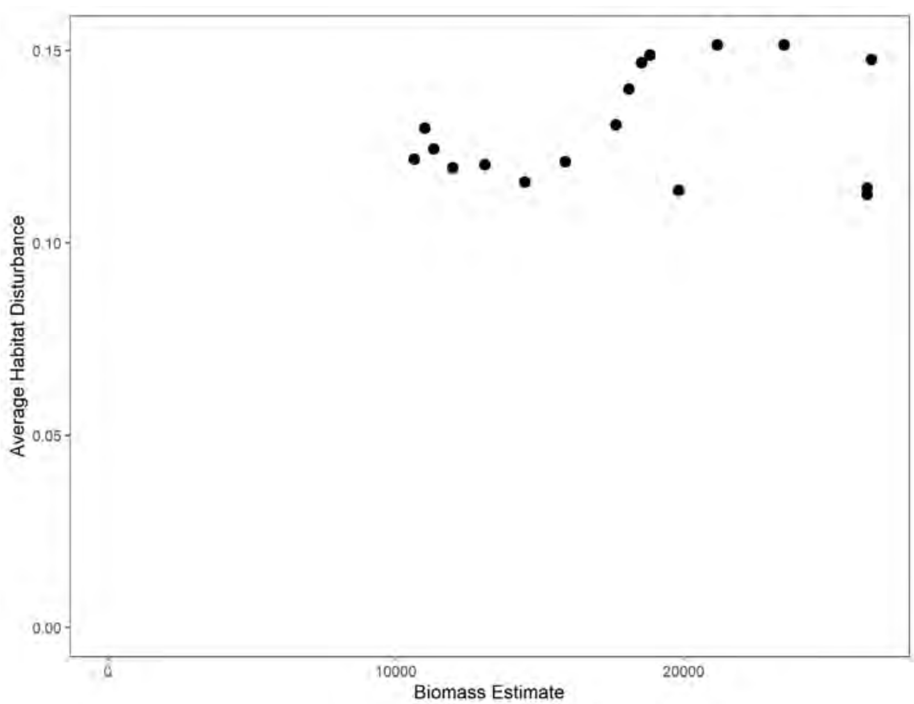


Figure 29. The biomass estimate for EBS rex sole from the most recent Tier 5 assessment (x-axis) plotted against habitat disturbance (averaged over months of the year) for EBS rex sole in the previous year.

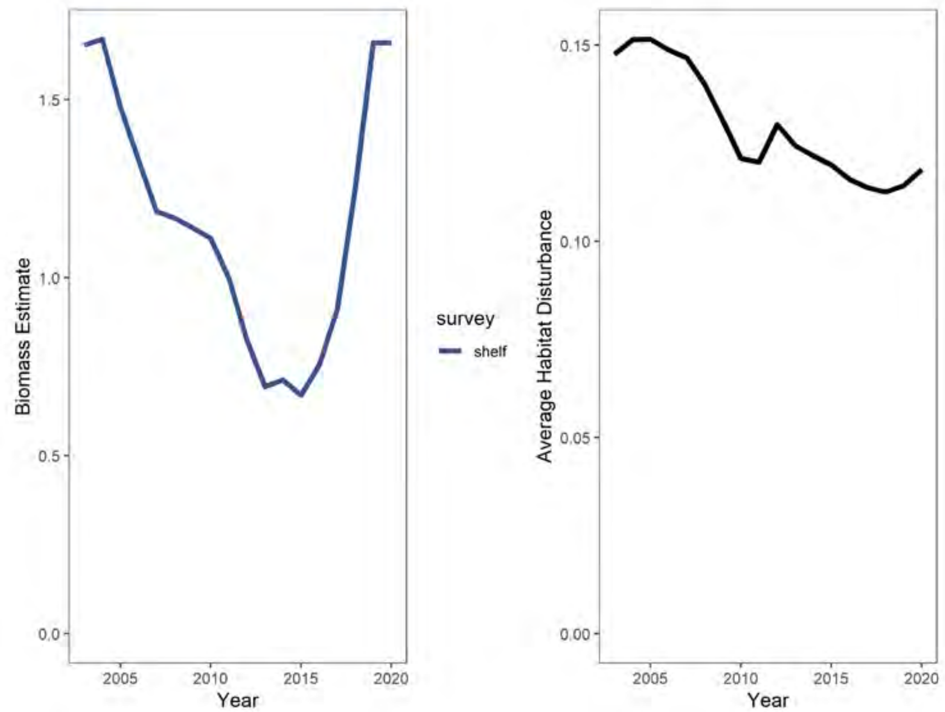


Figure 30. EBS rex sole biomass over time (as estimated in the 2020 Tier 5 assessment; left panel) and habitat disturbance over time (averaged over months within each year; right panel).

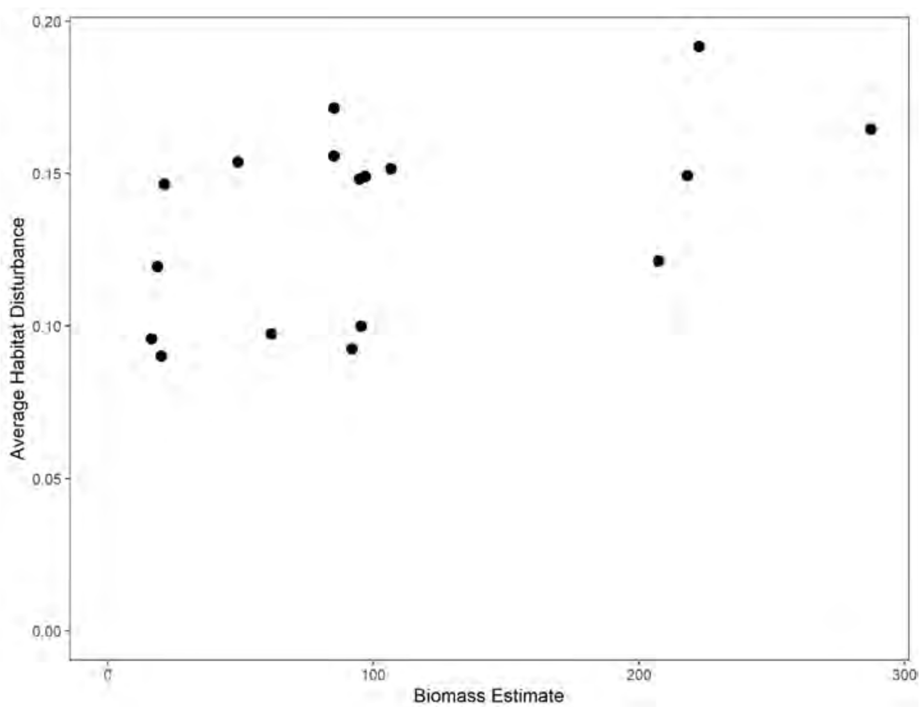


Figure 31. The biomass estimate for EBS Dover sole from the most recent Tier 5 assessment (x-axis) plotted against habitat disturbance (averaged over months of the year) for EBS rex sole in the previous year.

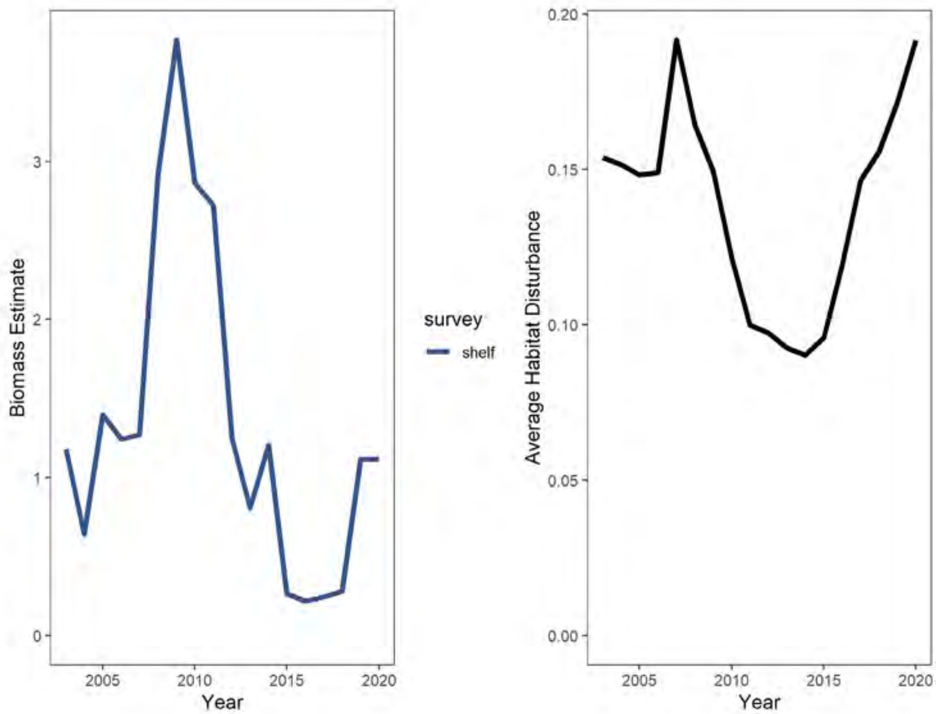


Figure 32. EBS Dover sole biomass over time (as estimated in the 2020 Tier 5 assessment; left panel) and habitat disturbance over time (averaged over months within each year; right panel).

4.4.6 Northern rockfish

This section provides the FE analysis figures from the FE model and SA's FE assessments for Northern rockfish.

FE analysis figures:

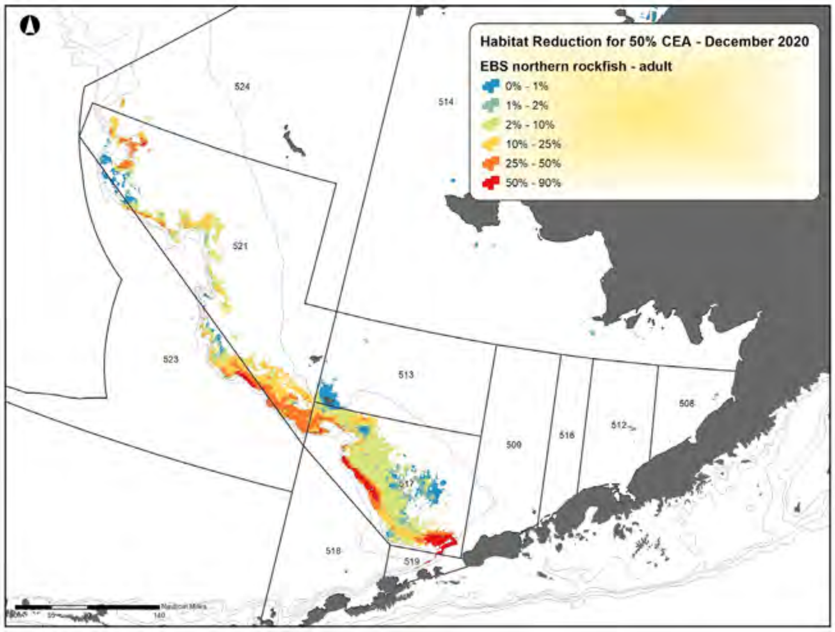


Figure 33. Proportion of habitat disturbance, December 2020 - EBS Northern rockfish.

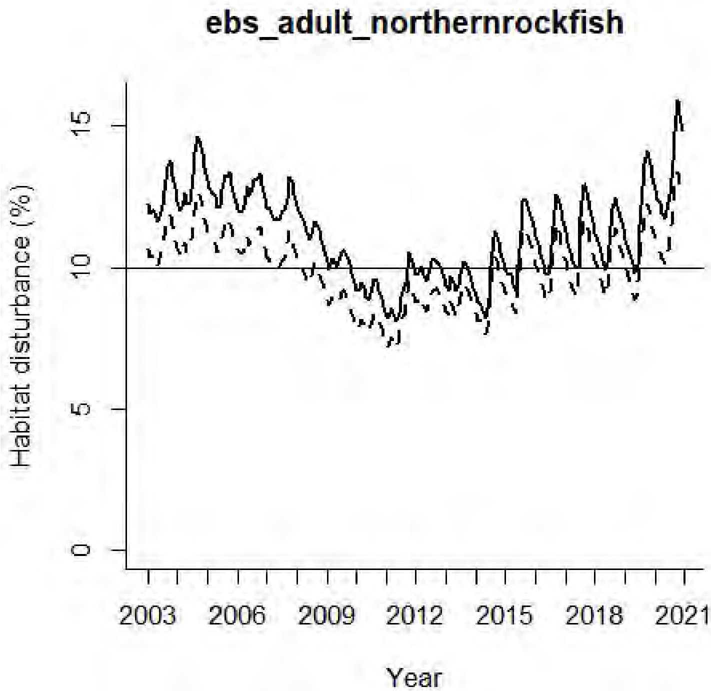


Figure 34. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Northern rockfish.

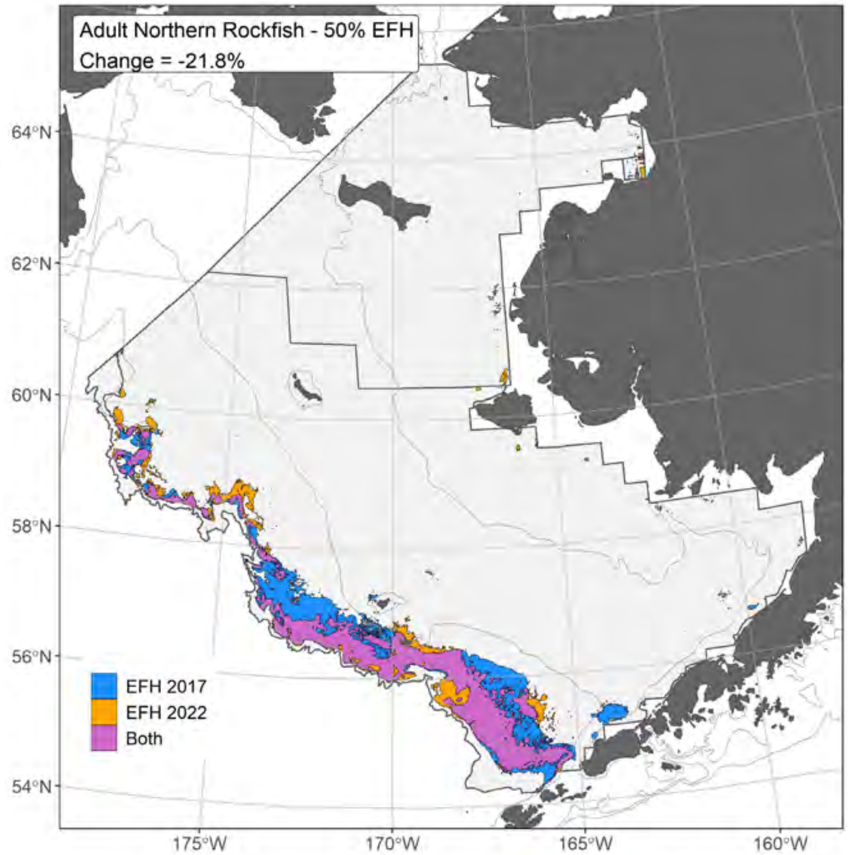


Figure 35. Change in 50% CEA, 2017 compared to 2022 - EBS Northern rockfish.

SA FE assessment for northern rockfish:

The FE model was applied to northern rockfish in the eastern Bering Sea. However, northern rockfish are assessed and managed as a unit across the BSAI. The BSAI northern rockfish stock is above the MSST, as indicated from the estimated 2021 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer and Ianelli 2021).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed. The cumulative effects analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 13.2% in 2004 to 9.1% in 2011, then increased to 13.3% in 2020 (Figure 36).

Although northern rockfish are a slope species, they are not commonly observed in the EBS slope survey. Typically, northern rockfish have been observed in a very small number of hauls (i.e., <= 6) per survey, which has led to very small estimates of biomass (ranging from 3 to 42 tons) compared to estimates of over 200,000 t in the AI slope survey. The coefficients of variation of the EBS slope survey biomass estimates range from 0.38 to 1. Otoliths are not available for northern rockfish in the EBS, and time series of life-histories indices such as age at 50% maturity, and size at age are not available. The rarity of northern rockfish in the EBS, and absence of life-history information, precludes meaningful analysis of correlations between life-history indices and estimates of habitat reduction.

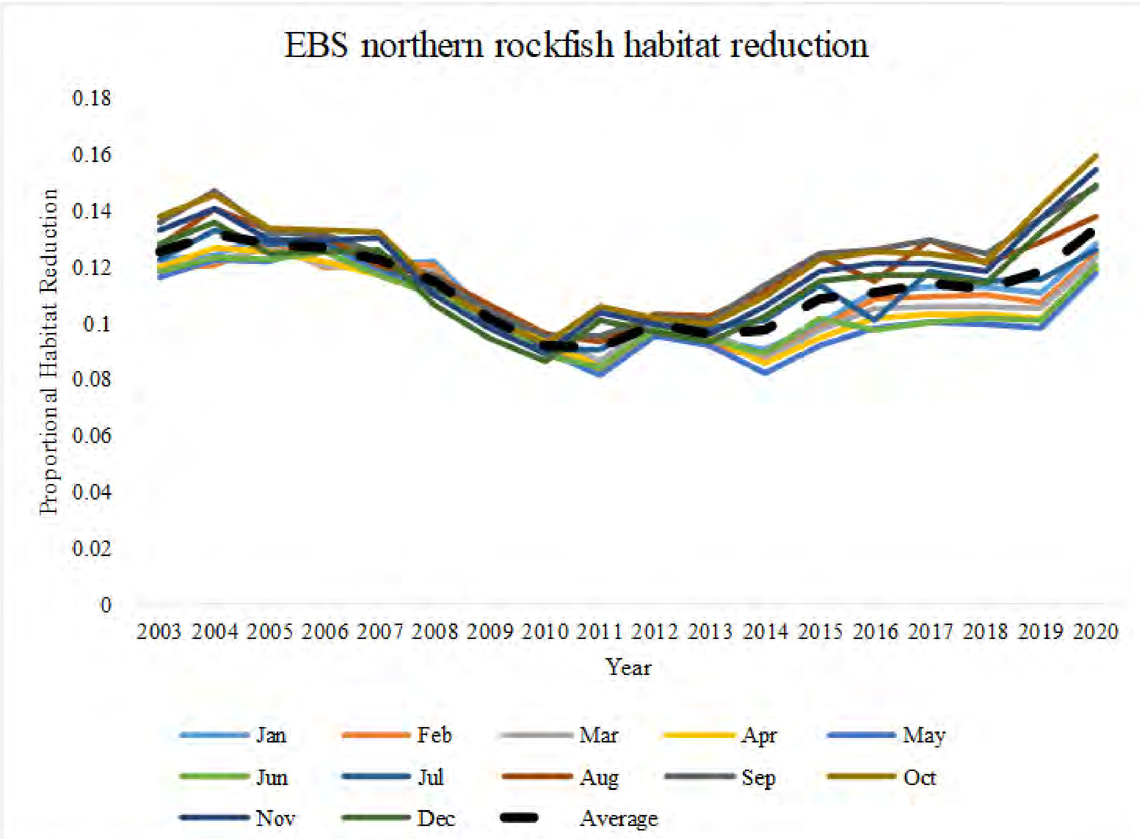


Figure 36. Proportional habitat reduction estimations for EBS northern rockfish by month.

4.4.7 Pacific ocean perch

This section provides the FE analysis figures from the FE model and SA's FE assessments for Pacific ocean perch.

FE analysis figures:

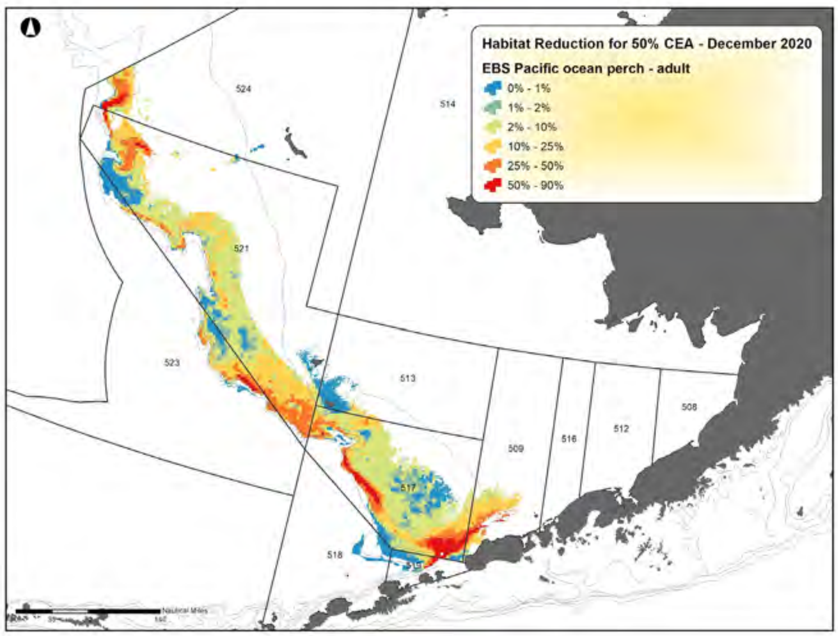


Figure 37. Proportion of habitat disturbance, December 2020 - EBS Pacific ocean perch.

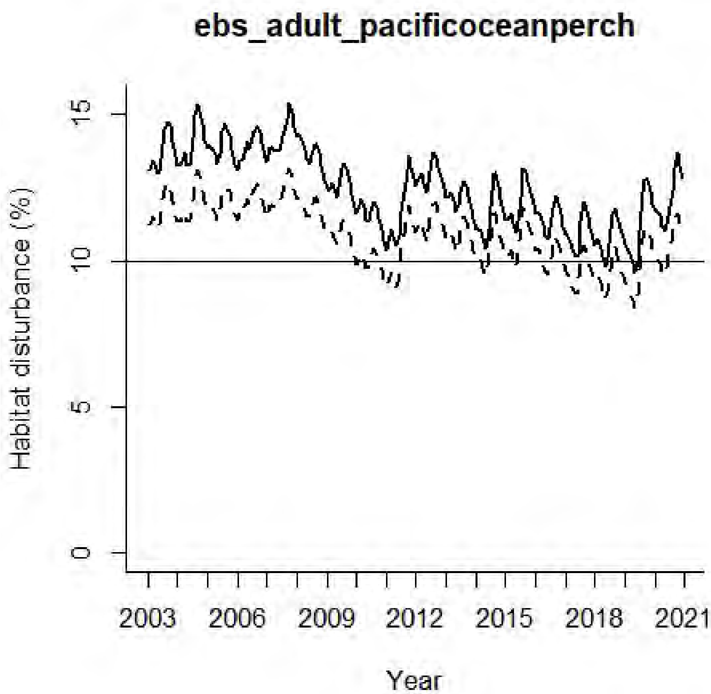


Figure 38. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Pacific ocean perch.

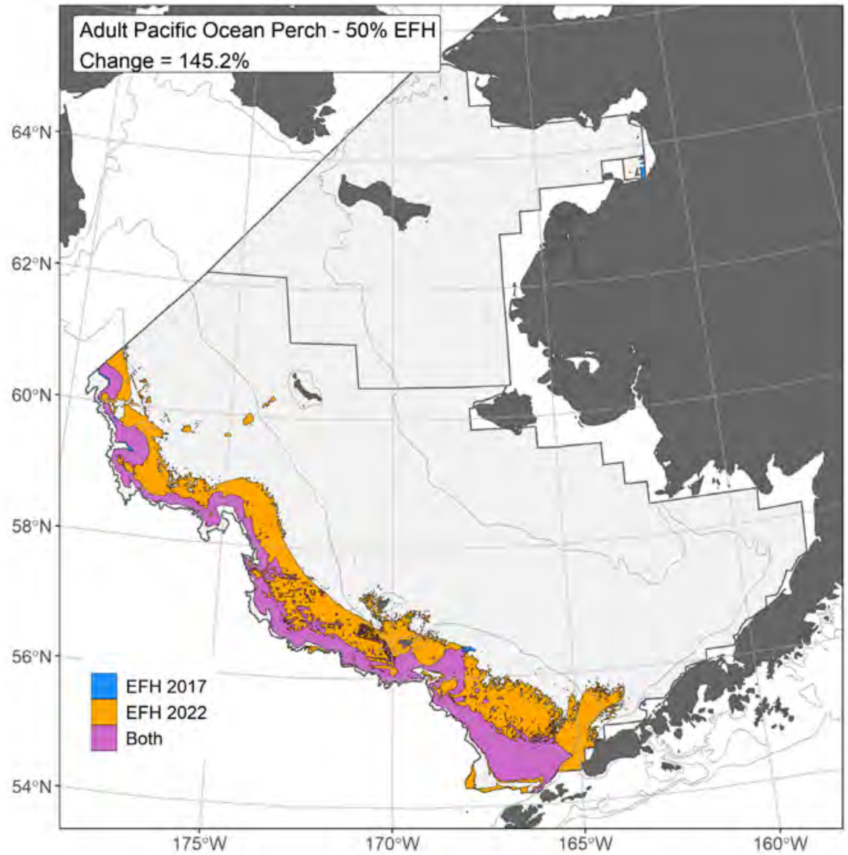


Figure 39. Change in 50% CEA, 2017 compared to 2022 - EBS Pacific ocean perch.

SA FE assessment for Pacific ocean perch:
The fishing effects model was applied to POP in the eastern Bering Sea. However, POP are assessed and managed as unit across the BSAI. The BSAI POP stock is above the MSST, as indicted from the estimated 2020 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer and Ianelli 2020).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed and used for analysis. The cumulative effects analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 13.6% in 2003 to 12.1% in 2020 (Figure 40).

Limited information is available to estimate trends in life history characteristics for POP along the EBS slope, and time series of age at 50% maturity, recruitment, and spawning distributions are not available for this region. Estimated size at age is available from otoliths sampled in the 2004, 2008, 2010, 2012, and 2016 EBS slope surveys. The correlation between size at age 8 in these survey years and the proportional habitat reduction was estimated; this age was chosen because rapid increases in size at this age may allow detection of the influence of habitat reduction. The estimated correlation coefficient was -0.26 (p-value = 0.67). In addition, the correlation between total biomass from the 2020 BSAI model and proportional habitat reduction for the year 2003 – 2020 was conducted. This correlation analysis assumes that the estimated total biomass is proportional to the area occupied of the "feeding distribution", and also that the temporal trends in total biomass from the BSAI assessment (which is largely driven by AI data) is similar to the trends in total biomass in the EBS region. The estimated correlation between estimated total biomass and proportional habitat reduction was -0.27, with a p-value of 0.27.

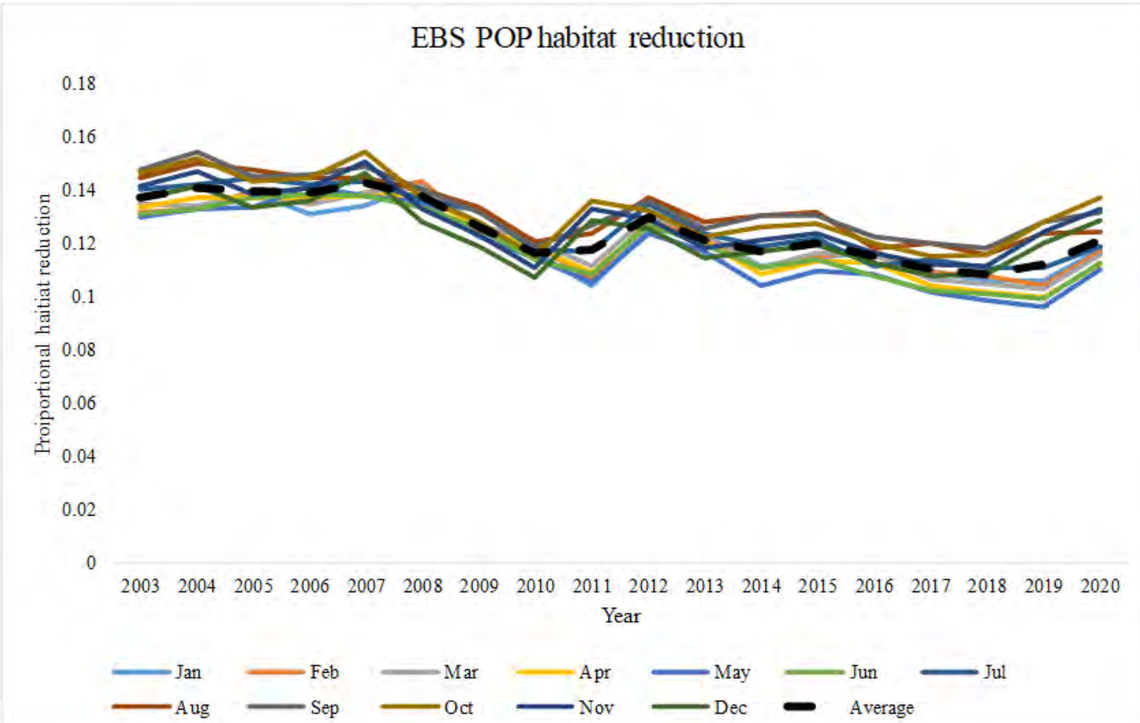


Figure 40. Proportional habitat reduction estimations for EBS Pacific ocean perch by month.

4.4.8 Sablefish

This section provides the FE analysis figures from the FE model and SA's FE assessments for sablefish.

FE analysis figures:

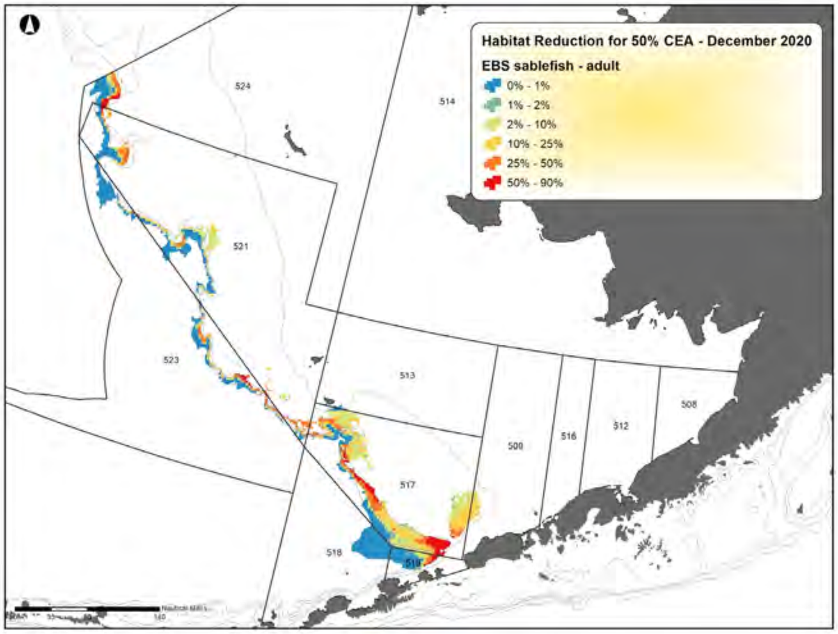


Figure 41. Proportion of habitat disturbance, December 2020 - EBS Sablefish.

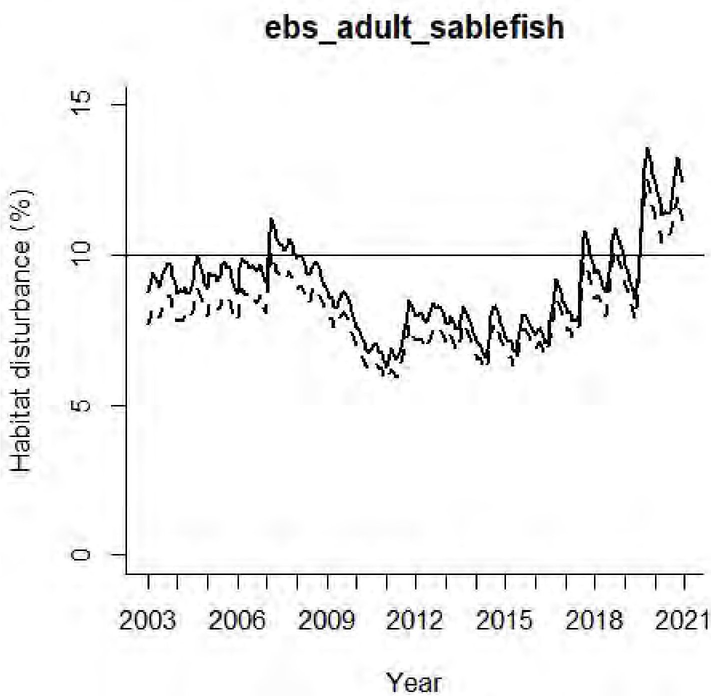


Figure 42. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Sablefish.

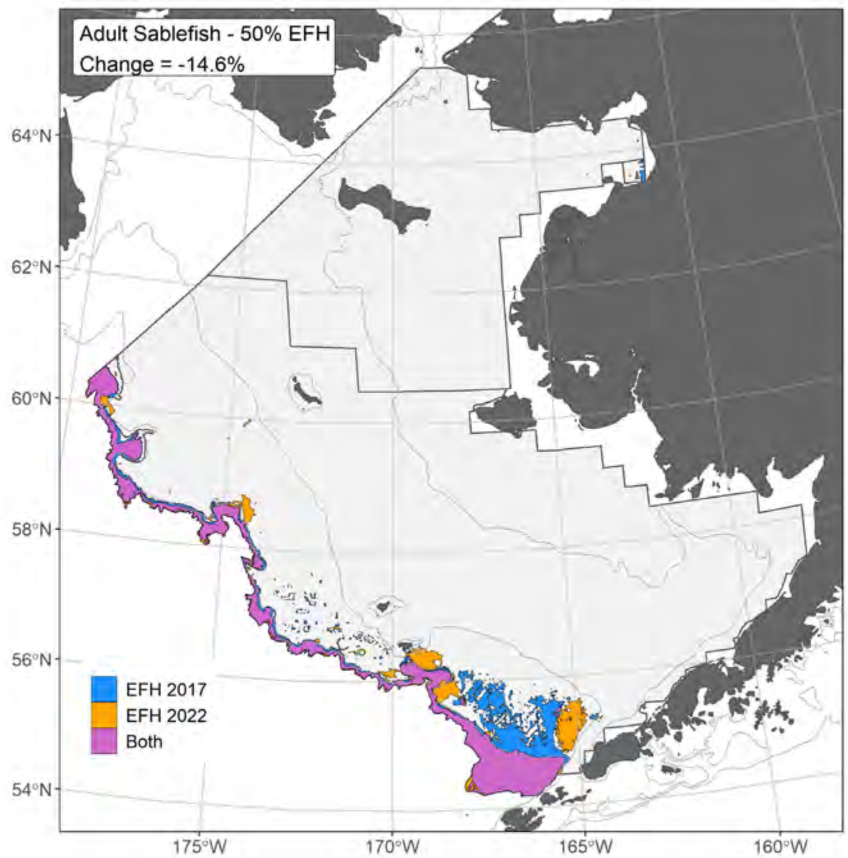


Figure 43. Change in 50% CEA, 2017 compared to 2022 - EBS Sablefish

SA FE assessment for sablefish:

The EBS shelf is likely a nursery area for juvenile sablefish when large year classes are present. As noted in the FE time series, the 10% threshold has only been exceeded in a few recent years and once in the late 2000s, all of which are associated with large year classes. Fishery effects tend to increase when large numbers of juveniles are present and interact with trawl gears in the EBS. These events include increased disturbance in the late 2000s following moderately strong late 1990s year classes and over the last ~5 years following a series of unprecedented 2014, 2016, and 2018 year classes. Analysis as part of the 2020 and 2021 sablefish SAFEs indicated that the impact of BS fisheries on the sablefish population were generally limited to juvenile fish and unlikely to exceed the impact of natural mortality in the region. Thus, it is unlikely that fishery effects have a large impact on either the juvenile sablefish in the BS or the entire Alaska wide population (see Appendix 3D of the sablefish SAFE, Goethel et al. 2020). Moreover, given the high mobility of sablefish and movement among management areas, it is likely that EFH should be viewed from a population-wide instead of localized outlook (i.e., because sablefish frequently move long distances, it is unlikely that disturbance in one localized area will broadly impact the population).

When considered in combination with EFH disturbance in the AI and GOA, it is unlikely that there is a strong impact on sablefish (i.e., population-wide CEA disturbance is likely <10%). However, the impact of fishery disturbance on potential sablefish juvenile nursery areas in the

EBS should not be discredited. There is a clear overlap between fishing activity and areas of high sablefish abundance in the EBS, particularly following large recruitment events, and these interactions should be carefully monitored along with levels of juvenile sablefish bycatch in these fleets. Increased effort to understand sablefish life history patterns, including spawning locations, larval dispersal patterns, juvenile nursery areas, and adult migration pathways, would enable a more holistic and informed evaluation of critical habitat areas along with the potential influence of fishing activities on EFH. Despite extensive adult tagging on the longline survey over the last ~30 years, many knowledge gaps remain regarding seasonal and spawning migrations (and associated habitat), while very little is known about ontogenetic movement patterns from young-of-the-year through adult stages.

4.4.9 Shortraker rockfish

This section provides the FE analysis figures from the FE model and SA’s FE assessments for shortraker rockfish.

FE analysis figures:

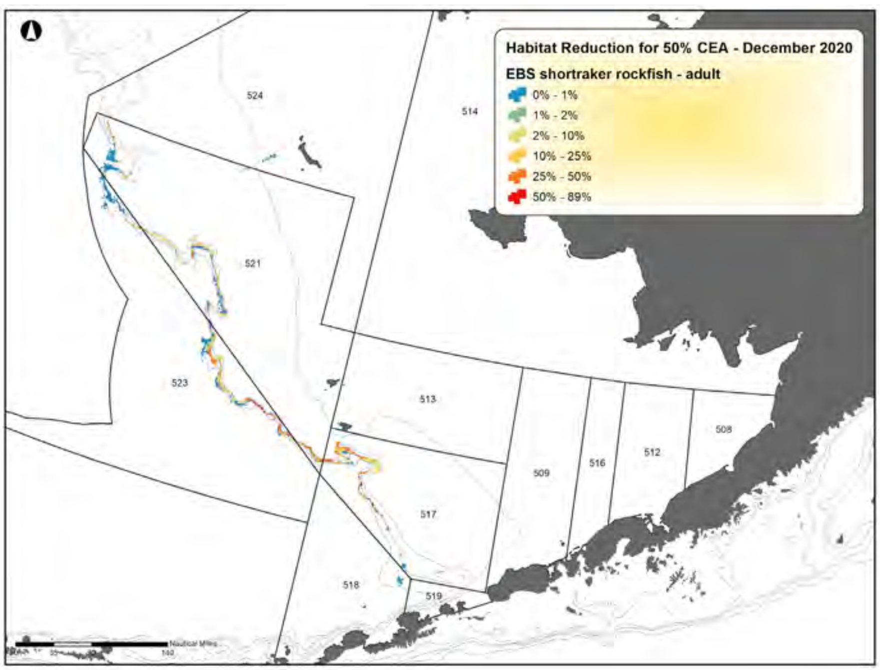


Figure 44. Proportion of habitat disturbance, December 2020 - EBS Shortraker rockfish.

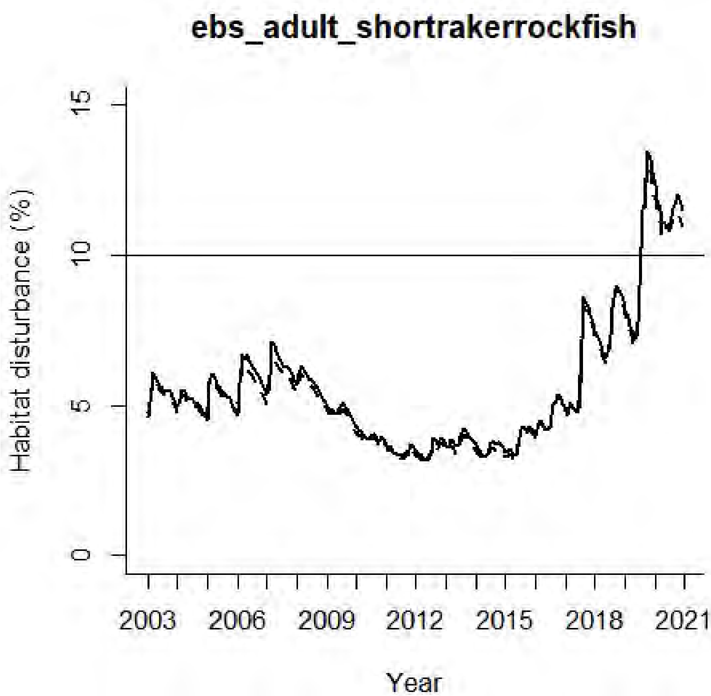


Figure 45. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Shortraker rockfish.

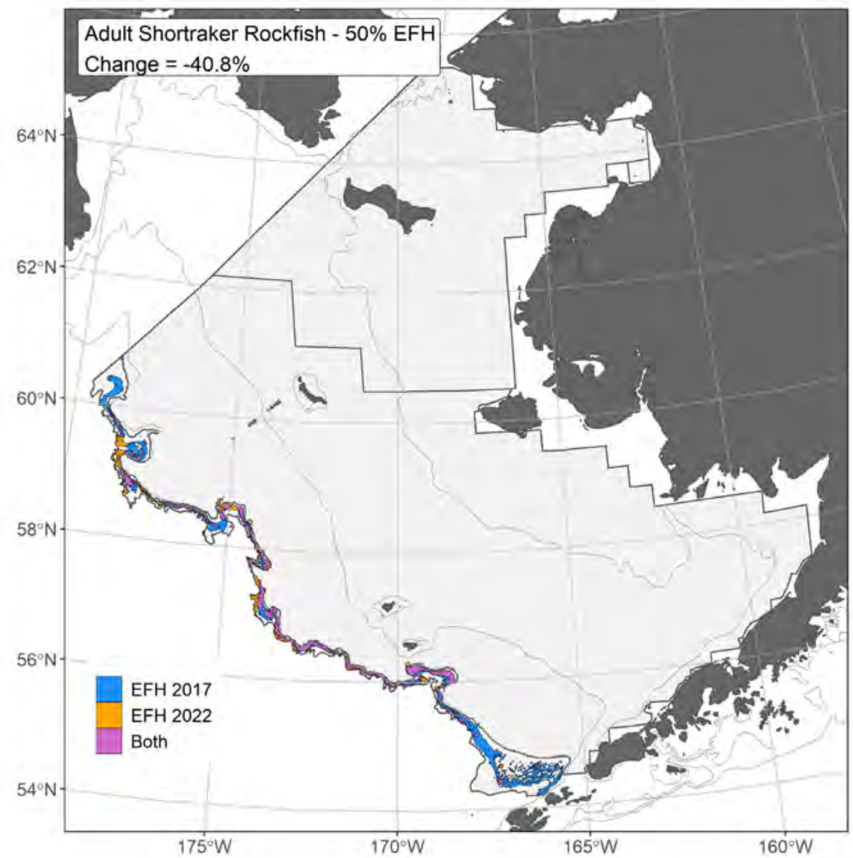


Figure 46. Change in 50% CEA, 2017 compared to 2022 – EBS.

SA FE Assessment for shortraker rockfish:

The impacts of commercial fishing on EFH are of interest as part of the EFH 5-year review. Similar to 2017, the 2022 FE model is run using the upper 50th percentile CEA from summer species distribution maps for adults or combined life stages for a given fish stock. Data to support this model are from the RACE GAP bottom trawl survey and various environmental covariates (SDM EFH Discussion Paper). Maps and habitat disturbance output provided from the FE model were used to assess the effects of fishing on Bering Sea shortraker rockfish (see Chapter 3).

A three-tiered approach is used for evaluating effects of fishing as suggested by the SSC EFH subcommittee. The first step of the evaluation was to determine whether Bering Sea shortraker rockfish are above their MSST. Shortraker in the Bering Sea are assessed and managed as a unit across the BSAI and are considered a Tier 5 stock (Shotwell et al., 2020b). As such, it is not possible to make a status determination of whether the stock is above or below its MSST.

The next step was to determine whether fishing in the CEA resulted in a disturbance in habitat of 10% or greater. Shortraker rockfish in the Bering Sea were evaluated to have greater than 10% disturbance in habitat in 2020 for the FE model for both the observed plus unobserved fishing events and the observed only model. If the 10% threshold of habitat impact is exceeded, correlation analyses are requested between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success. Similar annual trends were observed for the monthly time series of the habitat disturbance percentages for the observed plus unobserved model (Figure 47, top graph). The monthly trends somewhat diverge for the later in the year months (8 through 12) from 2016 to 2019; however, the monthly habitat disturbance percentages converge in 2020. These trends are similar for the observed only model (Figure 47, bottom graph). Therefore, the average habitat disturbance within each year was used for the correlation analyses. Data to examine growth trends for this stock are limited. Body condition (e.g., length-weight residuals) were considered but samples sizes were small (~275 on average per year), only available from the EBS slope survey (stopped in 2016), and limited in spatial coverage (primarily in slope subareas 3 and 4, Pribilof to Zhemchug canyon). Size-at-age and maturity data are not available for this stock because no validated method for aging currently exists (Kastelle et al., 2020). Therefore, habitat impact was compared with total (feeding) biomass as estimated by the random effects model and the relative population numbers (RPN) from the longline survey over the Bering Sea area based on the stock assessment for those regions (Shotwell et al., 2020b). We conducted correlation analyses for both the observed plus unobserved model and the observed model only. A visual representation of the correlation matrix from this analysis does not indicate any strong relationships between the habitat disturbance models and the random effects model or the RPN from the longline survey (Figure 48). Additionally, none of the correlation tests were significant (Table 11).

The final step is to consider if any mitigation measures are needed at this time for shortraker rockfish in the Bering Sea. Fishing effects appear to overall spatially have a low effect on habitat in the northern part of the Bering Sea slope area with more of the impact occurring in the Pribilof Canyon area. Since the AFSC longline survey data is not included in this analysis, it is unclear where the majority of shortraker rockfish would occur were the two data sources combined (e.g., hotspots may shift with addition of new data even if total area coverage does not). The proportion of habitat reduction in the Bering Sea CEA has been less than 10% for much of the recent time series since the 2017 analysis and only recently went above the 10% value starting in August 2019 and is now turning to a downward trajectory. Habitat impacts on the available data for Bering Sea shortraker rockfish growth-to-maturity, spawning success, breeding success and feeding success are not detectable, and mitigation measures are not needed at this time. However, shortraker rockfish are thought to be extremely long-lived (estimated ages equal to ~150 years, Munk, 2001) with late maturation (estimates of length-at-50% maturity equal to ~45 cm, McDermott, 1994) and so could be considered a low productivity species that may be more vulnerable to fishing effect or habitat disturbance. Although there is insufficient evidence at this time to elevate concern for this species, we suggested continued monitoring and research into shortraker rockfish life history, particularly in the early life history as juveniles are very seldom caught in any sampling gear (Shotwell et al., 2020b, Data Gaps and Research Priorities section).

Table 12. Results of correlation analysis between annual Bering Sea habitat impact and total biomass from the random effects model and longline survey relative population numbers (RPN) in the Bering Sea from the BSAI stock assessment (Shotwell et al., 2020b).

Correlation Compared with Habitat Disturbance (observed plus unobserved)	**Correlation Coefficient (r)**	**P-value**
Total biomass from random effects model	0.155	0.539
Longline RPN	0.246	0.325
Correlation Compared with Habitat Disturbance (observed only)	**Correlation Coefficient (r)**	**P-value**
Total biomass from random effects model	0.153	0.543
Longline RPN	0.251	0.314

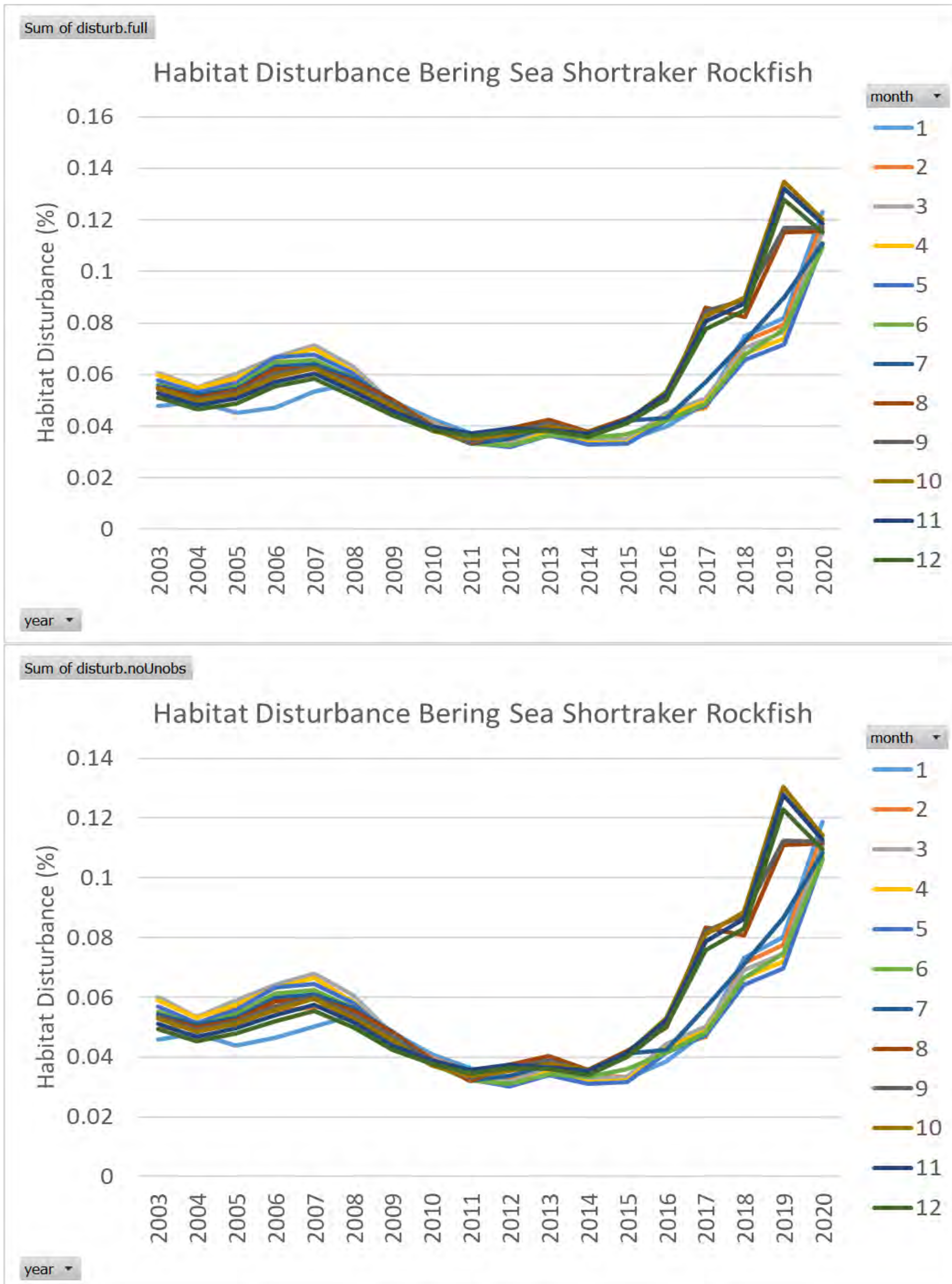


Figure 47. Habitat disturbance by month and year for shortraker rockfish in the Bering Sea for the observed plus unobserved model (top graph, sum of disturb.full) and observed only model (bottom graph, sum of disturb.noUnobs).

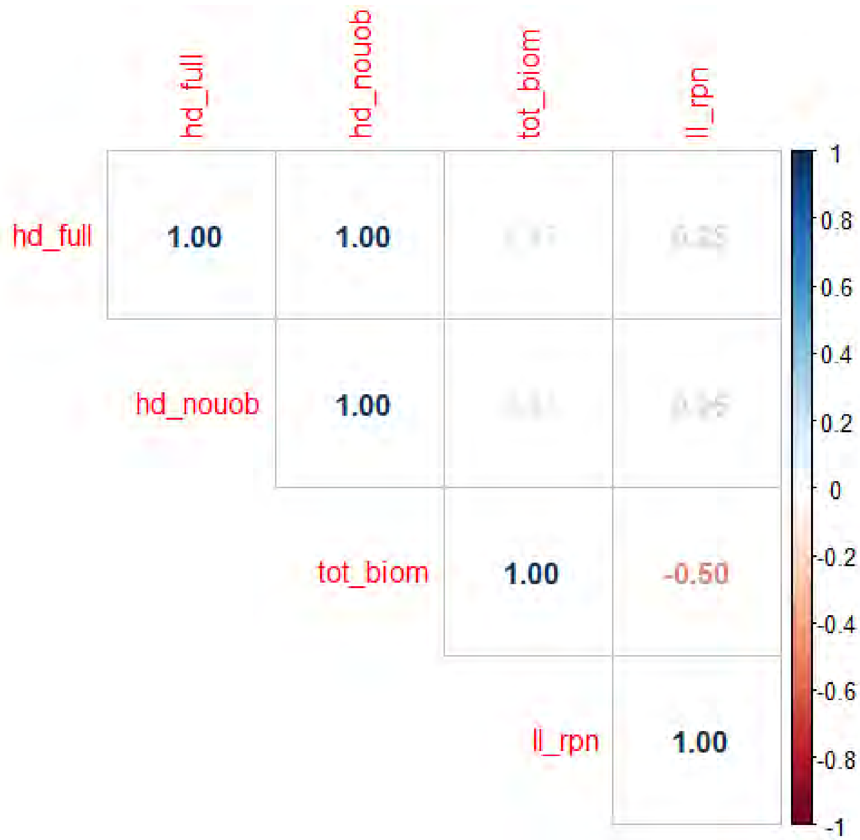


Figure 48. Correlation matrix visual for observed plus unobserved (hd_full) habitat disturbance, observed only (hd_nouob) habitat disturbance, total biomass (tot_biom) from the random effects model, and relative population number from the longline survey (ll_rpn) for BSAI shortraker rockfish.

4.4.10 Shortspine thornyhead rockfish

This section provides the FE analysis figures from the FE model and SA's FE assessments for shortspine thornyhead rockfish.

FE analysis figures:

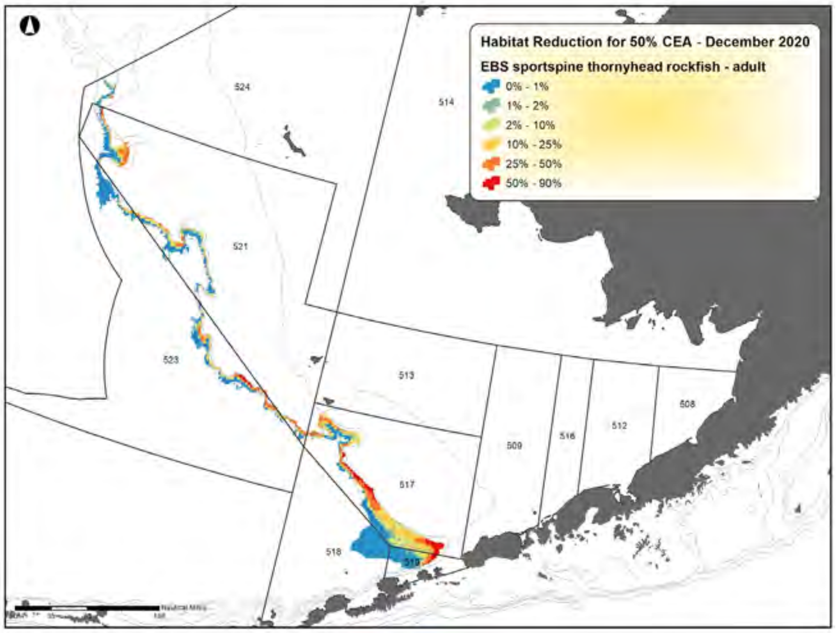


Figure 49. Proportion of habitat disturbance, December 2020 - EBS Shortspine thornyhead rockfish.

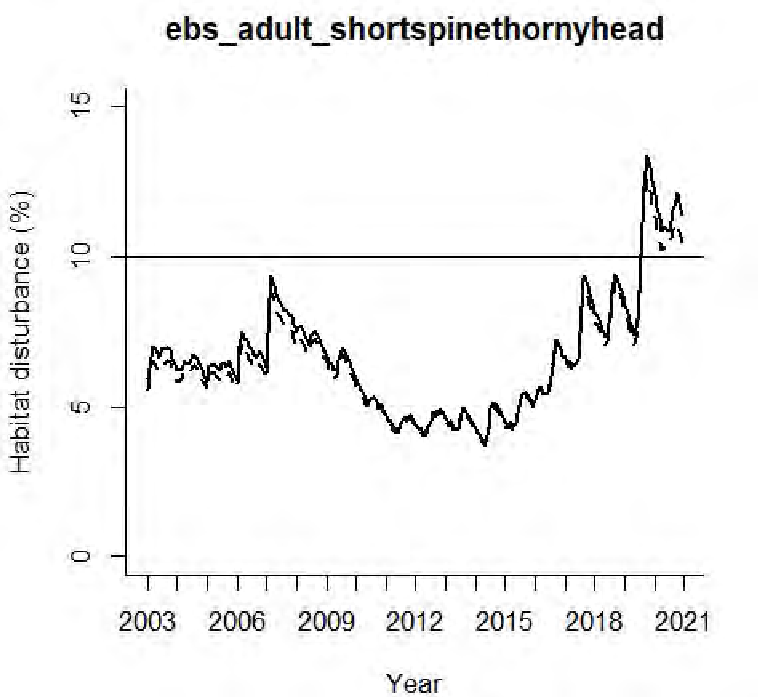


Figure 50. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Shortspine thornyhead rockfish.

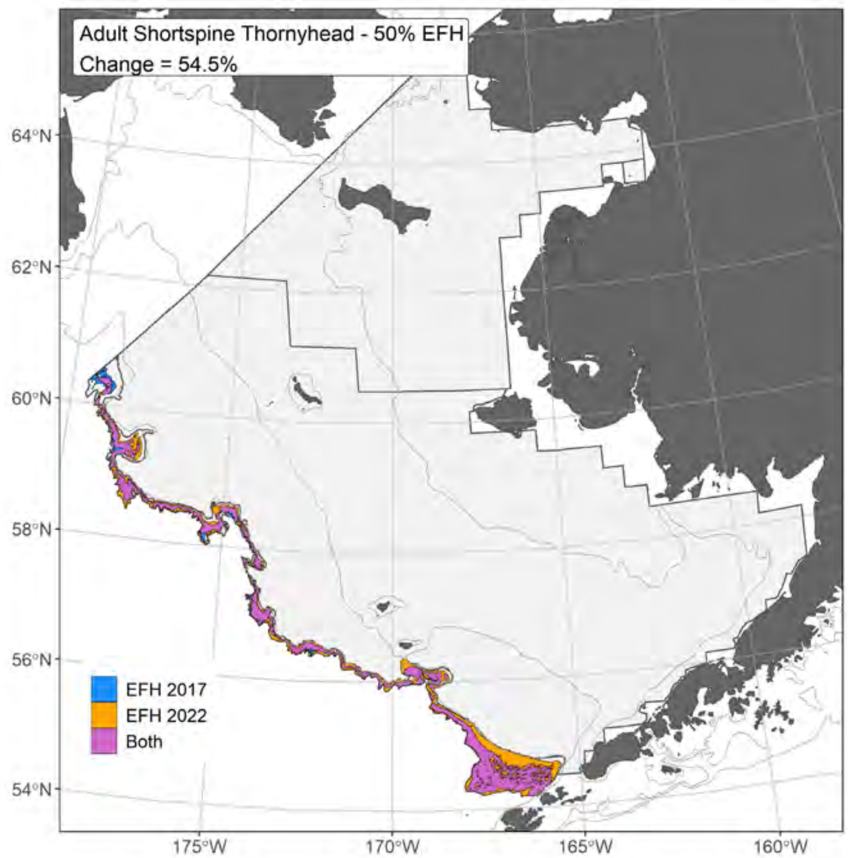


Figure 51. Change in 50% CEA, 2017 compared to 2022 - EBS Shortspine thornyhead rockfish.

SA FE Assessment for Shortspine thornyhead (SST):

If the ≥10% threshold for additional analyses is exceeded, correlation between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success are requested. The ≥10% threshold was exceeded for EBS SST starting in 2019 and limited correlation analysis was performed for this stock between the proportion of habitat disturbed and indices of SST abundance (Figure 13). Body condition (i.e. length-weight residuals) were considered for this analysis but were excluded due to small sample sizes and lack of spatiotemporal coverage in the EBS. Other indices of growth (e.g. size-at-age) and maturity are not available for this stock because no validated method for ageing SST currently exists (Kastelle et al. 2020). Additionally, the EBS slope bottom trawl survey has not been conducted since 2016, and therefore does not encompass the recent time period when the ≥10% threshold was exceeded. In lieu of the EBS slope bottom trawl survey biomass, we used the AFSC longline survey relative population numbers (RPN; i.e., area-weighted catch-per-unit-effort), AI bottom trawl survey biomass in the southern EBS (International North Pacific Fisheries Commission [INPFC] area 799), and commercial fisheries catch data as proxy indices of abundance for SST in the correlation analysis. The AFSC longline survey has operated in the EBS in odd years starting in 1997, and the AI bottom trawl survey has operated in southern EBS in even years since the early 1980s. Because the available abundance indices are not necessarily representative of feeding, spawning, or other seasonal habits for SST, the annual mean of the full disturbance metric was used in the correlation analysis. The results of the correlation analysis, along with the *p*-values, is shown in the table below. None of the variables evaluated were significantly correlated with the habitat disturbance variable.

Table 13. EBS shortspine thornyhead correlation analyses compared to the EFH percent disturbance estimate.

Variable	***ρ***	**p-value**
AFSC longline survey RPN	-0.22	0.57
AI bottom trawl survey in the southern EBS	-0.03	0.95
Commercial catch	0.29	0.23

The results of the correlation analysis suggest that EBS SST abundance is not significantly correlated with habitat disturbance. However, it is unclear if the three recent years in which habitat disturbance has exceeded the ≥10% threshold is long enough to cause an impact, or if the ≥10% threshold is meaningful for this species. Although age, growth, and maturity information for SST are limited, best available data suggests that SST are extremely long-lived, with reported maximum ages of 100 y (Kastelle et al. 2000; Kline 1996), 133 y (personal communication Kevin McNeel, Alaska Department of Fish and Game), and 158 y (Butler et al. 1995). Estimates of maturity suggest that female age-at-50% maturity is around 13 y (personal communication Todd TenBrink, AFSC) and length-at-50% maturity is 21.48 cm (Pearson and Gunderson 2003). Additionally, tagging research in Alaska has shown low movement rates for SST (Echave 2017). These life history characteristics are consistent with a low productivity species that may be disproportionately more vulnerable to fishing effects or habitat disturbance. While there is insufficient evidence to elevate concern for this species at this time, continued monitoring and research into SST life history and ageing methodology is warranted.

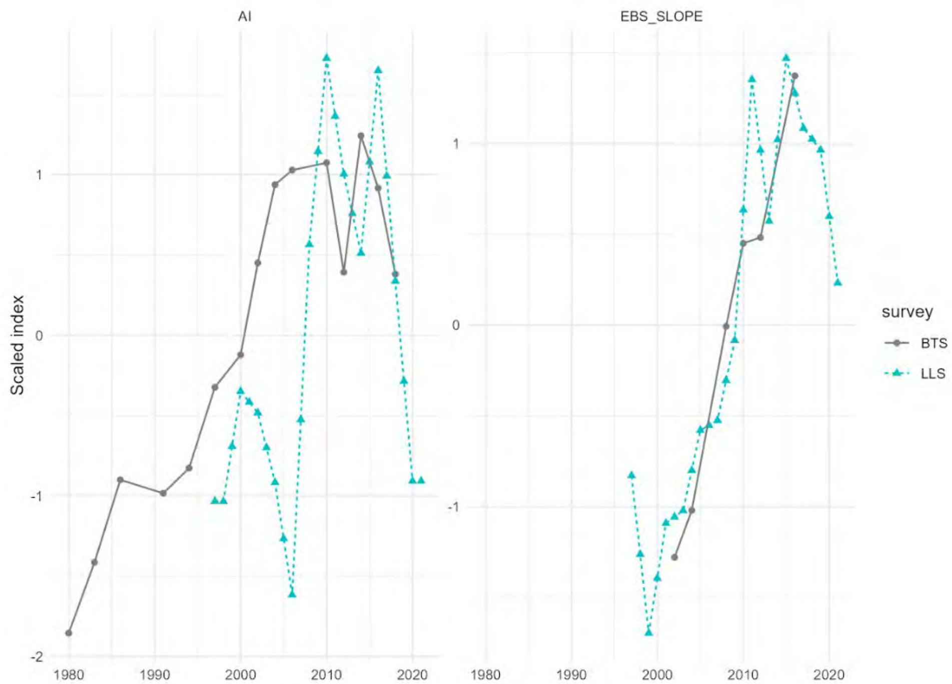


Figure 52. Shortspine thornyhead scaled abundance indices in the bottom trawl (BTS) and longline (LLS) surveys.

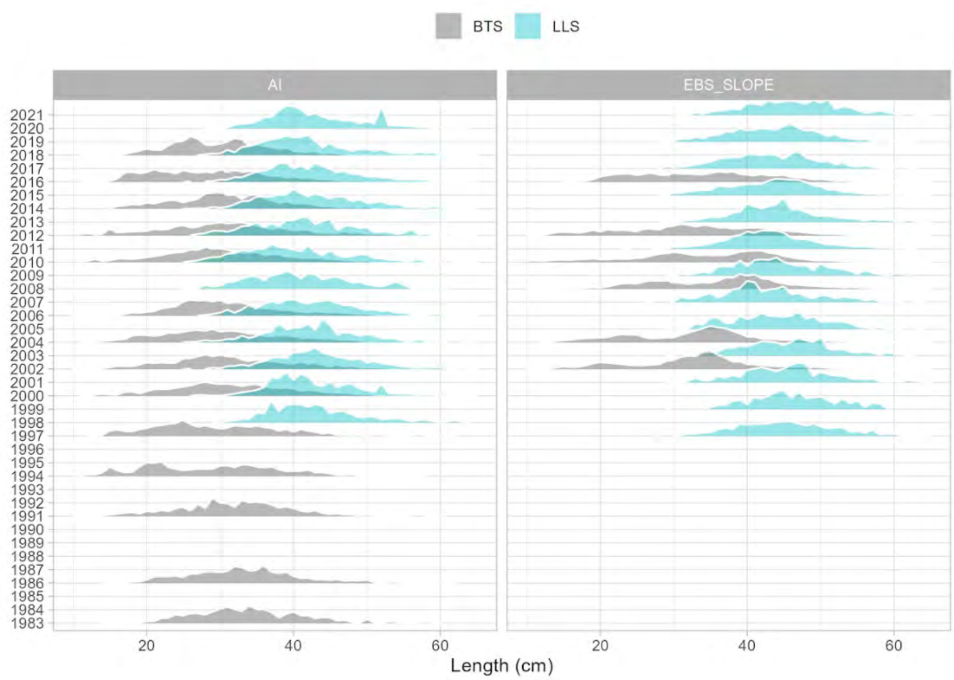


Figure 53. Shortspine thornyhead length frequencies in the bottom trawl (BTS) and longline (LLS) surveys.

4.4.11 Skate complex

This section provides the FE analysis figures from the FE model and SA's FE assessments for Aleutian skate, Bering Sea skate, mud skate, and whitebloched skate. *Please note that no 2017 EFH exists for the Bering Sea whiteblotched skate. Therefore, no Change in 50% EFH CEA comparison of 2017/2022 figure exists for this species.*

FE analysis figures for Aleutian skate:

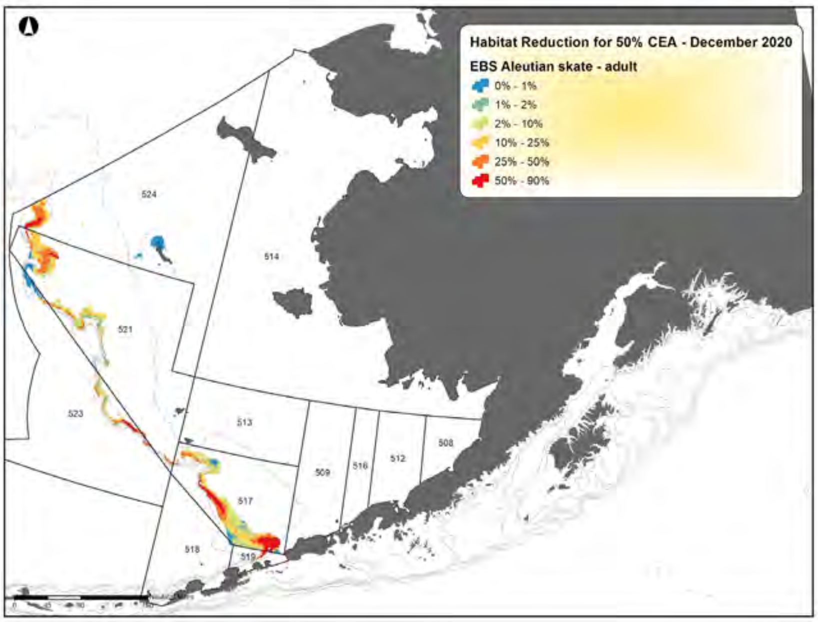


Figure 54. Proportion of habitat disturbance, December 2020 - EBS Aleutian skate.

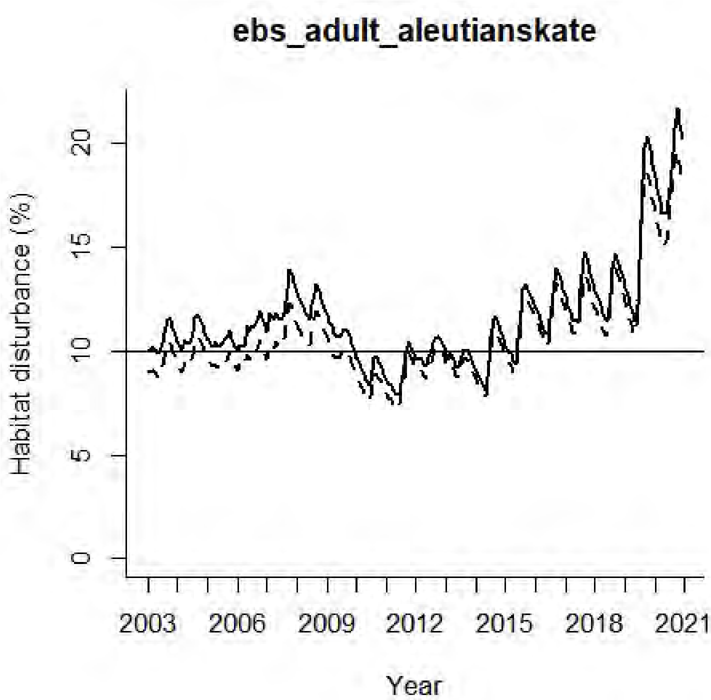


Figure 55. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Aleutian skate.

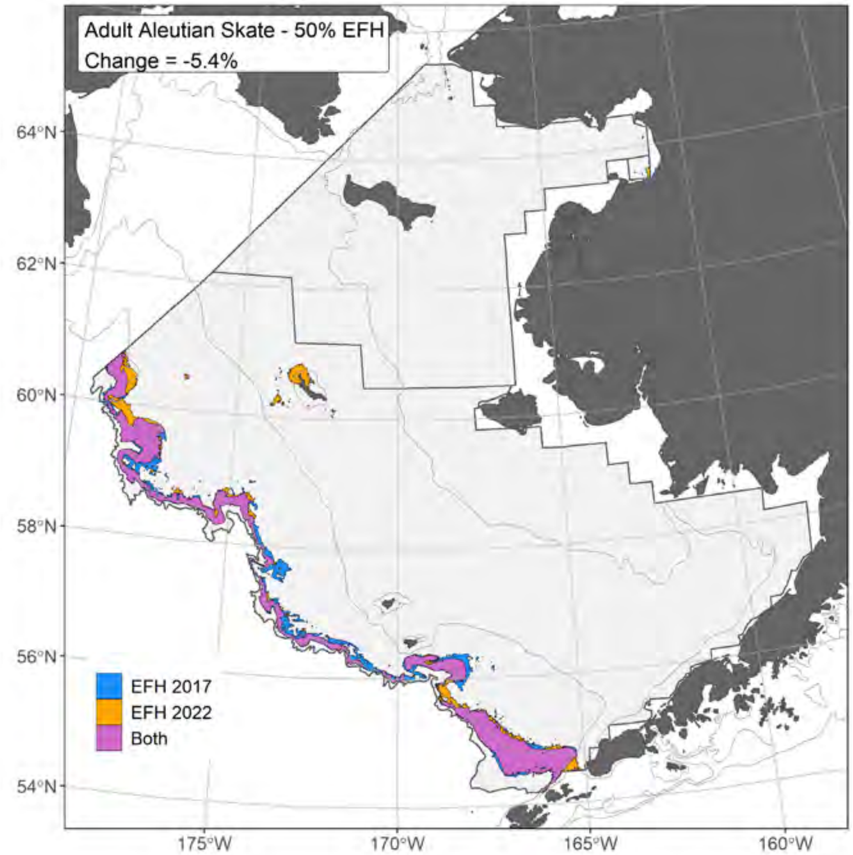


Figure 56. Change in 50% CEA, 2017 compared to 2022 - EBS Aleutian skate.

FE analysis figures for Bering Sea skate:

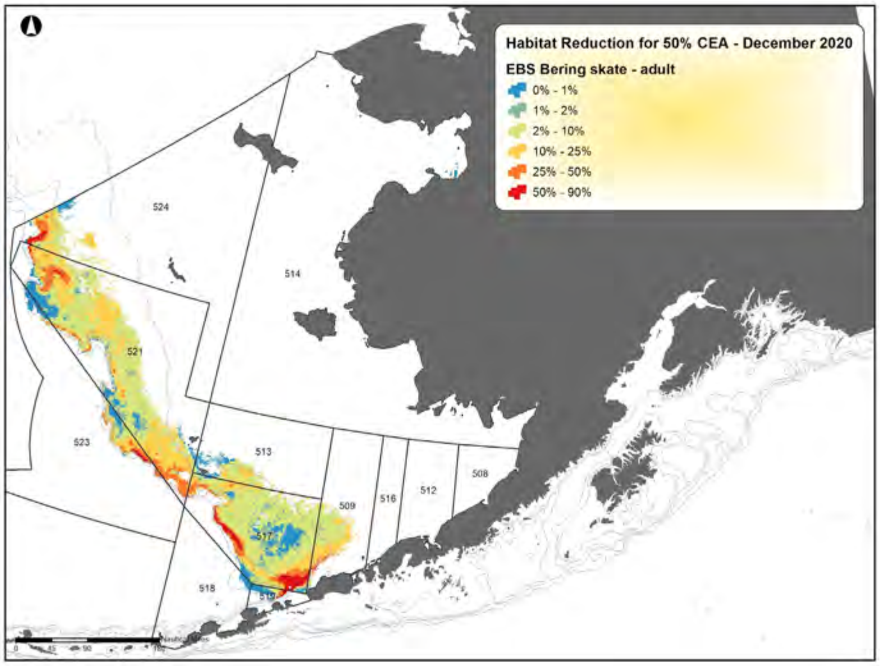


Figure 57. Proportion of habitat disturbance, December 2020 - EBS Bering Skate.

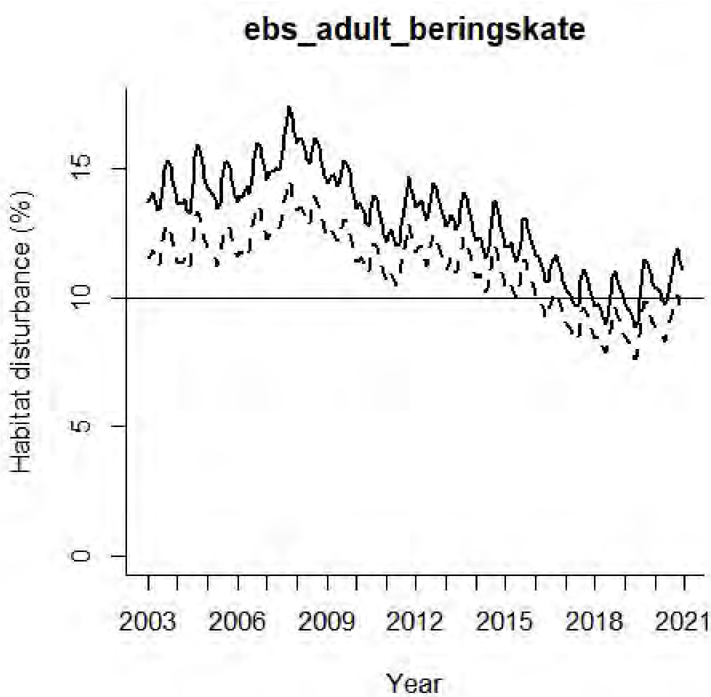


Figure 58. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Bering Skate.

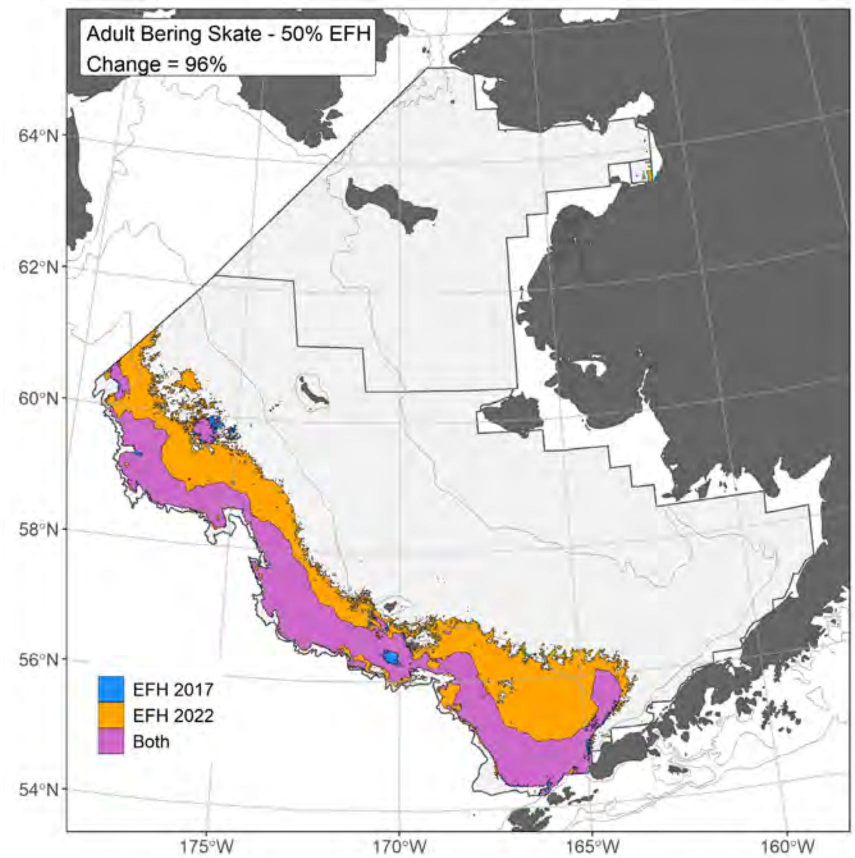


Figure 59. Change in 50% CEA, 2017 compared to 2022 - EBS Bering Skate.

FE analysis figures for mud skate:

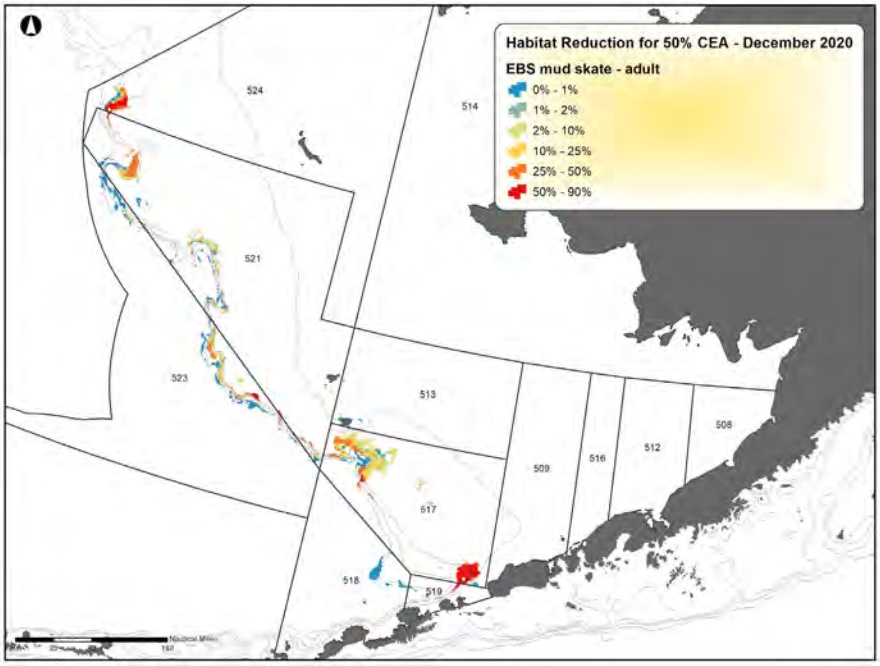


Figure 60. Proportion of habitat disturbance, December 2020 - EBS Mud Skate.

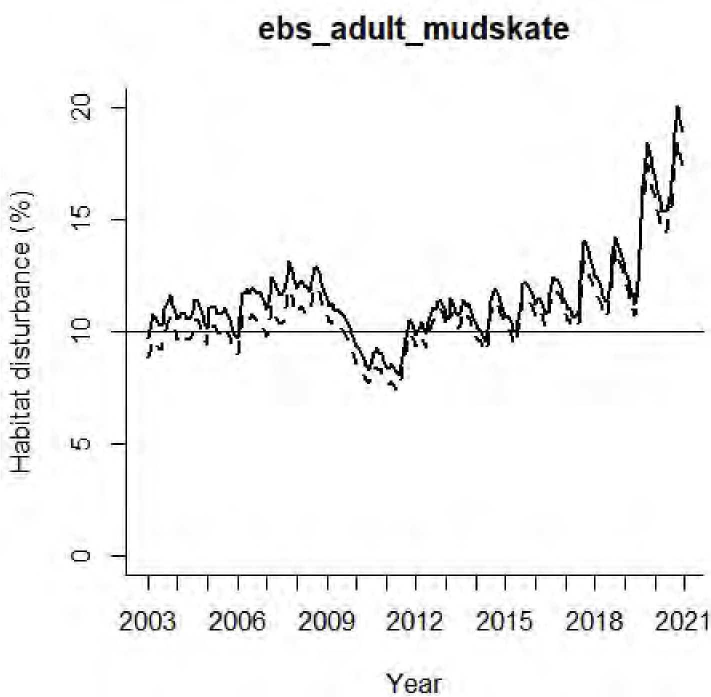


Figure 61. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Mud Skate.

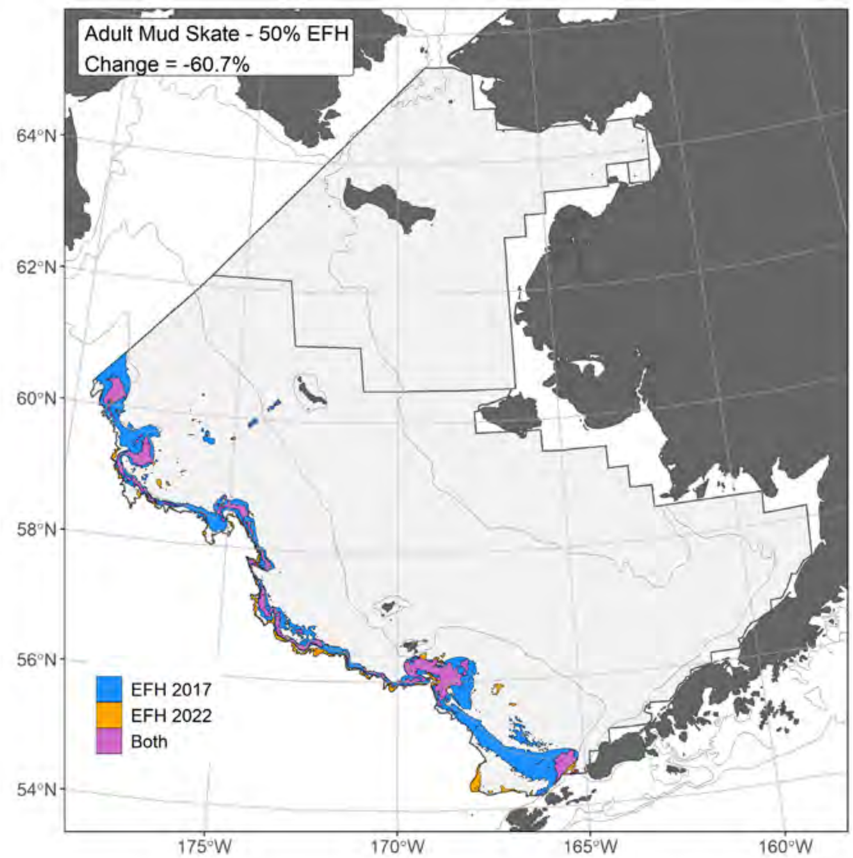


Figure 62. Change in 50% CEA, 2017 compared to 2022 - EBS Mud Skate.

FE analysis figures for whitebloched skate:

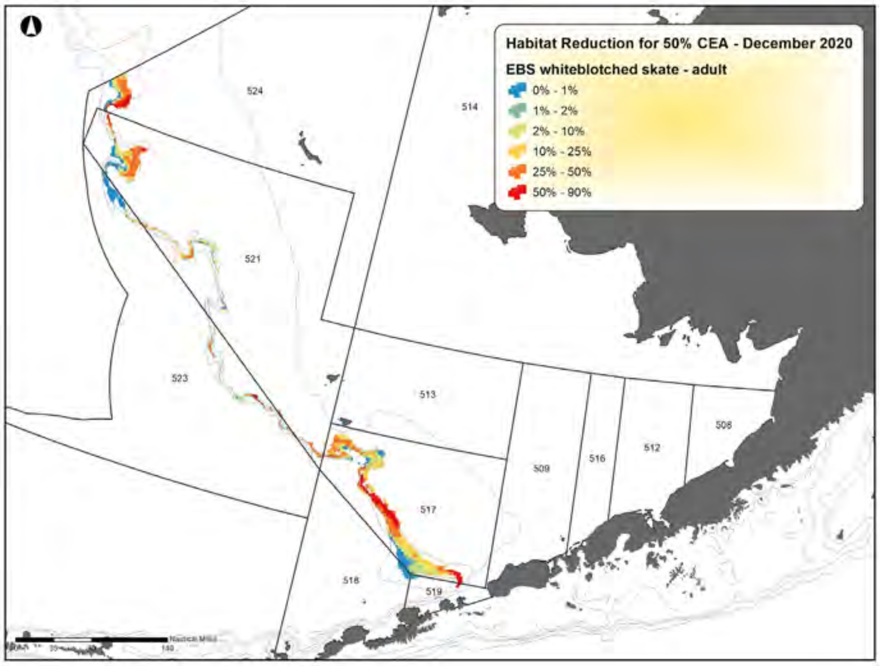


Figure 63. Proportion of habitat disturbance, December 2020 - EBS Whiteblotched skate.

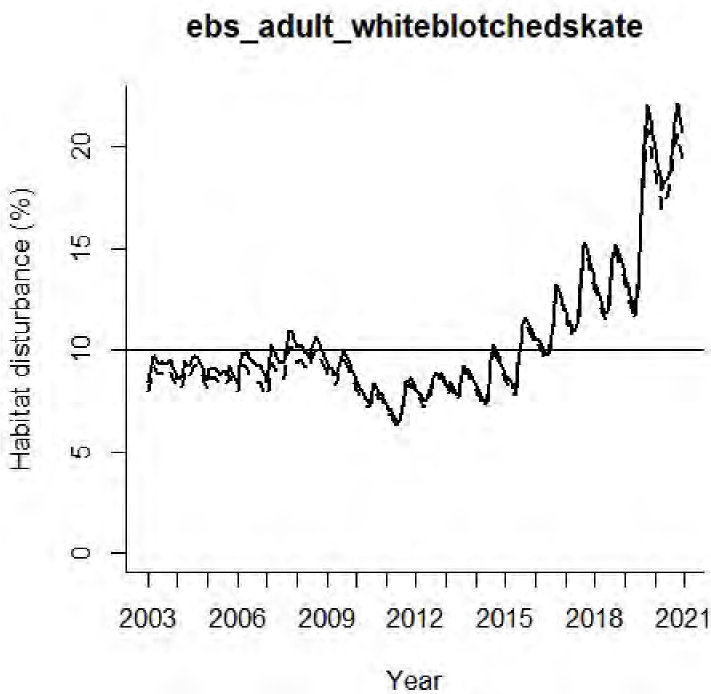


Figure 64. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line)- EBS Whiteblotched skate.

SA FE Assessment for Aleutian skate, Bering Sea skate, mud skate, and whitebloched skate:

The EBS likely represents a large portion of the skate complex species' distributions. However, except for Alaska skates, their distributions are not well known. The Alaska skate is the most abundant skate species in the EBS and is routinely observed in the EBS bottom trawl surveys. Observations in the EBS of skates (excluding Alaska skates), are patchy and sparse, and there is no directed fishery for skate complex species in the EBS.

Skates in general, are not well sampled by the bottom trawl surveys which only occur in the summer months. Without fishery observations, the survey data provide a very limited view of the skate complex distributions. However, there is a lot of fishing activity in the EBS. Due to the patchy and sparse occurrences of skates from the EBS bottom trawl survey data, it is unlikely that CEA disturbance is > 10% as determined by the FE analysis for four out of the five EBS skate complex species: Aleutian skate, Bering skate, mud skate, and whiteblotched skate; the results are most likely an artifact of the data.

4.4.12 Tanner crab

This section provides the FE analysis figures from the FE model and SA's FE assessments for Tanner crab.

FE analysis figures:

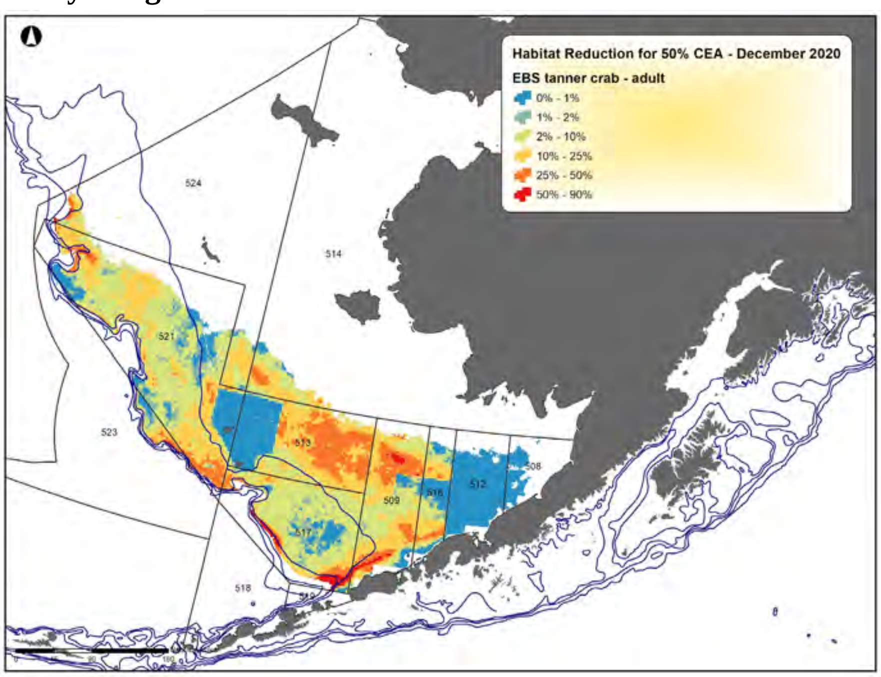


Figure 65. Proportion of habitat disturbance, December 2020 - EBS Tanner Crab.

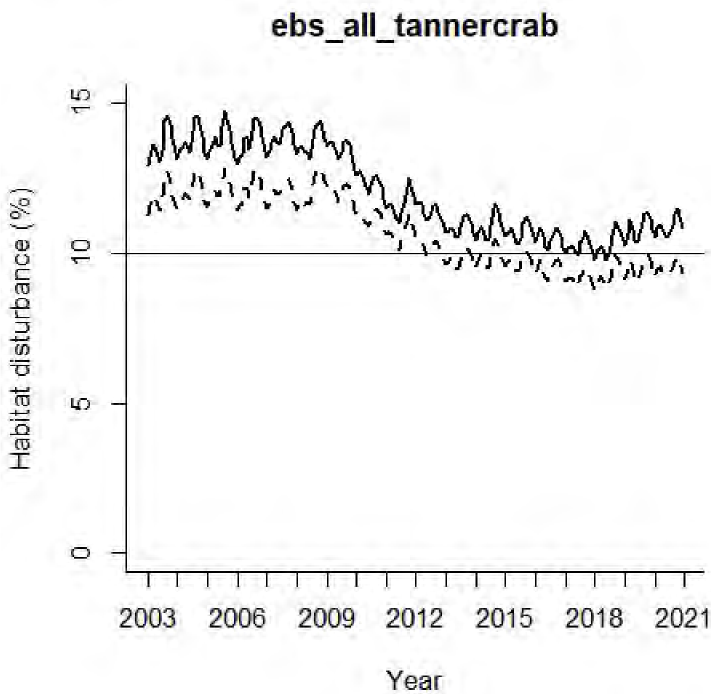


Figure 66. Time series of habitat disturbance comparisons, including 2022 FE model with observed and unobserved fishing (solid line) and with observed fishing only (dashed line) - EBS Tanner Crab.

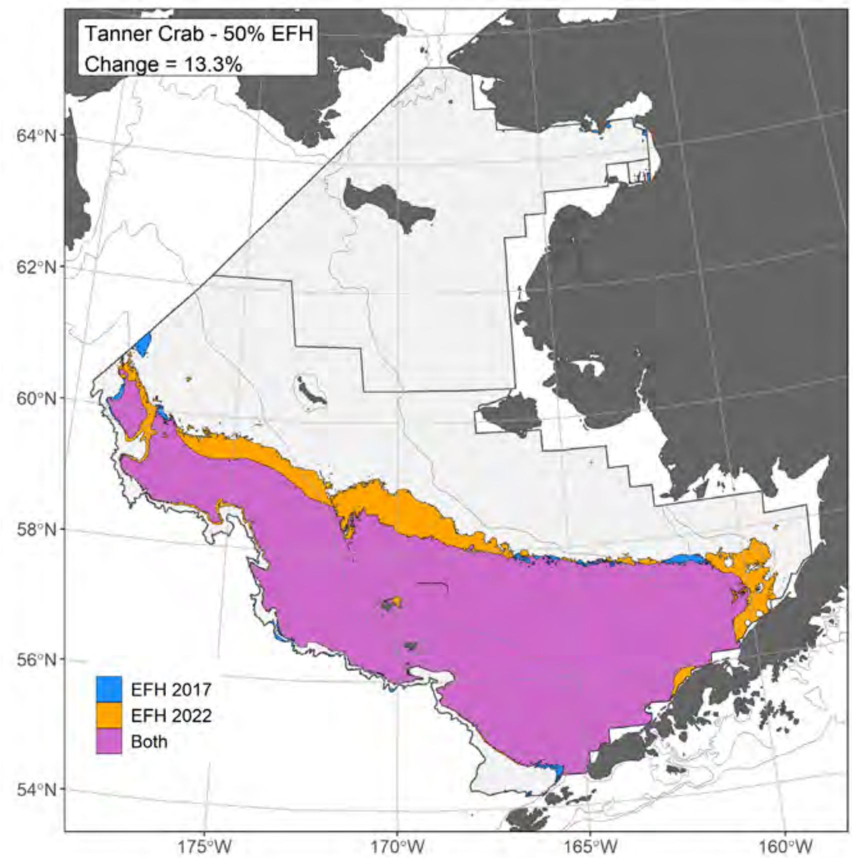


Figure 67. Change in 50% CEA, 2017 compared to 2022 - EBS Tanner Crab.

SA FE Assessment for Tanner crab:

The full FE assessment with tables and figures is available as a PDF file in the EBS Tanner crab folder along with the FE model results and figures provided for the SSC October, 2022 meeting[20]. The written portion of the EBS Tanner crab FE assessment is provided here; table and figure references correspond to those in the full FE assessment.

Introduction

Tanner crab (*Chionoecetes bairdi*) are distributed across the continental shelf as far south as Washington and Oregon, and westward to the Kamchatka peninsula and Hokkaido, Japan (NPFMC, 2021). They are particularly common in the southeastern Bering Sea and Aleutian Islands. Tanner crab show a strong preference for bottom temperatures above 2°C, but have not demonstrated a northward shift in their distribution during recent warm years (Murphy, 2020). These crabs undergo a terminal molt as they become sexually mature, after which they stop growing and will retain the same shell in future years (Tamone, 2017). Tanner crab exhibit sexually-dimorphic growth and both sexes mature over a range of sizes (NPFMC, 2021). Characterization of maturity for females is unambiguous on the basis of changes in abdominal morphology associated with the molt to maturity. Characterization for males is more ambiguous

[20] EFH Component 2 Fishing Effects September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

and interannual changes in population-level size-at-maturity are driven more by recruitment variability than by changes in the underlying maturation schedule (Murphy, 2021). Although regarded as a single stock for assessment purposes, Alaska Department of Fish and Game (ADF&G) manages the EBS Tanner crab population using two areas, demarcated by $166^{o}W$ longitude (NPFMC, 2021).

The first step in the FE Assessment for a species is to determine whether or not the population is above its *MSST*, which for federally-managed crab stocks in the Bering Sea is defined as $\frac{1}{2} \cdot B_{MSY}$, where B_{MSY} is generally represented by a proxy quantity based on mature male biomass-at-mating (*MMB*). For Tanner crab, the proxy for B_{MSY} is $B_{35\%}$, the *MMB* at 35% of the unfished stock *MMB*. The estimated *MSST* and current *MMB* from the latest stock assessment (NPFMC, 2021) are 17.97 and 42.57 thousand t respectively so the stock is not below its *MSST*.

Essential Fish Habitat for Bering Sea Tanner crab

EFH and additional habitat-related subareas (Figure 1 *in the full FE assessment*) were defined for Tanner crab using an ensemble of SDMs that potentially incorporated a suite of environmental covariates and were fit to estimates of Tanner crab presence/absence and numerical abundance from NMFS summer trawl surveys in the eastern Bering Sea (1982-2019). The area representing Tanner crab EFH was dispersed west across the EBS shelf from Bristol Bay in the southeast along the Alaska Peninsula in the south and northwestward to the northwestern extent of the survey area along the EEZ boundary past St. Matthew Island. The core EFH area (CEA), encompassing the upper 50%-ile of EFH, generally followed this pattern as well, but was somewhat more concentrated along the Peninsula and shelf edge than the full EFH area.

Fishing Effects on the Tanner crab CEA

The 2022 FE model was run using the Tanner crab CEA to obtain monthly estimates of the fraction of habitat disturbance in the CEA using both observed and unobserved fishing activity (Figures 2 and 3 *of the full FE assessment*). In addition to time series of habitat disturbance in the complete CEA, time series were also calculated for sub-areas of the CEA east and west of 166^{o}W longitude corresponding to the two ADF&G management areas. Across the 2003-2021 time period, the estimated fraction of habitat disturbed in the CEA when both observed and unobserved fishing activity were included decreased from ~14% at the start of the time series (2003) to ~10.5% in 2021. The level of disturbance was somewhat larger, and more temporally constant, east of 166^{o}W longitude than west of it, decreasing in the latter area by ~4 percentage points between 2009 and 2011 and remaining slightly less than 10% until 2021, when it rose to just above 10%.

Fishing effects on Tanner crab

If the population is below its *MSST* or the CEA disturbed by fishing is currently ≥ 10%, the FE analysis guidelines require that 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) be examined to determine whether there are correlations between those indices and the trends in the proportion of the CEA disturbed, and whether any correlations are significant at a *p*-value of 0.1. The guidelines suggest that this criterion provides an objective threshold to ensure that a “hard look” has been taken for each species. Because multiple time series may be examined for correlation to habitat disturbance, it is possible that spurious significant ($p < 0.1$) correlations will be found. For Tanner crab, the fraction of the CEA disturbed by fishing activity is currently ≥ 10%, and so these indices must be examined.

The indices available for Tanner crab for correlation analysis are limited: time trends in growth-to-maturity and feeding success are unknown: temporal variation in size-at-age cannot be determined (in general, age determination for crabs is problematic) and condition indices have not been developed. Trends in spawning success may be reflected in time series of estimated annual recruitment (*R*) and *MMB* (the measure of spawning stock size used in NPFMC crab assessments) from the most recent stock assessment. Trends in breeding success can be estimated for the Tanner crab stock using data on clutch fullness from the annual NMFS EBS summer shelf survey. Trends in survey biomass for different components of the population can also be examined. The assessment model treats the Tanner crab population as a single stock: available data is aggregated across ADF&G management areas to the entire EBS and estimated time series for recruitment and *MMB* are only available at the stock level. Trends in clutch fullness and survey biomass are also examined at this level.

Cross-correlations for each Tanner crab-related time series selected for analysis were calculated using the stock-specific time series of habitat disturbance ("FE CEA HD", Figure 4) using the "testcorr" package for R (Dalla et al., 2021; R Core Team, 2020). The "testcorr" package provides statistics for testing cross-correlations for significance against a null hypothesis of zero correlation that are robust to departures from the iid and non-skewness assumptions required for standard tests (Dalla et al., 2020). Because the available Tanner crab time series were at an annual time step, annual averages of the associated habitat disturbance time series were used in the correlation analysis. Additionally, because the impact of any effects of fishing-related habitat disturbance may be lagged in the biological response of the species, correlations at several lags were examined for each Tanner crab time series. Prior to the correlation analysis, the Tanner crab-related time series were pre-whitened to avoid spurious serial correlation (e.g., Dean and Dunsmuir, 2016) using functions modified from the R package "TSA" (Chan and Ripley, 2020) and ARIMA models fitted to the associated annual habitat disturbance time series. Significance of cross-correlations was assessed using the robust t-statistic significance levels reported from the function "cc.test" in the "testcorr" package (Dalla et al., 2021).

Spawning success

Trends in spawning success may be reflected in time series of annual recruitment (*R*) and mature male biomass (*MMB*, the measure of spawning stock size used in NPFMC crab assessments), but recruitment and *MMB* are only estimated for the entire stock as part of the stock assessment (the model does not estimate separate time series for the areas east and west of 166°W longitude). The time series of *R*, *MMB*, and *ln*(*R/MMB*) (a measure of relative spawning success) from the latest stock assessment (NPFMC, 2021) were compared to the time series of habitat disturbance in the CEA ("FE CEA HD", Figure 4 *of the full FE assessment*). To form the *ln*(*R/MMB*) time series, *R* was lagged 6 years to the presumptive fertilization year, assuming settlement occurs in the fall of the year following mating/fertilization (Punt et al., 2014). Based on considerations of potential causality of habitat reduction on biological characteristics of the population, only positive lags of the habitat reduction time series were examined for the cross-correlations with *R* and *MMB*, but both positive and negative lags were considered for *ln*(*R/MMB*) (correlations at negative lags correspond to effects occurring between hatching and recruitment).

The recruitment time series exhibited a correlation significantly different from zero (at an α level of 0.1) with the annually-averaged CEA disturbance time series at a lag of 4 years, while the *MMB* and *ln*(*R/MMB*) time series exhibited no correlations significantly different from zero (Tables 1-3; Figures 5 and 6 *of the full FE assessment*). A lag of four years corresponds to disturbance one year after the presumed year of settlement (i.e., two years after the presumed year of fertilization), but the correlation was positive, indicating a positive effect of habitat disturbance on eventual recruitment (possible, but seemingly unlikely, mechanisms include positive effects of disturbance on prey availability or predator disruption).

Breeding success

Using NMFS EBS shelf survey data, trends in mean clutch size for mature females were estimated on a stock-specific basis as indices of breeding success (Figure 7 *of the full FE assessment*). Annual mean values were calculated on the basis of area-swept estimates of both abundance and biomass, but the results from the two weighting methods were very similar. Interannual changes in mean clutch size for EBS exhibited high frequency variability imposed on a gradual decline over the time series.

The standardized time series for mean clutch size and habitat disturbance are illustrated in Figure 8. Cross-correlation between mean clutch size and the annually-averaged habitat disturbance time series was significantly different from zero and positive at a lag of 0 years (Table 4; Figure 9 *of the full FE assessment*).

Correlation with survey indices of abundance

Finally, trends in stock-specific NMFS EBS shelf survey biomass for immature and mature crab by sex were compared to the stock-specific time series of habitat disturbance. Tanner crab were characterized as immature or mature based on standard area- and sex-specific cutlines (Zacher et al., 2020), with the areas coincident with the ADF&G management areas. Annual survey biomass indices were obtained from AKFIN Answers (https://akfinbi.psmfc.org/analytics/, accessed 6/20/2022) for the East 166^{o}W and West 166^{o}W management areas and aggregated to the EBS before analysis. The standardized (z-score) trends for EBS survey biomass by stock component are shown in Figure 10 *of the full FE assessment*.

Cross-correlation results for the EBS stock components are shown in Tables 5-8 and Figure 11 *of the full FE assessment*. Immature male biomass was significantly correlated with habitat disturbance at 1- and 4-year lags; the former negative, the latter positive. No correlations were significant for mature males. Immature females were negatively correlated with habitat disturbance at a 2-year lag while mature females were positively correlated at a lag of 5 years.

Conclusions

A few of the cross-correlations between time series of biological characteristics and habitat disturbance due to fishing effects examined here were found to be statistically significant using the robust t-statistic from Dalla et al. (2020). Of these, 2 out of 5 were negative, indicating the possibility for some deleterious causal effect of habitat reduction on biological characteristics of the Tanner crab population. These were associated with 1- or 2-year lags between habitat disturbance and immature (males and females, respectively) survey biomass. These results suggest the possibility that mortality on early benthic instars may be positively correlated with habitat disturbance, with a lag between effect and observation because survey catchability for small crab is poor. The significant positive correlations were found for recruitment (4-year lag), clutch size (no lag), and immature male survey biomass (4-year lag). The results for recruitment and immature male survey biomass would appear to suggest that habitat disturbance enhances survival of small benthic instars (the 4-year lags being consistent with a positive effect a year after settlement), in contrast to the suggestion based on the negative correlations for immature survey biomass. It is also difficult to see how habitat disturbance could have a direct effect (positive *or* negative) on clutch size.

In any case, it is unlikely that any of the correlations would have been found to be statistically significant if the number of comparisons were taken into account (the smallest significant p-value, for immature male survey biomass, was 0.053). It should also be noted that most of the biological time series examined here (including recruitment) are rather problematic from a time series analysis perspective because age classes cannot be distinguished and the survey only starts to be selective for Tanner crab approximately 5 years after settlement, and thus any effects of habitat disturbance on a specific cohort or age class are combined with several other age classes and “smeared out”. Another difficulty is that, despite the level of disturbed area exceeding 10% of the core EFH area, the contrast in habitat disturbance across the time series is not all that substantial.

It is thus difficult to really draw any conclusions on the effects of fishing-related habitat disturbance on the Tanner crab population, despite the level of disturbed area exceeding 10% of the core EFH area.

5 REFERENCES

Baker, M., W. Palsson, M. Zimmermann, and C.N. Rooper. 2019. Model of trawlable area using benthic terrain and oceanographic variables—Informing survey design and habitat maps in the Gulf of Alaska. Fisheries Oceanography. 28. doi:10.1111/fog.12442

Blood, D.M., Matarese, A.C. and Busby, M.S., 2007. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the Gulf of Alaska.

Butler, J.L., C. Kastelle, K. Rubin, D. Kline, H. Heijins, L. Jacobson, A. Andrews, and W.W. Wakefield. 1995. Age determination of shortspine thornyhead, *Sebastolobus alascanus*, using otolith sections and 210Pb: 226Ra ratio. Admin. Rep. No. LJ-95- 12. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, Calif.

De Forest, L., Duffy-Anderson, J.T., Heintz, R.A., Matarese, A.C., Siddon, E.C., Smart, T.I. and Spies, I.B., 2014. Taxonomy of the early life stages of arrowtooth flounder (*Atheresthes stomias*) and Kamchatka flounder (*A. evermanni*) in the eastern Bering Sea, with notes on distribution and condition. Deep Sea Research Part II: Topical Studies in Oceanography, 109, pp.181-189.

Doherty, B., Johnson, S., and Cox, S.P. 2017. Using autonomous video to estimate the bottom-contact area of longline trap gear and presence–absence of sensitive benthic habitat. Collaborative fisheries research: The Canadian Fisheries Research Network Experience, 2017, 01:797-812,

Echave, K.B., 2017. First results of the tagging of shortspine thornyhead, *Sebastolobus alascanus*, in Alaska. Fisheries Research, 195, pp.46-51.

Fujioka, J. T. 2006. A model for evaluating fishing impacts on habitat and comparing fishing closure strategies. Canadian Journal of Fisheries and Aquatic Sciences, 63(October), 2330–2342. doi:10.1139/f06-120

Goethel, D. R., D. H. Hanselman, C. J. Rodgveller, K. H. Fenske, S. K. Shotwell, K. B. Echave, P. W. Malecha, K. A. Siwicke, and C. R. Lunsford. 2020. Assessment of the Sablefish Stock in Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 257 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/sablefish.pdf

Grabowski, J. H., Bachman, M., Demarest, C., Eayrs, S., Harris, B. P., Malkoski, V., Packer, D., et al. 2014. Assessing the Vulnerability of Marine Benthos to Fishing Gear Impacts. Reviews in Fisheries Science & Aquaculture, 22: 142–155. https://doi.org/10.1139/cjfas-2016-0483@cjfas-cfr/issue01

Jones, D. T., C.N. Rooper, C.D. Wilson, P.D. Spencer, D.H. Hanselman, and R.E. Wilborn. 2021. Estimates of availability and catchability for select rockfish species based on acoustic-optic surveys in the Gulf of Alaska. Fisheries Research, 236, p.105848.

Kastelle, C., T. Helser, T. TenBrink, C. Hutchinson, B. Goetz, C. Gburski, and I. Benson. 2020. Age validation of four rockfishes (genera *Sebastes* and *Sebastolobus*) with bomb-produced radiocarbon. Marine and Freshwater Research, 71(10), p. 1355-1366.

Kline, D.E. 1996. Radiochemical Age Verification for Two Deep-sea Rockfishes: *Sebastolobus altivelis* and *S. alascanus*. M.S. Thesis, Moss Landing Marine Laboratories, San Jose State University, CA, 124 pp.

Love, M. 2002. *Sebastes borealis*, p. 136-137. In M. S. Love, M. Yoklavich, and L. Thorsteinson, The rockfishes of the northeast Pacific. Univ. California Press.

McConnaughey, A. M. Parma, A. D. Rijnsdorp, P. Suuronen, J. S. Collie, R. Amoroso, K. M. Hughes and R. Hilborn. 2017. "Estimating the sustainability of towed fishing-gear impacts on seabed habitats: a simple quantitative risk assessment method applicable to data-limited fisheries." Methods in Ecology and Evolution 8(4): 472-480.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. M.S. thesis, University of Washington, Seattle. 76 pp.

Munk, K. M. 2001. Maximum ages of groundfishes in waters off Alaska and British Columbia and considerations of age determination. Alaska Fishery Research Bulletin 8(1), 12–21

National Marine Fisheries Service. 2005a. Final Environmental Impact Statement for Essential Fish Habitat Identification and Conservation in Alaska: Volume 1. National Marine Fisheries Service, Alaska Region, 1124 p. https://repository.library.noaa.gov/view/noaa/17391

National Marine Fisheries Service. 2021. Attachment 1: Report of Stock Assessment Author Review of Essential Fish Habitat (EFH) Components 1 and 7 for the 2022 EFH 5-year Review, December 2021. National Marine Fisheries Service, Alaska Region, 80 p. https://meetings.npfmc.org/CommentReview/DownloadFile?p=4d8e2ca8-fdd6-4137-9e7e-18bd239c5acd.pdf&fileName=D5%20EFH%20Distribution%20Models%20Stock%20Author%20Review%20Report.pdf

National Marine Fisheries Service. 2022. Discussion Paper on the Assessment of the Effect of Fishing on Essential Fish Habitat in Alaska for the 2022 5-year Review, January 2022. National Marine Fisheries Service, Alaska Region, 70 p. https://meetings.npfmc.org/CommentReview/DownloadFile?p=ec574180-9e2c-4cf6-bd08-9b8bd96309d0.pdf&fileName=D5%20Fishing%20Effects%20on%20EFH%20Discussion%20Paper.pdf

National Research Council. 2002. Effects of Trawling and Dredging on Seafloor Habitat. Washington, DC: The National Academies Press. doi:10.17226/10323

North Pacific Fishery Management Council. 2016. Methods to evaluate the effects of fishing on Essential Fish Habitat Proposal from the SSC subcommittee. D1 Fishing effects on EFH. December 2016. NPFMC, Anchorage, AK.

North Pacific Fishery Management Council. 2010. Essential Fish Habitat (EFH) 5-year Review for 2010. Summary Report Final. April 2010. Available online at: https://www.npfmc.org/wpcontent/PDFdocuments/conservation_issues/EFH/EFH5yr_rev1209.pdf

North Pacific Fishery Management Council. 2020a. Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area. NPFMC, Anchorage, AK.

North Pacific Fishery Management Council. 2020b. Fishery Management Plan for Groundfish of the Gulf of Alaska. NPFMC, Anchorage, AK.

North Pacific Fishery Management Council. 2021. Fishery Management Plan for Bering Sea/ Aleutian Islands King and Tanner Crabs. NPFMC, Anchorage, AK.

Pearson, K.E., and D.R. Gunderson, 2003. Reproductive biology and ecology of shortspine thornyhead rockfish (*Sebastolobus alascanus*) and longspine thornyhead rockfish (*S. altivelis*) from the northeastern Pacific Ocean. Environ. Biol. Fishes 67:11-136.

Shotwell, S.K., I. Spies, L. Brit, M. Bryan, D.H. Hanselman, D.G. Nichol, J. Hoff, W. Palsson, T.K. Wilderbuer, and S. Zador. 2020a. Assessment of the arrowtooth flounder stock in the Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 88 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIatf.pdf

Shotwell, S.K., I.B. Spies, K. Echave, I. Ortiz, J. Sullivan, P.D. Spencer, and W. Palsson. 2020b. Assessment of the shortraker rockfish stock in the Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Mngt. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. 40 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIshortraker.pdf

Smeltz, T.S., Harris, B., Olson, J., and Sethi, S. 2019. A seascape-scale habitat model to support management of fishing impacts on benthic ecosystems. Canadian Journal of Fisheries and Aquatic Sciences, 2019, 76(10): 1836-1844, https://doi.org/10.1139/cjfas-2018-0243

Spencer, P. D., and J. N. Ianelli. 2020. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 83 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIpop.pdf

Spencer, P. D., and J. N. Ianelli. 2021. Assessment of the Northern Rockfish stock in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 90 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2021/BSAInork.pdf

Spencer, P. D., A. B. Hollowed, M. F. Sigler, A. J. Hermann, and M. W. Nelson. 2017. Trait-based climate vulnerability assessments in data-rich systems: An application to eastern Bering Sea fish and invertebrate stocks. Global Change Biology 25: 3954-3971.

Spencer, P. D., J. N. Ianelli, and W. A. Palsson. 2020. Assessment of Blackspotted and Rougheye Rockfish stock complex in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 102 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIrougheye.pdf

Stone, R.P. 2006. Coral habitat in the Aleutian Islands of Alaska: depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25, 229–238. https://doi.org/10.1007/s00338-006-0091-z

Stone R.P., 2014. The ecology of deep-sea coral and sponge habitats of the central Aleutian Islands of Alaska. US Dep Commer, NOAA Prof Paper NMFS 16, 52 p.

Welsford, D., Ewing, G., Constable, A., Hibberd, T., and Kilpatrick, R. 2014. Demersal fishing interactions with marine benthos in the Australian EEZ of the Southern Ocean: an assessment of the vulnerability of benthic habitats to impact by demersal gears. Australian Antarctic Division. FRDC project 2006/042.

APPENDIX 1 FE MODEL DESCRIPTION

Alaska Pacific University's (APU) Fishing Effects (FE) model is run on a combination of Python and R code. APU's FE model code is now available upon request.

The FE model incorporates two mutually exclusive habitat states: undisturbed habitat, H, and disturbed habitat, h (see Table A1 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 $H \in [0,1]$ and $h \in [0,1]$. 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, $\phi_{i,s}$,

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

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:

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

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:

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

producing the constraint of $\tilde{I} \in [0,1)$. 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 $\tilde{I}$; uniformly distributed fishing activity would result in an underestimation (Ellis *et al.*, 2014). Note, the scale of the grid cell will affect this assumption. 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 habitat states are binary in the model, 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. Since $\tilde{\rho}_{i,t,s}$ 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 $H \rightarrow 1$. 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:

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

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 the 2022 NPFMC EFH 5-year review was 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 (e.g. NOAA, 2017b). High resolution information on the spatial distribution of specific 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) 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, k, with a specific sediment present, $\pi_{i,s} \in \{0, 1\}$, to the sum of sediment cells present for all five sediments,

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

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 states, 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 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 A1.1. 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

Model Parameters	Description
$\phi_{i,s}$	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

APPENDIX 2 GEAR PARAMETERS

Table A2.1. The gear parameter table provides the metrics used in the Fishing Effects model for each gear type, listed by fishery. Vessel types are either catcher vessels (CVs) or catcher-processors (CPs), and the definitions for gear type and target species and other species caught and retained can be found **here**. Contact adjustments are reported as either a range (low to high) or single metric if they were the same.

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
GOA Pollock Pelagic Trawl Sand Point	CV	GOA	PTR	P	all others	<75			50	1
GOA Pollock Pelagic Trawl	CV	GOA	PTR	P	all (but K, S)	≥75			75	0 - 0.4
GOA Slope Rockfish Pelagic Trawl	CV	GOA	PTR	K	S	≥75			75	0 - 0.4
GOA Slope Rockfish Pelagic Trawl	CP	GOA	PTR	K	W	all			100	0 - 0.4
GOA PCod Bottom Trawl	CV	GOA	NPT	C	B, P	≥75			90	1
GOA Deepwater Flatfish Bottom Trawl	CV	GOA	NPT	D	W, X	≥75			90	0.26
GOA Shallow Water Flatfish Bottom Trawl	CV	GOA	NPT	H	all others	≥75			90	0.26
GOA PCod Bottom Trawl Sand Point	CV	GOA	NPT	C	all others	<75			55	1
GOA Deepwater Flatfish Bottom Trawl CP	CP	GOA	NPT	D, W	X	all			193	0.26

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
GOA Shallow Water Flatfish/Cod Bottom Trawl CP	CP	GOA	NPT	H, C	L, all others	all			193	0.26
GOA Slope Rockfish Bottom Trawl CP	CP	GOA	NPT	K	S	all			75	1
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	≥90	62	0.2 - 0.6
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	60-90	58	0.2 - 0.6
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	A	<60	50	0.2 - 0.6
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	≥90	77	0.2 - 0.6
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	60-90	73	0.2 - 0.6
BS Pollock Pelagic Trawl (incl Mothership)	CV	BS	PTR	P	B, all others	<125 ≥300	B	<60	64	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	≥90	93	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	60-90	87	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	A	<60	75	0.2 - 0.6

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	≥90	115	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	60-90	109	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	125-151	B	<60	96	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	≥90	132	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	60-90	124	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	A	<60	106	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	≥90	163	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	60-90	154	0.2 - 0.6
BS Pollock Pelagic Trawl	CV	BS	PTR	P	B, all others	151-300	B	<60	137	0.2 - 0.6
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	≥90	142	0.7 - 0.9
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	60-90	133	0.7 - 0.9
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	A	<60	114	0.7 - 0.9
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	≥90	175	0.8 - 1
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	60-90	166	0.8 - 1
BS Pollock Pelagic Trawl	CP	BS	PTR	P	B, all others	all	B	<60	147	0.8 - 1

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
BS Pcod Bottom Trawl	CV	BS	NPT	C	all others	LE 100			90	1
BS Pcod Bottom Trawl	CV	BS	NPT	C	all others	GT100 LE250			110	1
BS Pcod YFS Bottom Trawl mothership	CV	BS	NPT	Y	C, all others	GT250 (or Processor M)			90	1
BS Pcod Bottom Trawl	CP	BS	NPT	C	B,P	<150			193	0.27
BS Rock Sole Bottom Trawl	CP	BS	NPT	R		<150			193	0.27
BS Yellowfin Sole Bottom Trawl a80	CP	BS	NPT	Y		<150			193	0.27
BS Flathead Sole/ Other Flat Bottom Trawl	CP	BS	NPT	L	F, W, all others	<150			193	0.27
BS Pcod Bottom Trawl	CP	BS	NPT	C	B, P	≥150 <225			259	0.27
BS Rock Sole Bottom Trawl	CP	BS	NPT	R		≥150 <225			259	0.27
BS Yellowfin Sole Bottom Trawl a80	CP	BS	NPT	Y		≥150 <225			259	0.27
BS Flathead Sole/ Other Flat Bottom Trawl	CP	BS	NPT	L	F, W, all others	≥150 <225			259	0.27
BS Bottom Trawl - non a80	CP	BS	NPT	Y	all others	225+			259	0.27
BS POP Bottom Trawl	CP	BS	NPT	K	S, T	<250			100	1

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
AI Pcod Bottom Trawl mothership	CV	AI	NPT	C	all others	>250 (or Processor M)			75	1
AI Pcod Bottom Trawl	CV	AI	NPT	C	all others	<99			55	1
AI Pcod Bottom Trawl	CV	AI	NPT	C	all others	≥99			90	1
AI Atka and Rockfish Bottom Trawl	CP	AI	NPT	A	K, all others	all			100	1
AI Pollock		AI	PTR	P	all				100	0 - 0.2
GOA PCod Pot		GOA	POT	C	all others				5.6	0.5 - 1
BSAI Pcod Pot		BSAI	POT	C	all others				5.6	0.5 - 1
BSAI Sablefish Pot		BSAI	POT	S	T				5.6	0.5 - 1
GOA Sablefish Pot		GOA	POT	S	T				5.6	0.5 - 1
GOA Sablefish Longline		GOA	HAL	S	T				6	0 - 1
GOA SE Demersal Shelf Rock Longline		GOA	HAL	K					6	0 - 1
GOA Halibut longline		GOA	HAL	I					6	0 - 1
GOA Pcod Longline		GOA	HAL	C	all others				6	0 - 1
BSAI Pcod Longline		BSAI	HAL	C	all others				6	0 - 1
BSAI Sablefish/ Greenland Turbot Longline		BSAI	HAL	S	T				6	0 - 1
BSAI Halibut longline		BSAI	HAL	I					6	0 - 1

Fishery	Vessel type	Area	Gear	Target Sp.	Other Sp.	Vessel Length (ft)	Season	Depth Range (fath.)	Nominal Width (m)	Contact Adjustment
PCod Jig (also rockfish and halibut)		GOA	JIG	C	all others				0.2	0 - 1
BS Pcod Jig		BS	JIG	C	all others				0.2	0 - 1
AI Jig		AI	JIG	C	all others				0.2	0 - 1

APPENDIX 3 SUSCEPTIBILITY AND RECOVERY TABLES

Table A3.1. Hook-and-line (HAL) susceptibility codes.

Feature Class	Feature	Mud	Sand	Gran/ Peb	Cobble	Boulder	Deep/ rocky
G	Bedforms	-	0	-	-	-	-
G	Biogenic burrows	1	1	-	-	-	-
G	Biogenic depressions	0	1	-	-	-	-
G	Boulder, piled	-	-	-	-	0	0
G	Boulder, scattered, in sand	-	-	-		0	0
G	Cobble, pavement	-	-	-	0	-	0
G	Cobble, piled	-	-	-	1	-	1
G	Cobble, scattered in sand	-	-	-	0	-	0
G	Granule-pebble, pavement	-	-	0	-	-	-
G	Granule-pebble, scattered, in sand	-	-	0	-	-	-
G	Sediments, surface/subsurface	0	0	-	-	-	-
G	Shell deposits	-	0	0	-	-	-
B	Amphipods, tube-dwelling	1	1	-	-	-	-
B	Anemones, actinarian	-	-	1	1	1	1
B	Anemones, cerianthid burrowing	1	1	1	-	-	-
B	Ascidians	-	1	1	1	1	1
B	Brachiopods	-	-	1	1	1	1
B	Bryozoans	-	-	1	1	1	1
B	Corals, sea pens	1	1	-	-	-	-
B	Hydroids	1	1	1	1	1	1
B	Macroalgae	-	-	1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	0	0	0	0	0	0
B	Mollusks, epifaunal bivalve, Placopecten magellanicus	0	0	0	0	0	0
B	Polychaetes, Filograna implexa	-	1	1	1	1	1
B	Polychaetes, other tube-dwelling	-	-	1	1	1	1
B	Sponges	-	0	1	1	1	1

Adapted from longline susceptibility table (Grabowski et al. 2014)

Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

[- dashes indicate that habitat features are not found, or there is insufficient information to provide habitat estimate]

Table A3.2. Pot (POT) susceptibility codes.

Feature Class	Feature	Mud	Sand	Gran/ Peb	Cobble	Boulder	Deep/ rocky
G	Bedforms	-	0	-	-	-	-
G	Biogenic burrows	1	1	-	-	-	-
G	Biogenic depressions	1	1	-	-	-	-
G	Boulder, piled	-	-	-	-	0	0
G	Boulder, scattered, in sand	-	-	-	-	0	0
G	Cobble, pavement	-	-	-	0	-	0
G	Cobble, piled	-	-	-	1	-	1
G	Cobble, scattered in sand	-	-	-	0	-	0
G	Granule-pebble, pavement	-	-	0	-	-	-
G	Granule-pebble, scattered, in sand	-	-	0	-	-	-
G	Sediments, suface/subsurface	1	1	-	-	-	-
G	Shell deposits	-	0	0	-	-	-
B	Amphipods, tube-dwelling	1	1	-	-	-	-
B	Anemones, actinarian	-	-	1	1	1	1
B	Anemones, cerianthid burrowing	1	1	1	-	-	-
B	Ascidians	-	1	1	1	1	1
B	Brachiopods	-	-	1	1	1	1
B	Bryozoans	-	-	1	1	1	1
B	Corals, sea pens	1	1	-	-	-	-
B	Hydroids	-	1	1	1	1	1
B	Macroalgae	-	-	1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	0	0	1	1	1	1
B	Mollusks, epifaunal bivalve, Placopecten magellanicus	-	0	0	0	-	-
B	Polychaetes, Filograna implexa	-	1	1	1	1	1
B	Polychaetes, other tube-dwelling	-	-	1	1	1	1
B	Sponges	-	0	1	1	1	1

Adapted from trap susceptibility table (Grabowski et al. 2014)

Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%

“-” are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

Table A3.3. Nonpelagic (NPT) and pelagic (PTR) trawl susceptibility codes.

Feature Class	Feature	Mud	Sand	Gran-Peb	Cobble	Boulder
G	Bedforms	-	2	-	-	-
G	Biogenic burrows	2	2	-	-	-
G	Biogenic depressions	2	2	-	-	-
G	Boulder, piled	-	-	-	-	2
G	Boulder, scattered, in sand	-	-	-	-	0
G	Cobble, pavement	-	-	-	1	-
G	Cobble, piled	-	-	-	3	-
G	Cobble, scattered in sand	-	-	-	1	-
G	Granule-pebble, pavement	-	-	1	-	-
G	Granule-pebble, scattered, in sand	-	-	1	-	-
G	Sediments, suface/subsurface	2	2	-	-	-
G	Shell deposits	-	1	1	-	-
B	Amphipods, tube-dwelling	1	1	-	-	-
B	Anemones, actinarian	-	-	2	2	2
B	Anemones, cerianthid burrowing	2	2	2	-	-
B	Ascidians	-	2	2	2	2
B	Brachiopods	-	-	2	2	2
B	Bryozoans	-	-	1	1	1
B	Corals, sea pens	2	2	-	-	-
B	Hydroids	1	1	1	1	1
B	Macroalgae	-	-	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	1	1	2	2	2
B	Mollusks, epifaunal bivalve, Placopecten magellanicus	-	2	1	1	-
B	Polychaetes, Filograna implexa	-	2	2	2	2
B	Polychaetes, other tube-dwelling	-	-	2	2	2
B	Sponges	-	2	2	2	2

Adapted from trap susceptibility table (Grabowski et al. 2014)

Susceptibility codes: 0: 0-10%; 1: 10-25%; 2: 25-50%; 3: >50%

Blank spaces are habitat features not associated with the given sediment class

G = Geological features; B = Biological features

Table A3.4. Recovery codes.

Feature Class	Features	Mud	Sand	Gran/ Peb	Cobble	Boulder	Deep/ rocky
G	Bedforms	-	0	-	-	-	-
G	Biogenic burrows	0	0	-	-	-	-
G	Biogenic depressions	0	0	-	-	-	-
G	Boulder, piled	-	-	-	-	3	3
G	Boulder, scattered, in sand	-	-	-	-	0	0
G	Cobble, pavement	-	-	-	0	-	0
G	Cobble, piled	-	-	-	3	-	3
G	Cobble, scattered in sand	-	-	-	0	-	0
G	Granule-pebble, pavement	-	-	0	-	-	-
G	Granule-pebble, scattered, in sand	-	-	2	-	-	-
G	Sediments, suface/subsurface	0	0	-	-	-	-
G	Shell deposits	-	2	2	-	-	-
B	Amphipods, tube-dwelling	0	0	-	-	-	-
B	Anemones, actinarian	-	-	2	2	2	2
B	Anemones, cerianthid burrowing	2	2	2	-	-	-
B	Ascidians	-	1	1	1	1	1
B	Brachiopods	-	-	2	2	2	2
B	Bryozoans	-	-	1	1	1	1
B	Corals, sea pens	2	2	-	-	-	-
B	Hydroids	1	1	1	1	1	1
B	Macroalgae	-	-	1	1	1	1
B	Mollusks, epifaunal bivalve, Modiolus modiolus	3	3	3	3	3	3
B	Mollusks, epifaunal bivalve, Placopecten magellanicus	-	2	2	2	-	-
B	Polychaetes, Filograna implexa	-	2	2	2	2	2
B	Polychaetes, other tube-dwelling	-	-	1	1	1	1
B	Sponges	-	2	2	2	2	2
B	Long-lived features[1]	-	-	-	-	-	4

Adapted from trawl recovery table (Grabowski et al. 2014)

Recovery codes: 0: < 1 year; 1: 1 – 2 years; 2: 2 – 5 years; 3: 5 – 10 years; 4: 10 – 50 years
Blank spaces are habitat features not associated with the given sediment class
G = Geological features; B = Biological features

[1] Long-lived features added to deep and rocky habitat category at request of SSC

APPENDIX 4 STOCK AUTHOR QUESTIONNAIRE

In April 2022, we began the Stock Author review of the fishing effects information. This appendix includes the information we provided to the Stock Authors for their review and FE assessment.

INTRODUCTIONS FOR STOCK ASSESSMENT AUTHORS

In February 2022, the SSC supported the use of new SDMs and EFH maps. We are now moving to component 2 of the EFH 5-year Review and are asking you to assess the impacts of commercial fishing on EFH in Alaska. We also provide you the opportunity to revisit any concerns you raised during your review of the SDM results, if necessary; we will be providing the Scientific and Statistical Committee (SSC) more detailed information on SA concerns with data limitations for the SDMs and the Fishing Effects (FE) model.

The end product of this review process will be a written report for each species or species complex by region produced from the Google Form that SAs will fill out and will be compiled by the FE Analysis team. A decision tree (***Figure A4 1***) is provided to aid in SA review and provide information to assist in SA feedback provided on the Google Form. The Google Form also provides SAs the opportunity to address the questions regarding data limitation raised by the SSC in February 2022[21].

SDM Review Follow-up

EFH is described and mapped for North Pacific groundfish and crab species for the 2022 EFH 5-year Review, using SDM ensembles based on the Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering Division Groundfish Assessment Program (RACE GAP) summer bottom trawl survey data and environmental covariates. More detail on the SDM methods and results for each species is provided in the *Discussion Paper on Advancing EFH Descriptions and Maps for the 2022 5-year Review* (Revised March 2022). Similar to the 2017 EFH 5-year Review, the 2022 FE model is run using the upper 50th percentile of abundance-ranked occupied habitat (core EFH area; CEA) from the summer EFH maps for adults, or for all life stages for a subset of species, including crabs. The FE model is also run using the aggregated SDM maps for species complexes, which represent the EFH of member species where an SDM was not possible at this time due to data limitations (i.e., < 50 hauls with positive catches over the analysis time series).

For certain species, the SAs and the SSC raised concerns that the bottom trawl survey data does not encompass the full distribution of those species and thereby the EFH maps are underrepresenting the full distribution of those species. This issue becomes acute when the CEA is used for the FE model. **The SSC requested that SAs provide more detailed information on their concerns expressed during the Stock Author Review of the SDMs to better understand the data limitations on the spatial representation, specifically, "Does the estimated EFH represent the distribution of the species within the FMP area or does the species extend substantially beyond the estimated EFH?"** The Google Form asks SAs to answer a number of questions to better understand the data limitations and data availability that are directly related to the use of the CEA in the FE model. SA response will provide clarity

[21] SSC February, 2022 Report https://meetings.npfmc.org/CommentReview/SSCReportFeb2022.pdf

based on the spatial representativeness of the SDM maps used in the FE model to estimate the amount of habitat disturbed in the CEA. **If you did not have concerns with the SDMs or if your concerns were addressed in the review of the SDMs, you can skip the SDM questions.**

We have developed an EFH Summary Table to provide SAs with the pertinent information for each species by region. Columns A through K provide a summary of the SDM results for your species or species complex. Column L indicates if the FE model results are $\geq$ 10% CEA disturbance. Column M indicates where the SA raised a concern and/or provided a future recommendation during their SDM review that distribution data in addition to the RACE GAP bottom trawl survey should be used to map EFH for this species. Column N lists the page number references from the *Stock Author SDM Review Report* with the SA concerns and the communication record between the SA and SDM analysts. More detail on the SDM ensemble methods and results for each species is provided in the *Discussion Paper on Advancing EFH Descriptions and Maps for the 2022 5-year Review* (Revised March 2022).

SAs should review this information along with the 2022 EFH map to aid in the process of assessing the suitability of the CEA maps for species where there is a concern that the survey data used to make the CEA map does not encompass the full distribution of the species. SA responses to questions 1, 2, 4, and 6 in Section 2 (listed below) may be informed by this information and should be reviewed prior to filling out the Google Form.

Fishing Effects Assessment

The MSA requires regional Councils to minimize, to the extent practicable, adverse effects of commercial fishing on EFH that are “more than minimal and not temporary in nature” (50 CFR 600.815(a)(2)(ii)). During the 2017 EFH 5-year Review, the FE model was developed to assess the effects of fishing on EFH. This model draws on the spatially explicit NMFS Alaska Region Catch-In-Areas (CIA) database[22] and uses habitat disturbance and recovery data from a global literature database to track habitat disturbance and recovery.

As in the 2017 EFH 5-year Review, the 2022 FE model is run using the upper 50th percentile CEA from summer SDM maps for adults or combined life stages, which are based on the RACE GAP bottom trawl survey data and environmental covariates. The Final Environmental Impact Statement for EFH Identification and Conservation in Alaska defines EFH as the area inhabited by 95% of a species’ population (NMFS 2005[23]). EFH is characterized for each species’ life stage as the spatial domain containing the upper 95% of abundance-ranked occupied habitat. As in the 2017 EFH 5-year Review, the 2022 SDM-based EFH maps are provided with additional area percentiles, representing the upper 75%, 50%, and 25% of occupied habitat (Section 3.2.8 SDM EFH Discussion Paper, March 2022[24]). **While reviewing the EFH maps, please note that all shaded EFH percentile areas within the maps are EFH.**

[22] Catch-In-Areas database https://www.fisheries.noaa.gov/inport/item/27363
[23] FEIS for EFH in Alaska https://repository.library.noaa.gov/view/noaa/17391
[24] EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

The three-tiered approach for the SA's FE assessment was developed by the SSC subcommittee and approved by SSC in December 2016[25]. Because EFH is defined for populations managed by the Council, the first consideration of the FE analysis is at the population level. SAs will indicate whether the population in question is above or below Minimum Stock Size Threshold (MSST) or note if MSST is not defined for the stock. **SAs are asked to provide a written FE assessment for any stock that is below MSST if the stock assessment author determines that there is a plausible connection to disturbance of EFH as the cause.** The FE assessment will be provided to the appropriate Plan Teams, SSC, and Council for consideration of mitigation measures. Additionally, in February 2022, the SSC noted it "encourages the use of habitat modeling outputs and methods, data inputs, and stock author input to help inform specific rebuilding plans and monitor progress towards rebuilding, as appropriate."

To investigate the potential relationships between fishing effects and stock production, the SAs will examine trends in life history parameters and the amount of disturbed habitat in the CEA for each species they assess. In 2016, the SSC subcommittee defined the CEA as the predicted upper 50th percentile of EFH area. In September and October 2016, the BSAI and GOA groundfish and BSAI crab Plan Teams, SSC, and Ecosystem Committee recommended that the SSC subcommittee investigate using alternate area percentiles for the CEA. In response, the SSC subcommittee reviewed information about the proportion of EFH in a disturbed state for the areas corresponding to the upper 25%, 50%, and 95% EFH areas for several species. After analyses, the SSC subcommittee continued to recommend the 50% area to represent the "core EFH" area to avoid the likelihood that important areas are excluded (if using the smaller area, 25%) and to avoid statistically minimizing the amount of habitat disturbance by using the larger area, 95% (total EFH area). For 2022, NMFS is recommending SAs consider a 75% CEA as well as a way to address SSC concerns for data limited stocks.

SAs will conduct additional analyses, as described below, for any stocks for which the proportion of habitat disturbed by fishing in the CEA is ≥ 10%. In September and October 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 (≥ 10%) 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 that habitat disturbance at levels higher than 10% does not indicate that impacts of fishing are more than minimal but would result in additional review by the SA, as described below**. The SSC subcommittee also noted that the 10% threshold does not preclude stock assessment authors from completing the evaluation for levels of habitat disturbance less than 10%, if other data suggest that impacts may be affecting the population.** Therefore, in 2016, the SSC subcommittee continued to recommend the ≥ 10% habitat disturbance threshold to trigger additional analyses by the SAs.

If ≥ 10% of the CEA is disturbed by fishing, SAs will next examine 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 there

[25] Methods to evaluate the effects of fishing on EFH proposal from the SSC subcommittee December, 2016 https://meetings.npfmc.org/CommentReview/EFHFishingEffectsProposedMethods.pdf

are correlations between those parameters and the trends in the proportion of the CEA disturbed. If a correlation exists (negative or positive), the SAs will determine whether the correlation is significant at a p-value of 0.1. This criterion provides an objective threshold to ensure that a "hard look" has been taken for each species, as appropriate. Because multiple parameters will be examined for correlation to habitat disturbance, it is somewhat likely that spurious significant ($p < 0.1$) correlations will be found.

Again, because the purpose of this criterion is not to determine statistical significance of impacts, but to provide an objective threshold to ensure that a "hard look" has been taken for each species, the SSC subcommittee did not feel that a written protocol is necessary to address multiple-test issues. Whenever a correlation is found to be significant ($p < 0.1$), the SA would elevate the potential impact to the Plan Teams and SSC for review or provide rationale for why it is not necessary; in other words, explain why the result is spurious. Similarly, SAs are not precluded from elevating a potential impact if they feel it is necessary. A correlation with a p-value between 0.1 and 0.25 could be elevated to the attention of the Plan Teams and SSC, with appropriate rationale from the SA; in other words, explain why the result could be significant.

Therefore, the SSC subcommittee recommended a p-value of 0.1 in 2016. Whenever significant correlations are found, the expert judgment and opinion of the SAs will be important to determine whether there is a plausible connection to disturbance in EFH as the cause, or if the result is spurious. If SAs determine that the correlation between the impacts to the CEA and life history parameter(s) suggest a plausible stock effect, they will raise that potential impact to the attention of the Plan Teams, SSC, and Council for additional analysis. If the impact is determined to be more than minimal and not temporary, the Plan Teams and SSC would recommend mitigation measures to the Council.

In 2022, the SSC raised issues with data limitations for the FE model, including habitat feature susceptibility and that it did not initially include unobserved fishing events for which VMS data was available. Both the observed and observed + unobserved model runs are now available and included. We provide the opportunity for SAs to express concerns with the data limitations in the FE model as well as the SDMs. The SSC recommended that the SA should consider the question of whether to elevate a species for possible mitigation based on other sources of information if the SA is concerned that the SDM map underestimates EFH. The Google Form includes a question for the SA's input on the other sources of information available for what other sources of information to inform the decision whether to elevate a species for possible mitigation and the primary concerns with using the FE model output to assess fishing effects for this species.

Finally, SAs were asked to consider EFH research activities or priorities that you would recommend for the identification or evaluation of impacts to EFH for your particular species of interest. Please include your recommendations within the Google form. If you already provided research recommendations for future work in your review of the SDMs, as summarized in the *Discussion Paper on Advancing EFH Descriptions and Maps for the 2022 5-year Review* (Revised March 2022), in section 3.5 and provided in the *SA SDM Review Repor*t in chapter 3, you do not need to repeat those ideas here. However, if there are new ideas specific to the FE model or that you came up with during this SA review, please list them. There is also an opportunity to raise habitat concerns that would be appropriate for the Habitat Areas of Particular Concern (HAPC) for Council consideration[26].

Documents for Stock Author Review

SDM EFH Map Documents for Review[27]

To re-address potential concerns with the SDM maps, stock assessment authors were provided with documents including:

- EFH Summary Table (April, 2022)[28];
- Report of Stock Assessment Author Review of EFH Components 1 and 7 for the 2022 5-year Review (December, 2022);
- Survey Effort Offset SDM Rerun Summary (March, 2022)[29];
- Discussion Paper on Advancing EFH Descriptions and Maps for the 2022 5-year Review (January, 2022; revised March, 2022); and
- The EFH maps detailed below.

Fishing Effects Documents for Review[30]

SAs were provided a Google folder with the following information for the FE assessment:
AI, BS, & GOA regional folders:

- A regional map of overall habitat disturbance by all gear types (r*egion_cumulative_habitat_disturbed.jpg*);

The regional folders also contain individual species folders by region (AI, BS, GOA) that each contain additional files:

- 2022 EFH map (*region_lifestage_species_EFHmap.png*). This map shows the upper 25th, 50th, 75th, and 95th percentiles of the EFH area. **All shaded areas are EFH.** The *status quo* CEA used in the 2017 EFH 5-year Review is the upper 50th percentile of the EFH area;
- A figure comparing 2017 and 2022 50% CEA overlay maps (*region_lifestage_species_efh50comp.png*);
- A figure of habitat disturbance percentages by month for the species-specific 50% CEA (*region_lifestage_species_CEA_timeseries.jpg*);

[26] NPFMC HAPC Process https://www.npfmc.org/wp-content/PDFdocuments/conservation_issues/HAPC/hapc_process092010.pdf
[27] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[28] Appendix 1 Table A1.1 in EFH Component 1 SDM EFH Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[29] Chapter 4 in EFH Component 1 SDM EFH Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[30] EFH Component 2 Fishing Effects September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- A time series file of habitat disturbance percentages by month for the species-specific 50% CEA that can be used to evaluate possible correlations with life history parameters (*region_lifestage_species_CEA_timeseries.csv*);
- A map of cumulative habitat disturbance for species-specific 50% CEA (*region_lifestage_species FEmap.jpg*); and
- The 2017 SA FE analysis (if available for the species' life stage in that region).
- **2017 worked examples**: Contains example fishing effects analysis from 2017.
SA Instructions for the Google Form

We requested stock assessment authors to provide the FE assessment along with any concerns regarding data limitations with the EFH maps and FE analysis, as requested by the SSC. All stock assessment author responses were compiled onto the Google Form. A decision tree (Figure 1) was constructed to aid stock assessment authors in navigating the logistics of the questions. The following are the questions, instructive prompts, and writing opportunities that were provided to stock assessment authors in the **Google Form:**

I. **Section 1 Instructive Prompt: Please complete a separate Google Form for each species or species complex by area. For species complexes, if you have a concern about an individual species within the complex, please either fill out an additional form for that species or explain the individual species concern in the writing sections of the form for the species complex.**

   Q1. Select species or species complex name from dropdown menu.
   Q2. Select species region from dropdown menu.
   Q3. Is the stock in question below MSST? *Yes/No/Stock does not have an MSST defined*

II. **Section 2 Instructive prompt:** Review the EFH Summary Table and the SDM documents in the SA FE Assessment Google Drive folder for your species and region. **While reviewing documents please note that all shaded areas within the maps are EFH.** See section 1.2 of the Instructions.

   Q1: *Please qualitatively score your concern (Column M of the EFH Summary Table) that the EFH map does not encompass the summer distribution of adults of this species in the fishery management unit as High (3), Medium (2), or Low (1).* ***If you did not report a concern in your earlier review, you can skip to question 3.*** *If you are concerned now, please rank your concern.*

      Q1a*: Please briefly explain your concern and qualitative score in the box below.*

   Q2: *Given your concerns, are species distribution data for the summer season available in addition to the RACE GAP bottom trawl survey and ready to use in future iterations of an SDM that will likely increase EFH for this species?*

      Q2a: *If Yes, please provide the data sources that you are recommending with references.*

      Q2b: *If Yes, are you interested in assisting with modifying the SDMs to include the additional species data for the next EFH 5-year Review?* This would involve working with the EFH SDM analysts to develop methods combining survey data in the SDM ensemble framework, running models, interpreting results, and reporting.

III. **Instructive prompt:** Review the SA FE Assessment Google Drive Folder for your species and region (time series data and maps- see 1.2.2 Fishing Effects Documents for review). If habitat disturbance within the CEA is ≥ 10%, continue to the next question. See section 1.2 of the Instructions. If not, **no further action is required**; however, please continue to complete the form if you are interested, or you have concerns with the EFH map or FE model results. You can skip to questions 8 and 9 if you want to recommend research or Habitat Areas of Particular Concern.

Q3: *Please qualitatively score your concerns that the FE model does not encompass the effects of fishing on your species due to FE model data limitations as High (3), Medium (2), or Low (1). Please briefly explain your concern and qualitative score in the box below. If you do not have a concern, you can move to the next question.*

Q3a: *Please briefly explain your primary concerns with using the FE model output to assess fishing effects for this species.*

Q4: *What is the most appropriate approach to assess the effects of fishing on EFH for your species?* If you have concerns that the SDM map underestimates EFH, you can choose using the FE model with a 75% CEA or qualitative assessment using other sources of information. Options:

a. Use the FE model with a 50% CEA (no or low concern; status quo) - Go to Q5.

b. Use the FE model with a 75% CEA - We will provide these results and maps to the SA upon request. Skip to Q7.

c. Qualitative assessment using other sources of information - Skip to Q6.

Q5: *If 50% CEA is appropriate, evaluate correlations between CEA disturbance and life history indices. If significant, perform analyses and upload files in the form of graphs or tables with the name* region_species_FE_eval.doc *into the species and region-appropriate Google folder. Use one of the Step 3 examples found in the worked examples Google folder as a template for your analysis (ex: GOA Pacific ocean perch). Please provide any written explanation in the box on the Google Form unless providing written analyses in the document uploaded with the graphs or tables.*

Q5a: *Did you upload your files to the google folder?*

Q6: *If you chose a qualitative FE assessment, conduct a qualitative FE assessment and provide other sources of information available to inform the decision on whether fishing effects would cause a species to be elevated for possible mitigation.*

Q7: *Based on your FE assessment, do you recommend this species be elevated to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH? If elevated for possible mitigation, the recommendation would be presented to the Plan Teams in the fall and the SSC in October 2022.*

a. No further action

b. Elevate for possible mitigation of habitat impacts

c. Insufficient information to make this decision

Q8: *Provide recommendations for EFH research activities and priorities to understand fishing effects on EFH.*

Q9*: Do you have any habitat concerns that would be appropriate as Habitat Areas of Particular Concern, or HAPC, for your species for Council consideration?*

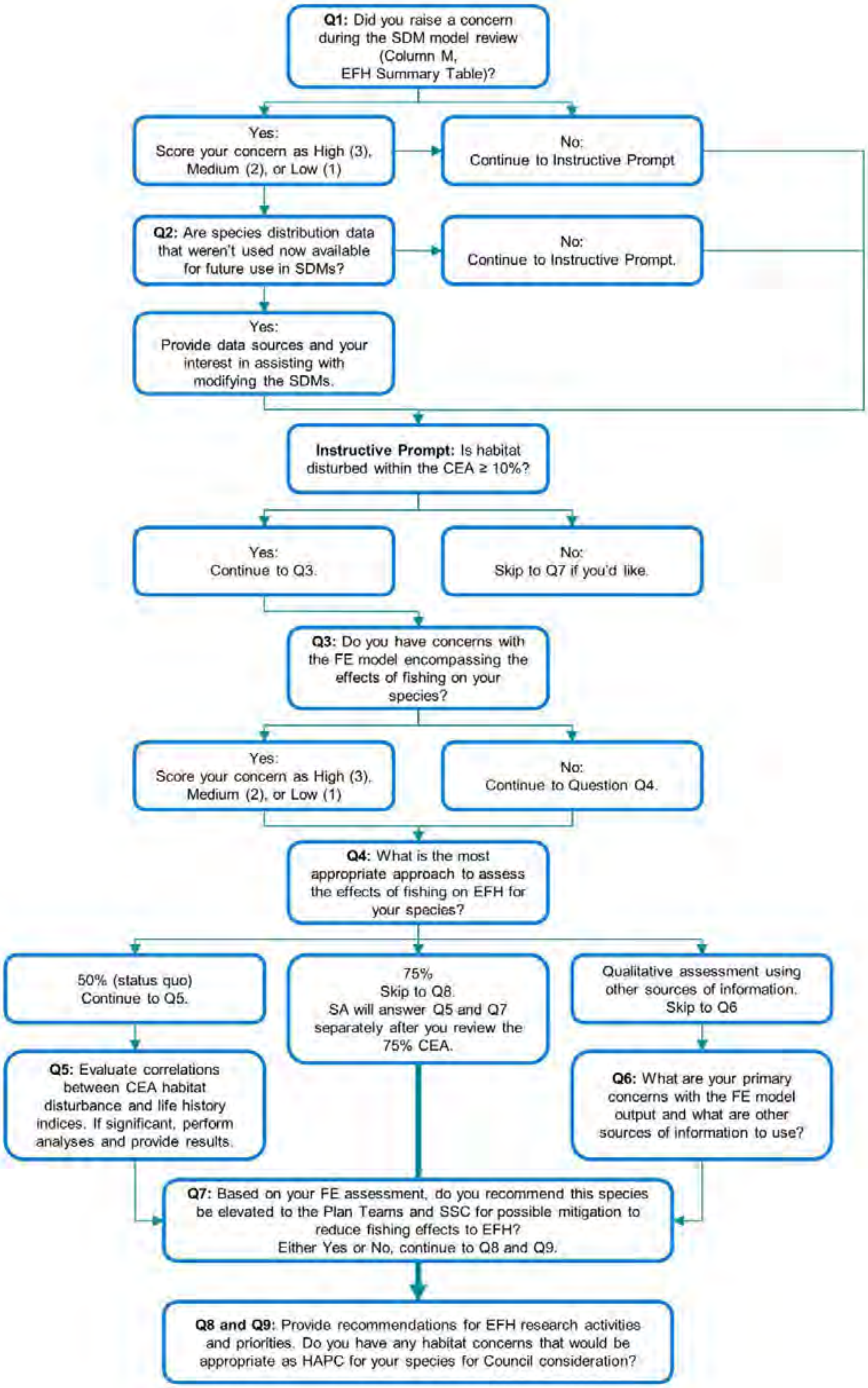


Figure A4.1. A decision tree for answering questions in Section 2 of the Google Form about the SDM review follow-up and FE assessment.

APPENDIX 5 STOCK AUTHOR FISHING EFFECTS ASSESSMENT AND QUESTIONNAIRE RESPONSES

Appendix 5 contains the complete results from the 22 Stock Authors (SAs) that participated in EFH component 2 FE assessment for the 2022 EFH 5-year Review. We received 86 responses in the Google Form and via email for individual species and/or stock complexes.

Tables

Figures

Contents

Appendix 5 is organized by region and species, where SA comments and analyses provided with the 2022 FE assessment questionnaire are reported in the following order:

- Concerns with EFH map(s);
- Concerns with FE model;
- EFH research recommendations;
- HAPC considerations[31]; and
- FE assessment;
    - If warranted, additional supporting analysis for the quantitative FE assessment using the FE model and 50% CEA, or
    - Qualitative FE assessment using other information sources.

If the SA did not provide concerns, recommendations, additional information for their FE assessment, those bullet points are omitted from the species section.

We received a written FE assessment for 17 species. SAs provided FE assessments if their species experienced ≥ 10% CEA disturbance, if their species was below MSST, and/or if they preferred a qualitative assessment. Only two species have stocks below MSST: EBS blue king crab and EBS snow crab. **None of the SAs concluded that fishing effects on EFH were more than minimal and not temporary. None of the SAs recommended their species for elevation to the Plan Teams and SSC for possible mitigation or recommended any change in management with regards to fishing within EFH at this time. However, some SAs concluded that there was insufficient information to make this decision for some species at this time.**

BSAI Groundfish

The following species or species complexes were reviewed by the SAs and were determined not need any additional supporting analysis to assess fishing effects on EFH for their stocks. They had *no concerns* with the EFH maps or the FE model and they *approved* the use of the 50% CEA in determining the percent of habitat disturbed by fishing for each species/species complex.

- ***Alaska plaice***
- ***Flathead sole-Bering flounder complex***
- ***Northern rock sole***
- ***Pacific cod***
- ***Yellowfin sole***

The BSAI groundfish species are listed below with the SA comments, concerns, recommendations, and FE analysis supporting their FE assessment, if provided by the SA.

5.1.1 Arrowtooth flounder

- Concerns with EFH maps
    - For both the EBS and AI arrowtooth flounder, the SA marked *no concerns* but noted: "A comment was submitted previously regarding additional data that are

[31] HAPC considerations were provided for two species: EBS Blue king crab and WAI Red king crab.

available for arrowtooth flounder on the longline and IPHC surveys. This would likely expand the EFH footprint further into the slope region as arrowtooth flounder are found there regularly. The eastern Bering Sea slope survey has not been conducted since 2016 and there are no plans to continue this survey. These alternative data sources would be useful to include in the future."

    - Response: This recommendation was reported and discussed on page 21 in the December 2021 EFH Stock Author Review Report[32]. This recommendation as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data* and *EBS Arrowtooth flounder example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[33].

  - The SA suggested these species distribution data to use in future SDM: AFSC longline survey[34] and the IPHC survey[35].

- EFH research recommendations
  - The SA recommended: "Include the [additional] slope data sources in the next iteration of these models and maps. When evaluating the 10% impact, it might be useful to first determine if habitat is an important factor for the stock. Reference to the habitat specificity variables in the climate vulnerability assessment[36] and the habitat assessment prioritization for Alaska stocks[37] would be very helpful here and might allow for a more targeted approach to stocks that have already been deemed vulnerable to habitat disturbance."

- **SA chose a quantitative FE assessment and provided additional supporting analysis:**

Arrowtooth Flounder Fishing Effects Assessment by Stock Author

The impacts of commercial fishing on essential fish habitat (EFH) are of interest as part of the EFH 5-year review. Similar to 2017, the 2022 fishing effects (FE) model is run using the upper 50th percentile core EFH area (CEA) from summer species distribution maps for adults or combined life stages for a given fish stock. Data to support this model are from the RACE GAP bottom trawl survey and various environmental covariates (SDM EFH Discussion Paper). Maps and habitat disturbance output provided from the FE model were used to assess the effects of fishing on Bering Sea arrowtooth flounder (see section 4.3).

A three-tiered approach is used for evaluating effects of fishing as suggested by the SSC EFH subcommittee. The first step of the evaluation was to determine whether Bering Sea arrowtooth flounder are above their Minimum Stock Size Threshold (MSST). The MSY level is defined as B35% for Tier 3 stocks. Please note that arrowtooth flounder are assessed and managed as a unit

[32] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[33] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[34] Siwike et al. 2022 https://repository.library.noaa.gov/view/noaa/37523
[35] IPHC survey sampling manual https://iphc.int/uploads/pdf/manuals/2022/iphc-2022-vsm01.pdf and data visualization requests https://iphc.int/data/datatest/fishery-independent-setline-survey-fiss
[36] Spencer et al. 2017 https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14763
[37] McConnaughey et al. 2017 https://repository.library.noaa.gov/view/noaa/15500

across the Bering Sea and Aleutian Islands (BSAI). The BSAI arrowtooth flounder female spawning biomass is above B35%; therefore, BSAI arrowtooth flounder are above their MSST (Shotwell et al., 2020a).

The next step was to determine whether fishing in the CEA resulted in a disturbance in habitat of 10% or greater. Arrowtooth flounder in the Bering Sea were evaluated to have greater than 10% disturbance in habitat in 2020 for the FE model using observed plus unobserved fishing events but not for the observed only model. If the 10% threshold of habitat impact is exceeded, correlation analyses are requested between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success. Similar annual trends were observed for the monthly time series of the habitat disturbance percentages for the observed plus unobserved model (Figure A5.1, top graph). These trends are similar for the observed only model (Figure A5.1, bottom graph). Therefore, the average habitat disturbance within each year was used for the correlation analyses. Habitat impact was compared with total (feeding) biomass, female spawning stock biomass, and age-1 recruitment estimated over the BSAI based on the stock assessment for those regions (Shotwell et al., 2020a). There is no data to examine growth-to-maturity. We conducted correlation analyses for both the observed plus unobserved model and the observed model. A visual representation of the correlation matrix from this analysis does not indicate any strong relationships between the habitat disturbance models and the stock assessment model output (Figure A5.2). Additionally, none of the correlation tests were significant (Table A5.1). The only close to significant relationship was between the observed plus unobserved model and the spawning stock biomass. However, arrowtooth flounder spawning takes place in deep water greater than 400m so the documented habitat impact would be unlikely to affect the areas that arrowtooth flounder select for spawning (DeForest et al. 2014, Blood et al. 2007).

The final step is to consider if any mitigation measures are needed at this time for arrowtooth flounder in the Bering Sea. Fishing effects appear to overall spatially have a low effect on habitat; the majority of fishing effects reduced 2-10% of habitat in the main areas where Bering Sea for arrowtooth flounder are observed on the bottom trawl survey (Shotwell et al., 2020a). The proportion of habitat reduction in the Bering Sea CEA has been less than 10% for much of the recent time series since the 2017 analysis and is below 10% for the observed FE model. Habitat impacts on the available data for Bering Sea arrowtooth flounder growth-to-maturity, spawning success, breeding success and feeding success are not detectable, and mitigation measures are not needed at this time.

Table A5.1. Results of correlation analysis between annual Bering Sea habitat impact and total biomass, female spawning biomass, and age 3 recruitment from the BSAI stock assessment (Shotwell et al., 2020a).

Correlation Compared with Habitat Disturbance (observed plus unobserved)	**Correlation Coefficient (r)**	**P-value**
Total Biomass	0.136	0.592
Spawning Stock Biomass	-0.447	0.063
Recruitment	-0.081	0.748

Correlation Compared with Habitat Disturbance (observed only)	**Correlation Coefficient (r)**	**P-value**
Total Biomass	0.193	0.444
Spawning Stock Biomass	-0.344	0.162
Recruitment	-0.104	0.681

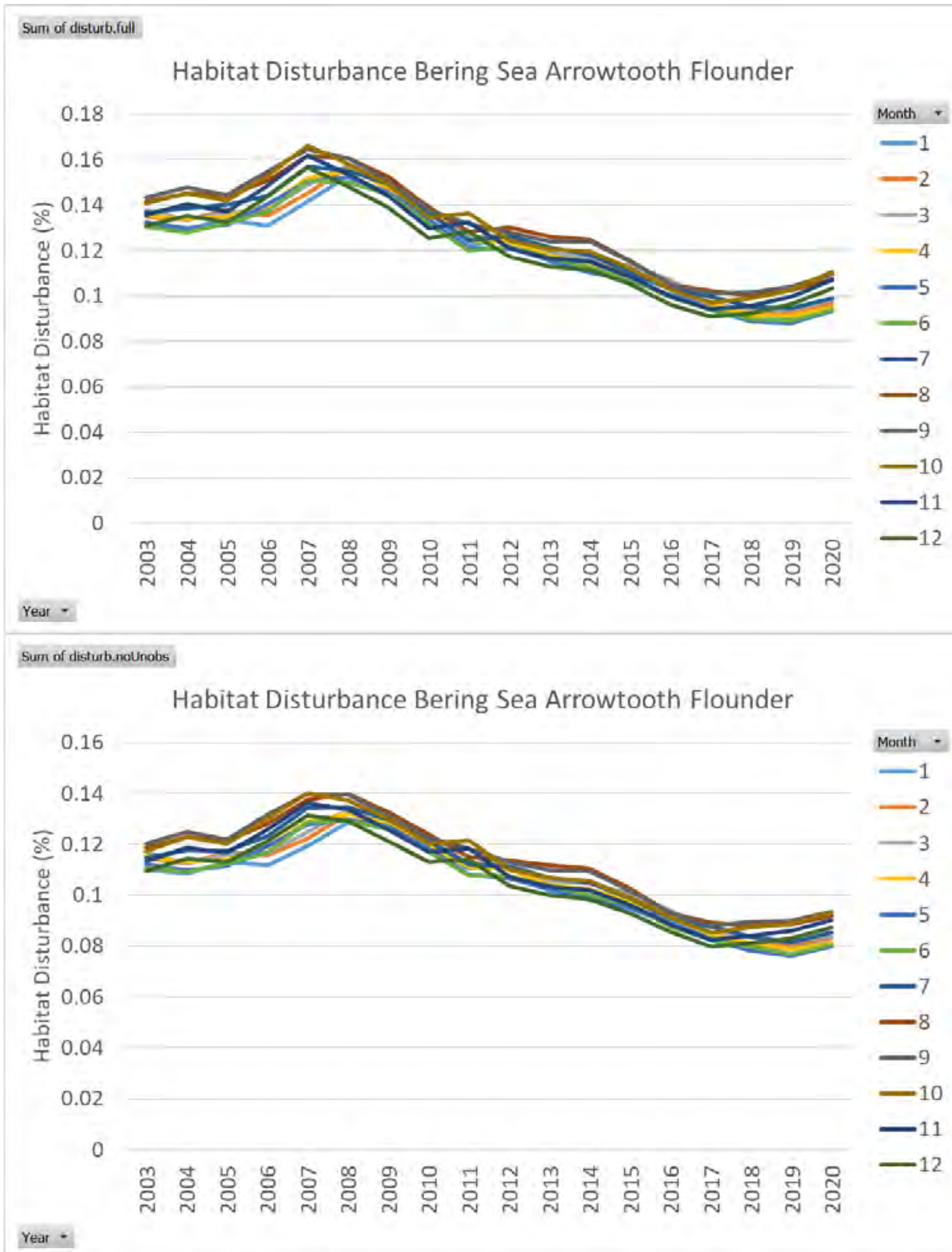


Figure A5.1. Habitat disturbance by month and year for arrowtooth flounder in the Bering Sea for the observed plus unobserved model (top graph, sum of disturb.full) and observed only model (bottom graph, sum of disturb.noUnobs).

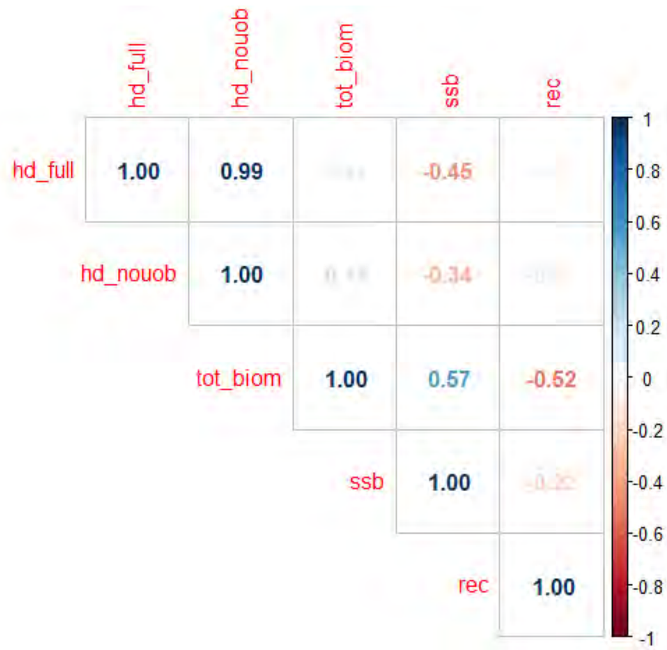


Figure A5.2. Correlation matrix visual for observed plus unobserved (hd_full) habitat disturbance, observed only (hd_nouob) habitat disturbance, total biomass (tot_biom), spawning stock biomass (ssb), and recruitment (rec) for BSAI arrowtooth flounder.

5.1.2 Atka mackerel

- Concerns with EFH maps
    - For EBS Atka mackerel, the SA noted *medium (2) concern* and commented: “The EBS data for Atka mackerel are very limited and sparsely distributed.”
    - For AI Atka mackerel, the SA noted *low (1) concern* and commented: “I still have a low level of concern due to the SDM performance, i.e., poor-moderate fits and overall SDM fit ranked as “fair”. Atka mackerel are a very patchily distributed species in time and space. Those factors may affect the determination of EFH with survey data which are highly variable.”
        - Response: This concern was reported and discussed on page 22 in the December 2021 EFH Stock Author Review Report[38]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and *Atka mackerel example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[39].
- Concerns with FE model
    - For EBS Atka mackerel, the SA noted *high (3)* concern and commented: “There was a 91% reduction in the EFH map from 2017 to 2021. Atka mackerel are only

---

[38] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[39] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents
https://meetings.npfmc.org/Meeting/Details/2947

sparsely detected in the EBS where there is heavy fishing pressure. They have never been observed in large numbers in the EBS, so determining EFH for Atka mackerel is problematic."

- For AI Atka mackerel, the SA noted *no concern*.
    - Response: Comparing the 2017 SDMs and 2022 ensembles demonstrated that the type of model used in 2017 had a large effect on the performance metrics and calculated EFH area. Approximately 18% of ensembles resulted in EFH areas that were smaller by at least half; in each of these cases the 2017 SDM was a presence-only MaxEnt model. The large reduction in CEA observed in the 2022 EBS Atka mackerel map compared to the 2017 map was largely attributed to moving from the single use of a presence-only MaxEnt model in 2017 to an SDM ensemble in 2022. Mapping EFH using SDM ensembles rather than single SDMs helps mitigate the influence of any one SDM method on the resulting EFH area and should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping efforts, making it easier to detect changes in species distribution or habitat impacts. For more information on the 2022 SDM ensemble EFH mapping approach see the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting and supporting EFH component 1 documents[40].

- EFH research recommendations
    - The SA did not provide research recommendations for EBS Atka mackerel but commented, "I'm not sure that EBS EFH for Atka mackerel can be meaningfully determined"
    - For AI Atka mackerel, the SA recommended: "Further stratification of data in time and space would be interesting. I think patterns could become apparent at more local scales.
        - Response: The SSC 2017 cutoff for sample size in the SDMs is n = 50 hauls with positive catches, retained in the SSC June 2020 review of SDM methods. The EFH Summary Table provided to SAs to support their FE assessment reports sample size and SDM performance. Sample size of hauls with adult Atka mackerel present in the EBS and AI were n = 72 and n = 2,030, respectively. Overall performance of both the EBS and AI adult Atka mackerel SDM ensembles was fair. EFH was also mapped for adult Atka mackerel in the EBS and AI in the 2017 5-year Review. Analysts agree that mapping EFH for Atka mackerel is challenging. The SDM ensemble EFH mapping methods and results for EBS and AI Atka mackerel are provided in the EFH component 1 documents[27].
- **SA chose a *qualitative* FE assessment using other sources of information:** The SA chose the FE model with 50% CEA as the most appropriate approach to assess the effects

[40] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

of fishing on EFH for AI Atka mackerel. The SA chose a qualitative assessment for EBS Atka mackerel.

EBS Atka Mackerel Fishing Effects Assessment by Stock Author

The EBS represents the margin of Atka mackerel distributions. Their center of abundance is the Aleutian Islands. Observations in the EBS of Atka mackerel are very sparse, and there is no directed fishery for Atka mackerel in the EBS. However, there is a lot of fishing activity in the EBS. Due to the very low occurrences of Atka mackerel in the EBS, it is unlikely that CEA disturbance is >10% as determined by the fishing effect analysis; it is an artifact of the data.

Response: The SA indicated that EBS Atka mackerel exceeding the 10% threshold is an artifact of the data. However, the new analysis in the document indicates that the cause of exceeding the 10% threshold is due to the **FE model correction and updates** (Table 9).

5.1.3 Blackspotted/Rougheye rockfish complex

- Concerns with EFH maps
    - For both EBS and AI rougheye/blackspotted rockfish, the SA noted *low (1) concern* and commented: “In general, the depth and aerial extent of the trawl survey covers the stock grounds. However, a general concern with rockfish is that the densities observed in trawl surveys for the trawlable and untrawlable habitats may differ, and potentially biased results may result from considering only the densities in trawlable grounds.”
        - Response: This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[41].
- EFH research recommendations
    - For both EBS and AI rougheye/blackspotted rockfish, the SA recommended: “Continued research on observing and modeling stock densities in untrawlable grounds, particularly in the Aleutian Islands and Bering Sea slope.”
- **SA chose a quantitative FE assessment and provided additional supporting analysis:**

Blackspotted/Rougheye Fishing Effects Assessment by Stock Author

The fishing effects model was applied to the blackspotted and rougheye rockfish stock complex in the eastern Bering Sea. However, blackspotted/rougheye rockfish are assessed and managed as a unit across the Bering Sea and Aleutian Islands (BSAI). The BSAI POP stock is above the minimum sustainable stock threshold (MSST), as indicated from the estimated 2020 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer et al. 2020).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed and used for analysis. The cumulative effects

[41] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 12.4% in 2004 to 7.5% in 2014, then increased to 20.0% in 2020 (Figure A5.3).

Limited information is available to estimate trends in life history characteristics for blackspotted/rougheye rockfish along the EBS slope, and time series of age at 50% maturity, recruitment, and spawning distributions are not available for this region. Estimated size at age is available from otoliths sampled in the 2004, 2008, 2010, 2012, and 2016 EBS slope surveys. The correlation between size at age 8 in these survey years and the proportional habitat reduction was estimated; this age was chosen because rapid increases in size at this age may allow detection of the influence of habitat reduction. The estimated correlation coefficient was 0.34 (p-value = 0.58).

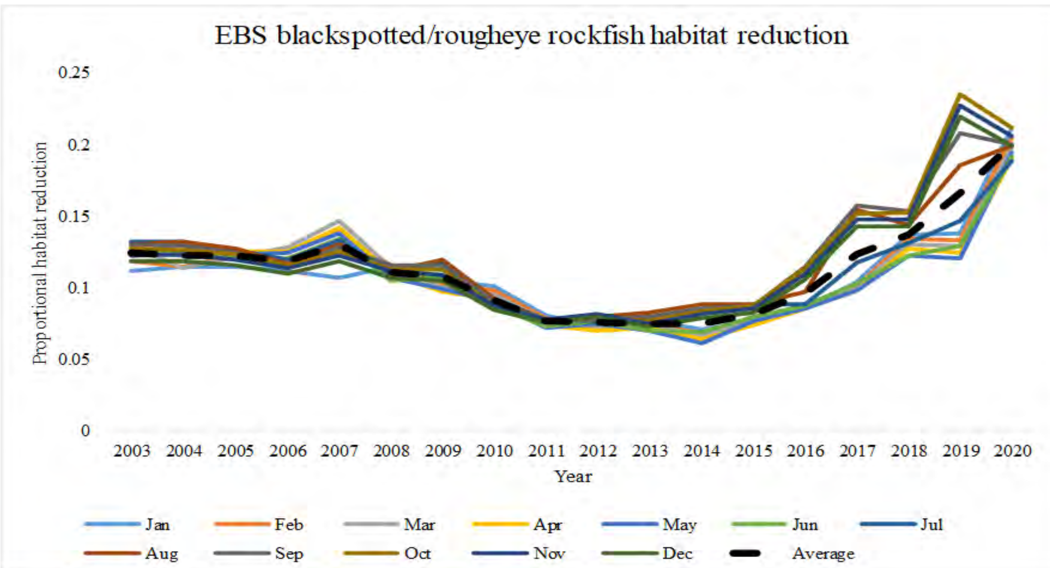


Figure A5.3. Proportional habitat reduction estimations for the EBS blackspotted/rougheye rockfish complex by month.

5.1.4 Flathead sole-Bering flounder complex

The SA reported *no concerns* regarding the SDM EFH maps or the FE model. The stock author noted requests for mapping to include early life stages.

- EFH research recommendations
  - For both EBS and AI flathead sole-Bering flounder complex model results, the SA recommended: "As for GOA [flathead sole], investigate impacts of environment on early life history and recruitment distribution. Because we don't see these individuals in the fishery until age 2 it would be good to know if habitat/fishing impacts are affecting the early stages."

5.1.5 Giant octopus

- Concerns with EFH maps

    - For EBS octopus, the SA noted *medium (2)* concern and commented: “Giant octopus are not well sampled by bottom trawl gear. Thus SDM based on summer survey data are not likely to be good representations of octopus habitat.”
        - Response: This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and *Giant octopus example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[42].
- Concerns with FE model
    - For EBS octopus, the SA noted *medium (2)* concern and commented: “I question whether the SDM for giant octopus is useful given that they are not well sampled by bottom trawl gear. Thus the FE may not be appropriate.”
        - Response: See *concerns with EFH maps* response.
- **SA chose a *qualitative* FE assessment using other sources of information:** The SA chose the FE model with 50% CEA as the most appropriate approach to assess the effects of fishing on EFH for AI Giant octopus. The SA chose a qualitative assessment for EBS Giant octopus.

EBS Giant Octopus Fishing Effects Assessment by Stock Author

Observations in the EBS of giant octopus are very sparse, and they are not well sampled by the bottom trawl survey. There is no directed fishery for giant octopus in the EBS. However, there is a lot of fishing activity in the EBS. Due to the very low occurrences of giant octopus in the EBS, the CEA disturbance is likely very low as determined by the fishing effects analysis. It is noted that the data is not sufficient to appropriately conduct a quantitative analysis, but a qualitative assessment supports the <10% CEA disturbance determined by the fishing effects analysis.

5.1.6 Greenland turbot

- Concerns with EFH maps
    - For EBS Greenland turbot, the SA noted *medium (2) concern* and commented: “The EBS slope bottom trawl survey has not been conducted since 2016. Given Greenland turbots ontogeny, as they age they move from the continental shelf to the slope. The EFH analysis includes adult data, but over time there will be less information about adult habitat.”
    - For AI Greenland turbot, the SA noted *low (1) concern* and commented: “The Aleutian Islands bottom trawl survey does not sample deep water and therefore could be underestimating adult Greenland turbot habitat.”
        - Response: This concern was reported and discussed on page 23 in the December 2021 EFH Stock Author Review Report[43]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data* with *Greenland turbot example*) of the EFH

[42] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[43] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[29].

- The SA suggested these species distribution data to use in future SDM: the AFSC longline survey, noting it is, "conducted in the Bering Sea during odd years and fishes at depths from ~0m-1200m" and in, "the Aleutian Islands in even years", and that, "It would be prudent to evaluate whether these data can be used in the future" and, "in addition to the bottom trawl survey".

- EFH research recommendations
  - In email correspondence, the SA offered: "[We] are currently working on a proposal to look at potential mechanisms for spatially varying growth in flatfish" "Forming a small team to reevaluate the life stage breaks and look at spatially varying growth differences is a great idea [leading into the next EFH 5-year Review]."
    - Response: We would like to encourage the project team to consider submitting an Alaska EFH Research Plan proposal.
- **SA chose a quantitative FE assessment.**

5.1.7 Kamchatka flounder

There were no comments, concerns, or recommendations provided for AI Kamchatka flounder.

- Concerns with EBS EFH map
  - For EBS Kamchatka flounder, the SA noted *low (1) concern* and commented: "Kamchatka flounder are found on the [Bering Sea] continental slope, which has not been surveyed since 2016. As more years pass without this information, we may underestimate Kamchatka CEA."
    - Response: This concern was reported and discussed on page 23 in the December 2021 EFH Stock Author Review Report[44]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data* with a similar species example for *Greenland turbot*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[45].
  - The SA noted a possible data source to use in future SDM: "The AFSC longline survey started to separately identify arrowtooth flounder and Kamchatka flounder. Over the next several years, these data may be useful for the EFH analysis."
- **SA chose a quantitative FE assessment and provided additional supporting analysis:** Their reason for EBS Kamchatka flounder was because they noted an upward trend in habitat disturbance from the time series.

EBS Kamchatka Flounder Fishing Effects Assessment by Stock Author

---

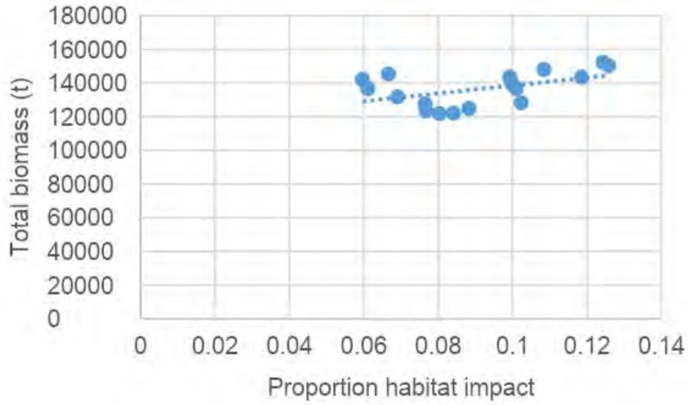
[44] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

[45] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

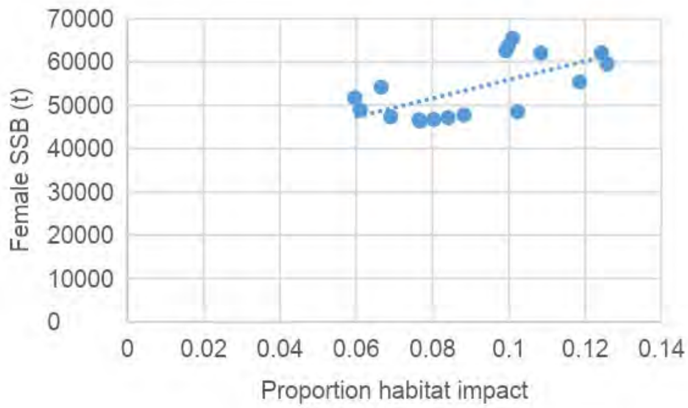
If the 10% threshold of habitat impact is exceeded, correlation analyses are requested between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success. The 10% threshold of habitat impact was not exceeded for Bering Sea and Aleutian Islands Kamchatka flounder, but a correlation analysis was performed for exploratory purposes. Correlations were based on the habitat impact in the Bering Sea rather than the Aleutian Islands because the habitat impact in this region has been increasing toward 10% in recent years. Habitat impact in one year was compared with age-2 recruitment, female spawning biomass, and total (feeding) biomass in the following year estimated over the entire Bering Sea and Aleutian Islands based on the stock assessment for those regions (Bryan et al. 2020). The correlation analyses indicate that spawning stock biomass and total biomass have a significant positive correlation with habitat impact (Table A5.2 and Figure A5.4). The correlation between age-2 recruitment and habitat impact was not significant.

Given the positive relationship between habitat impact and female spawning biomass and total biomass, mitigation measures are not needed at this time.

a.



b.



c.

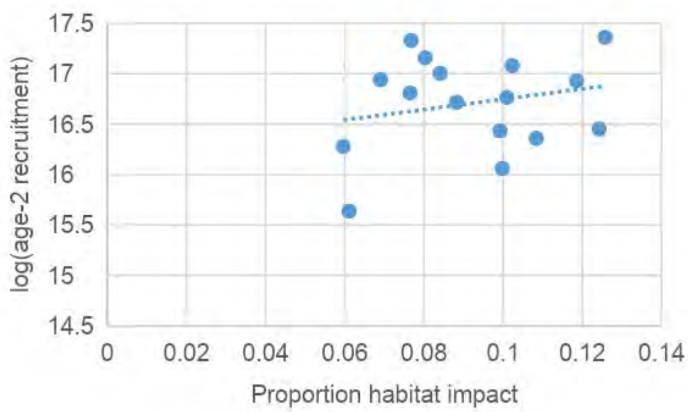


Figure A5.4. Results of habitat reduction versus biological correlation analysis for a. total biomass of Kamchatka flounder in the BSAI, b. Kamchatka flounder female spawning biomass in the BSAI, and c. number of Kamchatka flounder age-2 recruits in the BSAI.

Table A5.2. Results of correlation analysis between annual Bering Sea habitat impact in the previous year and total biomass, female spawning biomass, and age-2 recruitment from the BSAI stock assessment (Bryan et al. 2020). Years included in the analysis were 2003-2020.

Metric compared to habitat impact	correlation	n	t	p
Total biomass	0.485	17	2.148	0.0484
Spawning stock biomass	0.642	17	3.241	0.0055
log(Recruitment)	0.228	17	0.908	0.3781

5.1.8 Northern rock sole

- The SA had no concerns and commented on the new EFH map: “Compared to maps in the BSAI [northern rock sole] assessment of summer survey distribution, it looks like the EFH maps encompass relevant areas.”

5.1.9 Northern rockfish

- Concerns with EFH maps
    - For both EBS and AI northern rockfish, the SA noted *low (1) concern* and commented: “In general, the depth and aerial extent of the trawl survey covers the stock grounds. However, a general concern with rockfish is that the densities observed in trawl surveys for the trawlable and untrawlable habitats may differ, and potentially biased results may result from considering only the densities in trawlable grounds. In addition, northern rockfish are not commonly observed in the EBS surveys, and I am concerned that estimating EFH maps from such sparse data could result in high uncertainty for the species distribution maps.”
        - Response: This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[46].
- EFH research recommendations
    - The SA recommended: “Continued research on observing and modeling stock densities in untrawlable grounds, particularly in the Aleutian Islands and Bering Sea slope.”
- **SA chose an quantitative FE assessment and provided additional supporting analysis:**

Northern Rockfish Fishing Effects Assessment by Stock Author

The fishing effects model was applied to northern rockfish in the eastern Bering Sea. However, northern rockfish are assessed and managed as a unit across the Bering Sea and Aleutian Islands (BSAI). The BSAI northern rockfish stock is above the minimum sustainable stock threshold

[46] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

(MSST), as indicated from the estimated 2021 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer and Ianelli 2021).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed. The cumulative effects analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 13.2% in 2004 to 9.1% in 2011, then increased to 13.3% in 2020 (Figure A5.5).

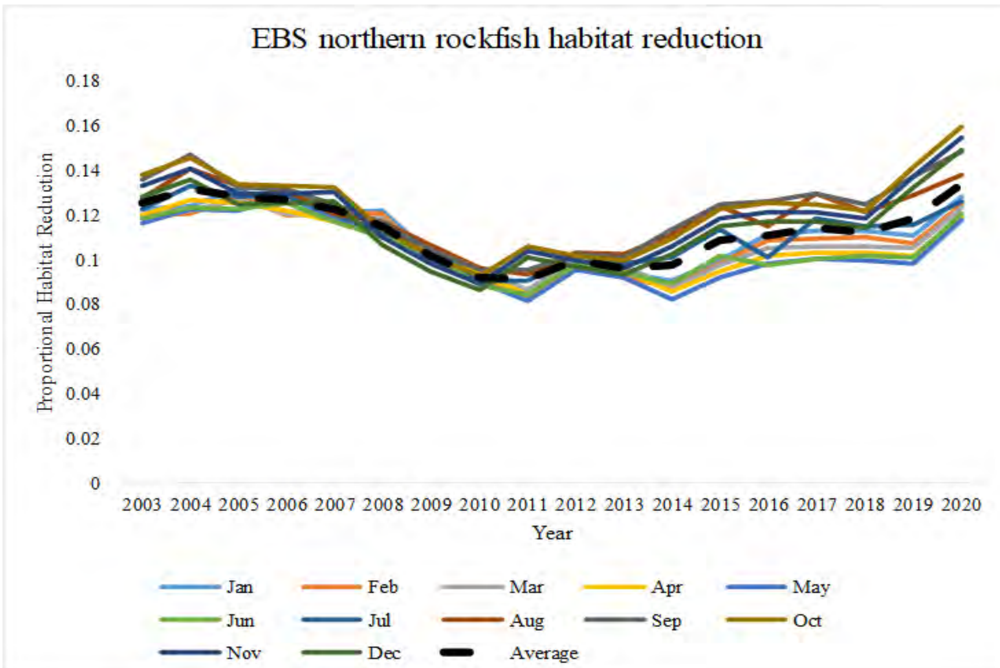


Figure A5.5. Proportional habitat reduction estimations for EBS northern rockfish by month.

Although northern rockfish are a slope species, they are not commonly observed in the EBS slope survey. Typically, northern rockfish have been observed in a very small number of hauls (i.e., <= 6) per survey, which has led to very small estimates of biomass (ranging from 3 to 42 tons) compared to estimates of over 200,000 t in the AI slope survey. The coefficients of variation of the EBS slope survey biomass estimates range from 0.38 to 1. Otoliths are not available for northern rockfish in the EBS, and time series of life-histories indices such as age at 50% maturity, and size at age are not available. The rarity of northern rockfish in the EBS, and absence of life-history information, precludes meaningful analysis of correlations between life-history indices and estimates of habitat reduction.

5.1.10 Other flatfish complex

The Other flatfish complex had a team of three SAs working together to complete the questionnaire and provide an FE assessment. They provided responses for the EBS and AI complexes and separate responses for Dover sole and rex sole in the EBS only. They cited *no concerns* for the stock complex overall.

5.1.10.1 Dover sole and Rex sole

- EFH research recommendations
  - The SAs recommended: “Group life history stages by age rather than length where possible.”
    - Response: This future recommendation is related to discussion of concerns regarding the SDM EFH maps for flatfishes with spatially varying growth in sections 6.6 and 6.7 of this document and in Chapter 5 (*life history considerations* with the *flatfishes example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[47].
- **SA chose a quantitative FE assessment and provided additional supporting analysis:**

EBS Rex and Dover Sole Fishing Effects Assessment by Stock Author
EBS Rex and Dover sole are both component stocks within the Other Flatfish Complex in the EBS. Both species exhibited greater than 10% habitat disturbance within the CEA in recent years, while other stocks within the complex did not. Pearson’s correlation coefficient and p-values from a t-distribution to evaluate significance of correlations were used to assess the relationship between EBS shelf survey biomass (as estimated in the Tier 5 stock assessment) and habitat disturbance in the previous year (averaged over months for each year) for EBS rex and Dover sole. The biomass estimates for the EBS slope were excluded, as only 7 data points existed over the period for which habitat disturbance was calculated and the most recent slope survey occurred in 2016. Pearson’s correlation coefficient was positive for both species, indicating that biomass increased with increased habitat disturbance. The correlation was significant (< 0.05) for EBS Dover sole. However, concern is low for this species because biomass did not decline with increased habitat disturbance.

Table A5.3. Pearson’s correlation coefficient and the p-value from a test of significance of the correlation based on a t-distribution, comparing estimated survey biomass of EBS rex and Dover sole to habitat disturbance in the previous year, averaged over months within each year, for each species. The years 2003-2021 were included in the analysis. Additional figures are included below.

Species	Pearson's correlation coefficient	p-value
EBS rex sole	0.261	0.311
EBS Dover sole	0.493	0.044

[47] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

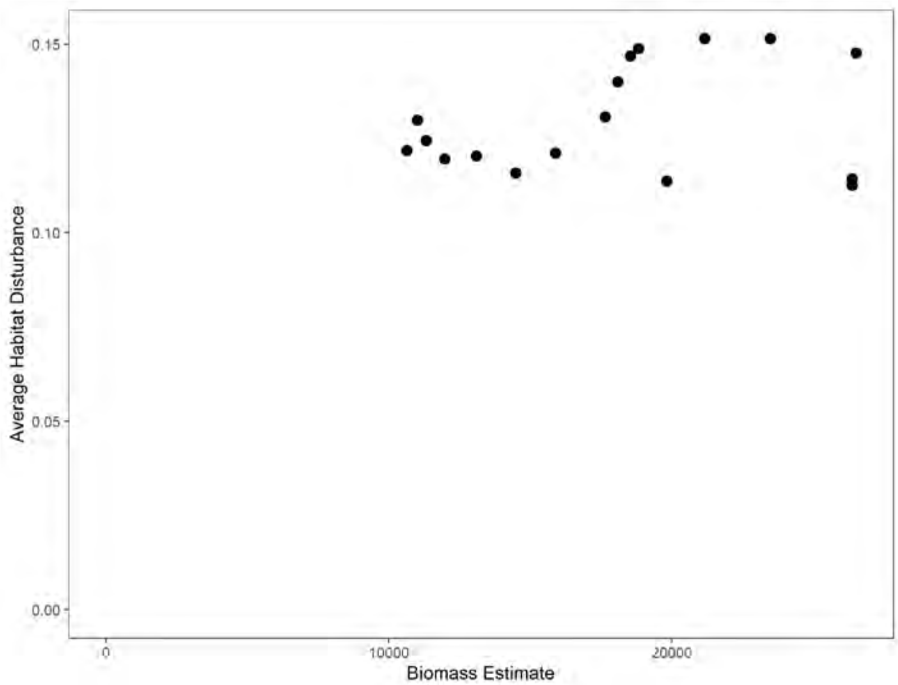


Figure A5.6. The biomass estimate for EBS rex sole from the most recent Tier 5 assessment (x-axis) plotted against habitat disturbance (averaged over months of the year) for EBS rex sole in the previous year.

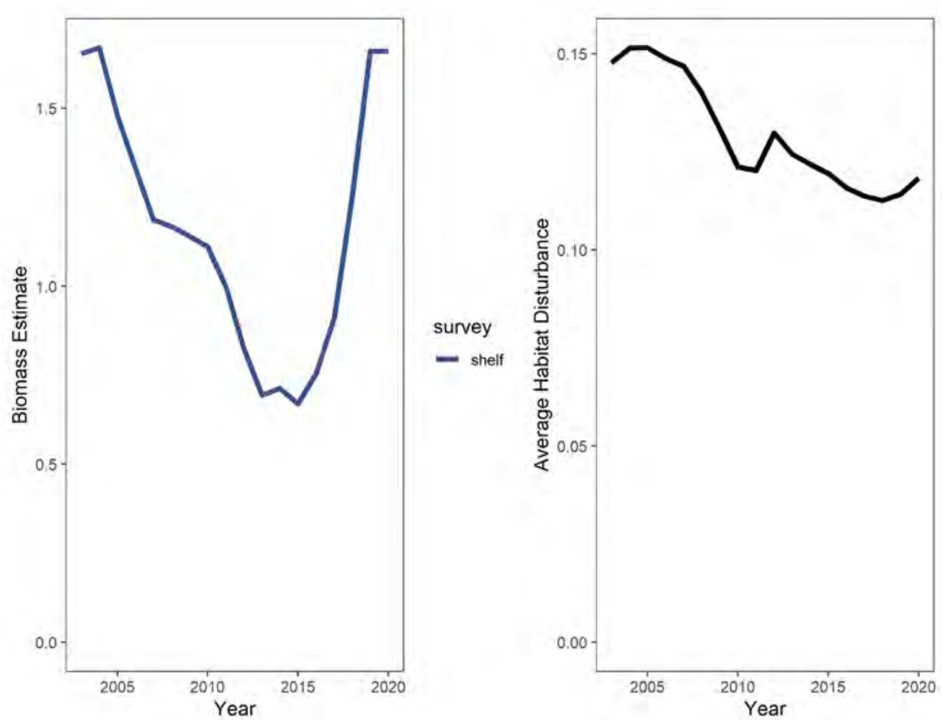


Figure A5.7. EBS rex sole biomass over time (as estimated in the 2020 Tier 5 assessment; left panel) and habitat disturbance over time (averaged over months within each year; right panel).

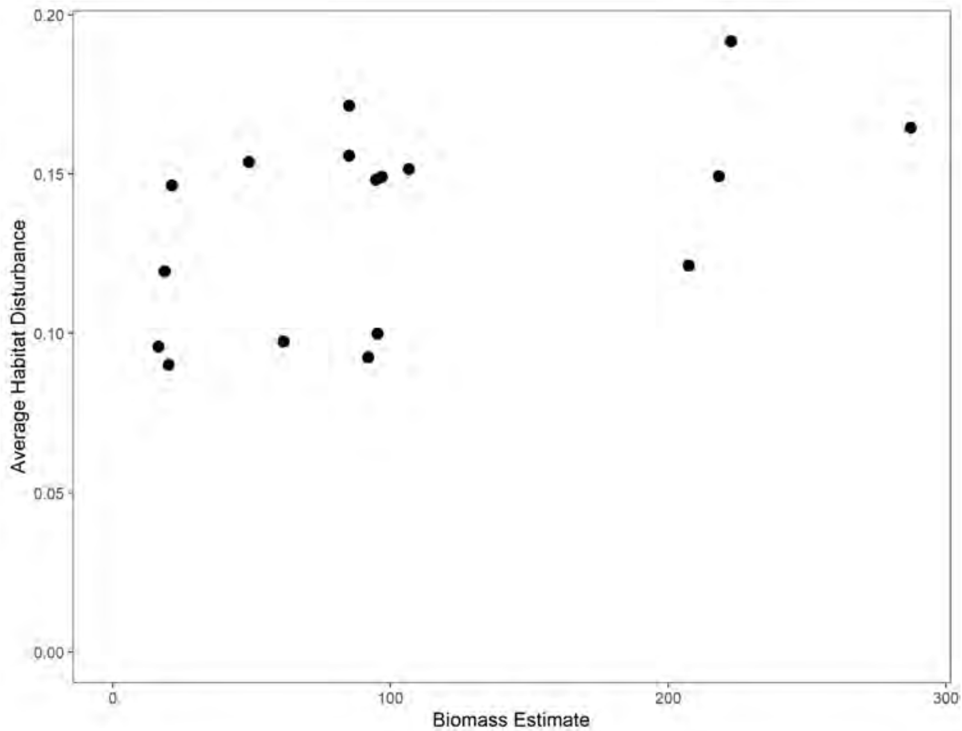


Figure A5.8. The biomass estimate for EBS Dover sole from the most recent Tier 5 assessment (x-axis) plotted against habitat disturbance (averaged over months of the year) for EBS rex sole in the previous year.

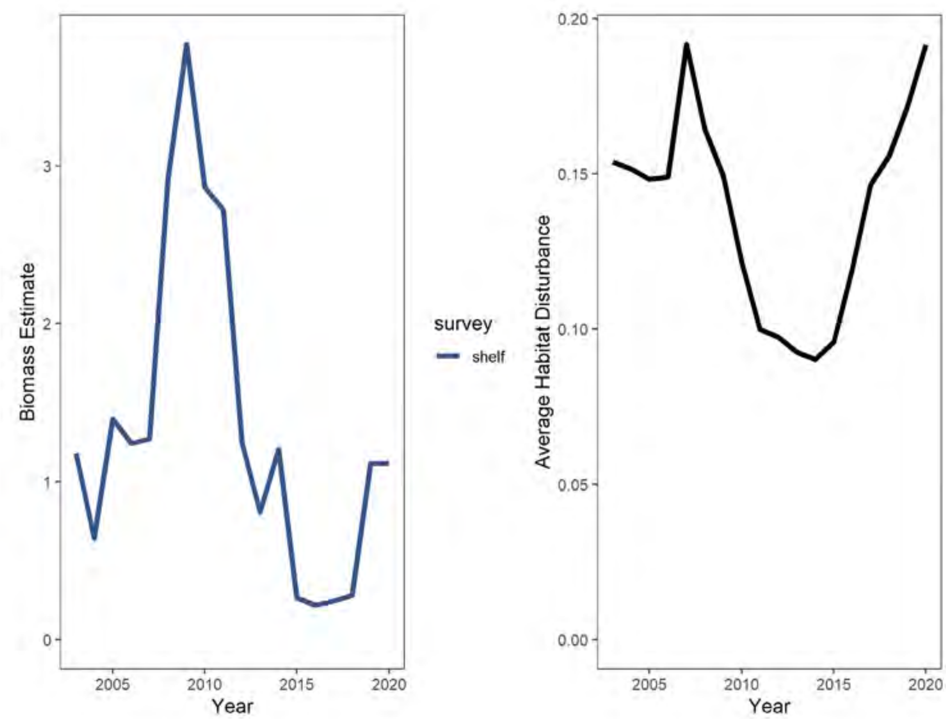


Figure A5.9. EBS Dover sole biomass over time (as estimated in the 2020 Tier 5 assessment; left panel) and habitat disturbance over time (averaged over months within each year; right panel).

5.1.11 Other rockfish complex

- Concerns with EFH maps
  - For AI dusky and AI harlequin rockfish, the SA noted that they had *no concerns*, however they provided the following context for their review of the AI other rockfish species' EFH maps: "It is important to note that both dusky and harlequin rockfish have been shown to have different relative abundances in trawlable vs. untrawlable habitat. For example, one recent study using combined acoustics and stereo-camera tools in the GOA found relative densities of dusky and harlequin rockfish were approximately three times higher in untrawlable versus trawlable areas (Jones et al. 2021)."
  - The SA also noted *no concerns* for the AI shortspine thornyhead rockfish, and offered: "My understanding is that the AI [bottom trawl survey] does not thoroughly sample deeper strata. Consequently, the [shortspine thornyheads] sampled are considerably smaller than the NMFS longline survey, which means there are portions of the summer distribution of adults that are not well-sampled by the [bottom trawl survey]. I've included length comps and relative indices of abundance from the longline survey [in the FE assessment]."
  - The SA further noted *no concerns* for the EBS shortspine thornyhead rockfish and continued their comments on the other rockfish complex: "My previous comments were related to the cessation of the EBS slope survey in 2016. The only current available data for this stock is from the NMFS longline survey. The longline survey clearly samples a larger and likely older component of the

population. It is therefore a reasonable assumption that including the longline survey data may increase EFH for this species."

  - Response: These recommendations were reported and discussed on page 26 in the December 2021 EFH Stock Author Review Report[48]. Recommendations to add species data to future SDM EFH mapping are discussed in Chapter 5 (*add species data* of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[49].

- The SA noted a possible data source to use in future SDM: they suggested the NMFS longline survey and provided two files with EBS and AI shortspine thornyhead rockfish length comps and relative indices of abundance from the longline survey.

- **SA chose quantitative FE assessment and provided additional supporting analysis:** The SA provided a written summary for EBS shortspine thornyhead rockfish and noted: "I did explore potential covariates but there were no significant correlations. This species is data limited in general. There is not a validated method for aging, though [shortspine thornyhead rockfish] are assumed to be very long-lived, slow growing, late to mature, etc."

EBS Shortspine thornyhead (SST) Fishing Effects Assessment by Stock Author
If the 10% threshold for additional analyses is exceeded, correlation between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success are requested. The 10% threshold was exceeded for EBS SST starting in 2019 and limited correlation analysis was performed for this stock between the proportion of habitat disturbed and indices of SST abundance. Body condition (i.e. length-weight residuals) were considered for this analysis but were excluded due to small sample sizes and lack of spatiotemporal coverage in the EBS. Other indices of growth (e.g. size-at-age) and maturity are not available for this stock because no validated method for ageing SST currently exists (Kastelle et al. 2020). Additionally, the EBS slope bottom trawl survey has not been conducted since 2016, and therefore does not encompass the recent time period when the 10% threshold was exceeded. In lieu of the EBS slope bottom trawl survey biomass, we used the AFSC longline survey relative population numbers (RPN; i.e., area-weighted catch-per-unit-effort), AI bottom trawl survey biomass in the southern EBS (International North Pacific Fisheries Commission [INPFC] area 799), and commercial fisheries catch data as proxy indices of abundance for SST in the correlation analysis. The AFSC longline survey has operated in the EBS in odd years starting in 1997, and the AI bottom trawl survey has operated in southern EBS in even years since the early 1980s. Because the available abundance indices are not necessarily representative of feeding, spawning, or other seasonal habits for SST, the annual mean of the full disturbance metric was used in the correlation analysis. The results of the correlation analysis, along with the *p*-values, is shown in the table below. None of the variables evaluated were significantly correlated with the habitat disturbance variable.

[48] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[49] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents
https://meetings.npfmc.org/Meeting/Details/2947

Table A5.4. EBS shortspine thornyhead correlation analyses compared to the EFH percent disturbance estimate.

Variable	ρ	p-value
AFSC longline survey RPN	-0.22	0.57
AI bottom trawl survey in the southern EBS	-0.03	0.95
Commercial catch	0.29	0.23

The results of the correlation analysis suggest that EBS SST abundance is not significantly correlated with habitat disturbance. However, it is unclear if the three recent years in which habitat disturbance has exceeded the 10% threshold is long enough to cause an impact, or if the 10% threshold is meaningful for this species. Although age, growth, and maturity information for SST are limited, best available data suggests that SST are extremely long-lived, with reported maximum ages of 100 y (Kastelle et al. 2000; Kline 1996), 133 y (personal communication Kevin McNeel, Alaska Department of Fish and Game), and 158 y (Butler et al. 1995). Estimates of maturity suggest that female age-at-50% maturity is around 13 y (personal communication Todd TenBrink, AFSC) and length-at-50% maturity is 21.48 cm (Pearson and Gunderson 2003). Additionally, tagging research in Alaska has shown low movement rates for SST (Echave 2017). These life history characteristics are consistent with a low productivity species that may be disproportionately more vulnerable to fishing effects or habitat disturbance. While there is insufficient evidence to elevate concern for this species at this time, continued monitoring and research into SST life history and ageing methodology is warranted.

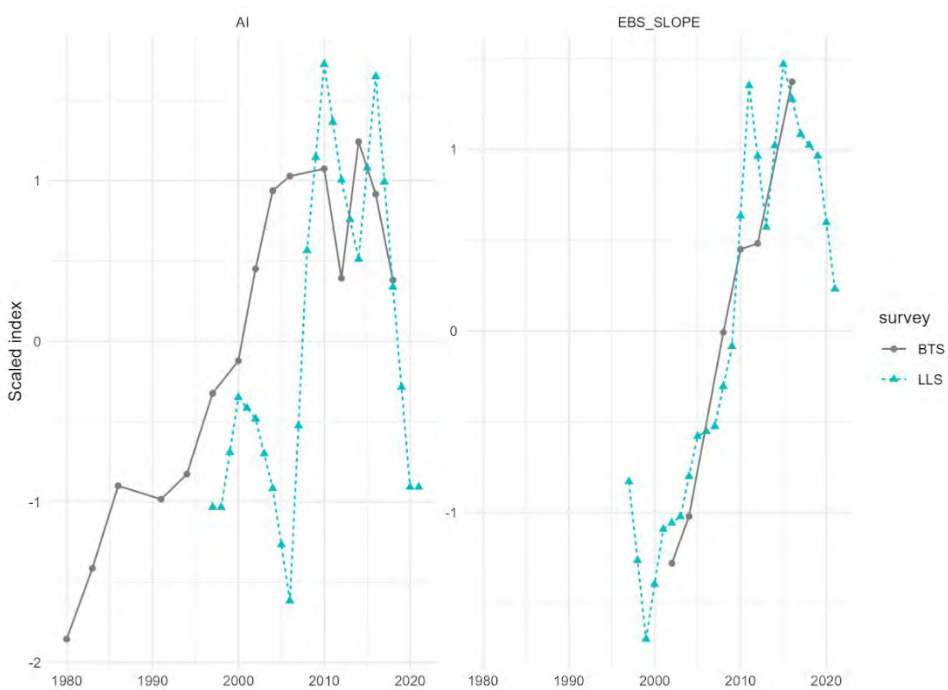


Figure A5.10. Shortspine thornyhead scaled abundance indices in the bottom trawl (BTS) and longline (LLS) surveys.

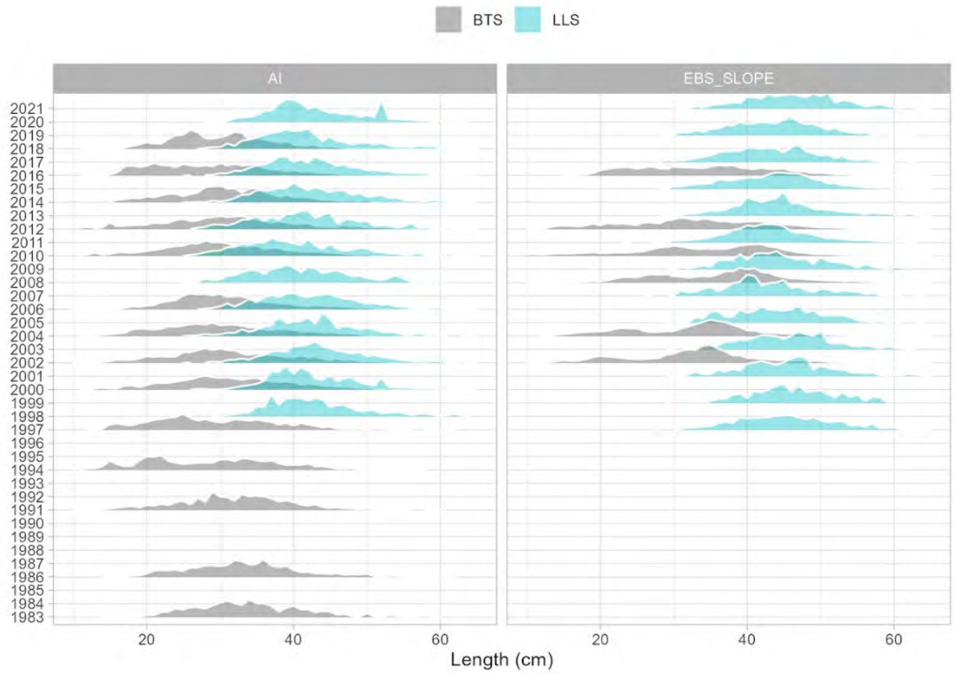


Figure A5.11. Shortspine thornyhead length frequencies in the bottom trawl (BTS) and longline (LLS) surveys.

5.1.12 Pacific ocean perch

- Concerns with EFH maps
    - For both EBS and AI Pacific ocean perch, the SA noted *low (1) concern* and commented: “In general, the depth and aerial extent of the trawl survey covers the stock grounds. However, a general concern with rockfish is that the densities observed in trawl surveys for the trawlable and untrawlable habitats may differ, and potentially biased results may result from considering only the densities in trawlable grounds.”
        - Response: This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[50].
- EFH research recommendations
    - The SA recommended: “Continued research on observing and modeling stock densities in untrawlable grounds, particularly in the Aleutian Islands and Bering Sea slope.”
- **SA chose a quantitative FE assessment and provided additional supporting analysis:**

Pacific Ocean Perch Fishing Effects Assessment by Stock Author

[50] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

The fishing effects model was applied to POP in the eastern Bering Sea. However, POP are assessed and managed as a unit across the Bering Sea and Aleutian Islands (BSAI). The BSAI POP stock is above the minimum sustainable stock threshold (MSST), as indicated from the estimated 2020 spawning biomass being larger than the estimated $B_{35\%}$ (Spencer and Ianelli 2020).

The proportional habitat reductions are estimated for the EBS area, by month, from January 2003 to December 2020. Similar annual trends were observed for each of the months, and the average habitat reduction within each year was computed and used for analysis. The cumulative effects analysis of habitat impacts indicate that the proportion of habitat disturbed declined from 13.6% in 2003 to 12.1% in 2020 (Figure A5.12).

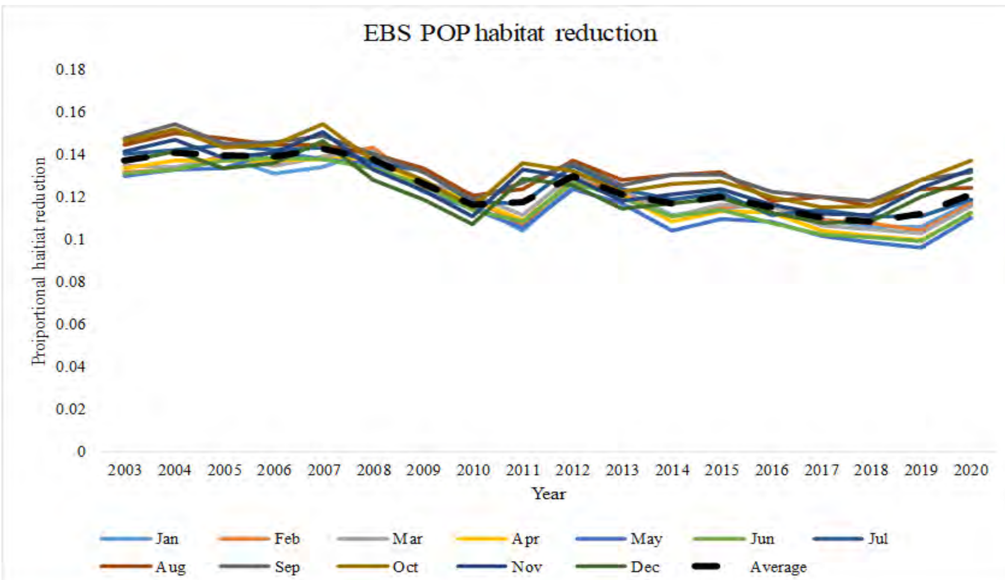


Figure A5.12. Proportional habitat reduction estimations for EBS Pacific ocean perch by month.

Limited information is available to estimate trends in life history characteristics for POP along the EBS slope, and time series of age at 50% maturity, recruitment, and spawning distributions are not available for this region. Estimated size at age is available from otoliths sampled in the 2004, 2008, 2010, 2012, and 2016 EBS slope surveys. The correlation between size at age 8 in these survey years and the proportional habitat reduction was estimated; this age was chosen because rapid increases in size at this age may allow detection of the influence of habitat reduction. The estimated correlation coefficient was -0.26 (p-value = 0.67). In addition, the correlation between total biomass from the 2020 BSAI model and proportional habitat reduction for the year 2003 – 2020 was conducted. This correlation analysis assumes that the estimated total biomass is proportional to the area occupied of the “feeding distribution”, and also that the temporal trends in total biomass from the BSAI assessment (which is largely driven by AI data) is similar to the trends in total biomass in the EBS region. The estimated correlation between estimated total biomass and proportional habitat reduction was -0.27, with a p-value of 0.27.

5.1.13 Sablefish

- Concerns with EFH maps

- For EBS sablefish, the SA noted *medium (2) concern* and commented: “As noted in the SDM EFH review, the trawl survey is generally not believed to adequately sample sablefish or their habitat. As denoted in the sablefish SAFE, the trawl survey does not consistently sample deeper than 500 m, which is primary sablefish habitat and adult sablefish may be able to outswim the trawl gear. Thus, the EBS trawl survey data is not used in the sablefish assessment. It is likely that the EFH maps based on the trawl survey are adequate to delineate general sablefish hotspots (excluding important state water locations). However, the dedicated sablefish longline survey is designed explicitly to sample sablefish and would provide a more appropriate delineation of EFH. Moreover, the high mobility of sablefish may indicate a lack of preference to specific habitat, though little is known about spawning locations or preferred habitats for early life history stages.”
- For AI sablefish, the SA noted *medium (2) concern*, echoed their EBS comments, and added: “[G]iven the relatively low sablefish biomass and limited number of adult sablefish generally caught, the AI trawl survey data is not used in the sablefish assessment. It is likely that the EFH maps based on the AI trawl survey are adequate to delineate general sablefish hotspots. However, the dedicated sablefish longline survey is designed explicitly to sample sablefish and would provide a more appropriate delineation of EFH.”
    - Response: These concerns and recommendations were reported and discussed on page 30 in the December 2021 EFH Stock Author Review Report[51]. These concerns and recommendations as reported in the 2022 FE assessment questionnaire are discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[52].
- The SA noted a possible data source to use in future SDM: the NOAA longline survey.

* Concerns with FE model
    - For EBS sablefish, the SA noted *medium (2) concern* and commented: “Data concerns are expressed in question 1, but there are also concerns whether sablefish FE should be examined on a regional or population-wide scale. Given the mobility and wide distribution of sablefish, the population is assessed as a single unit across the entire Alaska region. Thus, it may be more appropriate to address FE cumulatively across the entire population, given that local effects may not have a strong impact on the entire population. However, given that the EBS is likely an important juvenile sablefish habitat during years following large recruitment events, the results of the FE provide important indications of potential habitat disturbance impacts on these younger age classes in certain years (e.g., following large year classes).”

[51] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[52] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- For the AI sablefish, the SA noted *low (1) concern* and commented that his FE model concerns were the same as his EFH map concerns, but added: “However, it is unlikely that the incorporation of [longline] survey data would greatly alter the EFH or FE analysis.”
    - Response: Species-specific FE analysis uses EFH maps that are produced regionally. While stocks are managed differently depending on the species (either across regions or at smaller scales), EFH is designated and mapped for each FMP species (50 CFR 600.815(a)(1)(i)). There is interest in refining EFH designations in the future, and there are opportunities for further analysis by researchers using FE model outputs depending on the area of interest.

- EFH research recommendations
  - The SA offered the following recommendations for EBS sablefish:
    - Incorporate longline survey data in future analyses of EFH.
    - Emphasize developing a holistic understanding of sablefish life history patterns and habitat utilization. As noted, little is known about spawning locations, larval dispersal, juvenile nursery areas, or ontogenetic movement patterns, all of which are necessary to understand when attempting to delineate EFH.
    - Future FE analysis should provide both local and Alaska-wide time series of FE disturbance, given that the population is assessed and managed as a single Alaska population. Although it is important to understand local and regional impacts of fishing, it is also necessary to recognize the cumulative impact on the entire population.
  - The SA offered the following recommendations for AI sablefish:
    - Incorporate [longline] survey data into the SDM.
    - Collect data on spawning locations (requires winter sampling) and [early life history] distributions. Better understanding of movement among management units within the Alaska-wide sablefish population would help to elucidate patterns of habitat usage across the entire range, helping to identify regional and local EFH. Similarly, the dynamics of juvenile migrations are not well understood, which prevents understanding the role that the EBS shelf plays as a potential nursery area for large sablefish year classes (i.e., whether juvenile sablefish from all areas move into the EBS or if it is only used by locally spawned sablefish, as well as whether juveniles subsequently leave or remain resident in the EBS as they mature).

- **SA chose (to provide an additional) *qualitative* FE assessment using other sources of information:** The SA indicated that using the FE model with 50% CEA was the most appropriate approach to assess the effects of fishing on BSAI sablefish, however they noted: “Because an Alaska-wide assessment is utilized, there are no regional indices or model outputs that can be used to develop correlative analyses. Similarly, the EBS shelf survey is not believed to provide reliable trends of sablefish abundance, which makes any correlative analysis using these data similarly uncertain."

Sablefish Fishing Effects Assessment by Stock Author

The EBS shelf is likely a nursery area for juvenile sablefish when large year classes are present. As noted in the FE time series, the 10% threshold has only been exceeded in a few recent years and once in the late 2000s, all of which are associated with large year classes. Fishery effects tend to increase when large numbers of juveniles are present and interact with trawl gears in the EBS. These events include increased disturbance in the late 2000s following moderately strong late 1990s year classes and over the last ~5 years following a series of unprecedented 2014, 2016, and 2018 year classes. Analysis as part of the 2020 and 2021 sablefish SAFEs indicated that the impact of BS fisheries on the sablefish population were generally limited to juvenile fish and unlikely to exceed the impact of natural mortality in the region. Thus, it is unlikely that fishery effects have a large impact on either the juvenile sablefish in the BS or the entire Alaska wide population (see Appendix 3D of the sablefish SAFE, Goethel et al. 2020). Moreover, given the high mobility of sablefish and movement among management areas, it is likely that EFH should be viewed from a population-wide instead of localized outlook (i.e., because sablefish frequently move long distances, it is unlikely that disturbance in one localized area will broadly impact the population). When considered in combination with EFH disturbance in the AI and GOA, it is unlikely that there is a strong impact on sablefish (i.e., population-wide CEA disturbance is likely <10%). However, the impact of fishery disturbance on potential sablefish juvenile nursery areas in the EBS should not be discredited. There is a clear overlap between fishing activity and areas of high sablefish abundance in the EBS, particularly following large recruitment events, and these interactions should be carefully monitored along with levels of juvenile sablefish bycatch in these fleets. Increased effort to understand sablefish life history patterns, including spawning locations, larval dispersal patterns, juvenile nursery areas, and adult migration pathways, would enable a more holistic and informed evaluation of critical habitat areas along with the potential influence of fishing activities on EFH. Despite extensive adult tagging on the longline survey over the last ~30 years, many knowledge gaps remain regarding seasonal and spawning migrations (and associated habitat), while very little is known about ontogenetic movement patterns from young-of-the-year through adult stages.

5.1.14 Shortraker rockfish

- Concerns with EFH maps
    - For both EBS and AI shortraker rockfish, the SA noted *no concern* and added: "A comment was submitted previously regarding additional data that are available for shortraker rockfish on the longline and IPHC surveys. This may expand the EFH footprint further along the slope region as these surveys sample in different depths and locations than the bottom trawl survey. The eastern Bering Sea slope survey has not been conducted since 2016 and there are no plans to continue this survey. The EBS slope survey is the primary survey for EBS shortraker rockfish and the

longline and IPHC alternative data sources would be useful to include in the future."

- Response: This recommendation was reported and discussed on page 32 in the December 2021 EFH Stock Author Review Report[53]. This recommendation as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[54].

- The SA suggested these species distribution data to use in future SDM: AFSC longline survey[55] and the IPHC survey[56].

- EFH research recommendations
    - The SA recommended: "Include the slope data sources in the next iteration of these models and maps. When evaluating the 10% impact, it might be useful to first determine if habitat is an important factor for the stock. Reference to the habitat specificity variables in the climate vulnerability assessment[57] and the habitat assessment prioritization for Alaska stocks[58] would be very helpful here and might allow for a more targeted approach to stocks that have already been deemed vulnerable to habitat disturbance."
- **SA chose a quantitative FE assessment and provided additional supporting analysis:**

Shortraker Rockfish Fishing Effects Assessment by Stock Author

The impacts of commercial fishing on essential fish habitat (EFH) are of interest as part of the EFH 5-year review. Similar to 2017, the 2022 fishing effects (FE) model is run using the upper 50th percentile core EFH area (CEA) from summer species distribution maps for adults or combined life stages for a given fish stock. Data to support this model are from the RACE GAP bottom trawl survey and various environmental covariates (SDM EFH Discussion Paper). Maps and habitat disturbance output provided from the FE model were used to assess the effects of fishing on Bering Sea shortraker rockfish (see section 4.3).

A three-tiered approach is used for evaluating effects of fishing as suggested by the SSC EFH subcommittee. The first step of the evaluation was to determine whether Bering Sea shortraker rockfish are above their Minimum Stock Size Threshold (MSST). Shortraker in the Bering Sea are assessed and managed as a unit across the Bering Sea and Aleutian Islands (BSAI) and are considered a Tier 5 stock (Shotwell et al., 2020b). As such, it is not possible to make a status determination of whether the stock is above or below its MSST.

---

[53] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

[54] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

[55] Siwike et al. 2022 https://repository.library.noaa.gov/view/noaa/37523

[56] IPHC survey sampling manual https://iphc.int/uploads/pdf/manuals/2022/iphc-2022-vsm01.pdf and data visualization requests https://iphc.int/data/datatest/fishery-independent-setline-survey-fiss

[57] Spencer et al. 2017 https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14763

[58] McConnaughey et al. 2017 https://repository.library.noaa.gov/view/noaa/15500

The next step was to determine whether fishing in the CEA resulted in a disturbance in habitat of 10% or greater. Shortraker rockfish in the Bering Sea were evaluated to have greater than 10% disturbance in habitat in 2020 for the FE model for both the observed plus unobserved fishing events and the observed only model. If the 10% threshold of habitat impact is exceeded, correlation analyses are requested between the proportion of habitat disturbed by fishing with time trends in indices of growth-to-maturity, spawning success, breeding success, and feeding success. Similar annual trends were observed for the monthly time series of the habitat disturbance percentages for the observed plus unobserved model (Figure A5.13, top graph). The monthly trends somewhat diverge for the later in the year months (8 through 12) from 2016 to 2019; however, the monthly habitat disturbance percentages converge in 2020. These trends are similar for the observed only model (Figure A5.13, bottom graph). Therefore, the average habitat disturbance within each year was used for the correlation analyses. Data to examine growth trends for this stock are limited. Body condition (e.g., length-weight residuals) were considered but samples sizes were small (~275 on average per year), only available from the EBS slope survey (stopped in 2016), and limited in spatial coverage (primarily in slope subareas 3 and 4, Pribilof to Zhemchug canyon). Size-at-age and maturity data are not available for this stock because no validated method for aging currently exists (Kastelle et al., 2020). Therefore, habitat impact was compared with total (feeding) biomass as estimated by the random effects model and the relative population numbers (RPN) from the longline survey over the Bering Sea area based on the stock assessment for those regions (Shotwell et al., 2020b). We conducted correlation analyses for both the observed plus unobserved model and the observed model only. A visual representation of the correlation matrix from this analysis does not indicate any strong relationships between the habitat disturbance models and the random effects model or the RPN from the longline survey (Figure A5.14). Additionally, none of the correlation tests were significant (Table A5.5. Results of correlation analysis between annual Bering Sea habitat impact and total biomass from the random effects model and longline survey relative population numbers (RPN) in the Bering Sea from the BSAI stock assessment (Shotwell et al., 2020b).).

The final step is to consider if any mitigation measures are needed at this time for shortraker rockfish in the Bering Sea. Fishing effects appear to overall spatially have a low effect on habitat in the northern part of the Bering Sea slope area with more of the impact occurring in the Pribilof Canyon area. Since the AFSC longline survey data is not included in this analysis, it is unclear where the majority of shortraker rockfish would occur were the two data sources combined (e.g., hotspots may shift with addition of new data even if total area coverage does not). The proportion of habitat reduction in the Bering Sea CEA has been less than 10% for much of the recent time series since the 2017 analysis and only recently went above the 10% value starting in August 2019 and is now turning to a downward trajectory. Habitat impacts on the available data for Bering Sea shortraker rockfish growth-to-maturity, spawning success, breeding success and feeding success are not detectable, and mitigation measures are not needed at this time. However, shortraker rockfish are thought to be extremely long-lived (estimated ages equal to ~150 years, Munk, 2001) with late maturation (estimates of length-at-50% maturity equal to ~45 cm, McDermott, 1994) and so could be considered a low productivity species that may be more vulnerable to fishing effect or habitat disturbance. Although there is insufficient evidence at this time to elevate concern for this species, we suggested continued monitoring and research into shortraker rockfish life history, particularly in the early life history as juveniles are very seldom caught in any sampling gear (Shotwell et al., 2020b, Data Gaps and Research Priorities Chapter).

Table A5.5. Results of correlation analysis between annual Bering Sea habitat impact and total biomass from the random effects model and longline survey relative population numbers (RPN) in the Bering Sea from the BSAI stock assessment (Shotwell et al., 2020b).

Correlation Compared with Habitat Disturbance (observed plus unobserved)	**Correlation Coefficient (r)**	**P-value**
Total biomass from random effects model	0.155	0.539
Longline RPN	0.246	0.325

Correlation Compared with Habitat Disturbance (observed only)	**Correlation Coefficient (r)**	**P-value**
Total biomass from random effects model	0.153	0.543
Longline RPN	0.251	0.314

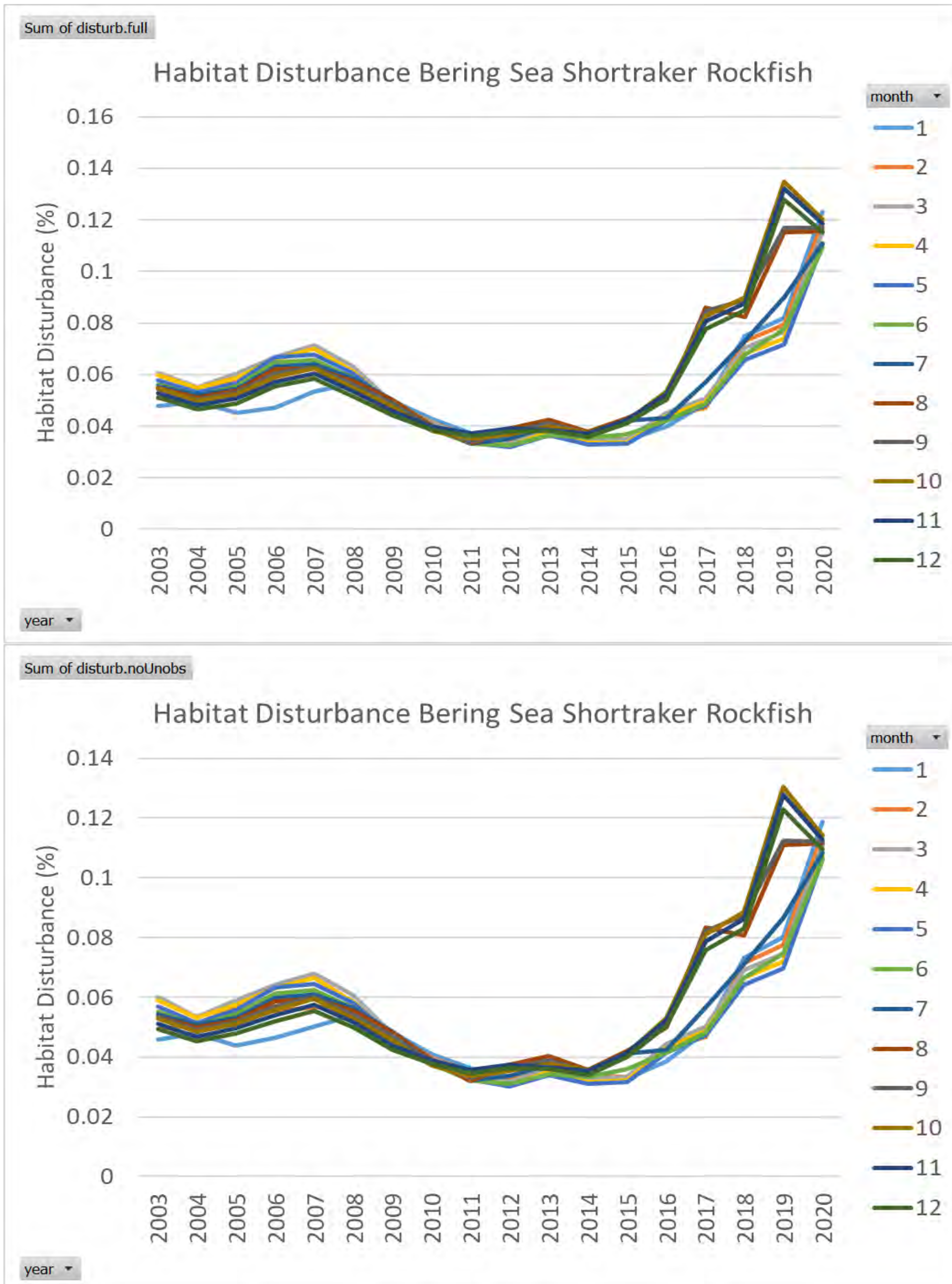


Figure A5.13. Habitat disturbance by month and year for shortraker rockfish in the Bering Sea for the observed plus unobserved model (top graph, sum of disturb.full) and observed only model (bottom graph, sum of disturb.noUnobs).

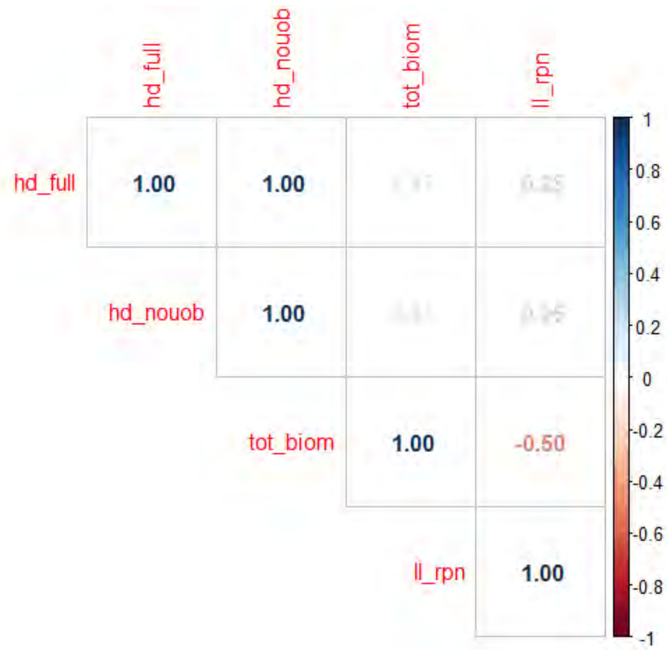


Figure A5.14. Correlation matrix visual for observed plus unobserved (hd_full) habitat disturbance, observed only (hd_nouob) habitat disturbance, total biomass (tot_biom) from the random effects model, and relative population number from the longline survey (ll_rpn) for BSAI shortraker rockfish.

5.1.15 Skate complex

- **SA chose (to provide an additional) *qualitative* FE assessment using other sources of information:** This additional qualitative assessment was provided for the EBS skate species within the complex that had ≥ 10% CEA disturbed. Otherwise, the SA chose the FE model with 50% CEA as the most appropriate approach to assess the effects of fishing on EFH for BSAI skates.

EBS Skate Complex Fishing Effects Assessment by Stock Author

The EBS likely represents a large portion of the skate complex species' distributions. However, except for Alaska skates, their distributions are not well known. The Alaska skate is the most abundant skate species in the EBS and is routinely observed in the EBS bottom trawl surveys. Observations in the EBS of skates (excluding Alaska skates), are patchy and sparse, and there is no directed fishery for skate complex species in the EBS. Skates in general, are not well sampled by the bottom trawl surveys which only occur in the summer months. Without fishery observations, the survey data provide a very limited view of the skate complex distributions. However, there is a lot of fishing activity in the EBS. Due to the patchy and sparse occurrences of skates from the EBS bottom trawl survey data, it is unlikely that CEA disturbance is >10% as determined by the fishing effect analysis for four out of the five EBS skate complex species: Aleutian skate, Bering skate, mud skate, and whiteblotched skate; the results are most likely an artifact of the data.

5.1.16 Walleye pollock

- EFH research recommendations

    - The SA noted: “Being a pelagic species (at least for a significant period during early life and spawning) EFH research requirements seem limited.”
- **SA chose a *qualitative* FE assessment using other sources of information:** The SA chose the FE model with 50% CEA as the most appropriate approach to assess the effects of fishing on EFH for AI Walleye pollock. The SA chose a qualitative assessment for EBS Walleye pollock.

EBS Walleye Pollock Fishing Effects Assessment by Stock Author
Presently the fishery is closely monitored for bottom contact by the mandatory pelagic trawls. If bottom contact were to increase substantially (based on infauna within sets) then this should be evaluated further.

5.2 GOA Groundfish

The following species or species complexes were reviewed by the SAs and were determined not need any additional supporting analysis to assess fishing effects on EFH for their stocks. They had *no concerns* with the EFH maps or the FE model and they *approved* the use of the 50% CEA in determining the percent of habitat disturbed by fishing for each species/species complex.

- ***Giant octopus***
- ***Pacific cod***
- ***Pacific ocean perch***
- ***Shallow water flatfish complex***
- ***Skate complex***
- ***Walleye pollock***

The GOA groundfish species are listed below with the SA comments, concerns, recommendations, and FE analysis supporting their FE assessment, if provided by the SA.

5.2.1 Arrowtooth flounder

- Concerns with EFH map
    - The SA marked *no concerns* but noted: “A comment was submitted previously regarding additional data that are available for arrowtooth flounder on the longline and IPHC surveys. This would likely expand the EFH footprint further into the slope region as arrowtooth flounder are found there regularly. The eastern Bering Sea slope survey has not been conducted since 2016 and there are no plans to continue this survey. These alternative data sources would be useful to include in the future.”
        - Response: This recommendation was reported and discussed on page 35 in the December 2021 EFH Stock Author Review Report[59]. This recommendation as reported in the 2022 FE assessment questionnaire is

[59] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[60].

    - The SA suggested these species distribution data to use in future SDM: AFSC longline survey[61] and the IPHC survey[62].

- EFH research recommendations
    - The SA recommended: "Include the slope data sources in the next iteration of these models and maps. When evaluating the 10% impact, it might be useful to first determine if habitat is an important factor for the stock. Reference to the habitat specificity variables in the climate vulnerability assessment[63] and the habitat assessment prioritization for Alaska stocks[64] would be very helpful here and might allow for a more targeted approach to stocks that have already been deemed vulnerable to habitat disturbance."
- **SA chose a quantitative FE assessment.**

5.2.2 Atka mackerel

- Concerns with EFH map
    - The SA noted *high (3) concern* and commented: "There was a 250% increase in the CEA in 2022! The 2022 results are not meaningful due the sparse data used over a timeframe that is not appropriate."
        - Response: Comparing the 2017 SDMs and 2022 ensembles demonstrated that the type of model used in 2017 had a large effect on the performance metrics and calculated EFH area. Approximately 25% of ensembles predicted EFH areas larger by 100% or more; in almost all of these cases the 2017 SDM was hGAM. The large increase in CEA observed in the 2022 GOA Atka mackerel map compared to the 2017 map was largely attributed to moving from the single use of an hGAM in 2017 to an SDM ensemble in 2022. Mapping EFH using SDM ensembles rather than single SDMs helps mitigate the influence of any one SDM method on the resulting EFH area and should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping efforts, making it easier to detect changes in species distribution or habitat impacts. For more information see Chapter 5 (*ongoing data issues* and *Atka mackerel example*) of the EFH Component 1 Discussion Paper

---

[60] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[61] Siwike et al. 2022 https://repository.library.noaa.gov/view/noaa/37523
[62] IPHC survey sampling manual https://iphc.int/uploads/pdf/manuals/2022/iphc-2022-vsm01.pdf and data visualization requests https://iphc.int/data/datatest/fishery-independent-setline-survey-fiss
[63] Spencer et al. 2017 https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.14763
[64] McConnaughey et al. 2017 https://repository.library.noaa.gov/view/noaa/15500

prepared for the SSC October, 2022 meeting and supporting EFH component 1 documents[65].

        - This concern for Atka mackerel was also reported and discussed on page 35 in the December 2021 EFH Stock Author Review Report[66]. EFH analysts worked with the SA following their 2021 SDM EFH review to revise the SDM ensemble by removing one constituent to "improve" the EFH map. The 2022 CEA evaluated by the SA in the 2022 FE assessment questionnaire is centered on the main distribution of the RACE-GAP haul locations (n = 700) where Atka mackerel was present in the GOA, including hauls in the top 10% of samples occurring east of Kodiak Island. SSC's minimum sample size for SDM EFH mapping in the 2017 Review was n = 50, which was retained in their June 2020 review of the 2022 SDM methods, which this species exceeds in the GOA. EFH was also mapped for GOA Atka mackerel in 2017.
        - Future EFH mapping efforts for GOA Atka mackerel and other species may be able to explore mapping EFH over smaller time series (e.g., 5 year hindcasts), which may improve ability to identify events in shifting species distributions due to climate change or other impacts to habitat, which will also be enhanced with improved SDM forecasting methods (e.g., Rooper et al. 2021, Barnes et al. 2022).

- EFH research recommendations
    - The SA did not provide research recommendations but commented, "I'm not sure there is enough data to meaningfully determine essential habitat for GOA Atka mackerel."
        - Response: See response under *concerns with EFH map*.
- **SA chose a *qualitative* FE assessment using other sources of information:**

Atka mackerel Fishing Effects Assessment by Stock Author

The GOA represents the western-most margin of the Atka mackerel population. Their center of abundance is the Aleutian Islands. Observations in the GOA of Atka mackerel are very sparse, and there is no directed fishery for Atka mackerel in the GOA. However, there is a lot of fishing activity in the GOA. Due to the very low occurrences of Atka mackerel in the GOA, the CEA disturbance is likely very low as determined by the fishing effects analysis. It is noted that the data is not sufficient to appropriately conduct a quantitative analysis, but a qualitative assessment supports the < 10% CEA disturbance determined by the fishing effects analysis.

[65] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

[66] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

5.2.3 Blackspotted/Rougheye rockfish complex

- Concerns with EFH map
  - The SA noted *no concern* but commented: "I do think the EFH map encompasses "the summer distribution of adults of this species", therefore I rated my response as "No concern". However, the GOA [bottom trawl survey] may not provide the most accurate depiction of relative densities for many species (e.g. slope rockfish and sablefish) and [I] think the NMFS longline survey is a better data source to inform this question. While NMFS longline survey stations generally overlap with trawl survey tows, the relative densities of [rougheye/blackspotted rockfish] between the two surveys would likely result in different EFH percentiles (i.e., CEA, hotspots). A comparison of catch rates by area and depth strata has revealed inconsistencies in both relative catch rates and estimates of abundance between the longline survey and GOA BTS (Figures 13-4a and 13-4b in the 2021 SAFE [Report][67]."
    - Response: This recommendation was reported and discussed on page 39 in the December 2021 EFH Stock Author Review Report[68]. This recommendation as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[69].
  - The SA suggested this species distribution data to use in future SDM: NMFS longline survey. They noted: "The GOA would be the best place to start as EBS and AI are sampled in alternating years."
- **SA chose a quantitative FE assessment.**

5.2.4 Dover sole

- Concerns with EFH map
  - The SA noted *no concern* but commented: "I think the distribution of adults is encompassed. I think some adults were categorized as subadults using the length-based categorization system that was used, and fixing this may change the percentiles on the EFH map."
    - Response: This future recommendation is related to discussion of concerns regarding the SDM EFH maps for flatfishes with spatially varying growth in sections 6.6, 6.7, and 6.10 of this document and in Chapter 5 (*life history considerations* with the *flatfishes example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[70].
- **SA chose a quantitative FE assessment.**

---

[67] 2021 SAFE Report https://apps-afsc.fisheries.noaa.gov/refm/docs/2021/GOArougheye.pdf
[68] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[69] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[70] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

5.2.5 *Dusky rockfish*

- Concerns with EFH map
  - The SA noted *medium (2) concern* and commented: “Same concerns as in [the EFH Stock Author Review Report], the species is poorly represented by bottom trawl survey gear/locations (a long-standing challenge for this and other rockfish species). Though the current analysis versus the 2017 analysis appears to include more habitat area and is likely to more correctly identify potential habitat.”
    - Response: This concern was reported and discussed on page 41 in the December 2021 EFH Stock Author Review Report[71]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[56].
- Concerns with FE model
  - The SA noted *medium (2) concern* and commented: “Fishing effects on life stages other than adult are poorly informed and could very well be impacting the population negatively.”
    - Response: This concern echoes other species concerns when it comes to life history stages and best ways to assess fishing impacts. Future recommendations for FE analysis could include using 50% CEA from EFH maps developed for different life history stages for the FE model outputs; for dusky rockfish this would be subadults and adults.
- EFH research recommendations
  - The SA recommended: “For this species it would be great to prioritize/research fishery location data and early life history information.”
- **SA chose a quantitative FE assessment.**

5.2.6 *Flathead sole*

- EFH research recommendations
  - The SA recommended to research the “[i]mpacts of environmental indicators such as temperature on GOA flathead sole, specifically growth and/or distribution of recruits, since we don't see these in the surveys.”
- **SA chose a quantitative FE assessment.**

[71] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

5.2.7 Northern rockfish

- Concerns with EFH map
    - The SA noted *medium (2) concern* and referred to the comments provided for the GOA dusky rockfish.
        - Response: This concern was reported and discussed on page 41 in the December 2021 EFH Stock Author Review Report[57]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[41].
- EFH research recommendations
    - The SA recommended: "Early life history and incorporating stakeholder/fleet understanding of fish locations."
- **SA chose a quantitative FE assessment.**

5.2.8 Other rockfish (OR) complex demersal subgroup

- EFH research recommendations and HAPC consideration
    - The stock expert reviewing this complex represents a team with ADF&G and commented: "We will not be utilizing EFH for managing our [demersal shelf rockfish] fisheries at this time. We currently use our ROV surveys to assess and manage the [demersal shelf rockfish] stock in the EGOA. We have data from our surveys that could be incorporated into the NOAA SDM ensemble framework to map EFH when helpful for certain species and life stages."
        - Response: Thank you for the offer and interest in collaborating.
- **SA chose a *qualitative* FE assessment using other sources of information:**

Other Rockfish Complex Demersal Subgroup Fishing Effects Assessment by Stock Author
We have ADF&G ROV survey data for EGOA primarily for yelloweye rockfish, but we could provide information on quillback and rosethorn rockfish as well, if needed. Ultimately, we do not have a great deal of concern whether FE would cause DSR complex to be elevated for possible mitigation. We do not have a concern for the gear types currently used in EGOA in DSR complex habitat (i.e., hook and line gear). We do not have trawling in our area, so that is not a concern for EGOA.

5.2.9 OR complex slope subgroup

EFH component 1 requires individual species maps for the FMU corresponding to the FMP (50 CFR 600.805(b)). However, where appropriate, may be designated for assemblages of species or life stages that have similar habitat needs and requirements (50 CFR 600.815(a)(1)(iv)(E)). As a new approach in 2022, NMFS provided maps for species complexes, including the OR complex slope subgroup, to represent the EFH of member species where an SDM was not possible (e.g., due to low sample size and/or other reasons). These **complex EFH maps** are an additive map of the area of occupied habitat from the combined individual species

2022 SDM ensemble EFH maps for this subgroup[72]. The complex EFH maps will be reported with the other new SDM ensemble EFH maps for member species of those complexes in the 2022 EFH 5-year Review, and were provided to the SAs as an option for completing their 2022 FE assessments.

For the GOA OR complex slope subgroup, the SA chose the FE model with 50% CEA from the **complex EFH map** as the most appropriate approach to assess the effects of fishing on EFH for the slope subgroup and **recommended no further action** with respect to elevating the slope subgroup to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH. However, the SA reported concerns over only using of the complex map rather than maps for individual species to assess fishing effects on EFH (i.e., "Lumping the species has the risk of hiding critical changes within the complex. Assessing SDMs or FE at this level runs the risk of being too low of a resolution to detect significant results.").

For certain species in the slope subgroup, the SA also chose the FE model with 50% CEA from the **species EFH maps** and **recommended no further action** (Table A5.6). The SA preferred a qualitative assessment for the remaining species with an EFH map due to data limitation concerns and reported **insufficient information** to make the decision to elevate for possible mitigation regarding fishing effects to EFH. In the case of the species where the SA reported insufficient information, NMFS recommends that the complex map be used as a proxy for the individual species EFH maps for EFH component 2, however those individual species EFH maps should be retained for EFH component 1.

Due to SA concerns for assessing the effects of fishing on EFH for the GOA OR complex slope subgroup, regarding a) only using the complex EFH map rather than the EFH maps for individual species, and b) concerns of data limitations for some of the species with an EFH map, **we are seeking SSC recommendations as to whether the GOA OR complex slope subgroup should be assessed for fishing effects on EFH, using one of the following approaches, or an alternative approach:**

- As a subgroup, using only the CEA from the GOA OR complex slope subgroup map;
- As individual species with an EFH map AND using the subgroup map for individual species without an EFH map AND for data limited species with an EFH map where the SA is concerned about insufficient information; or
- As individual species only, where an EFH map is available.

[72] For more information on mapping EFH for species complexes, refer to section 3.2.8.3 of the EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

Table A5.6. GOA other rockfish complex slope subgroup RACE-GAP summer bottom trawl survey haul records and EFH maps. Each record represents a haul with a positive catch of the listed rockfish species. The SSC's 2017 minimum sample size in the EFH SDMs was n = 50 hauls with positive catches, which was retained in their June 2020 review of the SDM methods for the 2022 EFH Review. Species with and without an SDM EFH map in 2022 and 2017 are noted (X). Species without an SDM EFH map in 2022 are accounted for by proxy in the 2022 GOA other rockfish complex slope subgroup map. The SA chose the FE model with 50% CEA to assess the effects of fishing on EFH for the slope subgroup and some individual species (Quantitative assessment) with no further action (X). The SA chose a qualitative assessment for other individual species using other sources of information (Qualitative FE assessment) and reported that there was insufficient information (X) to make the decision of whether or not these species should be elevated for possible mitigation to reduce fishing effects on EFH.

GOA other rockfish complex slope subgroup species	**Subadult Records (n)**	**Adult Records (n)**	**2022 EFH Map**	**2017 EFH Map**	**Quantitative assessment**	**Qualitative assessment**	**No further action**	**Insufficient information**
Harlequin rockfish	102	514	X	X	X	–	X	–
Redbanded rockfish	829	321	X	X	–	X	–	X
Redstripe rockfish	133	234	X	X	X	–	X	–
Sharpchin rockfish	498	425	X	X	X	–	X	–
Silvergray rockfish	159	557	X	X	–	X	–	X
Pygmy rockfish	63 (n = 54 2017 SDM)		X	X	–	X	–	X
Greenstriped rockfish	–	120	X	–	–	X	–	X
Darkblotched rockfish	54	–	–	–	–	–	–	–
Yellowtail rockfish	–	58	–	–	–	–	–	–
Total	1721	2234	–	–	–	–	–	–
Combined Total (accounted for by complex subgroup map)	3955		X	–	X	–	X	–

5.2.9.1 Slope subgroup

- Concerns with EFH map
  - The SA noted *low (1) concern* and commented: "As a complex, the EFH for the slope sub group likely encompasses the distribution of the combined species. However, as noted in the individual species reviews, there is a wide variety of data availability and catchability that come into play." [For several species in the slope subgroup, the reviewing SA reported concerns at various levels about the need for additional data to capture the full geographic distribution of these species.]
    - Response: EFH component 1 mapping requirements are "some or all portions of the geographic range of the species" 50 CFR 600.815(a)(1)(iii)(1)), which has been comprehensively met for the new summer distribution EFH maps presented to the SSC in February, 2022 for the EFH 5-year Review. NMFS' position on EFH component 1 mapping requirements for data limited species is that it is better to include an EFH map accounting for some of the geographic distribution of a species (i.e., when high quality presence-absence data are available such as from the RACE-GAP summer bottom trawl survey) than no EFH map for habitat conservation purposes. Even if some of the EFH component 1 maps are likely showing only some of the distribution, those maps meet the mapping requirements for those species and form a foundation for future improvements. The EFH component 2 FE assessment can be done using the FE model and 50% CEA from the complex EFH map, as an alternative to using the species maps where the SA is concerned about data limitations.
    - Analysts have included a future recommendation to add other data sources where the additional data would add value to the EFH map. Adding data sources and gear types to the SDM ensemble EFH mapping framework will be challenging, as this is not computationally straightforward and requires additional research to develop those analytical methods. It is possible however, that a "data robust" approach could be developed for a subset of species, where additional data sources have high potential to add value to the EFH maps for those species, including slope rockfish. Future efforts to meet this need would benefit greatly from collaboration between EFH analysts who are SDM, habitat, and survey data experts, and stock assessment authors and/or other species and survey data experts. Opportunity for continued improvements of EFH component 1 is possible through research leading up to a future EFH 5-year Review, which are by design an iterative process and occurring at least every five years (50 CFR 600.815(a)(10)).
    - All species in the slope subgroup with a new SDM ensemble EFH map in 2022 also had an SDM EFH map in 2017 with the exception of Greenstriped rockfish (Table A5.6). Analysts worked with the SA to

address their concerns following the first SA review of the draft SDMs in 2021. Due to data limitation concerns, analysts and the SA agreed on not advancing the SDM ensemble EFH maps for two species (darkblotched rockfish and yellowtail rockfish) that met the minimum sample size threshold. There was agreement to proceed with the new SDM ensemble EFH maps for the other species; this discussion was reported (page 45-50) in the December 2021 EFH Stock Author Review Report[73]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[74].

    - The SA suggested this species distribution data to use in future SDM: AFSC and IPHC [longline] survey data, [GOA rockfish] fishery data. Fishery data includes summer incidental catch data. NMFS AKR Sustainable Fisheries Division staff noted: "Much of the rockfish incidental catch is during the trawl rockfish fisheries that begin in May (changing to April) through November 15. Also, some is taken during the IFQ halibut and sablefish fisheries and that season is March to the first week of December. Data is reported daily to NMFS and our catch accounting database is updated daily, so the database has almost "real time" catch data."
- Concerns with FE model
    - The SA noted *low (1) concern* and commented: "Lumping the species [in the case that FE are assessed using the slope subgroup complex EFH map as opposed to for individual species with an EFH map] has the risk of hiding critical changes within the complex. Assessing SDMs or FE at this level runs the risk of being too low of a resolution to detect significant results."
        - Response: After conversation with the SA to address their concerns, we are confident that the FE model has presented the best available science for the stock complex in the 2022 EFH 5-year Review. However due to SA concerns, **we are seeking SSC recommendations as to whether the GOA Other rockfish complex slope subgroup should be assessed for fishing effects on EFH as a subgroup or as individual species or a combination of both approaches.**
- **SA chose a quantitative FE assessment.**

5.2.9.2 Greenstriped rockfish

- Concerns with EFH map
    - The SA noted *medium (2) concern* and commented: "This species is quite rare, and likely at the northern extent of its range. However, it is regularly caught in small numbers in both the AFSC and IPHC [longline] surveys. It's possible that

[73] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[74] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

EFH map captures the adult summer distribution, but it is too data limited to truly assess. This species can be caught by [longline] gear and fishery data would likely inform this better than survey data. Fishery catch for this species mostly occurs in NMFS 640, which doesn't align with the EFH map."

    - Response: See our *response reported in section for the subgroup* and refer to *Table A5.6.* Greenstriped rockfish CEA is present west of 140 west longitude in NMFS area 640. EFH component 1 mapping requirements are "some or all portions of the geographic range of the species" 50 CFR 600.815(a)(1)(iii)(1)). Analysts agree that including additional data sources in the future if possible could add value to the EFH map for this species; success will require collaboration by the stock author. The reviewing SA's concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[75]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[76].

  - The SA suggested this species distribution data to use in future SDM: AFSC and IPHC [longline] survey data, [GOA rockfish] fishery data.

- Concerns with FE model
  - The SA noted *medium (2) concern* and commented: "Most of the fishery catch of this species occurs in the [non-pelagic trawl] fishery in NMFS 640, which is not encompassed by the FE model."
    - Response: This concern relates to the data used in the SDM maps and the suggestion by the SA to incorporate fishery data. Greenstriped rockfish CEA is present west of 140 longitude west in NMFS area 640. Discussion on incorporation of more data sources into the next iteration of the SDMs can be found in the two reports listed above.

- EFH research recommendations
  - The SA recommended: "Expand data used in the assessment and incorporate feedback into the next round. Species need to be evaluated to determine if they even have enough data to move forward. This species is an example of one that is poorly informed."
    - Response: EFH component 1 mapping requirements are "some or all portions of the geographic range of the species" 50 CFR 600.815(a)(1)(iii)(1)). NMFS' position on EFH component 1 mapping requirements for data limited species is that it is better to include an EFH map accounting for some of the geographic distribution of a species (i.e.,

[75] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[76] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

when high quality presence-absence data are available such as from the RACE-GAP summer bottom trawl survey) than no EFH map for habitat conservation purposes and that these maps provide a foundation for improvements leading up to a future EFH Review. The EFH analysts worked with SA to evaluate species with data limitations in their review of the draft SDM EFH maps in 2021 and removed two maps for data limited rockfish species from consideration based on those conversations. We value input from the SAs and other reviewers that have improved the EFH component 1 maps and reporting for the 2022 5-year Review.

- **SA chose a *qualitative* assessment using other sources of information:** However, they noted "The FE is based on an SDM which likely does not fully encompass the species distribution. There is insufficient data on this species at this time to compare life history parameters to what is known about fishing activities in their habitat."
    - **Response:** The SA has assessed FE for the slope subgroup as a whole using the FE model and the 50% CEA, which can serve as a proxy for assessing FE for this species until more information is available.

5.2.9.3 Harlequin rockfish

- Concerns with EFH map
    - The SA noted *low (1)* concern and commented: "Due to the low survey catchability, the EFH likely does not encompass the full adult summer distribution."
        - Response: See our *response reported for the subgroup* above and refer to *Table A5.6.* EFH component 1 mapping requirements are "some or all portions of the geographic range of the species" 50 CFR 600.815(a)(1)(iii)(1)). Analysts agree that including additional data sources in the future if possible could add value to the EFH map for this species; success will require collaboration by the stock author. The reviewing SA's concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[77]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[78].
    - The SA suggested this species distribution data to use in future SDM: [GOA rockfish] fishery data
- Concerns with FE model

[77] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[78] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- The SA noted *low (1) concern* and commented: “This species is caught primarily in fishery non-pelagic trawl gear, but poorly sampled by the survey. There is a mis-match of the two.”
  - Response: This concern relates to the data used in the SDM maps and the suggestion by the SA to incorporate fishery data. Discussion on incorporation of more data sources into the next iteration of the SDMs can be found in the two reports listed above.

- EFH research recommendations
  - The SA recommended: “Incorporate fishery data to more accurately represent spatial extent of the population”

- **SA chose a quantitative FE assessment.**

5.2.9.4 Pygmy rockfish

- Concerns with EFH map
  - The SA noted *high (3) concern* and commented: “Data to inform the SDM is extremely sparse for this species and do not support creation of an SDM for the species.”
    - Response: See our *response reported in the subgroup section* and refer to *Table A5.6.* EFH component 1 mapping requirements are “some or all portions of the geographic range of the species” 50 CFR 600.815(a)(1)(iii)(1)). An SDM EFH map was advanced for Pygmy rockfish in the 2017 EFH 5-year Review and a new SDM ensemble EFH maps is provided for the 2022 Review. NMFS’ position on EFH component 1 mapping requirements for data limited species is that it is better to include an EFH map accounting for some of the geographic distribution of a species (i.e., when high quality presence-absence data are available such as from the RACE-GAP summer bottom trawl survey) than no EFH map for habitat conservation purposes and that these maps provide a foundation for improvements leading up to a future EFH Review. The EFH analysts worked with SA to evaluate species with data limitations in their review of the draft SDM EFH maps in 2021 and removed two maps for data limited rockfish species from consideration based on those conversations. We value input from the SAs and other reviewers that have improved the EFH component 1 maps and reporting for the 2022 5-year Review. The reviewing SA’s concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[78]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH

Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[79].

- Concerns with FE model
    - The SA noted *high (3)* concern and commented: "This is ranked high simply because a model is being created based on extremely sparse data, and likely not a valid model. This species is exceedingly rare in AK waters, so it is unlikely that there are substantial FE due to the limited presence of the species."
- **SA chose a *qualitative* assessment using other sources of information:** However, the SA noted "The FE is based on a poorly informed SDM. This species is exceedingly rare in Alaska waters, so it is unlikely that there are substantial FE due to the limited presence of the species."
    - **Response:** The SA has assessed FE for the slope subgroup as a whole using the FE model and the 50% CEA, which can serve as a proxy for assessing FE for this species until more information is available.

5.2.9.5 Redbanded rockfish

- Concerns with EFH map
    - The SA noted *low (1) concern* and commented: "This species is relatively well sampled by the trawl survey, however, it does miss larger fish, which are seen in the AFSC LL survey."
        - Response: See our *response reported in the subgroup section* and refer to *Table A5.6.* The reviewing SA's concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[80]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[79].
    - The SA suggested this species distribution data to use in future SDM: AFSC longline survey with length data and maybe the IPHC longline survey data
- Concerns with FE model
    - The SA noted *medium (2) concern* and commented: "The SDM does not include data from surveys which sample more of the adult size range."
        - Response: This concern carries over from concerns with data used in the SDM, and those concerns are addressed in separate discussion papers listed above.
- EFH research recommendations

[79] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[80] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

- The SA recommended: “Incorporate both longline survey indices and length data when available.”

- **SA chose a *qualitative* assessment using other sources of information:** However the SA noted “The FE is based on an SDM which may not represent the full adult distribution due to gear selectivity. Without inclusion of the longline survey data, with sizes, it is impossible to determine if the FE model adequately represents the impact on the species.”
  - **Response:** The SA has assessed FE for the slope subgroup as a whole using the FE model and the 50% CEA, which can serve as a proxy for assessing FE for this species until more information is available.

5.2.9.6 Redstripe rockfish

- Concerns with EFH map
  - The SA noted *low (1) concern* and commented: “Trawl survey data may accurately represent the summer adult distribution in the GOA, and is not mis-matched with fishery data.”
    - Response: See our *response reported in the subgroup section* and refer to *Table A5.6.* The reviewing SA’s concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[81]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[82].
  - The SA suggested this species distribution data to use in future SDM: rockfish fishery data.
- Concerns with FE model
  - The SA noted *low (1) concern* and provided this as an explanation: “Small sample size of data informing the models.”
- **SA chose a quantitative FE assessment.**

5.2.9.7 Sharpchin rockfish

- Concerns with EFH map
  - The SA noted *low (1) concern* and commented: “Of the GOA Other rockfish, this is probably the best candidate for EFH efforts. It is relatively well sampled by the trawl survey, and less by longline surveys. Fishery data supports the SDM model.”

[81] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[82] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents
https://meetings.npfmc.org/Meeting/Details/2947

        - Response: See our *response reported in the subgroup section* and refer to *Table A5.6.* The reviewing SA's concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[81]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[82].
    - The SA suggested this species distribution data to use in future SDM: rockfish fishery data.
- Concerns with FE model
    - The SA noted *low (1) concern* and provided this as an explanation: "Insufficient data."
- **SA chose a quantitative FE assessment.**

5.2.9.8 Silvergray rockfish

- Concerns with EFH map
    - The SA noted *low (1) concern* and commented: "Species is relatively well sampled by the trawl survey, but SDMs could be better informed in untrawlable habitat by inclusion of longline survey data."
        - Response: See our *response reported in the subgroup section* and refer to *Table A5.6.* The reviewing SA's concerns and recommendations for this species and the slope subgroup overall were discussed and reported (page 45-50) in the December 2021 EFH Stock Author Review Report[83]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*ongoing data issues* and with the *GOA other rockfish slope subgroup example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[84].
    - The SA suggested this species distribution data to use in future SDM: both longline surveys and [GOA rockfish] fishery data.
- Concerns with FE model
    - The SA noted *low (1) concern*.
- **SA chose a *qualitative* assessment using other sources of information:** However the SA noted, "The SDM ignores other valuable data sources for the species, therefore the FE is not fully informed." The SA concluded that there is not enough information to determine if fishing effects are more than minimal and not temporary.

[83] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[84] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- **Response: Response:** The SA has assessed FE for the slope subgroup as a whole using the FE model and the 50% CEA, which can serve as a proxy for assessing FE for this species until more information is available.

5.2.10 Rex sole

- Concerns with EFH map
    - The SA noted *high (3) concern* and commented: "It looks to me like the EFH map encompasses the summer distribution of adults, but it still would be wise to revisit whether the splitting of adults vs subadults by length categories miscategorizes some older rex sole as subadults, which might change the percentile rankings over space, or maybe it wouldn't."
        - Response: This concern regarding the SDM EFH maps for flatfishes with spatially varying growth was also discussed in sections 6.6, 6.7, 6.10, and 7.4 of this document and in Chapter 5 (*life history considerations* with the *flatfishes example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[84].
- **SA chose a quantitative FE assessment.**

5.2.11 Sablefish

- Concerns with EFH map
    - The SA noted *medium (2) concern* and commented: "As noted in the SDM EFH review, the trawl survey is generally not believed to adequately sample sablefish or their habitat. As denoted in the sablefish SAFE, the trawl survey does not consistently sample deeper than 500 m, which is primary sablefish habitat and adult sablefish may be able to outswim the trawl gear. Thus, the GOA trawl survey data is only used as an index of young (not adult) sablefish in the sablefish assessment. It is likely that the EFH maps based on the GOA trawl survey are adequate to delineate general sablefish hotspots (excluding important state water locations). However, the dedicated sablefish longline survey is designed explicitly to sample sablefish and would provide a more appropriate delineation of EFH. Moreover, the high mobility of sablefish may indicate a lack of preference to specific habitat, though little is known about spawning locations or preferred habitats for early life history stages."
        - Response: These concerns and recommendations were reported and discussed on page 51 in the December 2021 EFH Stock Author Review Report[85]. These concerns and recommendations as reported in the 2022 FE assessment questionnaire are discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[86].

---

[85] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

[86] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents
https://meetings.npfmc.org/Meeting/Details/2947

    - The SA suggested this species distribution data to use in future SDM: NOAA longline survey data
- Concerns with FE model
    - The SA noted *low (1) concern* and commented that it was the same as with the SDM map. They continued: "However, I do not think that using the [longline] survey data would lead to a different interpretation of the impacts of fishing."
- EFH research recommendations
    - The SA recommended: "Incorporate longline survey data into the SDM. Collect data to better understand spawning areas (requires winter sampling) and ELH [early life history] habitat preferences. Develop a better understanding of connectivity among management units within the Alaska-wide sablefish population, particularly the dynamics of juvenile fish and how they utilize the EBS shelf (i.e., is this a nursery area and fish migrate to other areas as they mature or do juveniles that settle in the EBS tend to remain in the BS as they mature)."
- **SA chose a quantitative FE assessment.**

5.2.12 Spiny dogfish

- Concerns with EFH map
    - The SA noted *medium (2) concern* and commented: "The adult model doesn't make sense. This outcome is likely due to the issues with catchability and only using bottom trawl survey data. Adults are far more abundant across the GOA than these maps suggest. Incorporate the AFSC and IPHC longline surveys, with their length data and the models will likely change substantially."
        - Response: These concerns were reported and discussed on page 55 in the December 2021 EFH Stock Author Review Report[85]. These concerns and recommendations as reported in the 2022 FE assessment questionnaire are discussed in Chapter 5 (*ongoing data issues* and with the *spiny dogfish/shark complex example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[86].
        - Due to data limitation concerns for the adult life stage of spiny dogfish, analysts combined the subadult (n = 1,262) and adult (n = 127) life stages for this species into a revised SDM ensemble EFH map and recommend that this replace the draft subadult and adult SDM ensemble EFH maps that the SSC reviewed for this species in February, 2022. EFH component 1 requires individual species maps for the fishery management unit (FMU) corresponding to the FMP (50 CFR 600.805(b)). However, where appropriate, may be designated for assemblages of species or life stages that have similar habitat needs and requirements (50 CFR 600.815(a)(1)(iv)(E)). The revised SDM ensemble EFH maps for spiny dogfish is reported in Chapter 5 of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting and the GOA EFH

NOAA Technical Memorandum[87]. The revised spiny dogfish SDM EFH map that combines the subadult and adult life stages is available for the 2022 FE assessment.

  - The SA suggested this species distribution data to use in future SDM: AFSC/IPHC longline survey catch and length data and Fishery catch data.

- Concerns with FE model
  - The SA noted *medium (2) concern* and commented: "The SDM used to inform the FE does not accurately represent the adult spiny dogfish distribution, therefore the FE cannot be accurate."
    - Response: See response under *EFH map concerns*. The revised spiny dogfish SDM EFH map that combines the subadult and adult life stages is available for the 2022 FE assessment.
- **SA chose a *qualitative* assessment using other sources of information:** The SA also commented "The FE is based on an SDM which may not represent the full adult distribution due to gear selectivity. It is not possible to detect what the fishing effects would be for this species."
- EFH research recommendations
  - The SA recommended: "[I]ncorporating data that are more informative for this species."

5.2.13 Shortraker rockfish

- Concerns with EFH map
  - The SA noted *low (1) concern* and commented: "There has been concern that the exclusion of the longline survey data set would lead to an incomplete representation of the distribution of shortraker rockfish. However, this map shows proper summer distribution of adults of this species."
    - Response: This concern was reported and discussed on page 58 in the December 2021 EFH Stock Author Review Report[88]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[87].
  - The SA suggested this species distribution data to use in future SDM: longline survey data.
- **SA chose a quantitative FE assessment.**

5.2.14 Shortspine thornyhead rockfish

- Concerns with EFH map

[87] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[88] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

- The SA noted *low (1) concern* and commented: “There has been concern that the exclusion of the longline survey data set would lead to an incomplete representation of the distribution of shortraker rockfish. However, this map shows proper summer distribution of adults of this species.”
  - Response: This concern was reported and discussed on page 59 in the December 2021 EFH Stock Author Review Report[88]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*add species data*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[87].
- The SA suggested this species distribution data to use in future SDM: longline survey data.

- **SA chose a quantitative FE assessment.**

5.3 BSAI Crab

The BSAI crab species are listed below with a summary of SA comments, concerns, recommendations, and FE analysis supporting their FE assessment, if provided by the SA.

5.3.1 Blue king crab

- EFH research recommendations
  - The SA recommended: “Blue king crab utilize cobble and shell hash as important benthic nursery habitat. Expand EFH to include early benthic life stages, produce high resolution maps for nursery habitats near Pribilof Islands, St. Matthew Island, St. Lawrence Island, quantify potential/actual effects of fishing in these habitats.”
  - The SA recommended: “General understanding of female spawning and juvenile habitat needs. Unfortunately [the] summer trawl survey doesn't capture this well.”
  - The SA noted that blue king crab stocks are below MSST for both the Pribilof Islands and St. Matthews areas, but are not assessed in the area of St. Lawrence Island.
- HAPC considerations
  - The SA commented: “Activities such as dredging which could remove or substantially alter cobble and shell hash habitat. Any such activities near the Pribilof Islands, St. Matthew Island, or St. Lawrence Island should be evaluated for their potential impact on these important benthic nursery habitats for blue king crab. I'm not sure whether these would be appropriate, however, for consideration as HAPC areas.”
- **SA chose a quantitative FE assessment and provided additional supporting analysis:** The SA completed analyses for EBS blue king crab because that stock is below MSST. The full FE assessment with tables and figures is available (as a PDF file) in the EBS BKC folder along with the FE model results and figures provided for the SSC October,

2022 meeting[89]. The written portion of the EBS BKC FE assessment is also provided here; table and figure references correspond to those in the full FE assessment.

Blue King Crab Fishing Effects Assessment by Stock Author

Introduction

Blue king crab (*Paralithodes platypus*; BKC) in the eastern Bering Sea (EBS) form discrete populations in cooler waters around St. Lawrence Island, St. Matthew Island, and the Pribilof Islands. The EBS population has previously supported commercial fisheries near St. Matthew Island and the Pribilof Islands, although the fisheries in both areas are currently closed. The subpopulations in these areas are regarded as separate stocks for the purposes of fishery management; separate stock assessments are conducted for the St. Matthew Island and Pribilof Islands stocks (SMBKC and PIBKC, respectively). The subpopulation around St. Lawrence Island is not included in the Fishery Management Plan for Bering Sea and Aleutian Islands King and Tanner Crab and is not included in a stock assessment.

The first step in the FE Analysis for a species is to determine whether or not the population is above its MSST, which for federally-managed crab stocks in the Bering Sea is defined as 1 2 · BMSY , where BMSY is generally represented by a proxy quantity based on mature male biomass-at-mating (MMB). For SMBKC and PIBKC, the proxies for BMSY are MMB, as estimated from the assessment, averaged over a specified (stock-specific) specified time period. Stock-level MSSTs and current MMB estimates are available for the PIBKC and SMBKC stocks, but not for the St. Lawrence Island "stock" because an assessment is not conducted for the latter (NPFMC 2021). As a consequence, the MSST for the population is approximated here as the sum of the PIBKC and SMBKC MSSTs and the population-level MMB for comparison is approximated as the sum of the assessment-estimated current PIBKC and SMBKC MMBs. Using this approach, 1) the MSST and current MMB for the PIBKC stock are 2049 t and 180 t, respectively (NPFMC 2021); 2) the MSST and current MMB for the SMBKC stock are 1,670 t and 1,120 t (NPFMC 2021); and 3) the MSST and current MMB for the BKC population are 3,719 t and 1,300 t. Thus, the EBS population is regarded as being **below its MSST** and an analysis to determine whether fishing effects on habitat may have an impact on the species is required.

Essential Fish Habitat for Bering Sea blue king crab

EFH and additional habitat-related subareas (Figure 1) were defined for BKC using an ensemble of species distribution models that potentially incorporated a suite of environmental covariates and were fit to estimates of BKC presence/absence and numerical abundance from NMFS summer trawl surveys in the eastern Bering Sea (1982-2019). The area representing BKC EFH was dispersed across the EBS from Bristol Bay in the south to the northern extent of the survey area. Hot spots were predicted around the Pribilof Islands and St. Matthew Island as well as north of St. Lawrence Island. Most of the core EFH area (CEA) surrounded these hot spots, where the CEA was defined as encompassing the upper 50-percentile of EFH.

Fishing Effects on the BKC CEA

[89] EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

The 2022 FE model was run using the BKC CEA to obtain monthly estimates of the fraction of habitat disturbance in the CEA using both observed and unobserved fishing activity (Figures 2 and 3). Across the 2003-2021 time period, the estimated fraction of habitat disturbed was greater than 10% only in the PIBKC CEA prior to 2010 when both observed and unobserved fishing activities were considered. Otherwise, the estimated fraction was less than 10% regardless of the stock or activity type considered. Fishing effects on BKC If the population is below its MSST or the CEA disturbed by fishing is currently ≥ 10%, the FE analysis guidelines require that 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) be examined to determine whether there are correlations between those indices and the trends in the proportion of the CEA disturbed, and whether any correlations are significant at a p-value of 0.1. The guidelines suggest that this criterion provides an objective threshold to ensure that a "hard look" has been taken for each species. Because multiple time series may be examined for correlation to habitat disturbance, it is possible that spurious significant ($p < 0.1$) correlations will be found.

For BKC, the indices available for correlation analysis are limited: time trends in growth-to-maturity and feeding success are unknown: temporal variation in size-at-age cannot be determined (age determination for crabs in general is problematic) and condition indices have not been developed. Trends in spawning success may be reflected in time series of annual recruitment (R) and mature male biomass (MMB, the measure of spawning stock size used in NPFMC crab assessments), but recruitment is only estimated for the SMBKC stock as part of its stock assessment (the model for PIBKC does not estimate recruitment to that stock). Trends in breeding success, in contrast, can be estimated for the PIBKC and SMBKC stocks using data on clutch fullness from the annual NMFS EBS summer shelf survey. Trends in survey biomass can also be examined for the PIBKC and SMBKC stocks. Similar information for the St. Lawrence Island component of the Bering Sea BKC population is unavailable on an annual basis, so the available indices are examined individually on a stock-specific basis for correlation with the associated stock-level habitat disturbance time series.

Cross-correlations for each BKC-related time series selected for analysis was calculated using the stock-specific time series of habitat disturbance ("FE CEA HD", Figure 4) using the "testcorr" package for R (Dalla et al., 2021; R Core Team, 2020). The "testcorr" package provides statistics for testing cross-correlations for significance against a null hypothesis of zero correlation that are robust to departures from the iid and non-skewness assumptions required for standard tests (Dalla et al., 2020). Because the available BKC time series were at an annual time step, annual averages of the associated habitat disturbance time series were used in the correlation analysis. Additionally, because the impact of any effects of fishing-related habitat disturbance may be lagged in the biological response of the species, correlations at several lags were examined for each BKC time series. Prior to the correlation analysis, the BKC-related time series were pre-whitened to avoid spurious serial correlation (e.g., Dean and Dunsmuir, 2016) using ARIMA models fitted to the associated annual habitat disturbance time series and functions modified from the R package "TSA" (Chan and Ripley, 2020). Significance of cross-correlations was assessed using the robust t-statistic significance levels reported from the function "cc.test" in the "testcorr" package (Dalla et al., 2021).

Spawning success
Trends in spawning success may be reflected in time series of annual recruitment (R) and mature male biomass (MMB, the measure of spawning stock size used in NPFMC crab assessments), but recruitment is only estimated for the SMBKC stock as part of its stock assessment (the model for PIBKC does not estimate recruitment to that stock). The time series of R, MMB, and ln(R/MMB) (a measure of relative spawning success) from the latest stock assessment for SMBKC (NPFMC, 2021) were compared to the stock-specific time series of habitat disturbance ("FE CEA HD", Figure 4). To form the ln(R/MMB) time series, R was lagged 7 years to the presumptive fertilization year (K. Palof, ADFG, pers. comm.). Based on considerations of potential causality of habitat reduction on biological characteristics of the population, only positive lags of the habitat reduction time series were examined for the cross-correlations with R and MMB, but both positive and negative lags were considered for ln(R/MMB) (negative correlations correspond to effects occurring between hatching and recruitment).

The recruitment time series exhibited correlations significantly different from zero (at an α level of 0.1) with the annually-averaged SMBKC CEA disturbance time series at lags of 3 and 8 years, while the MMB time series exhibited no correlations significantly different from zero (Tables 1 and 2; Figure 5). The ln(R/MMB) time series exhibited a significant correlation at a 1-year lag. All three significant correlations were negative, as one would expect given that habitat disturbance (assuming an unproved causal linkage) would be expected to have a negative effect on the population. The significant correlations at lags of 8 years for R and 1 year for ln(R/MMB) are consistent with one another (and perhaps redundant), given the 7-year lag applied to the R time series to form ln(R/MMB). These potentially indicate an impact of habitat disturbance on mating success, although the mechanism is not clear (possibilities include potential disruptions of movement patterns related to mate selection or hatching area).

Breeding success
Using NMFS EBS shelf survey data, trends in mean clutch size for mature females were estimated on a stock-specific basis as indices of breeding success (Figure 7). Annual mean values were calculated on the basis of area-swept estimates of both abundance and biomass, but the results from the two weighting methods were very similar. Interannual changes in mean clutch size for SMBKC were highly variable, which may be the due to the timing of sampling relative to the hatch cycle–rather than truly reflecting changes in mean clutch size. As a consequence, only the time series of abundance-weighted mean clutch size for PIBKC was compared with the mean annual FE CEA disturbance time series.

The standardized time series for mean clutch size and habitat disturbance are illustrated in Figure 8. Crosscorrelations between the two time series were not significantly different from zero at any lag (Table 4; Figure 9).

Correlation with survey indices of abundance
Finally, trends in stock-specific NMFS EBS shelf survey biomass for immature and mature crab by sex were compared to the stock-specific time series of habitat disturbance. Annual survey biomass indices were obtained from AKFIN Answers (https://akfinbi.psmfc.org/analytics/, accessed 6/9/2022) for the SMBKC and PIBKC stocks. BKC were characterized as immature or mature based on standard stock- and sex-specific cutlines (Zacher et al., 2020). The standardized

(z-score) trends for SMBKC and PIBKC survey biomass by stock component are shown in Figure 10.

Cross-correlation results for SMBKC stock components are shown in Tables 5-8 and Figure 11. No correlations were significant between habitat disturbance and mature male or female biomass. For immature crab, a single correlation was found to be significant for both sexes: positive at a lag of 6 years for males and negative at a lag of 2 years for females.

Cross-correlation results for PIBKC stock components are shown in Tables 9-12 and Figure 12. Significant correlations were not found at any lags for immature males, immature females, or mature females. Significant correlations were found for mature males at lags of 3, 4, and 5 years. The correlations at 3 and 5 year lags were negative, but positive at the 4-year lag.

Conclusions

Habitat disturbance from fishing effects is estimated to be less than 3% for the blue king crab population in the Bering Sea. A few of the cross-correlations between biological and habitat disturbance time series examined here were found to be statistically significant using the robust t-statistic from Dalla et al. (2020). Of these, 6 out of 8 were negative, indicating the possibility for some deleterious causal effect of habitat reduction on biological characteristics of the BKC population. However, it is highly unlikely that any of these would have been found to be statistically significant if the number of comparisons were taken into account. Given the minimal amount of fishing-related habitat disturbance estimated in the core EFH area, I see no need for further mitigation measures for BKC beyond those currently-implemented, such as the various Habitat Conservation Zones.

5.3.2 Golden king crab

- Concerns with FE model
    - The SA noted *high (3) concern* for AI golden king crab (GKC) and commented: “No bottom/slope survey information was considered [in the SDMs].” The SA followed up by explaining their data concern: “The RACE conducted biennial (trawl) slope surveys in the Aleutian Islands starting in 1980. The Poly'Noreastern (PNE) net was used in the trawl since 1991. Due to logistic problems, there were some gaps in survey periodicity during the 1980-2018 period. You may contact Wayne Palsson [Ned Laman] from the RACE division of AFSC for further information on AI GKC slope survey details.”
        - Response: In discussion with the SA, we noted this was a concern on the SDM map used for the FE analyses. We informed the SA that the **RACE-GAP AI summer bottom-trawl survey was included in the SDMs for survey years 1991-2019.** The RACE-GAP AI survey strata have a max depth of 500 m. The ADFG pot surveys have a max depth of approximately 600 m. EFH component 1 mapping requirements have been met for AI GKC (i.e., some or all portions of the geographic range of the species). However, this species is an example of how the EFH map and EFH component 2 FE assessment may be improved by the addition of other species data sources to the SDM ensemble for a future EFH 5-year Review. This concern was reported and discussed on page 61 in the

December 2021 EFH Stock Author Review Report[90]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*crab life history considerations* with the *AI GKC example*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[91]. AI GKC was a featured results case study in the EFH Component 1 Discussion Paper prepared for the SSC February, 2022 meeting (revised March 2022) that is included as a supporting document for the SSC October, 2022 meeting.

- EFH research recommendations
    - The SA recommended: “Bottom and slope survey information should be considered.”
- **SA chose a quantitative FE assessment:** The SA indicated that there is insufficient information to make the decision to elevate this species to the Plan Teams and SSC for possible mitigation to reduce fishing effects to EFH.

5.3.3 Red king crab

A team of four SAs provided comments and recommendations for red king crab (RKC). Three SAs focused on EBS RKC and one SA on AI RKC, who reviewed the EBS FE assessment results.

- Concerns with EFH maps
    - For EBS RKC, the SAs noted either *no concern* or *low (1) concern* and commented: “Given how large the EFH was, I'm pretty sure [the core habitat of RKC] is in there. I think the important question is whether or not there [are] specific places (and times) in there that matter more than others.”
    - “Concern is over different components of the stock/population being represented for habitat use. For example, key habitat for female spawning or juvenile rearing. Maps by immature/mature or some incorporation of life stages will aid in this understanding.”
    - For AI RKC, the SA noted *low (1) concern* and commented: “Given that the RACE Aleutian Island bottom trawl survey primary objective is to define distribution and estimate relative abundance of ground-fish species, the survey may not adequately assess the western Aleutian Island red king crab (WAIRKC) stock either because WAIRKC distribution may extend outside the RACE survey distribution and/or the gear may not adequately sample crab (e.g. roller gear).”
        - Response: This life history related concern was reported and discussed on page 62 in the December 2021 EFH Stock Author Review Report[90]. This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*crab life history considerations*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[91].

---

[90] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[91] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

- The SA suggested this species distribution data to use in future SDM: “While WAIRKC occurs as bycatch in the AI [GKC] fishery, the fishery occurs mostly outside of summer months. However, those non-summer AI [GKC] observer data may be useful for this purpose. In addition, [there were] three ADF&G industry-cooperative surveys occurred (2006, 2009, 2016) for determining Petrel Bank [RKC] distribution and abundance. While these surveys occurred in Nov-Dec in those years, data may have utility for determining WAIRKC EFH.”

- Concerns with FE model
    - For EBS red king crab, the SAs noted *medium (2) concern* and commented: “Timing and life stage are key variables that are not considered. Molting puts the crab in a vulnerable state after, so the timing and location of fishing could be very important to determining fishing impacts. This is particularly important given the stock is currently on a long downward slide in terms of abundance.”
    - “My primary concern is that all habitat within the 50% CEA is considered equally important, while this is certainly not the case for red king crab. Although the habitat reduction is below 10%, it is fairly high along the Alaska Peninsula (25-50%). Some of these areas are likely important mating/molting grounds and thus much more important than other areas in the 50% CEA.”
    - “Impacts to juvenile rearing habitat or female spawning habitat aren't really addressed in this framework. It would be good to see female/male maps overlaid with FE. Historic knowledge of important female spawning areas may be good to attempt to incorporate in the future.”
    - For AI red king crab, the SA noted *medium (2) concern* and commented: “Critical spawning habitat and post-larval settlement habitat is unknown for this stock, thus there is some concern as to fishing effects on these critical life history habitats. While CEA reduction is less than 10% overall for adults, there are certain areas where habitat disturbance is well over 10%. It is unknown whether these areas are critical for certain aspects of RKC life history (such as spawning, post-larval settlement, mating, juveniles, etc).”
        - Response: The FE assessment approach was developed by an SSC subcommittee and approved by the SSC in December 2016[92]. This approach was used again for the 2022 EFH 5-year Review. Fishing impacts to EFH were assessed for the summer distribution of adults or all life stages combined for groundfishes and crabs in the EBS, GOA, and Crab FMPs. Fishing impacts to EFH for crabs was assessed for the summer distribution of the late juvenile and adult life stages combined.
- EFH research recommendations
    - The SAs recommended: “Maybe identify important areas for spawning using IBMs and calculate the impact to these areas during spawning. Do the same

[92] EFH Component 1 Stock Author Review Report December, 2021
https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

during times of molting. This is a timely and important topic given the long slow decline of red king crab over the past couple of decades.”

    - “Because the majority of fishing effects on red king crab occur outside the summer season, it will be important to improve EFH and Fishing Effect Maps for other seasons. Unfortunately, this is not easily done because distributions are poorly described in other seasons. An SDM is currently under development for fall legal male red king crab distributions, which can hopefully be incorporated in future EFH cycles. Elucidating the location of spring molting/mating grounds is of utmost importance to properly evaluate the fishing effects on red king crab EFH. Tagging efforts in 2021/22 could provide some of this information on mating/molting EFH, but more years of data will likely be necessary.” [This study was funded by AKR/AFSC in FY22 from the Alaska EFH Research Plan request for proposals]
    - “We need more understanding of female distributions and effective spawning habitat. Some of this is ongoing with limited tagging studies out of Kodiak lab but more is needed to preserve female habitat.”
    - “Research projects to better understand critical spawning, settlement, and juvenile areas/habitats. Movement studies to better understand spatial patterns outside of summer months. Focused research on the Petrel Bank area to evaluate this zone for is ecological importance for [RKC].”
- HAPC considerations
    - The SA commented: “Habitat disturbance is quite high on Petrel Bank, north of Semisopochnoi Island. While the overall spatial scale of this high disturbance area is small relative to the Aleutian Island chain and effects of this disturbance are unknown for WAIRKC populations, it may have significant ecological importance for [red king crab]. Most of the historical WAIRKC stock catch came from the Petrel Bank area; however, the most recent industry-cooperative survey (2016) indicated very low [red king crab] abundance with reduced spatial distribution in this area, likely caused by recruitment failure. It's unclear if increased localized habitat disturbance in this area caused the [red king crab] decline in the Petrel Bank area, but it should be considered.”
- **SAs chose a quantitative FE assessment and also requested to provide additional information using a *qualitative* FE assessment:**

Red King Crab Fishing Effects Assessments by Stock Authors

The EBS SA indicated that a qualitative assessment was preferred over the *status quo* approach for EBS red king crab. **Upon request, the SA was provided with additional FE model output by subregion is reviewing and analyzing it, however was unable to finalize results for this current report.**

The AI SA requested FE model output using the 75% CEA overlay and, when comparing the two, was satisfied with the original 50% CEA approach noting that they both captured the same key areas of higher percent disturbances and that, for consistency's sake, sticking with the 50% CEA approach is adequate.

5.3.4 Snow crab

- Concerns with EFH maps
  - The SA noted *low (1) concern* and commented: "My concern is low that the EFH map does not encompass the summer distribution, but the winter distribution I'm less certain and the late-winter distribution might be more important given that's when they're molting and more vulnerable to potential non-directed fishery impacts."
    - Response: This concern as reported in the 2022 FE assessment questionnaire is discussed in Chapter 5 (*crab life history considerations*) of the EFH Component 1 Discussion Paper prepared for the SSC October, 2022 meeting[93]. This concern is due to the timing over which FE are assessed for this species, which is currently for the summer season. EFH maps were developed for EBS snow crab in the summer, fall, winter, and spring in the 2017 EFH 5-year Review using fishery observer data in presence-only MaxEnt models.
- Concerns with FE model
  - The SA noted *high (3) concern* and provided their reasoning in their FE assessment (see below).
- EFH research recommendations
  - The SA provided EFH research recommendations in their FE assessment (see below).
- **SA chose a quantitative FE assessment and provided additional supporting analysis:** The SA completed analyses for EBS snow crab because that stock is below MSST.

Snow Crab Fishing Effects Assessment by Stock Author

A review of essential fish habitat and fishing effects for snow crab in the eastern Bering Sea
This document follows the decision tree for the review for essential fish habitat and fishing effects analyses. I raised two issues during the initial SDM review. First, a large number of crab exist in the northern Bering Sea, but it's not clear how many of them come south, grow enough to be impacted by the EBS fishery, or contribute to the population dynamics of the EBS. Given the prevailing currents, it is possible that a much smaller fraction of the population is important in reproduction than suggested by the essential fish habitat maps. Parada et al. (2010) suggested the portion of the population in the middle domain in lower latitudes is the most important reproductively, but there has been debate around this issue. Some areas of the middle domain have high fishing effects disturbance (large chunks east of the Pribilof Islands were in the 25-50% range), but, when the entire NBS is included in the EFH, this 'dilutes' the impact of the disturbance in those areas and keeps the habitat disturbed within the CEA less than 10%.

[93] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

Secondly, crab settle out of their pelagic larval stage onto the north-eastern portion of the shelf. As they grow and mature, they undertake a south-westerly ontogenetic migration. Juveniles occur in colder waters than mature animals. This suggests that the essential fish habitat could be different by life-stage. Successful reproduction requires both the successful mating of mature crab on the southern portion of the shelf and appropriate habitat for rearing juveniles in the north. When considering fishing effects, fishing will not influence the temperatures of the north, but it is possible that fishing could impact the success of mating in the south. This is another reason that including the NBS in the EFH may dilute the importance of the fishing disturbance on snow crab population dynamics.

The above points suggest that it is possible that the fishing effects models may not accurately convey the potential impacts of fishing on the population dynamics of snow crab. I do not think changing the percentage of the EFH included in the CEA can appropriately address either of these concerns. Closer examination of the spatio-temporal changes in potential fishing effects is needed. A better understanding of the history of disturbance in the middle domain could better characterize the potential impacts of fishing on the mating dynamics of the portion of the population hypothesized to contribute to reproduction. Furthermore, characterization of spatio-temporal disturbance dynamics during the molting period (a period of time in which crab are particularly vulnerable) could be useful to understanding potential fishing effects. I do not currently have the information available to explore either of these questions.

Those concerns aside, the next step in the decision tree was to evaluate correlations between CEA disturbance and life history indices. Two indices available for comparison to the habitat disturbance were estimated recruitment and the observed probability of having undergone terminal molt at size by year (Figure A5 15). Estimated recruitment used here was the estimated male recruitment from the most recent GMACS model accepted for use in May 2022. The observed probability of having undergone terminal molt at size by year was produced through analyses performed by the Kodiak lab based on chelae height measurements taken during the survey. The CEA disturbance was averaged within a year to calculate correlations. Given that fishing disturbances could have lagged effects, cross-correlations were performed in which correlations were performed at different lags for each variable. No significant correlations were identified for recruitment (Figure A5 16) or the probability of having undergone terminal molt (Figure A5 17). Still, the coarse nature of this analysis and short time series make this a questionable method to attempt to identify the impacts of fishing effects on the stock. Short, auto-correlated time series and high cut-off value for significance produce conditions ripe for spurious correlations. Further, “where” and “when” fishing-related disturbance occurs are key variables for snow crab that are not considered here.

Given the recent dynamics of snow crab, understanding all potential stressors on the stock is important. Outside of managing the directed fishery, the potential impact of mortality imposed by other fleets in the Bering Sea is the only lever management has to alter anthropogenic impact on the stock. The largest pseudocohort of crab (i.e. a group of similarly sized crab) was spawned around the year 2010 and began to be seen in the survey gear in 2015. The year 2010 occurs during a transition from higher fishery disturbance to lower fishery disturbance. Parsing the disturbances out spatially and in time may better inform the quantification of potential fishing effects. However, the time series length may ultimately be a constraining factor in understanding the impacts of fishing disturbances. If possible, an understanding of the fishery disturbance in the 1990s (which was when the stock was at its previous highs and producing much larger catches than currently are taken) would provide useful contrast in the time series. As it stands, I do not think I have sufficient information to elevate this species to the Plan Team and SSC for possible mitigation. Analyses focused on areas thought to be important in reproductive dynamics (e.g. the middle domain around the Pribilofs) could be useful in making the decision on whether or not to elevate this species for mitigation.

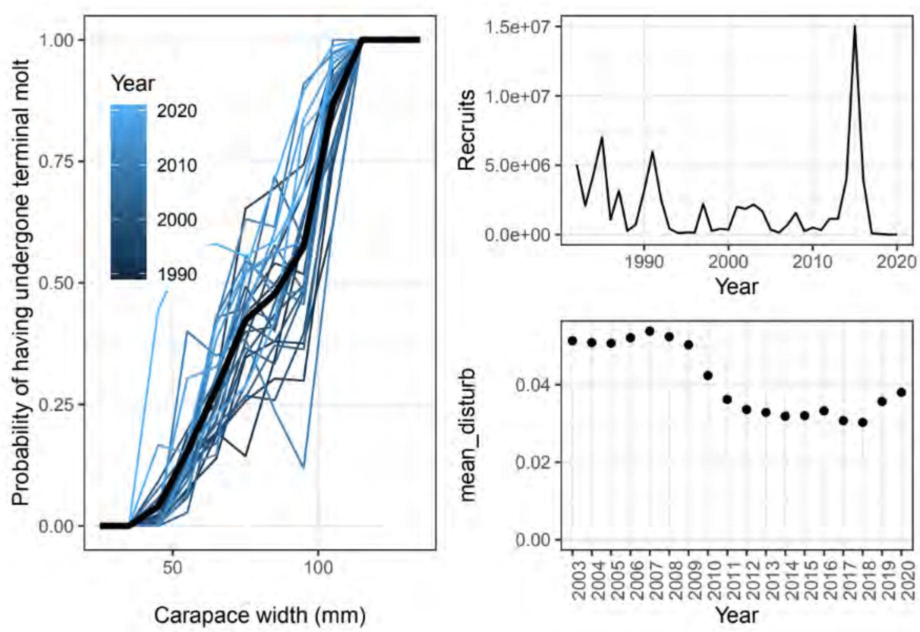


Figure A5.15. Estimated recruitment, fishing disturbance averaged over the year, and observed probability of having undergone terminal molt at size over time.

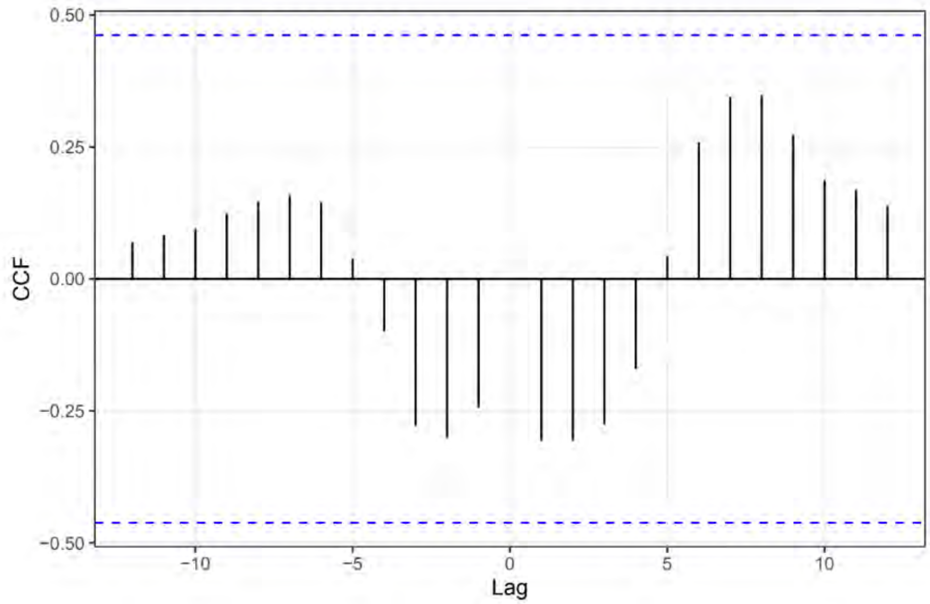


Figure A5.16. Cross-correlation between estimated recruitment and fishing effects.

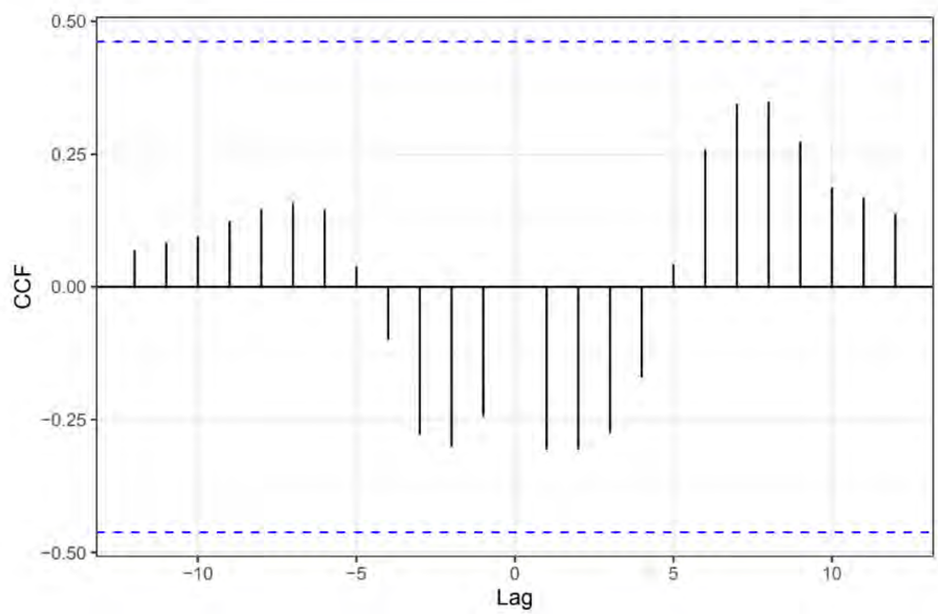


Figure A5.17. Cross-correlation between the observed probability of having undergone terminal molt at 75 mm carapace width and the mean fishing disturbance.

5.3.5 Tanner crab

- Concerns with FE model
    - The SA reported *no concern* with the FE model but noted in their FE assessment "It should also be noted that most of the biological time series examined here (including recruitment) are rather problematic from a time series analysis

perspective because age classes cannot be distinguished and the survey only starts to be selective for Tanner crab approximately 5 years after settlement, and thus any effects of habitat disturbance on a specific cohort or age class are combined with several other age classes and "smeared out". Another difficulty is that, despite the level of disturbed area exceeding 10% of the core EFH area, the contrast in habitat disturbance across the time series is not all that substantial." This is mainly a concern over the life history stages assessed by the FE analysis and the timing.

- EFH research recommendations
    - The SA recommended other measures of fishing impacts: "Observations of immediate and longer term responses to nearby fishing effects (effects of increased sediment load in the water column on respiration, fishing effects on prey abundance and quality, fishing effects on predator distributions)."
- **SA chose a quantitative FE assessment and provided additional supporting analysis:** The SA provided an FE assessment based on the 50% CEA used with the FE model results. *The full FE assessment with tables and figures is available (as a PDF file) in the EBS Tanner crab folder along with the FE model results and figures provided for the SSC October, 2022 meeting*[94]. The written portion of the EBS Tanner crab FE assessment is also provided here; table and figure references correspond to those in the full FE assessment.

Fishing Effects Assessment: Bering Sea Tanner Crab

Introduction

Tanner crab (*Chionoecetes bairdi*) are distributed across the continental shelf as far south as Washington and Oregon, and westward to the Kamchatka peninsula and Hokkaido, Japan (NPFMC, 2021). They are particularly common in the southeastern Bering Sea and Aleutian Islands. Tanner crab show a strong preference for bottom temperatures above 2°C, but have not demonstrated a northward shift in their distribution during recent warm years (Murphy, 2020). These crabs undergo a terminal molt as they become sexually mature, after which they stop growing and will retain the same shell in future years (Tamone, 2017). Tanner crab exhibit sexually-dimorphic growth and both sexes mature over a range of sizes (NPFMC, 2021).

Characterization of maturity for females is unambiguous on the basis of changes in abdominal morphology associated with the molt to maturity. Characterization for males is more ambiguous and interannual changes in population-level size-at-maturity are driven more by recruitment variability than by changes in the underlying maturation schedule (Murphy, 2021). Although regarded as a single stock for assessment purposes, ADF&G manages the EBS Tanner crab population using two areas, demarcated by $166^{o}W$ longitude (NPFMC, 2021).

The first step in the Fishing Effects (FE) Analysis for a species is to determine whether or not the population is above its Minimum Stock Size Threshold (*MSST*), which for federally-managed crab stocks in the Bering Sea is defined as $\frac{1}{2} \cdot B_{MSY}$, where B_{MSY} is generally represented by a proxy quantity based on mature male biomass-at-mating (*MMB*). For Tanner crab, the proxy for

---

[94] EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

B_{MSY} is $B_{35\%}$, the *MMB* at 35% of the unfished stock *MMB*. The estimated *MSST* and current *MMB* from the latest stock assessment (NPFMC, 2021) are 17.97 and 42.57 thousand t respectively so the stock is not below its *MSST*.

Essential Fish Habitat for Bering Sea Tanner crab

Essential Fish Habitat (EFH) and additional habitat-related subareas (Figure 1) were defined for Tanner crab using an ensemble of species distribution models that potentially incorporated a suite of environmental covariates and were fit to estimates of Tanner crab presence/absence and numerical abundance from NMFS summer trawl surveys in the eastern Bering Sea (1982-2019). The area representing Tanner crab EFH was dispersed west across the EBS shelf from Bristol Bay in the southeast along the Alaska Peninsula in the south and northwestward to the northwestern extent of the survey area along the EEZ boundary past St. Matthew Island. The core EFH area (CEA), encompassing the upper 50%-ile of EFH, generally followed this pattern as well, but was somewhat more concentrated along the Peninsula and shelf edge than the full EFH area.

Fishing Effects on the Tanner crab CEA

The 2022 FE model was run using the Tanner crab CEA to obtain monthly estimates of the fraction of habitat disturbance in the CEA using both observed and unobserved fishing activity (Figures 2 and 3). In addition to time series of habitat disturbance in the complete CEA, time series were also calculated for sub-areas of the CEA east and west of 166^{o}W longitude corresponding to the two ADF&G management areas. Across the 2003-2021 time period, the estimated fraction of habitat disturbed in the CEA when both observed and unobserved fishing activity were included decreased from ~14% at the start of the time series (2003) to ~10.5% in 2021. The level of disturbance was somewhat larger, and more temporally constant, east of 166^{o}W longitude than west of it, decreasing in the latter area by ~4 percentage points between 2009 and 2011 and remaining slightly less than 10% until 2021, when it rose to just above 10%.

Fishing effects on Tanner crab

If the population is below its *MSST* or the CEA disturbed by fishing is currently ≥ 10%, the FE analysis guidelines require that 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) be examined to determine whether there are correlations between those indices and the trends in the proportion of the CEA disturbed, and whether any correlations are significant at a *p*-value of 0.1. The guidelines suggest that this criterion provides an objective threshold to ensure that a “hard look” has been taken for each species. Because multiple time series may be examined for correlation to habitat disturbance, it is possible that spurious significant ($p < 0.1$) correlations will be found. For Tanner crab, the fraction of the CEA disturbed by fishing activity is currently ≥ 10%, and so these indices must be examined.

The indices available for Tanner crab for correlation analysis are limited: time trends in growth-to-maturity and feeding success are unknown: temporal variation in size-at-age cannot be determined (in general, age determination for crabs is problematic) and condition indices have not been developed. Trends in spawning success may be reflected in time series of estimated annual recruitment (*R*) and *MMB* (the measure of spawning stock size used in NPFMC crab assessments) from the most recent stock assessment. Trends in breeding success can be estimated for the Tanner crab stock using data on clutch fullness from the annual NMFS EBS summer shelf survey. Trends in survey biomass for different components of the population can also be examined. The assessment model treats the Tanner crab population as a single stock: available data is aggregated across ADF&G management areas to the entire EBS and estimated time series for recruitment and *MMB* are only available at the stock level. Trends in clutch fullness and survey biomass are also examined at this level.

Cross-correlations for each Tanner crab-related time series selected for analysis were calculated using the stock-specific time series of habitat disturbance ("FE CEA HD", Figure 4) using the "testcorr" package for R (Dalla et al., 2021; R Core Team, 2020). The "testcorr" package provides statistics for testing cross-correlations for significance against a null hypothesis of zero correlation that are robust to departures from the iid and non-skewness assumptions required for standard tests (Dalla et al., 2020). Because the available Tanner crab time series were at an annual time step, annual averages of the associated habitat disturbance time series were used in the correlation analysis. Additionally, because the impact of any effects of fishing-related habitat disturbance may be lagged in the biological response of the species, correlations at several lags were examined for each Tanner crab time series. Prior to the correlation analysis, the Tanner crab-related time series were pre-whitened to avoid spurious serial correlation (e.g., Dean and Dunsmuir, 2016) using functions modified from the R package "TSA" (Chan and Ripley, 2020) and ARIMA models fitted to the associated annual habitat disturbance time series. Significance of cross-correlations was assessed using the robust t-statistic significance levels reported from the function "cc.test" in the "testcorr" package (Dalla et al., 2021).

Spawning success

Trends in spawning success may be reflected in time series of annual recruitment (*R*) and mature male biomass (*MMB*, the measure of spawning stock size used in NPFMC crab assessments), but recruitment and *MMB* are only estimated for the entire stock as part of the stock assessment (the model does not estimate separate time series for the areas east and west of 166^{o}W longitude). The time series of *R*, *MMB*, and *ln*(*R/MMB*) (a measure of relative spawning success) from the latest stock assessment (NPFMC, 2021) were compared to the time series of habitat disturbance in the CEA ("FE CEA HD", Figure 4). To form the *ln*(*R/MMB*) time series, *R* was lagged 6 years to the presumptive fertilization year, assuming settlement occurs in the fall of the year following mating/fertilization (Punt et al., 2014). Based on considerations of potential causality of habitat reduction on biological characteristics of the population, only positive lags of the habitat reduction time series were examined for the cross-correlations with *R* and *MMB*, but both positive and negative lags were considered for *ln*(*R/MMB*) (correlations at negative lags correspond to effects occurring between hatching and recruitment).

The recruitment time series exhibited a correlation significantly different from zero (at an α level of 0.1) with the annually-averaged CEA disturbance time series at a lag of 4 years, while the *MMB* and *ln*(*R/MMB*) time series exhibited no correlations significantly different from zero (Tables 1-3; Figures 5 and 6). A lag of four years corresponds to disturbance one year after the presumed year of settlement (i.e., two years after the presumed year of fertilization), but the correlation was positive, indicating a positive effect of habitat disturbance on eventual recruitment (possible, but seemingly unlikely, mechanisms include positive effects of disturbance on prey availability or predator disruption).

Breeding success

Using NMFS EBS shelf survey data, trends in mean clutch size for mature females were estimated on a stock-specific basis as indices of breeding success (Figure 7). Annual mean values were calculated on the basis of area-swept estimates of both abundance and biomass, but the results from the two weighting methods were very similar. Interannual changes in mean clutch size for EBS exhibited high frequency variability imposed on a gradual decline over the time series.

The standardized time series for mean clutch size and habitat disturbance are illustrated in Figure 8. Cross-correlation between mean clutch size and the annually-averaged habitat disturbance time series was significantly different from zero and positive at a lag of 0 years (Table 4; Figure 9).

Correlation with survey indices of abundance

Finally, trends in stock-specific NMFS EBS shelf survey biomass for immature and mature crab by sex were compared to the stock-specific time series of habitat disturbance. Tanner crab were characterized as immature or mature based on standard area- and sex-specific cutlines (Zacher et al., 2020), with the areas coincident with the ADF&G management areas. Annual survey biomass indices were obtained from AKFIN Answers (https://akfinbi.psmfc.org/analytics/, accessed 6/20/2022) for the East 166^{o}W and West 166^{o}W management areas and aggregated to the EBS before analysis. The standardized (z-score) trends for EBS survey biomass by stock component are shown in Figure 10.

Cross-correlation results for the EBS stock components are shown in Tables 5-8 and Figure 11. Immature male biomass was significantly correlated with habitat disturbance at 1- and 4-year lags; the former negative, the latter positive. No correlations were significant for mature males. Immature females were negatively correlated with habitat disturbance at a 2-year lag while mature females were positively correlated at a lag of 5 years.

Conclusions

A few of the cross-correlations between time series of biological characteristics and habitat disturbance due to fishing effects examined here were found to be statistically significant using the robust t-statistic from Dalla et al. (2020). Of these, 2 out of 5 were negative, indicating the possibility for some deleterious causal effect of habitat reduction on biological characteristics of the Tanner crab population. These were associated with 1- or 2-year lags between habitat disturbance and immature (males and females, respectively) survey biomass. These results suggest the possibility that mortality on early benthic instars may be positively correlated with habitat disturbance, with a lag between effect and observation because survey catchability for small crab is poor. The significant positive correlations were found for recruitment (4-year lag), clutch size (no lag), and immature male survey biomass (4-year lag). The results for recruitment and immature male survey biomass would appear to suggest that habitat disturbance enhances survival of small benthic instars (the 4-year lags being consistent with a positive effect a year after settlement), in contrast to the suggestion based on the negative correlations for immature survey biomass. It is also difficult to see how habitat disturbance could have a direct effect (positive *or* negative) on clutch size.

In any case, it is unlikely that any of the correlations would have been found to be statistically significant if the number of comparisons were taken into account (the smallest significant p-value, for immature male survey biomass, was 0.053). It should also be noted that most of the biological time series examined here (including recruitment) are rather problematic from a time series analysis perspective because age classes cannot be distinguished and the survey only starts to be selective for Tanner crab approximately 5 years after settlement, and thus any effects of habitat disturbance on a specific cohort or age class are combined with several other age classes and "smeared out". Another difficulty is that, despite the level of disturbed area exceeding 10% of the core EFH area, the contrast in habitat disturbance across the time series is not all that substantial.

It is thus difficult to really draw any conclusions on the effects of fishing-related habitat disturbance on the Tanner crab population, despite the level of disturbed area exceeding 10% of the core EFH area.

5.4 APPENDIX 5 REFERENCES

Blood, D.M., A. C. Matarese, M. S. Busby. 2007. Spawning, egg development, and early life history dynamics of arrowtooth flounder (*Atheresthes stomias*) in the Gulf of Alaska. NOAA Professional Paper NMFS 7, 28 p. Available online: https://repository.library.noaa.gov/view/noaa/3512/noaa_3512_DS1.pdf.

Bryan, M. D., K. Shotwell, S. Zador, and J. Ianelli. Assessment of the Kamchatka Flounder stock in the Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 91 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIkamchatka.pdf.

Butler, J.L., C. Kastelle, K. Rubin, D. Kline, H. Heijins, L. Jacobson, A. Andrews, and W.W. Wakefield. 1995. Age determination of shortspine thornyhead, *Sebastolobus alascanus*, using otolith sections and ^{210}Pb: ^{226}Ra ratio. Admin. Rep. No. LJ-95-12. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, Calif.

Chan, K.-S. and B. Ripley. 2020. TSA: Time Series Analysis. R package version 1.3. https://CRAN.Rproject.org/package=TSA.

Dalla, V., L. Giraitis and P.C.B. Phillips. 2020. Robust Tests for White Noise and Cross-Correlation. Cowles Foundation, Discussion Paper No. 2194R. Available online: https://cowles.yale.edu/sites/default/files/files/pub/d21/d2194- r.pdf.

Dalla, V., L. Giraitis and P.C.B. Phillips. 2021. testcorr: Testing Zero Correlation. R package version 0.2.0. https://CRAN.R-project.org/package=testcorr.

De Forest, L., Duffy-Anderson, J.T., Heintz, R.A., Matarese, A.C., Siddon, E.C., Smart, T.I. and Spies, I.B. 2014. Taxonomy of the early life stages of arrowtooth flounder (*Atheresthes stomias*) and Kamchatka flounder (*A. evermanni*) in the eastern Bering Sea, with notes on distribution and condition. DSR II 109: 181–189.

Dean, R.T., and W.T.M. Dunsmuir. 2016. Dangers and uses of cross-correlation in analyzing time series in perception, performance, movement, and neuroscience: The importance of constructing transfer function autoregressive models. Behav. Res. 48: 783–802.

Donaldson, W.E., R.T. Cooney and J.R. Hilsinger. 1981. Growth, age and size at maturity of Tanner crab, *Chionoecetes bairdi* M. J. Rathbun, in the northern Gulf of Alaska (Decapoda, Brachyura). Crustaceana 40(3): 286–302.

Echave, K.B., 2017. First results of the tagging of shortspine thornyhead, *Sebastolobus alascanus*, in Alaska. Fish. Res. 195: 46–51.

Goethel, D. R., D. H. Hanselman, C. J. Rodgveller, K. H. Fenske, S. K. Shotwell, K. B. Echave, P. W. Malecha, K. A. Siwicke, and C. R. Lunsford. 2020. Assessment of the Sablefish Stock in Alaska. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 257 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/sablefish.pdf

Kastelle, C., T. Helser, T. TenBrink, C. Hutchinson, B. Goetz, C. Gburski, and I. Benson. 2020. Age validation of four rockfishes (genera *Sebastes* and *Sebastolobus*) with bomb-produced radiocarbon. Mar. Freshwater Res. 71(10): 1355–1366.

Kline, D.E. 1996. Radiochemical Age Verification for Two Deep-sea Rockfishes: *Sebastolobus altivelis* and *S. alascanus*. M.S. Thesis, Moss Landing Marine Laboratories, San Jose State University, CA, 124 pp.

Love, M. 2002 Sebastes borealis, p. 136-137. In M. S. Love, M. Yoklavich, and L. Thorsteinson, The rockfishes of the northeast Pacific. Univ. California Press.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. M.S. thesis, University of Washington, Seattle. 76 pp.

Munk, K. M. 2001. Maximum ages of groundfishes in waters off Alaska and British Columbia and considerations of age determination. AK Fish. Res. Bul. 8(1): 12–21

Murphy, J.T. 2020. Climate change, interspecific competition, and poleward vs. depth distribution shifts: Spatial analyses of the eastern Bering Sea snow and Tanner crab (*Chionoecetes opilio* and *C. bairdi*). Fish. Res. 223: 105417.

Murphy, J.T. 2021. Temporal and spatial variability in size-at maturity fir the eastern Bering Sea snow and Tanner crab (*Chionoecetes opilio* and *C. bairdi*). Fish. Res. 234: 105761.

NPFMC. 2021. Stock Assessment and Fishery Evaluation Report for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands Regions 2021 Final Crab SAFE. North Pacific Fishery Management Council 1007 West Third, Suite 400 Anchorage, AK 99501-2252. Available online: https://www.npfmc.org/safe-stock-assessment-and-fishery-evaluation-reports/.

Parada, C, Armstrong, DA, Ernst, B, Hinckley, S, Orensanz, JM. 2010. Spatial dynamics of snow crab in the eastern Bering Sea–Putting together the pieces of the puzzle. Bul. Mar. Sci. 86(2): 413–437.

Pearson, K.E., and D.R. Gunderson, 2003. Reproductive biology and ecology of shortspine thornyhead rockfish (*Sebastolobus alascanus*) and longspine thornyhead rockfish (*S. altivelis*) from the northeastern Pacific Ocean. Environ. Biol. Fishes 67: 11–136.

Punt, A.E., C.S. Szuwalski, and W. Stockhausen. 2014. An evaluation of stock–recruitment proxies and environmental change points for implementing the US Sustainable Fisheries Act. Fish. Res. 157: 28–40.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Shotwell, S. K., I.B. Spies, L. Britt, M. Bryan, D. H. Hanselman, D. G. Nichol, J. Hoff, W. Palsson, T. K. Wilderbuer, and S. Zador. 2020a. Assessment of the arrowtooth flounder stock in the Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific

Fishery Management Council, Anchorage. 88 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIatf.pdf.
Shotwell, S. K., I. B. Spies, K. Echave, I. Ortiz, J. Sullivan, P. D. Spencer, and W. Palsson. 2020b. Assessment of the shortraker rockfish stock in the Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Mngt. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. 40 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIshortraker.pdf.
Smeltz, T. S., B. P. Harris, J. V. Olson, and S. A. Sethi. 2019. A seascape-scale habitat model to support management of fishing impacts on benthic ecosystems. Can. J. Fish. Aquat. Sci. 76(10): 1836–1844.
Spencer, P. D., and J. N. Ianelli. 2020. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 83 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIpop.pdf.
Spencer, P. D., and J. N. Ianelli. 2021. Assessment of the Northern Rockfish stock in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 90 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2021/BSAInork.pdf.
Spencer, P. D., J. N. Ianelli, and W. A. Palsson. 2020. Assessment of Blackspotted and Rougheye Rockfish stock complex in the Bering Sea/Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage. 102 p. Available online: https://apps-afsc.fisheries.noaa.gov/refm/docs/2020/BSAIrougheye.pdf.
Zacher, L. S., J. I. Richar, and R. J. Foy. 2020. The 2019 eastern and northern Bering Sea continental shelf trawl surveys: Results for commercial crab species. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-400, 234 p. Available online: https://repository.library.noaa.gov/view/noaa/22919.