Supplemental Analysis for the species distribution model ensemble EFH maps for the 2022 5-year Review

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Abstract: This Discussion Paper and supporting documents present an update to the information that NMFS is developing under EFH component 1, species distribution model (SDM) ensemble-based EFH maps, for the 2022 5-year Review. 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 EFH components as warranted based on available information (50 CFR 600.815(a)(10)). For component 1, FMPs are required to describe and identify EFH in text that clearly states the habitats determined to be EFH for each life stage of the managed species and to include maps that display the geographic locations of EFH (50 CFR 600.815(a)(1)). The requirements for EFH component 1 are that some or all portions of the geographic range of the species are mapped (50 CFR 600.815(a)(1)(iii)(1)).

SDMs were used to map EFH component 1 in the 2017 EFH 5-year Review. A revised SDM ensemble EFH mapping approach was developed for the 2022 EFH 5-year Review. The new set of EFH component 1 maps include the summer distribution of 32 North Pacific groundfish species in the eastern Bering Sea (EBS), 25 in the Aleutian Islands (AI), and 42 in the Gulf of Alaska across up to three life stages. In addition, EFH is described and mapped for four crabs in the EBS, two crabs in the AI, and octopus in all three regions. The 2022 SDM ensemble EFH mapping approach is a foundational improvement over the single SDM method of 2017. In particular, analysts identified that certain SDMs tend to under or over predict area occupied. The SDM ensemble helps mitigate that bias and provides a universal SDM application across multiple FMPs that can be easily expanded to consider additional constituent models in the future. Moving from using single SDMs to SDM ensembles (and other important methods advancements in 2022) should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping, and improve our ability to identify events in shifting species distributions due to climate change or other impacts to habitat.

The SSC reviewed the new set of EFH component 1 maps in February, 2022. Overall, the SSC noted that a large majority of the new EFH maps reflect the best available science for characterizing EFH component 1. Additionally, the SSC requested clarification for some of the new information provided for EFH component 1, including for a subset of species/region combinations (N = 34) where reviewing stock authors reported concerns and future recommendations. Detailed in this document are updates made to the SDM ensembles, EFH maps, reporting, and knowledge gained from stock authors based on SSC recommendations from the February, 2022 review. Analysts provide the SSC with a description of the main categories of stock author concern, how we addressed those concerns, and recommendations for continuing to improve the EFH maps where possible for future iterations. EFH Reviews are an iterative process by design, creating opportunity for incremental and continual improvements over time.

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EXECUTIVE SUMMARY

The objective of an essential fish habitat (EFH) 5-year Review is to review the ten EFH components of Fishery Management Plans (FMPs) and revise or amend EFH components as warranted based on available information (50 CFR 600.815(a)(10)). For component 1, FMPs are required to describe and identify EFH in text that clearly states the habitats determined to be EFH for each life stage of the managed species and to include maps that display the geographic locations of EFH (50 CFR 600.815(a)(1)). **The requirements for EFH component 1 are that some or all portions of the geographic range of the species are mapped (50 CFR 600.815(a)(1)(iii)(1)). These mapping requirements have been comprehensively met for the new summer distribution species distribution model (SDM) ensemble EFH maps.** NMFS recommends that the complete set of new summer distribution SDM ensemble EFH maps represents the best available science for mapping EFH for these species life stages at this time and provides a substantial improvement over the 2017 summer distribution SDM EFH maps[6]. **Opportunity for continued improvement of EFH component 1 mapping is possible through research leading up to a future EFH 5-year Review; these Reviews by design are an iterative process occurring at least every five years.**

Each North Pacific Fishery Management Council FMP contains EFH information in the appendices**—**

- Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area (BSAI FMP), Appendix D Life History Features and Habitat Requirements of Fishery Management Plan Species, Appendix E Maps of Essential Fish Habitat.
- Fishery Management Plan for Groundfish of the Gulf of Alaska (GOA FMP), Appendix D Life History Features and Habitat Requirements of Fishery Management Plan Species, Appendix E Maps of Essential Fish Habitat.
- Fishery Management Plan for Bering Sea/ Aleutian Islands King and Tanner Crabs (Crab FMP), Appendix D.3: Essential Fish Habitat and Habitat Areas of Particular Concern.

In addition to the summer distribution EFH component 1 maps from the 2017 EFH 5-year Review, each FMP contains EFH maps for fall, winter, and spring as available. EFH mapping efforts for the 2022 5-year Review did not revise those maps and they will remain in the FMPs**—**

- The focus for EFH component 1 in the 2022 5-year Review was to refine the 2017 SDM approach to mapping EFH to an SDM ensemble approach as a new foundation, which was applied to map EFH for the summer distribution of groundfishes and crabs using AFSC RACE-GAP summer bottom trawl survey data, including for additional species' life stages where possible and without an SDM EFH map in 2017 (Chapter 2).
- The SSC's 2017 approach to assess the effects of fishing on EFH (EFH component 2) focused on the EFH component 1 summer maps for adult life stages of groundfishes and crabs mapped using AFSC RACE-GAP summer bottom trawl survey data, which was extended for the 2022 EFH Review.
- EFH for groundfishes and crabs was mapped for the fall, winter, and spring seasons for the 2017 Review, using fishery observer data in presence-only MaxEnt SDMs. Additional research is required to develop methods to potentially improve the 2017 maps for other seasons (i.e., applying fishery dependent data in SDMs).

[6] Chapter 2 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

This Discussion Paper and attachments present an update to the information that NMFS is developing under EFH component 1, SDM ensemble-based EFH maps, for the 2022 5-year Review. This work is guided by the Alaska EFH Research Plan (Sigler et al. 2017). The SSC reviewed the new set of EFH component 1 maps in February, 2022. Overall, the SSC noted that a large majority of the new EFH maps reflect the best available science for characterizing EFH component 1. Additionally, the SSC recommended clarification for some of the new information provided for EFH component 1. Detailed in this document are updates made to the SDM ensembles (survey area offset correction), EFH maps, and reporting, and knowledge gained from stock authors based on SSC recommendations from the February, 2022 review. Analysts provide the SSC with a description of the main categories of stock author concern (add species data, life history, and ongoing data issues) and recommendations for continuing to improve the EFH maps where possible in future iterations. NMFS is grateful for the large amount of effort that the stock authors and other species experts brought to bear by request of the SSC to improve EFH component 1 in the iterative EFH 5-year Review process. We thank the SSC for their reviews and recommendations that have improved this work and the process. **At this meeting, we are seeking feedback from the SSC on the SDM ensemble re-run, revised reporting, EFH maps for data limited species, and future research recommendations from additional stock author feedback since February, 2022. The main components of this paper for this review are—**

- Survey effort area offset correction applied to the SDM ensembles (Chapter 4).
- Review of stock author concerns surrounding the summer distribution SDM ensemble EFH maps developed for EFH component 1 (descriptions and identification) and applied to the EFH component 2 fishing effects (FE) evaluation (Chapter 5 and summarized in Table 3).
- Incorporation of reviewer feedback into the current and future EFH 5-year Reviews (Chapters 2 and 5).

Detailed below are areas where NMFS made improvements to EFH component 1 since the February, 2022 SSC review—

- 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)). We provided information to more clearly identify those species life stages where stock authors have concerns that the EFH maps could be improved to more fully represent the distribution of the species. Table A1.1 is a summary table of SDM ensemble performance with references to species life stages where reviewing stock authors reported concerns and/or future recommendations to improve the EFH maps for those species in their 2021 review[7]. Table 3 lists the species where reviewing stock authors restated their concern in the FE assessment with a qualitative plain language score (low, medium, or high concern) based on SDM ensemble performance and EFH map concerns.
- To address data concerns at a higher level, analysts compiled a questionnaire, to gain insight into whether stock authors felt that the current data captured: survey reliability, seasonal representativeness, and spatial representativeness. Results of the questionnaire are reported in Chapter 5 and summarized in Table 3, and also described in the context of the 2022 FE evaluation[8].
- To better address concerns for a subset of species' SDM ensemble EFH maps, analysts continued conversation with stock authors to identify additional datasets that may be incorporated in future EFH component 1 mapping. This aims to satisfy the SSC recommendations for the inclusion of additional data sources to the extent possible at this time. Recommended data sources are

[7] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[8] Appendix 5 and section 4 in EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947

reported in Chapter 5, summarized in Table 3, and described in detail in the stock author FE assessments in Appendix 5 of the EFH Component 2 Fishing Effects Discussion Paper (September, 2022)[9].

- EFH analysts worked with the reviewing stock authors to add data caveat statements to the applicable species results chapters of the three regional EFH NOAA Technical Memoranda, communicating stock author recommendations to add data sources and/or additional life history information if possible to improve the spatial representativeness of the summer season EFH maps in future EFH mapping efforts for those species. These statements communicate uncertainties with plain language for this portion of the EFH maps and can be included in other EFH component 1 reporting for the 2022 5-year Review.
- While the addition of more species/life stage information is not possible at this time, analysts collaborated with stock authors to gain insight on data sources and research recommendations that could add value to the 2022 SDM ensemble EFH maps. This information was added to the Future Recommendations sections of the three regional EFH NOAA Technical Memoranda[10] and can be included in other EFH component 1 reporting for the 2022 5-year Review, including the forthcoming EFH Review Summary report and any FMP amendments if warranted as an outcome of the EFH Review. EFH Reviews are an iterative process by design, creating opportunity for incremental and continual improvements over time as new information and techniques become available.

EFH Component 1 Key Messages—

- This EFH review focused on improving the SDM methods for mapping EFH component 1. The SDM ensemble approach is a foundational improvement to the single SDM method of 2017. In particular, we identified that certain SDMs tend to under or over predict area occupied. The SDM ensemble helps mitigate that bias and provides a universal SDM application across multiple FMPs that can be easily expanded to consider additional constituent models in the future.
- Some of the revised EFH maps have smaller or larger EFH areas than the 2017 EFH maps that stakeholders and reviewers may have become accustomed to for their species of interest. Moving from using single SDMs to SDM ensembles should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping.
- The 2022 SDM ensemble EFH mapping approach has the potential to improve our ability to identify events in shifting species distributions due to climate change or other impacts to habitat, in particular when EFH is mapped over smaller time series (e.g., 5 year hindcasts) and with improved SDM forecasting methods (e.g., Rooper et al. 2021, Barnes et al. 2022).
- Research supporting a future EFH 5-year Review could develop methods if resources are available to add other data sources to the SDM ensembles for a subset of species life stages, where additional data would really add value to EFH maps.
- Habitat science is a critical element of ecosystem based fishery management (EBFM). The new EFH maps are an improved foundation to meet the EFH mandates. The underlying SDMs are an advancement of habitat science that can inform EBFM through several pathways (e.g., Goldstein et al. 2020, Rooper et al. 2021, Barnes et al. 2022, Shotwell et al. 2022).

[9] EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents 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

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1 INTRODUCTION

This Discussion Paper focuses on the application of the new summer distribution SDM ensemble EFH maps available for the 2022 5-year Review to:

1. Revise the EFH component 1 for groundfishes and crabs in the BSAI, GOA, and Crab FMPs; and
2. Assess the effects of fishing on EFH for the summer distribution of groundfishes and crabs in the Aleutian Islands (AI), eastern Bering Sea (EBS), and Gulf of Alaska (GOA) for EFH component 2.

In February 2022, the SSC reviewed the new set of summer distribution EFH component 1 maps that are based on SDM ensembles that NMFS developed and recommends for replacing the 2017 summer distribution EFH maps based on a single SDM. The EFH component 2 FE evaluation that launched in April 2022 applied the new SDM ensemble EFH maps for the summer distribution of adults (or all combined life stages) of groundfishes and crabs to the fishing effects model output based on the 2017 EFH 5-year Review approach[11] and carried forward for the 2022 EFH 5-year Review[12].

Based on the SSC's February 2022 request for more input from the stock authors who reported a concern for a subset of the SDM ensemble EFH maps in their 2021 review, EFH analysts continued conversations with stock authors. We provide the SSC with a description of the main categories of concern (add species data, life history, and ongoing data issues), how we have addressed these concerns now, how these concerns may be addressed if possible for a future EFH Review, and recommendations for proceeding in the 2022 EFH 5-year Review for EFH component 1.

In **Chapter 2** we provide an overview of the foundational SDM advancements and new EFH maps available for EFH component 1 in the 2022 5-year Review. **Chapter 3** is a summary of the iterative review process for the 2022 EFH 5-year Review, where stages of review to date have occurred for EFH component 1 (descriptions and maps) and EFH component 2 (fishing effects). **Chapter 4** describes updates to the SDM ensemble methods and results (error rerun), EFH maps, and reporting, following SSC review in February, 2022. **Chapter 5** addresses additional stock author input on the SDM EFH maps requested by the SSC in February, 2022 with recommendations for EFH component 1. **Chapter 5** also addresses the two species that exceeded the FE habitat disturbance threshold attributable to SDM changes.

2 NEW SDM ENSEMBLE EFH MAPS FOR THE 2022 REVIEW

The study *Advancing Model-Based Essential Fish Habitat Descriptions for North Pacific Species* by Ned Laman[9F13], Jodi Pirtle0[F14], Jeremy Harris11F[15], Margaret Siple[10], Chris Rooper[12F16], Tom Hurst13F[17], and Christina Conrath14F[18] was described in detail in the EFH Component 1 SDM EFH Discussion Paper for

[11] Methods to evaluate the effects of fishing on EFH proposal from the SSC subcommittee December, 2016 https://meetings.npfmc.org/CommentReview/EFHFishingEffectsProposedMethods.pdf
[12] EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
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SSC review in February, 2022[19]. This study (hereafter referred to as Laman et al. study) was funded by the Alaska EFH Research Plan (FY19-FY21) to refine the 2017 EFH 5-year Review SDM approach to mapping EFH for the summer distribution of groundfishes and crabs using AFSC RACE-GAP bottom trawl survey data to an SDM ensemble approach for the 2022 EFH 5-year Review as a new foundation to mapping EFH component 1, including for additional species' life stages where currently missing. This study is guided by the Alaska EFH Research Plan (Sigler et al. 2017) research priority 1 to characterize habitat utilization and productivity using the best available scientific information to accomplish the specific research objectives of the revised plan.

The Laman et al. study demonstrates a new SDM ensemble EFH approach for the 2022 EFH 5-year Review, where EFH is described and mapped for 32 North Pacific groundfish species in the EBS, 25 in the AI, 42 in the GOA across up to three life stages. In addition, EFH is described and mapped for four crabs in the EBS, two crabs in the AI, and octopus in all three regions. The ensembles describing and mapping EFH in this study advance EFH information levels and refine EFH area maps for North Pacific species' life stages from none to Level 1 and from none or Level 1 to Level 2. This study also applies habitat-related vital rates from other studies to the ensemble outcomes to describe and map EFH Level 3 for the first time for eight species. The EFH descriptions and maps from this study comprise the bulk of new EFH component 1 information available for the 2022 EFH 5-year Review and also support the EFH component 2 FE evaluation.

Our modeling strategy for this 5-year EFH Review has been to fit multiple habitat-based SDMs to fish and crab abundances, skill test among SDMs using the root-mean-square-error to indicate model performance (RMSE; Hastie et al. 2009), and incorporate the best performing models into an ensemble in R (R Core Team 2020). Ensemble models essentially average predictions across constituent models, making them more robust to overfitting and less sensitive to differences in predictive performance among constituents. For example, Rooper et al. (2017) found that ensembles performed better than the generalized linear or generalized additive models alone when predicting distributions of structure-forming invertebrates. **The SDM ensemble EFH mapping approach of the 2022 EFH 5-year Review provides a universal SDM application across multiple FMPs and can be easily expanded to consider additional constituent models in the future.**

The Laman et al. study's approach to using SDM ensembles for mapping EFH is described in detail and contrasted with the SDM EFH approach of the 2017 EFH 5-year Review in the Methods section and Table 1 of the EFH Component 1 SDM EFH Discussion Paper (January, 2022, and revised March, 2022)[20]. Highlights from our study approach are developing several data updates and modeling refinements, introducing EFH Level 3, and advancing EFH information levels—

- Expanding the SDM approach from the 2017 5-year EFH Review to include up to five constituent SDMs in an ensemble that provides a robust modeling framework for future EFH Reviews (three SDMs were applied in 2017 and a single SDM was selected *a priori* for each species' life stage based on prevalence in the bottom trawl surveys).
- Refining our methodology by modeling numerical abundance instead of 4th root transformed CPUE facilitated skill testing (lowest cross-validated root mean square error; RMSE) to identify the best fitting models for inclusion and weighting in the ensemble and improved stakeholder interpretability of model results (i.e., predicting numbers of animals instead of a heavily derived abundance index).

[19] EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[20] Methods section and Table 1 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

- Incorporating new sources of species response data for the settled early juvenile life stage of groundfishes in the GOA from nearshore areas not previously modeled demonstrated for the first time that we could evaluate EFH for this critical life stage.
- Updating habitat covariates applied as independent predictors in the ensembles provided the opportunity to expand our observed temperature data set with an additional five years of AFSC RACE-GAP summer trawl survey bottom temperature observations, include recently modeled bottom temperature data from the coastal GOA regional ocean modeling system 3 km grid (applied to early juvenile SDMs only), update the GOA bathymetry and seafloor slope covariates, include additional derived seafloor terrain metrics in all regions, develop and include a seafloor rockiness metric for the AI and GOA, and to incorporate the most recent substrate data in the Bering Sea.
- Enhancing existing data sets (both response and predictor variables) with the addition of five recent years of survey results from the AFSC RACE-GAP summer bottom trawl surveys (2015–2019) extended our temporal coverage in the EBS to 38 years (1982-2019), in the AI to 29 years (1991-2019), and to 27 years in the GOA (1993-2019).
- Updating length-based life stage definitions for North Pacific groundfish species in the SDM ensembles based on updated maturity schedules or life stages definitions documented in the recent scientific literature tailored our abundance predictions to the best available scientific information and increased the number of life stages we could model.
- Extending EFH to include settled early juvenile life stages allowed us to model this critical ontogenetic phase for North Pacific groundfish species in the EBS, AI, and GOA for the first time.

A total of 229 new and revised EFH descriptions and maps for the BSAI, GOA, and Crab FMPs are available for the 2022 EFH 5-year Review—

- New EFH Level 1 descriptions and maps for settled early juvenile life stages in the GOA FMP (11).
- New and revised EFH Level 2 descriptions and maps for the BSAI (115), GOA (76), and Crab (7) FMPs (200 total).
- New EFH Level 2 descriptions and maps for stock complexes as a proxy for member species where a model was not possible at this time for the BSAI (6) and GOA (4) FMPs (10 total).
- New EFH Level 3 descriptions and maps for settled early juvenile life stages for the BSAI (2) and GOA (6) FMPs (8 total).

In comparing the 2017 SDMs and 2022 ensembles, it is apparent that the type of model used in 2017 had a large effect on the performance metrics and calculated EFH areas[21]. In the majority of cases, the performance metrics from the 2022 ensembles demonstrated clear improvements over the 2017 SDMs. The 2022 ensemble showed improvements—

- Lowest cross-validated root mean square error (RMSE) in 88% of models.
- Spearman's correlation (ρ) in 69% of models.
- Area under the receiver operating characteristic curve (AUC) in 52% of models.
- Poisson deviance explained (PDE) in 99% of models.

[21] Results Synthesis (page 102) and Table A3.2 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

- In other cases, where clear improvement was not observed, the difference between the models was usually small, and in no instance was a decline observed across all metrics.
- Approximately 25% of ensembles in the present work predicted EFH areas larger by 100% or more; in almost all of these cases the 2017 SDM was hGAM.
- 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 MaxEnt model.

The SDM ensemble EFH mapping approach for the 2022 EFH 5-year Review provides several advantages. Certain classes of SDMs have tendencies to over- or under-predict distribution and abundance (i.e., MaxEnt and hGAM). Ensemble modeling essentially averages the predictions from multiple, best-performing constituent SDMs, which can provide abundance predictions that are more representative of habitat-related distribution and abundance than those produced by single SDMs in isolation. Due to the effect of moving from mapping EFH using single SDMs in 2017 to SDM ensembles in 2022, and barring large methods changes in future EFH mapping efforts, **we expect that changes in future EFH maps should be less attributable to the underlying mapping methods so that changes in species distribution due to the environment or other impacts may be more easily detected.**

In completing this body of work, and through the 2022 EFH 5-year Review process, we have identified refinements and recommendations that could be considered for future EFH 5-year Reviews. These recommendations are in three categories:

1. Prioritizing and improving EFH for select species (data and modeling);
2. Increasing the scope and applicability of the habitat science supporting EFH; and
3. Improving the EFH 5-year Review process and communication.

A Future Recommendations section is included in the EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022) and in each regional NOAA Technical Memorandum[22], which provides more detailed descriptions of the research and collaborative pathways the EFH component 1 analysts are recommending.

This body of work is a significant advancement of the SDM approach for mapping EFH in the BSAI and GOA compared to the methods used in the 2017 EFH 5-year Review. In the present 5-year Review, we advanced EFH descriptions and maps for many groundfish and crab species in the BSAI and GOA, including new and revised EFH Level 1 and 2, and for the first time EFH Level 3 information. The ensemble approach we applied here was an innovation over the 2017 EFH 5-year Review approach and, along with the other data and modeling refinements described, will provide a robust and flexible framework for the development of EFH descriptions and maps for future EFH 5-year Reviews. In addition, the ensembles described here provide valuable information that can be extended to stock assessment and other EBFM information needs in our region.

3 ITERATIVE REVIEW

Since the 2017 EFH 5-year Review, NMFS has worked to improve the EFH descriptions and maps, focusing on foundational SDM improvements and where possible mapping EFH for species without an EFH map in 2017. During the 2022 EFH 5-year Review process to date, the research contributing new information for EFH component 1 has been reviewed by the SSC, Ecosystem Committee (EC), Plan

[22] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents, including three NOAA Technical Memoranda in publication process https://meetings.npfmc.org/Meeting/Details/2947

Teams, stock authors, species experts, and other stakeholders (Figures 1–3). EFH analysts have incorporated feedback from each of these reviews into revisions to the new SDM ensemble methods, EFH maps, and EFH component 1 reporting available for the 2022 5-year Review. As some recommended improvements are not possible at this time without additional extensive research, input will inform priorities for the next iteration of EFH mapping, where continued incremental improvements will add value to EFH component 1. This section provides an overview of the stages of the iterative process by which NMFS and the Council have reviewed the EFH component 1 descriptions and maps for the 2022 EFH 5-year Review—

- NMFS and the Council launched the 2022 EFH 5-year Review in April 2019 with a presentation by NMFS to the Ecosystem Committee (EC) of the preliminary plan for review of the ten EFH components in the Council's FMPs (Figure 1).
- The SSC in June 2020 and a joint meeting of the Groundfish Plan Teams (JGPT) in September 2020 provided input to NMFS on proposed methods and planned research to support the new EFH component 1 information for the 2022 5-year Review[23].
- In January 2021, NMFS EFH component 1 analysts and senior stock assessment scientists convened a summit of stock authors to co-develop the process for the stock author review of EFH component 1, which was an innovation by NMFS of the 2022 EFH 5-year Review process.
- NMFS presented the 2022 EFH 5-year Review Plan to the SSC in April 2021, when EFH component 1 analysts responded to the SSC and Plan Team input received in 2020, by providing an update on methods and revised draft results examples. The 2022 5-year Review Plan was also presented to the Crab Plan Team (CPT) in May 2021, including draft SDM ensemble results for crabs.
- The stock author review of the draft SDM ensemble methods, results, EFH maps, and current EFH component 1 information in the FMPs occurred from May to September 1 2021. EFH analysts presented a response plan to address all reviewing stock author concerns to the extent possible at this time to JGPT in September 2021.
- Between September 2021 and January 2022, EFH component 1 analysts worked with reviewing stock authors to address their concerns, revised the draft methods, updated the results, and submitted three regional Draft NOAA Technical Memoranda to the NMFS publication process (Figure 2).
- Stock author review of the draft SDM ensemble methods, results, and EFH maps is discussed in detail in the Stock Author Review EFH Component 1 Report (December, 2021)[24]. EFH analysts presented a draft of this report and how we worked with stock authors SAs to address to the JGPT in November, 2021. The Plan Teams thanked the EFH analysts for all that they had done over the past several months to address the stock author concerns reported in their review of the draft SDM methods and results for EFH component 1.
- EFH analyst responses to extensive SSC and Plan Team input on EFH component 1 from June 2020 through November 2021 were provided in the EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022)[25].

[23] EFH Component 1 SDM EFH Discussion Paper and Presentation to SSC January, 2020 https://www.npfmc.org/efh-distribution/

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

[25] Appendix 1 Table A1.1 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

- EFH analysts presented the new draft EFH component 1 information available for the 2022 EFH 5-year Review to the CPT and EC in January, 2022 and to the SSC for review in February, 2022.
- In February 2022, SSC reviewed the revised SDM ensemble methods, updated draft results, and draft EFH maps, incorporating revisions from the stock author 2021 review addressing concerns to the extent possible at this time. We provided the SSC with the following documents for their review: three regional EFH draft NOAA Technical Memoranda, EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022)[26] summarizing the process and work to date, Stock Author Review of EFH Component 1 Report (December, 2021)[27], and other supporting materials.
- In October 2022, SSC will review an update to the EFH component 1 SDM ensemble EFH maps and how remaining stock author concerns have been addressed, and the EFH component 2 fishing effects (FE) model, results, and stock author FE assessment. Remaining stages of the 5-year Review will follow (TBD) (Figure 3).

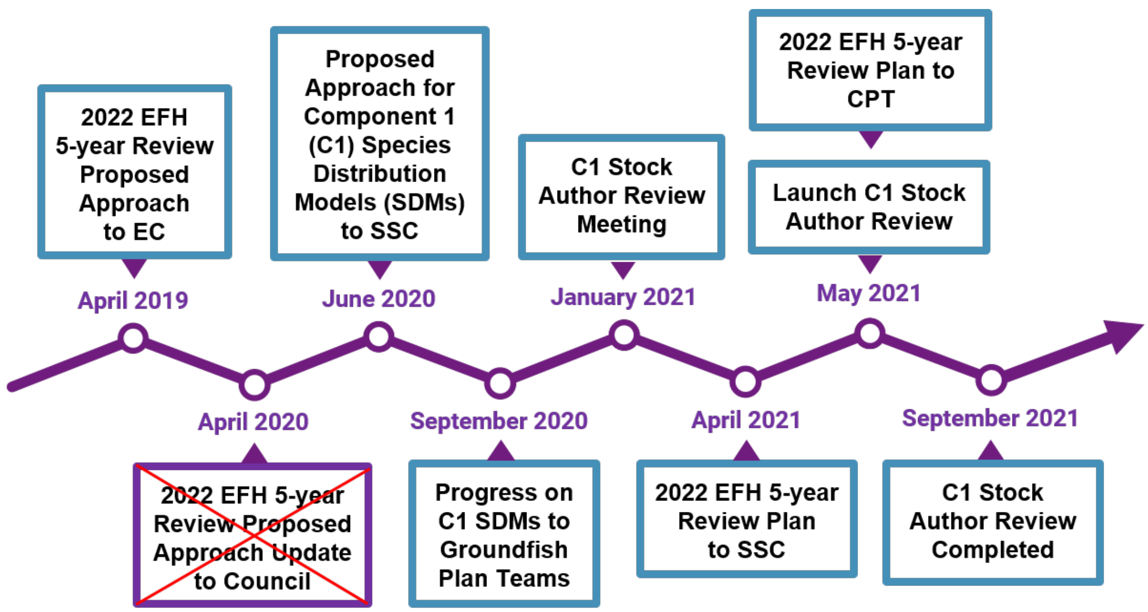


Figure 1. Iterative review process and timeline for the 2022 EFH 5-year Review, beginning with review of the 5-year Review plan in April 2019, and stepping through stages of review for EFH component 1 (C1) species distribution model (SDM) methods and results, through September 2021.

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

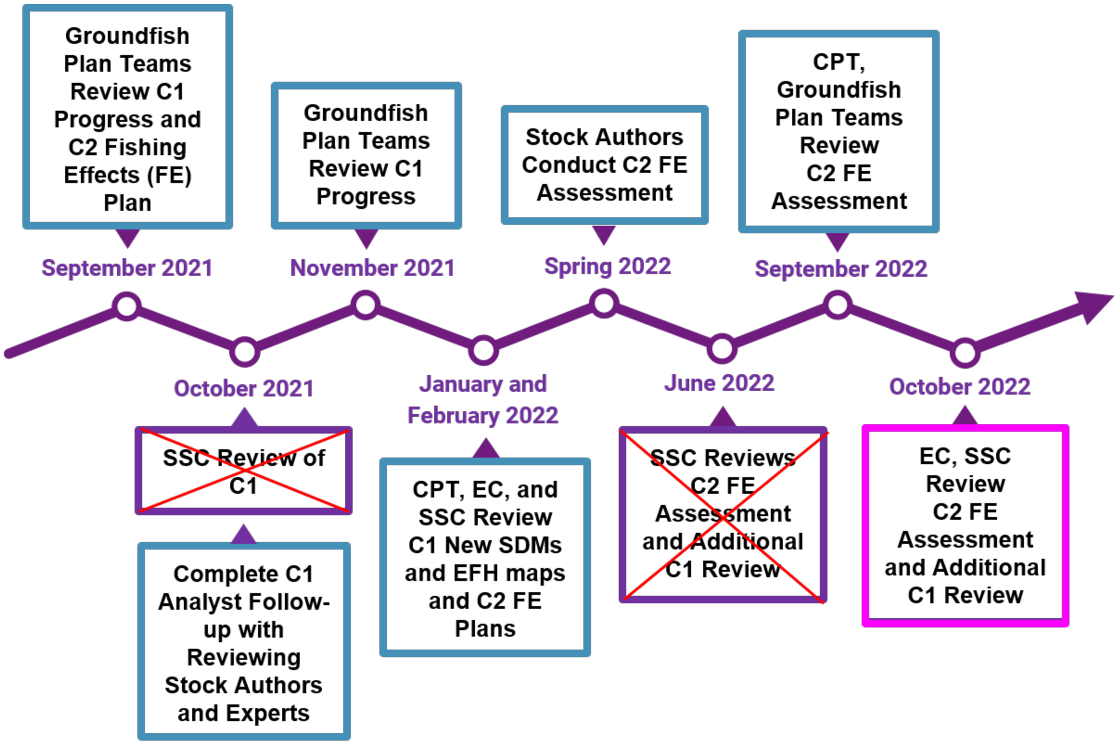


Figure 2. Iterative review process and timeline for the 2022 EFH 5-year Review, continuing through review stages for EFH component 1 (C1) species distribution model (SDM) methods and results and launching review of EFH component 2 (C2) fishing effects, through October 2022.

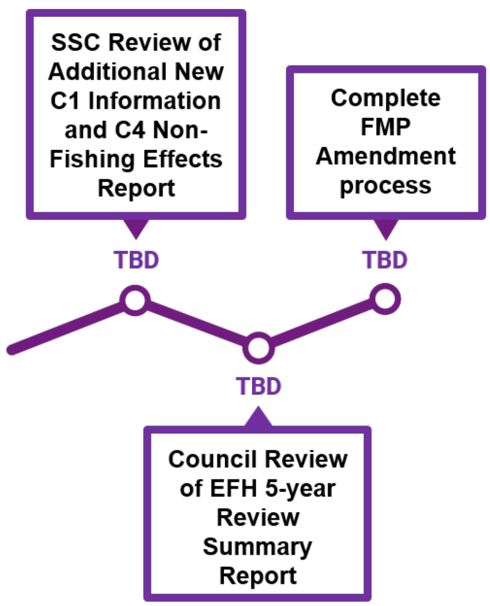


Figure 3. Following October 2022, SSC review will take place for remaining EFH C1 maps (Arctic FMP; and GOA FMP pelagic early life stages based on individual-based models). NMFS will then compile the EFH 5-year Review Summary Report with all proposed improvements to EFH, including the EFH component 4 (C4) non-fishing effects report, leading to Council review, and completing the FMP Amendment Process as warranted (timeline dates to be determined).

4 SDM EFH UPDATES AND PROGRESS SINCE FEBRUARY 2022

This chapter describes progress and updates to the SDM ensemble methods, results, EFH maps, and reporting following SSC review in February, 2022. We describe a comprehensive error correction to the SDMs and EFH maps, and progress on reporting and making the SDM code available to stakeholders.

4.1 Survey effort area offset correction

Regarding the correction, the following SDM ensemble EFH component 1 information was provided to the stock authors in April, 2022 to support their FE assessments:

- Explanation of the error correction to properly account for survey effort as an offset in the SDM ensembles and EFH maps.
- Metrics of species' life stage EFH maps where area was affected > 10% by this correction.
- The EFH Component 1 SDM EFH Discussion Paper and the collection of new ensemble SDM EFH maps (provided for February, 2022 SSC review)[28] that were revised in March, 2022.

4.1.1 The Reason for a Rerun

The full set of SDM ensembles were rerun in February, 2022 to produce a revised set of EFH maps. The reason for this update is that a bug was found in modeling code related to the handling of the survey area swept offset when packaging the code for public sharing on GitHub following the February SSC meeting. Specifically, the area was unintentionally used in its untransformed state, instead of being log transformed to match the link-function being used in the SDMs. While the effect of this error is minor in most cases, the decision was made to rerun all the SDM ensembles and produce updated maps so as to provide the best possible basis for the EFH component 1 descriptions and maps and their application to the EFH component 2 FE evaluation.

4.1.2 Statistical Background and Methods

It is generally assumed that the observed count of fish in a survey is proportional to fishing effort employed in that survey. While this is often represented by dividing the count by the effort (CPUE), it is more appropriate to model the rate of catch directly, e.g., to allow area-swept to have an interpretable, parsimonious, and "scale-free" relationship on sampling variance and encounter probabilities. The offset term allows count predictions from a Poisson model (or similar model) to be modeled directly:

Standard Poisson modeling count (Equation 4.1):

$$log(\lambda) = \beta_0 + BX$$

Poisson with Offset modeling count as a rate (Equation 4.2):

$$log(\lambda) = \beta_0 + BX + log(effort)$$

where λ is the observed count, β_0 is the intercept, B is the set of coefficients and X is a matrix of predictors. This formulation allows λ to be modeled as a count with an appropriate distribution (i.e., λ cannot be negative) while still accounting for unequal sampling effort. It also allows for predictions to be made for the count that would be observed under different levels of effort. In the maps for this project, we made predictions at the average survey effort to facilitate direct comparison to the data.

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

EFH is the area containing the top 95% of occupied habitat. To explore the magnitude of changes from this update, we compute the core EFH area (CEA), defined as the area containing the top 50% of occupied habitat, for the previous set of 2022 EFH maps and the new set of 2022 EFH maps with the correction applied. We compare the change in CEA using two metrics:

Mean Percent Difference (MPD) (Equation 4.3):

$$\text{MPD} = \text{mean}\left(\frac{new\ area - old\ area}{old\ area} \right)$$

Mean Absolute Percent Difference (MAP) (Equation 4.4):

$$\text{MAP} = \text{mean}\left(\frac{|\text{new area - old area}|}{\text{old area}} \right)$$

We next interpret the consequences of these changes in terms of MPD and MAP.

4.1.3 Magnitude of Change Results

Equations 4.1 and 4.2 demonstrate that the effort variable should be log transformed. Because of the bug, nominal effort was used, which would result in a weak partial adjustment for effort. However, because standardized effort was applied to the vast majority of survey tows for a region, the observed effects on EFH area were close to zero for most species life stages (Figure 1). In all regions, the MPD and MAP were below 5% (Table 1). The region with the largest number of species' life stage EFH map areas affected was the eastern Bering Sea. Many of the most affected species maps were rockfishes or skates (Table 2), which are primarily caught near the continental shelf edge and upper slope. The AFSC RACE-GAP Bering Sea slope summer bottom-trawl survey uses different bottom trawl gear than the Bering Sea continental shelf summer bottom trawl survey with and tends to exert less effort per tow (mean BS = 0.05 km^2; mean slope = 0.04 km^2). As such, the previous set of model runs did not properly account for that difference in effort.

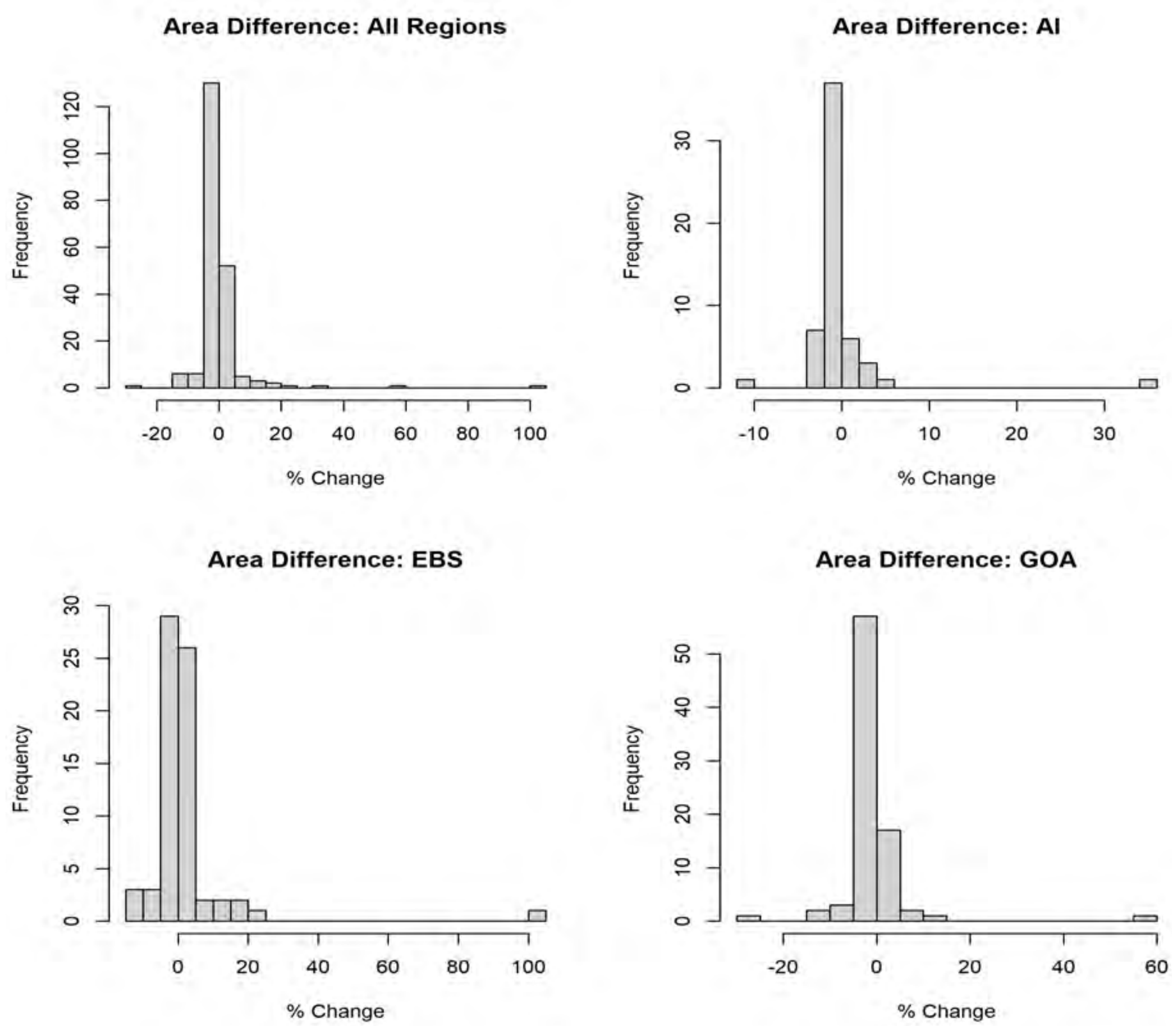
Table 1. A comparison of Mean Percent Difference (MPD; Equation 4.1) and Mean Absolute Percent Difference (MAP; Equation 4.2) for each region (Aleutian Islands (AI), eastern Bering Sea (EBS), and Gulf of Alaska (GOA)) and all regions, the count of species life stages with a > 10% change in core EFH area (CEA) resulting from the correction, and those species listed by common name.

Region	MPD	MAP	Count of species life stage maps with > 10% change in CEA	Species life stage combinations with > 10% change in CEA
AI	0.1 %	1.8 %	2 out of 56	adult Kamchatka Flounder; subadult dusky rockfish
EBS	2.2 %	4.6 %	9 out of 69	adult dover sole; adult northern rockfish; subadult and adult shortraker rockfish; adult whiteblotched skate; subadult big skate; subadult mud skate; subadult Pacific ocean perch; early juvenile yellowfin sole
GOA	0.1 %	2.5 %	5 out of 84	subadult and adult Alaska skate; adult sand sole; subadult Alaska plaice; subadult starry flounder
All	0.7 %	3.0 %	16 out of 211	See stocks listed by Region (Table 2)

Table 2. Details regarding the 16 species life stage combinations having a >10% change in core EFH area (CEA). Positive values represent an increase in the corresponding metric in the revised maps compared to the draft maps prior to the correction. Values are shown for the percent change in root mean square error (RMSE), and the change in the Spearman correlation coefficient (ρ), area under the receiver operating characteristic curve (AUC), and Poisson deviance explained (PDE).

Region	Species	Life Stage	% Diff RMSE	Δ ρ	Δ AUC	Δ PDE	CEA (km^2)	Revised CEA (km^2)	% Diff. CEA
AI	Kamchatka flounder	adult	-6.7	0.04	0	0.03	30,500	27,300	-10.5
AI	dusky rockfish	subadult	-1.4	0.05	0	-0.02	14,400	19,400	34.3
EBS	Dover sole	adult	-11.9	0.18	0	0.04	5,700	7,000	23.4
EBS	northern rockfish	adult	-1.3	0	0	0.01	49,300	44,100	-10.6
EBS	shortraker rockfish	adult	5.1	0.04	0	0	8,000	7,200	-10.5
EBS	whiteblotched skate	adult	0	0	0	-0.01	14,600	16,200	10.8
EBS	yellowfin sole	early juvenile	0.5	-0.01	-0.01	-0.01	238,800	265,300	11.1
EBS	big skate	subadult	0	0.01	0.01	0.01	3,000	3,500	19.6
EBS	mud skate	subadult	-1.9	0	0	0	11,000	12,900	17.1
EBS	Pacific ocean perch	subadult	0	-0.03	0	0	50,800	44,100	-13.1
EBS	shortraker rockfish	subadult	-1.1	-0.02	-0.01	-0.03	7,200	14,600	102.9
GOA	Alaska skate	adult	0	-0.06	-0.01	-0.02	7,000	6,200	13.7
GOA	sand sole	adult	3.3	-0.05	0	0.01	30,100	26,600	-11.7
GOA	Alaska plaice	subadult	-3.5	0.06	0	0.02	9,400	15,000	59.2
GOA	Alaska skate	subadult	0	0.01	0.01	0	10,900	7,700	-29.5
GOA	starry flounder	subadult	3.9	-0.03	0	-0.01	14,100	12,200	-13.8

Figure 4. The number of species life stages (y-axis) having a Mean Percent Difference (MPD; Equation 4.3) (x-axis) for each species life stage in all regions (top-left) or individual regions (Aleutian Islands (AI), eastern Bering Sea (EBS), Gulf of Alaska (GOA)), where a positive value indicates an increase in core EFH area (CEA).



4.2 SDM EFH Publications

4.2.1 NOAA Technical Memoranda

- Three NOAA Technical Memoranda were organized by the regions modeled by the Laman et al. study for the summer distribution of species life stages in the BSAI, GOA, and Crab FMPs. The individual documents describe region-specific methods, the full set of SDM ensemble results, and new and revised EFH maps showing the EFH area and percentile subareas (e.g., core EFH area (CEA) used in the 2022 FE evaluation), and future research and process recommendations.
- The three draft NOAA Technical Memoranda were provided to the SSC for review in February, 2022.
- Stock author review of these documents from May-September, 2021 was included by NMFS as part of the official internal review, as well as internal review by SDM experts and Division leadership.
- These documents were revised and resubmitted to the NMFS publication system in September 2022, after having incorporated input from additional reviews and updates from the survey area offset correction. These documents are part of the comprehensive EFH Component 1 package provided for the SSC's October, 2022 meeting[29].

4.2.2 Manuscript in Preparation

A manuscript by the Laman et al. study is undergoing NMFS internal review and will be submitted for publication to the journal Methods in Ecology and Evolution. The manuscript, *Ensemble models mitigate bias in area occupied from commonly used species distribution models by Harris, Pirtle, Laman, Siple, and Thorson,* is a helpful contribution to the rapidly developing field of SDMs with applications to EBFM.

4.2.3 SDM EFH R Package

It is a priority of NMFS to make available the SDM ensemble EFH code used to develop the new summer distribution EFH maps in the 2022 5-year Review so that our methods are transparent, repeatable, and available to all stakeholders. EFH analysts have developed the Alaska Groundfish Essential Fish Habitat repository that is available on GitHub: https://github.com/alaska-groundfish-efh. Updates will be forthcoming as we continue to finalize the R code (R Core Team 2020) and documentation.

5 ADDRESSING EFH COMPONENT 1 REVIEWS

The requirements for EFH component 1 are that some or all portions of the geographic range of the species are mapped (50 CFR 600.815(a)(1)(iii)(1)). These mapping requirements have been comprehensively met for the new SDM ensemble EFH maps, representing the upper 95% of the area of occupied habitat for the summer distribution of groundfishes and crabs in the BSAI, GOA, and Crab FMPs. The new summer distribution SDM ensemble EFH maps represent the best available science for mapping EFH for these species' life stages at this time and provides a substantial improvement over the 2017 summer distribution SDM EFH maps. **NMFS recommends that the complete set of new summer distribution SDM ensemble EFH maps advance for EFH component 1 in the 2022 5-year Review.** Chapter 2 of this document is a summary and highlights of the 2022 SDM ensemble EFH mapping

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

methods and results. The EFH component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022)[30] includes the complete methods and results (i.e., case studies, summary tables, and synthesis) and the three NOAA Technical Memoranda provide region specific methods, species results chapters, and future recommendations[31]. Improving EFH component 1 mapping is possible through research leading up to a future EFH 5-year Review; these Reviews are by design are an iterative process occurring at least every five years (50 CFR 600.815(a)(10)).

5.1 Stock Author Review of EFH Component 1

In May-September 2021, stock authors reviewed the new SDM ensemble EFH mapping methods and results, including a total of 229 new and revised EFH descriptions and maps for the BSAI, GOA, and Crab FMPs available for the 2022 EFH 5-year Review. For a subset of species (N = 34), stock authors provided a concern and/or recommendation regarding how the EFH map could be improved. **Following the stock author review, EFH analysts worked with individual stock authors in September–December 2021 to address concerns and incorporate their recommendations to the extent possible—**

- We removed EFH maps for three data limited species that did not have an EFH map in 2017 (Pacific sleeper shark, yellowtail rockfish, and darkblotched rockfish).
- We revised the SDM ensembles when the reviewer provided updated length-based life stage breaks (e.g., EBS Arrowtooth flounder).
- We revised the GOA Atka mackerel SDM ensemble to remove one constituent.
- We added data caveat statements and recommendations to the applicable species results chapters of the three regional EFH draft NOAA Technical Memoranda by the Laman et al. study to acknowledge stock author recommendations to add data sources and/or life history information if possible in future EFH mapping for those species and to communicate uncertainties surrounding those EFH maps in plain language.

The EFH component 1 materials provided to the SSC in February, 2022 reflected the outcomes of the EFH analysts working with the stock authors to address their concerns and recommendations as provided in their 2021 SDM EFH review.

The details of the stock author review process of EFH component 1 and EFH analyst responses to address concerns from this initial review are discussed in detail in the EFH Component 1 Stock Author Review Report (December, 2021)[32]. Chapters 2 and 3 of the stock author review report are relevant to inform understanding of the stock author EFH map concerns and future recommendations and how the EFH analysts worked with the stock authors to address concerns to the extent possible leading up to the February, 2022 SSC review. Table A1.1 is a summary of SDM ensemble performance and species life stages where reviewing stock authors provided a concern and/or future recommendation in their 2021 review to improve the EFH maps for those species.

In February, 2022, the SSC reviewed the new SDM ensemble EFH mapping methods and EFH component 1 maps. Overall, the SSC noted that a majority of the new and revised EFH maps reflect the best available science for characterizing EFH component 1. **The SSC also provided recommendations to clarify the new information provided for EFH component 1 and requested information to more**

[30] EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[31] EFH Component 1 SDM EFH Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[32] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

clearly identify those species where stock authors have concerns with the SDMs and EFH maps, which we provide in the following section.

5.2 Addressing Reviewer Concerns and Recommendations

To address SSC requests and to more clearly identify those species where stock authors have concerns with the SDMs and EFH maps, we compiled a questionnaire as part of the 2022 FE evaluation asking stock authors to restate their SDM EFH concerns and provide a qualitative plain language score of *low, medium, or high concern*. Table 3 lists the species where reviewing stock authors provided a concern in the FE assessment questionnaire based on the SDM ensemble EFH maps. Details of the stock author responses to the complete questionnaire are provided in the stock author FE assessment results for individual species in Appendix 5 of the EFH Component 2 FE Discussion Paper (September, 2022)[33]. It is important to note for reviewers that although the SDM EFH component 1 maps and EFH component 2 FE model results are developed through separate processes and currently by separate analytical teams (NMFS and Alaska Pacific University), they are combined to estimate the percent CEA disturbed by fishing and to complete the EFH component 2 FE evaluation.

To address the SSC recommendation to include additional data sources in the SDM ensemble EFH maps to the extent possible, we requested that stock authors indicate in the FE assessment questionnaire if additional summer species data are available and to list those sources (Table 3). While the addition of more species/life stage information is not possible at this time, analysts continued conversations with stock authors to gain insight on data sources and research recommendations that could add value to the SDM ensemble EFH maps for a subsequent EFH 5-year Review. EFH Reviews are an iterative process by design, creating opportunity for incremental and continued improvements over time to incorporate new information and techniques as they become available.

Stock authors provided SDM EFH map concerns and recommendations for 34 species/region combinations out of 103 evaluated (Table A1.1) in their responses to the FE assessment questionnaire Table 3. Reviewing stock author SDM EFH concerns and recommendations can be summarized as three primary response themes: *1) add species data; 2) life history considerations; and 3) ongoing (other) data issues*. **In the following sections, we review stock author concerns and recommendations under each theme and describe what analysts have done to address those concerns and recommendations for the 2022 EFH 5-year Review and future EFH Reviews.**

5.2.1 Add Species Data

The majority of the concerns and recommendations reported by stock authors in their 2021 SDM EFH review (Table A1.1) and in the 2022 FE assessment questionnaire were under the theme *add species data* (N = 24), where their qualitative plain language scores for two-thirds were *low concern*, one-third were *medium concern*, and none were *high concern* (Table 3). In two-thirds of the *add data* concerns, stock authors reported that additional summer species data were available that could be used to augment the AFSC RACE-GAP summer bottom trawl survey data in the SDM ensemble EFH maps.

5.2.1.1 Longline Survey Data

Stock authors reported that additional summer data for their species/regions were available from the longline surveys conducted by AFSC[34] and/or the International Pacific Halibut Commission (IPHC)[35] (N = 13) (Table 3). The 2022 SDM ensemble EFH maps for groundfishes and crabs were mapped to a maximum depth of 500 m in the AI and to 1000 m depth in the EBS and GOA based on available AFSC

[33] Appendix 5 in EFH Component 2 Fishing Effects Discussion Paper September, 2022 and supporting documents https://meetings.npfmc.org/Meeting/Details/2947
[34] NMFS AFSC longline survey https://www.fisheries.noaa.gov/resource/map/alaska-longline-survey-data-map
[35] IPHC longline survey https://iphc.int/management/fisheries

RACE-GAP summer bottom trawl survey species data. AFSC longline survey stations in the AI, EBS, and GOA sample depths from approximately 150–1000 m. **As an interim step to understand this issue better**, we created maps that overlay the longline survey station coverage[36] with the EFH maps to see the extent of potential gaps in the species distribution. Although we were not able to add longline survey data or other summer species data to the SDM ensembles at this time, in many cases the 2022 SDM ensemble EFH maps overlap or encompass the longline survey station coverage, including the upper percentiles of the predicted area of occupied habitat such as the core EFH area (CEA, upper 50% of EFH area used in the 2022 FE evaluation) and EFH hotspots (upper 25% of EFH area). As an example, we provide overlay maps of the AFSC longline survey historic haul locations (*without attribution to species data*) at stations along the continental shelf and slope in the AI, EBS, and GOA for species where the reviewing stock authors recommended that species data from this survey be included in future SDM ensemble EFH mapping in Appendix 2 (e.g., sablefish, Figures A2.1–6).

We provide an example in this section for EBS adult Greenland turbot (Figures 5–6), where the reviewing stock author reported *medium concern*, recommended that longline survey data be included to add value to the EFH map for this species at deeper depths, and expressed interest in collaborating to improve the EFH map for a future 5-year Review (Table 3). They stated, "The EBS slope bottom trawl survey has not been conducted since 2016. Given Greenland turbot 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." [37] EFH analysts agree that adding longline survey data could add value to the EFH maps for a subset of these species and are interested in working with stock authors and other longline survey data experts to develop a combined survey data approach if possible for a future EFH 5-year Review.

[36] The AFSC MESA program provided the file of historic haul locations at longline survey stations

[37] Appendix 5 (Greenland turbot section 5.1.6) in EFH Component 2 Fishing Effects Discussion Paper, September 2022 https://meetings.npfmc.org/Meeting/Details/2947

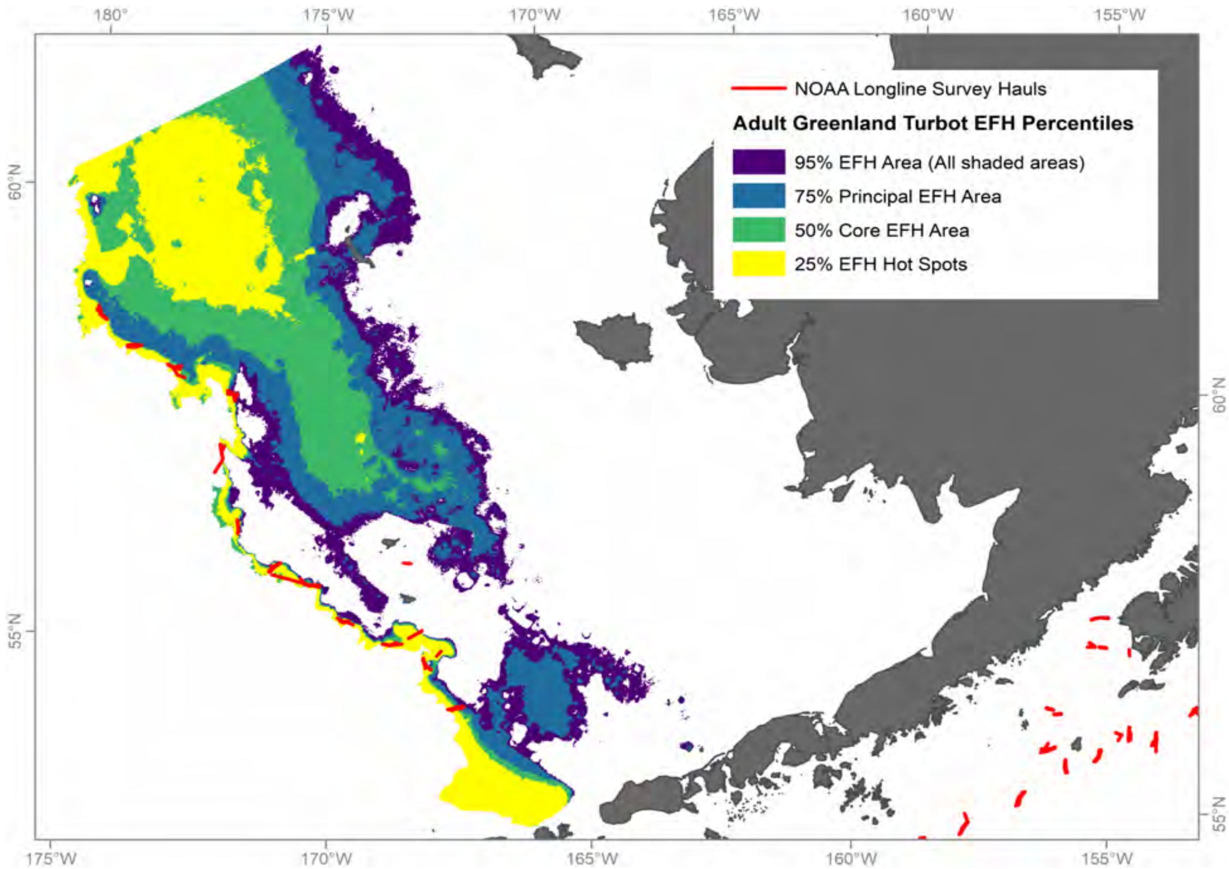


Figure 5. EFH map of adult Greenland turbot in the EBS with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to adult Greenland turbot catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult Greenland turbot distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1992–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

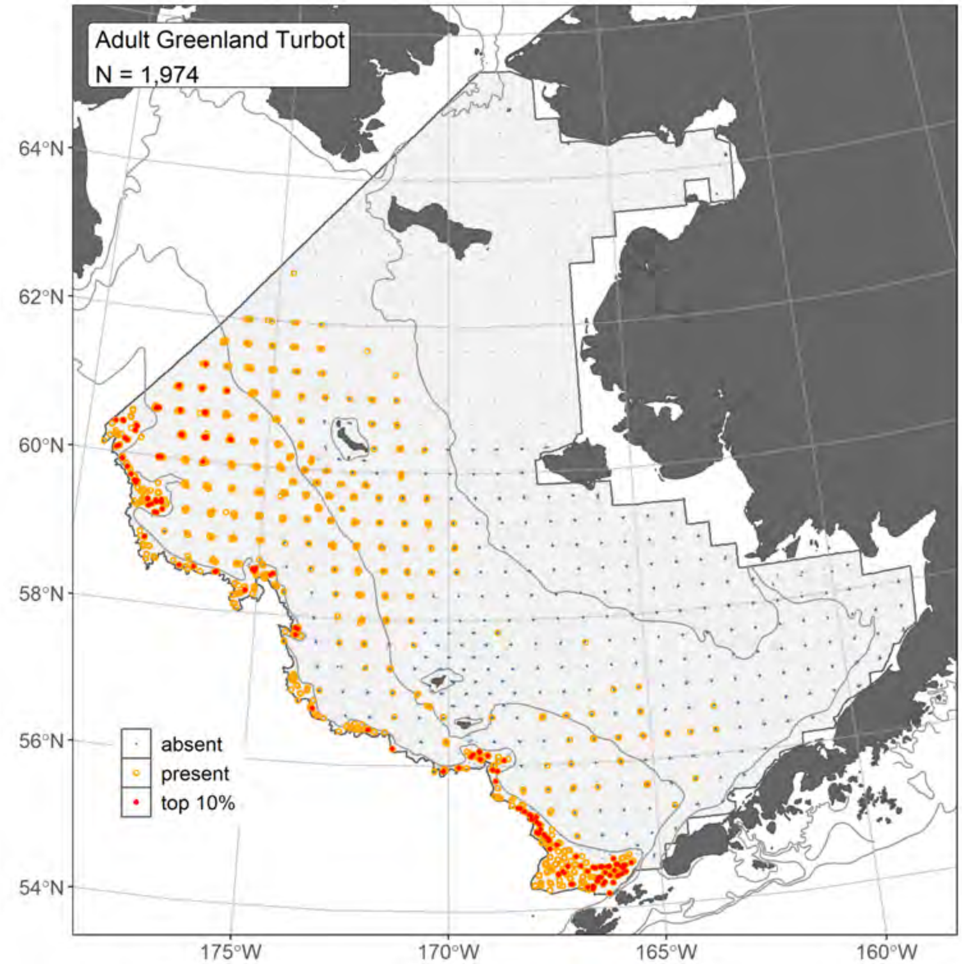


Figure 6. Distribution of adult Greenland turbot catches (N = 1,974) in 1982–2019 AFSC RACE-GAP summer bottom trawl surveys of the eastern Bering Sea Shelf, Slope, and Northern Bering Sea with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present. Each datum at a station represents a year of sampling at that location; multiple years are overplotted at each station.

5.2.1.2 Other Data Sources

Reviewing stock authors also reported that AFSC fishery observer data[38] may add value to the EFH maps for their species/regions (N = 7) (Table 3). Fishery observer data was used as a single data source in presence-only MaxEnt SDMs to map EFH for groundfishes and crabs in fall, winter, and spring seasons for the 2017 EFH 5-year Review (Laman et al. 2017, Simpson et al. 2017). The maps of other seasons that used fishery observer data will remain in the FMP and are not being revised with this action. Fishery observer data is also available for the summer season for some species (e.g., rockfishes). Fishery dependent observer data has not been used in SDMs requiring presence-absence data (i.e., GAMs), or combined in SDMs with fishery independent survey data to map EFH for Alaska species to date. Combining these two sources of data will require additional research to develop these analytical methods.

[38] NMFS AFSC Fisheries Monitoring and Analysis Division https://www.fisheries.noaa.gov/about/fisheries-monitoring-and-analysis

Other reviewing stock authors reported concern that their species associate with untrawlable seafloor habitats and were not able to identify additional summer data sources that could be used in EFH mapping (N = 17) (Table 3). Optical images from underwater surveys could be a source of species presence-absence data from untrawlable habitats (e.g., Winship et al. 2020, ICES 2021, Jones et al. 2021). Species presence-absence data would need to be available or developed from the image data holdings of AFSC (and/or external partners) to begin using data from images in a robust manner in the SDMs ensemble framework. There are ongoing efforts to begin establishing a linkage between camera-based abundance estimates over untrawlable ground and RACE-GAP bottom trawl survey trawl-based abundance estimates over trawlable ground. When available, this research could be integrated with other research supporting EFH component 1 mapping.

5.2.1.3 Summary of Addressing Add Species Data

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 the analytical methods to do this well. 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. Future efforts to meet this need would benefit greatly from collaboration between EFH analysts who are SDM, habitat, and survey data experts, and stock authors and/or other species and survey data experts. With respect to addressing reviewing stock author concerns and recommendations under the theme *add species data*:

- We advanced a research recommendation to develop methods to include additional species data sources in the SDM ensemble framework in future EFH mapping efforts (e.g., EBS EFH NOAA Technical Memorandum[39] and EFH Component 1 SDM EFH Discussion Paper January, 2022 and revised March, 2022[40]).
- We added data caveat statements to the applicable species results chapters in the three regional EFH NOAA Technical Memoranda by the Laman et al. study to acknowledge stock author recommendations to add data sources if possible in future EFH mapping for those species and to better communicate uncertainties in plain language surrounding that portion of the EFH maps;
    - e.g., EBS sablefish, "For these reasons, and because the AFSC longline surveys target adult sablefish . . . , we recommend that AFSC longline survey data be integrated with AFSC RACE-GAP summer bottom trawl survey data into future EFH reviews.", and "A request from the stock author review to include additional sources of data in future EFH mapping efforts for this species will be recommended as a focus of future research coming out of this 2022 EFH 5-year Review." (EBS EFH NOAA Technical Memorandum[41]).
- Other EFH component 1 reporting from the 2022 5-year Review could also include these data caveat statements and recommendations, including the forthcoming EFH Review Summary report and any FMP amendments if warranted as an outcome of the EFH Review.

[39] Future Recommendations (page 498) in EBS Laman Advancing Model-based EFH July, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[40] Section 3.5.1.1 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[41] EBS sablefish (page 283) in EBS Laman Advancing Model-based EFH July, 2022 https://meetings.npfmc.org/Meeting/Details/2947

5.2.2 Life History Considerations

5.2.2.1 Crab Life History

Reviewing stock authors reported concerns and recommendations surrounding life history information for crabs in their 2021 SDM EFH review (Table A1.1) and in the 2022 FE assessment questionnaire (Table 3). Currently, EFH is mapped for crabs in the AI and EBS by combining all life stages (benthic juveniles and adults) from the RACE-GAP summer bottom trawl survey data. Stock authors reporting *low concern* recommend added value in mapping crab EFH for individual life history stages and/or sexes (e.g., AI and EBS red king crab (RKC))[42]. Crab maturity data regularly collected on Bering Sea RACE-GAP bottom trawl surveys could inform life stage-specific SDMs for crabs in the next EFH 5-year Review. This effort should involve collaboration with scientists from the AFSC Kodiak Laboratory and the Alaska Department of Fish and Game (ADFG), both of which have crab size measurements and maturity data. These data could be used to apportion crab catches to mature and immature life stages and by sex to describe and map EFH.

Crab stock authors also emphasized the importance of mapping EFH and evaluating EFH fishing effects for crabs in other seasons (e.g., EBS snow crab)[42]. The new SDM ensemble EFH maps for the 2022 5-year Review were developed for the summer season and EFH fishing effects are currently evaluated using the SDM ensemble EFH maps. EFH was described and mapped for crabs in other seasons for the 2017 5-year Review[43], using fishery observer data in presence-only MaxEnt SDMs[44]. The maps of other seasons that used fishery observer data will remain in the FMP and are not being revised with this action. Fishery dependent observer data has not been used in SDMs requiring presence-absence data (i.e., GAMs), or combined in SDMs with fishery independent survey data to map EFH for Alaska species to date. Combining these two sources of data will require additional research to develop robust analytical methods to do this well. NMFS funded a study in FY22 (Alaska EFH Research Plan request for proposals) to develop SDMs for EBS RKC and snow crab life history stages in the summer, fall, and winter. The SDM maps and/or methods from this study could be incorporated in a future EFH 5-year Review.

The only *high concern* with respect to crab life history and the SDM EFH maps was reported for AI golden king crab (GKC). The reviewing stock author reported *high concern* with the FE model for this species and no SDM EFH concern. However, we reported their concern in Table 3 as they mentioned species data concerns relative to the life history of this species affecting data available for EFH mapping. This concern was also reported and discussed in the stock author SDM EFH review in 2021[45]. GKC are generally thought to associate with rugged and high relief habitats between 300–1,000 m depth and are targeted by the fishery using pot gear[46]. AI GKC are caught by the AFSC RACE-GAP summer bottom trawl survey to a maximum depth of 500 m and by ADFG pot surveys to a maximum depth of approximately 600 m. AI GKC EFH was mapped in 2017 and in 2022, using SDMs with AFSC RACE-GAP summer bottom trawl survey data and included as a case study example for SSC review in February, 2022[47]. EFH component 1 mapping requirements have been met for AI GKC (i.e., some or all portions of the geographic range of the species) (Figure 7). However, this species is an example of how the EFH

[42] Appendix 5 (RKC section 5.3.3 and Snow crab section 5.3.4) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[43] Crab FMP Amendment 49 https://media.fisheries.noaa.gov/BSAICrabFMPAmendment49.pdf
[44] Laman et al. 2017 EBS EFH NOAA Technical Memorandum https://apps-afsc.fisheries.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-357.pdf
[45] AI GKC (page 61) in Stock author EFH component 1 draft SDM Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[46] AI GKC Draft SAFE Report May 2022 https://meetings.npfmc.org/CommentReview/AIGKCSAFE2022.pdf
[47] AI GKC (section 3.3.2.3) in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

map and EFH component 2 FE evaluation may be improved by the addition of other species data sources to the SDM ensemble for a future EFH 5-year Review.

NMFS agrees that improving the SDM ensemble EFH maps and other EFH information for crabs is a priority. The only two HAPC considerations raised by reviewing stock authors in the 2022 FE evaluation were for crabs, including EBS blue king crab (BKC) EFH around St. Matthew Island and the Pribilof Islands and western AI RKC EFH[48], which would be further informed by crab EFH component 1 information for life history stages and other seasons. EFH mapping can also support EBFM for crabs beyond EFH (e.g., Shotwell et al. 2022). Success will depend on resources for additional research, data availability, and collaboration between EFH analysts and stock authors, species experts, and/or survey data and fishery experts. ADFG stock authors reported collaborative interest in future EFH mapping efforts for crabs in their 2022 FE assessment questionnaire and NMFS stock authors have indicated interest in other communications.

[48] Appendix 5 (EBS BKC section 5.3.1 and AI RKC section 5.3.3) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

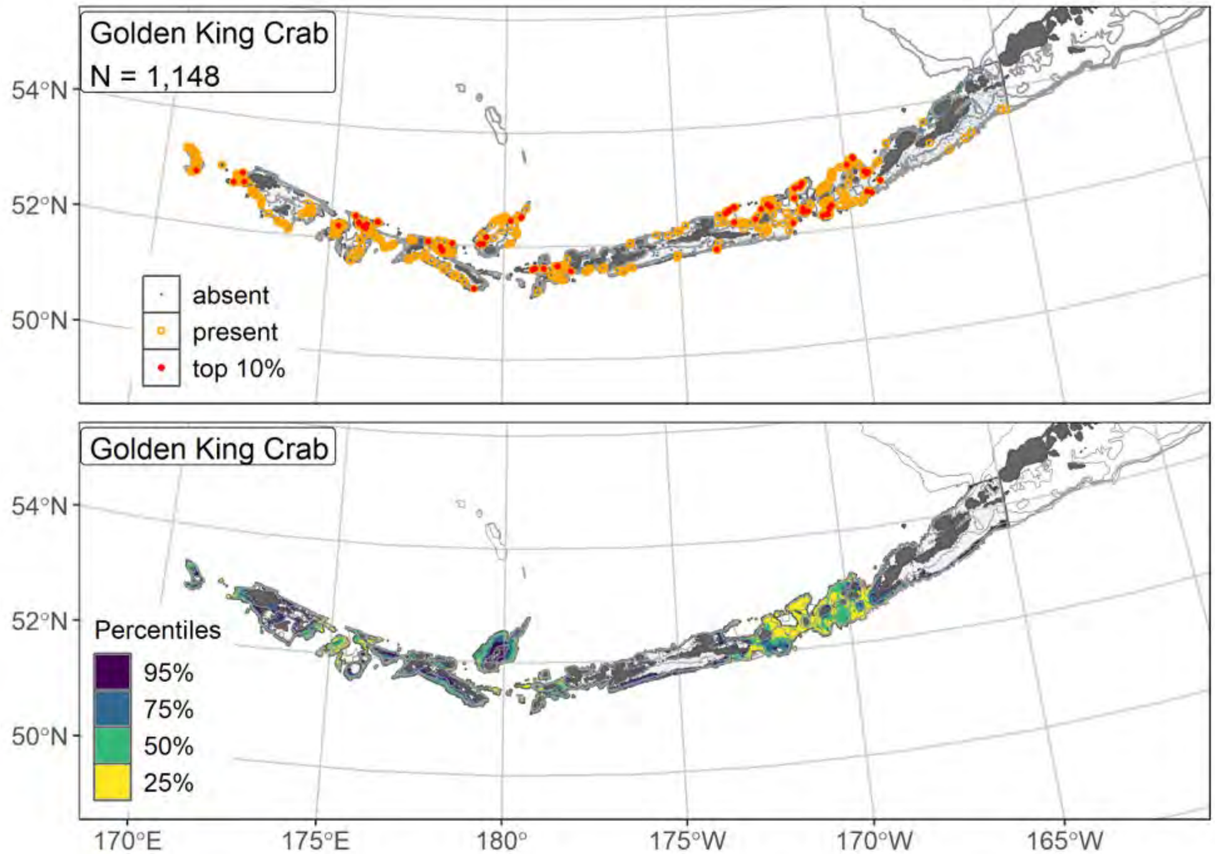


Figure 7. Distribution of golden king crab (GKC) catches (N = 1,148) in 1991–2019 AFSC RACE-GAP summer bottom trawl surveys of the AI with the 100 m, 300 m, and 500 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and small blue dots indicate absence, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station (upper panel). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to GKC distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys; within the EFH area map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area) (lower panel).

5.2.2.2 Flatfishes with Spatially Varying Growth

The reviewing stock author reported *high concern* for GOA rex sole SDM EFH information in their 2022 FE assessment (Table 3). Their explanation stated "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 and subadults by length categories miscategorizes some older rex sole as subadults, which might change the percentile rankings over space, or maybe it wouldn't"[49]. Continued conversation with flatfish stock authors regarding their FE assessments provided opportunity to discuss that rex sole, Dover sole, and other flatfishes exhibit spatially varying growth, which affects length at age observations across the regions due to sub-regional spatial growth rate variation, and so it is concerning to use one length-based life stage break for subadults and adults for the entire region. This presents a challenge when mapping

[49] Appendix 5 (GOA rex sole section 5.2.10) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

EFH, as EFH is mapped by species life stages for the area of the fishery management units corresponding to the FMPs and not sub-regionally (50 CFR 600.805(b)).

The flatfish stock authors are currently looking into flatfish spatially varying growth differences in the GOA, which should help inform future SDM EFH mapping efforts for these species. SDM EFH maps for subadult and adult rex and Dover soles were advanced for the 2017 EFH 5-year Review and SDM ensemble EFH maps were developed for the 2022 EFH Review using the best available length-based life stage breaks for these species at this time. If sub-regional life stage information is available, this could be incorporated into the regional SDM ensembles (e.g., based on catch location). EFH analysts will work with the stock authors to improve the EFH maps for flatfishes as more information becomes available.

5.2.2.3 Summary of Addressing Life History Considerations

EFH analysts are interested in working with the stock authors and other species experts to incorporate new research on crabs, flatfishes, and other species, including SDM methods development, field observations, and process studies of life history and ecological mechanisms to support future EFH 5-year Reviews. With respect to addressing reviewing stock author concerns and recommendations under the theme *life history considerations*:

- We advanced research recommendations to accomplish for future EFH 5-year Reviews, including map EFH for crabs by life history stages and improve the maps for other seasons, develop methods to include additional species data sources for crabs in the SDM ensembles, and update the life stage breaks when partitioning data for the SDMs ensembles for certain flatfishes when that information is available (e.g., EBS EFH NOAA Technical Memorandum[50] and EFH Component 1 SDM EFH Discussion Paper January, 2022 and revised March, 2022[51]).
- We added data caveat statements to the applicable species results chapters in the three regional EFH NOAA Technical Memoranda by the Laman et al. study to acknowledge stock author recommendations and to better communicate uncertainties in plain language surrounding that portion of the EFH maps;
    - o e.g., AI GKC, "The RACE-GAP summer bottom trawl surveys used trawl gear that is not ideally suited for surveying crab species, so this EFH description should be used with caution. However, the ensemble showed good performance across multiple metrics, so this map should be a useful resource until additional data sources can be incorporated into the EFH process." (AI EFH NOAA Technical Memorandum[52]).
    - o e.g., GOA rex sole, "A request from the stock author review to redefine the life stage breaks for this species based on sub-regional growth differences in future SDM ensemble EFH mapping efforts has been included as a future research recommendation from the 2022 EFH 5-year Review." (GOA EFH NOAA Technical Memorandum[53]).
- Other EFH component 1 reporting from the 2022 5-year Review could also include similar data caveat statements and recommendations, including the forthcoming EFH Review Summary report and any FMP amendments if warranted as an outcome of the EFH Review.

[50] Future Recommendations (page 498) in EBS Laman Advancing Model-based EFH July, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[51] Future Recommendations (section 3.5) in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[52] AI GKC (page 340) in AI Harris Advancing Model-based EFH August, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[53] GOA rex sole (page 85) in GOA Pirtle Advancing Model-based EFH September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

5.2.3 *Ongoing Data Issues*

Ongoing data issues exist for a subset of species that affected the 2022 SDM ensemble EFH maps. These ongoing data issues likely persisted for species with an SDM EFH map 2017. The reviewing stock authors reported these issues in their 2021 SDM EFH review (Table A1.1) and in completing the 2022 FE assessment questionnaire. These concerns are grouped under the theme *data other* in Table 3. These ongoing data issues were the primary concern for data limited species such as Atka mackerel and giant octopus (octopus are addressed in Section 5.3.3) and the reviewing stock author was not able to identify additional summer data sources to augment the RACE-GAP summer bottom trawl survey data in EFH mapping for these species. Ongoing data issues were an important concern for rockfishes in the GOA Other Rockfish complex slope sub-group and for spiny dogfish, however the reviewing stock author identified additional summer data sources for these species that could potentially be used to improve the EFH maps for these species.

Mapping requirements for EFH component 1 are some or all portions of the geographic range of the species (50 CFR 600.815(a)(1)(iii)(1)). Although ongoing data issues are present for some species, the 2022 SDM ensemble EFH maps provide the best available science for mapping EFH for these species at this time and represent an improvement over the 2017 SDM EFH maps. Improvements are clear in particular due to the 2022 SDM ensembles mitigating the influence of any one SDM method on the resulting EFH map. We are now aware of how the different SDM types applied to the single SDM mapping approach in 2017 affected the EFH component 1 maps, which would have also influenced the EFH component 2 FE evaluation of the 2017 EFH 5-year Review (Chapter 2). **Moving from using single SDMs to SDM ensembles should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping efforts and provides a universal SDM application across multiple FMPs that can be easily expanded to consider additional constituent models in the future**.

It is possible that the EFH maps may be improved for those species where additional data sources are available if the methods can be developed to include those sources in the SDM ensembles (i.e., data from different surveys, different gear types, and fishery independent and dependent data), which is not computationally straightforward and requires additional research to develop robust quantitative methods. 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)). Success in further improving the SDM EFH maps for species with ongoing data issues depends on the availability of other high quality data sources, resources for additional research, and collaboration between EFH analysts and the stock authors, and/or other species experts, and survey and fishery data experts.

In all cases of species with ongoing data issues, the EFH component 1 materials provided to the SSC in February, 2022 reflected the outcomes of the EFH analysts working with the stock authors to address the concerns and recommendations reported in their 2021 SDM EFH review; record of that communication is available[54]. The SSC's February, 2022 request to more clearly identify those species where stock authors have concerns with the SDMs and EFH maps provided opportunity for continued conversation between EFH analysts and the reviewing stock authors to improve the SDM ensemble EFH maps, EFH component 1 reporting, and clarity on future SDM EFH mapping research needs for this subset of species (Table 3). In the following section, we discuss ongoing data issues and how we have addressed those in the 2022 EFH 5-year Review for Atka mackerel, the GOA Other Rockfish complex slope sub-group, and spiny dogfish in the GOA.

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

5.2.3.1 Atka mackerel

Atka mackerel EFH was mapped in the AI, EBS, and GOA in the 2017 EFH 5-year Review and new SDM ensemble EFH maps are available for the 2022 Review. The reviewing stock author reported SDM EFH map concerns in their 2021 SDM EFH review (Table A1.1) and in the 2022 FE assessment questionnaire (Table 3), including *low concern* (AI), *medium concern* (EBS), and *high concern* (GOA)[55], regarding ongoing data issues for this species. Overall, they commented "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." Despite these concerns, they completed Atka mackerel FE assessments for the 2022 FE evaluation—

- AI Atka mackerel **did not exceed** the threshold of ≥ 10% CEA disturbed in the FE analysis. The SA chose a *quantitative* FE assessment using the FE model and the 50% CEA and recommended **no further action**.
- EBS Atka mackerel **exceeded** the threshold of ≥ 10% CEA disturbed in the FE analysis in 2022 but not in 2017, because the 2017 SDM would have led to exceeding ≥10% CEA disturbed in November 2016 using the corrected 2022 FE model[56]; the SA chose a *quantitative* FE assessment using the FE model and 50% CEA and recommended **no further action**.
- GOA Atka mackerel **did not exceed** the threshold of ≥ 10% CEA disturbed in the FE analysis. The SA chose a *qualitative* FE assessment using other sources of information and recommended **no further action**.

We discuss ongoing data issues for Atka mackerel in the GOA because the stock author reported *high concern* for the SDM EFH map and chose a qualitative FE assessment, as they were not confident using the CEA from the GOA map to evaluate fishing effects to EFH for this species. Although they concluded no further action needed for EFH component 2, it is helpful to understand their concerns for the EFH component 1 SDM ensemble EFH maps in the context of the mapping methods and results. Their explanation for *high concern* was:

- "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.", and commenting further in their qualitative FE assessment,
- "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."

The reviewing stock author reported similar *species data concerns* for GOA Atka mackerel in their 2021 draft SDM EFH review[57]. EFH analysts worked with them following their review to understand and address these concerns. Analysts revised the SDM ensemble by removing the MaxEnt constituent that may have been overpredicting the area of occupied habitat in the eastern GOA, where

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[55] Appendix 5 (Atka mackerel sections 5.1.2 and 5.2.2) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

[56] Species with ≥ 10% CEA disturbed (section 4.3) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

[57] GOA Atka mackerel (page 35) in EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

hauls with positive catches were present, yet occurring infrequently from 1993–2019 (Figure 8). The 2022 CEA from the revised SDM ensemble EFH map is now centered on the main distribution of the RACE-GAP haul locations for Atka mackerel in the GOA (N = 700), including hauls in the top 10% of samples occurring east of Kodiak Island, and was used in the FE evaluation. The 2022 GOA adult Atka mackerel SDM ensemble had fair performance (RMSE = 143, ρ = 0.33, AUC = 0.85, and PDE = 0.35) and the 2017 GOA combined subadult and adult hGAM (N = 593) also had fair performance (RMSE = 168, ρ = 0.36, AUC = 0.85, and PDE = 0.22) (Table A1.1). Given that the stock author was not able to recommend additional summer data sources to augment the RACE-GAP summer bottom trawl survey data in EFH mapping for this species, it is likely that the ongoing issue of Atka mackerel data availability will persist.

Regarding the stock author's *concerns with the 2022 CEA* for GOA Atka mackerel (Figure 8, Table A1.1), 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. We took the time to explain these changes to the stock author. Approximately 25% of ensembles predicted EFH areas larger by 100% or more; in almost all of these cases the 2017 SDM was hGAM. 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 MaxEnt model (e.g., EBS Atka mackerel[58]). 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, and shifting from 4th root transformed CPUE in 2017 to the prediction of numerical abundance as the response variable in 2022 (i.e., predicting numbers of animals instead of a heavily derived abundance index). Mapping EFH using SDM ensembles rather than single SDMs helped mitigate the influence of any one SDM method on the EFH area and should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping, making it easier to detect changes in species distribution or habitat impacts.

The approach to mapping EFH using SDMs in the 2017 and 2022 5-year Reviews takes into account the long term time series of species habitat-related distribution and abundance (e.g., GOA 1993–2019). The stock author raised concern about the time series over which EFH is mapped for Atka mackerel. Future EFH mapping for 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 is designated and mapped for each FMP species (50 CFR 600.815(a)(1)(i)). Although ongoing data issues are present for Atka mackerel, the 2022 SDM ensemble EFH maps provide the best available science for mapping EFH for these species at this time. **NMFS recommends that the revised 2022 EFH component 1 map for Atka mackerel advances in the 2022 EFH Review.**

[58] Table A3.2 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

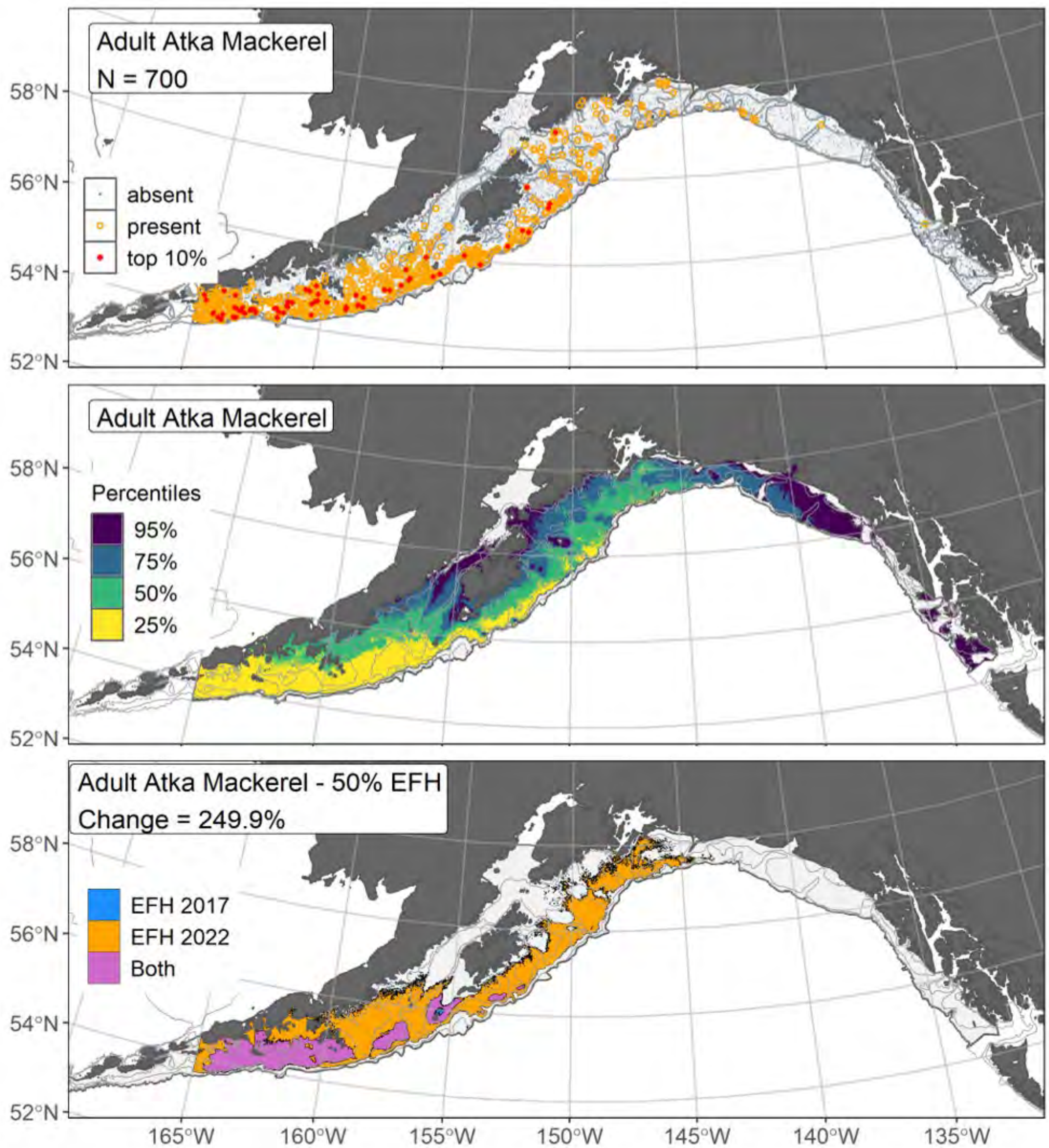

Figure 8. Distribution of adult Atka mackerel catches (N = 700) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and small blue dots indicate absence, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station (upper panel). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult Atka mackerel distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys; within the EFH area map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area (CEA)), and top 75% (principal EFH area) (middle panel). Change from 2017 to 2022 in GOA adult Atka mackerel CEA; colors represent CEA in 2017, 2022, or both (lower panel).

5.2.3.2 Gulf of Alaska Other Rockfish complex slope sub-group

In the GOA, the Other Rockfish (OR) stock complex includes the slope sub-group that is comprised of the following species: aurora, blackgill, darkblotched, greenstriped, harlequin, northern, pygmy, redbanded, redstripe, sharpchin, shortbelly, silvergray, splitnose, stripetail, vermilion, widow, yellowmouth, yellowtail rockfishes, boccacio, and chilipepper (Tribuzio et al. 2021). Northern rockfish are only included in this complex in the eastern GOA and their EFH is described and mapped separately from the GOA OR complex. 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)). Species including greenstriped, harlequin, pygmy, redbanded, redstripe, sharpchin, and silvergray rockfishes were common enough (N > 50) in GOA RACE-GAP summer bottom trawl survey catches (1993–2019) to support individual species life stage SDM ensembles of habitat-related abundance to map EFH (Table 4).

The reviewing stock author reported concerns regarding species data in the SDM ensemble EFH maps in their 2021 draft SDM EFH review (Table A1.1) and in the 2022 FE assessment questionnaire (Table 3). They ranked their concerns based on the three qualitative ranking options, as *low concern* for the sub-group and *low (5), medium (1), and high (1) concerns* for the seven member species with a 2022 SDM ensemble EFH map. They 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.” [59] Most of the slope sub-group species are at the northern extent of their range and/or associate with untrawlable habitats that are difficult to survey (Love et al. 2002, Mecklenberg 2002), lending to the challenges of mapping EFH for this subset of species.

All species in the slope sub-group with a new SDM ensemble EFH map in 2022 also had an SDM EFH map in 2017 with the exception of greenstriped rockfish (Table 4). Analysts worked with the stock author to address concerns following their review of the draft SDM EFH methods and results in 2021. Due to data limitations, analysts and the stock author agreed on not advancing the SDM ensemble EFH maps for two species (darkblotched and yellowtail rockfishes), although those species met the minimum sample size threshold and the SDMs did not raise red flags for the EFH analysts[60]. Analysts continued to work towards a solution for mapping EFH of data limited species to the extent possible at this time for the 2022 EFH 5-year Review.

As a new approach in 2022, NMFS provided maps for species complexes, including the GOA OR complex slope sub-group, to represent the EFH of member species where an SDM was not possible (e.g., due to low sample size and/or other reasons) (Figure 9)[61]. 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)). These **complex EFH maps** are an additive map of the area of occupied habitat from the combined individual species 2022 SDM ensemble EFH maps[62]. The complex EFH maps are intended for reporting with the other new EFH component 1 SDM ensemble EFH maps for member species of those complexes in the 2022 EFH 5-year Review, and were also provided to the stock authors as an option for completing their 2022 EFH component 2 FE assessments.

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[59] Appendix 5 (Other Rockfish complex slope sub-group section 5.2.9) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[60] GOA Other Rockfish slope sub-group (page 45-50) in EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[61] GOA OR complex slope sub-group (page 321) in GOA Pirtle Advancing Model-based EFH September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[62] Mapping EFH for species complexes (section 3.2.8.3) in EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised, March 2022) https://meetings.npfmc.org/Meeting/Details/2947

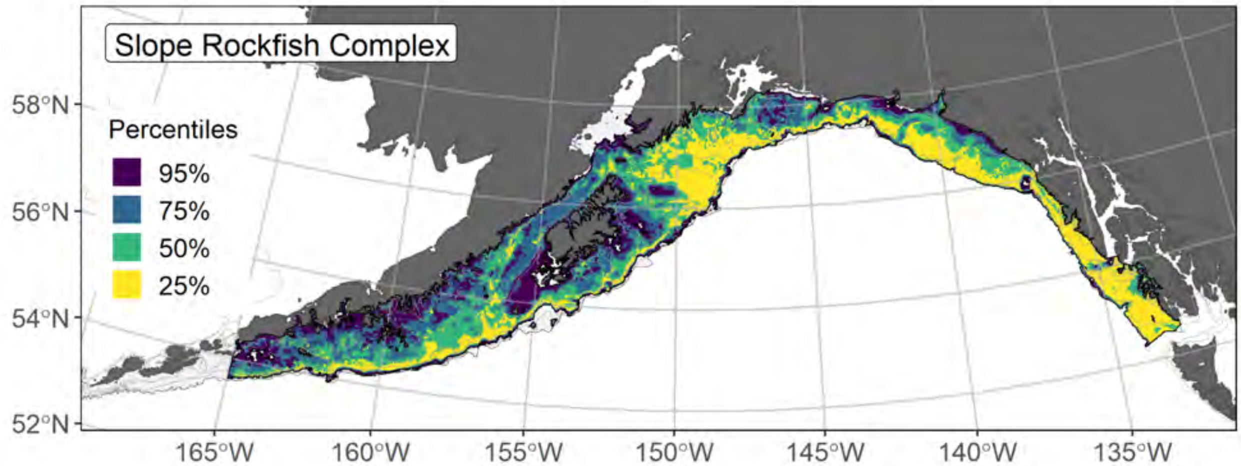

Figure 9. EFH (the area containing the top 95% of occupied habitat defined as encounter probabilities greater than 5%) of the Other Rockfish complex slope sub-group from the GOA in AFSC RACE-GAP summer bottom trawl surveys (1993–2019) with 100 m, 200 m, and 700 m isobaths indicated; within the EFH area map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area) of composite habitat-related, ensemble-predicted numerical abundance.

While the stock author identified additional summer data sources for the slope sub-group species, including longline survey data, and fishery-dependent observer data, to augment the RACE-GAP summer bottom trawl survey data in the SDM ensemble EFH maps (Table 3), adding other species data sources to the SDM ensembles will be challenging, as this is not computationally straightforward and requires additional research to develop methods to do this well. It is possible however, that a "data robust" approach could be developed specifically for the GOA OR complex slope sub-group for a future EFH 5-year Review, where additional data sources have high potential to add value to the EFH maps for those species. Collaboration between EFH analysts and the stock author and/or other species and survey/fishery data experts will help ensure that future EFH mapping efforts for the slope sub-group are successful in helping to close data gaps with respect to the EFH maps.

NMFS recommends the following approach for the GOA OR complex slope sub-group to meet the requirements of and advance EFH component 1 in the 2022 EFH 5-year Review:

- Use the new SDM ensemble EFH maps available for individual species for harlequin, greenstriped, pygmy, redbanded, redstripe, sharpchin, and silvergray rockfishes.
- Use the new composite SDM ensemble EFH map for the slope sub-group for darkblotched and yellowtail rockfishes, and other species in the GOA OR complex slope sub-group without an EFH map.

With this recommendation, all individual slope sub-group species EFH maps advancing for EFH component 1 would be based on SDM ensembles with good performance, with the exception of Pygmy rockfish where the SDM ensemble had fair performance, and none with poor performance (Table A1.1). While this may not be a permanent solution for all slope sub-group species, it is a solution to meet the EFH component 1 mapping requirements and include the new SDM ensemble EFH maps for species where available. Although ongoing data issues are present for the slope sub-group, the 2022 SDM ensemble EFH maps provide the best available science for mapping EFH at this time.

NMFS also offers a proposed approach for using a combination of the individual species CEAs and the complex map CEA for the **EFH component 2 FE evaluation** of the GOA OR complex slopesubgroup in the 2022 EFH 5-year Review[63]. As EFH component 1 and EFH component 2 have separate requirements, the recommended approaches for the 2022 EFH 5-year Review are different (i.e., use the complex EFH map more broadly for the FE evaluation of individual species, for greenstriped, pygmy, redbanded, and silvergray rockfishes, as the stock author chose a qualitative FE assessment and reported insufficient information to make the decision to elevate or not elevate for these species).

5.2.3.3 Spiny dogfish in the Gulf of Alaska

Spiny dogfish are a member of the shark complex (spiny dogfish, Pacific sleeper shark, salmon shark, and other/unidentified sharks) in the GOA (Tribuzio et al. 2020). Spiny dogfish EFH was not mapped in the 2017 EFH 5-year Review, nor was the EFH for any other shark complex species. SDM ensemble EFH maps were developed for subadult and adult spiny dogfish and combined subadult and adult Pacific sleeper shark. The stock author reported concerns over data limitations in the SDM EFH maps in their 2021 review of the draft SDM EFH methods and results[64]. Following that review, EFH analysts and the stock author agreed to remove the Pacific sleeper shark EFH map from consideration in the 2022 EFH 5-year Review.

The stock author noted *medium concern* in the 2022 FE assessment questionnaire and commented, “The adult [spiny dogfish] 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.”[65]

To address data limitation concerns for spiny dogfish in the GOA to the extent possible at this time, EFH analysts combined the subadult (N = 1,262) and adult (N = 127) life stages for this species into a revised SDM ensemble EFH map (Figure 10)[66]. EFH component 1 requires individual species maps for the fishery management unit 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)). The draft adult spiny dogfish EFH area was encompassed by the area of the upper percentiles of the draft subadult EFH area (EFH hot spots and CEA) and so it was plausible that combining the two life stages would be an improvement in mapping EFH for this species until other data sources can be combined in the SDM ensemble. This combined life stages map is intended to replace the individual draft subadult and adult spiny dogfish SDM ensemble EFH maps that the SSC reviewed in February, 2022 for the EFH 5-year Review. **NMFS recommends that the new combined life stages spiny dogfish EFH component 1 map advance for the 2022 EFH 5-year Review.** NMFS also offers a proposed approach that **EFH component 2 FE evaluation** uses the FE model and the 50% CEA from the new combined life stages spiny dogfish EFH map[67].

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[63] Section 4.2.1 in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[64] Spiny dogfish (page 85) in EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[65] Spiny dogfish (section 5.2.2) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[66] Spiny dogfish (page 405) in GOA Pirtle Advancing Model-based EFH September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[67] Section 4.2.3 in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

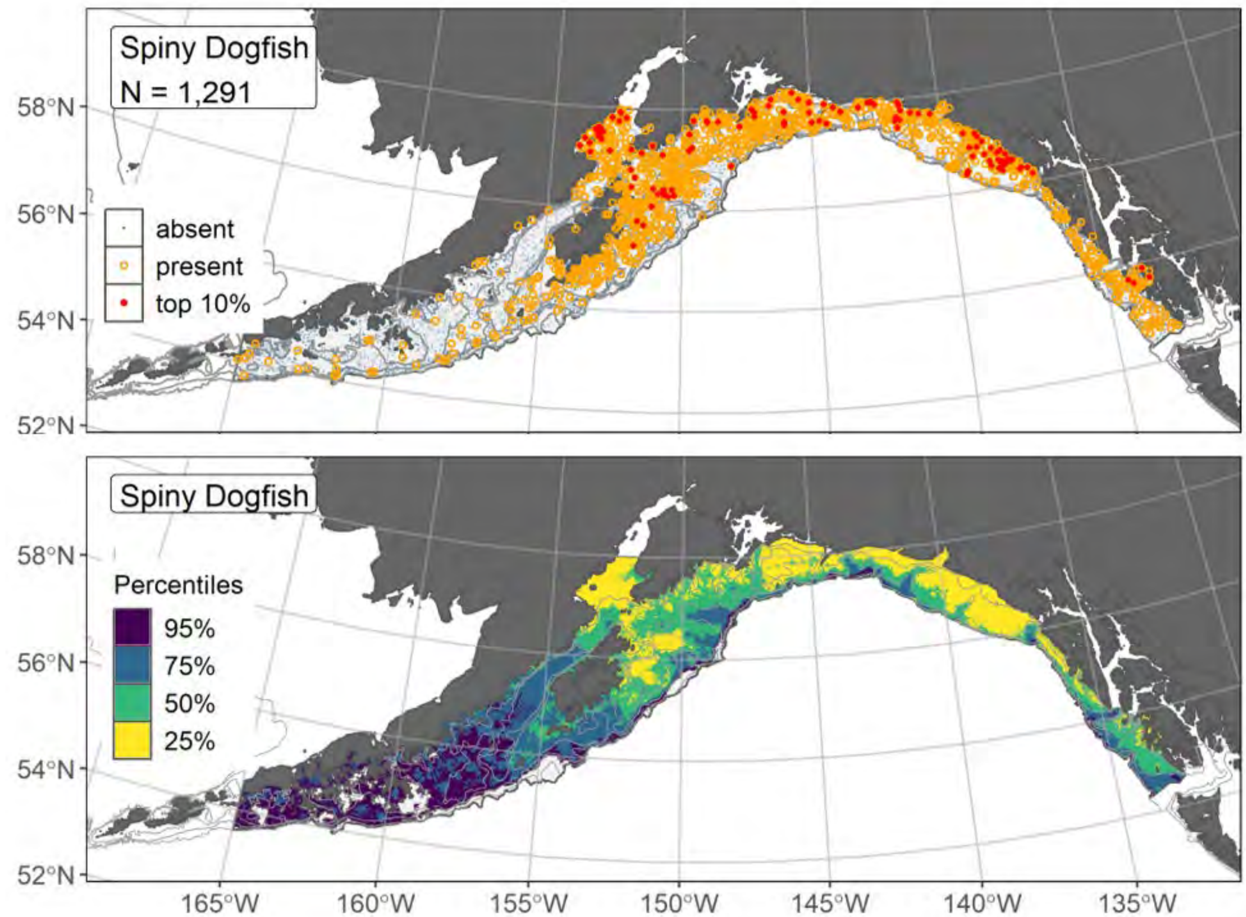

Figure 10. Distribution of spiny dogfish catches (N = 1,291) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station (upper panel). EFH is the top 95% of locations where the species' life stage is present, ordered by numerical abundance from a habitat-based ensemble fitted to spiny dogfish distribution and abundance from GOA RACE-GAP summer bottom trawl surveys; integral to the EFH map are the shapes of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area) of habitat-related, ensemble-predicted numerical abundance (lower panel).

5.2.3.4 Summary of Addressing Ongoing Data Issues

The SSC's February, 2022 request for more information on the subset of species where stock authors reported SDM EFH map concerns, created opportunity for the EFH analysts and stock authors to continue conversation towards deeper understanding of the concerns and recommendations and how to address them in the 2022 EFH 5-year Review and in future EFH Reviews. With respect to reviewing stock author concerns and recommendations under the theme *ongoing data issues*:

- We revised the GOA Atka mackerel SDM ensemble to remove one constituent and continued conversation with the stock author to help them understand the changes in the EFH map between 2017 and 2022.

- We removed the SDM ensemble EFH maps from consideration in the 2022 5-year Review for three data limited GOA OR complex slope sub-group species that did not have an EFH map in 2017 (yellowtail and darkblotched rockfishes).
- We advanced the composite SDM ensemble EFH map for the GOA OR complex slope sub-group to represent EFH for the species in the complex without an EFH map at this time.
- We removed the Pacific sleeper shark EFH map from consideration in the 2022 5-year Review; this species did not have an EFH map in 2017 and so it remains unmapped with respect to EFH component 1 requirements.
- We combined subadult and adult life stages of GOA spiny dogfish in the SDM ensemble to help mitigate the effects of species data limitations on the EFH map until additional summer data sources can be included in EFH mapping for this species; this species will be the only member of the shark complex with an EFH map if advanced in the 2022 EFH 5-year Review.
- We offered a future recommendation to develop methods to include additional data sources in the SDM ensembles in future EFH mapping efforts, in particular for data limited species where other high quality data sources are available to add value to the EFH map (e.g., EBS EFH NOAA Technical Memorandum[68] and EFH Component 1 SDM EFH Discussion Paper January, 2022 and revised March, 2022[69]).
- We added data caveat statements to the applicable species results chapters in the three regional EFH NOAA Technical Memoranda by the Laman et al. study to acknowledge stock author concerns and recommendations for species with ongoing data issues and to better communicate uncertainties in plain language surrounding this portion of the EFH maps.
    - e.g., GOA spiny dogfish, "As spiny dogfish are also caught by the longline surveys, including additional data from these surveys may be helpful in future SDM EFH mapping for this species.", "A request from the stock author review to include additional sources of data in future SDM ensemble EFH mapping efforts for this species will be included as a future research recommendation from the 2022 EFH 5-year Review." (GOA EFH NOAA Technical Memorandum)[70].
- Other EFH component 1 reporting from the 2022 5-year Review could also include these data caveat statements and recommendations, including the forthcoming EFH Review Summary report and any FMP amendments if warranted as an outcome of the EFH Review.

[68] Future Recommendations (page 498) in EBS Laman Advancing Model-based EFH July, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[69] Future Recommendations (section 3.5) in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[70] GOA spiny dogfish (page 405) in GOA Pirtle Advancing Model-based EFH September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

Table 3. SDM concerns reported as a qualitative score (low, medium, high) selected by individual reviewing stock authors (SAs) for their species in the 2022 EFH component 2 SA FE assessment questionnaire to clarify reviewer concerns and recommendations regarding the 2022 SDM ensemble EFH component 1 maps, as requested by the SSC in February, 2022. Concerns are listed by theme (add data, life history, data other). The theme *add data* has an added specification for data concerns regarding species in untrawlable habitats (UT). Stock authors listed additional summer species data sources if available for possible addition to future EFH mapping efforts and whether or not they are interested in either assisting with or informing future SDM development given their concerns and recommendations.

Region	Species	Concern qualitative score	Concern theme	Additional summer data available?	Additional summer data sources	Can assist with new models?
AI	Greenland turbot	Low	Add Data	Yes	longline surveys	Yes
EBS	Greenland turbot	Medium	Add Data	Yes	longline surveys	Yes
EBS	Kamchatka flounder	Low	Add Data	Yes	longline surveys	Yes
GOA	Shortspine thornyhead	Low	Add Data	Yes	longline surveys	Yes
AI	Sablefish	Medium	Add Data	Yes	longline surveys	No
EBS	Sablefish	Medium	Add Data	Yes	longline surveys	No
GOA	Sablefish	Medium	Add Data	Yes	longline surveys	No
GOA	Spiny dogfish	Medium	Add Data/Data Other	Yes	longline surveys, fishery observers	No
GOA	Shortraker rockfish	Low	Add Data (UT)	Yes	longline surveys	Yes
AI	Northern rockfish	Low	Add Data (UT)	No		
EBS	Northern rockfish	Low	Add Data (UT)	No		
GOA	Northern rockfish	Medium	Add Data (UT)	No		
AI	Pacific ocean perch	Low	Add Data (UT)	No		
EBS	Pacific ocean perch	Low	Add Data (UT)	No		
AI	Rougheye Blackspotted Rockfish Complex	Low	Add Data (UT)	No		
EBS	Rougheye Blackspotted Rockfish Complex	Low	Add Data (UT)	No		
GOA	Dusky rockfish	Medium	Add Data (UT)	No		
GOA	*Other Rockfish Complex Slope Sub-group*	Low	Add Data (UT)/Data Other	Yes	longline surveys, fishery observers	No
GOA	Greenstriped rockfish	Medium	Add Data (UT)/Data Other	Yes	longline surveys, fishery observers	No
GOA	Harlequin rockfish	Low	Add Data (UT)/Data Other	Yes	fishery observers	No
GOA	Pygmy rockfish	High	Data Other/Add Data (UT)	No		No
GOA	Redbanded rockfish	Low	Add Data (UT)/Data Other	Yes	longline surveys	No
GOA	Redstripe rockfish	Low	Add Data (UT)/Data Other	Yes	fishery observers	No
GOA	Sharpchin rockfish	Low	Add Data (UT)/Data Other	Yes	fishery observers	No
GOA	Silvergray rockfish	Low	Add Data (UT)/Data Other	Yes	longline surveys, fishery observers	No
EBS	Snow crab	Low	Life History	No		No
EBS	Red king crab	Low	Life History	No		
AI	Red king crab	Low	Life History/Data Other	No		Yes
AI	Golden king crab	High	Life History/Add Data (UT)	No		
GOA	Rex sole	High	Life History	No		
AI	Atka mackerel	Low	Data Other	No		
EBS	Atka mackerel	Medium	Data Other	No		
GOA	Atka mackerel	High	Data Other	No		
EBS	Giant octopus	Medium	Data Other	No		

Table 4. Gulf of Alaska (GOA) Other Rockfish complex slope sub-group haul records and EFH maps available or *explored for species members in the 2022 EFH 5-year Review. 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 proposed SDM methods for the 2022 5-year Review. Species with and without an SDM EFH map in 2022 and 2017 are noted. Species without an SDM EFH map in 2022, including those where an EFH map was not explored in 2022 due to data limitations, are accounted for by proxy in the 2022 GOA Other Rockfish complex slope sub-group map that is an additive map of the area of occupied habitat from the combined individual species 2022 SDM ensemble EFH maps for this sub-group.

Species	**Subadult Records (n)**	**Adult Records (n)**	**2022 EFH Map**	**2017 EFH Map**
Harlequin rockfish	102	514	Y	Y
Redbanded rockfish	829	321	Y	Y
Redstripe rockfish	133	234	Y	Y
Sharpchin rockfish	498	425	Y	Y
Silvergray rockfish	159	557	Y	Y
Pygmy rockfish	63 (N = 54 2017 SDM)		Y	Y
Greenstriped rockfish	–	120	Y	–
Darkblotched rockfish*	54	–	–	–
Yellowtail rockfish*	–	58	–	–
Total	1721	2234	–	–
Combined Total	3955		Y	–

5.3 Species EFH map changes attributed to exceeding the FE habitat disturbance threshold

The EFH Component 2 FE Discussion Paper (September, 2022) reports the methods and results of the 2022 FE model and the FE analysis of the percentage of the core EFH area (CEA) disturbed by fishing, which combines the FE model results with the SDM ensemble EFH map CEA (upper 50% of the EFH area). A total of 16 species in the EBS exceeded the SSC's threshold of ≥ 10% of the CEA disturbed in the 2022 EFH FE analysis. No species in the AI, EBS, or GOA regions met this threshold in the EFH FE analysis supporting the FE evaluation of the 2017 EFH 5-year Review. Following the 2017 EFH Review:

- The FE model error that was identified in 2018 was corrected with additional model updates for the 2022 FE evaluation.
- The 2017 SDM EFH mapping methods were revised to the 2022 SDM ensemble approach.
- Commercial fishing activities continued.

To identify whether or not the habitat disturbance threshold was met due to either changes in the FE model, changes in the SDM EFH map, or changes in fishing effort, an analysis compared the 2017 FE model and 2017 SDM EFH maps, 2022 corrected FE model and 2017 SDM EFH maps, and 2022 corrected FE model and 2022 SDM EFH maps and was reported in the FE assessment Discussion Paper (September, 2022)[71].

The results describe that the habitat disturbance threshold was exceeded due to FE model changes (9 species), fishing effort changes (3 species), and EFH map changes (2 species). The two species where this threshold was exceeded due to changes in the EFH maps between 2017 and 2022 were arrowtooth flounder (ATF) and giant octopus in the EBS. **We describe how the EFH maps changed between 2017 and 2022 for these species in the following sections.** Details of the SDM ensemble EFH mapping methods of the 2022 EFH 5-year Review are provided in the EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022)[72] and in the three regional EFH NOAA Technical Memoranda (e.g., EBS EFH NOAA Technical Memorandum[73]).

5.3.1 Arrowtooth flounder in the Bering Sea

The habitat disturbance threshold (≥ 10% CEA disturbed) was exceeded for EBS ATF in the FE analysis (10.3%) and was attributed to changes in the SDM EFH map CEA between 2017 and 2022. The CEA was reduced by 15.5% from the 2017 CEA (Figure 11). The 2017 SDM for adult ATF in the EBS was a generalized additive model (GAM). The 2022 SDM ensemble included the GAM_P, hGAM, paGAM, and MaxEnt models. Overall, the ensemble fit to observed adult ATF distribution and abundance was excellent and an improvement over the 2017 GAM[74]. The ensemble was excellent at predicting catches of high and low adult ATF abundance (ρ = 0.81), presence-absence (AUC = 0.96), and at explaining deviance (PDE = 0.64). Habitat-related ensemble-predicted numerical abundance of ATF life stages collected in RACE-GAP summer bottom trawl surveys of the EBS (1992–2019) was translated into EFH areas and additional habitat-related subareas (Figure 12). The EFH area of adult ATF was focused over the middle and outer shelf domains with core EFH area and EFH hot spots in deeper waters. EFH area was reduced on the continental shelf, including inside Norton Sound, and expanded in patchy

[71] Species with ≥ 10% CEA Disturbed (section 4.3) in EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[72] Future Recommendations (section 3.5) in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947
[73] Future Recommendations (page 498) in EBS Laman Advancing Model-based EFH July, 2022 https://meetings.npfmc.org/Meeting/Details/2947
[74] EBS ATF case study (section 3.3.2) in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

areas inside Bristol Bay. Comparing the 2017 SDM and 2022 ensemble for EBS adult ATF demonstrated that shifting the response variable from 4th root transformed CPUE in 2017 to the prediction of numerical abundance in 2022 had the largest effect on reducing the CEA in 2022. Although comparing the 2017 SDMs and 2022 ensembles overall demonstrated that the type of model used in 2017 had a large effect on the performance metrics and calculated EFH area, this was a larger difference when the 2017 SDM was an hGAM or MaxEnt model.

The reviewing stock author did not report a concern with the SDM EFH map or FE model in their 2022 FE assessment. In their 2021 SDM EFH review, they provided a future research recommendation to include longline survey data to potentially account for more ATF habitat on the continental slope[75]. The reviewing stock author chose a quantitative FE assessment using the FE model and 50% CEA and provided a written assessment with further supporting analysis. Based on their assessment, they reported **no further action and recommended that fishing has not had an impact on EBS ATF habitat that is more than minimal and not temporary.**

Mapping requirements for EFH component 1 are some or all portions of the geographic range of the species (50 CFR 600.815(a)(1)(iii)(1)). **EFH mapping requirements have been met for EBS ATF. The 2022 SDM ensemble EFH map provides the best available science for mapping EFH for this species at this time and represents an improvement over the 2017 SDM EFH map.** If possible, EFH component 1 may be improved for this species 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)).

[75] EBS ATF (page 20) in EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf

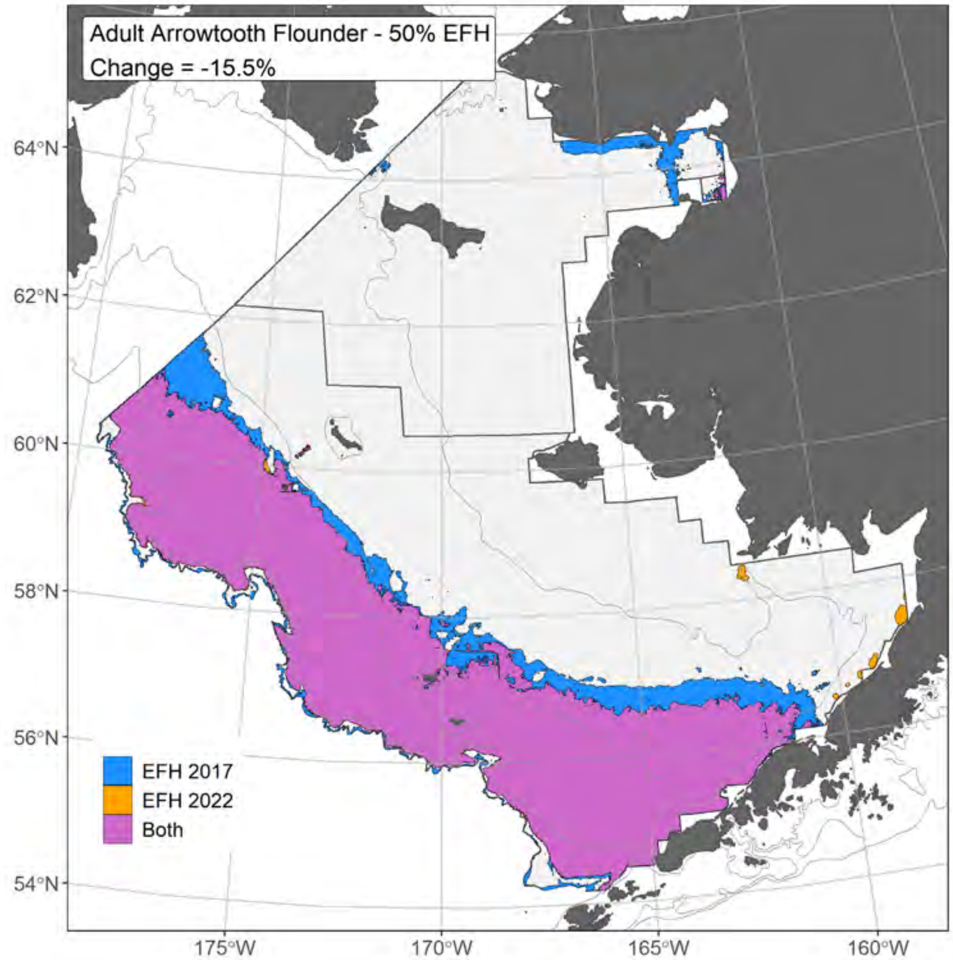

Figure 11. Change from 2017 to 2022 in EBS adult arrowtooth flounder core EFH area (CEA, top 50% of EFH area); colors represent CEA in 2017, 2022, or both.

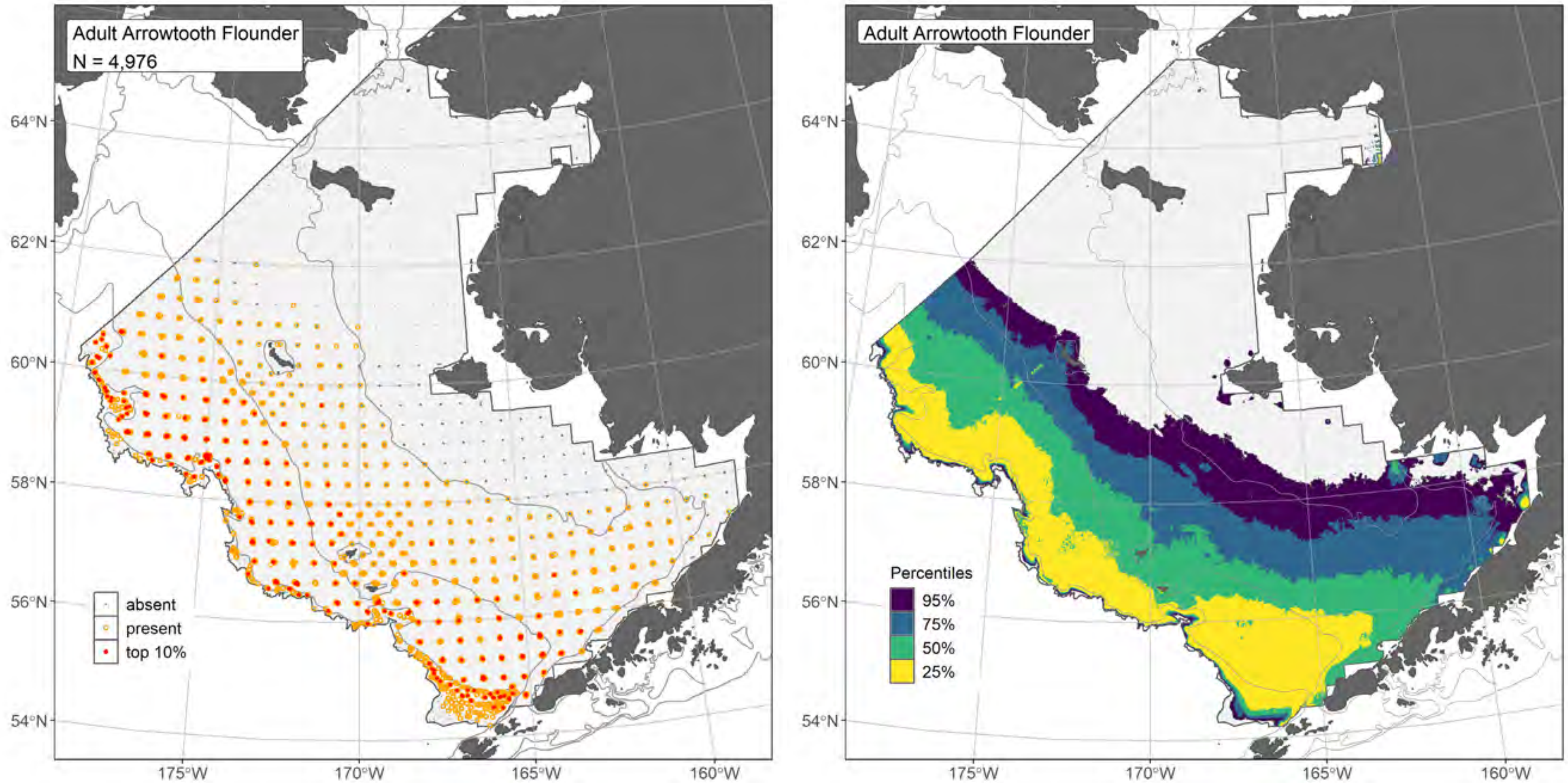

Figure 12. Distribution of adult arrowtooth flounder (ATF) catches (N = 4,976) in AFSC RACE-GAP EBS summer bottom trawl surveys of the EBS Shelf (1982–2019), EBS Slope (2002, 2004, 2008, 2012, 2016), and Northern Bering Sea (2010, 2017, 2019), with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station (left panel). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult ATF distribution and abundance from AFSC RACE-GAP EBS summer bottom trawl surveys (1982–2019), with 50 m, 100 m, and 200 m isobaths indicated; colors indicate the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area) of habitat-related, ensemble-predicted numerical abundance (right panel).

5.3.2 *Giant octopus in the Bering Sea*

The habitat disturbance threshold (≥ 10% CEA disturbed) was exceeded for EBS giant (Pacific) octopus in the FE analysis (13.5%) and was attributed to changes in the SDM EFH map CEA between 2017 and 2022. The CEA was reduced by 38.0% from the 2017 CEA (Figure 13). The 2017 SDM for giant octopus in the EBS was a presence-only MaxEnt model. The 2022 SDM ensemble included the GAM_P, hGAM, paGAM, and MaxEnt models. Overall, the ensemble fit to observed octopus distribution and abundance was fair. The 2017 AUC (0.87) was very similar to the 2022 AUC (0.88) (i.e., the only performance metric available for comparison with the 2017 presence-only MaxEnt model)[76]. The ensemble was fair at predicting catches of high and low octopus abundance ($\rho = 0.28$), at explaining deviance (PDE = 0.31), and good at discriminating presence-absence (AUC = 0.88). Habitat-related ensemble-predicted numerical abundance of giant octopus life stages collected in RACE-GAP summer bottom trawl surveys of the EBS (1992–2019) was translated into EFH areas and additional habitat-related subareas (Figure 14). The EFH area of giant octopus was mapped primarily to the outer shelf domain and extended onto the upper continental slope. CEA and EFH hotspots for giant octopus were located progressively further offshore within the larger EFH area.

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 MaxEnt model. The relatively large decrease in CEA observed in the 2022 EBS giant octopus 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 helped mitigate the influence of any one SDM method on the EFH area and should reduce the magnitude of the change in EFH area attributable to modeling methods in future EFH mapping, making it easier to detect changes in species distribution or habitat impacts.

The reviewing stock author reported *medium concern* with the SDM EFH map for giant octopus in the EBS 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." They were unable to recommend other existing data sources that could augment the RACE-GAP bottom trawl survey data in the SDM ensemble to improve the EFH map for this species. They reported *medium concern* with the FE model 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." The stock author provided a qualitative assessment of the effects of fishing on giant octopus EFH. Based on their assessment, they reported **no further action and recommended that fishing has not had an impact on EBS giant octopus habitat that is more than minimal and not temporary.**

Data availability issues for giant octopus are ongoing in the AI, EBS, and GOA. Mapping requirements for EFH component 1 are some or all portions of the geographic range of the species (50 CFR 600.815(a)(1)(iii)(1)). **EFH mapping requirements have been met for giant octopus in the EBS. The 2022 SDM ensemble EFH map provides the best available science for mapping EFH for this species at this time and represents an improvement over the 2017 SDM EFH map.** If possible, EFH component 1 may be improved for this species 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)).

[76] Table A3.2 in EFH Component 1 SDM EFH Discussion Paper January, 2022 (revised March, 2022) https://meetings.npfmc.org/Meeting/Details/2947

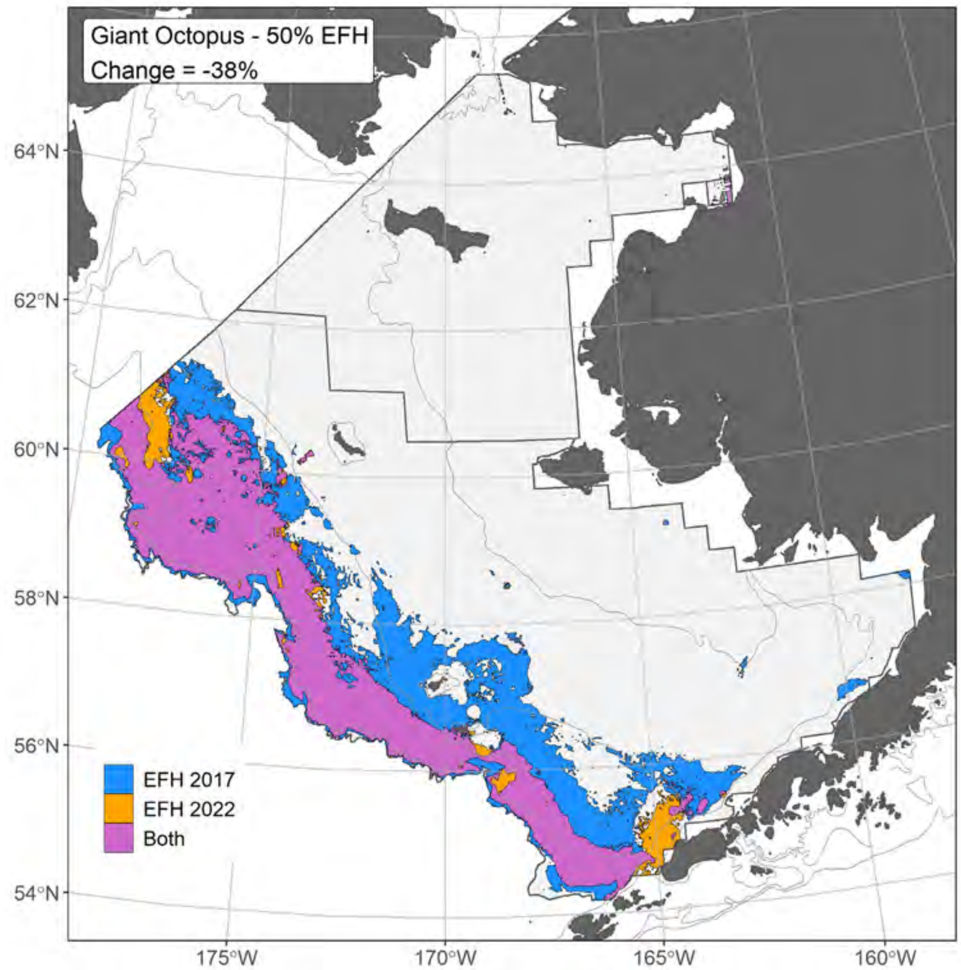

Figure 13. Change from 2017 to 2022 in EBS giant octopus core EFH area (CEA, top 50% of EFH area); colors represent CEA in 2017, 2022, or both.

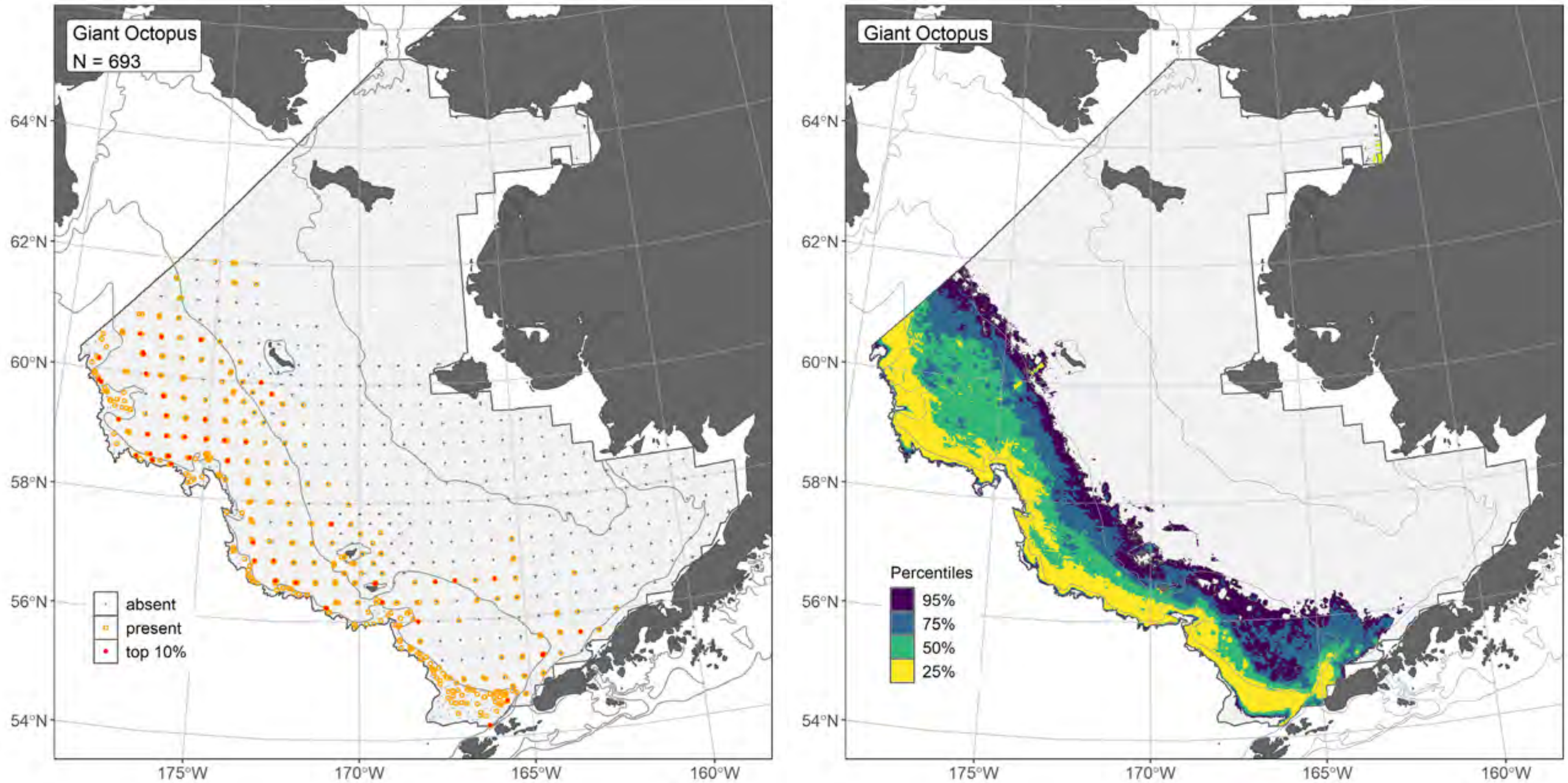

Figure 14. Distribution of giant octopus catches (N = 693) in AFSC RACE-GAP EBS summer bottom trawl surveys of the EBS Shelf (1982–2019), EBS Slope (2002, 2004, 2008, 2012, 2016), and Northern Bering Sea (2010, 2017, 2019), with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station (left panel). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to giant octopus distribution and abundance from AFSC RACE-GAP EBS summer bottom trawl surveys (1982–2019), with 50 m, 100 m, and 200 m isobaths indicated; colors indicate the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area) of habitat-related, ensemble-predicted numerical abundance (right panel).

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APPENDIX 1 EFH SUMMARY TABLE FOR THE STOCK AUTHOR FISHING EFFECTS ASSESSMENT

Table A1.1. EFH Summary Table of the summer distribution of adults or all life stages of groundfishes and crabs provided to stock authors (SAs) for the 2022 EFH component 2 fishing effects (FE) evaluation (*indicates all life stages). SDM Performance Metric Rubric (ρ: < 0.20 (poor), 0.21–0.40 (fair), 0.41–0.60 (good), 0.61–0.99 (excellent); AUC: < 0.70 (poor), 0.71–0.90 (good), 0.90–0.99 (excellent); PDE: < 0.20 (poor), 0.21–0.40 (fair), 0.41–0.60 (good), 0.61–0.99 (excellent)). CEA (core EFH area) was applied to the FE model output to determine the percent CEA disturbed by fishing, based on the SSC's threshold of ≥ 10%; species where that threshold was reached are indicated (Y). If the reviewing SA reported an SDM EFH map concern or future recommendation in their 2021 draft SDM EFH review, this is noted with the page number reference in the Stock Author Review Report (December, 2021)[77], which details the concern and/or recommendation and communication between EFH analysts and SAs to address concerns to the extent possible at this time leading up the SSC's February, 2022 review. SSC requested in February, 2022, that SAs restate their concerns for clarity in a questionnaire; their response is provided in Table 3 and in the FE Discussion Paper[78].

Region	Species	N	SDM Performance Metrics				SDM Performance Metrics Overall Score	CEA (upper 50% of EFH area km^2)	≥ 10% CEA Disturbed	SA 2021 SDM EFH Review Report concern and/or recommendation (page reference)
			RMSE	ρ	AUC	PDE				
AI	arrowtooth flounder	3,118	42.90	0.49	0.75	0.29	good	40,900		Y (pg. 21)
AI	flathead sole	1,374	13.50	0.56	0.86	0.48	good	35,700		
AI	Greenland turbot	359	11.60	0.41	0.96	0.70	excellent	14,000		
AI	Kamchatka flounder	918	19.40	0.54	0.90	0.75	excellent	27,300		
AI	northern rock sole	2,923	58.80	0.72	0.88	0.47	good	39,300		
AI	*other flatfish complex*	-	-	-	-	-	-	40,900		
AI	Dover sole	232	0.87	0.27	0.88	0.43	good	15,400		
AI	English sole	50	1.45	0.23	0.98	0.82	good	5,500		
AI	rex sole	1,891	22.60	0.56	0.82	0.43	good	40,600		
AI	southern rock sole	763	11	0.63	0.97	0.81	excellent	22,200		
AI	Atka mackerel	2,030	1190	0.52	0.65	0.36	fair	40,900		Y (pg. 22)
AI	Pacific cod	3,084	40.40	0.50	0.76	0.37	good	40,800		
AI	sablefish	368	8.11	0.40	0.95	0.67	good	17,400		Y (pg. 30)
AI	walleye pollock	2,773	447	0.50	0.71	0.28	good	40,900		
AI	northern rockfish	2,063	779	0.56	0.68	0.42	fair	40,900		
AI	Pacific ocean perch	2,908	1570	0.72	0.68	0.46	good	40,900		
AI	rougheye/blackspotted rockfish complex	711	19.40	0.52	0.94	0.76	excellent	18,300		
AI	shortraker rockfish	514	6.14	0.48	0.96	0.76	excellent	14,400		Y (pg. 32)
AI	*Other Rockfish complex*	-	-	-	-	-	-	40,900		
AI	dusky rockfish	380	9.17	0.27	0.78	0.45	fair	34,100		
AI	harlequin rockfish	111	23.40	0.18	0.86	0.40	fair	32,600		
AI	shortspine thornyhead	1,051	26.10	0.61	0.93	0.74	excellent	28,900		Y (pg. 26)
AI	*skate complex*	-	-	-	-	-	-	40,800		

[77] EFH Component 1 Stock Author Review Report December, 2021 https://meetings.npfmc.org/CommentReview/EFHSDMStockAuthorReviewReport.pdf
[78] EFH Component 2 Fishing Effects Discussion Paper September, 2022 https://meetings.npfmc.org/Meeting/Details/2947

Region	Species	N	SDM Performance Metrics				SDM Performance Metrics Overall Score	CEA (upper 50% of EFH area km^2)	≥ 10% CEA Disturbed	SA 2021 SDM EFH Review Report concern and/or recommendation (page reference)
			RMSE	ρ	AUC	PDE				
AI	Alaska skate	149	0.65	0.25	0.82	0.27	fair	25,600		
AI	Aleutian skate	221	0.35	0.21	0.76	0.18	fair	12,300		
AI	mud skate	290	0.42	0.28	0.82	0.26	fair	19,200		
AI	whiteblotched skate	544	2.05	0.49	0.92	0.72	excellent	19,500		
AI	giant octopus*	682	0.81	0.20	0.67	0.09	poor	37,900		
AI	golden king crab*	1,148	6.13	0.56	0.89	0.48	good	27,100		Y (pg. 61)
AI	red king crab*	83	1.55	0.15	0.85	0.27	fair	15,800		Y (pg. 62)
EBS	Alaska plaice	8,684	111	0.81	0.92	0.56	excellent	347,600		
EBS	arrowtooth flounder	4,976	26.60	0.81	0.96	0.64	excellent	224,400	Y	Y (pg. 21)
EBS	Greenland turbot	1,974	4.20	0.53	0.95	0.70	excellent	127,300		
EBS	Kamchatka flounder	1,752	2.14	0.51	0.91	0.63	excellent	145,400		
EBS	northern rock sole	7,790	472.0	0.82	0.89	0.49	good	354,100		
EBS	yellowfin sole	9,480	476.0	0.89	0.96	0.62	excellent	326,500		
EBS	*flathead sole Bering flounder complex*	-	-	-	-	-	-	359,700		
EBS	flathead sole	9,702	143.0	0.72	0.88	0.33	good	358,900		
EBS	Bering flounder	2,966	29.60	0.64	0.97	0.67	excellent	241,300		
EBS	*other flatfish complex*	-	-	-	-	-	-	360,100		
EBS	butter sole	177	13.70	0.20	0.98	0.60	good	65,200		
EBS	deepsea sole*	110	0.30	0.45	0.99	0.87	excellent	5,700		
EBS	Dover sole	91	0.37	0.30	0.99	0.73	good	7,000	Y	
EBS	longhead dab*	2,307	54.0	0.61	0.97	0.68	excellent	203,300		
EBS	rex sole	2,171	9.76	0.56	0.95	0.77	excellent	122,700	Y	
EBS	Sakhalin sole	225	2.10	0.22	0.97	0.68	good	105,200		
EBS	starry flounder	1,619	19.20	0.51	0.96	0.58	good	187,900		
EBS	Atka mackerel	72	0.69	0.09	0.85	0.28	fair	13,800	Y	Y (pg. 22)
EBS	Pacific cod	11,853	20.50	0.48	0.79	0.15	good	355,600		
EBS	sablefish	544	1.77	0.39	0.99	0.77	good	35,700	Y	Y (pg. 30)
EBS	walleye pollock	13,506	1020	0.63	0.63	0.24	fair	362,900		
EBS	northern rockfish	89	9.08	0.15	0.97	0.71	good	44,100	Y	
EBS	Pacific ocean perch	561	308	0.34	0.99	0.39	fair	101,000	Y	
EBS	rougheye/blackspotted rockfish complex	105	0.15	0.36	0.99	0.75	good	7,000		
EBS	shortspine thornyhead	696	16	0.55	0.99	0.92	excellent	25,100	Y	Y (pg. 26)
EBS	shortraker rockfish	142	1.65	0.33	0.99	0.85	good	7,200	Y	Y (pg. 32)
EBS	*skate complex*	-	-	-	-	-	-	362,100		
EBS	Alaska skate	5,162	5	0.55	0.78	0.29	good	354,600		
EBS	Aleutian skate	207	0.44	0.30	0.96	0.57	good	31,000	Y	

Region	Species	N	SDM Performance Metrics				SDM Performance Metrics Overall Score	CEA (upper 50% of EFH area km^2)	≥ 10% CEA Disturbed	SA 2021 SDM EFH Review Report concern and/or recommendation (page reference)
			RMSE	ρ	AUC	PDE				
EBS	Bering skate	1,429	0.88	0.51	0.90	0.48	good	140,700	Y	
EBS	mud skate	147	0.43	0.28	0.98	0.69	good	13,500	Y	
EBS	whiteblotched skate	201	0.34	0.33	0.99	0.70	good	16,200	Y	
EBS	giant octopus*	693	0.69	0.28	0.88	0.31	fair	109,200	Y	
EBS	blue king crab*	1,650	8.04	0.47	0.93	0.52	good	248,700		
EBS	red king crab*	3,376	74.60	0.67	0.95	0.52	good	191,500		Y (pg. 62)
EBS	snow crab*	10,628	1930	0.84	0.85	0.41	good	362,600		Y (pg. 64)
EBS	Tanner crab*	9,244	140	0.80	0.93	0.35	good	284,400	Y	Y (pg. 65)
GOA	arrowtooth flounder	7,043	189	0.55	0.76	0.29	good	148,300		Y (pg. 35)
GOA	flathead sole	4,201	63.30	0.72	0.88	0.54	good	135,700		
GOA	rex sole	4,455	36.30	0.59	0.80	0.37	good	147,400		
GOA	Dover sole	2,973	11	0.62	0.87	0.42	good	143,600		
GOA	*shallow water flatfish complex*	-	-	-	-	-	-	142,900		
GOA	Alaska plaice	442	3.60	0.38	0.97	0.71	good	46,100		
GOA	butter sole*	881	30.10	0.46	0.93	0.54	good	107,900		
GOA	English sole	746	13.30	0.34	0.84	0.52	good	127,200		
GOA	northern rock sole	1,980	25	0.69	0.95	0.58	excellent	100,400		
GOA	Pacific sanddab*	77	2.15	0.19	0.98	0.74	good	16,900		
GOA	Petrale sole	271	1.32	0.29	0.96	0.65	good	34,000		
GOA	sand sole	109	4.44	0.22	0.97	0.60	good	26,600		
GOA	slender sole*	751	4.99	0.44	0.94	0.68	excellent	66,900		
GOA	southern rock sole	2,772	22.10	0.76	0.94	0.65	excellent	111,700		
GOA	starry flounder	604	13.30	0.43	0.97	0.59	good	60,700		
GOA	yellowfin sole	491	58	0.40	0.98	0.79	good	62,600		
GOA	Atka mackerel	700	143	0.33	0.85	0.35	fair	123,100		Y (pg. 35)
GOA	Pacific cod	4,476	70.20	0.48	0.75	0.25	good	139,300		
GOA	sablefish	2,011	18.90	0.65	0.94	0.61	excellent	114,100		Y (pg. 51)
GOA	walleye pollock	4,351	237	0.49	0.74	0.23	good	148,300		
GOA	dusky rockfish	1,061	53.10	0.40	0.83	0.29	fair	138,900		Y (pg. 41)
GOA	northern rockfish	1,141	276	0.46	0.89	0.32	good	137,400		
GOA	Pacific ocean perch	2,992	692	0.65	0.81	0.39	good	148,100		
GOA	rougheye/blackspotted rockfish complex	878	9.94	0.46	0.93	0.70	excellent	67,700		Y (pg. 39)
GOA	shortraker rockfish	679	7.62	0.47	0.97	0.73	excellent	34,300		Y (pg. 58)
GOA	shortspine thornyhead	1,998	44.40	0.70	0.97	0.82	excellent	120,600		Y (pg. 59)
GOA	*Other Rockfish complex demersal sub-group*	-	-	-	-	-	-	59,000		Y (pg. 44)

Region	Species	N	SDM Performance Metrics				SDM Performance Metrics Overall Score	CEA (upper 50% of EFH area km²)	≥ 10% CEA Disturbed	SA 2021 SDM EFH Review Report concern and/or recommendation (page reference)
			RMSE	ρ	AUC	PDE				
GOA	quillback rockfish	73	0.44	0.17	0.96	0.51	fair	9,300		Y (pg. 44)
GOA	rosethorn rockfish	186	2.48	0.40	0.99	0.83	good	15,600		Y (pg. 44)
GOA	yelloweye rockfish	186	0.46	0.22	0.91	0.43	fair	33,900		Y (pg. 44)
GOA	*Other Rockfish complex slope sub-group*	-	-	-	-	-	-	144,200		Y (pg. 46)
GOA	greenstriped rockfish	120	1.41	0.30	0.99	0.86	good	10,200		Y (pg. 46)
GOA	harlequin rockfish	514	71.30	0.31	0.88	0.45	good	134,100		Y (pg. 46)
GOA	pygmy rockfish*	63	3.02	0.14	0.96	0.41	fair	39,400		Y (pg. 47)
GOA	redbanded rockfish	321	1.61	0.29	0.93	0.49	good	52,000		Y (pg. 47)
GOA	redstripe rockfish	234	47.90	0.25	0.94	0.65	good	112,900		Y (pg. 48)
GOA	sharpchin rockfish	425	97.90	0.34	0.95	0.54	good	115,100		
GOA	silvergray rockfish	557	33.30	0.37	0.93	0.63	good	97,000		Y (pg. 49)
GOA	spiny dogfish	127	0.29	0.15	0.86	0.36	fair	29,100		Y (pg. 56)
GOA	*skate complex*	-	-	-	-	-	-	138,400		
GOA	Alaska skate	78	0.15	0.13	0.85	0.25	fair	7,000		
GOA	Aleutian skate	147	0.19	0.17	0.84	0.25	fair	16,100		
GOA	Bering skate	407	0.32	0.28	0.84	0.31	fair	49,800		
GOA	big skate	195	0.21	0.19	0.86	0.27	fair	19,600		
GOA	longnose skate	845	0.46	0.25	0.74	0.15	fair	110,000		
GOA	giant octopus*	459	0.33	0.20	0.75	0.15	fair	71,000		

APPENDIX 2 2022 EFH MAPS WITH AFSC LONGLINE SURVEY STATION HISTORIC HAUL LOCATION OVERLAY

Appendix 2 is a collection of figures showing the 2022 EFH maps of the summer distribution of groundfishes in the BSAI and GOA FMPs with overlay of the AFSC longline survey station historic haul locations (without attribution to species catch locations) for species where the reviewing stock author recommended that longline survey data be included in future EFH mapping efforts in their review of the new SDM ensemble 2022 EFH maps. The longline survey station locations were provided to NMFS AKR by the AFSC Marine Ecology and Stock Assessment program. As an interim step to understanding the recommendation to add longline survey data for this subset of species, these figures demonstrate that new 2022 EFH areas presently include, either entirely or partially, the AFSC longline survey stations. Including longline survey data in the SDMs for these species may enhance the EFH maps.

FIGURES

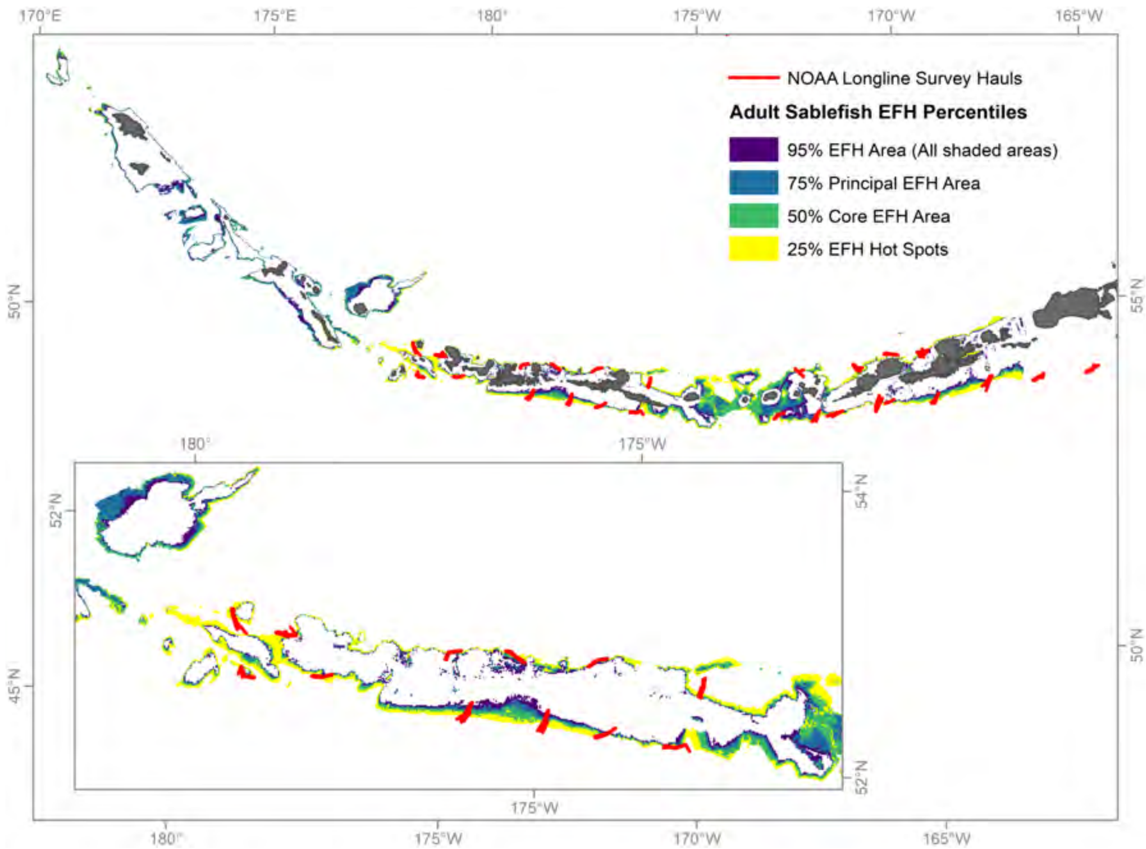

Figure A2.1. EFH map of adult sablefish in the AI with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to sablefish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult sablefish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1991–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

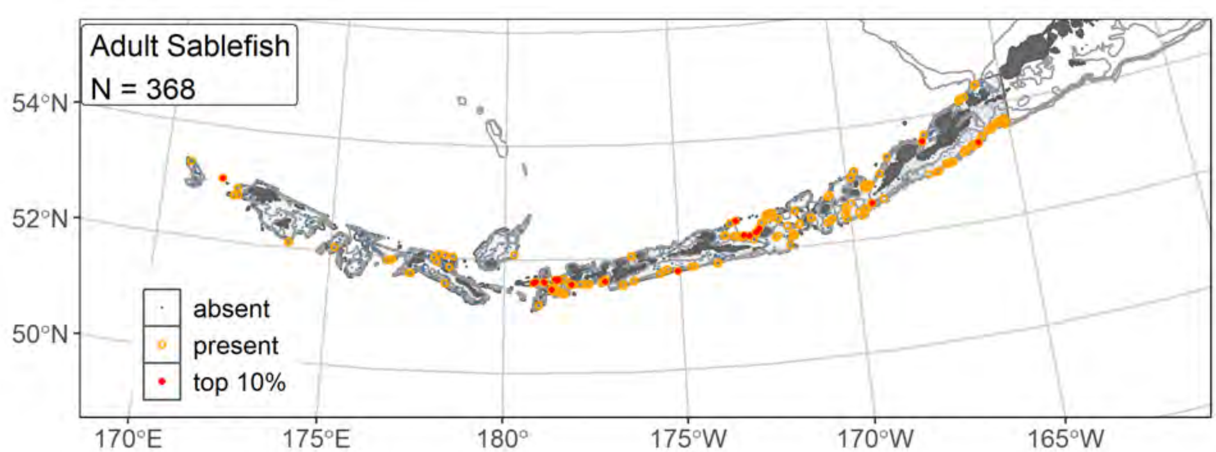

Figure A2.2. Distribution of adult sablefish catches (N = 368) in 1991–2019 AFSC RACE-GAP summer bottom trawl surveys of the AI with the 100 m, 300 m, and 500 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

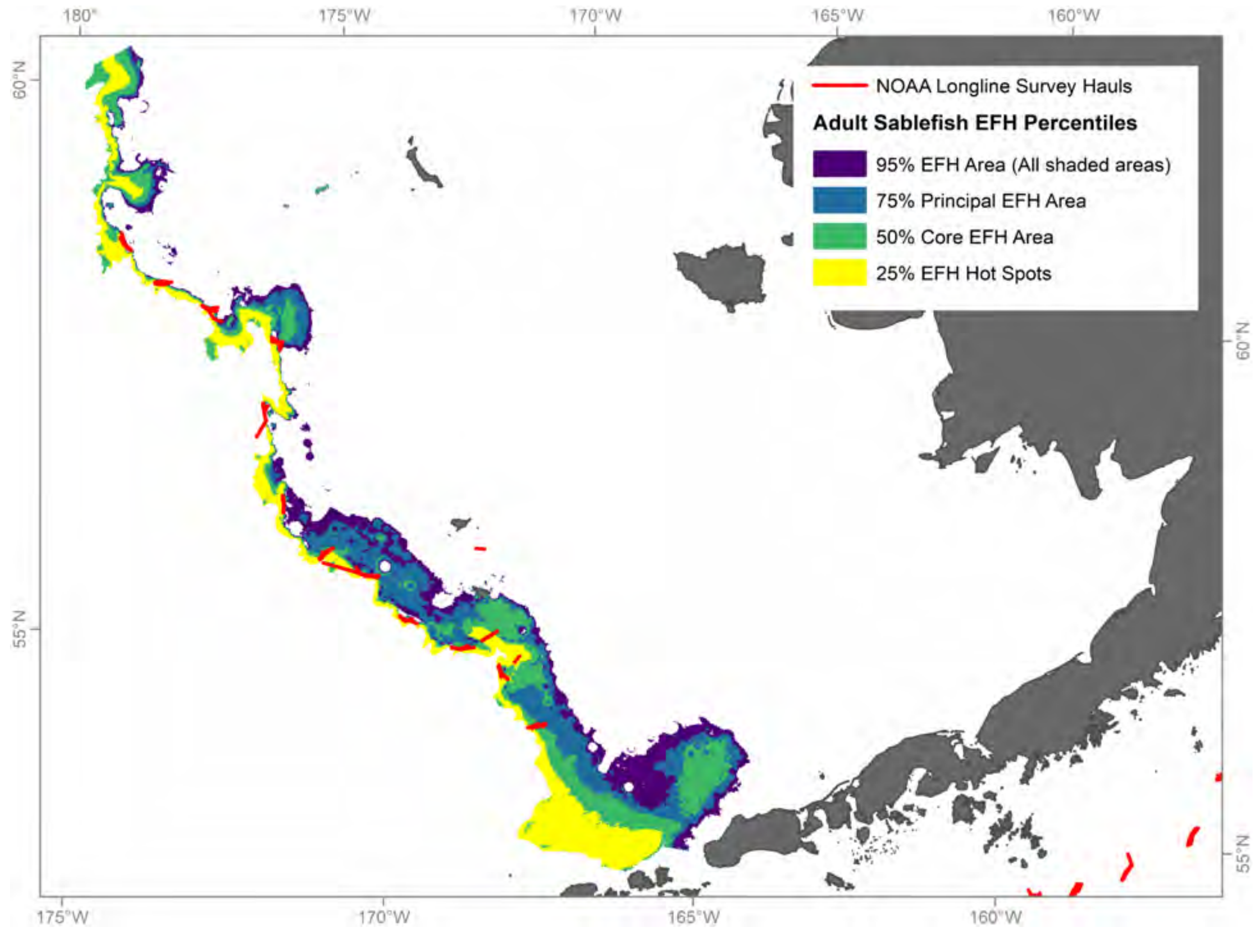

Figure A2.3. EFH map of adult sablefish in the EBS with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to adult sablefish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult sablefish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1992–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

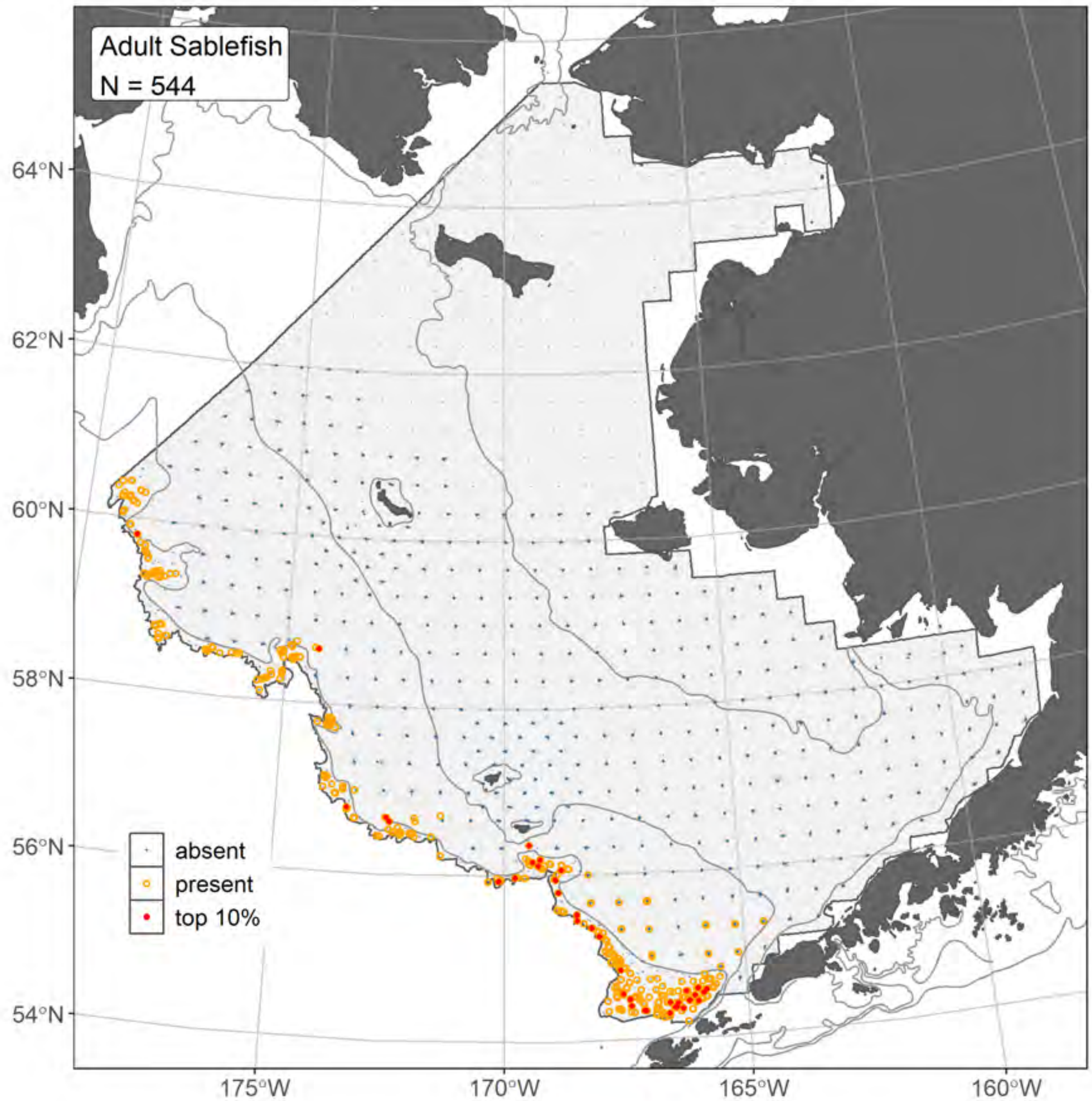

Figure A2.4. Distribution of adult sablefish catches (N = 544) in 1982–2019 AFSC RACE-GAP summer bottom trawl surveys of the eastern Bering Sea Shelf, Slope, and Northern Bering Sea with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

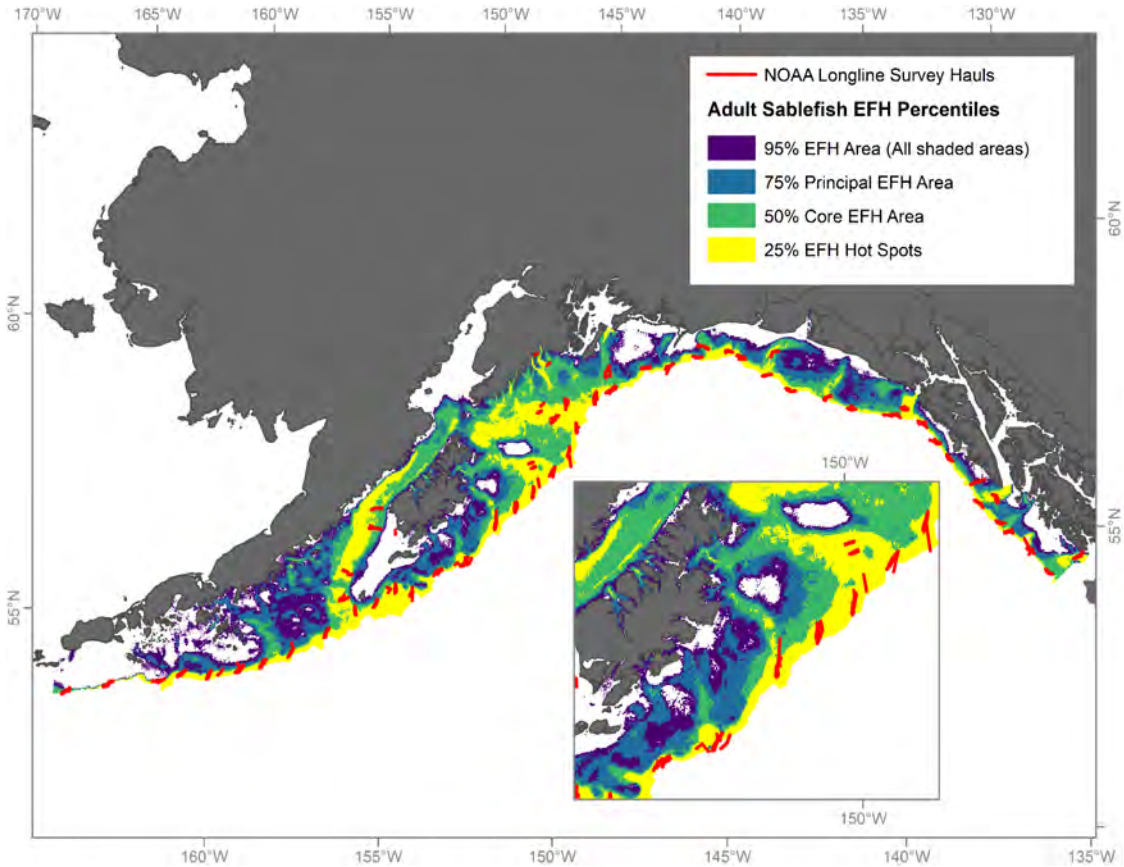

Figure A2.5. EFH map of adult sablefish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to sablefish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult sablefish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

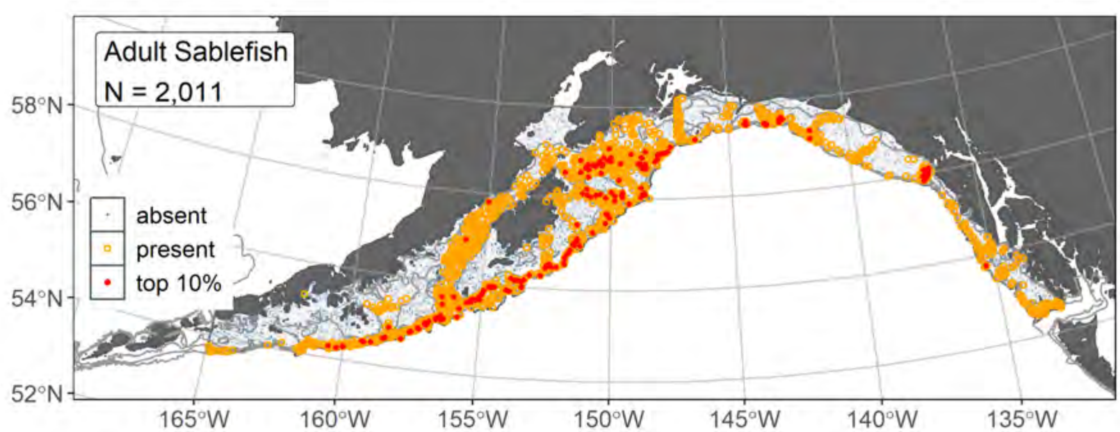

Figure A2.6. Distribution of adult sablefish catches (N = 2,011) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

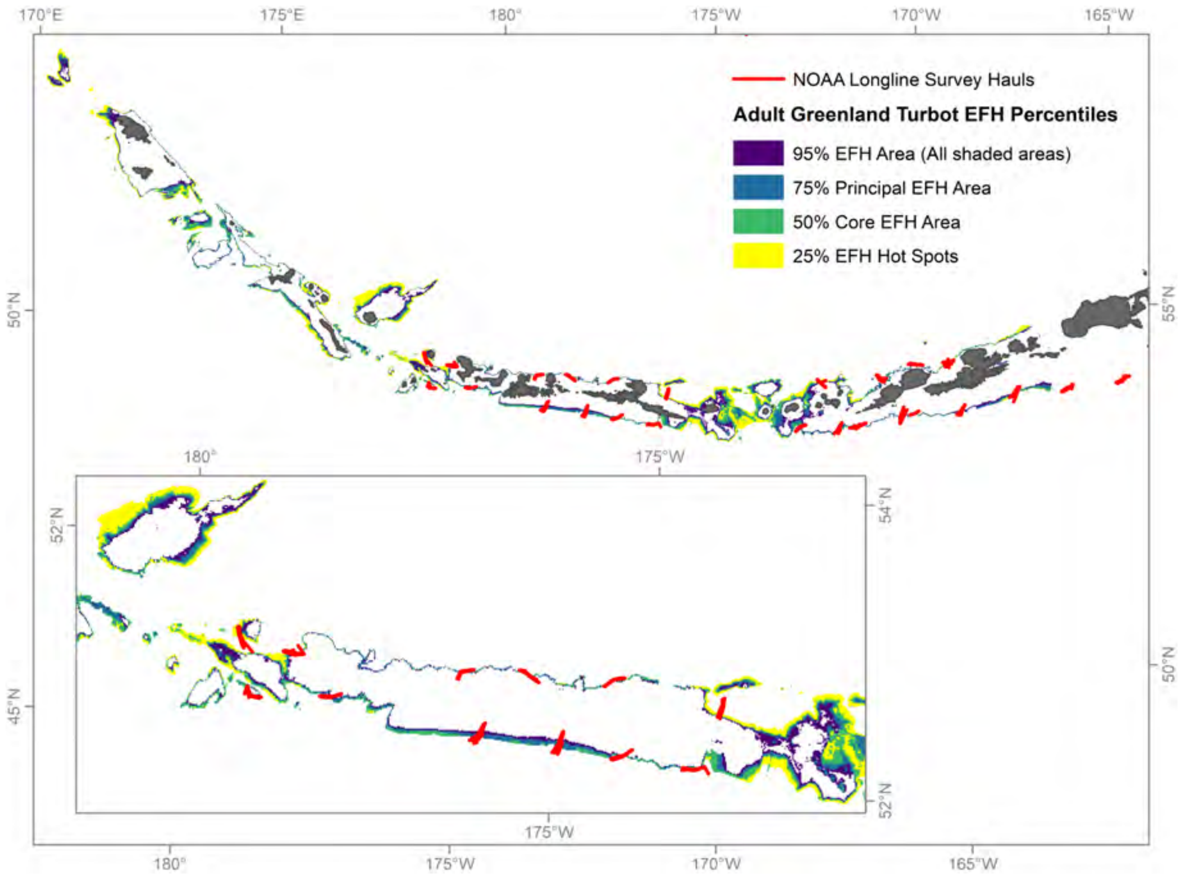

Figure A2.7. EFH map of adult Greenland turbot in the AI with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to Greenland turbot catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult Greenland turbot distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1991–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

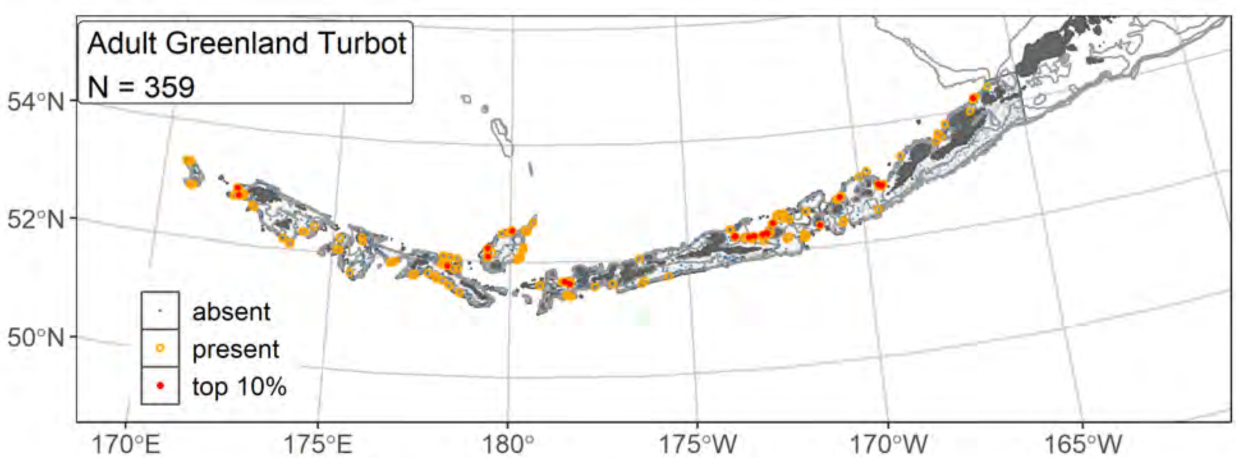

Figure A2.8. Distribution of adult Greenland turbot catches (N = 359) in 1991–2019 AFSC RACE-GAP summer bottom trawl surveys of the AI with the 100 m, 300 m, and 500 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and small blue dots indicate absence, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

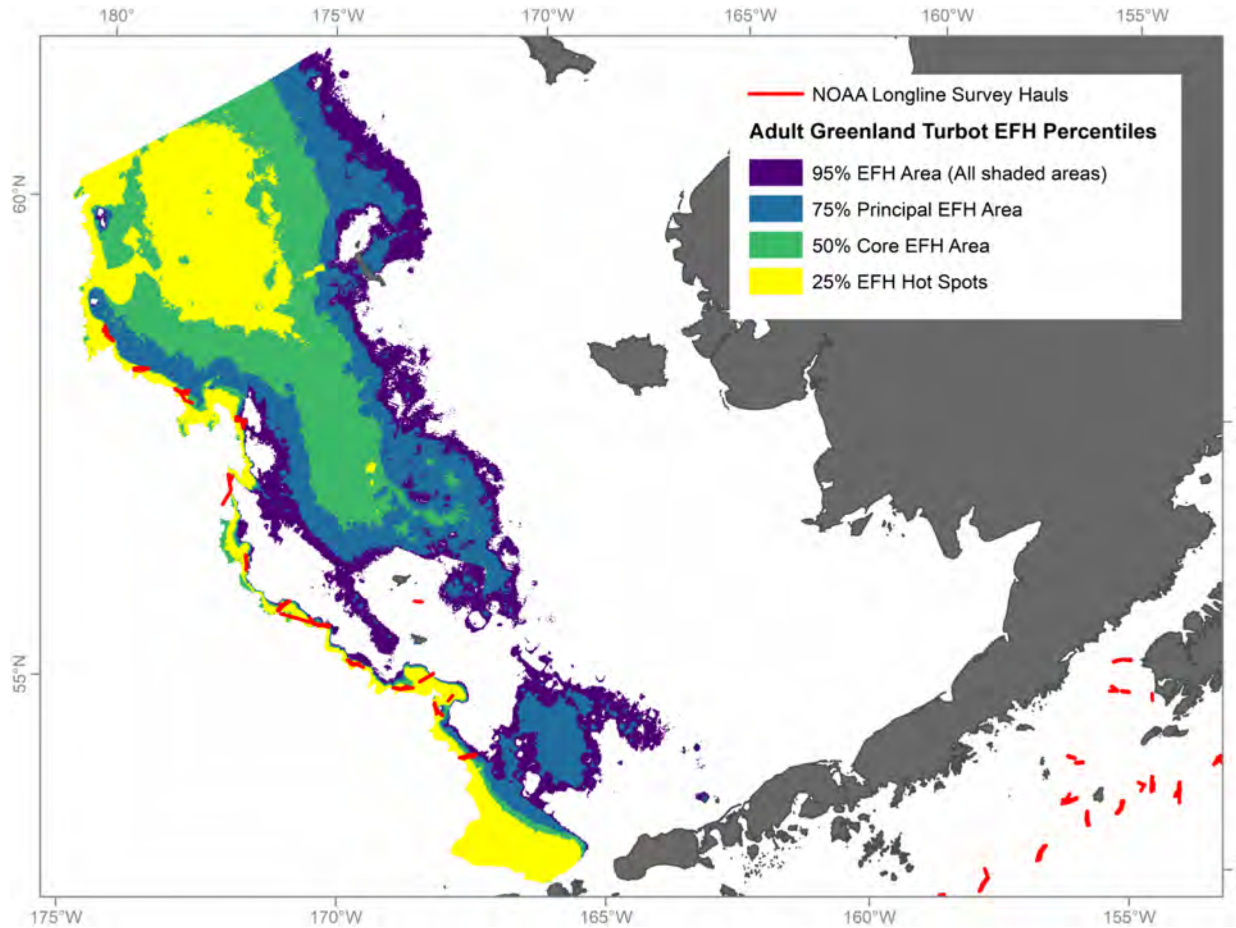

Figure A2.9. EFH map of adult Greenland turbot in the EBS with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to adult Greenland turbot catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult Greenland turbot distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1992–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

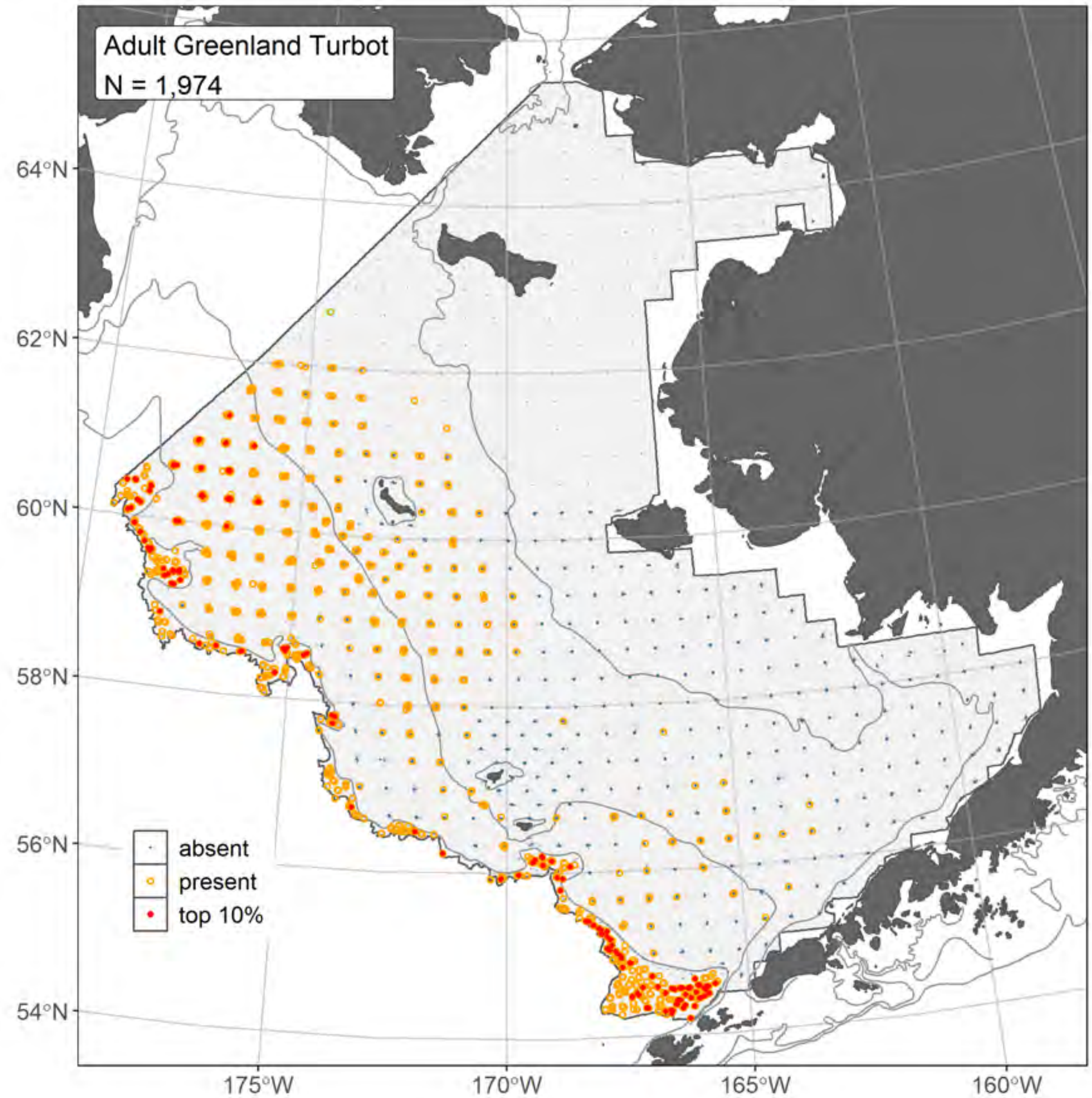

Figure A2.10. Distribution of adult Greenland turbot catches (N = 1,974) in 1982–2019 AFSC RACE-GAP summer bottom trawl surveys of the eastern Bering Sea Shelf, Slope, and Northern Bering Sea with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

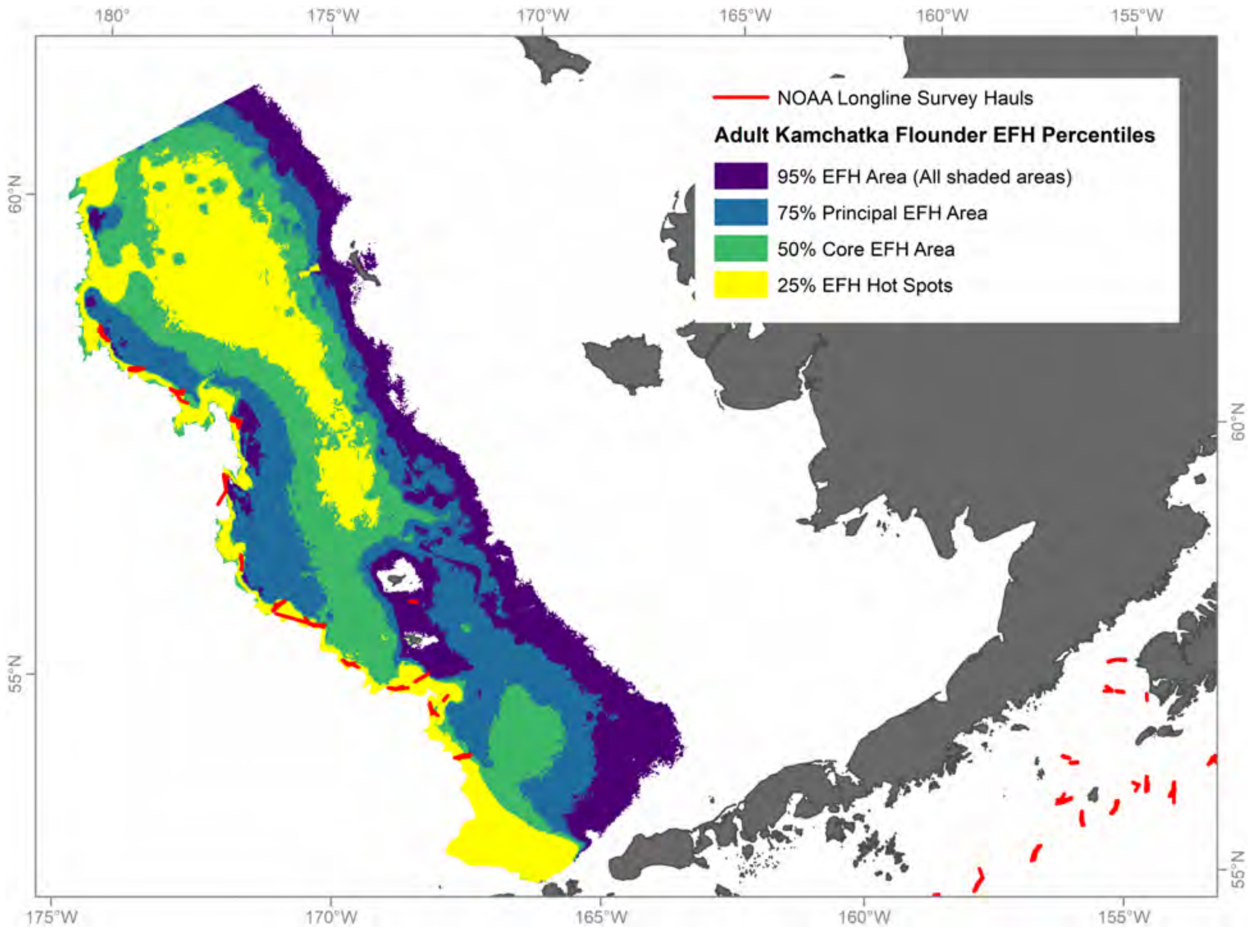

Figure A2.11. EFH map of adult Kamchatka flounder in the EBS with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to adult Kamchatka flounder catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult Kamchatka flounder distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1992–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

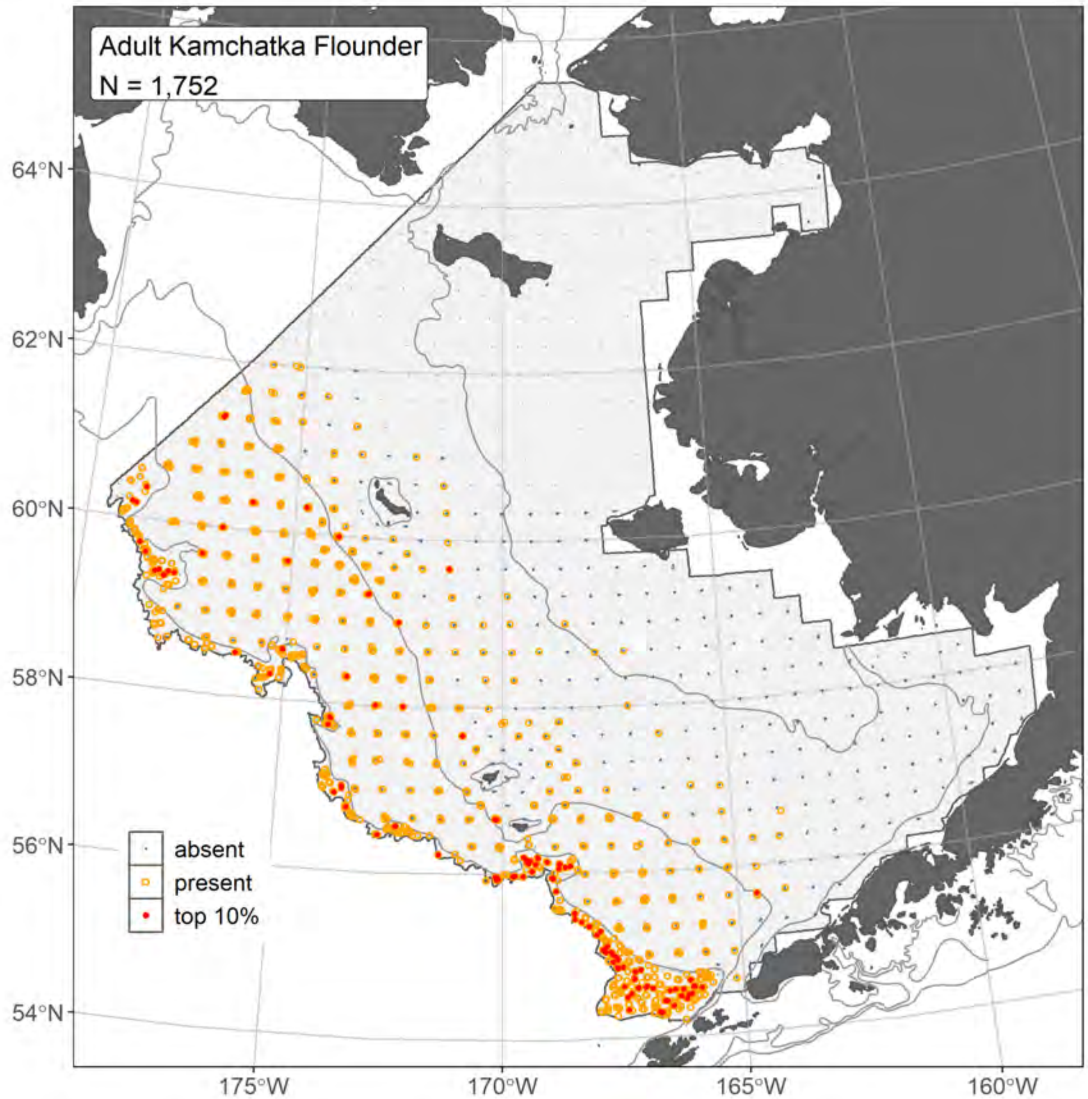

Figure A2.12. Distribution of adult Kamchatka flounder catches (N = 1,752) in 1982–2019 AFSC RACE-GAP summer bottom trawl surveys of the eastern Bering Sea Shelf, Slope, and Northern Bering Sea with the 50 m, 100 m, and 200 m isobaths indicated; filled red circles indicate catches in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

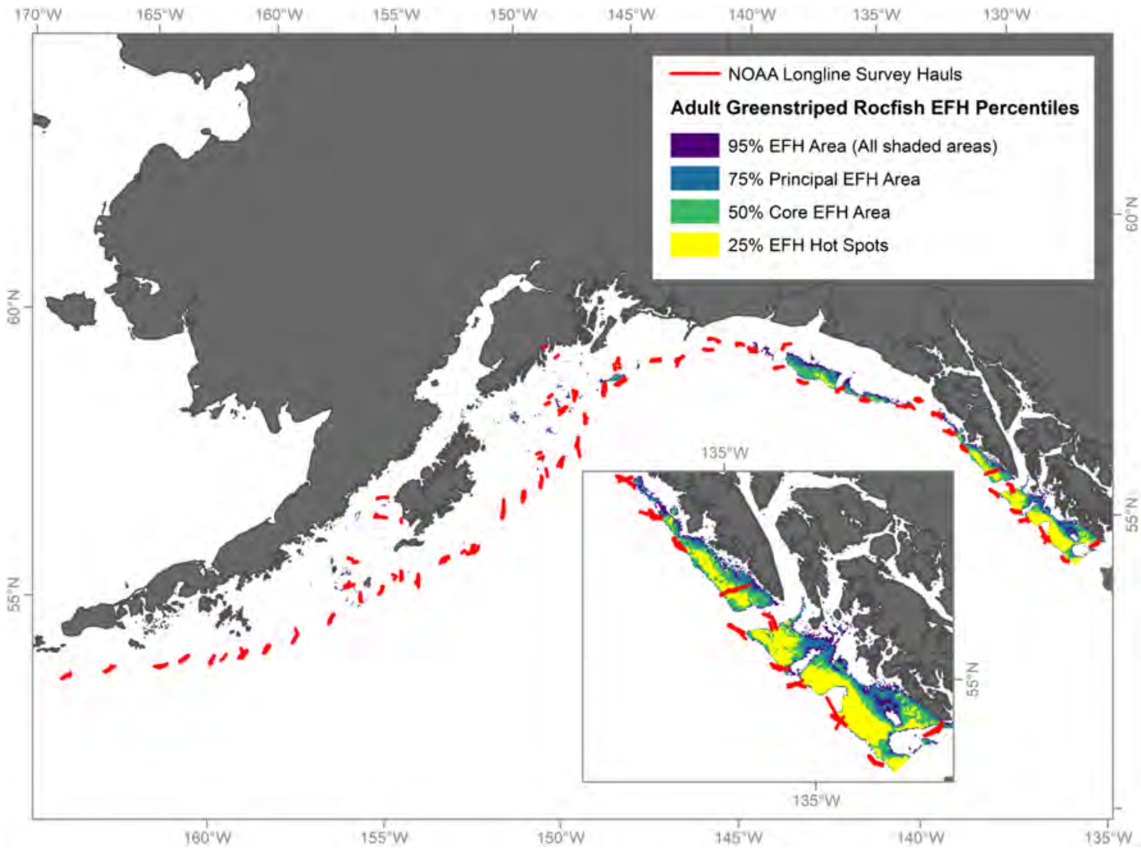

Figure A2.13. EFH map of adult greenstriped rockfish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to greenstriped rockfish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult greenstriped rockfish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

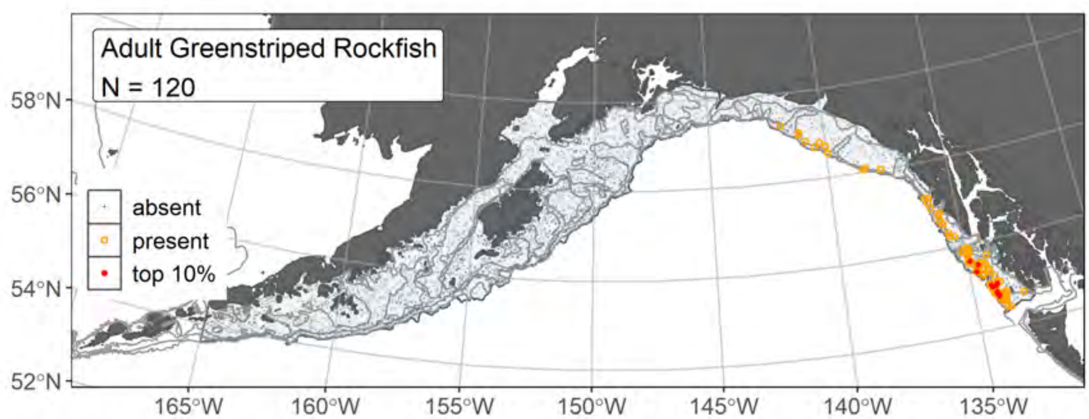

Figure A2.14. Distribution of adult greenstriped rockfish catches (N = 120) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

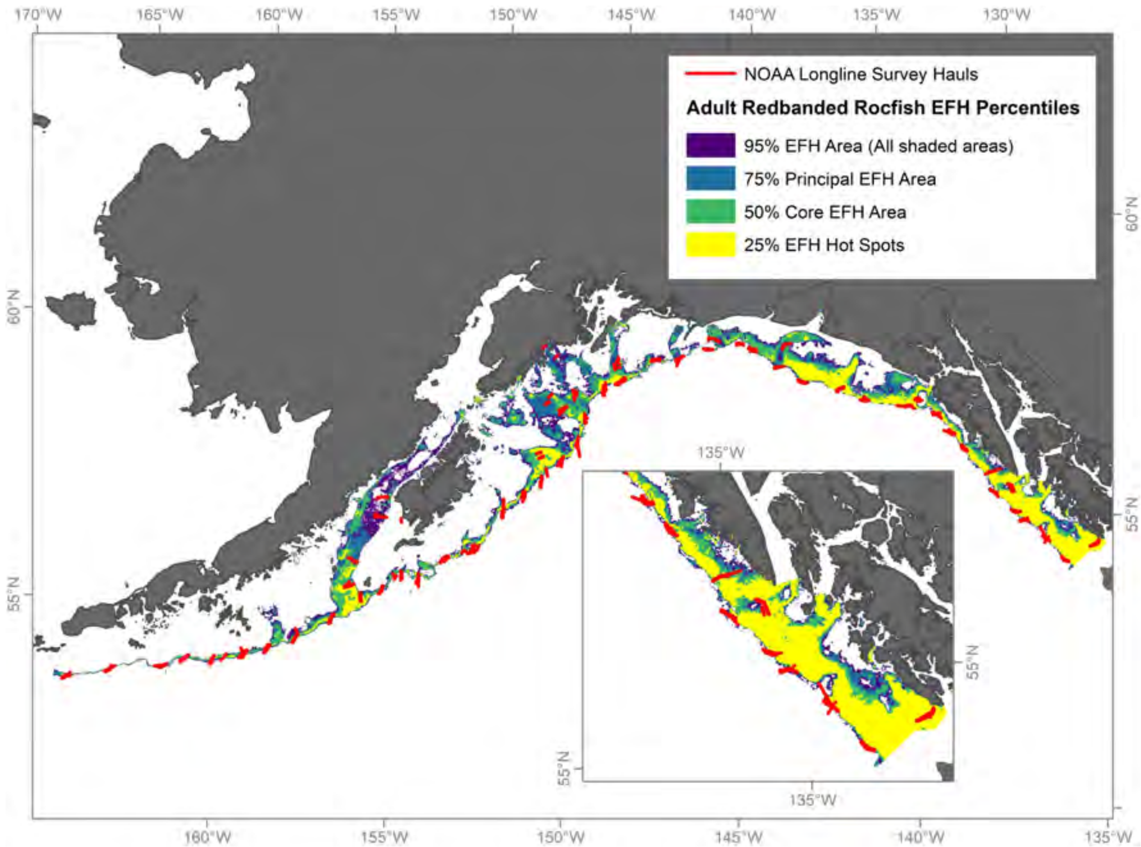

Figure A2.15. EFH map of adult redbanded rockfish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to redbanded rockfish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult redbanded rockfish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

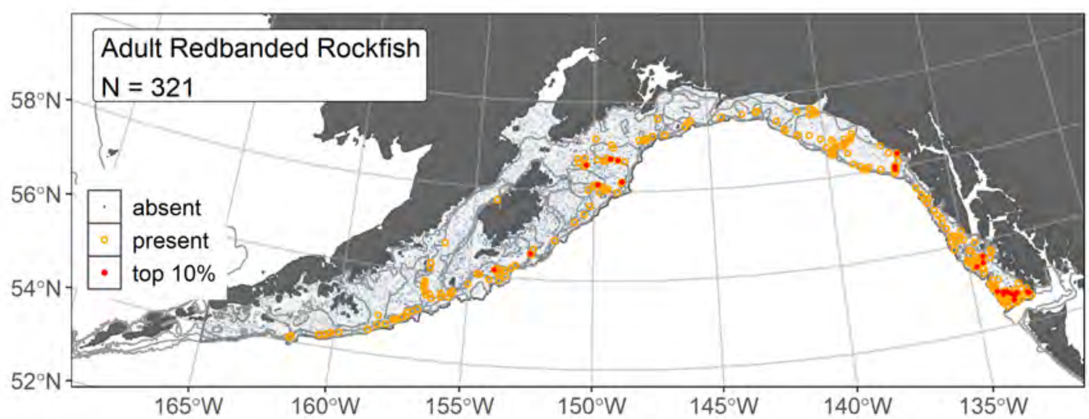

Figure A2.16. Distribution of adult redbanded rockfish catches (N = 321) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

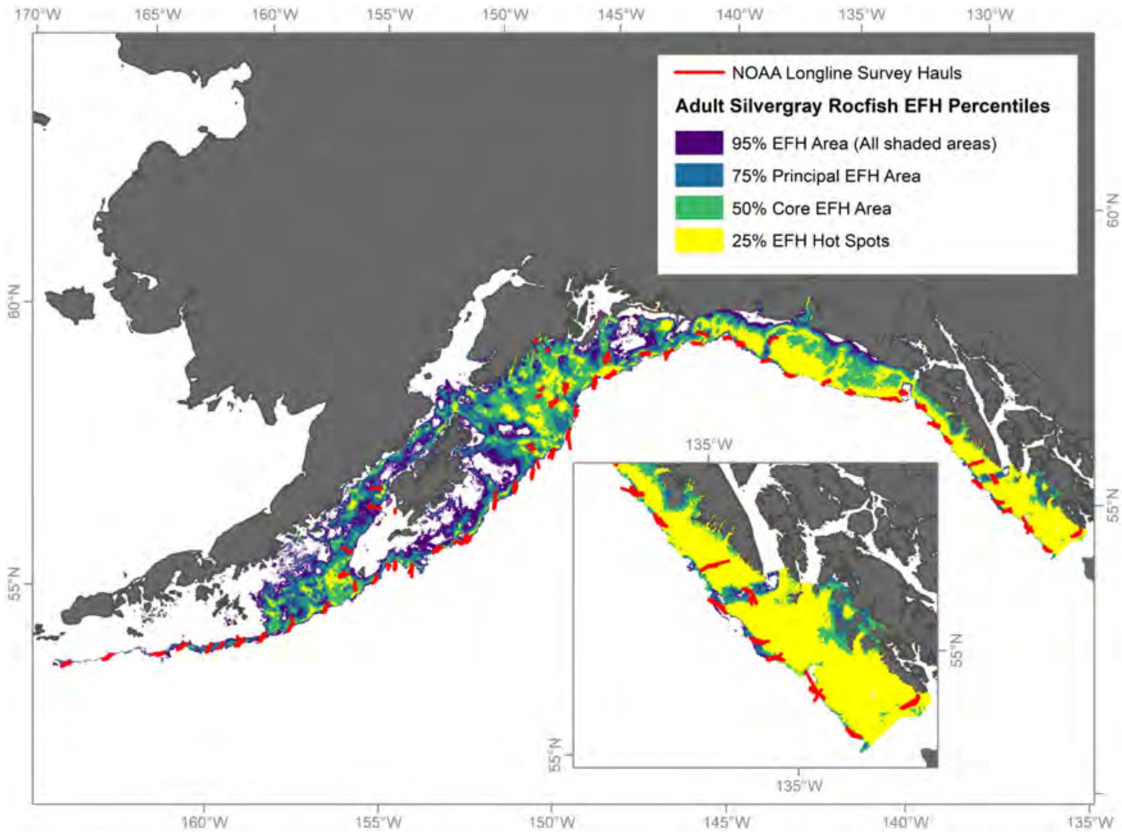

Figure A2.17. EFH map of adult silvergray rockfish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to silvergray rockfish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult silvergray rockfish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

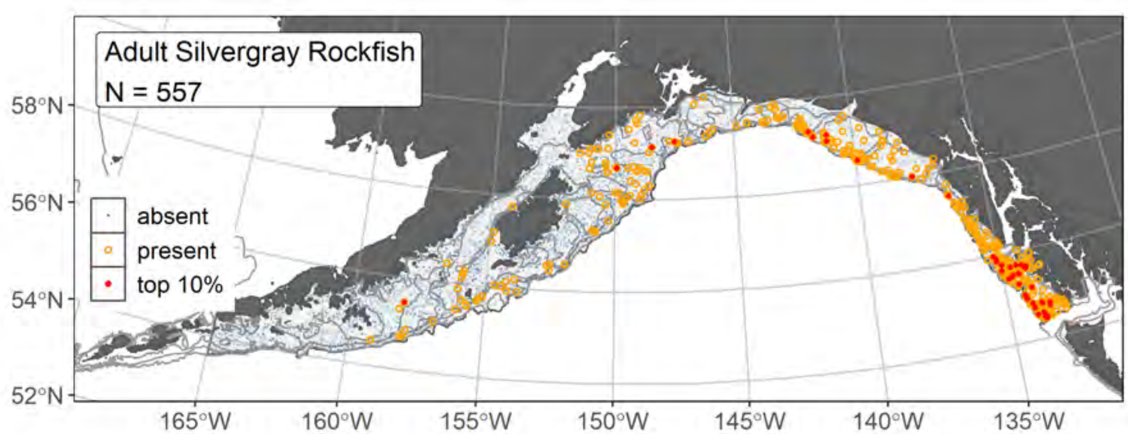

Figure A2.18. Distribution of adult silvergray rockfish catches (N = 557) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

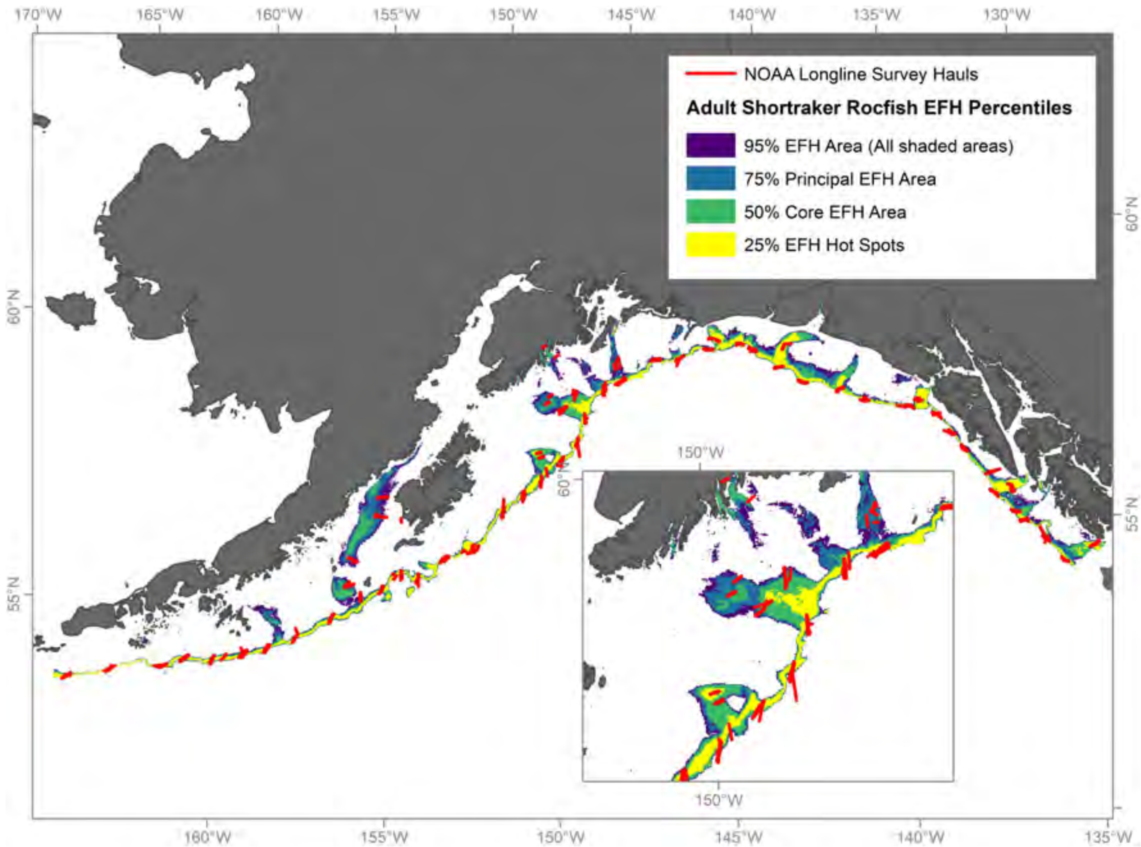

Figure A2.19. EFH map of adult shortraker rockfish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to shortraker rockfish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult shortraker rockfish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

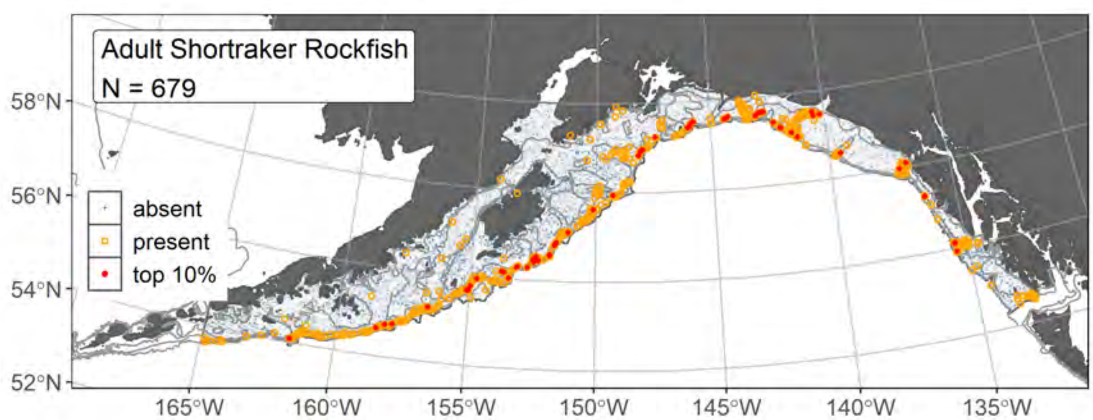

Figure A2.20. Distribution of adult shortraker rockfish catches (N = 679) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

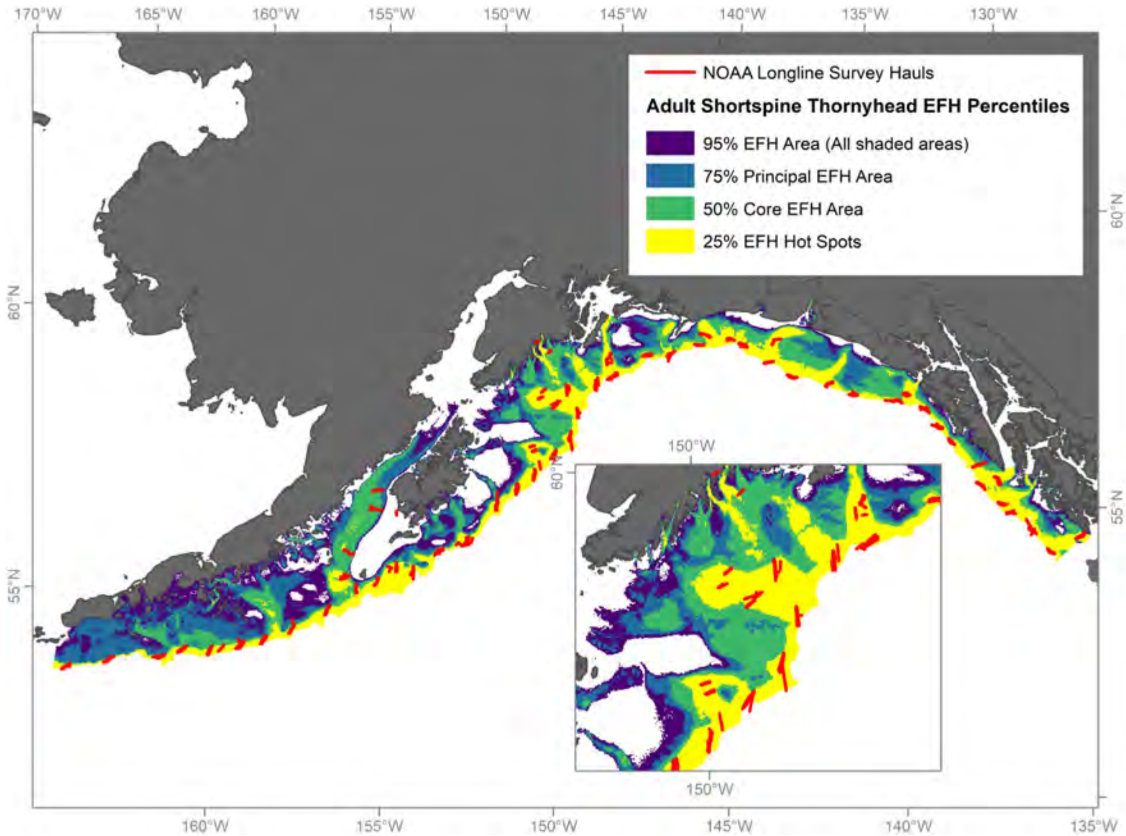

Figure A2.21. EFH map of adult shortspine thornyhead rockfish (SST) in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to SST catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to adult SST distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

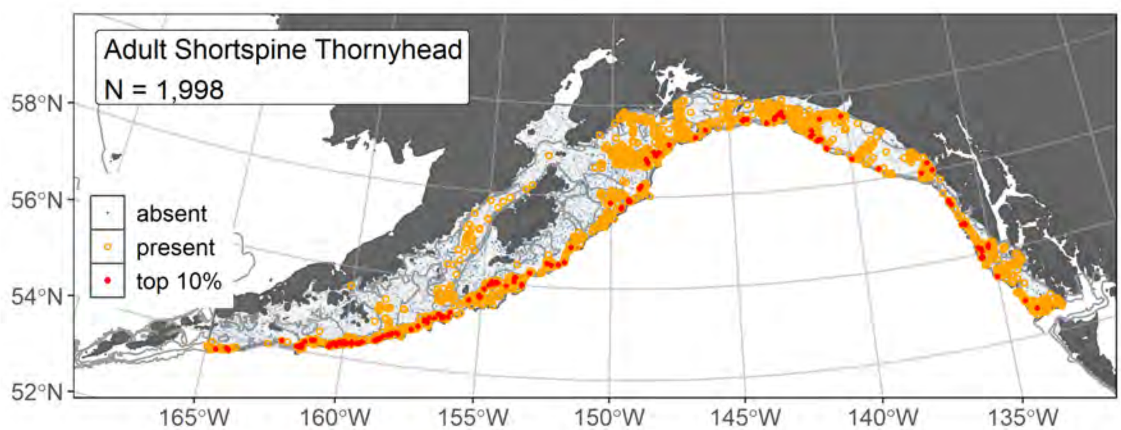

Figure A2.22. Distribution of adult SST catches (N = 1,998) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

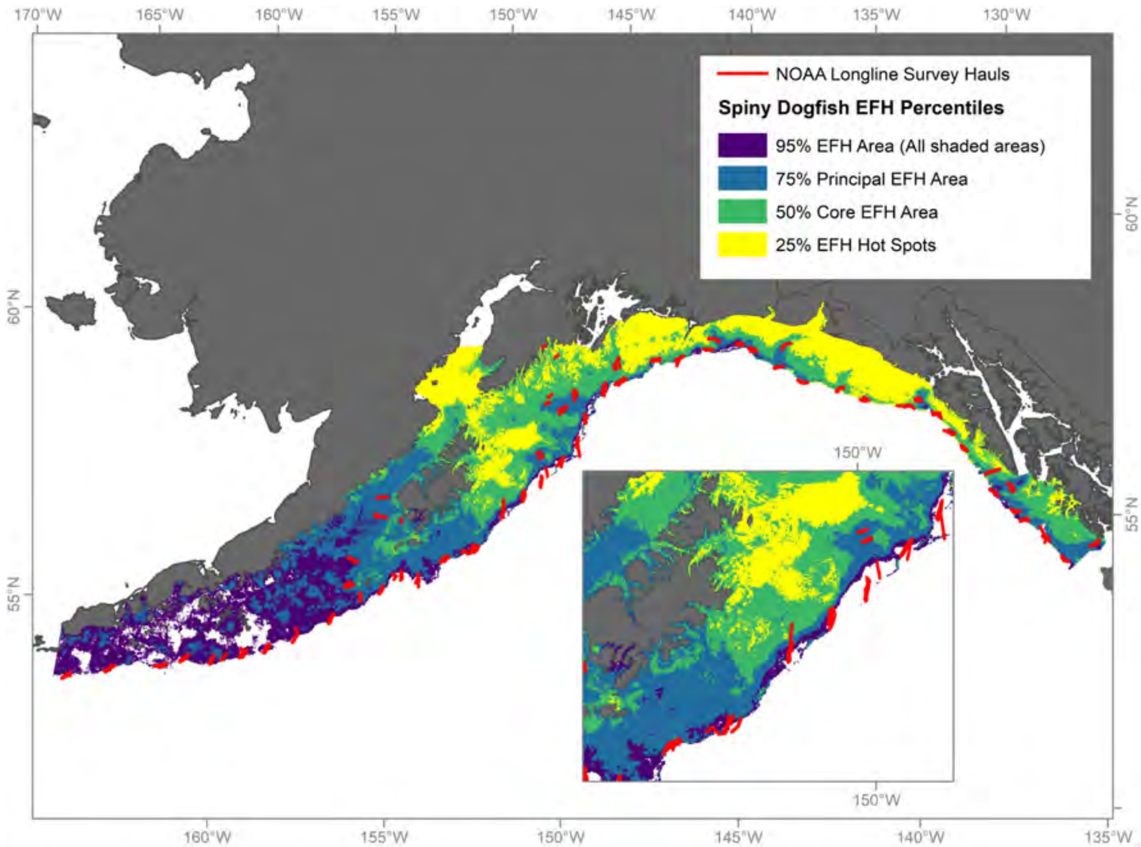

Figure A2.23. EFH map of spiny dogfish in the Gulf of Alaska with overlay of AFSC longline survey station historic haul locations (red lines) (*without attribution to spiny dogfish catch locations*). EFH is the area containing the top 95% of occupied habitat (defined as model estimated encounter probabilities greater than 5%) from a habitat-based ensemble fitted to spiny dogfish distribution and abundance in AFSC RACE-GAP summer bottom trawl surveys (1993–2019); within the EFH map are the subareas of the top 25% (EFH hot spots), top 50% (core EFH area), and top 75% (principal EFH area).

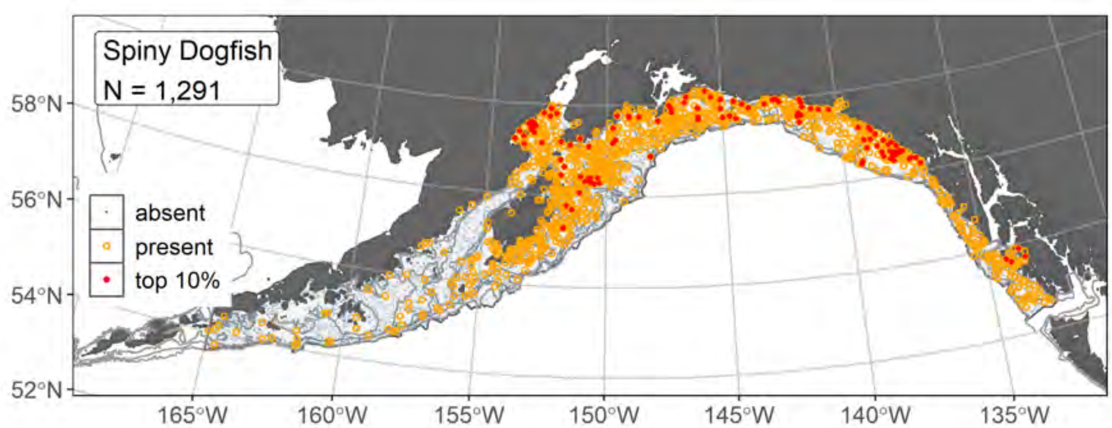

Figure A2.24. Distribution of spiny dogfish catches (N = 1,291) in 1993–2019 AFSC RACE-GAP summer bottom trawl surveys of the GOA with the 100 m, 200 m, and 700 m isobaths indicated; filled red circles indicate locations in top 10% of overall abundance, open orange circles indicate presence in remaining catches, and blue dots indicate stations sampled where the animals were not present, each datum at a station represents a year of sampling at that location, multiple years are overplotted at each station.

APPENDIX 3 SUPPORTING DOCUMENTS

Additional supporting documents are provided with this **EFH Component 1 SDM EFH Discussion Paper (September, 2022)** and referenced herein to support evaluation of **EFH component 1** in the 2022 EFH 5-year Review and specifically for the SSC's October, 2022 review. Please refer to the electronic agenda[79] for this meeting to view and download the following documents—

- **EFH Component 1 SDM EFH Discussion Paper (January, 2022 and revised March, 2022)**, presented to the SSC in February, 2022 and revised following the SDM survey area offset correction in March, 2022. This document includes the methods and results of the new SDM ensemble EFH maps (Laman et al. study) for EFH component 1 and that were also applied to the EFH component 2 FE evaluation for the 2022 5-year Review. This document provides a helpful synthesis of the methods and results, including regional case studies, and summary tables (e.g., Table A3.2) of SDM performance metrics and EFH areas for the 2022 and 2017 EFH maps.
- **Three documents prepared as NOAA Technical Memoranda** organized by the regions modeled by the Laman et al. study for the species life stages in the BSAI, GOA, and Crab FMPs. Refer to the individual documents for region-specific methods and the full set of species' life stage SDM EFH results, including the new 2022 summer distribution EFH maps showing the EFH area and percentile subareas (e.g., CEA used in the 2022 EFH 5-year Review FE evaluation), and research recommendations. The three documents have been reviewed internally by NMFS stock authors and other internal reviewers, and by the SSC in February, 2022. The three documents were resubmitted for publication in September, 2022.
    - **Al (Harris) Advancing Model-based EFH** (Harris et al. August, 2022)
    - **EBS (Laman) Advancing Model-based EFH** (Laman et al. July, 2022)
    - **GOA (Pirtle) Advancing Model-based EFH** (Pirtle et al. September, 2022)
- **2022 SDM ensemble EFH maps and comparing the 2017 and 2022 CEAs as overlay maps** are in a collection of figures for the EFH component 2 FE evaluation of the 2022 5-year Review, organized by regional folders (AI, EBS, GOA) and also containing the FE model and analysis results.
- **EFH Component 2 Fishing Effects Evaluation Discussion Paper (September, 2022)**, supports the review of the EFH component 2 FE evaluation of the 2022 5-year Review, and provides information for how the new EFH component 1 SDM ensemble EFH map CEAs were used in the FE evaluation, including details of stock author input on any SDM EFH map concerns and recommendations with EFH analyst responses on how those were addressed to the extent possible at this time (Appendix 5 and section 4.2).
- **Report of Stock Author Review of EFH Component 1 for the 2022 EFH 5-year Review (December, 2021)**, provides the full review of the draft SDM EFH methods and results by the stock authors in 2021, including a record of concerns, recommendations, and communication between EFH analysts and stock authors to address concerns and understand recommendations prior to the SSC's review in February, 2022.

[79] D8 EFH https://meetings.npfmc.org/Meeting/Details/2947