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Wild Species Analysis in Support of Marine Aquaculture in the Gulf of Mexico and the Southern California Bight

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Plain Language Summary

Recently, the United States has begun to study the potential for an expanded marine aquaculture sector in its territorial waters. Much of this effort centers on closing the gap between our domestic consumption and production of seafood products. Marine aquaculture is the farming of aquatic finfish, shellfish, and seaweeds in the ocean, using a) structures that organisms can attach themselves to (as in the case of shellfish and seaweed), or b) net pens or other infrastructure to contain organisms within the marine environment (as with finfish). As a lead agency dealing with the marine environment, NOAA has begun exploring the idea of Aquaculture Opportunity Areas—defined geographic areas that have been evaluated to determine their potential suitability for marine aquaculture.

The presence of aquaculture farms in the natural environment means that those farms, and their organisms, can interact with wild organisms. The impacts of such interactions can be related to disease, genetics, ecology, and more. To understand how to minimize or mitigate the impacts of farmed and wild organism interactions, it is helpful to first characterize the species that might be present and analyze the potential frequency of the interactions.

This document explores potential overlap between wild species and the areas under evaluation as potential Aquaculture Opportunity Areas (AOAs) in the Gulf of Mexico and the Southern California Bight (hereafter: "AOA study areas").[1] The paper uses NOAA's fishery-independent trawl survey data (data collected by sampling wild populations) in conjunction with geospatial data layers for the AOA study areas to determine if there is potential overlap. Using the two datasets, the paper seeks to answer three preliminary questions:

1. Has a given species been found within the AOA study areas?
2. Using spatial tools to estimate a species' biomass in the two regions, what percentage of that biomass do we estimate to reside in the AOA study areas?
3. Using spatial tools to estimate biomass abundance throughout the two regions, how densely concentrated is a species within the AOA study areas?

The results of the study were mixed. Some species appeared to be more abundant in the AOA study areas while others appear to be distributed mostly or entirely outside of them. The study has several limitations in terms of analysis and the means by which data were collected, but does help create a baseline understanding of the organisms that will likely be present in the event that AOAs are eventually established.

In addition, the methods used in the study can be repeated and can aid in the similar evaluation of other areas that come under consideration for the establishment of AOAs. We hope that this study catalyzes more thinking about how to prepare for and minimize the potential impacts of an expanded aquaculture industry on the marine environment while increasing our domestic seafood supply.

[1] As of the time of publication, no AOAs have been established.

Links used in this section:

- Marine aquaculture: https://www.fisheries.noaa.gov/topic/aquaculture
- Closing the gap: https://openknowledge.fao.org/items/11a4abd8-4e09-4bef-9c12-900fb4605a02
- Net pens: https://www.fisheries.noaa.gov/west-coast/aquaculture/sablefish-aquaculture-pacific-northwest
- Aquaculture Opportunity Areas: https://www.fisheries.noaa.gov/national/aquaculture/aquaculture-opportunity-areas
- Fishery-independent trawl survey data: https://apps-st.fisheries.noaa.gov/dismap/
- Geospatial data layers: https://dna.firstam.com/insights-blog/the-5-layers-of-gis-mapping-what-they-are-and-how-they-work

Glossary

AOA Atlas: NOAA's AOA Atlases are two marine spatial analysis documents written to inform the **Aquaculture Opportunity Area** identification process. The results identify areas that have the highest potential to support multiple marine aquaculture operations with the least amount of conflict with other ocean uses. The Atlases were developed for the specific purpose of preliminarily identifying locations that might be suitable for siting **AOAs**, and include limitations specific to that purpose. Thus far, Atlases have been published for the Gulf of Mexico and the Southern California Bight.

AOA options: Geographic information system (GIS) shapefiles reflecting areas that received the highest relative suitability scores following comprehensive spatial analysis (i.e., final suitability model results), published in the **AOA Atlases** (*1, 2*).

AOA study areas: Geospatial datasets reflecting areas characterized by specific parameters such as depth, political boundaries, regulation of submerged lands, outer continental shelf boundary, state and federal water borders, and marine protected areas.

Aquaculture Opportunity Area (AOA): An AOA is a defined geographic area that NOAA has evaluated through both spatial analysis and the National Environmental Policy Act (NEPA) process to determine its potential for commercial aquaculture.[1]

Distribution Mapping and Analysis Portal (DisMAP): DisMAP is an interactive website designed to provide visualization and analysis tools to track, understand, and respond to shifting distributions of marine species. It allows users to examine changes in species distributions over time by looking at both location maps as well as graphs of key indicators of the distribution of a species. DisMAP data were used to conduct the three analyses in this study.

Geographic information system (GIS): A computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface.

High–high cluster area: A geospatial dataset reflecting statistically significant clusters ($p < 0.05$) of the highest suitable scores resulting from the relative suitability analysis published in the **AOA Atlases**. When represented spatially as polygons, they contain the **AOA options**.

Interpolated Biomass: The method used in **DisMAP** in which catch data are used to estimate unobserved population density across the **AOA study areas**.

Inverse Distance Weighting (IDW): An interpolation method that estimates species biomass in unknown geographic areas. This method is rooted in the assumption that spatially closer data values are more related than values further apart.

Raster: Representation of geographic data type where data are stored as a grid of regularly sized pixels along with attribute data.

[1] As of the time of publication, no AOAs have been established.

Weight-catch-per-unit-effort (WTCPUE): This is a standardized measure of the biomass of species captured in one location, listed as kg/ha. WTCPUE higher than zero at a given coordinate indicates that a species was encountered (for point data) or predicted to be encountered (for interpolated biomass) at that location.

Executive Summary

The purpose of this study is to provide an exploratory analysis of the spatial overlap of wild species where the National Oceanic and Atmospheric Administration (NOAA) is currently working to identify Aquaculture Opportunity Areas (AOAs). No AOAs have been established thus far, but two AOA study areas are currently under evaluation—the Gulf of Mexico and the Southern California Bight—with a third in the initial stages of evaluation in Alaska. This study builds upon earlier work that determined the overlap of various protected species, essential fish habitat (EFH), and highly migratory species (HMS) distributions with the AOA study areas. This study was originally developed as a section on wild species overlap as part of an earlier technical memorandum evaluating the current science regarding potential disease transfer between aquacultured and wild organisms in the study areas. However, the authors determined that this spatial analysis may inform other uses, such as discussions of genetic hybridization or introgression potential between wild and farmed species, aquaculture's potential impacts on species distributions, and the overlapping uses of the marine environment by various interested parties. This paper seeks only to describe the spatial overlap of wild species using the available data, and does not estimate the potential risk level of any impacts associated with marine aquaculture in these regions.

In this study, we conducted three analyses to address different questions relating to degree of spatial overlap between AOA study areas and wild species using data found in NOAA's Distribution Mapping and Analysis (DisMAP) tool. In the first analysis, we sought to determine whether a species had been observed at any point within a study area's high–high clusters based on the fishery-independent bottom trawl survey data downloaded from the DisMAP tool. High–high clusters reflect subsections of the study areas that received the highest statistically significant ($p < 0.05$) scores in the relative suitability analysis published in the AOA Atlases. We performed this analysis for 52 species in the Gulf of Mexico and Southern California Bight (Appendix A). The second analysis sought to estimate the proportion of a species' biomass (within the DisMAP survey region) that fell within the study areas defined in the AOA Atlases. We performed this analysis on a twelve-species subset of the first 52. The third analysis sought to understand how much of the study areas was covered by areas of extremely low, low, moderate, and high biomass for each species. In other words, we evaluated the relative biomass (referred to as percent area occupied) of each species throughout the study areas. We performed this analysis for the same twelve-species subset as the second analysis.

We downloaded wild species data from the DisMAP tool. The data provided in DisMAP were collected by fishery-independent bottom trawl surveys. These surveys cover the years 2008–21 in the Gulf of Mexico and 2003–22 on the U.S. West Coast (used for the Southern California Bight AOA study area analysis). The surveys cover large portions of the Gulf of Mexico and the U.S. West Coast; however, the survey areas are not comprehensive of the entire Gulf and U.S. West Coast exclusive economic zone (EEZ); therefore, the distribution data provided represent the distributions within the survey areas, and not necessarily the full distribution for each species. Additionally, this study does not include any fishery-dependent data. Future data from fishery-dependent sources may elucidate potential use conflicts between aquaculture siting and fishing activities. We selected species for analysis based on the availability of survey distribution data in DisMAP, the species' importance as

a fishery, protected status, expert input on industry interest and viability, and a species' taxonomic similarity to candidate species for U.S. marine aquaculture (Appendix E). The species list is not exhaustive, as these analyses' primary purpose was to highlight the methods employed. We expect that the analysis will expand as more data on wild species distributions become available. We describe the methods in detail for replication or expansion in the future. For this analysis, we exclusively use NOAA data, consisting of data from fishery-independent bottom trawl surveys accessed through the DisMAP tool, and the GIS files for the study areas outlined in the Gulf of Mexico and Southern California Bight AOA Atlases. The AOA study areas do not represent the only areas where people are interested in marine aquaculture. They were shaped by the specific goals related to identifying AOAs.

Across the three analyses, we saw overlap between most wild species analyzed and the AOA study areas, with variation between individual species. In the first analysis, 31 of the 52 species evaluated were documented in the high–high cluster areas (usually in low numbers). The second analysis suggests that most species do not see a majority of their survey range biomass concentrated in the AOA study areas, with notable exceptions. The third analysis suggests that, with exceptions, most of the wild species' spatial overlap with study areas is composed of areas of low relative biomass. However, while the AOA study areas do not tend to overlap with hotspots of biomass density for these twelve species, we make no claim about how the results should affect decisions about the suitability of marine aquaculture in the AOA study areas. This study can serve as a replicable framework for the characterization of potential overlap of species with marine aquaculture infrastructure. We anticipate that this study will paint a more complete picture of the potential for wild species overlap with marine aquaculture and inspire similar evaluations of individual species for future AOA identification work.

Introduction

The United States is a leading importer of seafood, due to an imbalance between demand for seafood products and amount produced domestically (*3*), and has sought to improve its domestic aquaculture sector as one method to minimize the seafood trade deficit. The most recent effort is a component of the 2020 executive order to promote American seafood competitiveness, which included directives to plan for marine aquaculture development in U.S. waters (*4*). The anticipated expansion of marine aquaculture corresponds with an increased need to understand and mitigate its impacts on the environment and wild species. There is a growing body of work underway to characterize these impacts. Of primary concern are impacts related to disease and biosecurity, genetics, economic/user conflicts with different operators in the marine environment, and environmental impacts from farms.

The transmission of disease or pathogens between wild and cultured organisms is an important concern for marine aquaculture given that most of the mechanisms for transmission require spatial proximity of host organisms (*5*), and spatial overlap between cultured species and wild species may provide that opportunity. Aquaculture operations in the marine setting exist in an environment where water moves freely between farms and the surrounding environment. If not properly managed, this open exposure between the farm and surrounding water may increase risk from the amplification and transmission of disease from farmed to wild fish, and the introduction of non-native pathogens and parasites when fish are transported (*6, 7*). Additionally, an important consideration for marine aquaculture is the potential for introgression between the conspecific farmed and wild organisms, as well as hybridization between different, but related, farmed and wild organisms (*8, 9*). Understanding these impacts can inform siting and species selection decisions for marine aquaculture.

Currently, NOAA is working to identify Aquaculture Opportunity Areas (AOAs) in the Gulf of Mexico and the Southern California Bight (*1, 2*). These areas are used by an array of interested parties who depend on them for fishing, other natural resource extraction, recreation, shipping, and other activities. These users can benefit from an understanding of where aquaculture farms may be sited and their potential impacts on wild species. Good site selection can help minimize the impacts of disease or pathogen transmission, and reduce over-accumulation of organic waste discharged from farms (*10, 11*). NOAA Fisheries is collaborating with various scientists and subject matter experts to develop science advice products that can be used as part of the AOA identification process. Two earlier technical memorandums sought to broadly characterize the science surrounding marine aquaculture disease and the best practices to manage disease and biosecurity hazards (*6, 12*). During the writing process, the authors determined that disease transmission potential and discussion of any potential biological, chemical, and physical hazards to the environment from aquaculture in specific areas is better understood when investigators are aware of the wild species present in or near proposed sites.

In this report, we perform additional spatial analysis to characterize the overlap between wild species and the AOA study areas to complement the AOA Atlases for the Gulf of Mexico and Southern California Bight. The Atlases analyzed potential overlap with wild species essential fish habitat (EFH), high-use areas (HUA) for species listed under the Endangered Species Act (ESA), and other factors (*1, 2*). To build upon this work, we use fishery-independent survey data and spatial distribution products from NOAA's Distribution Mapping and Analysis Portal (DisMAP) tool[1] to perform three analyses of individual species overlap with the AOA study areas. The analyses include shellfish and finfish species found in the Gulf of Mexico and on the U.S. West Coast, of which six species are understood to be the same or similar to potential candidates for commercial aquaculture in each region. This study seeks to add a more precise understanding of individual species distribution, especially those with potential for pathogen transfer, hybridization, or introgression with aquaculture candidate species. We expect that this analysis will provide further information to support identification of AOAs in the Gulf of Mexico and Southern California Bight.

[1] https://apps-st.fisheries.noaa.gov/dismap/DisMAP.html

Methods

We conducted three analyses in this study. The first analysis (survey catch occurrence point analysis) used fishery-independent bottom trawl survey catch location data to determine if, at any time, a species was observed inside the study area's high–high cluster areas. High–high clusters reflect statistically significant clusters ($p < 0.05$) of the highest scores from the relative suitability analysis published in the AOA Atlases (*1, 2*). The second analysis (biomass proportion analysis) used the interpolated biomass distribution layers and the spatial extents generated by DisMAP using the fishery-independent bottom trawl survey data to estimate the proportion of the species survey range biomass found within the study areas. The third analysis (percent area occupied) sought to understand the amount of the study area covered by areas of extremely low, low, moderate, and high biomass of each species, or the relative biomass density distribution of a species throughout the study area. To our knowledge, this analysis is the first attempt to use fishery-independent species survey data to characterize wild species overlapping with AOA study areas. For the survey catch occurrence point analysis (the first analysis), the high–high clusters were deemed a more reasonable spatial extent of analysis during conversations with NOAA experts involved in the AOA identification process. For the biomass proportion analysis (the second) and percent area occupied analysis (the third), we evaluated species overlap with the larger AOA study areas given the large spatial ranges of the species distributions.

Spatial Data Layers

AOA Atlas spatial areas

In this report, we focus on AOA study areas in the Gulf of Mexico and the Southern California Bight. Each AOA study area includes three different area classifications: one for the overall study area (the largest), one for high–high cluster areas (the second-largest), and one for the AOA options (the smallest; Figure 1). AOA options are areas that received the highest relative suitability scores following comprehensive spatial analysis (i.e., final suitability model results) published in the AOA Atlases (*1, 2*).[2] Following discussion with subject matter experts, this report focuses on species overlap with the high–high clusters (survey catch occurrence analysis) and study areas (biomass proportion and percent area occupied analyses). The high–high clusters were deemed reasonable for the survey catch occurrence analysis to understand wild species presence, and the AOA options were determined to be too spatially limited for a reasonable analysis of overlap. There are 246 total high–high clusters throughout the Gulf of Mexico AOA study area, and seven total clusters in the Southern California Bight AOA study area. The shapefiles of the study areas used for the AOA Atlas spatial studies were obtained from the NOAA authors of the AOA Atlases.[3]

[2] AOA options are each named and classified, and those classifications are used in the results section, charts, and appendices of this study. For more information on individual AOA options, refer to the AOA Atlases.
[3] Note that the AOA options in the Gulf of Mexico and Southern California Bight are represented as polygons 500 to 2,000 acres in size; however, due to a difference in mapping scale, they do not appear in Figure 1.

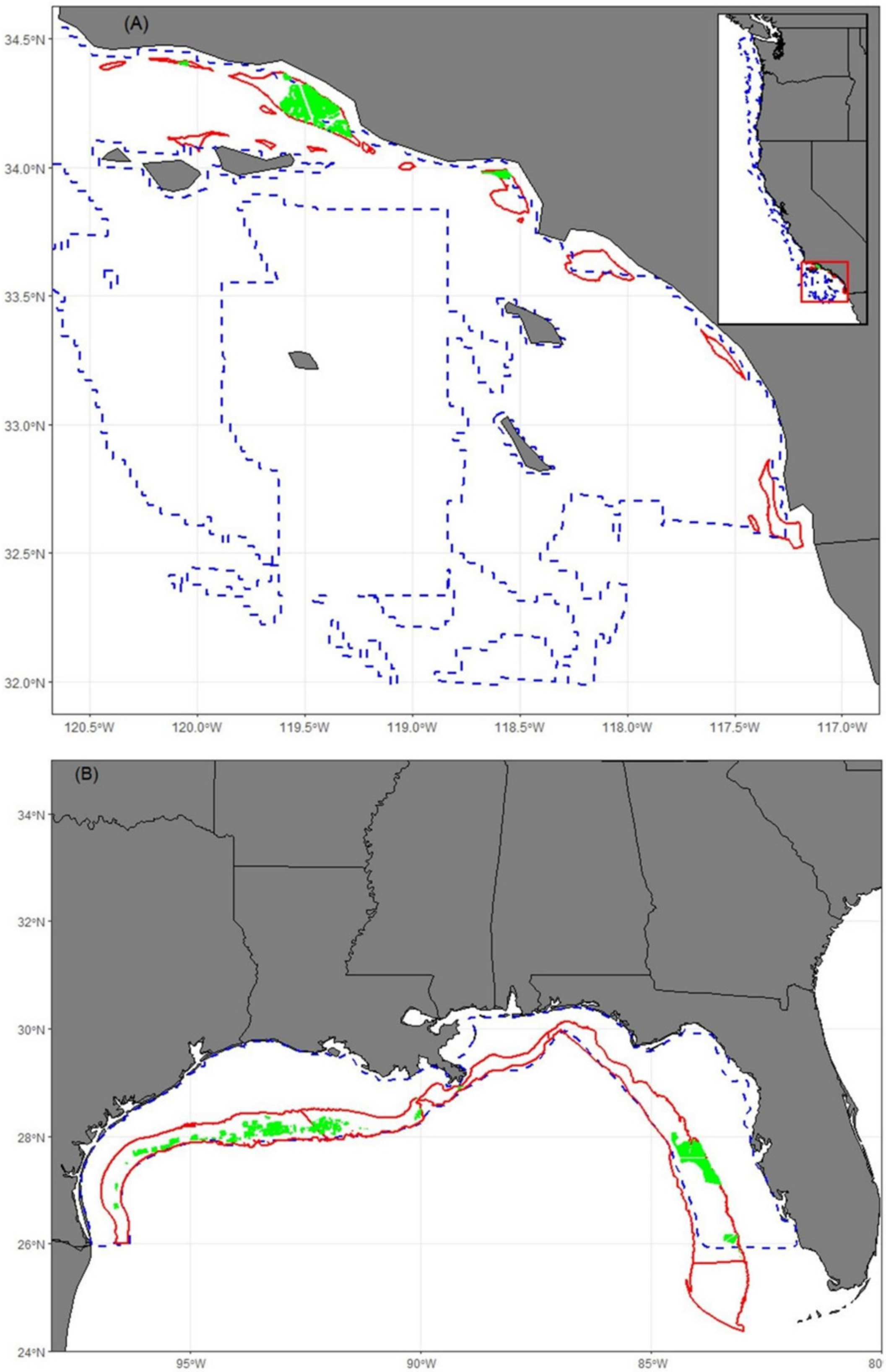

Figure 1. AOA study areas and survey extent in the Southern California Bight (top) and Gulf of Mexico (bottom). The survey extents are indicated by the dashed blue outlines, and the AOA study areas by the solid red outlines. The high–high clusters are indicated in green.

Species occurrence and distribution data

All species distribution data and products used in this report were obtained from the DisMAP website.[4] DisMAP is an online tool enabling users to access and visualize data on species distributions collected by NOAA fishery-independent bottom trawl surveys. We provide a brief summary of the processing used by DisMAP here, but for more detailed information on the data processing, please see the DisMAP Technical Report.[5] The DisMAP team compiled and processed data from fishery-independent surveys across the United States into a standard format with common data structures and variable names. DisMAP also standardizes each survey for a consistent footprint by removing strata that have poor temporal coverage, and years with poor sampling coverage. The data are further trimmed to only include species that are caught in at least 5% of tows in a year for at least 75% of the years surveyed. The final processed survey data include a haul ID, latitude, longitude, year, stratum, stratum area, depth, and weight-catch-per-unit-effort (WTCPUE) for each species. WTCPUE is a metric of the amount of biomass of a species caught by a survey at a given location, standardized to the amount of area swept (or sampled) by the survey tow and then converted to kilograms per hectare (kg/ha). We cleaned the survey catch data downloaded from the web for each species of interest prior to analysis in ArcGIS Pro (Esri, Redlands, California) to remove any points in which the WTCPUE was zero, indicating the species was not observed at that location. Individual coordinates with a WTCPUE above zero indicate locations where a species was documented. Additionally, data were cleaned to exclude the haul data, stratum, and depth, for easier uploading of points into the ArcGIS application as point data.

Interpolated biomass distribution layers were also obtained from DisMAP for the twelve species evaluated in the second and third analyses (see Species Evaluated). The data processing and interpolation methods are provided in detail in the DisMAP Technical Report, so we provide only a brief overview of those methods here. These layers were generated by interpolating the fishery-independent survey occurrence point data across the entire survey domain (areas outlined in blue in Figure 1) using the inverse distance weighting (IDW) interpolation method. A common approach for population estimates in aquatic species (*3*), IDW is an interpolation method that estimates species biomass in unsampled areas by assuming that closer data values are more related than further values. In this case, the values are the standardized WTCPUE (i.e., species biomass density in kg/ha) recorded at each sampling location in the fishery-independent bottom trawl surveys. IDW calculations help estimate the biomass density at coordinates that were not surveyed, therefore providing a raster of estimated species biomass density across the entire survey domain. For the purposes of this report, we combined the individual-year distribution layers obtained from DisMAP into five-year time blocks and then averaged across those five-year intervals. Polygons representing the fishery-independent survey domains of the U.S. West Coast and the Gulf of Mexico study areas used in this analysis were provided by DisMAP.

[4] https://apps-st.fisheries.noaa.gov/dismap/DisMAP.html#single-species-distributions
[5] https://apps-st.fisheries.noaa.gov/dismap/docs/DisMAP_Tech_Report_with_Table_04_2023.pdf

There are important caveats to the data and analysis that can be conducted using the DisMAP tool. For example, in the Southern California Bight, the trawl surveys omit a cowcod conservation area that may impact the overall species distribution by undercounting potential occurrences and subsequently underestimating distribution and abundance.[6] However, the conservation areas do not overlap with the AOA study areas. Additionally, the spatial extent of the survey catch data and interpolated biomass layers is based on the boundaries of the survey sampling domain (Figure 1). Analyses were done using these spatial extents, and any conclusions about biomass and distribution of wild species only reflect these ranges. This report makes no attempt to infer about overall species populations and distributions that fall outside of the Gulf of Mexico and U.S. West Coast surveys' spatial extents. Additionally, we note that the spatial extents of the surveys and AOA study areas do not overlap entirely. The southernmost region of the Gulf of Mexico AOA study area near Florida falls outside the Gulf of Mexico survey domain, and there are places in the Southern California Bight where the AOA study area extends slightly outside of the survey domain. Therefore, our estimates of potential overlap are likely conservative on the side of underestimating the true overlap for the species analyzed.

Species Evaluated

Species evaluated in this study were chosen on the basis of their importance to commercial and recreational fishing (*3*), ESA listing status, highly migratory species (HMS) status, and taxonomic similarities (especially if conspecific) to candidate species for marine aquaculture (*13–16*). Species were selected from DisMAP and then cross-referenced with the NOAA Fisheries website to confirm that the species was of commercial or recreational importance, or if it had a special designation (e.g., an ESA listing). Species that were taxonomically like candidate aquaculture species (Appendix E) were selected due to their potential for pathogen exchange, hybridization, and introgression with wild conspecifics and similar species. Apart from conspecifics, species were selected if they shared a genus with the candidate aquaculture species. Additionally, species were selected to loosely reflect different morphologies and locations in the water column, such as demersal flatfish, invertebrates, reef fish, and midwater finfish, even if they were not found to have an important fishery or similarity to candidate aquaculture species. Diverse species were selected to showcase the diverse results from the analyses, as well as the proof of concept for the study. Each species' rationale for selection is explained in Appendix B.

Given time constraints, the survey catch occurrence point analysis considered more species ($n = 52$) from the Gulf of Mexico and U.S. West Coast DisMAP database than were evaluated for the biomass proportion and area occupied analyses ($n = 12$; Appendix A, Appendix C, Appendix D). Of the 52 species in the survey catch occurrence point analysis, five are represented on the marine aquaculture candidate species list; these were sablefish, California halibut/flounder, southern flounder, greater amberjack, and black sea bass. One additional species from the *Seriola* genus was evaluated for overlap, the banded rudderfish, as three species from that genus are candidates for marine aquaculture. Furthermore, we evaluated eleven species of flatfish, including two from the *Paralichthys* genus.

[6] Scientific names of species analyzed in this report are provided in Appendix A.

For the proportion and percent area analyses, we used a subset of twelve species from the survey catch occurrence point analysis. We chose to again focus on wild species that are conspecific or share a genus with marine aquaculture candidate species, and that are of importance to recreational and/or commercial fishing. For the Southern California Bight, we evaluated aquaculture candidate species California halibut/flounder and sablefish. Additionally, we analyzed data for Pacific pompano, lingcod, and English sole, hoping to highlight a diverse set of fished species from the broader list of species on the U.S. West Coast. For the Gulf of Mexico, aquaculture candidate species southern flounder, greater amberjack, and black sea bass were evaluated, along with banded rudderfish, vermilion snapper, fringed flounder, and red snapper. Red snapper and vermilion snapper were selected given their importance to Gulf of Mexico fisheries, and fringed flounder was chosen to represent flatfish. This set of twelve species is not intended to be exhaustive, but we present results for these species here as a proof of concept of the methodology.

In the most recent update to the DisMAP tool, California halibut/flounder was removed from the U.S. West Coast, and greater amberjack and black sea bass were removed from the Gulf of Mexico, as their occurrences in the trawl surveys in those regions were deemed too infrequent to provide robust estimations of shifts in distribution.[7] Multiple other species were removed (see Appendix A and Appendix B). However, given that these three species are considered candidates for marine aquaculture, we kept their data as part of the analysis, using an earlier version of DisMAP data. We anticipate that the methods used in this study are replicable to evaluate additional species.

Analyses

First analysis: Survey catch occurrence point analysis

In this first analysis, we used ArcGIS Pro (ESRI, Redlands, California) to plot species occurrence data from the fishery-independent surveys alongside the AOA Atlases' high–high cluster polygon shapefiles (*1, 2*) to evaluate overlap (as binary yes/no), prior to more advanced analysis of distribution overlap.

We uploaded the AOA Atlas shapefiles into ArcGIS Pro, including separate files for the study areas, high–high clusters, and the AOA options. Afterwards, the positive species occurrence coordinate data were uploaded using the **Add XY Coordinates** function in ArcGIS Pro. Once uploaded, the data were then analyzed to count the number of points (referred to in this study as "occurrences") of overlap that a species had with the high–high cluster, as well as documenting any points within high–high clusters that contained AOA options. To do this analysis, we used the **Summarize Within** feature in ArcGIS. This tool counted the number of points in each cluster and the latest year in which a point occurred in each cluster.

[7] Species were kept for display in the portal if they were caught in at least 5% of tows in a given year for at least 75% of the survey years in a given region. Therefore, many species were removed in the update. Data from the earlier trawl surveys that include these organisms are available upon request from dismap.contact@noaa.gov.

Data from each species' attribute table were then used to write a summary of an individual species's overlap. For example, bocaccio overlapped with one high–high cluster in two places (Appendix B) out of 757 total positive catch occurrences. Additionally, some high–high clusters contained AOA options, areas that received the highest relative suitability scores in the AOA Atlases (*1, 2*). Therefore, additional observation was performed to determine if an occurrence overlapped with a high–high cluster containing an AOA option. Occurrences in the high–high clusters that also contained AOA options were documented and included in each species summary. Finally, we also determined if multiple occurrences were documented within 10 km of the AOA options while still falling outside of the **Summarize Within** analysis. This was done to provide a better indication of potential overlap, in consideration of the fact that survey hauls may not always be done within a high–high cluster but may be collected close to one.

Second analysis: Biomass proportion analysis

The second analysis used the interpolated biomass species distribution raster layers to estimate the proportion of each species' survey area biomass that was found within the AOA study areas. The calculation of this proportion involved two steps: 1) calculating the total biomass within the full survey extent, and 2) calculating the biomass within the AOA study area. To do this, we used the **Clip Raster** function to crop each five-year average biomass distribution raster to the AOA study area polygon. This created two rasters for comparison, one of biomass estimates within the survey area, and one of biomass residing only within the AOA study areas. The **Calculate Zonal Statistics** tool from ArcGIS Pro was then used to calculate the estimated biomass inside the AOA study area from the clipped raster, as well as the estimated biomass within the overall survey region using the full raster. GIS shapefiles for the fishery-independent survey areas of the U.S. West Coast and the Gulf of Mexico study areas used in this analysis were provided from DisMAP. The estimates for inside the AOA study area were divided by the estimates for the overall region, creating a proportion (represented as a percentage) of the average species biomass that was found in the AOA study area versus outside of the study area for each five-year period. When reporting results, two decimal places were used to quantify the extent of overlap. If nonzero figures did not occur by the second decimal, the overlap percent was reported as 0.00%.

Third analysis: Percent area occupied analysis

The third analysis focused on evaluating the percentage of each study area that was covered by a species' predicted distribution. We converted the biomass density distribution rasters into maps of the distribution of biomass quartiles to determine the overall or total area occupied within the study area and how much of the area comprised extremely low, low, medium, or high biomass values. Quartile distribution maps were produced from population percentiles resulting from the predicted WTCPUE distribution from the interpolated biomass distribution rasters. To do this, we extracted the raster values into a dataframe, removed WTCPUE values of zero, and then ordered the remaining values by their WTCPUE from greatest to least using *R* version 4.3.1. Three population quantiles were selected (25%, 50%, 75%) and identified using the **quantile()** function in R. These quantiles were then used as breakpoints to separate the WTCPUE values into four WTCPUE categories, then mapped to show the distribution of quantiles (*17*). For the purposes of this analysis, we refer to biomass values below the 25th percentile (lowest 25% of biomass values) as “extremely low relative biomass,” values between the 25th and 50th percentile values as “low relative biomass,” between the 50th and 75th percentiles as “moderate relative biomass,” and above the 75th percentile as “high relative biomass.”

Following the same process as for the proportion analysis, we then used the **Clip Raster** function to create a new raster representing the species biomass categories that fell within the AOA study area. After clipping the rasters to the AOA study area polygons, we used the **Calculate Zonal Geometry** tool from ArcGIS Pro to calculate the total area covered and the area of each relative biomass category within the AOA study area. We then divided these values by the area of the AOA study area to obtain a proportion occupied by each relative biomass category, represented as a percentage. As with the biomass proportion analysis, two decimal places were used to quantify the extent of overlap. If nonzero figures did not occur by the second decimal, the overlap percent was rounded to and listed as 0.00%.

Results

In this section, we provide high-level summaries of each of the three analyses. Individual characterizations of the overlap of each species can be found in Appendix B, Appendix C, and Appendix D. The analyses are descriptive in nature and do not seek to evaluate the level of impact posed by the extent to which an individual species overlaps with an AOA study area.

Survey Catch Occurrence Point Analysis

There were 8,623 unique hauls with positive catch occurrence for at least one species in the Southern California Bight AOA study area in the West Coast Bottom Trawl Survey (WCBTS) from 2003 to 2022, and 3,727 hauls in the SEAMAP Gulf of Mexico trawl survey from 2008 to 2021. Species occurrences are listed in Tables 1 and 2 in three ways: 1) the number of overall occurrences of the species in the study region, 2) the number of points documented inside high–high clusters, and 3) the number of points in clusters that contain AOA options. Also, the AOA options' names, as created in the AOA Atlases, are listed in the second column from the right. We also indicate in the tables if there were multiple points observed within 10 km of an AOA option, but outside of the high–high cluster. Finally, language that discusses the number of documented occurrences in an area of interest relates back only to the fisheries-independent bottom trawl surveys from which the occurrence data were derived, and does not include observer (fishery-dependent), commercial, or recreational fishing data.

In the Gulf of Mexico, 20 of the 35 species analyzed had documented occurrences in the high–high clusters that contained AOA options. In the Southern California Bight, 11 of the 17 species analyzed had documented occurrences in the high–high clusters that contained AOA options.

Of the five candidate species for aquaculture (Appendix E) reviewed in this study, four were found in the AOA study areas, and only two in high–high clusters. In the Southern California Bight, candidate species sablefish and California halibut/flounder were documented once each in high–high clusters. In the Gulf of Mexico, candidate species southern flounder was not observed as overlapping with any high–high clusters, but it did have several points within the overall AOA study area. Greater amberjack was not observed in the high–high clusters in the Gulf of Mexico and had few documented occurrences in the AOA study area. Finally, black sea bass was not documented in the high–high clusters nor in the AOA study area in the Gulf of Mexico, appearing to concentrate nearer to shore along the Florida coast.

Biomass Proportion Analysis

Of the seven Gulf of Mexico species analyzed for biomass proportion inside the Gulf of Mexico AOA study area, red snapper, southern flounder, and vermilion snapper had the highest estimated biomass proportions (Table 3, Figure 2). Red snapper trended downward in the proportion of its biomass in the AOA study area, falling under 50% in the final two periods. Southern flounder increased slightly, to nearly 50% in the final survey period. The proportion of vermilion snapper's survey range biomass found within the AOA study area

Table 1. Overlap of wild species evaluated in the data point analysis of the Gulf of Mexico. The first two columns summarize the number of trawl survey samples and the number of samples that resulted in an occurrence (*Occ.*) of that species. The last four columns show the number of occurrences documented in the high–high clusters, and additional information about specific AOA options within those clusters.

Species[a]	Samples taken in region since 2008	Occ. in region	Occ. in AOA HH clusters	Occ. in HH clusters containing an AOA option	AOA options in clusters of overlap	Points within 10 km of clusters containing AOA options
Finfish						
Atlantic croaker	3,727	1,523	31	1	C-11	14
Banded rudderfish*	3,727	38	0	0	n/a	0
Black sea bass*	3,727	63	0	0	n/a	0
Bluefish*	3,727	34	0	0	n/a	0
Dusky flounder	3,727	1,116	37	32	E-3, E-4	2
Fringed flounder	3,727	563	0	0	n/a	0
Gag grouper*	3,727	25	2	2	W-4, E-4	0
Gray flounder*	3,727	129	7	7	E-3, E-4	0
Gray snapper	3,727	251	3	3	E-3	0
Gray triggerfish	3,727	438	2	2	W-4, E-4	0
Greater amberjack*	3,727	76	0	0	n/a	0
Gulf butterfish	3,727	1,543	49	7	W-1, C-13, W-4	8
Gulf flounder*	3,727	63	0	0	n/a	0
Gulf menhaden*	3,727	144	0	0	n/a	0
King mackerel*	3,727	71	0	0	n/a	0
Red grouper	3,727	260	0	0	n/a	0
Red snapper	3,727	1,276	16	8	W-4, C-13, E-3	0
Sash flounder	3,727	493	47	6	W-1, W-4	9
Shelf flounder*	3,727	77	1	1	E-4	0
Shoal flounder	3,727	10	1	1	W-4	0
Southern flounder*	3,727	195	0	0	n/a	0
Spanish mackerel*	3,727	84	0	0	n/a	0
Spiny flounder*	3,727	182	5	1	W-4	0
Vermilion snapper	3,727	546	26	18	C-13, E-1, E-3, E-4	10
Mollusks						
Atlantic thorny oyster*	3,727	14	1	1	E-3	0
Atlantic wing oyster*	3,727	36	0	0	n/a	0
Calico scallop*	3,727	192	1	1	E-3	0
Mossy scallop*	3,727	48	0	0	n/a	0
Paper scallop	3,727	729	57	8	W-4, C-13, E-3	0
Ravenel scallop*	3,727	116	3	3	E-3, E-4	0

[a] Species marked with asterisks represent those whose survey data were removed in the most recent DisMAP update, but are archived and available upon request from dismap.contact@noaa.gov. Species were kept for display in the portal if they were caught in at least 5% of tows in a given year for at least 75% of the survey years in a given region.

Table 1 (continued). Overlap of wild species evaluated in the data point analysis of the Gulf of Mexico.

Species[a]	Samples taken in region since 2008	Occ. in region	Occ. in AOA HH clusters	Occ. in HH clusters containing an AOA option	AOA options in clusters of overlap	Points within 10 km of clusters containing AOA options
Crustaceans						
Blue crab	3,727	676	1	0	n/a	0
Brown shrimp	3,727	2,165	58	7	W-1, W-4, C-13	9
Northern white shrimp	3,727	687	0	0	n/a	0
Pink shrimp	3,727	791	6	4	E-3, E-4	0
Echinoderms						
Purple spined sea urchin*	3,727	177	0	0	n/a	0

Table 2. Overlap of wild species evaluated in the data point analysis of the Southern California Bight. The first two columns summarize the number of trawl survey samples and the number of samples that resulted in an occurrence (*Occ.*) of that species. The last four columns show the number of occurrences documented in the high–high clusters, and additional information about specific AOA options within those clusters.

Species[a]	Samples taken in region since 2,008	Occ. in region	Occ. in AOA HH clusters	Occ. in HH clusters containing an AOA option	AOA options in clusters of overlap	Points within 10 km of clusters containing AOA options
Finfish						
Arrowtooth flounder	8,623	793	0	0	n/a	0
Bocaccio	8,623	757	2	2	N1-A, N1-B, N1-C	12
California halibut/flounder*	8,623	80	1	1	N1-A, N1-B, N1-C	0
Canary rockfish	8,623	871	0	0	n/a	0
Dover sole	8,623	7,239	5	4	N1-A, N1-B, N1-C, CN1-A, CN1-B	33
English sole	8,623	4,264	31	11	N1-A, N1-B, N1-C, N2-A, N2-B, N2-C, N2-D, N2-E, CN1-A, CN1-B	20
Eulachon	8,623	722	1	1	N1-A, N1-B, N1-C	0
Lingcod	8,623	3,440	9	9	N1-A, N1-B, N1-C, N2-A, N2-B, N2-C, N2-D, N2-E, CN1-A, CN1-B	18
Northern anchovy	8,623	265	3	3	N1-A, N1-B, N1-C, N2-A, N2-B, N2-C, N2-D, N2-E	9

[a] Species marked with asterisks represent those whose survey data were removed in the most recent DisMAP update, but are archived and available upon request from dismap.contact@noaa.gov. Species were kept for display in the portal if they were caught in at least 5% of tows in a given year for at least 75% of the survey years in a given region.

Table 2 (continued). Overlap of wild species evaluated in the data point analysis of the Southern California Bight.

Species[a]	Samples taken in region since 2,008	Occ. in region	Occ. in AOA HH clusters	Occ. in HH clusters containing an AOA option	AOA options in clusters of overlap	Points within 10 km of clusters containing AOA options
Pacific halibut	8,623	793	0	0	n/a	0
Pacific pompano	8,623	564	20	19	N1-A, N1-B, N1-C, N2-A, N2-B, N2-C, N2-D, N2-E, CN1-A, CN1-B	19
Sablefish	8,623	5,053	1	1	CN1-A, CN1-B	7
Starry flounder	8,623	152	0	0	n/a	0
Yelloweye rockfish	8,623	251	0	0	n/a	0
Mollusks					n/a	
California market squid	8,623	2,111	3	3	N1-A, N1-B, N1-C, N2-A, N2-B, N2-C, N2-D, N2-E	10
Vancouver scallop*	8,623	83	0	0	n/a	0
Weathervane scallop*	8,623	67	1	1	CN1-A, CN1-B	3

Table 3. Proportions of species biomass estimated to overlap with the Gulf of Mexico and Southern California Bight AOA study areas, represented as percentages. While no proportions were numerically zero in absolute terms, in many cases the figures most closely rounded to 0.00% of the total estimated biomass in the regions.

	Estimated proportion of species biomass within AOA study areas (%)		
Species[a]	**2008–12**	**2013–17**	**2018–21**
Gulf of Mexico			
Banded rudderfish	0.00%	0.00%	0.00%
Black sea bass*	0.00%	0.00%	0.00%
Fringed flounder	1.09%	0.49%	1.02%
Greater amberjack*	2.85%	3.91%	6.87%
Red snapper	54.44%	47.62%	45.41%
Southern flounder*	43.50%	38.13%	48.88%
Vermillion snapper	27.00%	33.69%	52.53%
Southern California Bight			
California halibut/flounder*	15.10%	14.28%	9.74%
English sole	1.39%	2.43%	1.24%
Lingcod	0.02%	0.26%	1.00%
Pacific pompano*	25.13%	31.17%	14.70%
Sablefish	0.00%	0.00%	0.00%

[a] Species marked with asterisks represent those whose survey data were removed in the most recent DisMAP update, but are archived and available upon request from dismap.contact@noaa.gov. Species were kept for display in the portal if they were caught in at least 5% of tows in a given year for at least 75% of the survey years in a given region.

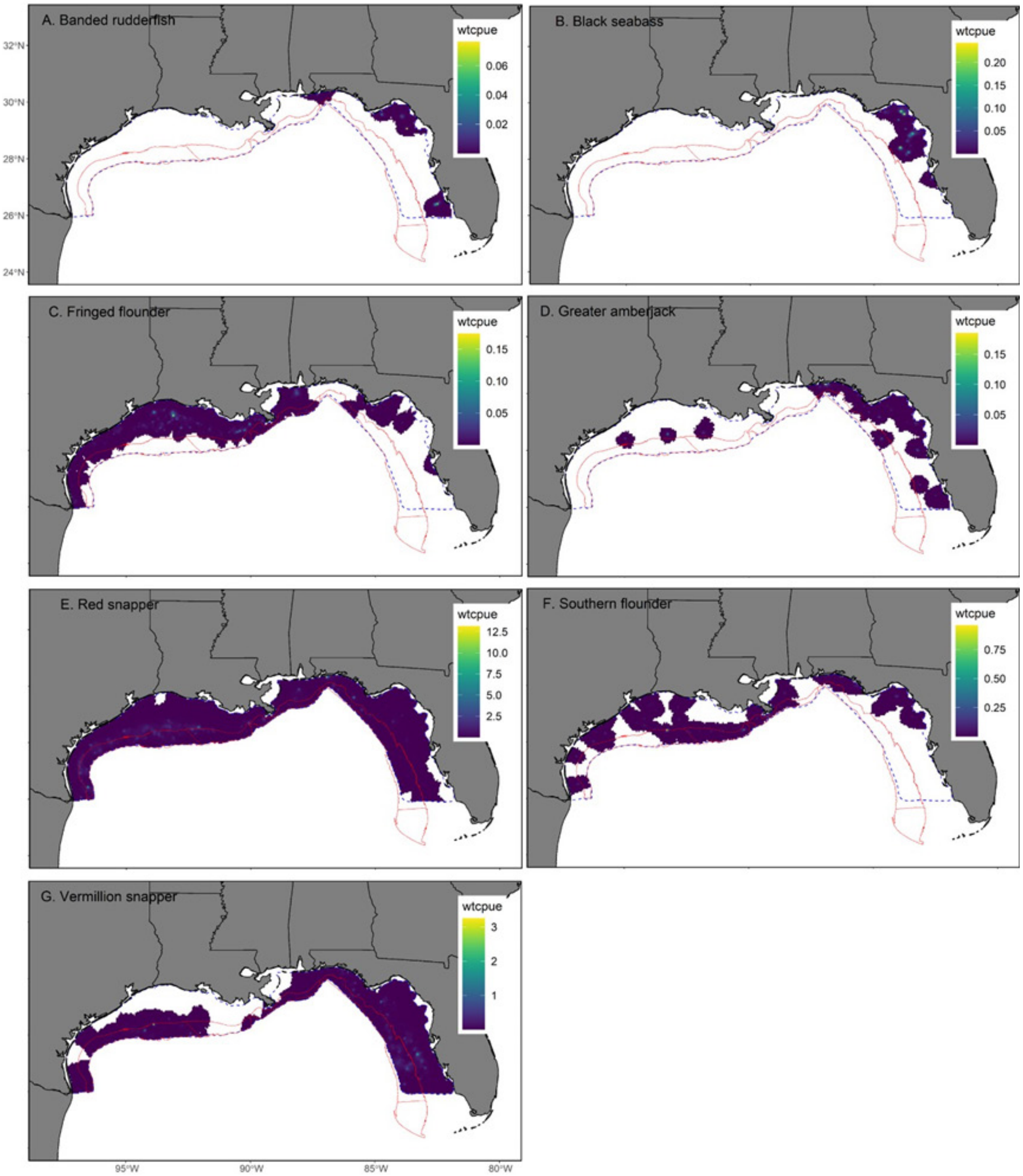

Figure 2. Maps of species distribution overlap with AOA study areas in the Gulf of Mexico for the biomass proportion analysis. WTCPUE units are displayed in kg/ha. This figure represents the most recent time block.

increased from 27% to 52% over the survey periods. Greater amberjack biomass was less represented, ranging from estimates of 2.85–6.87% of its estimated biomass in the Gulf of Mexico survey domain residing within the AOA study areas. The remaining three species (banded rudderfish, black sea bass, and fringed flounder) all had < 1% of their survey area biomass estimated within the AOA study area throughout all survey periods (Table 3, Figure 2a–c). For banded rudderfish and black sea bass, the proportions of their biomass found within the Gulf of Mexico study area rounded to 0.00%.

On the U.S. West Coast, while each of the species' biomass distributions showed some overlap with the AOA study area polygons, the proportional biomass found within the AOA study areas seems to depend on whether the species is broadly distributed throughout the

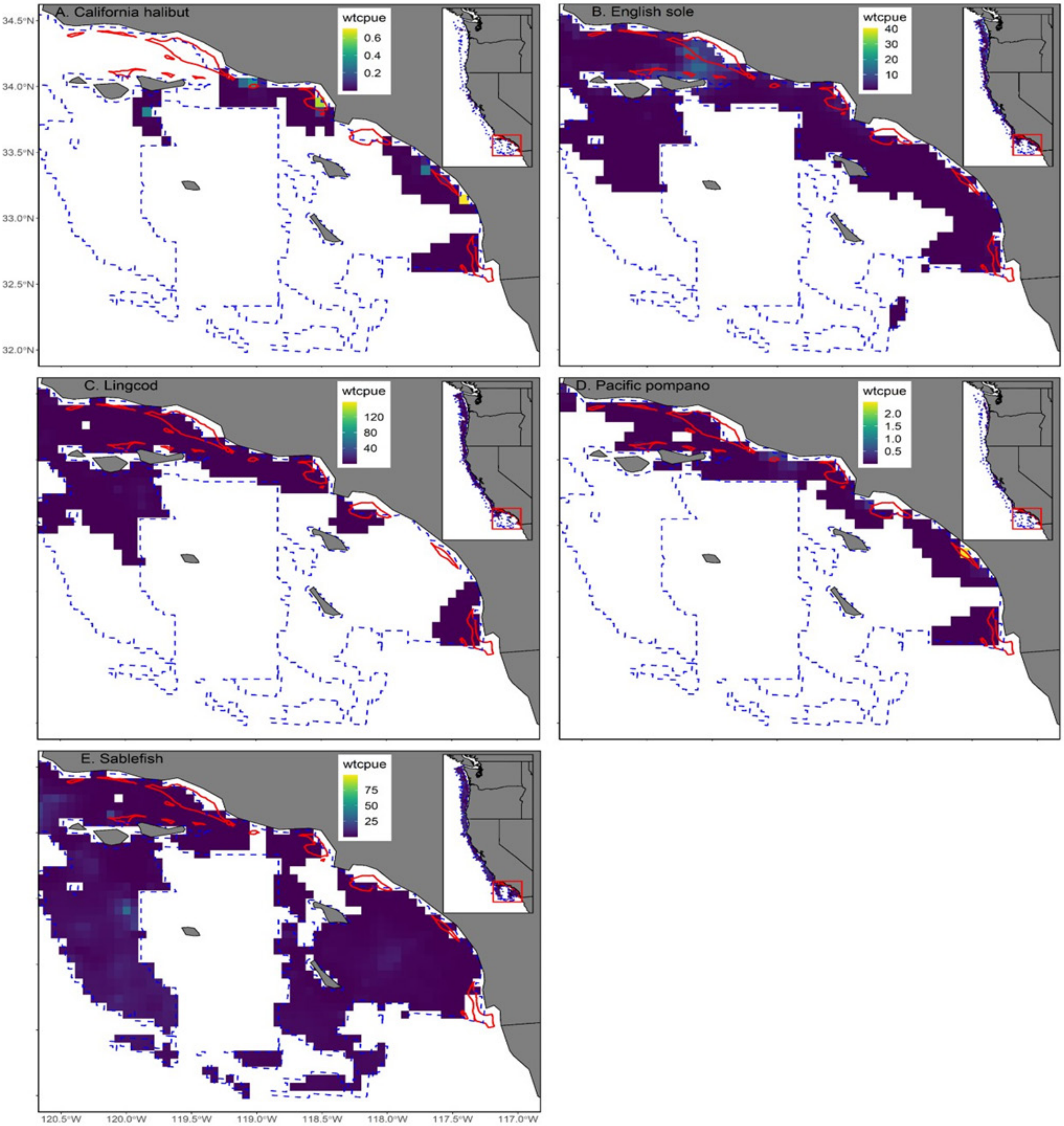

Figure 3. Maps of species distribution overlap with AOA study areas in the Southern California Bight for the biomass proportion analysis. WTCPUE units are displayed in kg/ha. This figure represents the most recent time block. Inset maps show the full distribution of species within the survey domain.

survey domain, more localized, or patchy (Table 3, Figure 3). California halibut/flounder and Pacific pompano, for instance, have more localized and patchy distributions within the survey domain, and had the greatest calculated proportions of their biomass found within the study area over the four survey periods. California halibut distributions were fairly consistent, with 15.10% and 14.28% of the biomass in the AOA study area in the 2003–07 and 2008–12 periods, respectively. The proportion declined to 9.74% from 2013–17, but then rebounded to 16.28% in 2018. For Pacific pompano, there is a decreasing trend in biomass within the AOA study areas through time. The 2003–07 and 2008–12 periods estimated 25.13% and 31.17% of the species biomass, respectively, to reside in the AOA study area; that proportion declined to an estimated 14.70% from 2013–17 and 15.42% in 2018, suggesting that the species is becoming less prominent within the AOA study area in Southern California. English sole, lingcod, and sablefish all had broader distributions throughout the entire survey domain, and had between 0.00% and 2.43% of their total survey range biomass calculated to reside in the AOA study areas.

Percent Area Occupied Analysis

In the Gulf of Mexico, banded rudderfish, black sea bass, and the greater amberjack's biomass distributions covered a small proportion of the AOA study area (< 10%) and were primarily represented by areas of extremely low or low relative biomass (i.e., biomass values less than the 25th and 50th percentile values). Fringed and southern flounders inhabit a greater proportion of the AOA study area, at 20–30%, and the AOA study area overlaps with areas of all four relative biomass categories; however, most of the overlap is with extremely low and low biomass for fringed flounder. Red and vermilion snapper cover the greatest proportion of the AOA study area, both exceeding 60% across all survey periods. Additionally, the overlapping area comprised a greater proportion of moderate and high relative biomass areas compared to the other species evaluated in the Gulf of Mexico. Additionally, red snapper saw a 10% increase in the area occupied from the 2008–12 time period to the 2018–21 period. It is also important to note that, while vermilion snapper occupied a larger proportion of the study area, with a large amount of that area being high relative biomass areas, the estimated WTCPUE for this species was quite low, with a highest predicted WTCPUE of 3.25 kg/ha. See Table 4 and Figure 4 for more details.

All species in the Southern California Bight had high coverage of the study area overall, with > 50% coverage in at least one survey period. Except for lingcod and sablefish, much of the area occupied within the study area (> 20%) was made up of high biomass areas. For California halibut/flounder, English sole, and Pacific pompano, this overlapping area within the AOA study area comprised mostly moderate and high relative biomass areas. For lingcod and sablefish, on the other hand, the AOA study area was covered primarily by areas of extremely low or low relative biomass. See Table 5 and Figure 5 for more specific details across species and time periods. We note that each species' data and results should be considered on an individual basis, given that the four biomass density categories are relative to each individual species' minimum and maximum densities. For example, areas of high relative biomass for vermilion snapper are still quite low in terms of density, ranging from 0.012–3.25 kg/ha, while English sole had a much higher range in the portions of its distribution raster classified as high, ranging from 3.44–40.44 kg/ha.

Table 4. Proportions of the Gulf of Mexic AOA study area occupied by wild species at different biomass values. Percentages listed under the survey period columns are cumulative. Not all species were shown to have every possible species biomass value. Such cells are marked with a line (—).

		Percentage of AOA study area occupied		
Species	**Species biomass value**	**2008–12**	**2013–17**	**2018+[a]**
Banded rudderfish	Extremely low	0.34%	0.05%	0.14%
	Low	0.24%	—	0.24%
	Moderate	0.68%	—	—
	High	—	—	—
	Total	1.26%	0.05%	0.39%
Black sea bass	Extremely low	0.10%	0.10%	0.19%
	Low	—	—	—
	Moderate	—	—	—
	High	—	—	—
	Total	0.10%	0.10%	0.19%
Fringed flounder	Extremely low	17.00%	16.66%	10.31%
	Low	7.83%	10.28%	5.73%
	Moderate	3.90%	3.17%	1.60%
	High	0.31%	0.19%	0.80%
	Total	29.03%	30.29%	18.45%
Greater amberjack	Extremely low	1.22%	2.55%	1.53%
	Low	2.04%	2.65%	2.29%
	Moderate	0.76%	1.48%	1.83%
	High	0.76%	0.81%	2.70%
	Total	4.79%	7.48%	8.35%
Red snapper	Extremely low	9.59%	12.42%	13.10%
	Low	16.77%	16.58%	16.58%
	Moderate	14.94%	15.93%	17.84%
	High	20.40%	22.85%	23.95%
	Total	61.70%	67.77%	71.48%
Southern flounder	Extremely low	9.42%	7.03%	5.91%
	Low	10.08%	5.65%	6.92%
	Moderate	6.97%	8.15%	6.57%
	High	6.92%	7.99%	8.20%
	Total	33.40%	28.81%	27.59%
Vermilion snapper	Extremely low	10.66%	10.20%	12.30%
	Low	16.89%	16.81%	11.69%
	Moderate	21.09%	21.43%	18.64%
	High	16.12%	20.13%	26.05%
	Total	64.75%	68.57%	68.69%

[a] Most recent time block varies by species, as follows: For banded rudderfish, black sea bass, fringed and southern flounder, and greater amberjack, 2018–19; for red and vermilion snapper, 2018–21.

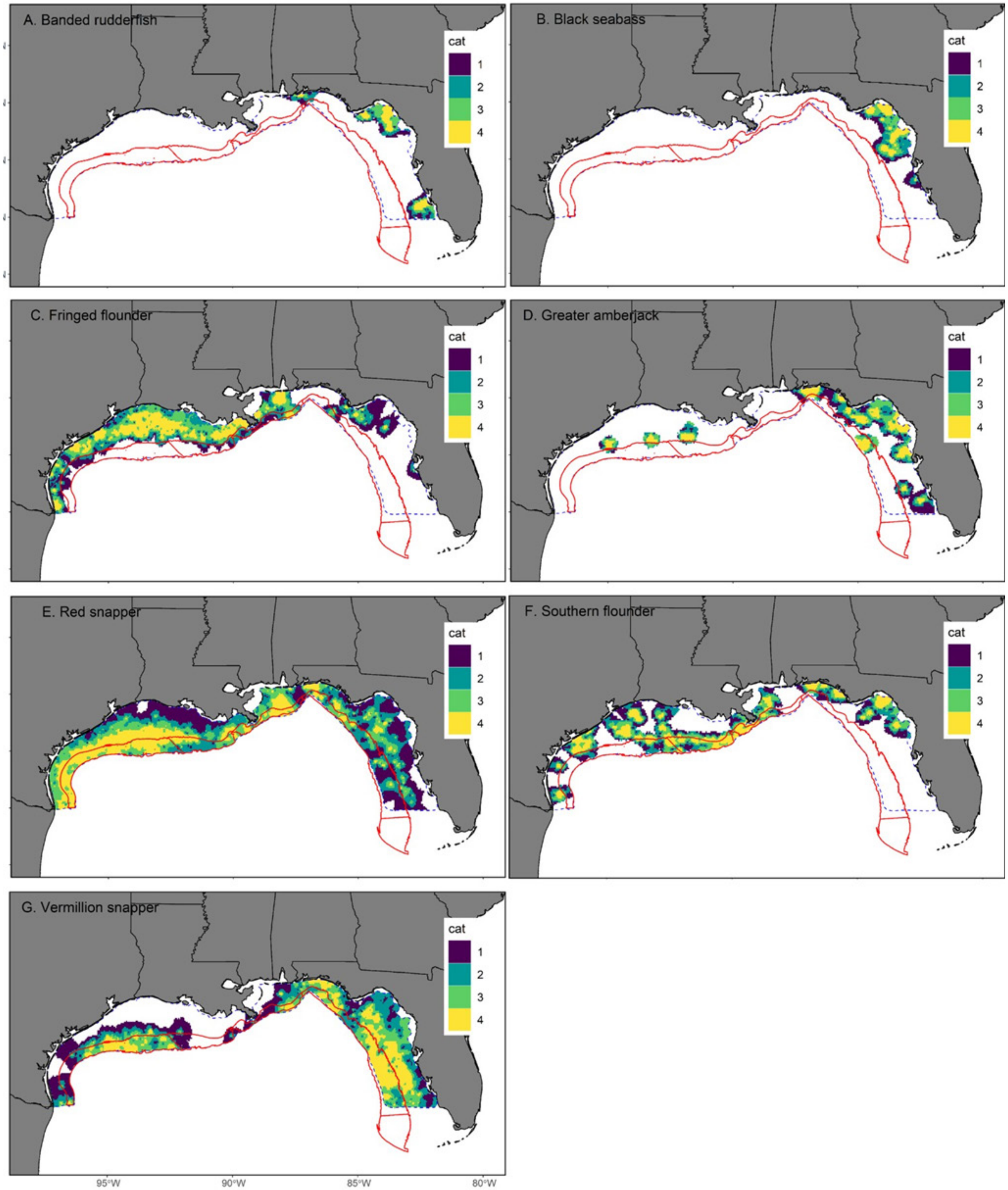

Figure 4. Maps of species relative biomass distribution overlap with AOA study areas in the Gulf of Mexico for the biomass proportion analysis. This figure represents the most recent time block.

Table 5. Proportions of the Southern California Bight AOA study area occupied by wild species at different biomass values. Percentages listed under the survey period columns are cumulative. Not all species were shown to have every possible species biomass value. Such cells are marked with a line (—).

		Percentage of AOA study area occupied			
Species	**Species biomass value**	**2003–07**	**2008–12**	**2013–17**	**2018+[a]**
California halibut/flounder	Extremely low	4.31%	4.31%	4.31%	12.93%
	Low	8.62%	12.93%	8.62%	12.93%
	Moderate	12.93%	17.24%	4.31%	8.62%
	High	25.86%	12.93%	17.24%	—
	Total	51.73%	47.42%	34.49%	34.49%
English sole	Extremely low	—	—	—	—
	Low	17.96%	8.98%	23.95%	11.97%
	Moderate	47.90%	29.94%	32.93%	47.90%
	High	23.95%	50.89%	32.93%	29.94%
	Total	89.81%	89.81%	89.91%	89.81%
Lingcod	Extremely low	35.92%	26.94%	11.97%	50.89%
	Low	44.90%	44.90%	44.90%	35.92%
	Moderate	8.98%	11.97%	29.94%	—
	High	—	5.99%	2.99%	—
	Total	89.81%	89.81%	89.81%	86.81%
Pacific pompano	Extremely low	4.31%	—	—	12.93%
	Low	8.62%	—	—	4.31%
	Moderate	4.31%	12.93%	21.55%	21.55%
	High	56.04%	51.73%	51.73%	34.49%
	Total	73.28%	64.66%	73.28%	73.28%
Sablefish	Extremely low	53.88%	74.84%	89.81%	65.86%
	Low	2.99%	—	—	2.99%
	Moderate	—	—	—	—
	High	—	—	—	—
	Total	56.88%	74.84%	89.81%	68.85%

[a] Most recent time block varies by species, as follows: For California halibut/flounder and Pacific pompano, 2018–19; for English sole, lingcod, and sablefish, 2018–22.

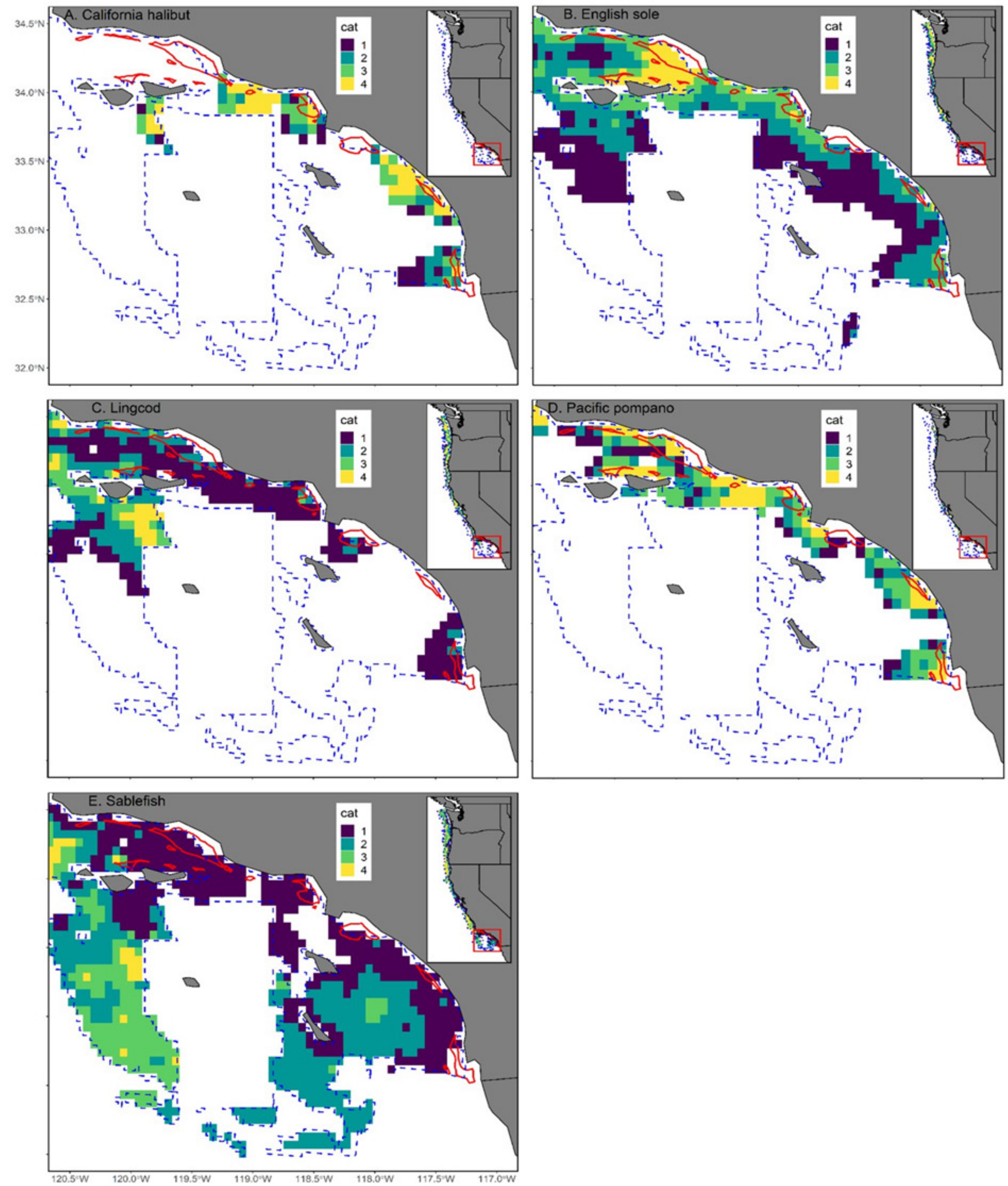

Figure 5. Maps of species relative biomass distribution overlap with AOA study areas in the Southern California Bight for the biomass proportion analysis. This figure represents the most recent time block. Inset maps show the full distribution of species within the survey domain.

Discussion

Our study suggests that most of the wild species studied are present to some degree in the AOA study areas. In addition to the study areas, several species overlapped with the high–high cluster areas, namely multiple clusters that contain AOA options. Of the species studied in the biomass proportion and area occupied analyses, most have consistent habitat overlap with the AOA study areas. Our limited study highlights that individual species distribution analysis can paint a more complete picture of the organisms likely to be present as aquaculture expands. Though we cannot make determinations about the degree to which any species is a concern for identifying AOAs, we can add to the discussion by informing the degree to which a species is potentially present within an AOA study area and how it is distributed within the areas. Furthermore, the data from this study can also serve as a baseline for analysis moving forward to determine potential impacts of distributional shifts due to climate change and other factors on interactions with marine aquaculture activities. The current study results, obtained in the absence of aquaculture, can serve as a baseline against which future analysis can be compared upon the establishment of aquaculture infrastructure. While the species studied tend to have overall distributions that extend well beyond the DisMAP survey extent, the areas surveyed can help us better understand distributions in U.S. coastal waters.

Limitations

While this analysis can provide a baseline for potential wild and farmed species overlap, there are limits to what the current data tell us about the distribution of wild species near and in AOA study areas. Limitations of the study may be created by the survey methods and timing of the surveys. The species analyzed in this study differ significantly in terms of life history, migration behavior, and their position in the water column, with some potentially being sampled more robustly with certain sampling methods than with others. For example, the trawling survey method used may create a higher likelihood that demersal and benthic species were encountered to the exclusion of pelagic species; therefore, the study results may underestimate the biomass of species less likely to be caught using bottom trawling. Additionally, species migration habits are difficult to discern and anticipate given the myriad of variables that impact movement. The survey data used in this study were collected during only one season in each region, meaning that the data presented have limits with respect to what they can tell us with regard to any potential seasonal migration patterns or movement through areas that fall within migration paths. Additional research with respect to seasonality may aid in making stronger determinations of overlap.

Results of the biomass proportion analysis depend on the spatial scale at which the biomass was evaluated. As previously mentioned, this report does not seek to estimate the overall biomass of a species, but only the biomass within the bounds of the area sampled by each fishery-independent trawl survey and the AOA study areas. For example, the analysis results indicate that over 50% of red snapper biomass may have resided within the study area during the 2008–12 survey period in the Gulf. That figure is based on the available biomass within the Gulf of Mexico survey area, not the entire population of red snapper, which extends into areas well beyond the survey domain (e.g., the south Atlantic U.S. states).

Our analysis is limited by the spatial extent of the distribution data provided by the surveys and analyzed and made available by DisMAP. An example from the U.S. West Coast is Pacific pompano, a species that has a range that also likely exceeds the DisMAP survey domain; therefore, our results likely overestimate the proportion of species' total biomass in the study areas.[8] Data from additional sources that expand on this range could be helpful for more precise analysis of species populations and their overlap with the AOA study areas.

The metrics used in this study are sensitive to decisions made by the authors. For the survey catch occurrence point analysis, many documented occurrences in the survey data fell near, but outside of, high–high clusters. Although not documented in the initial analysis, the proximity of an occurrence to the clusters merits consideration. This detail expresses limitations of using binary yes/no presence or absence based solely on looking at survey catch occurrences, as this depends largely on whether the survey sampled in or near to an AOA high–high cluster area. This was the motivation behind the additional analyses (biomass proportion and area occupied) employing interpolated biomass rasters from the DisMAP tool to provide deeper understanding of species' potential spatial overlap with AOA study areas.

Additional Research

The analysis framework employed in this study may be replicated and expanded to refine understanding of the two regions explored, or to extend the analysis to other regions. In our analysis, we used only available data from NOAA's DisMAP, but additional sources of species distribution data and models may help improve our understanding of wild species presence when discussing expanded marine aquaculture. Additionally, the data presented here can inform diverse research and investigation needs as they pertain to marine spatial planning and the identification of Aquaculture Opportunity Areas.

Impact of aquaculture infrastructure on wild species

There is abundant research that suggests marine aquaculture facilities can affect wild species aggregations, especially around net pens (*18–22*). Therefore, if eventual siting of aquaculture projects occurs, in situ research could help characterize farms' impacts on aggregation habits. Data on current and historic distributions, as were used in this report, may serve as control data for future analyses to determine if farms impact later distributions of important commercial, recreational, or protected species. Additional research can seek to categorize the species impacted by various diseases and determine the likelihood that those species will be at risk of transmission to each other. Understanding disease profiles of individual species is a logical next step in the research process, as understanding species distributions can help narrow the list of species (wild and cultured) evaluated for disease transfer potential, especially given that some diseases infect multiple species (*23, 24*). One of the concerns associated with the proximity between wild and aquaculture species is the potential for genetic impacts if escaped aquaculture animals take

[8] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=pacific+pompano

part in hybridization or introgression with wild organisms. Characterization of the wild species near an aquaculture operation may help inform containment protocols, sterilization requirements, breeding procedures, and the species selected for culture in an area.

Climate change

A major impact of a changing climate and ocean conditions is the large-scale shifts in distributions of many marine species as they attempt to remain within their preferred environmental conditions (e.g., temperature; *25*). Our analysis evaluated historic and current overlap of wild species with AOA study areas; however, as species distributions may change in response to changing climate, it will be important to take a more long-term, strategic approach, and consider these future changes when selecting appropriate areas for aquaculture development. Species distribution models fit to observed occurrences and forward-projected using regionally downscaled, high-resolution climate projections of future biogeochemical conditions can be used to predict future patterns and changes in species distributions under climate change (*26*). Future analysis could use these species' distribution projections to help understand if overlap with study areas and potential aquaculture infrastructure is likely to increase or decrease for certain wild species over the next 10, 20, and 50 years. Such an analysis can help to understand the future risk of disease transmission under different climate change scenarios.

Conclusion

Spatial analysis can help characterize the potential effects of marine aquaculture; for the most precise understanding, these characteristics are best described at the most local level possible. Regional spatial data for wild species help producers and regulators by framing potential interactions between wild and cultured animals. From here, based on our understanding of the organisms that are present, we can more accurately direct resources and research toward the species and interactions of concern. For example, abundant populations of a wild fish species known to carry a specific disease that also impacts a cultured species can inform risk assessment, as well as species choice and farm practices. If a species is abundant in a relevant area with a poorly understood disease profile, research and monitoring activities can be directed toward informing the level of hazard when that species occurs in proximity to aquaculture infrastructure.

We believe that this approach can serve as an efficient model for understanding the ecosystems in which marine aquaculture is being considered. The workflow here may be replicated as more species distribution data become available, either to refine the analysis presented here or to explore new regions using similar methods. More distribution data for fish species can bolster our understanding of the interplay between marine aquaculture and wild species. This study is an initial step in determining potential wild species overlap with potential marine aquaculture. Further analysis of the data should seek to include more advanced modeling of species abundance and distribution in these areas, as well as considerations for species migration due to climate change. As the United States continues to seek innovative ways to grow more healthy food locally, studies such as this can aid in accurate planning to maximize food production while minimizing impacts to the environment and wild species.

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Appendix A: List of Species Analyzed

Table A-1. Breakdown of species studied and the analyses in which they were included.

Species	Survey catch occurrence point analysis	Biomass proportion analysis	Percent area occupied analysis
Gulf of Mexico			
Atlantic croaker (*Micropogonias undulatus*)	Yes	No	No
Atlantic thorny oyster (*Spondylus americanus*)	Yes	No	No
Atlantic wing oyster (*Pteria colymbus*)	Yes	No	No
Banded rudderfish (*Seriola zonata*)	Yes	Yes	Yes
Black sea bass (*Centropristis striata*)	Yes	Yes	Yes
Blue crab (*Callinectes sapidus*)	Yes	No	No
Bluefish (*Pomatomus saltatrix*)	Yes	No	No
Brown shrimp (*Farfantepenaeus aztecus*)	Yes	No	No
Calico scallop (*Argopecten gibbus*)	Yes	No	No
Dusky flounder (*Syacium papillosum*)	Yes	No	No
Fringed flounder (*Etropus crossotus*)	Yes	Yes	Yes
Gag grouper (*Mycteroperca microlepis*)	Yes	No	No
Gray flounder (*Etropus surinamensis*)	Yes	No	No
Gray snapper (*Lutjanus griseus*)	Yes	No	No
Gray triggerfish (*Balistes capriscus*)	Yes	No	No
Greater amberjack (*Seriola dumerili*)	Yes	Yes	Yes
Gulf butterfish (*Peprilus burti*)	Yes	No	No
Gulf flounder (*Paralichthys albigutta*)	Yes	No	No
Gulf menhaden (*Brevoortia patronus*)	Yes	No	No
King mackerel (*Scomberomorus cavalla*)	Yes	No	No
Mossy scallop (*Flexopecten glaber*)	Yes	No	No
Northern white shrimp (*Litopenaeus setiferus*)	Yes	No	No
Paper scallop (*Amusium papyraceum*)	Yes	No	No
Pink shrimp (*Farfantepenaeus duorarum*)	Yes	No	No
Purple spined sea urchin (*Arbacia punctulata*)	Yes	No	No
Ravenel scallop (*Euvola raveneli*)	Yes	No	No
Red grouper (*Epinephelus morio*)	Yes	No	No
Red snapper (*Lutjanus campechanus*)	Yes	Yes	Yes
Sash flounder (*Monolene antillarum*)	Yes	No	No
Shelf flounder (*Etropus cyclosquamus*)	Yes	No	No
Shoal flounder (*Syacium gunteri*)	Yes	No	No
Spanish mackerel (*Scomberomorus maculatus*)	Yes	No	No
Spiny flounder (*Engyophrys senta*)	Yes	No	No
Southern flounder (*Paralichthys lethostigma*)	Yes	Yes	Yes
Vermilion snapper (*Rhomboplites aurorubens*)	Yes	Yes	Yes
Southern California Bight			
Arrowtooth flounder (*Atheresthes stomias*)	Yes	No	No
Bocaccio (*Sebastes paucispinis*)	Yes	No	No
California halibut/flounder (*Paralichthys californicus*)	Yes	Yes	Yes

Species	Survey catch occurrence point analysis	Biomass proportion analysis	Percent area occupied analysis
California market squid (*Doryteuthis opalescens*)	Yes	No	No
Canary rockfish (*Sebastes pinniger*)	Yes	No	No
Dover sole (*Microstomus pacificus*)	Yes	No	No
English sole (*Parophrys vetulus*)	Yes	Yes	Yes
Eulachon (*Thaleichthys pacificus*)	Yes	No	No
Lingcod (*Ophiodon elongatus*)	Yes	Yes	Yes
Northern anchovy (*Engraulis mordax*)	Yes	No	No
Pacific halibut (*Hippoglossus stenolepis*)	Yes	Yes	Yes
Pacific pompano (*Peprilus simillimus*)	Yes	Yes	Yes
Sablefish (*Anoplopoma fimbria*)	Yes	Yes	Yes
Starry flounder (*Platichthys stellatus*)	Yes	No	No
Vancouver scallop (*Chlamys hastata*)	Yes	No	No
Weathervane scallop (*Patinopecten caurinus*)	Yes	No	No
Yelloweye rockfish (*Sebastes ruberrimus*)	Yes	No	No

Appendix B: Individual Species Overlap Summaries

This appendix summarizes individual species' overlap from the survey catch occurrence point analysis. Species descriptions discuss the results presented in Table 3 while also adding important observations not captured in the table. Species descriptions also mention the rationale for their inclusion in the study. Subsequent appendices summarize the overlap for individual species during the biomass proportion analysis (Appendix C) and the percent area occupied analysis (Appendix D). Scientific names of species can be found in Appendix A.

The species in this appendix differ from each other in terms of distribution, migration behavior, and their position in the water column. Therefore, the bottom trawl survey method may limit our ability to draw conclusions for species, especially those that are exclusively or mostly pelagic throughout their lifecycle.

Gulf of Mexico

Atlantic croaker

Atlantic croaker is an important commercial and recreational species in the Gulf of Mexico.[1] Atlantic croaker was observed overlapping with 19 high–high clusters of 246 total clusters. There were 31 occurrences in the clusters out of 1,523 occurrences documented in the Gulf of Mexico since 2008. One point resides in a cluster that includes an AOA option, C-11. The occurrence near the C-11 option is from 2018. Additionally, the ArcGIS map showed multiple points that fell outside of the clusters containing options C-3, C-11, and C-13, but were in proximity. Three observations of Atlantic croaker fell within 10 km of C-3, seven fell within 10 km of C-11, and four fell within 10 km of C-13. The most recent of these observations were documented in 2019.

Atlantic thorny oyster

Atlantic thorny oyster was selected to represent sessile invertebrates available in DisMAP. The species was observed in one cluster (of 246 total clusters) one time out of 14 occurrences documented in the Gulf of Mexico since 2010. The point resides in a cluster that includes AOA option E-3. The most recent occurrence in a cluster containing an AOA option was in 2019.

Atlantic wing oyster

Atlantic wing oyster was selected to represent sessile invertebrates available in DisMAP. The species overlapped with zero clusters out of the 36 occurrences documented since 2008.

[1] http://www.asmfc.org/species/atlantic-croaker

Banded rudderfish

The banded rudderfish is a member of the jack family, along with other species in the *Seriola* genus,[2] in addition to having commercial and recreational value.[3,4] Specimens overlapped with zero clusters out of the 38 occurrences documented in the Gulf of Mexico since 2008.

Black sea bass

Black sea bass have commercial and recreational value in the United States.[5] Additionally, black sea bass is a candidate species for marine aquaculture in the Gulf of Mexico (*27*). Specimens overlapped with zero clusters out of the 63 occurrences documented in the Gulf of Mexico since 2008.

Blue crab

Blue crab is an important commercial and recreational species in the Gulf of Mexico.[6] Blue crabs were observed overlapping with one cluster of 246 total clusters out of 676 documented occurrences in the Gulf of Mexico since 2008. The cluster did not contain any AOA options.

Bluefish

Bluefish have commercial value mostly on the U.S. East Coast, but do occur in the Gulf of Mexico.[7] Specimens were observed overlapping with zero clusters out of the 34 occurrences documented in the Gulf of Mexico since 2008.

Brown shrimp

Brown shrimp are a commercially important species in the Gulf of Mexico, with some recreational fishing.[8] Specimens were observed in 29 clusters of 246 total clusters. There were 58 occurrences in the clusters out of 2,165 occurrences documented in the Gulf of Mexico since 2008. Seven points reside in clusters that include an AOA option. One point resides in the cluster that contains AOA option C-13. Five points reside in the cluster that contains AOA option W-4. One point resides in the cluster containing AOA option W-1. The most recent occurrence in a cluster containing an AOA option was in 2019, near W-4. Additionally, a number of occurrences were observed near, albeit not directly inside, many of the clusters west of the Mississippi River. We also observed multiple points that fell outside of the clusters containing AOA options W-1 and W-4, but were nevertheless in close proximity to them. Six points fell within 10 km of W-1, and three points fell within 10 km of W-4.

[2] https://www.fisheries.noaa.gov/species/federally-managed-gulf-mexico-reef-fish
[3] https://safmc.net/species/rudderfish-banded/
[4] https://gulfcouncil.org/fishing-regulations/banded-rudderfish-seriola-zonata/
[5] https://www.fisheries.noaa.gov/species/black-sea-bass#recreational
[6] https://www.fisheries.noaa.gov/species/blue-crab
[7] https://www.fisheries.noaa.gov/species/bluefish
[8] https://www.fisheries.noaa.gov/species/brown-shrimp

Calico scallop

The calico scallop was selected to represent invertebrates available in DisMAP. The species was observed once in one cluster (of 246 total clusters) out of 192 occurrences documented in the Gulf of Mexico since 2008. The point resides in a cluster that includes AOA option E-3. The most recent occurrence in a cluster containing the AOA option was 2015.

Dusky flounder

Dusky flounder was selected as an example of a flatfish with data available in DisMAP. Dusky flounder were observed overlapping with six clusters of 246 total clusters. There were 37 occurrences in the clusters, out of 1,116 occurrences documented in the Gulf of Mexico since 2008. Thirty-two points reside in clusters that contain AOA options. Thirteen points are in the cluster containing option E-3. Nineteen points reside in the cluster containing option E-4. The most recent occurrences in clusters containing AOA options were in 2018. One point each, falling outside of the high–high clusters, resides within 10 km of options E-3 and E-4. According to the results, dusky flounder's population concentrates in the eastern part of the Gulf of Mexico.

Fringed flounder

Fringed flounder was selected as an example of a flatfish with data available in DisMAP. Fringed flounder overlapped with zero clusters out of the 563 documented occurrences in the Gulf of Mexico since 2008.

Gag grouper

Gag grouper are an important commercial and recreational species in the Gulf of Mexico,[9] and, as of 2021, are considered to be overfished.[10] Gag grouper were observed overlapping with two clusters of 246 total clusters out of the 25 documented occurrences in the Gulf of Mexico since 2008. The points reside in clusters containing AOA options, one each in W-4 and E-4. The occurrences were documented in 2015 and 2016, respectively.

Gray flounder

Gray flounder was selected as an example of a flatfish with data available in DisMAP. Gray flounder were observed overlapping with two clusters of 246 total clusters. There were seven occurrences in the clusters out of 129 occurrences documented in the Gulf of Mexico since 2009. All seven points reside in clusters that contain AOA options. Four points reside in the cluster containing AOA option E-3. Three points reside in the cluster containing AOA option E-4. The most recent occurrence in each of the clusters was 2016.

[9] https://www.fisheries.noaa.gov/species/gag-grouper

[10] https://sedarweb.org/documents/sedar-72-gulf-of-mexico-gag-grouper-final-stock-assessment-report_august2021/

Gray snapper

Gray snapper is a commercially and recreationally important species in the Gulf of Mexico[11] that has been subject to overfishing.[12] Specimens were observed in one cluster of 246 total clusters. There were three occurrences in the clusters out of 251 occurrences documented in the Gulf of Mexico since 2008. All three points reside in a cluster that includes an AOA option, E-3. The most recent occurrence in a cluster containing an AOA option was in 2019, near E-3.

Gray triggerfish

Gray triggerfish has both commercial and recreational fisheries in the Gulf of Mexico.[13] Specimens were observed overlapping with two clusters of 246 total clusters. There were two total occurrences out of 438 documented occurrences in the Gulf of Mexico since 2008. One occurrence was in the cluster containing AOA option E-4, documented in 2016. The other point occurred in the cluster containing AOA option W-4, documented in 2015.

Greater amberjack

Greater amberjack are a commercially and economically relevant species in the Gulf of Mexico.[14] Additionally, they are a candidate species for marine aquaculture as well as a species that is currently being farmed U.S. waters.[15] Specimens overlapped with zero clusters out of the 76 occurrences documented in the Gulf of Mexico since 2008.

Gulf butterfish

Gulf butterfish were observed overlapping with 26 clusters of 246 total clusters. There were 49 occurrences out of 1,543 total occurrences documented in the Gulf of Mexico since 2008. Seven points overlapped with clusters containing AOA options. One point occurred in the cluster containing AOA option W-1, documented in 2011. Five points occurred in the cluster containing AOA option W-4, with the most recent documented in 2019. One point occurred in the cluster containing AOA option C-13, documented in 2016. Additionally, the ArcGIS map showed multiple points that fell outside of the clusters containing AOA options. Three occurrences were documented within 10 km of C-13 and five occurrences fell within 10 km of C-11.

Gulf flounder

Gulf flounder was selected as an example of a flatfish with data available in DisMAP. The species overlapped with zero clusters out of the 63 occurrences documented since 2008.

[11] https://safmc.net/species/snapper-gray/
[12] https://www.fisheries.noaa.gov/bulletin/final-rule-revises-annual-catch-limit-gray-snapper-gulf-mexico
[13] https://www.fisheries.noaa.gov/species/gray-triggerfish
[14] https://www.fisheries.noaa.gov/species/greater-amberjack
[15] https://bofish.com/

Gulf menhaden

Gulf menhaden overlapped with zero clusters out of the 144 occurrences documented in the Gulf of Mexico since 2008.

King mackerel

King mackerel is a commercially and recreationally relevant species in the Gulf of Mexico.[16] Specimens overlapped with zero clusters out of the 71 occurrences documented in the Gulf of Mexico since 2008.

Mossy scallop

Mossy scallop was selected to represent invertebrates available in DisMAP. The species was observed overlapping with zero clusters out of the 48 occurrences documented since 2008.

Northern white shrimp

Northern white shrimp are a commercially important species in the Gulf of Mexico, with some recreational fishing.[17] Northern white shrimp overlapped with zero clusters out of the 687 documented occurrences in the Gulf of Mexico since 2008. There was no overlap observed in clusters containing any AOA options.

Paper scallop

Paper scallop was selected to represent invertebrates available in DisMAP. The species was observed in 28 clusters (of 246 total clusters), with 57 occurrences in the clusters out of 729 occurrences documented in the Gulf of Mexico since 2008. Eight points reside in the cluster that includes AOA option E-3. One point resides in the cluster containing AOA option C-13. Five points reside in a cluster that contains AOA option W-4.

Pink shrimp

Pink shrimp are a commercially important species in the Gulf of Mexico, with some recreational fishing.[18] Specimens were observed in three clusters of 246 total. There were six occurrences in the clusters out of 791 occurrences documented in the Gulf of Mexico since 2008. Four points reside in clusters that include AOA options. Two points reside in the cluster that contains AOA option E-3. Two points also reside in the cluster that contains AOA option E-4. The most recent occurrence in a cluster containing an AOA option was in 2019, near E-3.

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[16] https://www.fisheries.noaa.gov/species/king-mackerel
[17] https://www.fisheries.noaa.gov/species/white-shrimp
[18] https://www.fisheries.noaa.gov/species/pink-shrimp

Purple spined sea urchin

Purple spined sea urchin was chosen to represent invertebrates available in DisMAP. The species was observed overlapping with zero clusters out of the 177 occurrences documented since 2008.

Ravenel scallop

Ravenel scallop was selected to represent invertebrates available in DisMAP. The species was observed in two clusters (of 246 total clusters) with three occurrences out of 116 occurrences documented in the Gulf of Mexico since 2008. Two points reside in a cluster that includes AOA option E-3. One point resides in a cluster that contains AOA option E-4. The most recent occurrence in a cluster containing an AOA option was in 2016.

Red grouper

Red grouper is a commercially and recreationally relevant species in the Gulf of Mexico.[19] Specimens overlapped with zero clusters out of the 260 occurrences documented in the Gulf of Mexico since 2008.

Red snapper

Red snapper is an important recreational and commercial species in the Gulf of Mexico.[20] Specimens overlapped with twelve clusters of 246 total clusters. There were sixteen occurrences in the clusters out of 1,276 occurrences documented in the Gulf of Mexico since 2008. Eight points reside in clusters that contain AOA options. Two points are in the cluster containing AOA option E-3, two are in the cluster containing option E-4, one is in the cluster containing option C-13, and three are in the cluster containing option W-4. The most recent occurrence in the cluster containing an AOA option was 2019, near option W-4, with the other two clusters containing occurrences as recently as 2018.

Sash flounder

Sash flounder was selected as an example of a flatfish with data available in DisMAP. Sash flounder were observed overlapping with 23 clusters of 246 total clusters. There were 47 occurrences in the clusters out of 493 occurrences documented in the Gulf of Mexico since 2008. Six points reside in clusters that contain an AOA option. One point resides in the cluster containing AOA option W-1, and five reside in the cluster containing option W-4. The most recent occurrence in the clusters was 2019. Additionally, we observed multiple points that fell outside of the clusters containing AOA option C-11, but were nevertheless in close proximity to the AOA option. Nine points fell within 10 km of C-11, the most recent documented in 2019.

[19] https://www.fisheries.noaa.gov/species/red-grouper
[20] https://www.fisheries.noaa.gov/species/red-snapper

Shelf flounder

Shelf flounder was selected as an example of a flatfish with data available in DisMAP. Shelf flounder were observed overlapping with one cluster of 246 total clusters. There was one occurrence out of 77 occurrences documented in the Gulf of Mexico since 2008. The point resides in the cluster that contains AOA option E-4. The most recent occurrence in the clusters was documented in 2010.

Shoal flounder

Shoal flounder was selected as an example of a flatfish with data available in DisMAP. Shoal flounder were observed overlapping with nine clusters of 246 total clusters. There were ten occurrences in the clusters out of 1,065 total occurrences documented in the Gulf of Mexico since 2008. One point resides in the cluster that contains AOA option W-4. The most recent occurrence in the clusters was in 2013.

Spanish mackerel

Spanish mackerel is a commercially and recreationally relevant species in the Gulf of Mexico.[21] Specimens overlapped with zero clusters out of the 84 occurrences documented in the Gulf of Mexico since 2008.

Spiny flounder

Spiny flounder was selected as an example of a flatfish with data available in DisMAP. Spiny flounder were observed overlapping with five clusters of 246 total clusters. There were five occurrences in the clusters out of 182 occurrences documented in the Gulf of Mexico since 2008. One point resides in the cluster that contains AOA option W-4. The most recent occurrence in the clusters was in 2015.

Southern flounder

Southern flounder was selected given its status as a candidate species for aquaculture in the United States. Southern flounder overlapped with zero clusters out of the 195 occurrences documented since 2008.

Vermilion snapper

Vermilion snapper is a commercially and recreational relevant species in the Gulf of Mexico.[22] Vermilion snapper was observed in twelve clusters of 246 total clusters. There were 26 occurrences in the clusters out of 546 documented occurrences in the Gulf of

[21] https://www.fisheries.noaa.gov/species/spanish-mackerel
[22] https://www.fisheries.noaa.gov/species/vermilion-snapper

Mexico since 2008. Eighteen points reside in clusters containing AOA options. One point resides in the cluster containing AOA option E-1, with the occurrence documented in 2015. Nine points reside in the cluster containing AOA option E-3, with the most recent occurrence documented in 2019. Seven points reside in the cluster containing AOA option E-4, with the most recent occurrence documented in 2018. One point resides in the cluster containing AOA option C-13, documented in 2016. Additionally, observations of the mapping tool indicate that many other occurrences were observed near high–high clusters, including those with options, throughout the Gulf, but that fell outside of the high–high clusters during analysis. Four observations fell within 10 km of E-3, and six points fell within 10 km of E-1, with the latest point documented in 2019.

Southern California Bight

Arrowtooth flounder

Arrowtooth flounder is a commercially relevant species on the U.S. West Coast.[23] Specimens were observed overlapping with zero clusters out of the 793 occurrences documented on the U.S. West Coast since 2008. The distribution of flounder, based on the DisMAP data, is mostly north of the AOA high–high clusters in the Southern California Bight.

Bocaccio

Bocaccio is a commercially and recreationally relevant species on the U.S. West Coast. While some populations are listed under the Endangered Species Act (ESA), the populations in the Southern California Bight are not, and are currently fished. The Puget Sound and Georgia Basin distinct population segment (DPS) is ESA-listed.[24] Specimens were observed in one cluster (of eight total clusters), with two occurrences out of 757 documented occurrences on the U.S. West Coast since 2003. Both points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C, with the most recent occurrence documented in 2014. Additionally, we observed multiple points that fell outside of the clusters containing AOA options, but were nearby. Twelve points fell within 10 km of two clusters, one containing AOA options N1-A, N1-B, and N1-C, and the other containing options N2-A, N2-B, N2-C, N2-D, and N2-E.

California halibut/flounder

The California halibut/flounder is a commercially and recreationally relevant species on the U.S. West Coast.[25] Specimens were observed in one cluster (out of eight clusters total), with one occurrence in the cluster. There were 80 documented occurrences on the U.S. West Coast since 2003. The occurrence was documented in the cluster containing AOA options N1-A, N1-B, and N1-C. The occurrence was documented in 2006.

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[23] https://www.fisheries.noaa.gov/species/arrowtooth-flounder
[24] https://www.fisheries.noaa.gov/species/bocaccio
[25] https://marinespecies.wildlife.ca.gov/california-halibut/false/

California market squid

California market squid are fished commercially on the U.S. West Coast.[26] Specimens were observed in two clusters (of seven total clusters) three times out of a total of 2,111 occurrences documented on the U.S. West Coast since 2003. Two points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C, with the most recent occurrence being in 2011. One point occurred in the cluster containing AOA options N2-A, N2-B, N2-C, N2-D, and N2-E, with the most recent occurrence documented in 2003. Additionally, several points fell near, though not directly in, the clusters containing AOA options. Ten occurrences were documented outside of the high–high cluster, but within 10 km of AOA options N1-A, N1-B, and N1-C.

Canary rockfish

Canary rockfish are fished commercially and recreationally on the U.S. West Coast.[27] Specimens were observed in zero clusters out of 871 documented occurrences on the U.S. West Coast since 2003. According to the canary rockfish DisMAP dataset, the distribution of animals is north of the Southern California Bight study areas, clusters, and AOA options.

Dover sole

Dover sole are fished commercially and recreationally on the U.S. West Coast.[28] Specimens were observed overlapping with three clusters of seven total clusters. There were five occurrences in the high–high clusters out of the 7,239 occurrences documented on the U.S. West Coast since 2008. Two points resided in the cluster containing AOA options N1-A, N1-B, and N1-C, with the most recent occurring in 2014. Two points occurred in the cluster containing AOA options CN1-A and CN1-B, with the most recent occurring in 2016. Additionally, we observed multiple points that fell outside of the clusters containing AOA options, but were nearby. Thirty-three points fell within 10 km of two clusters, one containing AOA options N1-A, N1-B, and N1-C, and the other containing AOA options N2-A, N2-B, N2-C, N2-D, and N2-E.

English sole

English sole are fished commercially and recreationally on the U.S. West Coast.[29] Specimens were observed overlapping with four clusters out of seven total clusters. There were 31 occurrences in the high–high clusters out of 4,264 documented occurrences on the U.S. West Coast since 2003. Eleven points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C. Four points occurred in the cluster containing AOA options N2-A, N2-B, N2-C, N2-D, and N2-E, with the most recent occurring in 2016. Five points occurred in the cluster containing AOA options CN1-A and CN1-B, with the most recent occurring in 2016.

[26] https://www.fisheries.noaa.gov/species/california-market-squid
[27] https://www.fisheries.noaa.gov/species/canary-rockfish
[28] https://www.fisheries.noaa.gov/species/dover-sole
[29] https://www.fisheries.noaa.gov/species/english-sole

Additionally, several points fell near, though not directly in, the clusters containing AOA options. Thirty-two occurrences were documented outside of the high–high clusters, but within 10 km of AOA options N1A, N1-B, and N1-C, with the most recent observation in 2017. Twenty points were observed within 10 km of the cluster containing AOA options CN1-A and CN1-B, with the most recent documented in 2018.

Eulachon

Eulachon are an anadromous species with an ESA-listed DPS in their southern population, which stretches from northern California to British Columbia.[30] However, DisMAP did indicate occurrences in the Southern California Bight region. Eulachon overlapped with one cluster (of seven total clusters) once out of 722 occurrences on the U.S. West Coast since 2003. The point occurred in the cluster containing AOA options N1-A, N1-B, and N1-C. The occurrence was documented in 2003.

Lingcod

Lingcod are fished recreationally and commercially on the U.S. West Coast.[31] Specimens were observed in three clusters (of seven total clusters), with nine occurrences out of 3,440 total documented occurrences on the U.S. West Coast since 2003. Five points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C, with the latest point occurring in 2014, and three points occurred in the cluster containing N2-A, N2-B, N2-C, N2-D, and N2-E, with the latest occurring in 2011. One point occurred in the cluster containing AOA options CN1-A and CN1-B, in 2011. Additionally, several points fell near, though not directly in, the clusters containing AOA options. Thirteen occurrences were documented outside of the high–high clusters, but within 10 km of AOA options N1-A, N1-B, and N1-C. Five points were observed within 10 km of the cluster containing AOA options CN1-A and CN1-B.

Northern anchovy

Northern anchovy are an important commercial species on the U.S. West Coast.[32] Specimens were observed overlapping with two clusters (of seven total clusters), with three occurrences out of the 265 documented occurrences on the U.S. West Coast since 2003. Two points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C, with the most recent occurrence documented in 2011. One point occurred in the cluster containing AOA options N2-A, N2-B, N2-C, N2-D, and N2-E, documented in 2003. Additionally, nine occurrences were documented outside of the high–high clusters, but within 10 km of AOA options N1-A, N1-B, and N1-C.

[30] https://www.fisheries.noaa.gov/species/eulachon
[31] https://www.fisheries.noaa.gov/species/lingcod
[32] https://www.fisheries.noaa.gov/species/northern-anchovy

Pacific halibut

Pacific halibut are an important commercial and recreational fishing species on the U.S. West Coast.[33] Specimens were observed overlapping with zero clusters out of the 793 occurrences documented on the U.S. West Coast since 2008. The distribution of Pacific halibut, based on the DisMAP data, is north of the AOA high–high clusters in the Southern California Bight.

Pacific pompano

Pacific pompano was selected to broaden species diversity beyond groundfish in the Southern California Bight analysis. Pacific pompano were observed overlapping with four clusters (of seven total clusters), with 20 occurrences out of the 564 documented occurrences on the U.S. West Coast since 2003. Ten points occurred in the cluster containing AOA options N1-A, N1-B, and N1-C, with the most recent occurrence documented in 2017. Four points were documented in the cluster containing AOA options N2-A, N2-B, N2-C, N2-D, and N2-E, with the most recent occurrence documented in 2011. Five points occurred in the cluster containing AOA options CN1-A and CN1-B, with the most recent occurrence in 2016. Additionally, several points fell near, though not directly in, the clusters containing AOA options. Twelve occurrences were documented outside of the high–high clusters, but within 10 km of AOA options N1-A, N1-B, and N1-C. Seven points were observed within 10 km of the cluster containing AOA options CN1-A and CN1-B.

Sablefish

Sablefish are fished commercially and recreationally on the U.S. West Coast.[34] Additionally, they are a candidate for marine aquaculture in the United States.[35] Specimens were observed in one cluster (of seven total clusters) once out of a total of 5,053 occurrences documented on the U.S. West Coast since 2003. The point occurred in the cluster containing AOA options CN1-A and CN1-B in 2016. Additionally, several points fell near, though not directly in, the clusters containing AOA options. Seven occurrences were documented outside of the high–high clusters, but within 10 km of AOA options N1-A, N1-B, and N1-C. Seven points were observed within 10 km of the cluster containing AOA options CN1-A and CN1-B.

Starry flounder

Starry flounder are fished commercially and recreationally on the U.S. West Coast.[36] They are also a marine aquaculture candidate species in the United States. Specimens were observed overlapping with zero clusters out of the 152 occurrences documented on the U.S. West Coast since 2008. The distribution of starry flounder, based on the DisMAP data, is north of the AOA high–high clusters in the Southern California Bight.

[33] https://www.fisheries.noaa.gov/species/pacific-halibut
[34] https://www.fisheries.noaa.gov/species/sablefish
[35] https://www.fisheries.noaa.gov/west-coast/aquaculture/sablefish-aquaculture-pacific-northwest
[36] https://wildlife.ca.gov/fishing/ocean/fish-id/sportfish/flatfishes#starry

Vancouver scallop

Vancouver (or spear) scallops have a limited U.S. West Coast fishery, occurring mostly in Canada.[37] Vancouver scallops were observed overlapping with zero clusters out of the 83 occurrences documented on the U.S. West Coast since 2003. However, three occurrences were documented within 10 km of the cluster containing AOA options CN1-A and CN1-B.

Weathervane scallop

Weathervane (or Alaska) scallops are fished on the U.S. West Coast, but relevant commercial fisheries are in Alaska.[38] Specimens were observed in one cluster (of seven total clusters) once out of 67 occurrences documented on the U.S. West Coast since 2004. The point occurred in 2006 in the cluster containing AOA options N1-A, N1-B, and N1-C.

Yelloweye rockfish

Yelloweye (or rasphead) rockfish have an ESA-listed DPS in the Puget Sound/Georgia Watershed region. However, the species is fished normally in other parts of the U.S. West Coast.[39] Yelloweye rockfish were observed overlapping with zero clusters out of the 251 occurrences documented on the U.S. West Coast since 2003.

[37] https://www.pac.dfo-mpo.gc.ca/fm-gp/shellfish-mollusques/scallop-petoncle-eng.html
[38] https://www.fisheries.noaa.gov/alaska/sustainable-fisheries/scallop-fisheries-management-alaska
[39] https://www.fisheries.noaa.gov/species/yelloweye-rockfish

Appendix C: Individual Species Summaries from the Biomass Proportion Analysis

The following paragraphs summarize the individual species' estimated biomass proportions that fell within the AOA study areas. Additionally, examples of each species' distribution in ArcGIS Pro, overlaid on the AOA study area shapes, are provided in footnotes. For the Southern California Bight, multiple maps were used to capture the overall biomass distribution given that the trawl survey area greatly exceeded that of the AOA study areas. Overlap proportions are rounded to the nearest 0.01%.

Gulf of Mexico

Many of these species have broad ranges, with significant biomass falling outside of the survey area captured in DisMAP, and results from this analysis are likely much higher than the actual proportion of species biomass in the AOA study areas.

Banded rudderfish

Banded rudderfish[1] had a consistent estimated proportion of 0.00% (a nonzero percentage of overlap did not appear until a third decimal point was added) of its biomass within the AOA study areas. Visual inspection of the distribution map confirms that practically all of the species' biomass falls outside of the AOA study areas.

Black sea bass

Black sea bass[2] had a consistent estimated proportion of 0.00% (a nonzero percentage of overlap did not appear until a third decimal point was added to the middle survey period) with respect to the species' biomass that resides within the Gulf of Mexico AOA study area. Visual inspection of the distribution map confirms that nearly all of the species' biomass falls outside of the AOA study areas. The range of black sea bass falls largely in the western Atlantic.

Fringed flounder

A low proportion of fringed flounder[3] biomass was found within the AOA study area across all time blocks. Only 1.09% of the biomass from 2008–12 resided in the study area, 0.49% from 2013–17, and then 1.02% in 2018. Although broadly distributed, fringed flounder was calculated to have low average biomass in the study area relative to its overall Gulf of Mexico biomass.

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[1] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=banded+rudderfish

[2] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=black+seabass

[3] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=fringed+flounder

Greater amberjack

Greater amberjack[4] has a broad longitudinal distribution within the Gulf of Mexico, but falls closer to shore than the Gulf of Mexico AOA study area. Nonetheless, greater amberjack did have an increase in overlap with the AOA study area over the previous survey periods. However, the proportion of its biomass found within the study area was still relatively low. For the earliest time block (2008–12), 2.85% of the species biomass resided in the Gulf of Mexico study area, increasing slightly to 3.91% for 2013–17, and then further increasing to 6.87% in the most recent period (2018–19).

Red snapper

Compared to other species, red snapper[5] had a higher proportion of its estimated survey range biomass within the AOA study areas during the three periods. From 2008–12, 54.44% of the species' estimated biomass resided in the AOA study areas, decreasing to 47.62% for 2013–17, and later to 45.42% for 2018–19. Except for the southeastern portion of the Gulf of Mexico AOA study area, the species appears to be distributed broadly throughout the study area. The species' common name in the alternative data set is listed as Caribbean red snapper.

Southern flounder

Like red snapper, southern flounder[6] has a high proportion of its biomass within the AOA study area. For the 2008–12 period, 43.50% of the biomass fell within the study area polygon. The proportion decreased to 38.13% for 2013–17, and then increased to 48.88% for 2018–19. Southern flounder's distribution is inshore and in the western portion of the study area across the survey periods.

Vermilion snapper

Vermilion snapper[7] was the only species for which the proportion of biomass within the AOA study area increased across the survey periods. For 2008–12, 27.00% of the estimated species biomass resided within the study area, increasing to 33.69% in 2013–17, and further increasing to 52.53% in 2018–19. Vermilion snapper biomass is distributed in the eastern and western portions of the AOA study area, with gaps in the central and southeastern portions. It is most concentrated in the eastern Gulf of Mexico, along the west coast of Florida.

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[4] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=greater+amberjack
[5] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=red+snapper
[6] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=southern+flounder
[7] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=vermilion+snapper

Southern California Bight

The following include the results for the AOA study areas in Southern California, based on the U.S. West Coast species distributions from DisMAP. Many of these species have broad ranges with significant biomass falling outside of the survey area captured in DisMAP, and results from this analysis are likely much higher than the actual proportion of species biomass in the AOA study areas.

California halibut/flounder

California halibut/flounder's biomass in the AOA study area remained consistent during the four time periods, with a dip during 2013–17. For 2003–07, 15.10% of its biomass resided within the study area, dropping slightly to 14.28% in 2008–12, and then increasing to 19.74% in 2013–17 and 16.28% in 2018–22. California halibut/flounder is more abundant in the southern portion of the U.S. West Coast, with little presence in most of Oregon and none in Washington. California halibut/flounder, when checked against other available data, appears to have a range like that of the DisMAP survey extents.[8]

English sole

The proportion of English sole[9] biomass within the Southern California Bight AOA study area was between 1.24% and 2.43% during the four time periods, with a high of 2.43% occurring during the 2008–12 period. English sole is distributed throughout the entire U.S. West Coast from Canada to Mexico; however, most of the biomass is concentrated further north along the U.S. West Coast, namely from central California through Washington. English sole has a large range, specifically a distribution that stretches north of the U.S. West Coast boundary and out to the Aleutian island chain.

Lingcod

The proportion of lingcod[10] biomass found in the Southern California Bight AOA study area was less than 1% during the four survey periods. Lingcod have a broad distribution across Oregon, Washington, and northern California, possibly explaining the low proportion of the overall biomass found within the AOA study areas.

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[8] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=california+halibut

[9] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=english+sole

[10] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=lingcod

Pacific pompano

Of the species analyzed on the U.S. West Coast, Pacific pompano[11] has the highest proportion of its overall biomass found within the AOA study area. The proportion of its biomass found within the AOA study area was highest for the earlier two time periods (25.13% in 2003–07 and 31.17% in 2008–12), and decreased in the latter two time periods (14.70% during 2013–17 and 15.42% in 2018–22). Overall, the distribution of Pacific pompano spans much of the U.S. West Coast; however, more biomass appears near the Southern California coast, possibly explaining the higher proportion of the biomass found in the AOA study area.

Sablefish

Sablefish[12] had the lowest proportion of its total biomass found within the AOA study area, with practically 0.00% of its total biomass being found within the study area during all four survey periods. Much of the species biomass is distributed north of the AOA study areas. Sablefish has a large range—specifically, a distribution that stretches across the Pacific Ocean from the U.S. West Coast survey extent to Russia and Japan.

[11] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldType=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=pacific+pompano

[12] https://www.aquamaps.org/CommonNameSearchList.php?Crit1_FieldName=common_names_all.Common_Name&Crit1_FieldTyp e=CHAR&Crit1_Operator=CONTAINS&Crit1_Value=sablefish

Appendix D: Individual Species Summaries from the Percent Area Occupied Analysis

This appendix summarizes the individual species' overlap from the percent area occupied analysis, describing the extent to which the AOA study areas overlapped with varying relative biomass levels of wild species.

Gulf of Mexico

Banded rudderfish

Banded rudderfish has little overlap with the Gulf of Mexico AOA study area across all time periods, covering only 1.26% of the study area in 2008–12, 0.05% in 2013–17, and 0.39% in 2018–19. In 2008–12, the area occupied was spread between areas of extremely low (0.34%), low (0.24%) and moderate (0.68%) relative biomass areas, but in 2013–17 it was entirely distributed among areas of extremely low biomass, and in 2018–19 it was split between extremely low (0.14%) and low (0.24%) relative biomass areas. The AOA study area did not overlap with any areas of high relative biomass in any survey period.

Black sea bass

Black sea bass has little overlap with the Gulf of Mexico AOA study area across all time periods, estimated to cover only 0.10% of the area in 2008–12 and 2013–17, and 0.19% in 2018–19. This overlapping area comprised only areas of extremely low relative biomass (< 0.00000608 kg/ha), with no overlap with any areas of high relative biomass.

Fringed flounder

Fringed flounder had a moderate and decreasing amount of overlap with the AOA study area, with 29.03% of the study area occupied by fringed flounder in 2008–12, 30.29% in 2013–17, and 18.45% in 2018–21. However, similar to many other species evaluated in this analysis, most of that overlap was with areas of extremely low (10–17%) and low (5–10%) relative biomass areas, with small amounts of overlap with areas of moderate relative biomass (1.6–3.9%), and < 1% of the AOA study area overlapped with areas of high relative biomass across all three time periods.

Greater amberjack

Greater amberjack occupied a small, but slightly increasing, proportion of the AOA study area. The proportion of study area covered was 4.79% during 2008–12, 7.48% in 2013–17, and 8.35% in 2018–19. The majority of this overlap consisted of areas of extremely low and low relative biomass. However, there were small amounts of the AOA study area covered (< 1%) by areas of moderate and high relative amberjack biomass in all years.

Red snapper

A large proportion (> 60%) of the AOA study area is covered by red snapper across all three survey periods. The proportion of the study area covered with red snapper steadily increased through time, from 61.70% in 2008–12, to 67.77% in the 2013–17 period, to 71.48% in 2018–21. This overlapping area comprises all four relative biomass categories, with the greatest proportion made up of areas of moderate and high relative biomass areas. In fact, approximately 20% of the AOA study area is covered by areas of high relative biomass of red snapper (between 0.03 and 13.16 kg/ha) in all three survey periods.

Southern flounder

Southern flounder's distribution covered about a third of the AOA study area in the Gulf of Mexico across all three years (33.40% in 2008–12, 28.81% in 2013–17, and 27.59% in 2018–19). All four biomass categories were present within the study area. The species was mostly distributed evenly across the biomass categories such that < 10% of the area was covered by any one relative biomass category. Additionally, southern flounder has low predicted WTCPUE in the Gulf of Mexico, and even the high relative biomass areas have a WTCPUE that is < 1 kg/ha.

Vermilion snapper

Vermilion snapper had one of the highest distribution overlaps with the AOA study area in the Gulf of Mexico, with over 60% of the study area occupied by vermilion snapper's biomass distribution across all three survey periods (64.75% in 2008–12, 68.57% in 2013–17, and 68.69% in 2018–21). Additionally, all four biomass categories were found within the study area, with the majority of the overlapping area comprising areas of moderate (18–21%) and high relative biomass (16–20%). However, we note that vermilion snapper does not have a high predicted WTCPUE in the Gulf of Mexico, and thus even the high relative biomass areas are only between 0.012 and 3.25 kg/ha).

Southern California Bight

California halibut/flounder

California halibut/flounder had a high degree of overlap with the AOA study area in the Southern California Bight in the earliest survey period, 2003–07, with 51.73% of the area overlapping with its distribution. The amount of overlap decreased over the following three survey periods. The proportion decreased to 47.42% in 2008–12 and again to 34.49% in the 2013–17 and 2018–22 periods. In the early survey period, the largest proportion of this overlap was with areas of moderate and high relative biomass (12.93% and 25.86%, respectively). However, over time, the amount of overlap with the moderate and high relative biomass areas declined.

English sole

Of the U.S. West Coast species, English sole was shown to be the most prevalent in the Southern California Bight AOA study area. 89% of the study area in all four survey periods was predicted to have English sole present. The overlapping area is composed of areas of low, moderate, and high relative biomass, with over half of the overlapping area being moderate (0.26–3.44 kg/ha) or high (3.44–40.44 kg/ha) biomass areas.

Lingcod

Lingcod has a high degree of overlap with the AOA study area, with 86–90% of the study area in all four survey periods covered by lingcod, albeit mostly with areas of extremely low and low biomass. There was some overlap with moderate biomass areas in the first three survey periods, increasing from ~9% in 2003–07 to ~30% in 2013–17, then falling to zero in 2018–19. Similarly, there was minor overlap with areas of high relative biomass (~3–6%) in 2008–12 and 2013–17, but no overlap with high biomass area in the first and last survey periods.

Pacific pompano

During all four time periods, a high proportion of the AOA study area (over 65%) is predicted to have Pacific pompano present. The area occupied by Pacific pompano is comprised primarily of high relative biomass areas (> 50% in first three survey periods, and 34.49% in the most recent period). However, it is important to note that even these high relative biomass areas are estimated to have WTCPUE of between 0.00253 and 5.36 kg/ha, which is a relatively low density compared to other species found in the area.

Sablefish

Over half of the AOA study area is covered by sablefish's distribution; however, in all survey periods, the distribution is composed of areas of extremely low relative biomass. In the earliest and most recent survey periods, ~3% of the study area was covered by areas of low relative biomass. There was no overlap with areas of moderate or high relative biomass in any of the four survey periods.

Appendix E: List of Candidate Species for U.S. Marine Aquaculture

Per discussion with various subject matter experts via workshops and other symposia, and recent research into species suitability (*13–16*, *27–30*), the table below lists the species of interest for marine finfish and shellfish aquaculture in the Gulf of Mexico and the Southern California Bight. Rationales from the discussions include a history of culture, consumption of wild conspecifics in the United States, and/or high potential for economic and biological suitability for culture in U.S. waters (*31*). As an example, a marine finfish aquaculture feasibility workshop and stakeholder survey held in 2017 assessed and reported on 18 nonsalmonid finfish species.[1] While a small industry relative to shellfish, some finfish species on this list are already being grown in U.S. waters[2] or waters adjacent to the United States,[3] specifically almaco jack. Species in bold were included in this study.

Table E-1. List of candidate species for U.S. marine aquaculture.

Aquatic Organism	**Region**
Abalone (*Haliotis* spp.)	Southern California Bight
Almaco jack (*Seriola rivoliana*)	Gulf of Mexico
Bay scallop (*Argopecten irradians*)	Gulf of Mexico
Black sea bass (*Centropristis striata*)	Gulf of Mexico
California halibut/flounder (*Paralichthys californicus*)	Southern California Bight
California mussel (*Mytilus californianus*)	Southern California Bight
California yellowtail (*Seriola lalandi*)	Southern California Bight
Cobia (*Rachycentron canadum*)	Gulf of Mexico
Eastern oyster (*Crassostrea virginica*)	Gulf of Mexico
Florida pompano (*Trachinotus carolinus*)	Gulf of Mexico
Greater amberjack (*Seriola* spp.)	Gulf of Mexico
Hard clam (*Mercenaria mercenaria*)	Gulf of Mexico
Manila clam (*Venerupis philippinarum*)	Southern California Bight
Mediterranean mussel (*Mytilus galloprovincialis*)	Southern California Bight
Olive flounder (*Paralichthys olivaceus*)	Southern California Bight
Olympia oyster (*Ostrea lurida*)	Southern California Bight
Pacific oyster (*Magallana gigas*)	Southern California Bight
Pismo clam (*Tivela stultorum*)	Southern California Bight
Purple-hinged rock scallop (*Crassadoma gigantea*)	Southern California Bight
Red drum (*Sciaenops ocellatus*)	Gulf of Mexico
Sablefish (*Anoplopoma fimbria*)	Southern California Bight
Southern flounder (*Paralichthys lethostigma*)	Gulf of Mexico
Southern quahog (*Mercenaria campechiensis*)	Gulf of Mexico
Spotted seatrout (*Cynoscion nebulosus*)	Gulf of Mexico
Striped bass (*Morone saxatilis*)	Southern California Bight
Tripletail (*Lobotes surinamensis*)	Gulf of Mexico
Urchin (*Lytechinus variegatus*)	Gulf of Mexico
White sea bass (*Atractoscion nobilis*)	Southern California Bight

[1] https://www.fau.edu/hboi/research/aquaculture-innovation/center-for-marine-and-warm-water-aquaculture/educationoutreach/status-of-marine-fish/
[2] https://bofish.com/
[3] https://www.pacificoaquaculture.com/

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