Draft Programmatic Environmental Impact Statement for the Identification of Aquaculture Opportunity Areas in U.S. Federal Waters of the Gulf of Mexico

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How to Comment:
NMFS is soliciting public comment on the Proposed Action and environmental review described in this draft Programmatic Environmental Impact Statement (DPEIS). Submit all electronic comments via the Federal eRulemaking Portal. Go to http://www.regulations.gov and enter NOAA-NMFS-2024-0135 in the Search box, click the “Comment Now!” icon, complete the required fields, and enter or attach your comments. Comments are due on the date specified in the instructions. For additional ways to provide comments, please visit: https://www.fisheries.noaa.gov/southeast/aquaculture/get-involved-gulf-mexico-aquaculture-opportunity-area-peis

Abstract

As directed by the Executive Order 13921, "Promoting American Seafood Competitiveness and Economic Growth" (May 7, 2020), the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS) Southeast Region is developing a draft programmatic environmental impact statement (DPEIS), in accordance with the National Environmental Policy Act (NEPA), to evaluate the potential adverse and beneficial impacts of identifying one or more Aquaculture Opportunity Areas (AOAs) in U.S. federal waters of the Gulf of Mexico (Gulf) and the potential impacts associated with siting future commercial aquaculture operations in those locations. The intent of this DPEIS is to support long-term planning for offshore aquaculture in the Gulf. The identification of AOAs does not support a specific regulatory or permitting action and does not authorize or permit any specific aquaculture-related activities or individual aquaculture operations

EXECUTIVE SUMMARY

ES.1 Introduction

This Draft Programmatic Environmental Impact Statement (DPEIS) assesses the impacts of identifying Aquaculture Opportunity Areas (AOAs) in U.S. federal waters of the Gulf of Mexico (Gulf) and evaluates the impacts of siting aquaculture in those AOA locations. An AOA is a defined geographic area that has been determined to be potentially suitable for commercial aquaculture. The AOA Alternatives analyzed in this DPEIS were derived from a marine spatial planning process that considered environmental, economic, social, and cultural data to identify areas that were the most suitable for sustainable offshore aquaculture development (see Riley et al 2021, incorporated by reference). The AOA Alternatives take into consideration available spatial data for federal waters of the Gulf, feedback received from the public during the public scoping process on this PDEIS and from federal agencies involved in offshore aquaculture permitting and authorizations, as well as the best available science and literature on aquaculture and the Gulf region.

NMFS prepared this DPEIS to comply with the National Environmental Policy Act (NEPA) and Executive Order 13921, *Promoting American Seafood Competitiveness and Economic Growth*. This DPEIS is a long-term planning effort, and will not result in the approval of any aquaculture permits or activities. NMFS is developing this DPEIS to identify AOAs and to streamline future permitting decisions and authorizations by informing project-specific evaluations of the impacts of siting aquaculture in those locations. This DPEIS is not a regulatory or permitting action and does not propose to authorize or permit any specific aquaculture-related activities or individual aquaculture projects. Any project-specific NEPA analyses, consultations, and permits for future proposed aquaculture projects may tier from this DPEIS, once finalized, if the lead agency determines the final PEIS is appropriate for its needs.

ES.2 Purpose and Need

The purpose of the proposed action is to apply a science-based approach to identify AOAs in federal waters of the Gulf. The goal of identifying AOAs is to promote American seafood competitiveness, food security, economic growth, and support the development of domestic commercial aquaculture, while sustaining and conserving marine resources, consistent with applicable laws, regulations, and policies. The proposed action is needed to meet the directives of Executive Order (E.O.) 13921, *Promoting American Seafood Competitiveness and Economic Growth*, to address the increasing demand for seafood; facilitate long-term planning for marine aquaculture development; and address interests and concerns regarding offshore marine aquaculture siting.

ES.3 Public Involvement

Following the publication of E.O. 13921 on May 7, 2020, NMFS began a public outreach effort that included stakeholder engagement, video and print informational products, and soliciting input from stakeholders, including commercial and recreational fishing communities, academia, non-governmental organizations (NGOs), the general public, and coastal and ocean managers. Part of the initial public outreach effort included publication of a Request for Information (RFI) in the *Federal Register* (85 FR 67519, Oct. 23, 2020). The RFI solicited public input on the identification of AOAs in federal waters of the Gulf and Southern California, requesting help to identify data needs, data sources, and project requirements for offshore aquaculture. At the same time, the National Ocean Service (NOS), National Center for Coastal Ocean Science (NCCOS) worked with the NMFS Southeast Regional Office (SERO) and Southeast Fisheries Science Center to collect data for a spatial modeling analysis for the Gulf region. The work by NCCOS was published as an independently peer-reviewed technical memorandum entitled, "An Aquaculture Opportunity Area Atlas for U.S. Gulf of Mexico," hereafter referred to as "the Atlas" (Riley et al. 2021).

Through the end of 2021, and into the Spring of 2022, NMFS used the results in the Atlas, along with public input gathered through the RFI, to develop the Notice of Intent (NOI) for this PEIS. NMFS published the NOI in the *Federal Register* on June 1, 2022 (87 FR 33124) to initiate the NEPA process. The NOI included prompts to gather input from the public for the Gulf and Southern California AOA PEISs. Public comments for the Gulf AOA PEIS were accepted from June 1, 2022 to August 1, 2022 (60 days). Three webinar-based public listening sessions were held during this scoping period, in which comments could be submitted orally. On June 21, 2022, NMFS also provided a presentation on the AOA initiative to the Gulf of Mexico Fishery Management at its public meeting in Ft. Myers, Florida. The meeting included an opportunity for public comment and the Council provided those comments to NMFS as part of the formal written comments submitted during scoping. Written comments were accepted during the scoping period via letter and the federal docket NOAA-NMFS-2022-0044. NMFS published a Public Scoping Report to the Gulf AOA website and to the Office of Aquaculture (OAQ) AOA website (NMFS 2023a).

Through this public outreach process, NMFS SERO gathered information to inform this DPEIS from pre-scoping outreach, the scoping period, a review of the best available science, and additional expertise from NOAA offices and other federal agencies. The publication of the DPEIS in the *Federal Register* initiates the 90-day public review and comment period on the draft, after which all the comments received will be assessed and considered by NMFS in preparation of a Final PEIS.

ES.4 Alternatives

NMFS considered a reasonable range of alternatives during the DPEIS development process that were identified through coordination with cooperating and participating agencies and through public comments received during the public scoping period for the DPEIS. The DPEIS evaluates the No Action Alternative and six Action Alternatives that are a subset of the potential AOA options described in the Atlas. Alternatives considered but eliminated from detailed analysis and the rationale for their dismissal are described in Chapter 2, Section 2.9. NMFS may select more than one Alternative and identify one or more AOAs. The alternatives analyzed are:

Alternative 1: No Action

In **Alternative 1** (No Action), NMFS would not identify AOAs in federal waters of the Gulf. This would be inconsistent with the direction in Section 7 of E.O. 13921. However, offshore aquaculture development could still occur in federal waters of the Gulf. Operations sited outside of the areas discussed in this PEIS would not benefit from this preliminary environmental review of potentially suitable sites that will inform the permitting and environmental review process for future aquaculture operations proposed in an AOA. This functions as the analytic basis for comparison of the proposed action and other alternatives (i.e., baseline).

Preferred Alternative 2: Atlas AOA Option W-1

In **Alternative 2**, NMFS would identify W-1, a 2,000 acre area located approximately 79 km (43 nm) east of Port Mansfield, TX, and 90 km (48.6 nm) northeast of Port Isabel, TX, as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations.

Preferred Alternative 3: Atlas AOA Option W-4

In **Alternative 3**, NMFS would identify W-4, a 2,000 acre area located approximately 89.8 km (48.5 nm) southeast of the Port Aransas Inlet entering Corpus Christi Bay and 103.4 km (55.8 nm) to the inlet into Matagorda, TX, as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations.

Preferred Alternative 4: Atlas AOA Option W-8

In **Alternative 4**, NMFS would identify AOA Option W-8, a 500 acre area located approximately 107.4 km (58.0 nm) southeast of Freeport, TX, as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations.

Preferred Alternative 5: Atlas AOA Option C-3

In **Alternative 5**, NMFS would identify AOA Option C-3, a 2,000 acre area located approximately 133.4 km (72.0 nm) south of Pecan Island, LA and 137.5 km (74.2 nm) south of Marsh Island, LA, as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations.

Alternative 6: Atlas AOA Option C-13

In **Alternative 6**, NMFS would identify AOA Option C-13, a 500 acre area located approximately 36 km (20 nm) downriver from Venice, LA, 9.6 km (5.2 nm) from the inlet at South Pass and 21.8 km (11.8 nm) from Southwest Pass, as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations.

ES.5 Environmental Impacts

This DPEIS analyzes the environmental effects of identifying AOAs in federal waters of the Gulf. Resource areas analyzed include the administrative environment, the physical environment, the biological environment, the socioeconomic environment, the cultural and historic environment, and climate change. Although this Proposed Action is a planning effort and does not authorize aquaculture operations, the DPEIS incorporates information on both the direct impacts of identifying the AOAs and the potential impacts of finfish, shellfish, macroalgae or multi-species aquaculture operations that may be sited within each of the AOA Alternatives in the future. NMFS summarized differences in impacts between alternatives when it was reasonably possible to do so using the best available information. NMFS included additional information on the potential impacts of siting aquaculture operations within each of the AOA alternatives to support and inform future environmental review and permitting processes, consistent with the purpose and need for the proposed action and E.O. 13921. Future aquaculture projects proposed for siting in an identified AOA will be evaluated on an individual project basis during required permitting and review processes, consistent with federal law.

ES.6 Comparison of Alternative Summary

The tables in this section are intended to provide a brief summary and comparison of the environmental effects of the alternatives to identify AOAs in federal waters of the Gulf, and the potential effects of siting future offshore aquaculture operations in those areas. Chapter 3 of this DPEIS provides a more detailed description of affected resources. Potential effects to the physical, biological, socioeconomic, cultural and historical environments, and climate change can be found in Chapter 4.

Table ES-1. Summary comparison of alternatives for direct impacts of identifying AOAs on the Administrative Environment.

Alternative	Summary and Comparison of Potential Impacts on the Administrative Environment
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects to permitting and environmental review processes for future aquaculture operations through ad hoc siting analyses. Severity of effect could be increased or decreased given location of proposed aquaculture operation, information available for location, and type of operation proposed.
Alternative 2 (W-1)	Potential to cause beneficial administrative effects through increased efficiency in permitting and environmental review for offshore aquaculture operations sited in an AOA, including the identification of potentially suitable sites for marine aquaculture and minimization or avoidance of impacts to natural resources and ocean user groups through siting analysis.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 2. However, the potential benefits are expected to be less than those provided by Alternatives 2-5, due to overlap with identified areas of high vessel traffic and commercial fishing. Efficiencies in the permitting and environmental review process may be reduced due to these conflicts with navigation and commercial fishing activities, and may affect the suitability of this alternative AOA location for future aquaculture development.

Table ES-2. Summary comparison of alternatives for potential impacts of aquaculture on the Physical Environment.

Alternative	Summary and Comparison of Potential Impacts on Benthic Resources
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given physical disturbance of seafloor from gear, deposition and accumulation of waste and uneaten feed around aquaculture operations and changes in composition of benthic organism communities. Potential for effects could be more or less severe depending on site proximity to sensitive benthic habitats (i.e. hard-bottom, reefs) and physical site conditions (i.e. current, sediment composition).
Alternative 2 (W-1)	The types of potential adverse effects are similar to those described under Alternative 1, but the severity is expected to be reduced or minimized by suitable current conditions and sediment composition present in this location. Sensitive benthic habitat (Coral 9 HAPC, Harte Bank) is in the vicinity, but outside the expected area of impact of any aquaculture operation sited in AOA.
Alternative 3 (W-4)	Potential adverse effects are similar to those expected under Alternative 1. Potential severity of effects are reduced by suitable current conditions and sediment composition. Further, there is no known sensitive benthic habitat in the vicinity of the AOA.
Alternative 4 (W-8)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.
Alternative 5 (C-3)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.
Alternative 6 (C-13)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.

Alternative	Summary and Comparison of Potential Impacts on Protected Habitat, Marine Protected Areas and Special Resource Areas
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on sensitive habitats given increased vessel traffic, acoustic and light disturbances, wild species aggregation, marine debris, disease and pathogen transmission. Effects may be more or less severe depending on site proximity and type of aquaculture operation proposed.
Alternative 2 (W-1)	Potential adverse effects are similar to those expected under Alternative 1. However, the AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens and artificial reefs, HAPCs, or areas of known hard-bottom so the impacts would be less severe. Sensitive benthic habitat (Coral 9 HAPC, Harte Bank) is in the vicinity, but outside the expected area of impact associated with aquaculture sited in AOA. The risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 3 (W-4)	Potential adverse effects are the same as discussed in Alternatives 1. AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens and artificial reefs, HAPCs, or areas of known hard-bottom. Risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 4 (W-8)	Potential adverse effects, avoidance of overlap and reduction in risk and severity of potential effects are the same as discussed in Preferred Alternative 3.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed in Preferred Alternative 3. AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, HAPCs, or areas of known hard-bottom, reducing severity of potential effects. Sensitive resource area (i.e. fish haven with artificial reefs) is in the vicinity, but outside the expected area of impact associated with aquaculture sited in AOA. The risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 6 (C-13)	Potential adverse effects, avoidance of overlap and reduction in risk and severity of potential effects are the same as discussed in Preferred Alternatives 3.

Alternative	Summary and Comparison of Potential Impacts on Water Quality
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations are discharge of pollutants, generation of marine debris, interaction with HABs. Potential beneficial or adverse effects on nutrient levels, turbidity and primary production, depending on type of aquaculture. Site conditions (i.e. background nutrient levels, current speed and depth) may increase or decrease the severity of effects.
Alternative 2 (W-1)	Potential effects are similar to those expected under Alternative 1. However, The AOA has known site conditions, which include adequate depth, current speed, and low ambient nutrient levels; conditions are expected to decrease the severity of effects.
Alternative 3 (W-4)	Potential effects and severity are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects and severity are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 2. Ambient nutrient (nitrogen and phosphorus) levels are elevated compared to Alternatives 2-4, but not likely to increase the severity of effects.
Alternative 6 (C-13)	Potential adverse and beneficial effects and site conditions are the same as discussed in Alternative 2. Ambient nutrient (nitrogen and phosphorus) levels are elevated compared to Alternatives 5, and may affect the severity of effects. Seasonal variability in salinity and light transmissivity may also impact effects.

Alternative	Summary and Comparison of Potential Impacts on Air Quality
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse or neutral effects of future aquaculture operations from emissions associated with type farm operation (i.e. finfish, shellfish, macroalgae or multispecies), power generation and vessel use and transit patterns (i.e. distance and frequency), and operational considerations (i.e. type of aquaculture operations, culture systems employed, how vessels or farm systems are powered).
Alternative 2 (W-1)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 3 (W-4)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 4 (W-8)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 5 (C-3)	Potential for effects and variable severity of effects are the same as discussed in Alternatives 1. However, the AOA is the greatest distance from shore of all alternatives and could cause longer transit times between AOA and port and increased vessel emission effects.
Alternative 6 (C-13)	Potential for effects and variable severity of effects are the same as discussed in Alternatives 1. AOA is the shortest distance from shore of all alternatives and could cause shorter transit times between AOA and port and decreased vessel emission effects.

Alternative	Summary and Comparison of Potential Impacts on Aesthetic Quality (Visual and Acoustic Environment)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given acoustic disturbance, including construction and maintenance, aquaculture operation, power generation and vessel traffic. Potential adverse or beneficial effects given visibility of aquaculture operation, support vessels and lighting. Potential severity of effects may be increased or decreased given proximity to shore, coastal development near aquaculture operation, environmental conditions, ambient soundscape and ambient viewscape.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. However, any adverse acoustic and visual effects are expected to be minimal and only in the immediate area of AOA. No effects on shore-based areas are expected.
Alternative 3 (W-4)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.

Table ES-3. Summary comparison of alternatives for potential impacts of aquaculture on the Biological Environment.

Alternative	Summary and Comparison of Potential Impacts on Fish and Invertebrates
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects of future aquaculture operations given wild species aggregation and water quality. Adverse effects to water quality may be greater for finfish operations, whereas shellfish and macroalgae operations might provide localized benefits to water quality. Use of multitrophic aquaculture systems may mitigate adverse water quality effects. Potential adverse effects given waste and unconsumed feed, acoustic and light disturbances, escapement of aquaculture species, disease and pathogen transmission, antibiotic use introduction on non-native species, use of forage fish in fishmeal and feeds and marine debris. Severity of effects could be more or less severe depending on the type of aquaculture operation proposed (e.g., finfish, shellfish, macroalgae or integrated multitrophic), species being grown, location and site conditions (e.g., ambient water quality, depths, current conditions, sediment composition or proximity to sensitive habitats) at proposed site.
Alternative 2 (W-1)	Potential adverse or beneficial effects of future aquaculture operations given wild species aggregation and water quality are the same as Alternative 1. Potential adverse effects given waste and unconsumed feed, acoustic and light disturbances, escapement, disease and pathogen transmission, antibiotic use, introduction of non-native species, use of forage fish in fishmeal and feeds and marine debris are the same as Alternative 1. Severity of effects given acoustic and light disturbances, marine debris and use of forage fish in meal in feed are the same as Alternative 1. Severity of effects given water quality, wild species aggregation, escapement, disease and pathogen transmission, and antibiotic use may be more or less severe depending on the type of aquaculture operation and species produced. Severity of effects given water quality, waste and unconsumed feed may be less severe given suitable site conditions for ambient water quality, depths, current conditions, sediment composition and distance from sensitive habitats.
Alternative 3 (W-4)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential effects and severity of effects are the same as discussed in Alternatives 2, except where the severity of water quality effects may be more or less severe given ambient water quality.

Alternative	Summary and Comparison of Potential Impacts on ESA-listed Species
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects given water quality light disturbances and wild species aggregation around aquaculture structures. Beneficial effects could include the attraction of prey items and increased opportunities for feeding and refuge. Adverse effects could include disruption of typical feeding and movement behaviors and increased risk of entanglement, vessel strikes given attraction to aquaculture structure. Water quality could be improved or impaired locally by type of aquaculture operation. Potential adverse effects given entanglement and entrapment, acoustic disturbance, marine debris, vessel strikes, waste and unconsumed feed and antibiotic use, could cause increased risk of disease, serious injury or death. The location of and aquaculture operations and ESA-listed species present may reduce the risk of effects. Severity of effects could be more or less severe depending on the type of aquaculture operation and species being grown.

Alternative 2 (W-1)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative does not overlap with, but is closest in proximity (3.0 km [1.6 nm]) to proposed Rice's whale critical habitat of all alternatives. Alternative does overlap with proposed green sea turtle critical habitat, which covers the majority of Gulf waters. The Alternative's overlap with high use areas of giant manta rays increases risk of effects, while overlap with low use areas for sea turtles makes effects less likely for species. Alternative is a nearby sensitive benthic habitat for ESA-listed coral species (Coral 9 HAPC, Harte Bank), but outside of expected area of effects from aquaculture operations sites in AOA. Overall, Alternative may have similar potential to effect to listed species as Alternative 4, and lower potential for impacts to listed species than Alternatives 3, 5 and 6.
Alternative 3 (W-4)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles increases risk of effects, while overlap with low use areas for leatherback and green sea turtle makes effects less likely. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 5 and 6.
Alternative 4 (W-8)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, low use areas for sea turtles and risk of effects are the same as Alternative 2. Overall, Alternative may have similar potential to affect listed species as Alternative 2, and lower potential affect than Alternatives 3, 5 and 6.
Alternative 5 (C-3)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative does not overlap with, and is furthest (29.7 km [16.0 nm]) from proposed Rice's whale critical habitat of all alternatives. The Alternative's overlap with high use areas of giant manta rays, loggerhead, Kemp's ridley and leatherback sea turtles, increasing risks for effects and low use areas for green sea turtles, making effects less likely. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 3 and 6.
Alternative 6 (C-13)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles, low use areas for leatherback and green sea turtles and risk of effects are the same as Alternative 2. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 3 and 5.

Alternative	Summary and Comparison of Potential Impacts on Seabirds
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects given water quality and wild species aggregation around aquaculture structures. Beneficial effects could include the attraction of prey items and increased opportunities for feeding and refuge. Adverse effects could include disruption of typical feeding and movement behaviors and increased risk of entanglement, vessel strikes given attraction to aquaculture structure. Water quality could be improved or impaired locally by type of aquaculture operation. Potential adverse effects given entanglement and entrapment, light disturbances and acoustic disturbance, marine debris, vessel strikes, waste and unconsumed feed, disease and pathogen transmission, and antibiotic use, could cause increased risk of disease, serious injury or death. The location, type of aquaculture operation and seabird species present may increase or reduce the severity and risk of effects.
Alternative 2 (W-1)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.
Alternative 3 (W-4)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.
Alternative 4 (W-8)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.
Alternative 5 (C-3)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species. Alternative is further from shore of all Alternatives which may increase or reduce the severity and risk of effects to seabirds.
Alternative 6 (C-13)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species. Alternative is closest to shore of all Alternatives which may increase the severity and risk of effects on seabirds.

Table ES-4. Summary and comparison of alternatives for potential impacts of aquaculture on the Socioeconomic Environment.

Alternative	Summary and Comparison of Potential Impacts on Commercial Fishing
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given displacement or disruption of commercial fishing associated with fixed gear and other equipment placement in the water column, surface and bottom; marine debris; disease transmission, and increased vessel traffic in and out of coastal areas. Potential fish aggregation effects may be beneficial, by creating new structures and habitat that could concentrate commercially important fish species and/or adverse effects, such as increasing fishing pressure on commercial important species, increased risk of disease transmission and genetic impacts from escaped cultured species. Potential effects on seafood markets may be adverse (increased domestic competition) or beneficial (increased consumer demand for domestic seafood). Workforce effects may be adverse (competition for limited labor resources) or beneficial (diversification of job opportunities). Potential for effects to increase or decrease in magnitude depending on overlap with or proximity to commercial fishing activities or markets.
Alternative 2 (W-1)	Potential effects are similar to those expected in Alternative 1. However, because this area overlaps with low levels of bandit gear fishing, and shrimp trawling and does not overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining, any adverse effects are reduced as compared to Alternative 1.

Alternative	Summary and Comparison of Potential Impacts on Commercial Fishing
Alternative 3 (W-4)	Potential effects, overlap and avoidance of fishing areas and reduction of adverse effects compared to Alternative 1 are similar to Alternative 2.
Alternative 4 (W-8)	Potential effects are similar to those expected in Alternative 1. AOA overlaps with relatively low levels of reef fish longline and shrimp trawling activity, and does not overlap with bandit gear fishing, menhaden fishing, HMS pelagic longlining. As a result, adverse effects are reduced as compared to Alternative 1.
Alternative 5 (C-3)	Potential effects, overlap and avoidance of fishing areas, and the reduction of adverse effects compared to Alternative 1 are similar to Alternative 2.
Alternative 6 (C-13)	Potential effects are similar to those expected in Alternative 1. AOA overlaps with areas of moderate shrimp trawling activity and low levels of bandit gear fishing and does not overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining. As a result, adverse effects to shrimp trawling may occur while adverse effects are reduced for other fishing activities.

Alternative	Summary and Comparison of Potential Impacts on Recreational Fishing
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations from displacement or disruption of recreational fishing associated with fixed gear and other equipment placement in the water column, surface and bottom; marine debris; disease transmission from cultured stocks; and increased vessel traffic in and out of coastal areas. Potential fish aggregation effects may be beneficial, concentrating target fish species and/or adverse, increased fishing pressure on local stocks. Severity of effects could increase or decrease given overlap with or proximity to recreational fishing activities.
Alternative 2 (W-1)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Port Mansfield and South Padre Island, which have moderate to high recreational fishing engagement and reliance, could be affected from future aquaculture development in this AOA.
Alternative 3 (W-4)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Matagorda, Port Aransas, and Port O'Connor, which have high recreational fishing reliance, could be affected future aquaculture development in this AOA.
Alternative 4 (W-8)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Clute, Quintana, and Surfside, which have moderate to high recreational fishing engagement and/or reliance, could be affected future aquaculture development in this AOA.
Alternative 5 (C-3)	Potential effects and severity are the same as discussed in Alternative 1. Potential adverse effects reduced by minimizing overlap of AOA with recreational fishing activities through site suitability analysis. Louisiana coastal communities nearby with low recreational fishing engagement and reliance, could be affected by future aquaculture development in this AOA.
Alternative 6 (C-13)	Potential effects and severity are the same as discussed in Alternative 1. Nearby Louisiana coastal communities, including Grand Isle and Venice, which have high recreational fishing, engagement and reliance, could be affected by future aquaculture development in this AOA.

Alternative	Summary and Comparison of Potential Impacts on Seafood Markets and Regional Food Systems
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential beneficial and adverse effects of future aquaculture operations given introduction of new domestic products, increase in the supply of domestic products, new or increased interactions with wild-caught seafood products (competition or complimentary), new or increased interactions with existing interstate or international trade markets. The overall growth in a market may be considered an economic benefit, but local or regionally-scaled costs may occur simultaneously. Effects of offshore aquaculture development on existing aquaculture and fisheries industries could be adverse and/or beneficial. As development of offshore aquaculture can require high capital investment, large, established businesses (domestic or international), could have an advantage over local or regional stakeholders.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. The type (adverse/beneficial) and severity of effects could depend largely on the details of potential future aquaculture operations which may be sited within an AOA (e.g., species and volume produced, target markets), and overlap with or proximity to existing aquaculture and or commercial fishing activities and markets. Nearby Texas coastal communities, including Port Mansfield and South Padre Island, could benefit if offshore aquaculture were to integrate into the existing ocean economy (which includes commercial fishing, seafood dealers, and other seafood-related businesses) in a complementary way and provide accessible jobs.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Texas coastal communities nearby, including Matagorda, Port Aransas, and Port O'Connor could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Texas coastal communities nearby, including Clute, Quintana, and Surfside could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Louisiana coastal communities nearby could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Louisiana coastal communities nearby, including Grand Isle and Venice, could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.

Alternative	Summary and Comparison of Potential Impacts on Tourism Economies
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations from displacement or disruption of recreational activities given fixed gear and other equipment placement in the water column and surface, increased vessel traffic in and out of coastal areas, or changes in ecosystem services that support recreation and tourism. Potential beneficial and/or adverse effects given new areas where wildlife aggregations may occur. Fish aggregation effects may be beneficial and/or adverse, improving recreation fishing opportunities and/or increasing fishing pressure on wild stocks.

Alternative	Summary and Comparison of Potential Impacts on Tourism Economies
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Port Mansfield and South Padre Island, which have moderate to high recreational fishing engagement and reliance, could be affected. The broader tourism economies of nearby Texas coastal communities, including South Padre Island and Port Isabel, could be affected from potential future aquaculture development.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Matagorda Bay, Port O'Connor, and Port Aransas which have high recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Texas coastal communities, including Port Aransas, Fulton, and Seadrift could be impacted (positive or negative) from potential future aquaculture development.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Clute, Quintana, and Surfside which have moderate to high recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Texas coastal communities, including Clute and Surfside Beach could be impacted (positive or negative) from potential future aquaculture development.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. Louisiana coastal communities nearby, which have low recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Louisiana coastal communities, including those in Assumption Parish, Iberia Parish, St. Mary Parish, and Vermillion Parish, could be affected by future aquaculture development.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. Louisiana coastal communities nearby, including Grand Isle and Venice which have high recreational fishing engagement and reliance, could be impacted (positive or negative) from potential future aquaculture development. The broader tourism economies of nearby Louisiana coastal communities, including those in Jefferson Parish and Plaquemines Parish could be affected by future aquaculture development.

Alternative	Summary and Comparison of Potential Impacts on Offshore Industrial Activities and Infrastructure
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations sited in areas of conflict with other ocean industry sectors, including oil, gas and wind energy development, marine mineral operations, and submarine utilities, given introduction of new structures, navigational impediments, increased vessel traffic. Severity of effects may be increased or decreased given aquaculture operations proximity to industrial activities and vessel transit corridors.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity (within 3 km [1.62 nm]) to existing oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes), offshore wind energy development areas or mineral mining activity. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity, but is located 2.64 km (1.43 nm) east of an active oil and gas lease block with infrastructure. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.

Alternative	Summary and Comparison of Potential Impacts on Offshore Industrial Activities and Infrastructure
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity, but is located 750m from a single oil and gas pipeline. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity. However there is a variety of oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]) of the AOA, including three oil and gas pipelines, including one within 700m (2297 ft) of the AOA, two active oil and gas platforms and 13 borehole. Potential impacts are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes), offshore wind energy development areas or mineral mining activity. However there is a variety of oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]) of the AOA, including one oil and gas platform, two oil and gas pipelines and 4 boreholes. Potential impacts are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.

Alternative	Summary and Comparison of Potential Impacts on Public Health and Safety (Military Readiness and Operations)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations proposed in areas that have not been evaluated for compatibility with military operations. Operations could be proposed in controlled waterspace, restricted areas, danger zones, and or conflict with training and testing, or overlap with unexploded ordnance areas. Conflict with military training and testing areas would cause inefficient permitting and environmental review processes and may cause the need to re-site proposed operations.
Alternative 2 (W-1)	This Alternative overlaps with a Special Use Airspace Warning Area and a Military Operating Area. Alternative does not overlap with controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in this location, at this time. No adverse effects to military readiness and operations are anticipated.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternatives 2.
Alternative 4 (W-8)	This Alternative overlaps with a Special Use Airspace Warning Area, but does not overlap with a Military Operating Area. Alternative does not overlap with controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in that location, at this time. No adverse effects to military readiness and operations are anticipated.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternatives 4.

Alternative	Summary and Comparison of Potential Impacts on Public Health and Safety (Military Readiness and Operations)
Alternative 6 (C-13)	This Alternative does not overlap with any Special Use Airspace Warning Area, Military Operating Area, controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in that location, at this time. No adverse effects to military readiness and operations are anticipated.

Alternative	Summary and Comparison of Potential Impacts on (Public Health and Safety Navigational Safety)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations sited in areas of high conflict with other ocean use sectors given navigational hazard via vessel traffic, new structures, obstructions and marine debris.
Alternative 2 (W-1)	Potential adverse effects are the same as Alternative 1. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with low vessel traffic observed. Alternative averages 19 AIS monitored vessel transits through Alternative per year.
Alternative 3 (W-4)	Potential adverse effects are the same as Alternative 1-2. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with low vessel traffic observed. Alternative averages 32 AIS monitored vessel transits through Alternative per year.
Alternative 4 (W-8)	Potential adverse effects are the same as Alternative 1-3. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with lowest vessel traffic observed of all alternatives. Alternative averages 12 AIS monitored vessel transits through Alternative per year.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternatives 1-4. Alternative does not with shipping fairways and anchorage areas. Potential risk for navigational hazards is higher given higher levels of vessel traffic transiting Alternative than Alternatives 2-4. Alternative averages 106 AIS monitored vessel transits through Alternative per year.
Alternative 6 (C-13)	Alternative 6 (C-13) Potential effects are the same as discussed in Alternatives 1-5. Alternative has the highest potential risk for navigational hazards given Alternative having the highest average number of vessel transits per year of all Alternatives, with 1,340 AIS monitored vessel transits through Alternative per year.

Alternative	Summary and Comparison of Potential Impacts on Environmental Justice
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations sited in areas without the fair treatment and meaningful involvement of all people, regardless of race, color, gender, sexual orientation, national origin, tribal affiliation, religion, disability, or income.
Alternative 2 (W-1)	This Alternative is located outside and away from any coastal community given it is in federal waters. Although the closest communities are 79 km (42.7 nautical miles) from Port Mansfield, TX and 90 km (48.6 nautical miles) from Port Isabel, TX, to the site, there still could be adverse or beneficial effects on human health and environmental effects on minority, low-income populations, or EJ communities.
Alternative 3 (W-4)	The closest port and associated community is 89.8 km (48.5 nautical miles) from Port Aransas, to the site. Potential effects are the same as discussed in Alternatives 2.
Alternative 4 (W-8)	The closest port and associated community is 107.4 km (58 nautical miles) from Freeport, TX, to the site. Potential effects are the same as discussed in Alternatives 2-3.

Alternative	Summary and Comparison of Potential Impacts on Environmental Justice
Alternative 5 (C-3)	The closest port and associated community is 133 km (71.8 nautical miles) from Morgan City, to the site. Potential effects are the same as discussed in Alternatives 2-4.
Alternative 6 (C-13)	The closest port and associated community is 9.6 km (5.18 nautical miles) from South Pass, LA to the site. Potential effects are the same as discussed in Alternatives 2-5.

Alternative	Summary and Comparison of Potential Impacts on Cultural, Historic, and Archaeological Resources
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on cultural, historical or archaeological resources due to seafloor disturbance and deposition of uneaten feed and fish waste. Effects may be more or less severe depending on the type of aquaculture operation and its proximity to cultural, historical or archaeological resources.
Alternative 2 (W-1)	Potential adverse effects are the same as described in Alternative 1. Potential adverse effects to known cultural, historical or archaeological resources are avoided, as there are none documented within the anticipated field of impact from aquaculture operations sited in this location.
Alternative 3 (W-4)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential adverse effects are the same as discussed and Alternative 1. Alternative is located approximately 2.5 km (2.17 nm) from a known shipwreck. However, this shipwreck is far enough away from the Alternative that it is anticipated to be outside the potential field of impact for an aquaculture operation sited in this Alternative and would not be impacted.

Table ES-5. A summary and comparison of alternatives for potential climate change impacts.

Alternative	Summary and Comparison of Potential Climate Change Impacts
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on Gulf communities given climate change from natural hazards (i.e. hurricanes, flooding, heat and cold waves), storm surge risk, sea level rise, economic indicators and housing characteristics and infrastructure vulnerability. Individual communities within distance from a future aquaculture operation may be more or less affected by climate change effects than Alternatives 2-6, which could include effects to supportive shoreside infrastructure and local housing dependent on the location of the aquaculture site and adjacent communities associated with the operation.
Alternative 2 (W-1)	Potential adverse effects are the same as discussed in Alternative 1. Most communities within distance of the AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, while fewer communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities ranged between Alternative 3 and Alternative 5.

Alternative	Summary and Comparison of Potential Climate Change Impacts
Alternative 3 (W-4)	Potential adverse effects are the same as discussed in Alternative 1. Some communities within distance from AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing. Sea level was a concern less concern, with only one community in proximity to the AOA noted as vulnerable, although four of eight locations did not have data available for sea level rise. The communities in proximity to Alternative 3, had the fewest number of climate vulnerable communities.
Alternative 4 (W-8)	Potential adverse effects are the same as discussed in Alternative 1. Most communities within distance from AOA have high vulnerability to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, and sea level rise. The communities in proximity to Alternative 4 had the greatest number of climate vulnerable communities.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed in Alternative 1. Most Communities within distance from AOA are vulnerable to natural hazards and storm surge impacts that could affect shoreside infrastructure and workforce housing, while a few communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities was higher than Alternatives 2 and 6, but less than Alternative 4.
Alternative 6 (C-13)	Potential adverse effects are the same as discussed in Alternative 1. Most Communities within distance from AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, while a few communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities ranged between Alternative 3 and Alternative 5.

ES.7 Cumulative Impacts

The cumulative impacts of each AOA Alternative were analyzed for each resource addressed in Chapter 4 (Environmental Consequences) in combination with past, present, and reasonably foreseeable future actions. This action is not expected to have significant beneficial or adverse cumulative effects on the physical, biological, cultural and historic environments, public health and safety or climate change because the action is a planning action. This action would likely have variable direct and indirect, but generally beneficial effects, on the socioeconomic and administrative environments by streamlining future aquaculture permitting processes and authorizations. Most effects are likely minimal as the Proposed Action, along with other past actions, present actions, and reasonably foreseeable future actions, are not expected to alter existing ocean uses or the ocean economy in the Gulf.

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ACRONYMS AND ABBREVIATIONS

%	percent
ac	acre
AIS	Automated Identification System
AOA	Aquaculture Opportunity Area
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
C	Central
C.F.R.	Code of Federal Regulations
Chl-a	chlorophyll-a
COVID-19	Coronavirus Disease 2019
CSVI	Community Social Vulnerability Indicator
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DAF	Department of the Air Force
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DPEIS	Draft Programmatic Environmental Impact Statement
DPS	Distinct Population Segment
E	East
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EJ	Environmental Justice
ELB	Electronic Logbook
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FAD	Fish-aggregating device
FAO	Food and Agriculture Organization of the United Nations
FDA	U.S. Food and Drug Administration
FMP	Fishery Management Plan
FR	Federal Register
ft	feet
FWC	Florida Fish and Wildlife Conservation Commission
GHG	Greenhouse gas
GIS	Geographic Information System
Gulf	Gulf of Mexico

GMFMC	Gulf of Mexico Fishery Management Council
GSMFC	Gulf States Marine Fisheries Commission
ha	hectare
HAB	harmful algal bloom
HAPC	Habitat Areas of Particular Concern
HMS	Highly Migratory Species
km	kilometer
L	liter
LDWF	Louisiana Department of Wildlife and Fisheries
µmol/L	micromoles per liter
MC	Marine Cadastre
mi	statute mile
ml	milliliter
MMPA	Marine Mammal Protection Act
MOA	Military Operating Area
MPA	Marine Protected Area
MSP	Marine Spatial Plan/Planning
mt	metric ton
NAHPS	National Aquaculture Health Plan and Standards
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NCCOS	National Centers for Coastal Ocean Science
NEPA	National Environmental Policy Act
nm	nautical mile
N	North
NE	Northeast
NW	Northwest
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NOS	National Ocean Service
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NRI	National Risk Index
OCS	Outer Continental Shelf
ONMS	Office of National Marine Sanctuaries
PEIS	Programmatic Environmental Impact Statement
PRD	Protected Resources Division
RFI	Request for Information
S	South

SE	Southeast
Section 10	Section 10 of the Rivers and Harbors Act of 1899
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SUA	Special Use Airspace
SW	Southwest
TPWD	Texas Parks and Wildlife Department
UN	United Nations
U.S.	United States of America
USACE	U.S. Army Corps of Engineers
U.S.C.	U.S. Code
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USM	University of Southern Mississippi
W	West
WEA	Wind Energy Area(s)

1. INTRODUCTION

1.1 Introduction

The global human population is currently estimated at 8.2 billion people, and it is expected to grow to around 10.3 billion over the next fifty to sixty years (U.N. 2024). As the human population grows, the global food demand increases, including the demand for seafood. In 2022, global seafood production (capture fisheries and aquaculture) reached a record high of 223.2 million metric tons (mt), constituting approximately 15 percent of the world's animal protein supply (FAO 2024). Seafood accounted for over half of the animal protein supply for some countries in Asia and Africa (FAO 2024). Of the global aquatic animal production in 2022, an estimated 89 percent was used for direct human consumption, highlighting the importance of seafood in maintaining global food security (FAO 2024). Seafood is widely recognized as a nutritious source of high quality protein, nutrients including omega-3 fatty acids, vitamins and minerals that are essential for human health.

In the United States, seafood is an increasing component of the population's diet. Reported annual per-capita consumption of fish and shellfish in the U.S. ranged from 16.8 pounds to 18.8 pounds during 2011 through 2016, increasing to around 19 pounds during 2017 through 2020 (NMFS 2020). To meet the growing demand, the U.S. imported 6.1 million pounds of seafood valued at $21.4 billion in 2020; a trade deficit of $17.0 billion (NMFS 2020). In 2020, an estimated 70-85 percent of all seafood consumed in the U.S. was imported (NMFS 2020). The U.S. seafood trade deficit increased $3.3 billion in 2023 to $20.3 billion. As such, the U.S. Department of Homeland Security has identified U.S. dependency on imported seafood as an economic and food supply vulnerability, and has indicated the need to promote domestic U.S. aquaculture production to meet seafood demand (DHS 2021). The COVID-19 epidemic and its impacts on fisheries and global supply chains further highlighted the importance of domestic seafood production and its role in national food security.

The U.S. is a global leader in managing sustainable seafood production. In fact, U.S. capture fisheries and aquaculture are managed under some of the most robust environmental standards in the world. Under various statutes, NMFS is responsible for the stewardship of the nation's ocean resources and their habitat, including the management of marine fisheries within federal waters. Through science-based management, NOAA sustains, protects, and attempts to increase the domestic seafood supply while protecting ecosystem health and sustainability.

Over the past 20 years, the increasing global and domestic seafood demand has largely been met by aquaculture production (NMFS 2023d), and the sector's growth trajectory is indicative of its capacity for continued contributions toward meeting this increasing demand (FAO 2024). While capture fisheries remain an essential source of seafood production, global capture fisheries production has not notably increased since the 1980s (FAO 2024), despite the increasing demand. Conversely, aquaculture production has continued to increase, growing by over 6% since 2020 (FAO 2024). In 2022, aquaculture production reached a historic milestone, surpassing capture fisheries as the major global producer of aquatic animals (FAO 2024).

NOAA has directives to preserve ocean sustainability and facilitate domestic aquaculture in the U.S. through the National Aquaculture Act of 1980, the NOAA Marine Aquaculture Policy, and Executive Order 13921 (E.O. 13921), *Promoting American Seafood Competitiveness and Economic Growth* (85 FR 28471, May 7, 2020). Through a science-based approach, NOAA supports regionally appropriate and sustainable growth of domestic aquaculture that considers and mitigates impacts to protected resources, essential fish habitat, and marine ecosystems (NMFS 2023d), and complements wild-capture fisheries, working waterfronts, and our nation's seafood processing and distribution infrastructure.

1.2 Proposed Action

The Proposed Action for this Draft Programmatic Environmental Impact Statement (DPEIS) is to identify locations, referred to as Aquaculture Opportunity Areas or AOAs, that may be suitable for multiple future offshore aquaculture operations in U.S. federal waters in the Gulf of Mexico (Gulf), and to evaluate the potential impacts associated with siting aquaculture in those locations in the future. For the purpose of this DPEIS, offshore aquaculture is defined as aquaculture operations in federal waters of the Gulf. The AOAs identified through this process would be considered potentially suitable for finfish, shellfish, macroalgae, or multi-species aquaculture. The Proposed Action to identify AOAs supports long-term planning for marine aquaculture development in federal waters of the Gulf and may be used to inform permitting, consultation, and review processes for future aquaculture operations. It does not support a specific regulatory or permitting action and does not authorize or permit any specific aquaculture-related activities or individual projects.

This DPEIS analyzes and discusses the potential impacts of identifying up to five AOAs in federal waters of the Gulf and discusses the potential impacts of siting commercial aquaculture operations within those locations at a future time. These five areas are a subset of areas identified as potential AOA Options in the marine spatial planning study conducted by the NOAA National Centers for Coastal Ocean Science (NCCOS), published in the Aquaculture Opportunity Atlas for the U.S. Gulf of Mexico (Atlas), which is incorporated by reference (Riley et al. 2021).

1.3 Purpose and Need

The purpose of the proposed action is to apply a science-based approach to identify AOAs in federal waters of the Gulf. The goal of identifying AOAs is to promote American seafood competitiveness, food security, economic growth, and support the development of domestic commercial aquaculture, while sustaining and conserving marine resources, consistent with applicable laws, regulations, and policies. The proposed action is needed to meet the directives of Executive Order (E.O.) 13921, *Promoting American Seafood Competitiveness and Economic Growth*, to address the increasing demand for seafood; facilitate long-term planning for marine aquaculture development; and address interests and concerns regarding offshore marine aquaculture siting.

1.4 Background

1.4.1 Marine Aquaculture Policy in the U.S.

The National Aquaculture Act 1980

In 1980, Congress authorized the National Aquaculture Act (NAA) (16 U.S.C. § 2801 *et seq*.) to establish a national aquaculture policy, recognizing the need to reduce the U.S. fisheries product trade deficit, augment existing commercial and recreational capture fisheries, produce renewable resources, and therefore meet future domestic food needs and contribute to the global seafood supply. Under this law, the Secretaries of Agriculture, Commerce, and Interior were designated to co-lead a coordinating committee, established as the Joint Subcommittee on Aquaculture within the White House Office of Science and Technology Policy, and charged with creating a National Aquaculture Development Plan.

U.S. Department of Commerce and NOAA Aquaculture Policies

After the NAA was enacted in 1980, several government initiatives and high-level reports promoted offshore aquaculture and coordinated marine spatial planning in U.S. waters; however, offshore aquaculture development in the U.S. was inhibited by scientific, economic, legal, and production factors (Cicin-Sain et al. 2005; Rubino 2008; Lester et al. 2018). Consistent with the NAA, the U.S. Department of Commerce (DOC) developed an Aquaculture Policy (2011) to specify the goals, objectives, and priorities for all DOC Bureaus, including NOAA. The Aquaculture Policy (2011) emphasized jobs, the economy, innovation, and international competitiveness. Subsequently, the U.S. Department of Agriculture (USDA), Food and Drug Administration (FDA), Department of the Interior (DOI), and the Joint Subcommittee on Aquaculture have been working in partnership "to make the U.S. a world leader in developing, demonstrating, and employing innovative and sustainable aquaculture technologies and in encouraging worldwide adoption of sustainable aquaculture practices and systems." Expanding upon the DOC Aquaculture Policy, the NOAA Marine Aquaculture Policy (2011) reaffirmed aquaculture as an important component of NOAA's marine stewardship mission and strategic goals for healthy oceans and resilient coastal communities and economies. Under various statutory authorities (e.g., Magnuson–Stevens Fishery Conservation and Management Act [MSA], Endangered Species Act [ESA], and Marine Mammal Protection Act [MMPA]), NMFS is responsible for permitting certain types of aquaculture operations, and for protecting habitats, vulnerable species, and sustainable fisheries, and thus has responsibility for considering, preventing, and mitigating potential adverse environmental impacts of proposed and existing marine aquaculture development and operational plans.

Executive Order 13921

Presidential E.O. 13921, *Promoting American Seafood Competitiveness and Economic Growth*[1] (85 FR 28471, May 7, 2020), called for the expansion of sustainable seafood production in the U.S. to ensure food security; provide environmentally safe and sustainable seafood; support American workers; ensure coordinated, predictable, and transparent federal actions; and remove unnecessary regulatory burdens. Importantly, specific action items with defined deliverables are required for the purpose of increasing transparency and coordination among government agencies, reducing regulatory barriers, and facilitating environmentally responsible U.S. offshore aquaculture development. Section 7 of the E.O. directs the Secretary of Commerce to identify AOAs in consultation with the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Homeland Security, the Administrator of the Environmental Protection Agency, other appropriate federal officials, and appropriate Regional Fishery Management Councils, and in coordination with appropriate state and tribal governments. This includes:

- Phase 1: Within one year of the E.O., identify at least two geographic areas containing locations suitable for commercial aquaculture.
- Phase 2: Within two years of identifying each area, complete a Programmatic Environmental Impact Statement (PEIS) for each area to assess the impact of siting aquaculture facilities there (as well as alternatives).
- For each of the following four years, identify two additional geographic areas containing locations suitable for commercial aquaculture and complete a PEIS for each within two years.

1.4.2 Marine Aquaculture in the Gulf of Mexico

The Gulf is one of the most biologically productive ocean regions in the world, supporting a wide variety of industries, and highly productive commercial and recreational fisheries (NOAA 2021a). The Gulf Region's waterfronts support commercial and recreational fisheries and nearshore aquaculture. Its coastal infrastructure, which includes, but is not limited to seafood processing, wholesale and retail seafood marketing, and land and marine shipping, can also provide considerable support for future offshore aquaculture development. Opportunities for offshore aquaculture in the Gulf have been the subject of discussion and research since the early

[1]https://www.federalregister.gov/documents/2020/05/12/2020-10315/promoting-american-seafood-competitiveness-and-economic-growth

1990s, and policies and regulations to support offshore aquaculture in the Gulf have been in development for over twenty years. Aquaculture interests have included various taxonomic groups, such as live rock (i.e., corals and sponges), molluscan shellfish, macroalgae (i.e., seaweed), food fish, and bait fish. Information about candidate finfish, shellfish and microalgae species for commercial offshore aquaculture operations in the Gulf is discussed in detail in Appendix D. Examples of past and current offshore aquaculture projects in the Gulf are highlighted below.

Many recognize that macroalgae offer ecosystem services that could help alleviate impacts of ocean acidification, eutrophication, and hypoxia. In addition to macroalgae harvest for food and non-food uses (e.g., cosmetics, animal feed, and fertilizer), macroalgae production for biofuels is a topic of investigation by the U.S. Department of Energy (DOE). To date, the DOE has supported multiple feasibility studies to assess candidate species, cultivation practices, and scalability of macroalgae cultivation for biofuels in the Gulf.

Over the years, several commercial finfish projects and federally sponsored demonstration projects have occurred in state and federal waters of the Gulf (Stickney 1998). For instance, SeaFish Mariculture was the first applicant to pursue development of an experimental offshore aquaculture operation in the Gulf in association with Shell Offshore Services, Inc; the project was located approximately 89 km (48 nm) south-southwest of Freeport, Texas (Riley et al. 2023). For this project, three net pens were permitted by the U.S. Army Corps of Engineers (USACE) Galveston District in 1997. NMFS supported that project by issuing an exempted fishing permit that authorized SeaFish Mariculture to harvest, possess, and sell red drum *(Sciaenops ocellatus*), greater amberjack (*Seriola dumerili*), and red snapper (*Lutjanus campechanus*) from federal waters of the Gulf, to possess or sell greater amberjack or red snapper below the minimum size limit, and to harvest or possess red snapper in excess of established trip limits or during closed seasons.

Permitting for the SeaFish Mariculture demonstration project was fairly streamlined given its co-location with an existing offshore platform, and the operation did not significantly interfere with navigation, fishing, or other ocean user groups. Although SeaFish Mariculture successfully demonstrated production of red drum in a growth cycle of less than twelve months, the project encountered a series of setbacks and ceased operations after two years of production when Shell Offshore Services developed a nearby natural gas well and required the platform to resume energy production. The SeaFish Mariculture project is not active and the permit is now expired.

One study (Waldemar 1998) concluded that offshore aquaculture holds great attention and potential for public and private entities in the northern Gulf, but its feasibility remains untested. A major hindrance to development is the lack of easily accessible information about the environment in the Gulf and opportunities that may capture efficiencies in siting with energy infrastructure. The study concluded that the establishment of an offshore aquaculture industry is practicable with existing technology, but it needs to be scaled appropriately to be economically viable (Waldemar 1998).

The NOAA's Office of Oceanic and Atmospheric Research, National Sea Grant College Program (Sea Grant) and NMFS Office of Aquaculture (OAQ), in partnership with the Gulf States Marine Fisheries Commission (GSMFC), have supported several research and demonstration projects for offshore aquaculture in the Gulf. In 2000, Sea Grant funded a demonstration project to the University of Southern Mississippi (USM) so they could evaluate emerging technology with submersible net pens. The objective was to assess fish production and survivability of net pens during tropical storms and hurricanes. The project secured permitting from the USACE to deploy a net pen approximately 35 km (22 mi) south of Pascagoula, Mississippi (Bridger and Costa-Pierce 2002). The project also supported several workshops with stakeholders to document the permitting framework and to assess opportunities for offshore aquaculture development. Unfortunately, the demonstration project concluded when the net pen was detached from its mooring in a winter storm shortly after deployment and prior to execution of any research trials.

In 2009, NOAA, through the GSMFC and USM, contracted with Waldemar S. Nelson and Co., Inc. to participate in a planning effort for a demonstration-scale aquaculture project in the Gulf. A feasibility study was conducted to identify offshore energy platforms that would support co-siting of an aquaculture operation with net pens ranging in size from 3,400 to 11,000 cubic meters (120,070 to 388,461 cubic ft) . A comprehensive report was produced providing guidance for site selection, equipment evaluation, candidate species selection, feed and nutrition assessment, and strategies for risk management (Waldemar 2009). This study was one of the first in the region to include use of Geographic Information Systems (GIS) and modern spatial planning techniques for identifying areas for aquaculture development.

In 2021, the Gulf Offshore Research Institute, a not-for-profit corporation, completed feasibility assessments of two offshore platforms that could potentially support aquaculture development co-sited with energy production infrastructure (Satterlee et al. 2021). The platforms are located approximately 56 km (30 nm) northeast of Port Mansfield, Texas. Study results indicate the economics of an offshore platform-based aquaculture system could be cost competitive. Geospatial analysis and site characterization revealed favorable conditions for an offshore aquaculture farm, and the study did not identify conflicts that would preclude farm development (Satterlee et al. 2021).

Currently, there are several demonstration and commercial aquaculture projects in development in the Gulf. Ocean Era, Inc's, Velella Epsilon Project, is a single-cage demonstration project proposing to grow almaco jack (*Seriola rivoliana*) approximately 72 km (39 nm) southwest of

Sarasota, Florida; it was issued an NPDES permit from the U.S. Environmental Protection Agency (EPA) in September 2020[2] . The permit became effective in July 2022 following an administrative challenge and review by the EPA's Environmental Appeals Board. Ocean Era has since requested modifications to the permit, changing the cage design and species to be grown for the demonstration project to red drum (*sciaenops ocellatus*). Those proposed modifications are currently under review by the EPA and U.S. Army Corps of Engineers (USACE). A commercial aquaculture operation, Manna Fish Farms, Inc has submitted permit applications to the USACE and EPA proposing to produce red drum and striped bass (*Morone saxatilis*) in a commercial scale finfish operation at a 300 acre (0.47 sq mi) site located approximately 30 km (16 nm) offshore of Pensacola, Florida (Lucas et al. 2021). Additionally, a demonstration-scale project featuring the use of integrated multitrophic aquaculture techniques to produce native finfish, shellfish, and macroalgae species is being proposed in state waters of Alabama.

1.4.3 Identification of Aquaculture Opportunity Areas Process

The AOA planning process for the Gulf uses marine spatial planning (MSP). Generally, an MSP process is applied to minimize user conflicts and interactions with protected species and habitats (Riley et al. 2021). MSP has been applied to manage a wide range of renewable and nonrenewable ocean resources (Ehler and Douvere 2009). In U.S. waters, MSP has been applied in the planning of marine protected areas (MPAs), navigation and transportation management, and energy development. For example, the Bureau of Ocean Energy Management (BOEM) has used MSP to establish Wind Energy Areas (WEA) and oil and gas planning areas and define potential lease sales on the Outer Continental Shelf (Kaiser et al. 2011; DOE 2015).

The application of MSP is central to applying an ecosystem approach for aquaculture; MSP helps ensure accountability and equitable sharing of the resources (Stelzenmüller et al. 2017; Gimpel et al. 2018). An ecosystem approach integrates aquaculture activities within the wider ecosystem and promotes sustainable development, equity, and resilience of interlinked social-ecological systems (Brugère et al. 2019). Spatio-temporal planning for different types of aquaculture is used to balance tradeoffs among economic, cultural, and management considerations (Couture et al. 2021). Incorporating spatial and temporal planning strategies into the aquaculture planning process facilitates initial potential compatibility assessments, while also increasing efficiency of meaningful communications within and between permitting agencies, and potentially with permit applicants.

As NMFS identifies AOAs, MSP provides a valuable foundation for offshore siting decisions to drive an informed, forward-looking, and sustainable industry to maximize production efficiency and limit adverse interactions (Lester et al. 2018a). A well-developed, comprehensive spatial

[2] https://www.epa.gov/npdes-permits/ocean-era-inc-velella-epsilon-aquatic-animal-production-facility-national-pollutant

planning approach can enhance investor and industry confidence and decrease the risks associated with offshore aquaculture (Aguilar-Manjarrez et al. 2018; Lester et al. 2018; Froehlich et al. 2021). And several researchers have described MSP as essential for minimizing adverse ecological, social, and interactions with ocean user groups (Kapetsky et al. 2013; Froehlich et al. 2021). With these goals, a marine spatial planning study was initiated by NCCOS in collaboration with NMFS to identify potential AOA Options across the Gulf. This is the first application of MSP for planning and siting offshore aquaculture.

NCCOS used the best available spatial data to account for key environmental, economic, social, and cultural considerations to identify areas that may be capable of supporting three to five commercial-scale aquaculture operations. The spatial modeling approach was specific to the planning goal of identifying discrete areas, between 500 and 2,000 acres (0.78 and 3.13 sq mi) that met the industry and engineering requirements of depth and distance from shore and that may be suitable for the cultivation of finfish, macroalgae, shellfish, or a combination of species. Areas identified as AOAs are expected to support multiple commercial aquaculture operations, but all portions of an identified AOA may not be appropriate for every type of aquaculture. Individual locations for farm operations and types would require further precision siting within an AOA. Future aquaculture operations proposed within an AOA would be required to comply with all applicable federal and state laws and regulations, including obtaining any applicable permits. The sizes, locations, and configurations of AOAs may differ. The final size, configuration, and operation of any aquaculture operations proposed in an identified AOA, including species cultivated, would be informed by extensive scoping and project planning, future permitting, and environmental review, including all associated consultations.

This DPEIS evaluates the direct impacts of identifying AOAs in the Gulf, and the potential environmental impacts of siting aquaculture facilities in alternative AOA locations, as informed by the Atlas and other relevant sources of information. One or more AOAs will be identified only after completing this National Environmental Policy Act (NEPA) process, including and considering the information presented in this DPEIS, as required by the E.O. 13921.

1.5 Lead Agency

NMFS is responsible for the stewardship of the nation's ocean resources and associated habitats, providing vital natural resource management services to ensure productive and sustainable fisheries, safe sources of seafood, recovery and conservation of protected resources, and healthy ecosystems. In partnership with Regional Fishery Management councils, NMFS manages fisheries in federal waters under the MSA. NMFS conducts consultations, and issues permits and authorizations under the MSA, ESA, and MMPA, and supports other Federal agencies involved in permitting commercial aquaculture by providing technical expertise and supporting environmental reviews.

NOAA is identifying AOAs as directed by E.O. 13921. Identifying AOAs under E.O. 13921 is consistent with directives in the National Aquaculture Act of 1980 and the NOAA Marine Aquaculture Policy, for NOAA to promote sustainable aquaculture in the U.S. While E.O. 13921 establishes NMFS as the lead agency for this DPEIS, it does not confer any authority.

1.6 Cooperating and Participating Agencies

The EPA is a cooperating agency for this DPEIS based on its authority under the Clean Water Act (CWA) and expertise related to pollutants and potential impacts to water quality. The USACE is a cooperating agency based on its authority under Section 10 of the Rivers and Harbors Act of 1899. The Department of the Air Force (DAF) is also a cooperating agency based on its jurisdiction over Special Use Airspace (SUA) and range activities in the Gulf.

The U.S. Fish and Wildlife Service (USFWS), BOEM, and U.S. Coast Guard (USCG) have also provided expertise and technical assistance in support of this DPEIS, but are not serving as cooperating agencies in this effort.

1.7 Public Scoping

The public scoping process for the Gulf AOA DPEIS began on June 1, 2022, with the publication of a NOI to prepare the DPEIS and conduct scoping (87 FR 33124); it concluded on August 1, 2022. This was the public's first opportunity to learn about AOAs and the AOA process, and provide input on the nine potentially suitable AOA Options identified in the Atlas.

The NOI invited the public to submit written comments by mail and through the federal e-Rulemaking Portal (http://www.regulations.gov) within the 60-day scoping period. Verbal comments were accepted at three virtual public scoping meetings that were held on June 8, June 16 and July 12, 2022. Throughout this scoping period, NMFS distributed information about the AOA planning process and solicited comments from Gulf stakeholders, national leaders interested in aquaculture and aquaculture planning, and community leaders and organizations geographically located in close proximity to the nine potential AOA Options identified in the Atlas.

NMFS also presented the AOA initiative to the Gulf of Mexico Fishery Management Council on June 21, 2022, in Ft. Myers, Florida, which is geographically close to one of the nine locations identified in the Atlas. The meeting included an opportunity for public comment and the Council provided those comments to NMFS as part of the formal written comments submitted during public scoping. The continued presence of COVID-19 and NMFS's COVID-19 guidance on group gatherings limited NMFS's ability to conduct additional in-person scoping meetings in communities located near the nine potential AOA locations. In reviewing the written and verbal submissions received during the public comment period, NMFS considered each submission and compiled all of the verbatim submissions into a Public Scoping Summary for the Gulf AOA PEIS[3] (NOAA 2023a), herein incorporated by reference, for public access and review.

1.8 Draft PEIS (DPEIS)

NMFS developed this DPEIS in collaboration with the cooperating and participating agencies, noted in Section 1.6, and considered the public comments received during scoping. The DPEIS conforms to agency policy and procedures for complying with NEPA (NOAA Administrative Order 216-6A) and related guidance documents. This DPEIS was prepared using the 2020 CEQ NEPA Regulations (40 C.F.R. §§ 1500-1508) that became effective on September 14, 2020 (85 FR 43304) and applies CEQ's Phase I NEPA Regulations (87 FR 23453) because the review of this proposed action began on June 1, 2022, preceding the effective date of CEQ's Phase 2 NEPA Regulations (July 1, 2024).

1.9 Public Comment Period for Draft PEIS

NMFS is providing a 90-day public review and comment period, which will begin on November 22, 2024 and conclude on February 20, 2025. This period will offer an opportunity for the public to review the DPEIS and share comments and information for consideration by the agency. In addition to accepting written comments on this DPEIS, NMFS will also hold three virtual public meetings on Tuesday, December 17, 2024, 6:30 p.m.-8:30 p.m. CST/7:30 p.m.-9:30 p.m. EST; Wednesday January 15, 2025, 3:30 p.m.-5:30 p.m. CST/4:30 p.m.-6:30 p.m. EST; and Thursday, February 13, 2025, 6:30 p.m.-8:30 p.m. CST/7:30 p.m.-9:30 p.m. EST. Information on how to provide public comment and/or to join these virtual public meetings can be found at: *https://www.fisheries.noaa.gov/news/gulf-mexico-aquaculture-opportunity-area-programmatic-environmental-impact-statement.*

1.10 Final PEIS

NMFS will analyze and respond to substantive comments received on the DPEIS and may make changes to the PEIS in the Final PEIS. Should NMFS elect to proceed in finalizing the PEIS after reviewing public comments on the DPEIS, the agency will publish a Final PEIS, followed by the Record of Decision.

2. ALTERNATIVES

2.1 Action: Identify AOAs

The six AOA alternatives described and compared below were developed in accordance with Section 102(2)(E) of NEPA and the CEQ regulations in 40 C.F.R. § 1502.14. **Alternative 1** is

[3] https://www.fisheries.noaa.gov/resource/document/public-scoping-summary-gulf-mexico-aquaculture-opportunity-area-peis

the No Action Alternative, and the other five alternatives are a subset of the potential AOA Options described in the Atlas.

Although this Proposed Action is a planning effort and does not authorize aquaculture operations, the summary comparison of impacts included here incorporates information on both the direct impacts of the Proposed Action to identify AOAs and the potential impacts of finfish, shellfish, macroalgae, or multi-species aquaculture operations that may be sited within each of the AOA Alternatives in the future. NMFS identified and summarized the differential impacts of alternatives when it was possible to do so using the best available information. NMFS included the additional information on potential future impacts to support and inform future environmental review and permitting processes, consistent with the purpose and need for the proposed action and E.O. 13921. Future aquaculture projects proposed for siting in an identified AOA will be evaluated on an individual project basis when proponents propose those projects under the applicable permitting and review processes, consistent with federal law.

2.2 Alternative 1: No Action

NMFS would not identify AOAs in federal waters of the Gulf. This would be inconsistent with the direction in Section 7 of E.O. 13921. However, offshore aquaculture development could still occur in federal waters of the Gulf. Operations sited outside of the areas discussed in this PEIS would not benefit from this preliminary environmental review of potentially suitable sites that will inform the permitting and environmental review process for future aquaculture operations proposed in an AOA. This functions as the analytic basis for comparison of the proposed action and other alternatives (i.e., baseline).

2.3 Preferred Alternative 2: Atlas AOA Option W-1

Identify W-1 as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations. W-1 is a 2,000-acre area located approximately 79 km (43.0 nm) east of Port Mansfield, TX, and 90 km (48.6 nm) northeast of Port Isabel, TX (Figure 2.3-1). Of the three AOA Alternatives located off the Texas coast, W-1 is the closest distance to an inlet (65 km [35.1 nm]). The corner coordinates and general characteristics of W-1 are found in Table 2.3-1.

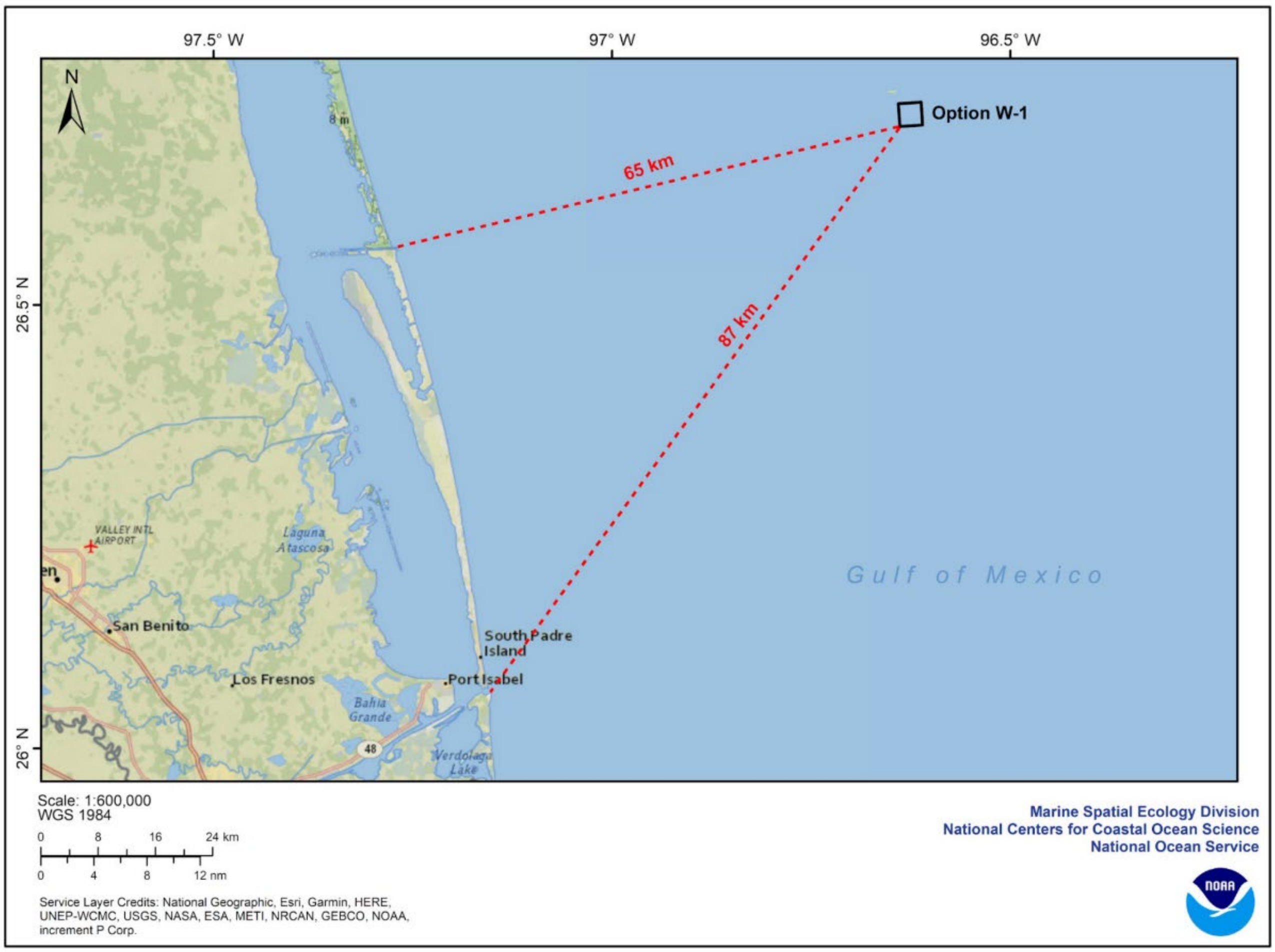

Figure 2.3-1. Map depicting **Preferred Alternative 2 (W-1)**, represented by the black outlined box, and distance to the nearest inlet from the closest corner point of W-1. The area includes Port Mansfield, South Padre Island, and Port Isabel, TX. (Source: Riley et al. 2021).

Table 2.3-1. Site characterization summary for **Preferred Alternative 2** (W-1). (Source: adapted from Riley et al. 2021).

Characteristics of Preferred Alternative 2: W-1	—
Size (ac)	2000
Closest inlet (km)	65
Minimum depth (m)	84.4
Mean depth (m)	90.8
Maximum depth (m)	93.7
Mean Water temperature at 5-m depth (°C)	24.1
Mean Salinity at 5-m depth (ppt)	34.2

Corner Coordinates	**Latitude, Longitude (decimal degrees)**
SW	26.7004, -96.6387
NW	26.7260, -96.6405
NE	26.7276, -96.6120
SE	26.7020, -96.6101

2.4 Preferred Alternative 3: Atlas AOA Option W-4

Identify W-4 as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations. W-4 is a 2,000-acre area located approximately 89.8 km (48.5 nm) southeast of the Port Aransas Inlet entering Corpus Christi Bay, TX and 103.4 km (55.8 nm) to the inlet entering Matagorda Bay, TX (Figure 2.4-1).The corner coordinates and general characteristics of W-4 are found in Table 2.4-1.

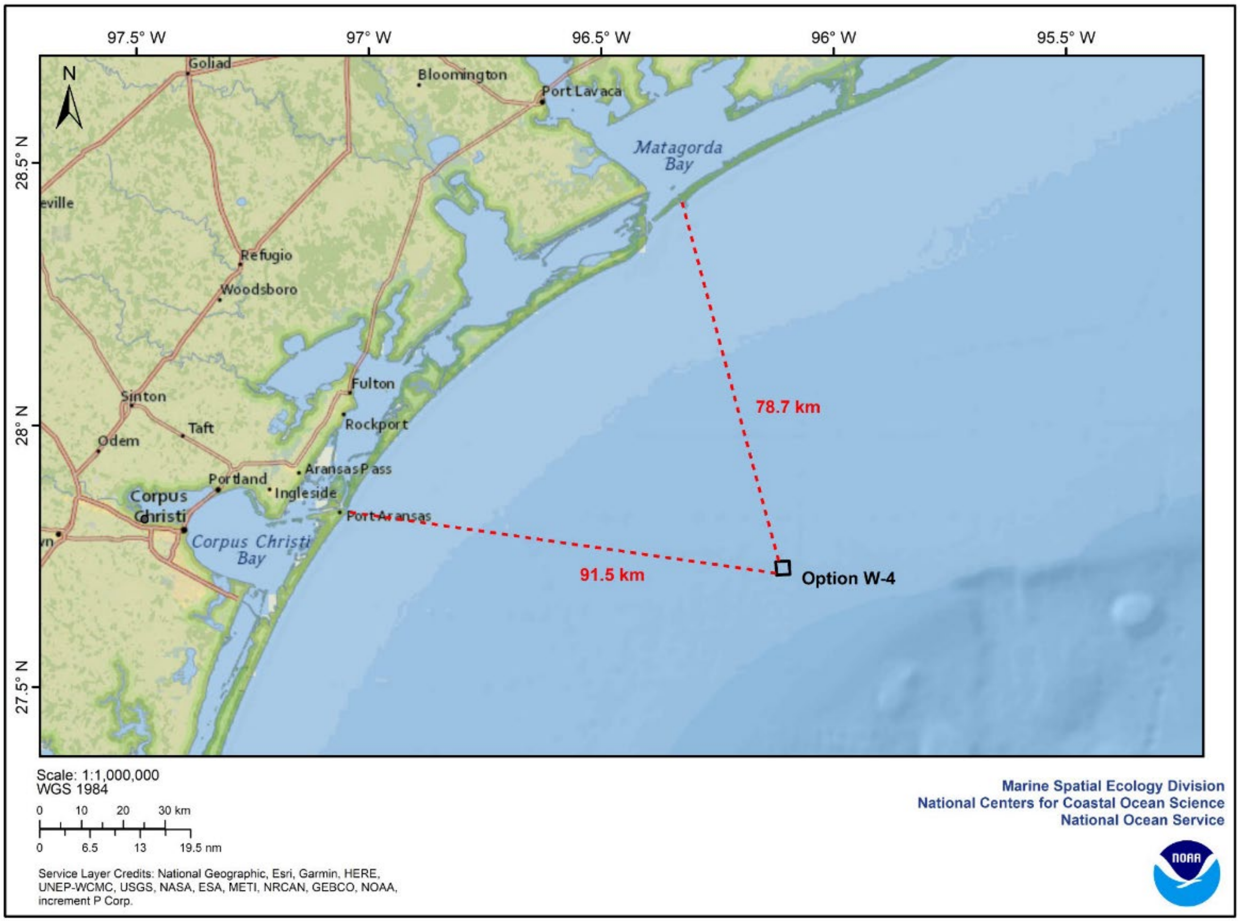

Figure 2.4-1. Map depicting **Preferred Alternative 3 (**W-4), represented by the black outlined box, and distance to the nearest inlet from the closest corner point of W-4. The area includes Matagorda and Port Aransas, TX. (Source: Riley et al. 2021).

Table 2.4-1. Site characterization summary for **Preferred Alternative 3** (W-4). (Source: adapted from Riley et al. 2021).

Characteristics of Preferred Alternative 3: W-4	—
Size (ac)	2000
Closest inlet (km)	78.7
Minimum depth (m)	80.6
Mean depth (m)	84.1
Maximum depth (m)	88.4
Mean Water temperature at 5-m depth (°C)	24.1
Mean Salinity at 5-m depth (ppt)	34.2

Corner Coordinates	Latitude, Longitude (decimal degrees)
SW	27.7142, -96.1229
NW	27.7398, -96.1247
NE	27.7414, -96.0959
SE	27.7158, -96.0941

2.5 Preferred Alternative 4: Atlas AOA Option W-8

Identify W-8 as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations. W-8 is a 500-acre area located approximately 107.4 km (58.0 nm) southeast of Freeport, TX (Figure 2.5-1). The corner coordinates and general characteristics of W-8 are found in Table 2.5-1.

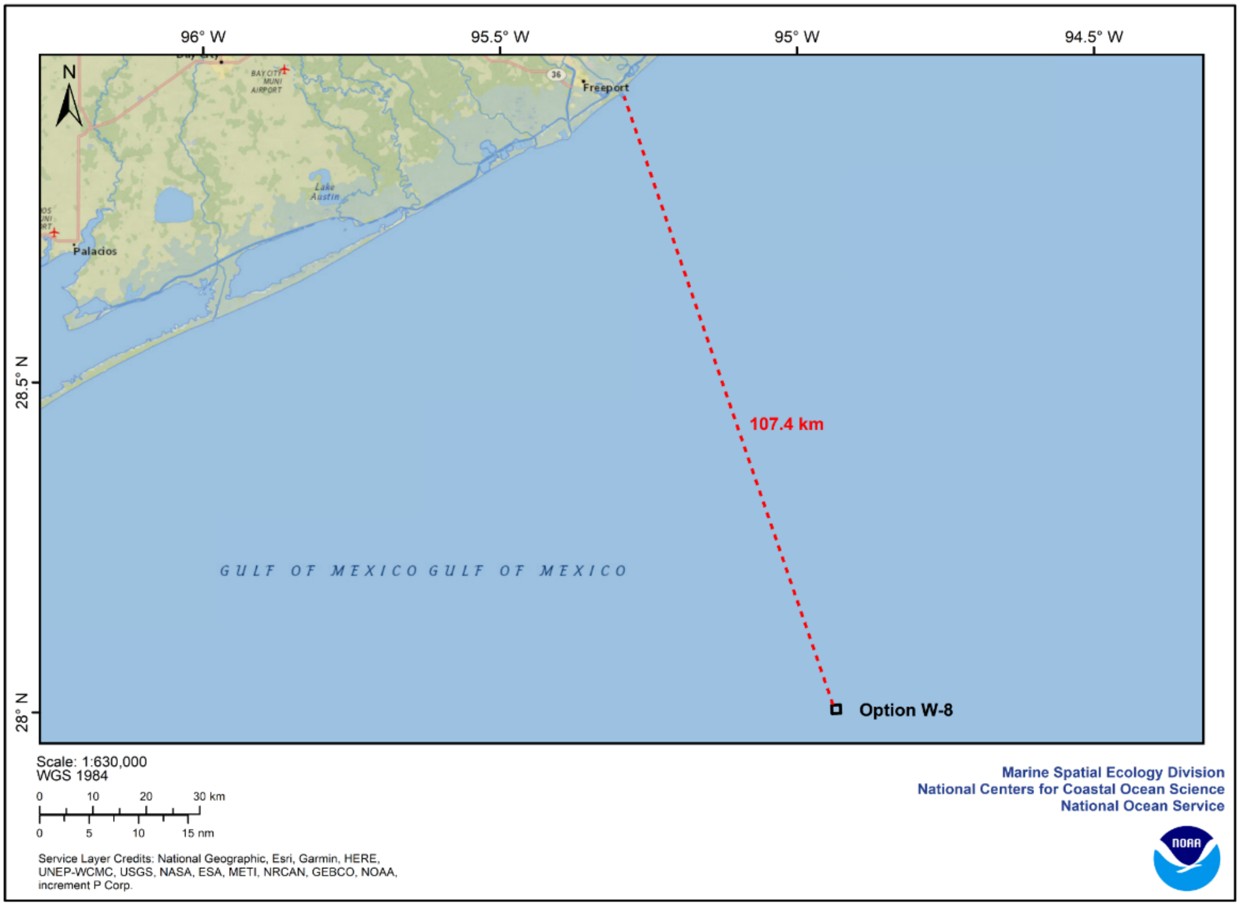

Figure 2.5-1. Map depicting **Preferred Alternative 4 (W-8)**, represented by the black outlined box, and distance to the nearest inlet from the closest corner point of W-8. The area includes Freeport, TX (Source: Riley et al. 2021).

Table 2.5-1. Site characterization summary for **Preferred Alternative 4** (W-8). (Source: adapted from Riley et al. 2021).

Characteristics of Preferred Alternative 4: W-8	—
Size (ac)	500
Closest inlet (km)	107
Minimum depth (m)	78.9
Mean depth (m)	80.6
Maximum depth (m)	82.3
Mean Water temperature at 5-m depth (°C)	24.4
Mean Salinity at 5-m depth (ppt)	34.5

Corner Coordinates	Latitude, Longitude (decimal degrees)
SW	27.9980, -94.9409
NW	28.0108, -94.9417
NE	28.0115, -94.9272
SE	27.9986, -94.9265

2.6 Preferred Alternative 5: Atlas AOA Option C-3

Identify C-3 as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations. C-3 is a 2,000-acre area located approximately 133.4 km (72.0 nm) south of Pecan Island, LA and 137.5 km (74.2 nm) south of Marsh Island, LA (Figure 2.6-1), The corner coordinates and other general characteristics of C-3 are found in Table 2.6-1.

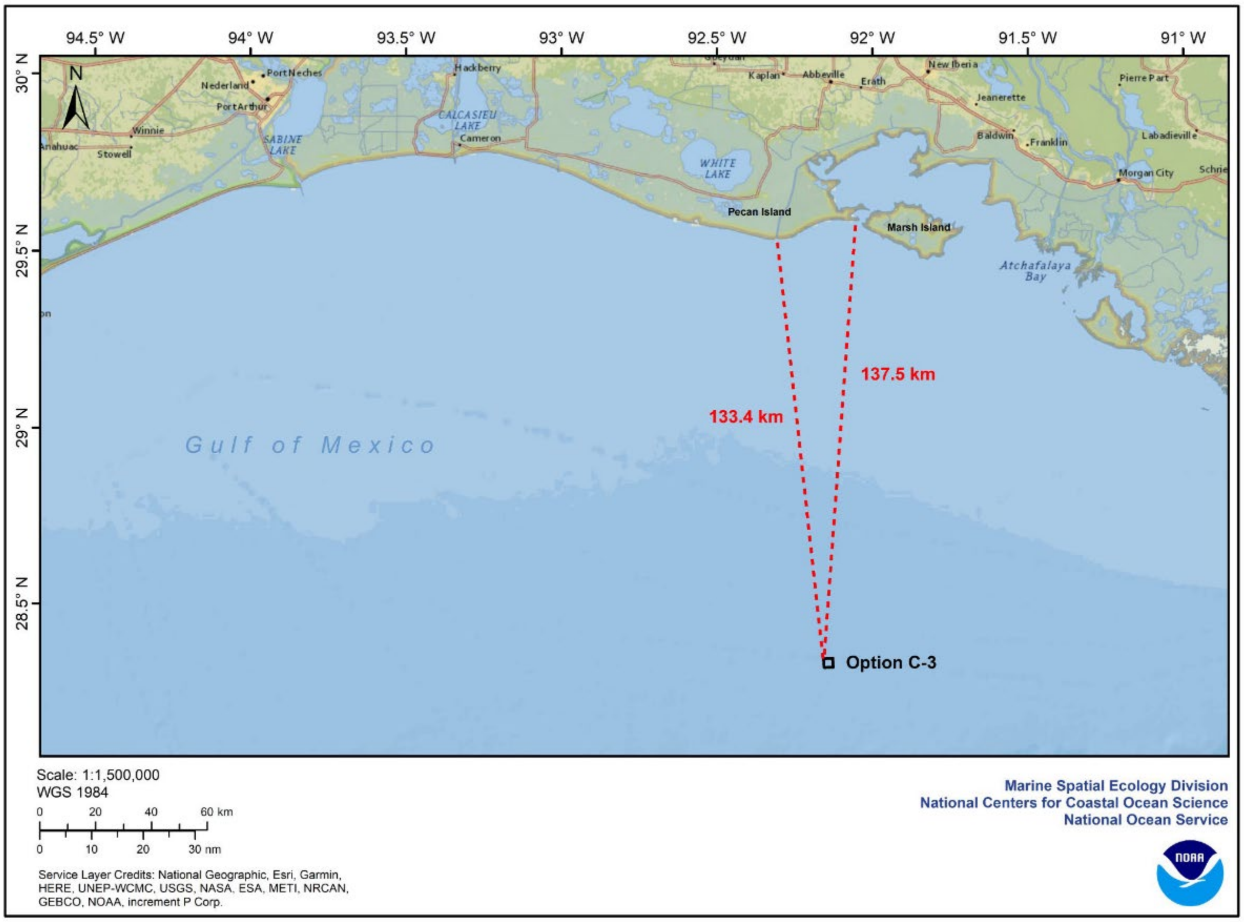

Figure 2.6-1. Map depicting **Preferred Alternative 5** (C-3), represented by the black outlined box, and distance to the nearest inlet from the closest corner point of C-3. The area includes Pecan Island and Marsh Island, LA. Morgan City is to the east of Marsh Island. (Source: Riley et al. 2021).

Table 2.6-1. Site characterization summary for **Preferred Alternative 5** (C-3). (Source: adapted from Riley et al. 2021).

Characteristics of Preferred Alternative 5: C-3	—
Size (ac)	2000
Closest inlet (km)	133.4
Minimum depth (m)	59.8
Mean depth (m)	60.5
Maximum depth (m)	61.4
Mean Water temperature at 5-m depth (°C)	24.7
Mean Salinity at 5-m depth (ppt)	32.7

Corner Coordinates	Latitude, Longitude (decimal degrees)
SW	28.3176, -92.1548
NW	28.3432, -92.1557
NE	28.3440, -92.1267
SE	28.3184, -92.1258

2.7 Alternative 6: Atlas AOA Option C-13

Identify C-13 as an AOA in federal waters of the Gulf. The location would be considered potentially suitable for all types of commercial aquaculture, including finfish, shellfish, macroalgae or multi-species operations. C-13 is a 500-acre area located approximately 36 km (20 nm) downriver from Venice, LA; 9.6 km (5.2 nm) from the inlet at South Pass and 21.8 km (11.8 nm) from Southwest Pass (Figure 2.7-1). Of all the AOA alternatives considered, C-13 is the closest to an inlet. The corner coordinates and other characteristics of C-13 are found in Table 2.7-1

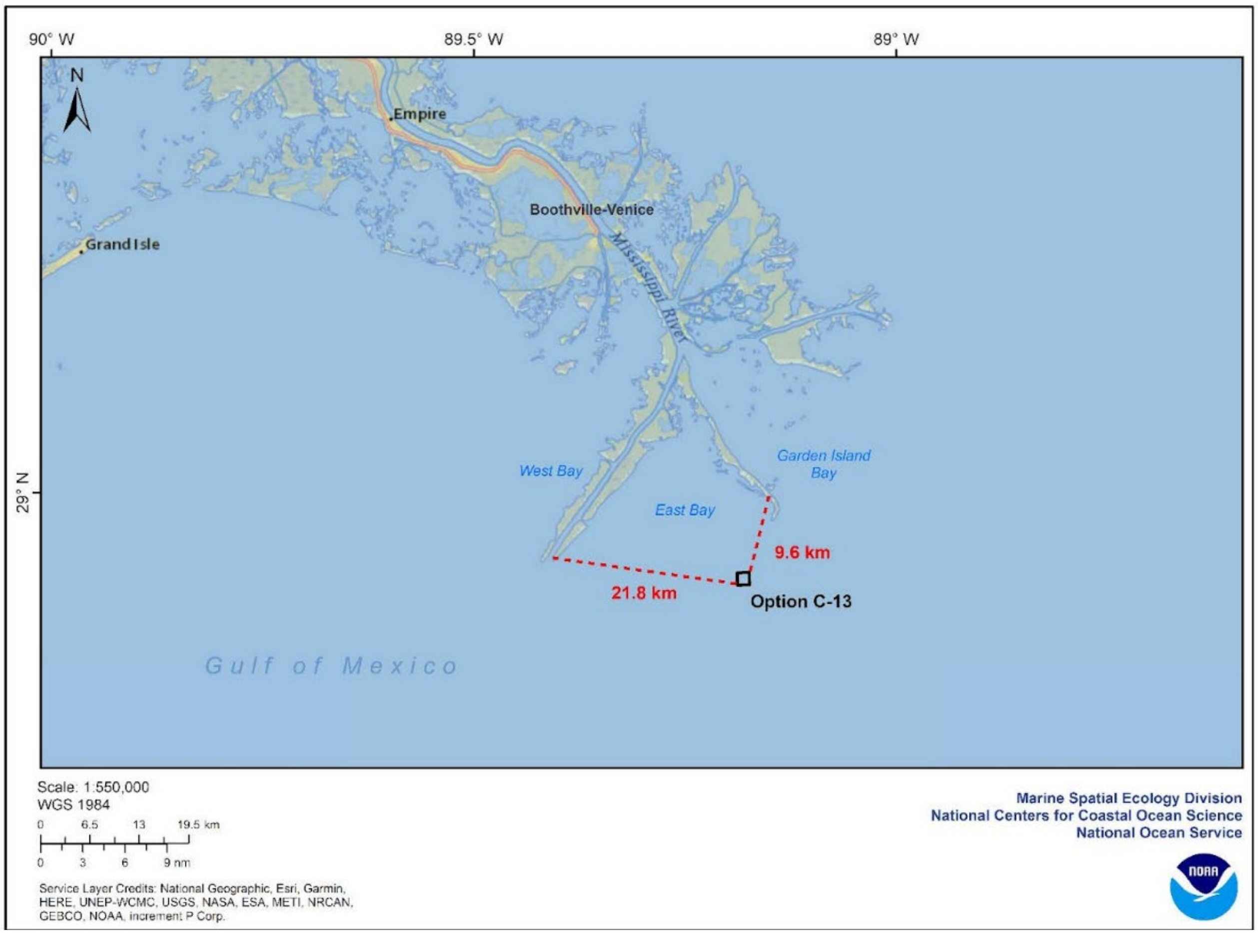

Figure 2.7-1. Map depicting **Alternative 6** (C-13) represented by the black outlined box, and distance to the nearest inlet from the closest corner points C-13. The area is located south of the Mississippi River and outside of the East Bay area in southern Louisiana (Source: Riley et al. 2021).

Table 2.7-1. Characterization summary for **Alternative 6** (C-13). (Source: adapted from Riley et al. 2021).

Characteristics of Alternative 6: C-13	—
Size (ac)	500
Closest inlet (km)	9.6
Minimum depth (m)	56.4
Mean depth (m)	62.2
Maximum depth (m)	69.2
Mean Water temperature at 5-m depth (°C)	24.3
Mean Salinity at 5-m depth (ppt)	31.4

Corner Coordinates	**Latitude, Longitude (decimal degrees)**
SW	28.9039, -89.1882
NW	28.9167, - 89.1883
NE	28.9168, -89.1737
SE	28.9040, -89.1736

2.8 Comparison of the Alternatives

The tables in this section are intended to provide a brief summary and comparison of the environmental effects of the alternatives to identify AOAs in federal waters of the Gulf and the potential effects of siting future offshore aquaculture operations in those areas. A more detailed description of affected resources can be found in Chapter 3 of this DPEIS. Potential effects to the physical, biological, socioeconomic, cultural and historical environments and climate can be found in Chapter 4.

Table 2.8-1. Summary comparison of alternatives for direct impacts of identifying AOAs on the Administrative Environment.

Alternative	Summary and Comparison of Potential Impacts on the Administrative Environment
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects to permitting and environmental review processes for future aquaculture operations through ad hoc siting analyses. Severity of effect could be increased or decreased given location of proposed aquaculture operation, information available for location, and type of operation proposed.
Alternative 2 (W-1)	Potential to cause beneficial administrative effects through increased efficiency in permitting and environmental review for offshore aquaculture operations sited in an AOA, including the identification of potentially suitable sites for marine aquaculture and minimization or avoidance of impacts to natural resources and ocean user groups through siting analysis.

Alternative	Summary and Comparison of Potential Impacts on the Administrative Environment
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 2. However, the potential benefits are expected to be less than those provided by Alternatives 2-5, due to overlap with identified areas of high vessel traffic and commercial fishing. Efficiencies in the permitting and environmental review process may be reduced due to these conflicts with navigation and commercial fishing activities, and may affect the suitability of this alternative AOA location for future aquaculture development.

Table 2.8-2. Summary comparison of alternatives for potential impacts of aquaculture on the Physical Environment.

Alternative	Summary and Comparison of Potential Impacts on Benthic Resources
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given physical disturbance of seafloor from gear, deposition and accumulation of waste and uneaten feed around aquaculture operations and changes in composition of benthic organism communities. Potential for effects could be more or less severe depending on site proximity to sensitive benthic habitats (i.e. hard-bottom, reefs) and physical site conditions (i.e. current, sediment composition).
Alternative 2 (W-1)	The types of potential adverse effects are similar to those described under Alternative 1, but the severity is expected to be reduced or minimized by suitable current conditions and sediment composition present in this location. Sensitive benthic habitat (Coral 9 HAPC, Harte Bank) is in the vicinity, but outside the expected area of impact of any aquaculture operation sited in AOA.
Alternative 3 (W-4)	Potential adverse effects are similar to those expected under Alternative 1. Potential severity of effects are reduced by suitable current conditions and sediment composition. Further, there is no known sensitive benthic habitat in the vicinity of the AOA.
Alternative 4 (W-8)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.
Alternative 5 (C-3)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.
Alternative 6 (C-13)	Potential adverse effects and reduction of potential severity of effects are similar to those expected in Alternative 3.

Alternative	Summary and Comparison of Potential Impacts on Protected Habitat, Marine Protected Areas and Special Resource Areas
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on sensitive habitats given increased vessel traffic, acoustic and light disturbances, wild species aggregation, marine debris, disease and pathogen transmission. Effects may be more or less severe depending on site proximity and type of aquaculture operation proposed.

Alternative	Summary and Comparison of Potential Impacts on Protected Habitat, Marine Protected Areas and Special Resource Areas
Alternative 2 (W-1)	Potential adverse effects are similar to those expected under Alternative 1. However, the AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens and artificial reefs, HAPCs, or areas of known hard-bottom so the impacts would be less severe. Sensitive benthic habitat (Coral 9 HAPC, Harte Bank) is in the vicinity, but outside the expected area of impact associated with aquaculture sited in AOA. The risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 3 (W-4)	Potential adverse effects are the same as discussed in Alternatives 1. AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens and artificial reefs, HAPCs, or areas of known hard-bottom. Risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 4 (W-8)	Potential adverse effects, avoidance of overlap and reduction in risk and severity of potential effects are the same as discussed in Preferred Alternative 3.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed in Preferred Alternative 3. AOA does not overlap with national marine sanctuaries, MPAs, marine reserves, deep-sea corals, HAPCs, or areas of known hard-bottom, reducing severity of potential effects. Sensitive resource area (i.e. fish haven with artificial reefs) is in the vicinity, but outside the expected area of impact associated with aquaculture sited in AOA. The risk and severity of potential effects on sensitive areas are reduced or eliminated given distance from AOA.
Alternative 6 (C-13)	Potential adverse effects, avoidance of overlap and reduction in risk and severity of potential effects are the same as discussed in Preferred Alternatives 3.

Alternative	Summary and Comparison of Potential Impacts on Water Quality
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations are discharge of pollutants, generation of marine debris, interaction with HABs. Potential beneficial or adverse effects on nutrient levels, turbidity and primary production, depending on type of aquaculture. Site conditions (i.e. background nutrient levels, current speed and depth) may increase or decrease the severity of effects.
Alternative 2 (W-1)	Potential effects are similar to those expected under Alternative 1. However, The AOA has known site conditions, which include adequate depth, current speed, and low ambient nutrient levels; conditions are expected to decrease the severity of effects.
Alternative 3 (W-4)	Potential effects and severity are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects and severity are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 2. Ambient nutrient (nitrogen and phosphorus) levels are elevated compared to Alternatives 2-4, but not likely to increase the severity of effects.
Alternative 6 (C-13)	Potential adverse and beneficial effects and site conditions are the same as discussed in Alternative 2. Ambient nutrient (nitrogen and phosphorus) levels are elevated compared to Alternatives 5, and may affect the severity of effects. Seasonal variability in salinity and light transmissivity may also impact effects.

Alternative	Summary and Comparison of Potential Impacts on Air Quality
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse or neutral effects of future aquaculture operations from emissions associated with type farm operation (i.e. finfish, shellfish, macroalgae or multispecies), power generation and vessel use and transit patterns (i.e. distance and frequency), and operational considerations (i.e. type of aquaculture operations, culture systems employed, how vessels or farm systems are powered).
Alternative 2 (W-1)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 3 (W-4)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 4 (W-8)	Potential for effects and variability in severity of effects are the same as discussed in Alternative 1.
Alternative 5 (C-3)	Potential for effects and variable severity of effects are the same as discussed in Alternatives 1. However, the AOA is the greatest distance from shore of all alternatives and could cause longer transit times between AOA and port and increased vessel emission effects.
Alternative 6 (C-13)	Potential for effects and variable severity of effects are the same as discussed in Alternatives 1. AOA is the shortest distance from shore of all alternatives and could cause shorter transit times between AOA and port and decreased vessel emission effects.

Alternative	Summary and Comparison of Potential Impacts on Aesthetic Quality (Visual and Acoustic Environment)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given acoustic disturbance, including construction and maintenance, aquaculture operation, power generation and vessel traffic. Potential adverse or beneficial effects given visibility of aquaculture operation, support vessels and lighting. Potential severity of effects may be increased or decreased given proximity to shore, coastal development near aquaculture operation, environmental conditions, ambient soundscape and ambient viewscape.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. However, any adverse acoustic and visual effects are expected to be minimal and only in the immediate area of AOA. No effects on shore-based areas are expected.
Alternative 3 (W-4)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential adverse effects and severity of effects are the same as discussed in Alternative 2.

Table 2.8-3. Summary comparison of alternatives for potential impacts of aquaculture on the Biological Environment.

Alternative	Summary and Comparison of Potential Impacts on Fish and Invertebrates
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects of future aquaculture operations given wild species aggregation and water quality. Adverse effects to water quality may be greater for finfish operations, whereas shellfish and macroalgae operations might provide localized benefits to water quality. Use of multitrophic aquaculture systems may mitigate adverse water quality effects. Potential adverse effects given waste and unconsumed feed, acoustic and light disturbances, escapement of aquaculture species, disease and pathogen transmission, antibiotic use introduction on non-native species, use of forage fish in fishmeal and feeds and marine debris. Severity of effects could be more or less severe depending on the type of aquaculture operation proposed (e.g., finfish, shellfish, macroalgae or integrated multitrophic), species being grown, location and site conditions (e.g., ambient water quality, depths, current conditions, sediment composition or proximity to sensitive habitats) at proposed site.
Alternative 2 (W-1)	Potential adverse or beneficial effects of future aquaculture operations given wild species aggregation and water quality are the same as Alternative 1. Potential adverse effects given waste and unconsumed feed, acoustic and light disturbances, escapement, disease and pathogen transmission, antibiotic use, introduction of non-native species, use of forage fish in fishmeal and feeds and marine debris are the same as Alternative 1. Severity of effects given acoustic and light disturbances, marine debris and use of forage fish in meal in feed are the same as Alternative 1. Severity of effects given water quality, wild species aggregation, escapement, disease and pathogen transmission, and antibiotic use may be more or less severe depending on the type of aquaculture operation and species produced. Severity of effects given water quality, waste and unconsumed feed may be less severe given suitable site conditions for ambient water quality, depths, current conditions, sediment composition and distance from sensitive habitats.
Alternative 3 (W-4)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential effects and severity of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential effects and severity of effects are the same as discussed in Alternatives 2, except where the severity of water quality effects may be more or less severe given ambient water quality.

Alternative	Summary and Comparison of Potential Impacts on ESA-listed Species
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects given water quality light disturbances and wild species aggregation around aquaculture structures. Beneficial effects could include the attraction of prey items and increased opportunities for feeding and refuge. Adverse effects could include disruption of typical feeding and movement behaviors and increased risk of entanglement, vessel strikes given attraction to aquaculture structure. Water quality could be improved or impaired locally by type of aquaculture operation. Potential adverse effects given entanglement and entrapment, acoustic disturbance, marine debris, vessel strikes, waste and unconsumed feed and antibiotic use, could cause increased risk of disease, serious injury or death. The location of and aquaculture operations and ESA-listed species present may reduce the risk of effects. Severity of effects could be more or less severe depending on the type of aquaculture operation and species being grown.

Alternative	Summary and Comparison of Potential Impacts on ESA-listed Species
Alternative 2 (W-1)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative does not overlap with, but is closest in proximity (3.0 km [1.6 nm]) to proposed Rice's whale critical habitat of all alternatives. Alternative does overlap with proposed green sea turtle critical habitat, which covers the majority of Gulf waters. The Alternative's overlap with high use areas of giant manta rays increases risk of effects, while overlap with low use areas for sea turtles makes effects less likely for species. Alternative is a nearby sensitive benthic habitat for ESA-listed coral species (Coral 9 HAPC, Harte Bank), but outside of expected area of effects from aquaculture operations sites in AOA. Overall, Alternative may have similar potential to effect to listed species as Alternative 4, and lower potential for impacts to listed species than Alternatives 3, 5 and 6.
Alternative 3 (W-4)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles increases risk of effects, while overlap with low use areas for leatherback and green sea turtle makes effects less likely. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 5 and 6.
Alternative 4 (W-8)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, low use areas for sea turtles and risk of effects are the same as Alternative 2. Overall, Alternative may have similar potential to affect listed species as Alternative 2, and lower potential affect than Alternatives 3, 5 and 6.
Alternative 5 (C-3)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative does not overlap with, and is furthest (29.7 km [16.0 nm]) from proposed Rice's whale critical habitat of all alternatives. The Alternative's overlap with high use areas of giant manta rays, loggerhead, Kemp's ridley and leatherback sea turtles, increasing risks for effects and low use areas for green sea turtles, making effects less likely. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 3 and 6.
Alternative 6 (C-13)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Proposed critical habitat avoidance and overlap is the same as Alternative 2. Alternative is in close proximity to proposed Rice's whale critical habitat. Alternative's overlap with high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles, low use areas for leatherback and green sea turtles and risk of effects are the same as Alternative 2. Overall, the Alternative has greater potential to affect listed species than Alternatives 2 and 4, and may have a similar potential to affect as Alternatives 3 and 5.

Alternative	Summary and Comparison of Potential Impacts on Marine Mammals
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects given water quality, light disturbances and wild species aggregation. Beneficial effects could include the attraction of prey items and increased opportunities for feeding and refuge. Adverse effects could include disruption of typical feeding and movement behaviors and increased risk of entanglement, vessel strikes given attraction to aquaculture structure. Water quality could be improved or impaired locally by type of aquaculture operation. Potential adverse effects given entanglement and entrapment, acoustic disturbance, marine debris, vessel strikes, use of forage fish for meal and feeds and antibiotic use, could cause increased risk of disease, serious injury or death. The location of an aquaculture operation and marine mammal species present may reduce the risk of effects. Severity of effects could be more or less severe depending on the type of aquaculture operation and species being grown.
Alternative 2 (W-1)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative's overlap with high use areas of Atlantic spotted dolphins increases risk of effects, while overlap with low use areas of common bottlenose dolphins makes effects less likely for the species. Alternative has the same risk of effects to marine mammals as Alternatives 3, 4 and 5.
Alternative 3 (W-4)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 2. Alternative's overlap with high and low use areas and effects are the same as described in Alternative 2. Alternative has the same risk of effects to marine mammals as Alternatives 2, 4 and 5.
Alternative 4 (W-8)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 2. Alternative has the same risk of effects to marine mammals as Alternatives 2, 3 and 5.
Alternative 5 (C-3)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 2. Alternative has the same risk of effects to marine mammals as Alternatives 2, 3 and 4.
Alternative 6 (C-13)	Potential adverse and beneficial effects and severity are the same as described in Alternative 1. Alternative's overlap with low use areas of Atlantic spotted dolphins and common bottlenose dolphins makes effects less likely for the both marine mammal species, and makes the Alternative the least likely to impact marine mammals of all Alternatives.

Alternative	Summary and Comparison of Potential Impacts on Seabirds
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse or beneficial effects given water quality and wild species aggregation around aquaculture structures. Beneficial effects could include the attraction of prey items and increased opportunities for feeding and refuge. Adverse effects could include disruption of typical feeding and movement behaviors and increased risk of entanglement, vessel strikes given attraction to aquaculture structure. Water quality could be improved or impaired locally by type of aquaculture operation. Potential adverse effects given entanglement and entrapment, light disturbances and acoustic disturbance, marine debris, vessel strikes, waste and unconsumed feed, disease and pathogen transmission, and antibiotic use, could cause increased risk of disease, serious injury or death. The location, type of aquaculture operation and seabird species present may increase or reduce the severity and risk of effects.
Alternative 2 (W-1)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.

Alternative	Summary and Comparison of Potential Impacts on Seabirds
Alternative 3 (W-4)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.
Alternative 4 (W-8)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species.
Alternative 5 (C-3)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species. Alternative is further from shore of all Alternatives which may increase or reduce the severity and risk of effects to seabirds.
Alternative 6 (C-13)	Potential adverse and beneficial effects, severity and risk of effects are the same as described in Alternative 1. Alternative does not overlap with existing or proposed critical habitat for ESA-listed bird species. Alternative is closest to shore of all Alternatives which may increase the severity and risk of effects on seabirds.

Table 2.8-4. Summary and comparison of alternatives for potential impacts of aquaculture on the Socioeconomic Environment.

Alternative	Summary and Comparison of Potential Impacts on Commercial Fishing
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations given displacement or disruption of commercial fishing associated with fixed gear and other equipment placement in the water column, surface and bottom; marine debris; disease transmission, and increased vessel traffic in and out of coastal areas. Potential fish aggregation effects may be beneficial, by creating new structures and habitat that could concentrate commercially important fish species and/or adverse effects, such as increasing fishing pressure on commercial important species, increased risk of disease transmission and genetic impacts from escaped cultured species. Potential effects on seafood markets may be adverse (increased domestic competition) or beneficial (increased consumer demand for domestic seafood). Workforce effects may be adverse (competition for limited labor resources) or beneficial (diversification of job opportunities). Potential for effects to increase or decrease in magnitude depending on overlap with or proximity to commercial fishing activities or markets.
Alternative 2 (W-1)	Potential effects are similar to those expected in Alternative 1. However, because this area overlaps with low levels of bandit gear fishing, and shrimp trawling and does not overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining, any adverse effects are reduced as compared to Alternative 1.
Alternative 3 (W-4)	Potential effects, overlap and avoidance of fishing areas and reduction of adverse effects compared to Alternative 1 are similar to Alternative 2.
Alternative 4 (W-8)	Potential effects are similar to those expected in Alternative 1. AOA overlaps with relatively low levels of reef fish longline and shrimp trawling activity, and does not overlap with bandit gear fishing, menhaden fishing, HMS pelagic longlining. As a result, adverse effects are reduced as compared to Alternative 1.
Alternative 5 (C-3)	Potential effects, overlap and avoidance of fishing areas, and the reduction of adverse effects compared to Alternative 1 are similar to Alternative 2.
Alternative 6 (C-13)	Potential effects are similar to those expected in Alternative 1. AOA overlaps with areas of moderate shrimp trawling activity and low levels of bandit gear fishing and does not overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining. As a result, adverse effects to shrimp trawling may occur while adverse effects are reduced for other fishing activities.

Alternative	Summary and Comparison of Potential Impacts on Recreational Fishing
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations from displacement or disruption of recreational fishing associated with fixed gear and other equipment placement in the water column, surface and bottom; marine debris; disease transmission from cultured stocks; and increased vessel traffic in and out of coastal areas. Potential fish aggregation effects may be beneficial, concentrating target fish species and/or adverse, increased fishing pressure on local stocks. Severity of effects could increase or decrease given overlap with or proximity to recreational fishing activities.
Alternative 2 (W-1)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Port Mansfield and South Padre Island, which have moderate to high recreational fishing engagement and reliance, could be affected from future aquaculture development in this AOA.
Alternative 3 (W-4)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Matagorda, Port Aransas, and Port O'Connor, which have high recreational fishing reliance, could be affected future aquaculture development in this AOA.
Alternative 4 (W-8)	Potential effects and severity are the same as discussed in Alternative 1.Texas coastal communities nearby, including Clute, Quintana, and Surfside, which have moderate to high recreational fishing engagement and/or reliance, could be affected future aquaculture development in this AOA.
Alternative 5 (C-3)	Potential effects and severity are the same as discussed in Alternative 1. Potential adverse effects reduced by minimizing overlap of AOA with recreational fishing activities through site suitability analysis. Louisiana coastal communities nearby with low recreational fishing engagement and reliance, could be affected by future aquaculture development in this AOA.
Alternative 6 (C-13)	Potential effects and severity are the same as discussed in Alternative 1. Nearby Louisiana coastal communities, including Grand Isle and Venice, which have high recreational fishing, engagement and reliance, could be affected by future aquaculture development in this AOA.

Alternative	Summary and Comparison of Potential Impacts on Seafood Markets and Regional Food Systems
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential beneficial and adverse effects of future aquaculture operations given introduction of new domestic products, increase in the supply of domestic products, new or increased interactions with wild-caught seafood products (competition or complimentary), new or increased interactions with existing interstate or international trade markets. The overall growth in a market may be considered an economic benefit, but local or regionally-scaled costs may occur simultaneously. Effects of offshore aquaculture development on existing aquaculture and fisheries industries could be adverse and/or beneficial. As development of offshore aquaculture can require high capital investment, large, established businesses (domestic or international), could have an advantage over local or regional stakeholders.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. The type (adverse/beneficial) and severity of effects could depend largely on the details of potential future aquaculture operations which may be sited within an AOA (e.g., species and volume produced, target markets), and overlap with or proximity to existing aquaculture and or commercial fishing activities and markets. Nearby Texas coastal communities, including Port Mansfield and South Padre Island, could benefit if offshore aquaculture were to integrate into the existing ocean economy (which includes commercial fishing, seafood dealers, and other seafood-related businesses) in a complementary way and provide accessible jobs.

Alternative	Summary and Comparison of Potential Impacts on Seafood Markets and Regional Food Systems
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Texas coastal communities nearby, including Matagorda, Port Aransas, and Port O'Connor could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Texas coastal communities nearby, including Clute, Quintana, and Surfside could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Louisiana coastal communities nearby could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. The type and severity of effects are dependent on the same factors discussed in Alternative 2. Louisiana coastal communities nearby, including Grand Isle and Venice, could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs.

Alternative	Summary and Comparison of Potential Impacts on Tourism Economies
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations from displacement or disruption of recreational activities given fixed gear and other equipment placement in the water column and surface, increased vessel traffic in and out of coastal areas, or changes in ecosystem services that support recreation and tourism. Potential beneficial and/or adverse effects given new areas where wildlife aggregations may occur. Fish aggregation effects may be beneficial and/or adverse, improving recreation fishing opportunities and/or increasing fishing pressure on wild stocks.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Port Mansfield and South Padre Island, which have moderate to high recreational fishing engagement and reliance, could be affected. The broader tourism economies of nearby Texas coastal communities, including South Padre Island and Port Isabel, could be affected from potential future aquaculture development.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Matagorda Bay, Port O'Connor, and Port Aransas which have high recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Texas coastal communities, including Port Aransas, Fulton, and Seadrift could be impacted (positive or negative) from potential future aquaculture development.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. Texas coastal communities nearby, including Clute, Quintana, and Surfside which have moderate to high recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Texas coastal communities, including Clute and Surfside Beach could be impacted (positive or negative) from potential future aquaculture development.

Alternative	Summary and Comparison of Potential Impacts on Tourism Economies
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. Louisiana coastal communities nearby, which have low recreational fishing engagement and/or reliance, could be affected by future aquaculture development. The broader tourism economies of nearby Louisiana coastal communities, including those in Assumption Parish, Iberia Parish, St. Mary Parish, and Vermillion Parish, could be affected by future aquaculture development.
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. Louisiana coastal communities nearby, including Grand Isle and Venice which have high recreational fishing engagement and reliance, could be impacted (positive or negative) from potential future aquaculture development. The broader tourism economies of nearby Louisiana coastal communities, including those in Jefferson Parish and Plaquemines Parish could be affected by future aquaculture development.

Alternative	Summary and Comparison of Potential Impacts on Offshore Industrial Activities and Infrastructure
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations sited in areas of conflict with other ocean industry sectors, including oil, gas and wind energy development, marine mineral operations, and submarine utilities, given introduction of new structures, navigational impediments, increased vessel traffic. Severity of effects may be increased or decreased given aquaculture operations proximity to industrial activities and vessel transit corridors.
Alternative 2 (W-1)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity (within 3 km [1.62 nm]) to existing oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes), offshore wind energy development areas or mineral mining activity. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity, but is located 2.64 km (1.43 nm) east of an active oil and gas lease block with infrastructure. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 4 (W-8)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity, but is located 750m from a single oil and gas pipeline. Potential effects to offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure, offshore wind energy development areas or mineral mining activity. However there is a variety of oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]) of the AOA, including three oil and gas pipelines, including one within 700m (2297 ft) of the AOA, two active oil and gas platforms and 13 borehole. Potential impacts are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.

Alternative	Summary and Comparison of Potential Impacts on Offshore Industrial Activities and Infrastructure
Alternative 6 (C-13)	Potential effects are the same as discussed in Alternative 1. AOA does not overlap and is not in close proximity to existing oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes), offshore wind energy development areas or mineral mining activity. However there is a variety of oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]) of the AOA, including one oil and gas platform, two oil and gas pipelines and 4 boreholes. Potential impacts are not expected given the geographical distance to the structures and regulatory setbacks from oil, gas and wind energy development.

Alternative	Summary and Comparison of Potential Impacts on Public Health and Safety (Military Readiness and Operations)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations proposed in areas that have not been evaluated for compatibility with military operations. Operations could be proposed in controlled waterspace, restricted areas, danger zones, and or conflict with training and testing, or overlap with unexploded ordnance areas. Conflict with military training and testing areas would cause inefficient permitting and environmental review processes and may cause the need to re-site proposed operations.
Alternative 2 (W-1)	This Alternative overlaps with a Special Use Airspace Warning Area and a Military Operating Area. Alternative does not overlap with controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in this location, at this time. No adverse effects to military readiness and operations are anticipated.
Alternative 3 (W-4)	Potential effects are the same as discussed in Alternatives 2.
Alternative 4 (W-8)	This Alternative overlaps with a Special Use Airspace Warning Area, but does not overlap with a Military Operating Area. Alternative does not overlap with controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in that location, at this time. No adverse effects to military readiness and operations are anticipated.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternatives 4.
Alternative 6 (C-13)	This Alternative does not overlap with any Special Use Airspace Warning Area, Military Operating Area, controlled waterspace, Danger Zones and Restricted Areas, or unexploded ordnance points or areas. There are no military vessel transits that have occurred within or vicinity of this Alternative (2015-2019). Consultation with DOD Siting Clearinghouse confirmed aquaculture's compatibility with military activities in that location, at this time. No adverse effects to military readiness and operations are anticipated.

Alternative	Summary and Comparison of Potential Impacts on (Public Health and Safety Navigational Safety)
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations sited in areas of high conflict with other ocean use sectors given navigational hazard via vessel traffic, new structures, obstructions and marine debris.

Alternative	Summary and Comparison of Potential Impacts on (Public Health and Safety Navigational Safety)
Alternative 2 (W-1)	Potential adverse effects are the same as Alternative 1. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with low vessel traffic observed. Alternative averages 19 AIS monitored vessel transits through Alternative per year.
Alternative 3 (W-4)	Potential adverse effects are the same as Alternative 1-2. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with low vessel traffic observed. Alternative averages 32 AIS monitored vessel transits through Alternative per year.
Alternative 4 (W-8)	Potential adverse effects are the same as Alternative 1-3. Alternative does not overlap with shipping fairways and anchorage areas. Potential risk for navigational hazards is decreased with lowest vessel traffic observed of all alternatives. Alternative averages 12 AIS monitored vessel transits through Alternative per year.
Alternative 5 (C-3)	Potential effects are the same as discussed in Alternatives 1-4. Alternative does not with shipping fairways and anchorage areas. Potential risk for navigational hazards is higher given higher levels of vessel traffic transiting Alternative than Alternatives 2-4. Alternative averages 106 AIS monitored vessel transits through Alternative per year.
Alternative 6 (C-13)	Alternative 6 (C-13) Potential effects are the same as discussed in Alternatives 1-5. Alternative has the highest potential risk for navigational hazards given Alternative having the highest average number of vessel transits per year of all Alternatives, with 1,340 AIS monitored vessel transits through Alternative per year.

Alternative	Summary and Comparison of Potential Impacts on Environmental Justice
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential for adverse effects of future aquaculture operations sited in areas without the fair treatment and meaningful involvement of all people, regardless of race, color, gender, sexual orientation, national origin, tribal affiliation, religion, disability, or income.
Alternative 2 (W-1)	This Alternative is located outside and away from any coastal community given it is in federal waters. Although the closest communities are 79 km (42.7 nautical miles) from Port Mansfield, TX and 90 km (48.6 nautical miles) from Port Isabel, TX, to the site, there still could be adverse or beneficial effects on human health and environmental effects on minority, low-income populations, or EJ communities.
Alternative 3 (W-4)	The closest port and associated community is 89.8 km (48.5 nautical miles) from Port Aransas, to the site. Potential effects are the same as discussed in Alternatives 2.
Alternative 4 (W-8)	The closest port and associated community is 107.4 km (58 nautical miles) from Freeport, TX, to the site. Potential effects are the same as discussed in Alternatives 2-3.
Alternative 5 (C-3)	The closest port and associated community is 133 km (71.8 nautical miles) from Morgan City, to the site. Potential effects are the same as discussed in Alternatives 2-4.
Alternative 6 (C-13)	The closest port and associated community is 9.6 km (5.18 nautical miles) from South Pass, LA to the site. Potential effects are the same as discussed in Alternatives 2-5.

Table 2.8-5. Summary and comparison of alternatives for potential impacts of aquaculture on cultural, historic and archaeological resources

Alternative	Summary and Comparison of Potential Impacts on Cultural, Historic, and Archaeological Resources
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on cultural, historical or archaeological resources due to seafloor disturbance and deposition of uneaten feed and fish waste. Effects may be more or less severe depending on the type of aquaculture operation and its proximity to cultural, historical or archaeological resources.
Alternative 2 (W-1)	Potential adverse effects are the same as described in Alternative 1. Potential adverse effects to known cultural, historical or archaeological resources are avoided, as there are none documented within the anticipated field of impact from aquaculture operations sited in this location.
Alternative 3 (W-4)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 4 (W-8)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed and Alternative 1, and avoidance of effects are the same as discussed in Alternative 2.
Alternative 6 (C-13)	Potential adverse effects are the same as discussed and Alternative 1. Alternative is located approximately 2.5 km (2.17 nm) from a known shipwreck. However, this shipwreck is far enough away from the Alternative that it is anticipated to be outside the potential field of impact for an aquaculture operation sited in this Alternative and would not be impacted.

Table 2.8-6. Summary and comparison of alternatives for potential climate change impacts.

Alternative	Summary and Comparison of Potential Climate Change Impacts
Alternative 1 (No Action, No AOAs identified in the Gulf)	No effects to the baseline conditions. Potential adverse effects of future aquaculture operations on Gulf communities given climate change from natural hazards (i.e. hurricanes, flooding, heat and cold waves), storm surge risk, sea level rise, economic indicators and housing characteristics and infrastructure vulnerability. Individual communities within distance from a future aquaculture operation may be more or less affected by climate change effects than Alternatives 2-6, which could include effects to supportive shoreside infrastructure and local housing dependent on the location of the aquaculture site and adjacent communities associated with the operation.
Alternative 2 (W-1)	Potential adverse effects are the same as discussed in Alternative 1. Most communities within distance of the AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, while fewer communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities ranged between Alternative 3 and Alternative 5.
Alternative 3 (W-4)	Potential adverse effects are the same as discussed in Alternative 1. Some communities within distance from AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing. Sea level was a concern less concern, with only one community in proximity to the AOA noted as vulnerable, although four of eight locations did not have data available for sea level rise. The communities in proximity to Alternative 3, had the fewest number of climate vulnerable communities.

Alternative	Summary and Comparison of Potential Climate Change Impacts
Alternative 4 (W-8)	Potential adverse effects are the same as discussed in Alternative 1. Most communities within distance from AOA have high vulnerability to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, and sea level rise. The communities in proximity to Alternative 4 had the greatest number of climate vulnerable communities.
Alternative 5 (C-3)	Potential adverse effects are the same as discussed in Alternative 1. Most Communities within distance from AOA are vulnerable to natural hazards and storm surge impacts that could affect shoreside infrastructure and workforce housing, while a few communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities was higher than Alternatives 2 and 6, but less than Alternative 4.
Alternative 6 (C-13)	Potential adverse effects are the same as discussed in Alternative 1. Most Communities within distance from AOA are vulnerable to natural hazards and storm surge that could affect shoreside infrastructure and workforce housing, while a few communities are also affected by sea level rise. In terms of communities in proximity to this Alternative, the number of climate vulnerable communities ranged between Alternative 3 and Alternative 5.

2.9 Alternatives Considered but Eliminated from Further Detailed Review

Three potential AOA Options identified in the Atlas and referenced in the NOI were considered for inclusion in the range of AOA alternatives to be evaluated in the DPEIS, but eliminated from further detailed study. All three are located off Florida's west coast within the Eastern Study Area of the Atlas (E-1, E-3, and E-4). Military readiness and training activities by all U.S. Armed Forces have increased in federal waters off Florida's west coast. This recent change in ocean use increases the potential for public health and safety concerns for projects sited within those areas, and makes it unlikely such projects would receive needed authorizations to proceed as they could impact military readiness. Additionally, stakeholder scoping comments on those areas expressed concerns related to extreme weather events (i.e., hurricanes) and water quality impairment from harmful algal blooms, which could present challenges for commercial aquaculture operations seeking permits within AOAs at these locations. For these reasons, NMFS determined potential AOA Options E-1, E-3 and E-4 were not consistent with the purpose of this action to ensure coordinated, predictable, and transparent federal actions, and remove unnecessary regulatory burdens, and eliminated those options from further detailed study in this DPEIS. The decision to remove these areas from further detailed study does not preclude individual aquaculture projects from being proposed in these areas, or elsewhere in the future. NMFS also considered but eliminated from further detailed study Atlas AOA Option C-11, located off the coast of Louisiana within the Central Study Area (Figure 2.9-2). Public scoping comments from various fisheries stakeholders (Gulf of Mexico Fishery Management Council, Southern Shrimp Alliance, and members of the fishing community) indicated Atlas AOA Option C-11 overlapped with important shrimp trawling grounds. NMFS subsequently verified high shrimp trawling activity within and near Atlas AOA Option C-11 (Figure 2.9-3) using electronic logbook data. The public scoping comments specifically requested NMFS consider adjusting the boundary of this Atlas AOA Option to avoid interfering with shrimp trawling activity, or eliminate it from further consideration as a potential AOA location. Atlas AOA Option C-11 also overlaps with high use areas for several protected species, including Kemp's ridley (*Lepidochelys kempii*) and loggerhead sea turtles (*C*aretta caretta), giant manta ray (*Mobula birostris*) and Atlantic spotted dolphin (*Stenella frontalis*) (Riley et al. 2021). Because of these considerations, NMFS eliminated Atlas AOA Option C-11 from further consideration and analysis in this DPEIS.

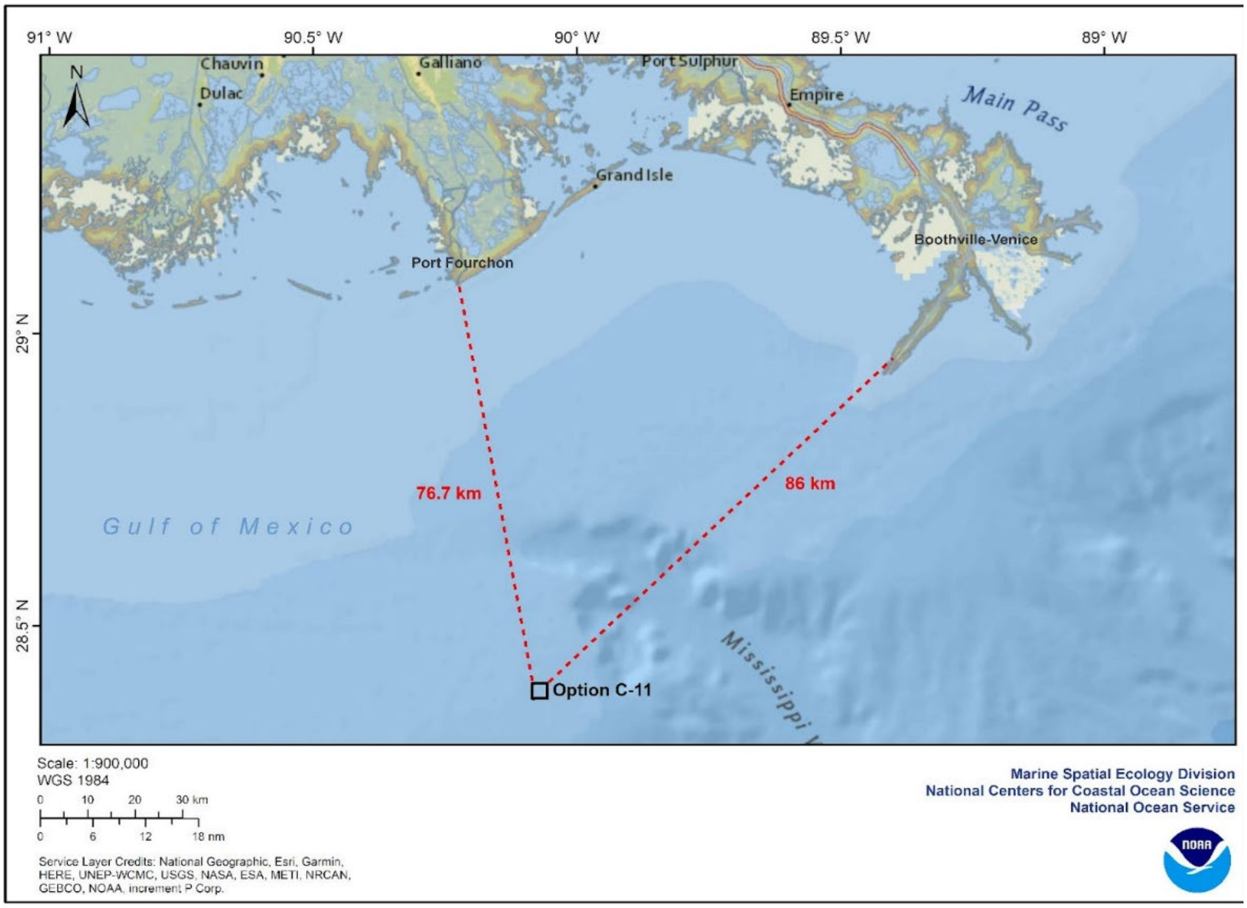

Figure 2.9-2. AOA Option C-11 represented by the black outlined box, and distance to the nearest inlet from the closest corner points of AOA Option C-11. The area is located south of Port Fourchon, Louisiana (Source: Riley et al. 2021

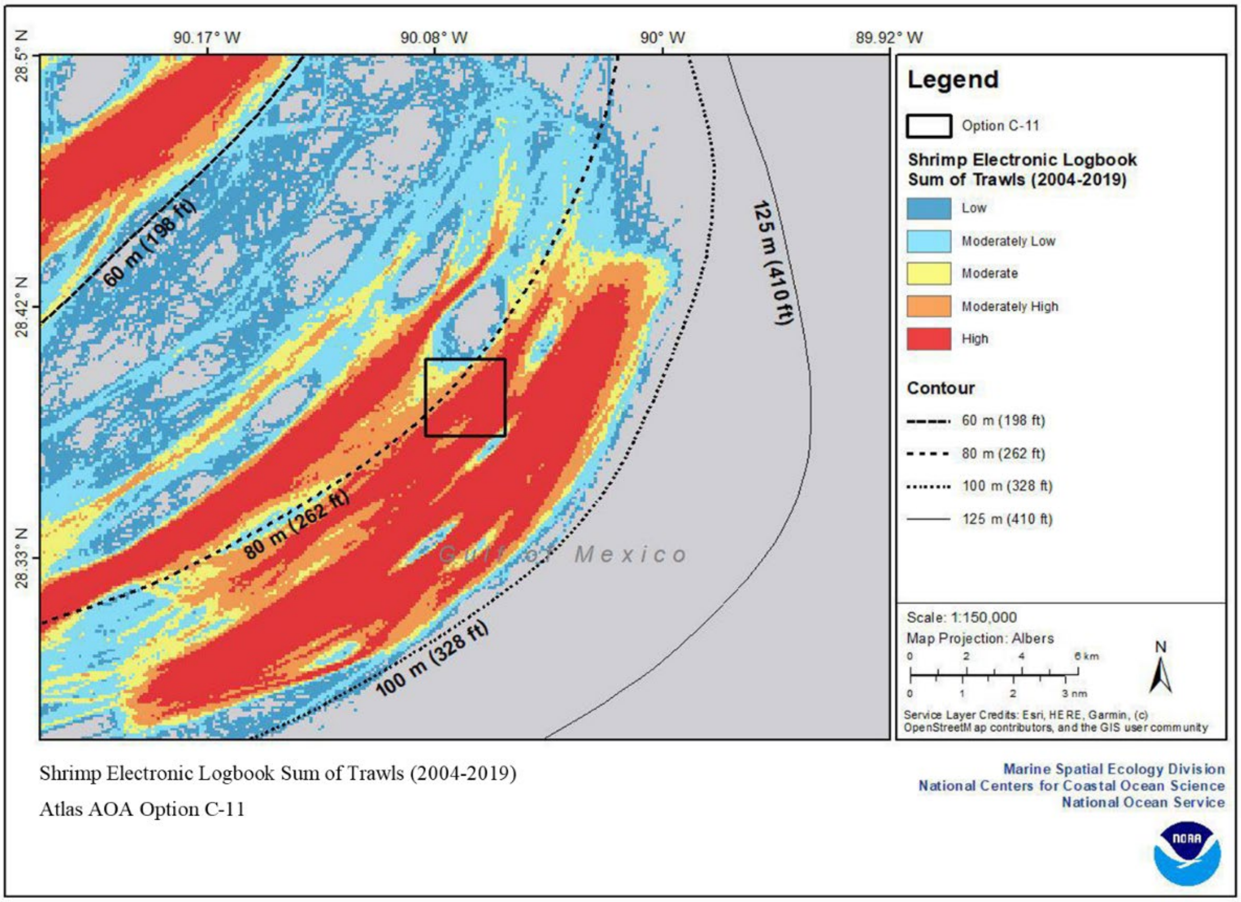

Figure 2.9-3. Shrimp Electronic Logbook data (2004-2019) identifying high levels of shrimp trawling activities overlapping with AOA Option C-11, which was removed from further detailed study in this DPEIS.

3. AFFECTED ENVIRONMENT

This chapter describes the environments potentially affected by the proposed action of identifying AOAs in federal waters of the Gulf, and the environments that may be affected by future aquaculture operations sited in the AOAs. The current status of these administrative (Section 3.1), physical (Section 3.2), biological (Section 3.3), socioeconomic (Section 3.4), and cultural and historical environments (Section 3.5), and climate change (Section 3.6) are discussed. Resources within these environments that are not expected to be impacted by the proposed action or by future aquaculture operations sited in an AOA are not discussed.

3.1 Administrative Environment

3.1.1 Federal and State Regulatory Environment for Offshore Aquaculture

This section provides an overview of the federal and state regulatory environment relevant to permitting, authorizing, reviewing, and consulting on offshore aquaculture operations in federal waters of the Gulf.

3.1.1.1 Jurisdictional Waters

The Submerged Lands Act (SLA) (43 U.S.C. § 1301 *et seq.*) grants coastal states title to "natural resources" located within their coastal submerged lands.[4] The states' submerged lands generally extend out to three nm from their coasts. A notable exception are the submerged lands of Texas and Florida in the Gulf, which extend out to three marine leagues or approximately nine nm from these states' coasts. The U.S. territorial sea extends 12 nm from the coast[5] and the U.S. Exclusive Economic Zone (EEZ) extends from the 12 nm boundary of the territorial sea to 200 nm from the coast.[6] In instances where the U.S. EEZ is adjacent to another country's EEZ, the boundaries are established through agreements and treaties. For the purpose of this DPEIS, all references to "federal waters" refer to waters seaward of each state's SLA boundary to the U.S. EEZ.

3.1.1.2 Federal Regulatory Environment for Offshore Aquaculture

In the United States, marine aquaculture operates in one of the most comprehensive environmental regulatory environments in the world (NMFS 2022). The complex regulatory framework that encompasses marine aquaculture includes laws and regulations enforced by local, state, and federal authorities (Rubino 2023), and through international treaties and cooperative international efforts. This subsection outlines the primary regulatory considerations for aquaculture operations in federal waters of the Gulf, including the permits, authorizations, and consultations generally required, and the authorities of the state and federal agencies responsible for implementing those processes. A detailed description of these processes is contained in NOAA's Guide to Permitting Marine Aquaculture in the United States (2022). The guide's list of federal permits (Table 1 in the guide), federal authorizations (Table 2A in the guide), and federal consultations (Table 3 in the guide) that would be applicable to aquaculture operations located in an AOA are incorporated by reference.

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[4] Natural resources include "oil, gas, and all other minerals, and fish, shrimp, oysters, clams, crabs, lobsters, sponges, kelp, and other marine animal and plant life." 43 U.S.C. § 1301(e).

[5] Presidential Proclamation No. 5928, 54 Fed. Reg. 777 (December 27, 1988).

[6] Presidential Proclamation No. 5030, 43 Fed. Reg. 10605 (Mar. 14, 1983).

3.1.1.2.1 Permits

NOAA's Guide to Permitting Marine Aquaculture in the United States (NMFS 2022) states that anyone who would like to establish a marine aquaculture operation must secure the appropriate federal permits, which may include a Clean Water Act National Pollutant Discharge Elimination System (NPDES) permit, a Rivers and Harbors Act Section 10 permit (Section 10) and/or verification, or a Clean Water Act Section 404 permit (Section 404) and/or verification.

Section 10 of the Rivers and Harbors Act of 1899 Permits
Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. § 403) prohibits the unauthorized obstruction or alteration of any navigable water of the U.S. The construction of any structure in or over any navigable water of the U.S., the excavating from or depositing of material in such waters, or the accomplishment of any other work affecting the course, location, condition, or capacity of such waters is unlawful unless the work has been authorized by USACE through Department of the Army permit (33 C.F.R. § 320.2(b)). The authority of the Secretary of the Army to prevent obstructions to navigation in navigable waters of the United States was extended to artificial islands, installations, and other devices located on the seabed, to the seaward limit of the outer continental shelf, by section 4(f) of the Outer Continental Shelf Lands Act of 1953 as amended (43 U.S.C. § 1333(e)).

Section 10 permitting would be required to attach or anchor offshore aquaculture structures to the sea floor. To aid in the streamlining of permitting, the USACE promotes the use of General Permits (GP) when activities cause minimal adverse or cumulative adverse effects (NOAA, 2022). This may include the use of Nationwide Permits[7] (e.g., NWP 48, NWP 55 and NWP 56) Regional General Permits and Programmatic General Permits. When proposed activities do not meet the terms and conditions of a GP, they are evaluated as an Individual Permit (IP). An IP may either be a Letter of Permission (LOP) or Standard Permit (SP). LOPs are reserved for Section 10 work that is determined to be minor, would not have significant individual or cumulative impacts on environmental values, and should encounter no appreciable opposition (33 C.F.R. § 325.5(b)(2)). SPs are used at the discretion of USACE or when an activity does not qualify for a GP or LOP. A more detailed description of the Section 10 permitting process can be found in Chapter I(A) of NOAA's Guide to Permitting Marine Aquaculture in the United States (2022), which is incorporated by reference.

National Pollutant Discharge Elimination System (NPDES) Permit
The U.S. EPA is responsible for ensuring the protection of U.S. water quality by regulating the point source discharge of pollutants into U.S. waters in accordance with the Clean Water Act (CWA) (33 U.S.C. § 1251 *et seq.*) Section 402. Section 301(a) of the CWA prohibits the discharge of any pollutant, except in compliance with prescribed provisions of the CWA,

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[7] https://usace.contentdm.oclc.org/utils/getfile/collection/p16021coll7/id/20099

including section 402, which establishes the National Pollutant Discharge Elimination System (NPDES). Section 402 also authorizes EPA or states and territories with delegated authority to issue NPDES permits Section 403 of the CWA prohibits the issuance of an NPDES for discharge into the ocean environment, unless compliant with guidelines for the determination of degradation, pursuant to 40 C.F.R. Part 125, Subpart M. If production levels and discharge frequency thresholds are met, an aquaculture facility is designated as a Concentrated Aquatic Animal Production (CAAP) facility pursuant to 40 C.F.R. § 122.24. Non-CAAP facilities may also warrant NPDES permitting. In warm-water environments, the production threshold to qualify as a CAAP is less than 100,000 pounds (45,454 harvest weight kg) of annual production (40 C.F.R. Part 122, Appendix C). Aquaculture operations designated as a CAAP are required to implement management practice to control pollutant discharge pursuant to the effluent limit guidelines and performance standards set in 40 C.F.R Part 451. A more detailed description of the U.S EPA's NPDES permitting process can be found in Chapter I(B) of *NOAA's Guide to Permitting Marine Aquaculture in the United States (2022)*, incorporated by reference.

U.S. water quality and NPDES permitting in federal waters of the Gulf is managed by two U.S. EPA Regions, each with their own geographic area of jurisdiction. Region 4 includes federal waters off Florida, Alabama, and Mississippi, and Region 6 includes federal waters off Louisiana and Texas. Because the Preferred Alternatives considered in this DPEIS are found in the Western and Central Study Areas of the Atlas off Texas and Louisiana, the U.S. EPA Region 6 would be responsible for addressing NPDES permit applications for future offshore aquaculture operations. An NPDES permit may not be necessary for all types of offshore aquaculture projects proposed within an AOA (i.e., operations where there is no input of pollutants or discharge into U.S. waters occurs, like macroalgae farms and typically molluscan shellfish production); however, aquaculture operations that discharge pollutants from point sources or qualify as a CAAP would require an NPDES permit. Pollutants that may be associated with offshore aquaculture operations, including marine finfish operations, and their potential impacts are discussed in detail in Section 3.2.4, *Water Quality* and Section 4.2.1.3 l, *Potential Impacts to Water Quality* of this DPEIS.

3.1.1.2.2 Authorizations

In addition to obtaining federal permits, offshore aquaculture operations may also require authorizations or reviews by non-permitting federal agencies before they become operational (NMFS 2022). These authorizations and reviews by the Department of Defense (DoD), Military Aviation and Installation Assurance Siting Clearinghouse, U.S. Department of Agriculture Animal and Plant Health Inspection Service Veterinary Services (USDA APHIS VS) and U.S. Coast Guard (USCG) are designed to minimize conflict with military readiness, prevent, detect, control and eradicate aquatic animal disease (21 U.S.C. § 111 *et seq*.) and ensure safe navigation respectively (14 U.S.C. § 83 *et seq*.). They may occur at various stages of the permitting process, including once permits have been issued for an operation, but are important considerations for offshore aquaculture operations to become active.

Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement Authorizations

Authorizations from and consultations with the Bureau of Ocean Energy Management (BOEM) and Bureau of Safety and Environmental Enforcement (BSEE) would be required for offshore aquaculture operations wishing to use or tether to existing oil, gas, and wind energy infrastructure, BOEM-designated Significant Sediment Resource Area (SSRA) blocks, Wind Energy Areas, or Wind Energy Options. The BOEM is responsible for managing and regulating offshore activities in the Outer Continental Shelf (OCS), such as oil and gas, alternative energy, and marine minerals operations. The Agency's mission is to manage development of OCS energy, mineral, and geological resources in an environmentally and economically responsible way, and BOEM manages the energy resources in the OCS under the authority of the Outer Continental Shelf Lands Act (OCSLA) of 1953 (43 U.S.C. §§ 1331-1356). The OCSLA implemented federal regulatory control of the OCS, defined as all submerged lands beyond the lands reserved to the States up to the edge of the United States' jurisdiction and control, which includes the U.S. EEZ, extending up to 200 nm (370 km) from the coastline, and includes areas next to the territorial sea of the U.S., Puerto Rico, the Northern Mariana Islands, and other U.S. territories. In addition to the OCSLA, the Submerged Lands Act (SLA) of 1953 was enacted to grant coastal states title to natural resources located within their coastal submerged lands. In the Gulf, Alabama, Mississippi, and Louisiana's submerged lands extend from the coastline to 3 nautical miles offshore, while the submerged lands of Texas and Florida extend out to 9 nautical miles. In 2005, the Energy Policy Act amended the OCSLA to extend BOEM's authority to manage marine renewable energy projects on Federal offshore lands, and other projects that make alternative use of existing oil and natural gas platforms. Besides this jurisdiction and regulatory authority, BOEM also relies on other Federal mandates to manage offshore energy structures and protect the environment, such as the Oil Pollution Act of 1990, NEPA, and CZMA.

Because the AOA Alternatives evaluated in this DPEIS do not overlap with existing oil, gas, or wind energy lease areas or infrastructure, BOEM and BSEE authorizations would not be applicable for future aquaculture operations located in those areas. As such, these processes are not discussed in further detail within this document; however, information about these processes is found in NOAA's Guide to Permitting Marine Aquaculture in the United States (NMFS 2022).

Military Aviation and Installation Assurance Siting Clearinghouse Review

The DoD's Military Aviation and Installation Assurance Siting Clearinghouse (DOD Siting Clearinghouse) was established in Sec. 358 of the Fiscal Year (FY) 2011 National Defense

Authorization Act. The DoD Siting Clearinghouse works with a variety of stakeholders, including private industry, state and local government, regulators, and non-governmental organizations to minimize adverse impacts to military training, testing, and operations, while promoting compatible development (DOD 2023). Reviews with the DoD Siting Clearinghouse may be informal or formal and occur through a project proponent initiating a request and providing details about a proposed project's siting and operational details[8]. The DoD Siting Clearinghouse then routes this information to various military departments including the Army, Air Force, Navy, Marine Corps, Space Force, Joint Staff, and Combatant Commands for review and comment. There is no approval or denial associated with a review; however, if a proposed project is likely to impact military operations, an appropriate military point of contact is provided so coordination can occur to mitigate potential impacts to military operations. Additionally, Hold Harmless Agreements and Waivers of Liability may be necessary for aquaculture operations located within military use areas.

Significant portions of the Gulf, including AOA Alternative locations, overlap with Military Operating Areas or Special Use Airspace. Coordination with the DoD Siting Clearinghouse occurred at several stages during the development of the Atlas and with the DAF when determining the range of AOA Alternatives to carry forward for analysis in the DPEIS. NMFS recommends that future aquaculture projects sited within an AOA Alternative undergo a project specific DoD Siting Clearinghouse review to consider any potential changes in the use of those areas by the military and any mitigation measures that might be necessary to minimize impacts military operations.

Private Aids to Navigation (PATON) Authorization

The USCG has the authority to control PATON in U.S. waters, which includes regulating the establishment, maintenance, and decommissioning of PATONs (14 U.S.C. § 542). The District Commander authorizes PATONs which may be used to mark navigation obstructions like aquaculture systems in navigable waters. PATONs are required to conform U.S. Aids to Navigation System (33 C.F.R. Part 66). Marine aquaculture operations located within the AOA Alternatives would apply for a PATON Authorization to deploy PATONs (e.g., buoys and markers) only after the applicant has received all other applicable permits for their operation. Future aquaculture operations located within an AOA would need to coordinate with USCG District 8 to determine if a PATRON authorization is necessary, and to implement any necessary measures per the authorization.

3.1.1.2.3 Consultations and Reviews

Federal agencies that issue permits or authorizations, or conduct other federal activities that may be necessary to authorize offshore aquaculture operations in federal waters, must also ensure

[8] https://www.dodclearinghouse.osd.mil/

they are in compliance with various applicable federal laws. Federal agencies coordinate, or consult as necessary, with other federal agencies during the permitting process to receive technical review and guidance, consider potential impacts, incorporate appropriate mitigation measures, and ensure actions comply with those laws. The consultations and reviews described in this section are not an exhaustive list of all the federal authorities that might apply to future potential aquaculture operations; however, they are the main statutory requirements that proposed aquaculture activities must comply with for a permit to be issued or authorized. A detailed description of these authorities and resources regarding consultation processes is found in Chapter IV, Federal Consultation and Review Requirements, of NOAA's Guide to Permitting Marine Aquaculture in the United States (NMFS 2022).

Federal Consultations

Endangered Species Act

Section 7(a)(2) of the Endangered Species Act (ESA) (16 U.S.C. § 1531 *et seq.*) requires federal agencies to consult with NMFS, the USFWS, or both (depending on the species jurisdiction), before taking any action that may affect an endangered or threatened species or designated critical habitat to insure their actions are not likely to jeopardize any listed species or cause the destruction or adverse modification of designated critical habitat. The type of consultation required depends on how the action is expected to affect ESA resources.The ESA provides 135 days to complete formal consultation on actions that are likely to adversely affect listed species or designated critical habitat. Informal consultations are often completed more quickly for actions that are not likely to adversely affect ESA listed species or designated critical habitat. The consultation process can be streamlined using tools like expedited informal consultations and programmatic informal and formal consultations. Programmatic consultations can be particularly beneficial to the administrative environment by streamlining the procedures and time involved in consultations for broad agency programs, or for multiple similar, frequently occurring, or routine actions with predictable effects on listed species and/or critical habitat, thus reducing the amount of time spent on individual project-specific consultations.

Magnuson-Stevens Fishery Conservation and Management Act; Essential Fish Habitat

The Essential Fish Habitat (EFH) provisions of the MSA (16 U.SC §§ 1801-1882) require federal agencies to consult with NMFS when activities they authorize, fund, or undertake, or propose to authorize, fund, or undertake, may adversely affect EFH. NMFS provides conservation recommendations, which may be adopted by the permitting agency. The permitting agency is required to provide a written response that describes measures proposed to avoid, minimize, or mitigate the impact of activities on EFH and, if applicable, explain the reason(s) why it is not following the conservation recommendation(s). EFH has been designated in the Gulf for numerous species managed by the Gulf of Mexico Fishery Management Council and by NMFS (e.g., reef fish, coastal migratory species, and highly migratory species).

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (16 U.S.C. § 661) authorizes the USFWS to review activities that are authorized, permitted or funded by the federal government and make recommendations to the responsible agencies regarding the interests of fish, wildlife and their habitats.

National Historic Preservation Act

Section 106 of the National Historic Preservation Act (NHPA) (16 U.S.C. § 470) requires any federal agency issuing a permit to account for potential effects of the proposed aquaculture activity on historic properties, such as shipwrecks, prehistoric sites, and cultural resources. If a proposed aquaculture activity has the potential to affect historic properties, these details must be provided by the applicant as part of the application package. Depending on the potential impacts, the consultation process may cause an agreement that requires the permitting agency to implement mitigation measures.

National Marine Sanctuaries Act

Section 304(d) of the National Marine Sanctuaries Act (NMSA) (16 U.S.C. §§ 1431-1445) requires any federal agency issuing permits to consult with NOAA's National Marine Sanctuary Program (NMSP) if the proposed aquaculture activity is likely to destroy, cause the loss of, or injure sanctuary resources. As part of the consultation process, the NMSP can recommend reasonable and prudent alternatives. While these recommendations may be voluntary, the NMSA requires the federal action agency(ies) issuing the permit to promptly prevent and mitigate damage, and restore or replace the damaged resources in a manner approved by NOAA when sanctuary resources are destroyed, lost, or injured in the course of the action.

Federal Agency Reviews

Coastal Zone Management Act

The Coastal Zone Management Act of 1972 (CZMA) (16 U.S.C. §§ 1451-1464) encourages coastal states to develop and implement coastal zone management plans as a basis for protecting, restoring, and establishing a responsibility in preserving and developing the nation's coastal communities and resources. Coastal states with an approved coastal zone management program are authorized to review certain federal actions affecting the land or water uses or natural resources of its coastal zone for consistency with its program. Under the CZMA, a state may review activities conducted by, or on behalf of, a federal government agency within or outside the coastal zone that may affect any land or water use, or a natural resource of the coastal zone, including an application for a federal license or permit.

Animal Health Protection Act

The Animal Health Protection Act ([AHPA]; 7 U.S.C. §§ 8301-8317) provides the Secretary of Agriculture authority over the prevention, detection, control, and eradication of animal diseases, including aquaculture. Section 8322 (National Aquatic Animal Health Plan) grants the Secretary authority to enter into cooperative agreements for the purpose of detecting, controlling, or eradicating diseases of aquaculture species and promoting species-specific best management practices. Section 10401 provides authority for the Secretary to regulate aquaculture, which includes health certification for export, negotiations of sanitary regulations, regulation of biologics, World Organization of Animal Health (WOAH) representation, regulation of, imported aquatic animals and products, diagnostic services, and disease control and eradication. Authorized by the AHPA, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) Veterinary Services is the lead federal agency for plant and animal health.

The National Aquaculture Health Plan and Standards (NAHPS) 2021-2023 has a primary goal of protecting and supporting the health of farm-raised aquatic livestock by establishing oversight and risk-based approaches to prevent the introduction, spread, or release of pathogens of concern. The NAHPS establishes criteria for health inspection of animals being stocked and harvested in federal waters of the U.S. and feed for those livestock in accordance with plan's goals. These criteria are outlined in further detail in Option 4: Aquaculture Health in the Exclusive Economic Zone (pages 28-29) in the NAHPS (2021-2023) and are incorporated by reference. These criteria are considered in the review conducted by USDA APHIS VS and must be met in order to authorize the stocking of aquatic animals into a permitted aquaculture operation in federal waters.

National Environmental Policy Act

NEPA (42 U.S.C. § 4332) requires federal agencies to prepare an Environmental Impact Statement (EIS) for any major federal action significantly affecting the quality of the biological or human environment. An Environmental Assessment (EA) may be prepared to assist the permitting agency in determining whether significant environmental impacts are likely to occur given the action. The EIS or EA requirement does not apply if the permitting agency determines the activity is categorically excluded from NEPA review.

Federal agencies may streamline the NEPA review process by preparing programmatic documents, like this DPEIS, to broadly or holistically evaluate policy or program alternatives and their effects and reduce duplication in the environmental review process for individual projects. Through a process called tiering, federal agencies can incorporate information from a programmatic NEPA document into their project-specific environmental reviews to eliminate repetitive discussions of the same issues, focus on the actual issues ripe for decision, and exclude from consideration issues already decided. This DPEIS is intended to provide that administrative benefit to future offshore aquaculture businesses seeking federal permits to site aquaculture operations within one of the AOA Alternative areas being considered here.

3.1.1.2.4 Other Federal Laws Applicable to Aquaculture

Marine Mammal Protection Act

The MMPA prohibits the “taking” of marine mammals, which includes harassing, hunting, capturing, or killing. “Take” also includes attempting to harass, hunt, capture, or kill a marine mammal, including feeding or attempting to feed a marine mammal in the wild. However, the MMPA has several exceptions to this prohibition, including the incidental (unintentional) takes of small numbers of marine mammals incidental to specified activities within a specified geographic region. NMFS authorizes the incidental take of marine mammals under the MMPA to U.S. citizens and U.S.-based entities, if the numbers are small, have no more than a "negligible impact" on those marine mammal species or stocks, and do not have an "unmitigable adverse impact" on the availability of the species or stock for subsistence uses. Section 118 of the MMPA authorizes the incidental take of marine mammals during commercial fishing operations. Under NMFS’s Marine Mammal Authorization Program (MMAP) commercial fishermen owning a commercial fishing vessel or non-vessel gear that operates in a Category I or II fishery must obtain a marine mammal authorization certificate each year. The certificate legally authorizes the incidental take of a marine mammal in a commercial fishery. Under the MMPA , all commercial fisheries are classified by the level of incidental marine mammal serious injury or mortality they cause. Commercial fishermen engaging in a Category I, II, or III fishery must report every incidental injury or morality of a marine mammal during commercial fishing operations within 48 hours. Fishery categories are published and reviewed annually in the List of Fisheries (LOF).[9]

Migratory Bird Treaty Act

Enacted in 1918, the Migratory Bird Treaty Act (MBTA) (16 U.S.C. §§ 703-712), implements four bilateral conservation treaties between the U.S., Canada (1916), Mexico (1936), Japan (1972) and Russia (1976), with the intent of sustaining populations of protected migratory bird species. The MBTA prohibits the take (including killing, capturing, selling, trading, and transport) of protected migratory bird species without prior authorization by the USFWS. As of 2023, 1,106 species of native migratory birds were afforded protection under the MBTA (50 C.F.R. § 10.13). In addition to the MBTA, E.O. 13186, *Responsibilities of Federal Agencies To Protect Migratory Birds* (66 FR 3853, January 10, 2001), directs executive departments and agencies to take certain actions to further implement the Act, including development of an MOU between agencies and the USFWS that outlines how the agency will promote the conservation of

[9] The 2024 LOF can be found at 89 Fed. Reg. 12257 (Feb. 16, 2024).

migratory bird populations. The E.O. 13186 also directs agencies to incorporate bird conservation considerations into agency planning, including NEPA analyses, and established the Council for the Conservation of Migratory Birds to oversee the implementation of the E.O.13186.

Federal Food, Drug, and Cosmetic Act

Aquaculture operations must abide by various regulations under the jurisdiction of the U.S. Food and Drug Administration (FDA), such as those implementing the Federal Food, Drug, and Cosmetic Act (FDCA) (21 U.S.C. § 301 *et seq.*), which protects public health by ensuring that foods are safe, wholesome, sanitary, and properly labeled, and that human and veterinary drugs are safe and effective (NOAA 2022). The FDA maintains jurisdiction over drugs used for the treatment or prevention of parasites and diseases of fish, the anesthetization of aquatic species and the alteration of sex and regulation of reproductive function in aquatic species. The FDA is also responsible for regulating therapeutic agents, establishing tolerance levels for safe human consumption.

The FDA (Center for Veterinary Medicine) is also responsible for the approval of new animal drugs and feeds that may be used in aquaculture production. This approval process involves the rigorous scientific evaluation of a drug's effectiveness and safety for the aquatic species, humans and the environment, before the drug receives approval for use. The FDA also participates in the U.S. Fish and Wildlife Service's Aquatic Animal Drug Approval Partnership (AADAP), which implements the National Investigational New Animal Drug (INAD) Program and supports the FDA approval process for new medications intended for fish culture and fisheries management uses.

The USFWS's AADAP program sponsors a variety of new aquaculture drugs and medications through the FDA's new drug approval process with its INAD program. Participation in the program by aquaculture producers, fishery biologists, and managers provides them with the legal access to medication still in the approval process. The use of the medication is permitted under strictly controlled drug use, monitoring, and data reporting conditions (Johnson and Bosworth 2012). In return, the data and information collected by the program participant is used to help inform the FDA's drug approval process. The AADAP program is responsible for the approval of most new aquatic medications and drugs used today by aquaculture producers and fisheries professionals, helping to ensure the proper health and welfare of cultured aquatic species.

The National Shellfish Sanitation Program (NSSP) is the federal/state cooperative program recognized by the FDA and the Interstate Shellfish Sanitation Conference for the sanitary control of bivalve molluscan shellfish produced and sold for human consumption. The purpose of the NSSP is to promote and improve the sanitation of shellfish (oysters, clams, mussels and whole or roe-on scallops) moving in interstate commerce through federal/state cooperation and uniformity of state shellfish programs. Participants in the NSSP include agencies from shellfish producing and non-producing States, FDA, EPA, NOAA, and the shellfish industry. Under international agreements with FDA, foreign governments also participate in the NSSP. Other components of the NSSP include program guidelines, state growing area classification and dealer certification programs, and FDA evaluation of state program elements (FDA 2023).

In U.S. federal waters, the FDA and NOAA are responsible for developing administrative procedures for regulating growing areas and harvest control for bivalve shellfish production. Both agencies ensure the operation's adherence to NSSP requirements. The FDA is responsible for conducting sanitary surveys and the classification of growing areas associated with an aquaculture operation. Federal waters are classified as Approved for shellfish harvesting unless the areas are polluted (i.e., microbiological, chemical, or marine biotoxin hazards) and involve commercial shellfish resources (FDA 2023).

The Lacey Act

The Lacey Act (16 U.S.C. §§ 3371-3378) and its broad reaching provisions govern the interstate transportation and importation of fish and wildlife and their parts, and generally prohibit the import of live or dead fish, mollusks, or crustaceans into the U.S. unless a permit is obtained from the USFWS at the port of entry (50 C.F.R. § 16.13). Species which have been determined to be injurious are prohibited from import. Regulations also prohibit the release of imported species into the wild unless authorized by the appropriate state fisheries management agency.

3.1.2 State Regulatory Environment for Offshore Aquaculture

Currently, marine aquaculture operations in the U.S., including the Gulf, are located exclusively within the state water boundaries of coastal states. All coastal states in the Gulf have comprehensive regulatory frameworks that support bivalve aquaculture in their state waters; however, most lack a similar regulatory regime for non-bivalve marine aquaculture (i.e., finfish, algae, multispecies) or offshore aquaculture, with Florida being a notable exception. While states may not have direct regulatory authority over aquaculture operations proposed in an AOA, they are responsible for conducting consistency reviews of proposed activities under the Coastal Zone Management Act (Section 3.1.1.2.3). States also have regulatory authority over aquaculture operations producing stock (e.g., seed and fingerlings) in their state for use in offshore aquaculture and over aquaculture products landed and sold in their state. Given the geographical locations of the proposed AOAs, Texas and Louisiana are the only states that would have authority under the CZMA.

3.1.2.1 Texas

The Texas Parks and Wildlife Department (TPWD) serves as the lead authority for regulating aquaculture in the state of Texas and its state waters extending nine nautical miles (nm) seaward from the coast into the Gulf. TPWD's regulatory oversight includes general provisions regulating the aquaculture species that may be possessed and cultured (5 Texas Admin. Code § 66.007), the collection of aquaculture broodstock (31 Texas Admin. Code §392 *et seq*.), the transportation and sale of aquaculture products (6 Texas Admin. Code § 134.017) and prohibition on the release of cultured species into public waters, unless authorized (31 Texas Admin. Code § 57.113(b)). TPWD also oversees the state's cultivated oyster mariculture program (31 Texas Admin. Code § 58.350 *et seq*.) and has developed regulations for offshore aquaculture in state waters of the Gulf. These offshore aquaculture regulations address permitting terms, facility inspection, and record keeping and reporting requirements (31 Texas Admin. Code § 57.252). Additionally, the Texas Department of Environmental Quality regulates any discharge to surface waters of the state that might occur from an aquaculture operation (2 Texas Admin. Code § 26.0345) and the Texas General Land Office is responsible for issuing commercial leases for aquaculture operations occurring on or above state submerged lands (2 Texas Admin. Code § 33.001). The Texas Department of State Health Services implements the state's shellfish sanitation program in compliance with the NSSP (25 Texas Admin. Code § 241.50 *et seq*.).

3.1.2.2 Louisiana

Noting the economic importance of aquaculture to the state's agriculture sector, in 2004 the Louisiana Legislature enacted the "Louisiana Aquacultural Development Act" (La. R.S. 3:559.1 *et seq*.). This law established a regulatory framework for orderly development of aquaculture in Louisiana and the promotion of aquaculture and aquaculture products. The Louisiana Department of Agriculture and Forestry is responsible for licensing and inspecting land-based aquaculture facilities with no inlet or outlet to public waters (La. R.S. 3:559.8). The Louisiana Department of Wildlife and Fisheries is the primary agency responsible for permitting and regulating marine aquaculture (La. Admin. Code tit. 76 § VII-900; La. R.S.56:431.2), authorizing the sale and transport of aquaculture products over state highways (La. R.S. 56:412 *et seq*.) and issuing submerged land leases for aquaculture activities occurring within its state waters (La. R.S. 56:425.1; La. R.S. 56:427; La. R.S. 56:428). The Molluscan Shellfish Program, within the Louisiana Department of Health, Office of Public Health, Sanitation Services Section, regulates and monitors the growing, harvesting, handling, and shipping of shellfish in the state of Louisiana (La. Admin. Code tit. 51 § IX). The Louisiana Department of Energy and Natural Resources, Office of Coastal Management also regulates activities affecting the resources of the state's Coastal Zone, ensuring they are compliant with the state's Coastal Use Guidelines (La. R.S. 49:214.21 *et seq*.).

3.2 Physical Environment

3.2.1 Oceanography and Climate

This section provides general information about the oceanography and climate of the Gulf; relevant details about the Physical Environment of each of the Alternatives is covered in the sections below. The Gulf is the ninth largest body of water in the world, spanning more than 564,600 square kilometers (sq km) (217,993 square miles [sq mi]) and one of the most ecologically and economically important in the United States (NOAA 2011; Ward and Tunnell 2017). This semi-closed, oceanic basin is bordered by 75,640 km (47,000 mi) of U.S. coastline (Texas to Florida) at its northern extent, by Cuba to the southeast and Mexico to the south and southwest. The Gulf's waters are connected to the Atlantic Ocean by the Straits of Florida and to the Caribbean Sea by the Yucatan Channel. (Mendelssohn et al. 2017).

The Gulf basin is characterized by its relatively shallow continental shelf that extends seaward from coastal waters 20 m in depth (66 ft) to a depth of 200 m (660 ft), accounting for 22% of the total area of the Gulf. The continental shelf is composed of terrigenous sediments, derived from eroded land deposited into the Gulf via river runoff in the west and northern Gulf, and carbonate sediments in the eastern Gulf, originating from the eroded exoskeletons of marine invertebrates and oceanic precipitates (Davis 2017). Thirty-seven major river systems, from the watersheds of 33 different states flow seaward to the Gulf, depositing nutrients and terrigenous sediments across the shelf (Wilkinson et al. 2009; NOAA 2021a).

Warm, tropical ocean waters make their way into the Gulf from the south between Yucatan Channel and Cuba. Water temperatures in the Gulf range from 13°C (55°F) in the winter months to 32°C (90°F) in the summer (Spies et al. 2016). This warm water flows northward following the continental shelf and circulates in a clockwise direction, forming the Loop Current. Flowing at an average speed of 0.8 m/s, the Loop Current is one of the fastest currents in the Atlantic basin (Ward and Tunnell 2017). It serves as the predominant source of warm water, energy and circulation in the basin and becomes the Gulf Stream once it exits southward through the Florida Straits (Leipper 1970; BOEM 2021). While the Loop Current is generally confined to the southeastern Gulf, large warm-core eddies that break free from the current can affect all parts of the continental shelf and Gulf basin (Vukovich 2005).

Another major source of circulation and water quality influence in the Gulf is freshwater river outflow. The Gulf's main river outflows occur by the Mississippi River and Atchafalaya River in the north, and the Grijalva River and Usumacinta River in the south. The complex interactions of these fresh and saltwater masses contribute to a seasonal oscillation of the prevailing currents across the western shelf of the Gulf from an eastern flow in the summer months, to a western flow the rest of year (Nowlin et. al 1998; Sturges and Lugo-Fernandez 2005). In total, the Gulf receives freshwater input from five countries, including two-thirds of the continental United States and features 33 river outlets, and 207 bays, estuaries, and lagoons (Ward and Tunnell 2017).

These Loop Current, eddies, and river outflows influence upwelling and downwelling of deep ocean water, transporting nutrients and organisms across the shelf, which ultimately impacts water quality (Spies et al. 2016). These nutrients support primary production in the Gulf, which serves as the basis of the food chain for hundreds of economically and ecologically important marine species, including fish, sharks, invertebrates, sea turtles, marine mammals, and seabirds (described in further detail the in Section 3.3, Biological Environment (Wilkinson et al. 2009; Cardona et al. 2016). The nutrient influx also contributes to the development of a seasonal hypoxic zone in the northern Gulf, which is described in further detail in Section 3.2.2.

The Gulf region maintains humid tropical and subtropical climates, influenced by the semi-permanent Bermuda High, that migrates over the western Atlantic most of the year. This area of high pressure generates as a southeasterly flow of warm humid air into the region (Spies et al. 2016). The Gulf is also influenced by dryer, cooler continental air masses that encroach from the north in the form of cold fronts in winter months. This can cause variability in winter weather patterns, which generally remain mild thanks in part to Gulf waters warmed by the Loop Current (Wang et al. 1998). The Gulf's warm waters make tropical storms (i.e. hurricanes) a major climatological feature of the region that affects the biological and human environments. These storms typically develop or enter the Gulf from June to November, with peak occurrence from August to October. The region also typically experiences severe weather events in the form of strong thunderstorms and tornadoes (Mendelssohn et al. 2017).

3.2.2 Benthic Environment

This section provides a brief overview and summary of the benthic environment in the Gulf that could be impacted from future siting of aquaculture operations in **Preferred Alternatives 2-5** (W-1, W-2, W-4, C-3), and **Alternative 6** (C-13) in the western and central Gulf, off Texas and Louisiana. The benthic environments in the Gulf are diverse ranging from sand/mud flats to hard bottom and corals. Important coastal and nearshore habitats (e.g., oyster reefs, submerged aquatic vegetation, and marshes) are not expected to be impacted from the Preferred Alternatives, and ongoing and planned activities in the geographic analysis area, given the locations of the AOA Alternatives range from 10 to 133 km (5.4 to 71.8 nm) from shore.

The Gulf is a semi-enclosed body of water that has a shallow continental shelf, continental slope, and abyssal plain. The continental shelf is the relatively flat, shallow expanse that extends from the coast to a water depth of approximately 120 m (394 ft). The shelf generally corresponds with the part of the Gulf that was exposed during the last glacial maximum approximately 20,000 years ago (Donoghue 2011). In the northern Gulf, the shelf extends from 100 to 200 km (54 to 108 nm) offshore; the surface of the shelf is topographically smooth, and such features as relict stream channels are evident. The topography along both the West Florida shelf and the Campeche Bank, located north of the Yucatan Peninsula, is low relief, and is broken only by reefs and relict shoreline features. At the edge of the continental shelf, the bathymetry steepens to form the continental slope, which extends to a depth of approximately 2,000 m (6,562 ft). In the northwestern Gulf, salt structures deform the seabed of the Central Slope and are the site of significant oil exploration and extraction. In many areas, the foot of the continental slope is marked by steep escarpments, such as the West Florida and Sigsbee areas. The Louisiana Delta is a massive lobe of sediment deposited over millions of years by the Mississippi River. Offshore, these sediments have built the Mississippi Fan, which covers some 160,000 sq km (61,776 sq mi), and contains many submarine channels and levees that funnel sediment to the deep abyssal plain (Jenkins 2011).

All of these geological features, along with the past and ongoing oceanographic and environmental conditions in the Gulf, have formed ecologically important benthic habitats that support diverse biological communities, including many fish and invertebrate (infaunal and epifaunal) species. The main benthic offshore environments in the Gulf consist of various seafloor substrates, such as soft bottom (sand, mud, sand/mud), hard bottom, rocks, and ledges. Some ledge/rock structures support deepwater coral communities, which are a type of hard bottom that is considered distinct given its physical and biological complexity. Various physicochemical factors determine the distribution, growth and success of organisms that form coral reefs (Briones 2008). Most of the seafloor on the continental shelf is mud, but some of the seafloor is a mixture of sand, gravel, shell, and coral fragments. Hard bottom is an important benthic environment that is found on the seafloor on the continental shelf; it is usually found scattered or in small patches. Hard bottom is made of limestone rocks, ledges, reef-like outcrops, rock rubble, and sponges; some reef-like outcrops can extend up to 2 m (6.6 ft) off the seafloor (Briones 2008). Hard bottom provides habitat for many commercially and recreationally valuable species. In fact, some hard bottom areas are classified as EFH or Habitat Areas of Particular Concern (HAPC), such as the East and West Flower Garden Banks; Stetson Bank; and 29 Fathom, MacNeil, and Rezak Sidner Banks.

The sediment composition varies within and among the Alternatives. Based on Riley et al. (2021), the sediment within **Preferred Alternative 2** (W-1) is 70% mud, but in the southwest corner it changes to fine sand, which covers the remaining 30% of W-1. Similarly, the sediment in **Preferred Alternative 3** (W-4) is primarily mud and silt (97-99%), and 3% sand in the northeastern corner. The sediment in **Preferred Alternative 4** (W-8) is over 90% sand and mud, with approximately 3% gravel. The sediment in **Preferred Alternative 5** (C-3) is 99% sand and mud, while the northeast corner has a slightly higher percent of sand relative to the southwest, where it is more mud. The sediment in **Alternative 6** (C-13) is 99% mud, which is probably associated with sediment from the Mississippi River.

3.2.3 Federally Protected Habitat, Marine Protected Areas and Special Resource Areas

This section includes information about federally protected and managed marine areas in federal waters of the Gulf that could be affected if aquaculture were to be sited in one of the AOA Alternatives locations. A list of the marine managed and protected areas that were considered in the suitability modeling are found in the Atlas (Riley et al. 2021). Based on Riley et al. (2021),

Alternatives 2-6 do not overlap with any Marine Protected Areas, Marine Reserves, national marine sanctuaries, artificial reefs, other habitats, HAPCs, mapped hard bottom areas (except for EFH), deep-sea corals or fish havens, but they differ in geographical proximity to them. ESA designated critical habitat is discussed in Section 3.3, Biological Environment.

Marine Protected Areas (MPAs) and Marine Reserves

MPA is a broad term that describes protected areas that have a clearly defined geographical space, and that are designated and managed to achieve long term conservation, ecosystem services, and cultural values (National Marine Protected Areas Center 2008). Executive Order 13158 (2000) directed the U.S. to develop, support, and conserve these valuable habitats through a national MPA system. Riley et al. (2021) considered the Madison-Swanson, Edges, and Steamboat Lumps MPAs (eastern study area of the Atlas) and the Tortugas North and South Marine Reserves (southeastern study area of the Atlas) in their spatial modeling. Results showed none of the AOA Alternatives overlapped with any MPAs or Marine Reserves.

National Marine Sanctuaries

National Marine Sanctuaries as recognized under the NMSA (1972) are protected areas that allow for specific uses described in each Sanctuary's Management Plan. The Florida Keys National Marine Sanctuary (FKNMS) and the Flower Garden Banks National Marine Sanctuary (FGBNMS) are the two Sanctuaries that are located in the Gulf, and were considered in the Atlas' spatial suitability modeling (Riley et al. 2021). The FKNMS is a National Marine Sanctuary in the Florida Keys that includes the Florida Reef, which is the only barrier coral reef in North America and the third-largest coral barrier reef in the world. The sanctuary protects 9,842 sq km (3,800 sq mi) of waters surrounding the Florida Keys, from south of Miami westward to the Dry Tortugas, excluding Dry Tortugas National Park. The FKNMS is not discussed further here because of its distance from the AOA Alternatives considered in the DPEIS.

The FGBNMS is a National Marine Sanctuary located in the northwestern Gulf, approximately 130 to 213 kn (70 to 115 nm) off the coast of Texas and Louisiana. With its boundaries expanded in 2021 (86 FR 4937), FGBNMS grew from 145 sq km (56 sq mi) to 414 sq km (160 sq mi) and is now composed of 17 distinct banks, formed by the movement of underlying salt deposits through sediment layers on the seafloor. These banks support the northernmost coral reefs in the U.S., and form a chain of suitable and protected habitat for numerous ecologically and economically important marine species (ONMS 2020). None of the AOA Alternatives overlap with FGBNMS. **Preferred Alternative 4** (W-8) and **Preferred Alternative 5** (C-3) are located closest to the boundaries of FGBNMS, with **Preferred Alternative 4** (W-8) 62.9 km (34.0 nm) from Stetson Bank and 102.8 km (55.5 nm) from West Flower Garden Bank, and **Preferred Alternative 5** (C-3) 27.2 km (14.7 nm) from Alderdice Bank and 28.8 km (15.6 nm) from Sonnier Bank. Because of the extensive distance between the AOA Alternatives and FGBNMS, future aquaculture operations sited in any AOA Alternatives are not expected to have direct effects on the Sanctuary.

Artificial Reefs

Artificial reefs are important habitats that support numerous marine species in the Gulf, including fish, invertebrates, sharks, sea turtles, and marine mammals. An artificial reef is a manmade structure that may mimic some of the characteristics of a natural reef. Fish havens are a type of artificial reef or "submerged structures deliberately constructed or placed on the seabed to emulate some functions of a natural reef, such as protecting, regenerating, concentrating, and/or enhancing populations of living marine resources" (UNEP 2009; NOAA 2016). They also serve as important areas for socioeconomic purposes, such as recreational fishing, diving, and ecotourism (Barnette 2017). NMFS supports artificial reef development, management, and regulation as the lead agency through the NOAA National Artificial Reef Plan as Amended: Guidelines for Siting, Construction, and Development of Artificial Reefs (NMFS 2007). Given their ecological importance, artificial reefs and fish havens were examined using MSP, and a 500 m (1,640 ft) distance buffer was incorporated into the spatial model to reduce the potential for future aquaculture operations to impact these areas of habitat (Riley et al. 2021). Of the AOA Alternatives, only three are located in proximity to permitted artificial reef areas. **Preferred Alternative 3** (W-4) is 5.3 km (2.9 nm) from Mustang Island A-85 Artificial Reef, **Preferred Alternative 5** (C-3) is 1.5 km (0.81 nm) from South Pass 37 Artificial Reef and **Alternative 6** (C-13) is 4.1 km (2.2 nm) from South Pass Reef 133.

Other Habitats

The BOEM establishes "No Activity Zones" to regulate the oil and gas industry's interaction with topographic features, which encompass ecologically sensitive areas. No Activity Zones apply only to the oil and gas industry and prohibit associated activities, such as construction and use of structures, operation of drilling rigs, laying of pipelines, and anchoring on the seafloor or in the water column. Riley et al. (2021) examined these zones in relation to the proposed AOAs and determined they were incompatible with aquaculture given the proximity to sensitive habitats. These areas were added to the MSP Constraints Model with a 1,000 m (3,281 ft) setback distance (Riley et al. 2021). The results showed there were no AOA Alternatives that overlap these No Activity Zones. A similar modeling approach was also used for deep sea coral and sponge observations, which also showed no AOA Alternatives overlapped these areas.

Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC)

The MSA requires that fishery management plans identify and describe EFH for managed fish stocks (16 U.S.C. 1853(a)(7)). The EFH provisions of the MSA support sustainable fisheries by maintaining suitable marine fishery habitat quality and quantity. Identified EFH in the GMFMC's FMPs includes marine and estuarine habitats, such as coral and coral reefs, hard bottom, oyster reefs, seagrass, mangroves, marshes, algal flats, and sand, shell, mud, and rock substrates[10]. EFH for Coastal Migratory and Atlantic HMS also includes coastal and pelagic habitats[11]. Riley et al. (2021) details overlap between AOA Alternatives and EFH; all areas overlap with EFH.

Habitat Areas of Particular Concern (HAPC) are discrete subsets of EFH that provide important ecological functions that are especially vulnerable to degradation. Several Gulf coral HAPCs are protected by a prohibition on bottom tending gear (50 C.F.R. 622.74). A detailed list of the HAPCs considered in suitability modeling are found in Appendix A of Riley et al. (2021). Riley et al. (2021) reported none of the AOA Alternatives overlap with HAPCs. Several HAPC are closed to shrimp trawling so they were considered in the spatial suitability modeling, as detailed in Appendix A of Riley et al. (2021).

3.2.4 Water Quality

Water quality is described and assessed using various physicochemical parameter measurements, such as water temperature, salinity, dissolved oxygen (DO), chlorophyll-a (i.e., a proxy for primary productivity), turbidity, and nutrients. These key indicators of water quality are considered proxies for ecosystem health; nutrient concentrations reflect ocean health (Ward and Tunnell 2017). Although the average range and specific tolerances for each physicochemical parameter differs among species, all of them are essential for healthy aquatic organisms. Ongoing stressors, natural processes, or anthropogenic activities can adversely impact key water quality parameters; impacts can be additive or compounded (Ward and Tunnell 2017). Historically, water quality in the Gulf has been altered by many types of anthropogenic activities, such as coastal development, agriculture, waterway diversions, industrial complexes (e.g., refineries and petrochemical facilities), and oil and gas operations (Kennicutt II 2017). Freshwater run-off is a major factor impacting water quality in the Gulf and the Mississippi River system is the primary source of nitrogen and phosphorus in the Gulf. Stormwater runoff associated with seasonal and rain events, tropical storms, and hurricanes can alter water quality conditions throughout the Gulf.

Water quality in the Gulf is usually site or region specific, varying by location, depth, and condition (e.g., low DO and high nutrients). Beyond the influence of coastal processes, water quality along the Gulf continental shelf and slope, and abyssal water quality are generally good. Exceptions are hypoxic (low oxygen) zones on the continental shelf, waters above natural oil and gas seeps, and ephemeral effects from water discharges during petroleum extraction (Ward and Tunnell 2017). Seasonally, waters with low concentrations of oxygen, known as “dead zones”, are geographically widespread along the northwest/central Gulf (Ward and Tunnell 2017).

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[10] https://www.fisheries.noaa.gov/content/essential-fish-habitat-gulf-mexico

[11] https://media.fisheries.noaa.gov/dam-migration/final_a10_ea_signed_fonsi_092017.pdf

Weather-driven water column stratification coupled with Mississippi River outflow that delivers excess nutrients to the offshore region are likely contributing factors to the creation of the dead zone. It has been suggested that anthropogenic changes to the Mississippi River drainage basin and its discharges (e.g., increased agricultural runoff) have increased the frequency and intensity of these low oxygen events (Ward and Tunnell 2017).

Contaminants

Water quality in the Gulf is also impacted by various harmful land-based contaminants. Heavy metals and other toxins have been detected in fish samples, causing fish consumption advisories and beach closures along the northern Gulf (Ward and Tunnel 2017). Based on the EPA, most of the fish consumption advisories in the Gulf are associated with mercury levels, but at a few sites they were linked to the high levels of PCBs, chlorinated pesticides, and dioxins/furans in fish tissues (Kennicutt II 2017). The EPA indicates over 50% of the oyster-producing areas along the northern Gulf are permanently or conditionally closed because of contaminants (Kennicutt II 2017). Consumption advisories have been connected to various contaminants (e.g., mercury, PCBs, mercury, hexachlorobenzene, and hexachlorobutadiene), and elevated bacteria levels. Consumption advisories (shellfish and/or finfish) and/or beach closures have occurred in every Gulf state at one time or another.

Natural Oil Seeps and Spills

Oil is another contaminate that can have short and long-term impacts on the water quality in the Gulf. Although it is somewhat difficult to estimate how oil influences water quality as a whole given the various ongoing stressors, it is considered a minor contributor of water degradation in the Gulf (Kennicutt II 2017). Oil in the Gulf is released into the water by natural and industrial activities, with discharge from natural seeps accounting for about 95% of all discharge into the Gulf (Ward and Tunnell 2017). In the 1990s an estimated 170,000 tonnes of oil was introduced into the Gulf by natural seeps, compared to 25,400 tonnes annually from anthropogenic sources (Kennicutt II 2017). The Gulf is reported to have more natural seeps than any other region in the world (Kennicutt II 2017).

Crude oil released from natural seeps are composed of various chemicals, including polycyclic aromatic hydrocarbons (PAHs), which are carcinogens that can adversely impact water quality and overall ecosystem health. Besides natural seeps, industry can accidentally release small and large amounts of crude oil. Accidental oil spills are rare events around the world, including the Gulf, but the magnitude and severity can cause detrimental short and long-term impacts (direct and indirect) to water quality and marine life (e.g., IXTOC I and MC-252 Deepwater Horizon). NMFS led and funded numerous research projects to examine the short and long-term impacts associated with the Deepwater Horizon oil spill under the Natural Resource Damage Assessment process. The CWA prohibits anybody from discharging "pollutants" through a "point source" into a "water of the United States" unless they have an NPDES permit. Following the criteria of the NPDES regulations, it limits on what you can discharge, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or people's health. As such, the oil and gas industry can release some water containing small amounts of dispersed crude oil, but it must comply with their NPDES permit.

Hypoxic Zone

Available information describing the water quality conditions in offshore areas (continental shelf, continental slope, and abyssal) is limited, but it's generally considered good and unimpaired in areas away from the influence of the Mississippi River, natural oil and gas seeps, and oil platforms (Kennicutt II 2017). In contrast, the waters that receive Mississippi River discharge are routinely impacted by the second largest bottom-water hypoxic zone (i.e., ≤ 2 mg/L dissolved oxygen ([DO]) in the world, which typically extends from Louisiana to Mississippi, and sometimes extends to Texas (Rabalais and Turner 2019). Excess nutrients from the Mississippi River has plagued the north central Gulf with regular hypoxic events since the 1950s (Rabalaisand Turner 2019).

The spatial extent of the hypoxic zone is directly linked to the amount of precipitation and nutrient (nitrogen and phosphorus) run-off from the Mississippi and Atchafalaya rivers (Kennicutt II 2017). Excessive nutrients can cause eutrophication and intense biological productivity that depletes oxygen when the remains of algal blooms and zooplankton fecal pellets sink to the lower water column and seabed (GMFMC 2004). Low oxygen concentrations can cause hypoxia when phytoplankton blooms decompose, especially when the water column is stratified. Stratification in the northern Gulf is most influenced by salinity differences year-round but is accentuated in summer when surface waters are warm and winds are calm.

Hypoxia occurs each year in the northern Louisiana continental shelf from nearshore to around 50 to 150 km (27 to 81 nm) offshore (Rabalais and Turner 2019). The hypoxic zone usually occurs at depths between 10 to 30 m (33 to 98 ft) but may range in depth between 5 and 60 m (16 and 197 ft). In the eastern Louisiana shelf, hypoxic conditions may persist in the lower 10 m (33 ft) of a 20 m (66 ft) water column, but in the western Louisiana shelf low DO is around 2 to 5 m (6.6 to 16.4 ft) above the seabed. Hypoxia usually occurs in summer, but it can occur at any time; it has been reported in every month except December and January (Rabalais and Turner 2019). The duration of a hypoxic event varies between one and two months, depending on the upwelling wind conditions and tidal advection, which transport oxygenated waters that increase the DO. Hypoxia alters the behavior, abundance, and spatial distribution of various marine organisms from benthic invertebrates to fishes (Zhang et al. 2010); it can also cause mortality for non-mobile and mobile organisms if they get trapped (Rabalais and Turner 2019).

In July 2024, scientists from the Louisiana State University and the Louisiana Universities Marine Consortium (LUMCON) conducted their annual survey of the Gulf hypoxic zone and found it to be 17,360 sq km (6,703 sq mi), stretching from Lousianna to Texas (LSU 2024). This was greater than the 15,092 sq km (5,827 sq mi) hypoxic NOAA had predicted in June 2024, based on the Mississippi River discharge and nutrient runoff data from the U.S. Geological Survey. The 2024 Gulf hypoxic zone was the 12th largest observed in the 38 years the hypoxic zone survey has been conducted (NOAA 2024). None of the AOA Alternatives overlap this hypoxic zone, and all are located outside the extent of the 2017 Gulf hypoxic zone, which was the largest ever observed at 22,730 sq km (8,776 sq mi) (NCCOS 2021).

Harmful Algal Blooms

Another factor that can influence and degrade water quality is large concentrations of harmful algae. Harmful algae are phytoplankton that produce biotoxins and can cause adverse effects on animals and humans during large blooms (i.e., HABs; Rhodes et al. 2023). HABs are caused by a variety of phytoplankton species that produce different toxins, such as the dinoflagellate *Karenia brevis*, which is responsible for a HAB known as "red tide." Most species that cause HABs are associated with poisoning syndromes (e.g., paralytic shellfish poisoning) but they can also cause various water quality problems, such as hypoxic and anoxic water conditions (Anderson et al. 2021). HABs can cause noxious impacts associated with the accumulation and decay of phytoplankton, and fish and wildlife mortalities (Anderson et al. 2021). HABs can not only impact public health and natural resources, but also severely impact local tourism and the economy. For instance, it is estimated the total economic impact of red tide in Galveston County, Texas was $21.3-24.6 million in 2000 given commercial oyster fishery closures, lost tourism, and costs of beach clean-up (NOAA 2024).

HABs periodically occur in the Gulf. Red tide sometimes occur in Texas, but rarely occurs in Alabama, Mississippi, and Louisiana. Reports of red tide events date back to the early Spanish explorers reporting fish kills from Texas to Mexico. Although HAB events have been occurring throughout the Atlantic and Pacific oceans for hundreds of years, they are difficult to pattern and predict. However, data suggest HAB-related marine wildlife morbidity and mortality events are increasing with time (Anderson et al. 2021).

Marine Debris

Marine debris is another anthropogenic factor that can impact water quality. Marine debris can include a wide variety of objects constructed of different materials (e.g., lost fishing gear, lost vessel cargo, plastics, metal military debris) that are released from multiple sources (e.g., stormwater runoff, landfills, recreational and commercial activities, military activities). Globally, plastic makes up most marine debris, which is composed of multiple chemical compounds; some are classified as persistent organic pollutants (Barnes et al. 2009). Marine debris can leach chemicals or microplastics (Smith et al. 2018; Andreas et al. 2021; Bennett et al. 2022; Unuofin and Igwaran 2023) causing a number of public health and safety concerns, and water quality issues.

Marine debris is a prevalent issue that threatens marine environments around the world, including the Gulf. Ribic et al. (2011) found marine debris is a problem throughout the Gulf, but the amount varied over time and space. For instance, the western Gulf had twice as much land-based debris and five times as much general-source (ocean or land-based origin) debris as the eastern Gulf. The western Gulf also had almost six times as much ocean-based debris as the eastern Gulf (Ribic et al. 2011). Throughout the Gulf, the highest debris amounts occurred in June and July. The data suggest the amount of marine debris from all sources is decreasing in the eastern Gulf, but only land-based marine debris is decreasing in the western Gulf; the trend in general and ocean-based debris is stable in the western Gulf (1996-2003). The prevalence of marine debris is affected by natural forces (e.g., currents) and anthropogenic drivers (e.g., coastal development, vessel traffic); movement is controlled by wind and currents. Mean wind direction in the eastern Gulf is offshore, and onshore in the western Gulf (Ribic et al. 2011). Also, the current flow on the continental shelf is counterclockwise in the western Gulf given the freshwater inputs. Fishing gear is also a source of marine debris in the Gulf (Posadas et al. 2021). O'Connell et al. (2023) reported derelict fishing gear was 63.7% of all marine debris found around the FGBNMS. Given the increasing trend in vessel traffic, commercial and recreational fisheries effort, population growth, and associated development throughout the Gulf, it is highly probable marine debris from land-based and ocean-based sources will increase over time (ONMS 2020; Steele and Miller 2022).

Water Quality Characteristics of AOA Alternatives

Riley et al. (2021) described the baseline water quality conditions (temperature, salinity, nutrient concentration, dissolved oxygen, chlorophyll-a, and water clarity) at the various AOA Alternatives locations. The mean water quality parameters varied slightly by location and season across ecoregions, levels of water quality parameters did not deviate outside of tolerable ranges for the majority of candidate aquaculture species; however, some species may be better acclimated for certain parameters (e.g., macroalgae for areas with elevated nitrate and phosphate levels, rather than finfish species).

The minimum mean daily surface water temperature for **Preferred Alternative 2** (W-1) was 16.0°C, and the maximum was 30.8°C during 2016 through 2020. The average daily salinity during this same time period remained consistent throughout the year at 34.2 parts per thousand (ppt). The mean dissolved nutrient levels at the surface for nitrate, phosphate, and silicate were 0.13 µmol/L, 0.07 µmol/L, and 1.05 µmol/L, respectively. The concentrations of nitrate (0.08 µmol/L), phosphate (0.06 µmol/L), and silicate (0.06 µmol/L) decreased at 30-m depth. At 70-m depth, nitrate concentrations increased to 1.26 µmol/L, and phosphate concentrations were 0.12 µmol/L and silicate concentrations were 1.06 µmol/L. The DO also changed slightly with depth.

The DO was 4.7 ml/L at the surface and 4.9 ml/L at around 50-m depth. The Chlorophyll-*a* concentration was highest (1.2 mg/m^3) in spring (April) and lowest (0.14 mg/m^3) in summer (August). The diffuse light attenuation coefficient at 490 nanometers was lowest (0.03 m^{-1}) in August and highest (0.09-0.10 m^{-1}) during April-June; it was low during June through September. % light transmissivity was relatively constant throughout the year, ranging from 88% in May to 92% in August.

The minimum mean daily surface water temperature for **Preferred Alternative 3** (W-4) was 17.7°C, and the maximum was 30.9°C during 2016 through 2020. The average daily salinity during this same time period remained consistent throughout the year at 34.2 ppt. The mean dissolved nutrient levels at the surface for nitrate, phosphate, and silicate were 0.11 µmol/L, 0.05 µmol/L, and 1.34 µmol/L, respectively. The concentrations of nitrate (0.98 µmol/L), phosphate (0.03 µmol/L), and silicate (1.1 µmol/L) decreased at 30-m depth. From 45- to 50-m depth, nitrate concentrations increased from 0.13 µmol/L to 0.70 µmol/L, and phosphate concentrations were 0.06 µmol/L and silicate concentrations were 1.66 µmol/L. The DO also changed slightly with depth. The DO ranged from 4.7 to 4.9 ml/L in surface water, with the highest DO level at around 45-50-m depth. The Chlorophyll-*a* concentration was highest (1.1 mg/m^3) in spring (June) and lowest (0.14 mg/m^3) in summer (August). The diffuse light attenuation coefficient at 490 nanometers was lowest (0.03 m^{-1}) in August and highest (0.09 m^{-1}) in May; it was low during June through September. Percent light transmissivity was relatively constant throughout the year, ranging from 86% in May to 93% in August.

The minimum mean daily surface water temperature for **Preferred Alternative 4 (**W-8) was 17.6°C, and the maximum was 30.9°C during 2016 through 2020. The average daily salinity during this same time period remained consistent throughout the year at 34.2 ppt. The mean dissolved nutrient levels at the surface for nitrate, phosphate, and silicate were 0.13 µmol/L, 0.12 µmol/L, and 1.96 µmol/L, respectively. The concentrations of nitrate (0.79 µmol/L), phosphate (0.06 µmol/L), and silicate (2.63 µmol/L) increased at 50-m depth. At 80-m depth, nitrate concentrations increased more to 1.38 µmol/L, and phosphate (0.12 µmol/L) and silicate (1.91 µmol/L) concentrations decreased; silicate was highest (3.62 µmol/L) at 30-m. The DO ranged from 4.6 to 4.9 ml/L throughout the water column. The Chlorophyll-*a* concentration was highest (0.43 mg/m^3) in spring (May) and lowest (0.14 mg/m^3) in summer (August). The diffuse light attenuation coefficient at 490 nanometers was lowest (0.3 m^{-1}) in August and highest (0.07 m^{-1}) in June; it was low during June through September. Percent light transmissivity was relatively constant throughout the year, ranging from 89% in May to 92% in August.

The minimum mean daily surface water temperature for **Preferred Alternative 5** (C-3) was 18.9°C, and the maximum was 32.1°C during 2016 through 2020. The average daily salinity during this same time period remained consistent throughout the year at 32.7 ppt. The mean dissolved nutrient levels at the surface to 5 m for nitrate, phosphate, and silicate were 1.11

µmol/L, 0.33 µmol/L, and 4.27 µmol/L, respectively. The concentrations of nitrate (1.76 µmol/L) and phosphate (0.36 µmol/L) and silicate (7.28 µmol/L) increased at 25-m depth. Around 45-m, nitrate (0.91 µmol/L), phosphate (0.12 µmol/L) and silicate (3.28 µmol/L) concentrations decreased with depth. The DO ranged from 4.5 to 4.8 ml/L throughout the water column. The Chlorophyll-*a* concentration was highest (0.79 mg/m^3) in July and December (0.75 mg/m^3) and lowest in May (0.17 mg/m^3). The diffuse light attenuation coefficient at 490 nanometers was lowest (0.04 m^{-1}) in April and May and highest (0.10 m^{-1}) in December; it was low during June through September. Percent light transmissivity was relatively constant throughout the year, ranging from 87% in May to 92% in August.

The minimum mean daily surface water temperature for **Alternative 6** (C-13) was 14.4°C, and the maximum was 32.1°C during 2016 through 2020. The surface water temperatures and average daily salinity at this location showed a high degree of variability, impacted by seasonal storm events, freshwater outfall from the Mississippi River and shifts in prevailing current patterns. The average daily salinity during those same years was 31.4 ppt, but ranged between a low of 13.3 ppt and a high of 35.4 ppt. The mean dissolved nutrient levels at the surface to 5-m for nitrate, phosphate, and silicate were 4.54 µmol/L, 0.44 µmol/L, and 8.96 µmol/L, respectively. The concentrations of nitrate (1.44 µmol/L), phosphate (0.31 µmol/L), and silicate (5.19 µmol/L) decreased at 30-m depth. From 55- to 60-m depth, nitrate concentrations increased from 2.25-2.89 µmol/L, and phosphate concentrations 0.17-0.20 µmol/L and silicate concentrations 2.20-3.10 µmol/L decreased with depth. The DO decreased with depth. The DO ranged from 4.1-5.0 ml/L. The Chlorophyll-*a* concentration was highest (18.2 mg/m^3) in July and lowest (5.1 mg/m^3) in January. The diffuse light attenuation coefficient at 490 nanometers was high (0.9-1.80 m^{-1}) throughout the year. Percent transmissivity was highest in August (40%), September (47%), October (39%), and November (39%). The remainder of the year transmissivity of PAR light at 1-m depth was between 26% and 36%.

3.2.5 Air Quality

The Clean Air Act, last amended in 1990, is a comprehensive federal statute responsible for the regulation of air emissions generated by stationary and mobile pollution sources. The CAA requires the EPA to establish National Ambient Air Quality Standards (NAAQS) (40 C.F.R. part 50) for six common pollutants, known as criteria air pollutants, that are considered harmful to public health and the environment (USEPA 2011a). These six criteria pollutants include carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, particulate matter with an aerodynamic diameter less than or equal to 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$), and lead (USEPA 2011b). An updated table with a list of the six criteria pollutants and NAAQS is available online at https://www.epa.gov/criteria-air-pollutants/naaqs-table. The CAA requires state governments to develop plans to comply with NAAQS. The states may establish their own Ambient Air Quality Standards ensuring compliance with air quality standards. They must however, be at least as stringent as the NAAQS. All states, including those bordering the Gulf, are required by the Clean Air Act to have a State Implementation Plan (SIP) to implement, maintain, and enforce the NAAQS (BOEM 2023).

Section 328 of the CAA authorized EPA (Region 4) to establish air-emission control requirements for the Gulf's Outer Continental Shelf (OCS) in the region east of the 87°30' W longitude and authorized the Department of Interior (DOI) to regulate air emissions westward of that boundary. The DOI's authority to regulate OCS air-emissions predates the 1990 amendments to the CAA and the EPA's authorization to establish air-emission controls, originating from the 1978 Outer Continental Shelf Lands Act (P.L. 95- 372). Before activities can occur in the OCS, operations must submit and obtain approval for activity specific plans that quantify a facility's projected emission of sulfur dioxide, carbon monoxide, nitrogen oxide, Particulate Matter (PM_{10}, $PM_{2.5}$) and volatile organic compounds (VOCs). The plan is then evaluated, and it is determined whether certain exceptions may apply (related to emissions output and distance from shore) or whether Best Achievable Control Technologies (BACTs) are necessary to control emissions (Ramseur 2012).

Generally, the nation's air quality has been improving over the last 30 years, as is the case for the majority of the Gulf region (EPA 2023). Only the area around St. Bernard Parish, LA, and the Houston-Galveston-Brazos area in Texas are in nonattainment for the criteria pollutants of sulfur dioxide (2010) and Ozone 8-hour (2015) respectively (EPA 2024). These areas are a substantial distance from the AOA Alternatives, making it unlikely that future aquaculture activities in any AOA would have effects on these areas or that these areas would impact the air quality in an AOA.

3.2.6 Aesthetic Quality

3.2.6.1 Visual Environment

Federal and state agencies have various standards, thresholds, and procedures for evaluating visual impacts. Many individual states have specific language related to scenic or aesthetic value, but the primary federal law that considers scenic value is the CZMA. The assessment of potential seascape, landscape, and visual impacts on important coastal scenic, historic, and recreational resources; Native American tribal properties and treasured seascapes; commercial interests dependent on tourism; and the private property of coastal residents can be a challenge for developers and regulators (BOEM 2021). In general, an assessment analyzes and evaluates impacts on both the physical elements and features that make up a landscape or seascape and the aesthetic, perceptual, and experiential aspects of the landscape or seascape that make it distinctive (BOEM 2021). Assessments of potential visual impacts are conducted in various ways, but usually require a graphic illustration of how the proposed structure fits into the existing landscape and consider where the general public could potentially view the project (Bliven and Kelty 2005). Mitigation and best management practices are often required by local, state, or federal agencies in permitting and consultation processes.

The aesthetic qualities of visible industrialized infrastructure are subjective but are generally regarded as adverse, particularly in landscape/seascape settings such as national parks or national marine sanctuaries, and most people dislike commercial development in undeveloped coastal landscapes (Bliven and Kelty 2005; BOEM 2023).The Gulf, in particular the coastline and waters off Texas and Louisiana, provides a unique sea and landscape that prominently features both the natural environment and industrial development. The marine economy of the Gulf serves as a major economic driver of the regional and national economy, and includes commercial fishing, aquaculture, ship building, marine construction, shipping and transportation, oil and gas extraction, recreation (i.e. boating, birding and recreational fishing), tourism, and emerging wind energy (McKinney et al. 2021). The Gulf contains some of the world's busiest ports, with shipping fairways that funnel thousands of cargo vessels, cruise ships, and other vessels annually, with on-going activities that generate spills, marine debris (e.g., derelict fishing gear), structure presence, and light emissions as part of the existing seascape (BOEM 2023). The Gulf has an extensive history of oil and gas development, and lighting and visible infrastructure from past and ongoing OCS oil- and gas-related activities has been a well-known aspect of coastal viewsheds for decades (BOEM 2023).

Preferred Alternatives 2-5 (W-1, W-4, W-8 and C-3) are located a considerable distance from shore (64.8 km [35nm] to 133.3 km [72 nm]) and beyond the visible line of sight. **Alternative 6** (C-13) is the closest AOA Alternative to shore, at 9.26 km (5 nm), but there are no residential homes, parks, or any public viewing spots within visible range of this location.

3.2.6.2 Acoustic Environment

The acoustic environment of the OCS of the Gulf is composed of a combination of natural and anthropogenic noise sources that emit sound into the air and water. Sources of ambient noise encompass a broad spectrum of frequencies, and includes sound wind and wave activity, precipitation (e.g., rain, hail, and thunder), geological events (e.g., seismic activity, underwater landslides), and biological organisms (e.g., marine mammals, fishes, crustaceans) (Sidorovskaia et al. 2016). These natural sources of noise may vary greatly in frequency and distribution, but the frequency of natural noises is generally greater in shallower water depth (less than 200 m [656 ft]) compared to deeper waters (BOEM 2023). Anthropogenic sources of noise in the Gulf can be directly attributed to the industrial and recreational uses of the area and include transportation (e.g., vessels and aviation), construction and dredging, energy exploration and development, scientific research, and explosions from military activities. Anthropogenic noise levels tend to occur at lower frequencies (<500 Hz) and have been known to disrupt the behaviors of marine life, especially marine mammals (BOEM 2023). The acoustic environmental conditions are somewhat similar across the Alternatives.

3.3 Biological Environment

The diverse environmental conditions and habitats in the Gulf support many valuable biological resources, including fish, invertebrates, seabirds, mammals, sea turtles, and plants. The offshore and nearshore coastal habitats of the Gulf support thousands of year-round, seasonal, and nomadic species from endangered whales to corals. This section provides a brief overview and summary of the biological resources in the Gulf that have the potential to be impacted by the identification of AOAs and by the siting of future aquaculture operations within **Alternatives 2-6** (W-1, W-2, W-4, C3, and C-13) in the western and central Gulf off Texas and Louisiana, including anthropogenic stressors that may impact those resources.

3.3.1 Fish and Invertebrates

The geologic, oceanographic, and hydrographic features in the Gulf provide habitat for a diversity of fish and invertebrates. Marine species are found in every habitat in the Gulf from shallow lagoons and salt marshes (estuarine dependent) to coastal and open blue water environments. The habitats and main environmental factors (i.e., temperature, depth, salinity, and bottom type) that influence species distribution and abundance vary considerably throughout the Gulf.

The Gulf supports 1,541 fish species classified under 736 genera, 237 families, and 45 orders (Felder and Camp 2009). It also includes 51 species of sharks, and 49 species of skates and rays (Ward and Tunnell Jr. 2017). The communities of fishes in the Gulf differ over space and time given the variety of habitats, life-history, environmental conditions, and seasonal and annual movement patterns (Chen 2017). Species abundance and distribution varies by finfish group, which usually changes by life-stage over space and time. Finfish and elasmobranchs (sharks, skates, and rays) are often divided or grouped by preferred habitat type and other life-history characteristics. The main fish groups include demersal (e.g., reef fish [snapper and grouper]), coastal pelagic (e.g., king mackerel and cobia), and pelagic or highly migratory (e.g., tuna and swordfish). Many of the species grouped in these categories support valuable recreational and commercial fisheries.

Regulatory measures for federally managed species are outlined in Fishery Management Plans in accordance with the MSA, and implemented for various reasons, including to end overfishing, promote sustainable fishing practices, and rebuild overfished stocks. In the Gulf, 31 finfish species are managed under the Reef Fish FMP and three finfish species are managed under the Coastal Migratory Pelagic FMP. Federally managed Gulf species undergoing overfishing as of September 2024 include cobia (*Rachycentron canadum*) and lane snapper (*Lutjanus synagris*). Gag grouper (*Mycteroperca microlepis*) and greater amberjack (*Seriola dumerili*) are overfished and undergoing overfishing (NMFS, 2024).

The Gulf also supports a variety of corals that are found from shallow-water to deep-water environments; some are reef-builders and others are solitary. Coral reefs serve as important marine ecosystems supporting high biological productivity and species biodiversity. They provide critical ecosystem functions like storm and erosion protections; serve as habitat for commercial and recreationally important marine species of all life stages; and provide socioeconomic functions, like supporting tourism (BOEM, 2021). Corals are managed and protected under the Coral FMP. With the exception of corals found on aquacultured live rock, possession of managed corals in the Gulf is prohibited. A full description of the biological environment in which Gulf corals are found is provided in Section 4.3.1 of the Final Environmental Impact Statement for the FGBNMS Expansion (ONMS, 2020) and Amendment 9 to the Coral FMP. Due to light limitation, the majority of reefs in the Gulf are considered mesophotic (30 to 200 m deep) or deep-water (deeper than 200 m). While most of the mesophotic corals species are considered non-reef building, species like stony corals (*Agaricia* spp. and *Leptoceris cucullata*), white stony branching corals (*Madracis* spp. and *Oculina* spp.), branching hydrocoral (*Stylaster* spp.), and the clustering solitary cup coral (*Rhizopsammia* sp.) may make modest contributions towards building new reefs (OOTIG, 2019). Deep water corals can be found on very small percentages of the seafloor in the Gulf at depths greater than 200 m (650 ft) (Boland et al. 2017; Hourigan et al. 2007). These slow growing and long-lived animals can be more than 1,000 years old and act as a foundational habitat for fish and invertebrates living in deep benthic communities (OOTIG, 2019).

Past and present natural processes and anthropogenic activities can cause a wide range of effects on fish and invertebrates in the Gulf, with the severity of effects ranging from acute behavioral changes to the morbidity and mortality of those species. Industrial development, habitat loss, pollution and commercial and recreational fishing pressures are some of the leading threats to fish and invertebrate populations of the Gulf (Strongin 2020). Natural processes and those exacerbated by climate change, such as more heavy rainfall events, warming water temperatures, can directly affect fish and invertebrate species or cause secondary effects such as poor water quality (e.g., excess nutrients and low dissolved oxygen), harmful algae blooms or hypoxic conditions, for which the Gulf is known for (Rabalais and Turner 2002).

3.3.2 ESA-Listed Fish and Invertebrates

In the Gulf, fish, elasmobranches, and invertebrates species listed under the ESA include the Gulf sturgeon, smalltooth sawfish, giant manta ray (*Manta birostris*), Oceanic whitetip shark (*Carcharhinus longimanus*), Nassau grouper (*Epinephelus striatus*), Queen conch, elkhorn coral (*Acropora palmata*), staghorn coral (*Acropora cervicornis*), boulder star coral (*Orbicella franksi*), mountainous star coral (*Orbicella faveolata*), lobed star coral (*Orbicella annularis*), rough cactus coral (*Mycetophyllia ferox*) and pillar coral (*Dendrogyra cylindrus*). Of these ESA-listed species found in the western and central Gulf, only the giant manta ray has a distribution that overlaps with all of the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8 and C-3] and **Alternative 6** [C-13]).

Giant manta ray (*Manta birostris*)

The giant manta ray was listed as a threatened species under the ESA in 2018 (83 FR 2916, January 22, 2018). It is the largest living ray species, attaining a maximum size of 700 cm disc width with anecdotal reports up to 910 cm (Compagno 1999; Alava et al. 2002). The species is recognized by its large diamond-shaped body with elongated wing-like pectoral fins with two cephalic lobes to introduce water into the mouth for feeding activities. The giant manta ray has two distinct color types: chevron (mostly black back dorsal side and white ventral side) and black (almost completely black on both ventral and dorsal sides). The giant manta ray primarily feeds on planktonic organisms (e.g., euphausiids, copepods, mysids, decapod larvae and shrimp), but also feeds on small and medium-size fishes. The species is long-lived, late to mature (10-15 years), and has one pup every two to three years. These life-history characteristics contribute to the species' slow population recovery.

The giant manta ray is found around the world in tropical and temperate waters from the surface to 1,000 m (3,281 ft) depth (Last et al. 2016). In the northwestern Atlantic Ocean, they are found from New Jersey to Florida, throughout the Gulf, U.S. Virgin Islands, and Puerto Rico (Farmer et al. 2022a). They are generally found in upwelling areas along coastlines, oceanic islands, offshore pinnacles, and seamounts (Marshall et al. 2009). Manta rays have a diel movement pattern, migrating inshore during the day to clean and socialize in shallow waters, and migrate offshore at night to feed in deep waters (~1,000 m [3,281 ft]) (Hearn et al. 2014; Burgess 2017). Giant manta rays are more commonly found in productive nearshore waters with temperatures between 20 and 30°C (Farmer et al. 2022a). In the Gulf, the highest predicted occurrence is around the Mississippi River delta from April to June, and October through November. Currently, there are only three documented nursery areas for the giant manta ray, two are in South Atlantic off Florida, and the other is the Gulf in the FGBNMS (Stewart et al. 2018; Pate and Marshall 2020).

The global giant manta ray population size is difficult to assess, but relative abundance has been estimated using sightings data collected at popular diving sites. Giant mantas are known to migrate great distances, but recent research suggests there are subpopulations that have limited population exchange (Marshall et al. 2022). In most regions, giant manta ray population sizes appear to be small, less than 1,000 individuals. The most significant threat to giant manta rays is from targeted commercial fisheries and incidental bycatch. While most of the mortality is associated with commercial fisheries mortality, sub-lethal effects are associated with various environmental factors (e.g., harmful algal blooms and climate change) and anthropogenic activities, including recreational fishing, tourism, vessel strikes, oil and gas activities, military activities, oil spills, pollution, and marine debris. The extent to which the effects of these activities may impact the health and population fitness of the giant manta ray is not fully understood (Stewart et al. 2018).

3.3.3 ESA-Listed Sea Turtles

The Gulf provides habitat for five ESA-listed sea turtle species: green (*Chelonia mydas*) (North Atlantic distinct population segment (NA DPS)), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriace*a), loggerhead (*Caretta caretta*) (Northwest Atlantic DPS), and hawksbill (*Eretmochelys imbricata*). Sea turtles are long-lived, broadly distributed, display highly migratory behavior, and nest in various locations throughout the Gulf from Mexico to Florida. Sea turtles use Gulf beaches to nest, and the nearshore and offshore waters to forage or as part of their migration routes (Valverde and Holzwwart 2017). The Gulf is home to some of the most important sea turtle nesting beaches in the world, including Rancho Nuevo, Mexico and Padre Island National Seashore in Texas, which are major nesting areas for Kemp's ridley sea turtles. Sea turtles use the Gulf during all life stages (hatchlings, juveniles, and adults), which varies by life stage and species. Some sea turtle species favor shallow productive Gulf waters while others prefer pelagic Gulf waters. (Valverde and Holzwwart 2017).

Green Sea Turtles

Green sea turtles are predominantly found in nearshore tropical and subtropical waters. Green sea turtles have specific foraging grounds (seagrasses and algae) and make long migrations between forage sites and nesting beaches (Hays et al. 2001). They nest on sandy beaches of mainland shores, barrier islands, coral islands, and volcanic islands in more than 80 countries (Hirth 1997). In the western North Atlantic Ocean, green sea turtles are found from the nearshore and offshore waters of Texas to Massachusetts and throughout the Gulf including the Caribbean Sea. The green sea turtle was listed under the ESA in 1978, and 11 DPSs of the green sea turtles were listed on April 6, 2016 (81 FR 20057). The North Atlantic, South Atlantic, Southwest Indian, North Indian, East Indian-West Pacific, Southwest Pacific, Central North Pacific, and East Pacific DPSs were listed as threatened. Only the North Atlantic DPS is found in the Gulf. All of the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]) overlap with green sea turtle proposed critical habitat (sargassum).

Kemp's Ridley Sea Turtle

The Kemp's ridley sea turtle is the smallest sea turtle in the world, with a carapace length around 58-66 cm (2 ft). The upper shell, or carapace, is oval-shaped, olive-gray in color, and almost as wide as it is long. It is primarily found in shallow, nearshore waters that are less than 37 m (121 ft) deep, but can also be found in deeper offshore waters. Kemp's ridley sea turtles prefer nearshore waters because their main prey is swimming crabs, but also includes fish, jellyfish, and mollusks. In the Gulf, nesting beaches are found from Mustang Island, Texas, to Veracruz, Mexico. Most of the population nests are on the beaches of Rancho Nuevo, Mexico (Pritchard

1969), but there is a small nesting population in Texas, which continues to grow. While these observations are encouraging, the species' limited range and low population makes them particularly vulnerable to various sources of mortality, including bycatch with commercial fishing and pollution. Given these threats, the Kemp's ridley sea turtle was initially protected under the Endangered Species Conservation Act (ESCA) of 1969, a precursor to the ESA, and later under the ESA; the Kemp's ridley is considered the most endangered sea turtle (Zwinenberg 1977; TEWG 2000). Of the AOA Alternative, **Preferred Alternatives 3 and 5** (W-4, C-3) and **Alternative** (C-13) overlap with high use areas for Kemp's ridley sea turtles.

Leatherback Sea Turtle

In contrast, the leatherback is the largest sea turtle in the world with a carapace length around 1.5 or 1.8 m (5 or 6 ft). It is distinguished by its ridged leather-like shell and large flippers. Unique to the species, leatherback sea turtles have a tough rubber-like skin and lack scales and a hard shell. Leatherback turtles are found throughout the western North Atlantic, Gulf, and Caribbean Sea. They are found in coastal waters but prefer oceanic waters; leatherback sea turtles have the widest global distribution and make some of the longest migrations on earth. Leatherback sea turtles nest in Florida, but the largest nesting aggregations are in Trinidad, French Guiana, and Panama (NMFS and USFWS 2020). Leatherback sea turtles forage in coastal and pelagic waters from the Gulf to the Gulf of St Lawrence in Canada. In the Gulf, leatherbacks feed primarily on pink meanie jellyfish (*Drymonema larsoni*), which are more abundant in summer; Aleska et al. (2018) and Sasso et al. (2021) reported the northeastern Gulf is a foraging hotspot. Leatherback sea turtles are found year-round in the Gulf (Aleska et al. 2018), but are more common in summer and fall after the nesting season (Sasso et al. 2021). Leatherback sea turtles are found on the western Florida shelf during fall and migrate either to the Caribbean or through the Gulf in late-fall/early winter. Similar to other sea turtles, the leatherback sea turtle population is low and vulnerable. As such, the species was initially listed as endangered throughout its entire range on June 2, 1970, (35 FR 8491) under the ESCA of 1969, and later protected under the ESA. Of the AOA Alternatives, only **Preferred Alternative 5** (C-3) overlaps with leatherback sea turtle high use areas.

Loggerhead Sea Turtle

Loggerheads are a medium-size (76-91 cm [2.5-3 ft]) sea turtle with a teardrop shaped carapace and a large head, which is needed to support the powerful jaw muscles that are used to feed on hard-shelled prey (e.g., whelks and conch). All life-stages of loggerhead sea turtles are found throughout the Gulf, including neritic and oceanic juveniles and adults, and nesting females. Juveniles are omnivorous, feeding on crabs, mollusks, jellyfish, and vegetation at or near the surface (Dodd Jr. 1988). Subadult and adult loggerheads are primarily found in coastal waters and prefer benthic invertebrates on hard bottom habitat, such as mollusks and decapod crustaceans. The Northwest Atlantic DPS of loggerhead turtles nests primarily along the Atlantic coast of Florida, South Carolina, Georgia, and North Carolina and along the Florida and Alabama coasts in the Gulf. Given the declining population, the loggerhead sea turtle was listed as a threatened species under the ESA in 1978, and later NMFS and USFWS designated nine DPSs for loggerhead sea turtles: (1) Northwest Atlantic Ocean (threatened), (2) Northeast Atlantic Ocean (endangered), (3) South Atlantic Ocean (threatened), (4) Mediterranean Sea (endangered), (5) North Pacific Ocean (endangered), (6) South Pacific Ocean (endangered), (7) North Indian Ocean (endangered), (8) Southeast Indo-Pacific Ocean (endangered), and (9) Southwest Indian Ocean (threatened). The Northwest Atlantic (NWA) DPS is the only one that is found within the Gulf.

The main stressors to sea turtles in the Gulf include destruction of nesting habitat from natural and anthropogenic activities, such as storms, pollution, coastal development, and fisheries interactions. Other stressors include vessel strikes, gear entanglement, habitat exclusion, and artificial lighting. Sea turtle interactions with commercial fishing gear is a major problem in the Gulf. Sea turtles can drown in shrimp trawls and become injured in gillnets, pot/trap lines, and hooked in pelagic longlines. Sea turtles are particularly vulnerable to commercial fisheries for various reasons including, but not limited to, body type (large size, long pectoral flippers, and lack of a hard shell), attraction to gelatinous organisms and algae that collect on buoys and buoy lines, locomotion style, and/or attraction to pelagic longline light sticks. Stressors also include marine debris because it can resemble prey (i.e., jellyfish) and usually floats (Shoop and Kenney 1992; Lutcavage et al. 1997). Fibropapillomatosis (FP) is an infectious disease that can cause tumors on soft external tissues (e.g., flippers, neck, and tail), the carapace, eyes, mouth, and internal organs (gastrointestinal tract, heart, and lungs) of sea turtles, especially the green sea turtle (Aguirre et al. 2002). Although the direct cause is unknown, researchers believe it's a combination of stressors, including environmental and biological factors (Jones et al. 2016).

Oil spills are a major concern for sea turtles. Oil spill impacts include direct oiling, contact with dispersants, inhalation of volatile compounds, disruption of foraging or migratory movements given surface or subsurface oil, ingestion of prey species contaminated with oil and/or dispersants, and potential loss of foraging resources, which could compromise growth and/or reproductive potential. Kemp's ridleys experienced the greatest negative impact associated with the Deepwater Horizon (DWH) oil spill event of any sea turtle, primarily because all Kemp's ridley turtles in the Gulf belong to one population (NMFS et al. 2011). Global climate change is another stressor impacting sea turtles; rising water temperatures are changing prey distribution (NMFS and USFWS 2008). Also, rising air temperatures can alter the hatchling sex ratio, skew the sea turtle population, and exceed the thermal threshold of most nests, leading to egg mortality (Hawkes et al. 2007). Rising sea surface temperatures have also been correlated with an earlier onset of loggerhead nesting (Hawkes et al. 2007), short inter-nesting intervals (Hays et al. 2002), and shorter nesting seasons (Pike et al. 2006). Of the AOA Alternative, **Preferred Alternatives**

3 and 5 (W-4, C-3) and **Alternative** (C-13) overlap with high use areas for loggerhead sea turtles.

3.3.4 Marine Mammals

The nearshore and offshore Gulf waters support 22 common marine mammal species (whales, dolphins, and the West Indian manatee [*Trichechus manatus*]). Cetaceans (Mysticeti [i.e., baleen whales] and Odontoceti [i.e., toothed whales]) are a diverse marine group ranging from the ubiquitous, nearshore and offshore variant common bottlenose dolphin (*Tursiops truncatus*) to the sperm whale (*Physeter macrocephalus*), which is the largest toothed whale in the world (Wursig 2017). Rare and extralimital cetacean species include the North Atlantic right whale, blue whale, fin whale, sei whale, minke whale, humpback whale, and Sowerby's beaked whale. There are no pinnipeds (seals, sea lions, and walrus) in the Northern Gulf. Marine mammals in the Gulf are found in a variety of habitats from shallow tidal bays and estuaries to offshore waters. The West Indian manatee is primarily found in shallow water with seagrass, which is their primary diet. Most marine mammals in the Gulf are found near the continental shelf and deep oceanic waters and highly mobile, making long seasonal and annual movements throughout the Gulf (Wursig 2017). Commercial whaling in the Gulf occurred during the late-1700s through the late-1800s. The primary species harvested were sperm whale, short-finned pilot whale, and Risso's dolphin. Today, all marine mammals are protected from take (injury or harassment) under the MMPA and some are also protected under the ESA given they are classified as Threatened or Endangered. The two endangered whales in the Gulf are the sperm whale and Rice's whale (*Balaenoptera ricei*); Rice's whales are an endemic species and the only resident baleen whale in the Gulf; the Rice's whale is one of the most endangered whales in the world with an estimated population at around 51 individuals.

Common Bottlenose Dolphin

The common bottlenose dolphin is characterized by its light gray appearance and short, wide rostrum. They are the most common and studied cetacean found in the Gulf given their distribution in coastal waters. The common bottlenose dolphin is found in bays, estuaries, coastal regions, and offshore waters throughout the Gulf. Common bottlenose dolphins are not listed under the ESA, and this stock is not strategic under the MMPA. While there are multiple common bottlenose dolphin stocks in the Gulf, the Northern Gulf of Mexico Continental Shelf Stock is the only population that overlaps with the AOA alternatives. The current population estimate is 63,280 individuals (Hayes et al. 2022). This stock has significant overlap with the oceanic and coastal bottlenose dolphin stocks and aerial surveys delineated the continental shelf stock by using sightings from the 20-200 m (66- 656 ft) isobath to estimate population size (Garrison et al. 2021). Bottlenose dolphins are known as opportunistic predators, preying on a wide variety of fish, squid, and crustaceans. Their opportunistic feeding strategies can often cause interactions with humans and various activities (Chávez-Martínez et al. 2022; Grewal et al.

2023). Bottlenose dolphins are known to interact with fisheries, particularly the Gulf shrimp fishery, the reef fish (snapper-grouper) fishery, the recreational hook and line fishery, and the shark bottom longline fishery (NMFS 2022). Potential threats also include other human interactions, marine debris, heavy metal pollution, aquaculture, construction, noise, habitat loss, and oil spills and spill cleanup (Phillips and Rosel 2014). The Deepwater Horizon Oil Spill caused about a 3% decline in the population (DWH MMIQT 2015). Studies showed 13% of continental shelf dolphins, including Atlantic spotted dolphins and the continental shelf stock of common bottlenose dolphins, in the Gulf were exposed to oil, which caused 6% of females to suffer reproductive failure, and 5% suffered adverse health effects (DWH MMIQT 2015). None of the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]) overlap with high use areas for common bottlenose dolphins.

Atlantic Spotted Dolphin

Atlantic spotted dolphins are found in temperate and tropical waters of the Atlantic Ocean and throughout the Gulf. They are identified by their unique spotted pattern, which does not occur until they reach one year old. This sometimes causes confusion with common bottlenose dolphins. They are divided into three stocks, the Northern Gulf, Puerto Rico and U.S. Virgin Islands, and Western North Atlantic stocks. In the Gulf, Atlantic spotted dolphins are generally found inshore of the 200 m (656 ft) isobath along the continental shelf, and there is some evidence that there are two morphotypes, one which is distributed along the shelf from Texas to western Florida, and the other which is in the eastern Gulf off the Florida shelf (Viricel and Rosel 2014; Garrison and Aichinger Dias 2020). They are found throughout their range in all seasons and are often found in groups. Atlantic spotted dolphins prey on fish, invertebrates, squid, and octopus. While there is some indication that the North Atlantic population may be declining (89 FR 5495, 2024), the most recent estimate of the Northern Gulf of Mexico stock is approximately 21,506 dolphins, although the population status is unknown. The main threats to Atlantic spotted dolphins are bycatch in the shrimp trawl fishery, oil spills, red tide events, shark predation (Herzing 1997), entanglement, noise, human harassment, and climate change. The DWH Oil Spill was estimated to have caused a 3% decline in the population for this bottlenose dolphin stock (DWH MMIQT 2015). Studies found 13% of continental shelf dolphins, including Atlantic spotted dolphins and the continental shelf stock of common bottlenose dolphins, in the Gulf were exposed to oil, which caused 6% of the females to suffer reproductive failure, and 5% of continental shelf dolphins to suffer adverse health effects (DWH MMIQT 2015). Of the AOA Alternatives, **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3), overlap with high use areas for Atlantic spotted dolphins.

Rice's Whale

Rice's whales are the only year-round resident baleen whale in the Gulf (Rosel et al. 2021). They are medium-sized rorqual whales with a unique low frequency broadband vocalization. The

Rice's whale was listed in April 2019 as endangered under the ESA under its previously known name, the Gulf of Mexico Bryde's whale (84 FR 15446). The most recent abundance estimate (2017-2018) in the northeastern Gulf is approximately 51 individual Rice's whales (Hayes et al. 2022). Passive acoustic monitoring and shipboard surveys have been used to understand Rice's whale distribution throughout the Gulf. Most sightings and acoustic detections have been concentrated in the northeastern Gulf off the west coast of Florida, but they have also been seen and detected in the western Gulf offshore of Louisiana, Texas, and off Mexico (Soldevilla et al. 2024). In the proposed rule to designate critical habitat for the Rice's whale (88 FR 47453, 2023), the area proposed included the 100 m (328 ft) isobath to the 400 m (1,312 ft) isobath in the Gulf beginning at the U.S. EEZ off Texas east to the boundary between the South Atlantic Fishery Management Council and the GMFMC off of the Florida Keys (88 FR 47453, July 24, 2023). Although there is limited data, tagging studies suggest that Rice's whale forage for prey diurnally and recent biopsy sampling and trawls surveys indicate their primary prey are demersal fish, such as silver-rag driftfish (*Ariomma mondi*) (Kiszka et al. 2023).

Low genetic diversity, small population size, and a restricted range makes the loss of any whale particularly significant. Threats include energy exploration and development, oil spills, vessel strikes, ocean noise, ocean debris, aquaculture, and entanglement in fishing gear. Vessel strike is a major threat to Rice's whales since they spend a significant amount of their time at the surface at night when it is difficult to see them, making them particularly vulnerable (Soldevilla et al. 2017). Rice's whales were estimated to be the most impacted shelf and oceanic stock of marine mammal exposed to the 2010 Deepwater Horizon (DWH) oil spill (Deepwater Horizon Natural Resource Damage Assessment Trustees 2016); much of the information was acquired after 2010.

Stressors on marine mammals vary by species, but include fishery interactions, vessel strikes, ocean noise, marine debris, energy exploitation, and oil spills, and low genetic diversity and population size. Rice's whales are particularly vulnerable to stressors given their low population; the loss of only one animal can potentially cause a population collapse. Rice's whales are vulnerable to vessel strikes because they spend a significant amount of time on the surface at night. While dolphins can also be at risk from vessel strike, they are more susceptible to interactions with fisheries, particularly the shrimp, reef fish, shark bottom longline, and recreational hook and line fishery (NMFS 2022). The main stressors on marine mammals are fishery interactions and vessel strikes. Many marine mammals can be incidentally hooked and entangled in commercial fishing gear and suffer serious injury and mortality. The latest Stock Assessment Report indicates there are seven commercial fisheries that interact or may interact with 32 bay, sound, and estuary stocks of common bottlenose dolphins in the northern Gulf; bottlenose dolphins occasionally become entangled in the net, lazy line, turtle excluder device, or tickler chain in the commercial shrimp trawl fishery (Hayes et al. 2023). Besides interactions with commercial fishing gear and collision with vessels, marine mammals in the Gulf can be impacted by unusual mortality events, climate change, pollution, marine debris, prey availability, and water quality. It should be noted that marine mammals in the Gulf are mobile and can sometimes avoid various stressors; however, their prey is often vulnerable to stressors (Gulland et al. 2022); climate change is altering the abundance and distribution of various finfish species. None of the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]) overlap with proposed Rice's whale critical habitat.

3.3.5 Seabirds

The northern Gulf supports around 500 bird species that either reside, migrate, or winter in the region (Wilson et al. 2019). The environmental conditions and the mixture of habitats are ideal for resting, foraging, breeding, and wintering (Gallardo et al. 2009). The pelagic and coastal (beaches, mudflats, salt marshes, coastal wetlands, and embayments) habitats of the Gulf support year-round, seasonal, and nomadic species (e.g., purple sandpiper [*Pluvialis dominica*]) (Clapp et al. 1982; Sibley 2000); seasonal or migratory species are birds from northern latitudes that either pass through or overwinter in coastal Gulf habitats in large numbers during spring and fall (Russell 2005). Habitat diversity, the migratory pathway to Mexico, Central and South America, and the warm coastal waters are essential features for resident and non-resident birds in the Gulf (Gallardo 2004). Researchers indicate the Gulf is the most important migratory pathway in North America for neotropical migrant landbirds, waterfowl, songbirds, and shorebirds given the four North American flyways converge in the northern Gulf (Rappole 1995; Withers 2002; Gallardo et al. 2004). The Gulf is also the breeding grounds for a large percentage of the reddish egret (*Egretta rufescens*), snowy plover (*Charadrius nivosus*), and various tern species (e.g., sandwich tern [*Sterna sandvicensis*], Forster's tern [*Sterna forsteri*], and royal tern [*Sterna maximus*]) populations (Remsen et al. 2019).

Seabirds in the Gulf are classified under three orders: Charadriiformes (gulls and terns, and phalaropes), Pelicaniforms (frigatebirds and pelicans, tropicbirds, gannets and boobies); and Procellariiforms (storm-petrels and shearwaters). Common seabirds in the Gulf are herring gull, laughing gull, black tern, royal tern, magnificent frigatebird, brown pelican, northern gannet, band-rumped storm-petrel, brown booby, and Sargasso shearwater. Most seabirds in the Gulf are usually found along the continental shelf break and adjacent coastal and inshore habitats; however, some (e.g., boobies, petrels, and shearwaters) are found primarily in deeper offshore waters of the continental slope and Gulf basin (Michael et al. 2023). Seabirds are a highly mobile group that migrate great distances from their breeding colonies to forage, and some can circumnavigate the globe in the nonbreeding season, such as the albatrosses (Spear 2019). Most seabirds congregate and forage in flocks consisting of various species, which are often associated with predatory fish and marine mammals during foraging events (Burger 2017; Michael et al. 2023).

Seabirds, shorebirds, marsh birds, wading birds, waterfowl, land birds, and raptors are the primary taxonomic groups found in the Gulf for some portion of their life history (Wilson et al.

2019). In terms of seabirds and shorebirds, their abundance, distribution, and species composition varies somewhat among Gulf states even though many are ubiquitous throughout the region, such as the brown pelican (*Pelecanus occidentalis*). The spatial and temporal abundance varies among taxonomic groups and within individual species because most birds are highly mobile, displaying annual and seasonal migratory behavior. In the Gulf, some species (e.g., northern gannet [*Morus bassanus*] are more abundant in winter, while others (e.g., coastal breeding population of least tern [*Sternula antillarum*]) are more abundant in summer given the breeding period (Burger 2017). Still others are in the Gulf for a portion of the year but are not associated with a particular season (e.g., black terns [*Chlidonias niger*]; Michael et al. 2024) and others (e.g., gulls, terns, and brown pelicans) are found year-round in the Gulf (Michael et al. 2023). A similar pattern was reported in the northern Gulf for Pomarine jaeger (*Stercorarius pomarinus*) and Sargasso Shearwater (*Puffinus lherminieri*), which are more abundant in fall/winter and summer, respectively (Ribic et al. 1997; Michael et al. 2023). Coastal birds (shorebirds, wetland birds, and waterfowl) are usually found nearshore and seabirds are usually found offshore (i.e., off the Continental Shelf), but they may also occur in shallower coastal waters (Jodice et al. 2019).

All species of seabirds that use the Gulf are protected under the MBTA, with some classified as threatened, endangered, or candidate species under the ESA, as well as under state law and designations. With the 2004 amendment to the FWCA (Migratory Bird Treaty Reform Act of 2004), the USFWS was also directed to identify bird species, subspecies, and populations that without the aid of additional conservation measures, would likely become candidates for listing under ESA, known as Birds of Conservation Concern (BCC) (USFWS 2021). The goal of the BCC List is to geographically identify non-ESA-listed, nongame migratory birds that are in need of additional conservation protection and to encourage coordinated, collaborative and proactive conservation actions for those species among international, federal, state, tribal and private partners (USFWS 2021). A list of all the BCC for the northern Gulf can be found in Appendix B, Table E.2. Additionally, a list of the ESA-listed bird species found in the northern Gulf can be found in Appendix B, Table B.1. This list includes the black-capped petrel (*Pterodroma hasitata*) that is classified as Endangered with only an estimated 1,000 breeding pairs remaining; Jodice et al. (2021) reported spotting 40 individuals in the northern Gulf during seabird vessel surveys (2010-2011; 2017-2019).

Recently, Michael et al. (2023) reported northern gannet (*Morus bassanus*), black tern, and sooty tern were the most abundant seabirds and seabird assemblages (dominant or co-dominant) spotted in the northern Gulf. The research also found the black tern assemblage, and the northern gannet and laughing gull assemblage, were more abundant nearshore, while the sooty tern assemblage was more abundant offshore. The sooty tern assemblage was primarily spotted along the continental slope in the central and eastern portions of the Gulf, but there were more birds along the continental slope, in waters 200 to 2,000 m (656 to 6,562 ft) deep, off southwestern

Florida. The sooty tern assemblage was more abundant in sea-surface temperatures between 25˚C (77˚F) and 29˚C (84˚F) and decreased with increasing temperature. Michael et al. (2023) noted that most (~76%) of the species representing the four main seabird assemblages were 'non-resident' species that breed outside of the northern Gulf with 41% breeding outside of the Gulf and Caribbean altogether. This underscores how important this region is for both "resident" and seasonal migrant seabirds. Overall, the relative density of seabirds in the northern Gulf was greater over the continental shelf than over the continental slope and pelagic waters, which was probably related to better foraging opportunities given the eddies, upwelling, and downwelling along the shelf. This observation supports earlier work by Ribic et al. (1997) that showed many seabirds were associated with either warm or cold eddies and positively or adversely associated with other oceanographic conditions (i.e., sea surface temperature, depth, sea surface salinity, thermocline slope, and chlorophyll-*a*) in the northern Gulf (Poli et al. 2017).

Similar to other regions around the world, seabird populations in the Gulf are impacted by various natural and anthropogenic factors, biological stressors (e.g., competition, predation, and disease; Burger 2017; Jodice et al. 2019). Natural stressors include tropical storms and hurricanes, temperature fluctuations, tidal fluctuations, and susceptibility to disease. Extreme weather events can disrupt various seabird biological processes, such as reproductive success, migration, foraging, over-wintering, and timing of biological events. Various bird species are also susceptible to parasites and diseases. For example, Garvin et al. (2006) found that 21% of migrant passerines were infected with blood parasites and parasitic worms were common in the brown pelican. Increasing climate variability is also causing sea-level rise, resulting in further loss of habitat, as well as more frequent complete nest failure for some species of ground-nesting shorebirds and seabirds (Von Holle et al. 2019). In addition to climate change, other anthropogenic stressors that may affect seabirds in the northern Gulf include oil and gas related activities, commercial fishing, coastal development, microplastics, point and nonpoint sources of pollution, and toxins (e.g., Ndu et al. 2020; Jodice et al. 2022, 2023).

Seabirds are susceptible to oil and gas contaminants (i.e., oil spills and produced waters) because these contaminants can easily adhere to their feathers upon contact (O'Hara and Morandin 2010), which can have short-term and long-term impacts to flying, foraging, and mating behaviors (King et al. 2021). Oil pollution is a significant source of ill-effects, disease, and even death, particularly in the Gulf given the large size of the oil and gas industry (DHNRDAT 2016). Following the DWH spill, the Deepwater Horizon Natural Resource Damage Assessment Trustees conducted a series of studies to quantify the spill's injury to seabirds. They estimated that between 56,100 and 102,400 individuals, representing at least 93 bird species, were injured, died or lost reproductive function due to the oil spill. It's believed that this accounts for only a portion of the total bird injury from the spill, as this estimate did not include injury expected to have occurred to marsh birds and colonial waterbirds, and did not include nonlethal injuries, such as impaired health (DHNRDAT 2016). Ongoing coastal habitat loss (1.2% of intertidal wetlands in the Gulf), alteration, and fragmentation can also adversely influence and impact foraging, habitat availability, nesting habitat availability, and overall reproductive output for various seabirds, especially in the Gulf. Coastal development is also adversely influencing nesting colonies and nesting behaviors and may be leading to increasing predation pressure on seabirds.

Historically, one of the most impactful stressor for birds has been harmful pollutants, which caused a variety of acute and chronic impacts, including mortality. In the 1960s, DDT (dichlorodiphenyltrichloroethane) caused the brown pelican population to crash from 5,000 to less than 20 individuals in Texas (King et al. 1977). Marine debris, particularly in the form of plastic pollution, can also have acute and chronic impacts to seabirds, including mortality. Discarded nets and fishing lines pose an entanglement risk to seabirds. In nearshore areas, an entangled seabird returning to its colony presents a risk for additional birds to become entangled (Burger 2017). Past and ongoing stressors have not only adversely impacted seabird populations, but seabirds are also vulnerable to future stressors, such as offshore wind development. Given this threat, BOEM has recently funded research to assess the exposure and collision risk of federally protected birds from offshore wind energy development in the U.S. Atlantic (e.g., Adams et al. 2022). Wind development activities could be a future stressor to seabirds. In 2023, BOEM issued the first Wind Energy lease for an area (41,472 hectares [102,480 acres]) approximately 70.8 km (38.2 nm) off the coast of Louisiana. In 2024, BOEM issued a Request for Competitive Interest following an unsolicited lease request for two Wind Energy Areas off the coast of Texas. While any leases issued only grant lessees the ability to conduct site assessment and site characterization activities, it is reasonably foreseeable that these activities could take place on the Gulf OCS. All of these stressors may impact seabirds independently and synergistically and cumulatively (e.g., Goodale et al. 2019) to adversely affect seabirds in the Gulf. The addition of climate change variability increases the potential for adverse effects. Although many seabirds are found throughout the Gulf breed elsewhere (Michael et al. 2023), there is a potential for these effects to carry over to other regions and populations.

3.4 Socioeconomic Environment

Major marine industries (e.g., oil and gas production, commercial seafood and shipping) in the Gulf contribute trillions of dollars annually to the national economy (NOAA 2021a). This section generally discusses the industrial activity in the Gulf region[12] and more specifically the areas that could be impacted by aquaculture facilities sited in the AOA locations identified in **Alternatives** 2-6 (W-1, W-4, W-8, C-3, C-13). Differences among Alternatives are highlighted where supporting data are available; state specific information could be considered more relevant to Alternatives off respective coastlines.

[12] The Gulf Region includes Texas, Louisiana, Mississippi, Alabama and West Florida.

3.4.1 Commercial Fishing and Aquaculture Production

3.4.1.1 Gulf Region Wild-Caught and Aquaculture Production Overview

Historically, the Gulf has been one of the most important regions in the United States for commercial fishery landings. In general, the Gulf Region is the second most economically important region in terms of total commercial landings and value; Alaska is the most important region in the United States. Commercial landings in the Gulf (capture fisheries) ranged from 0.53 million mt in 1967 to 1.29 million mt (2.84 billion lbs.) in 1984 (Figure 3.4.1.1-1), and the ex-vessel (dockside) value ranged from $581.38 million to $1.62 billion (1960-2020) (Figure 3.4.1.1-2). The Gulf accounted for around 28.1% of all U.S. commercial landings by weight and 25.1% by value (1960-1999), and 16.1% of all U.S. commercial landings by weight and 17.4% by value during 2000 through 2020.

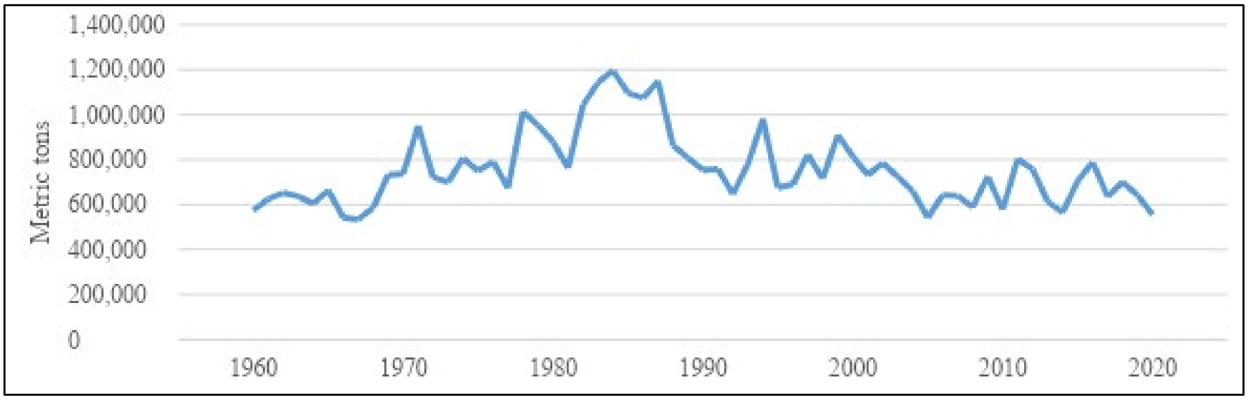

Figure 3.4.1.1-1. Gulf Region Commercial Landings by weight (metric tons) (1960 – 2020). Source: NMFS, NMFS Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, Accessed 1/31/2023.

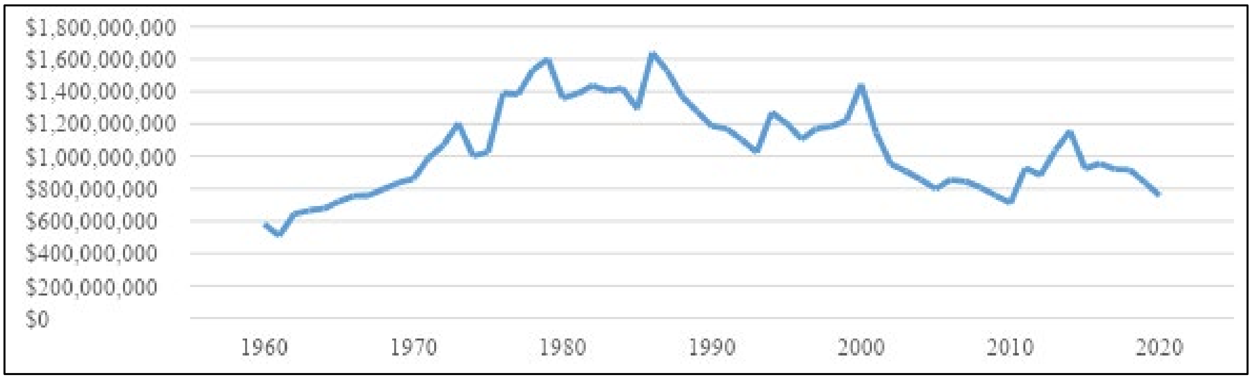

Figure 3.4.1.1-2. Gulf Region commercial landings by ex-vessel (dockside) value (2020 dollars) during 1960 – 2020. Source: NMFS, NMFS Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, Accessed 1/31/2023. BEA for GDP Implicit Price Deflator.

Commercial fisheries in the Gulf Region harvested around 1.34 billion pounds (607,798 mt) with an ex-vessel value of $842.19 million during 2018 though 2022 (Table 3.4.1.1-1), which accounted for about 15% of all U.S. capture fisheries by weight and value.

Table 3.4.1.1-1. Gulf Region commercial landings by weight (pounds and metric tons) and by ex-vessel (dockside) value (2020 dollars) (2018 – 2022).

Year	Pounds	Metric Tons	Dollars
2018	1,543,223,054	700,001	$917,712,302
2019	1,413,332,172	641,083	$840,018,403
2020	1,221,310,347	553,983	$755,360,080
2021	1,140,698,142	517,417	$882,691,871
2022	1,380,956,000	626,391	$912,444,000
Average	1,339,903,943	607,775	$861,645,331

Source: NMFS, NMFS Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, accessed 1/31/2023, BEA for GDP Implicit Price Deflator; NMFS 2024a.

Total commercial landings are dominated by Gulf menhaden, and shrimp are the most economically valuable species in the Gulf. Gulf menhaden accounted for 75% of all the commercial landings by weight and 11% by value (1970-2020), while shrimp accounted for 7% of total landings by weight and 29% by value (NMFS 2024a). Other key wild-caught species in the Gulf include blue crab, oysters, groupers, snappers, and tunas.

Aquaculture is a fast-growing food production sector, both around the world and in the United States. Based on Kumar et al. (2024), the total direct, indirect, and induced contribution of aquaculture to the U.S. economy in 2022 was $4 billion and supported around 22,000 jobs, which does not include the tax impacts. Aquaculture operators raise more than 1,500 different freshwater and marine species grouped into various categories (Kumar et al. 2024). Food fish operations generated the greatest contribution followed by mollusk operations. The primary food fish produced were catfish, salmon, tilapia, hybrid striped bass, and redfish. The main mollusks were oysters and clams; oysters ranked second and clams were the fourth most valuable species. Overall, freshwater aquaculture generated twice the amount of marine aquaculture (Kumar et al. 2024). In the Gulf region, aquaculture operators grow oysters, clams, shrimp, red drum, pompano, and macroalgae. In 2016, the Gulf states produced more shellfish by volume than any other region in the nation (NMFS 2024a)

Offshore aquaculture in the Gulf of Mexico has a relatively short list of commercially ready candidate species for offshore production (see Appendix D). Candidate species for offshore aquaculture have a variety of appealing characteristics that make them potentially suitable for commercial production, including known culture methods, suitable biological characters for mass production (e.g., fast growth, high yields, ability to culture at high densities) and existing or potential markets for the species (Ohs and Cresswell 2013). Depending upon the species produced and amount of production, aquaculture operations have the potential to affect wild-caught marine finfish market supply and demand dynamics. Taking those potential effects into consideration, aquaculture operations producing marine finish species that have limited commercial harvests due to those species being only being incidentally caught (e.g., almaco jack, cobia) or having restrictions on commercial harvest (e.g., red drum) could help to reduce increased aquaculture productions impacts of wild-caught species landing and pricing.

Gulf Region Imports and Exports of Seafood

Imports of seafood products into the Gulf Region[13] far exceeds seafood exports (Figure 3.4.1.1-3). On average, imports outweighed exports by about a $32 to $1 ratio during 2018 through 2022. Imports in the Gulf are primarily tilapia and pangasius catfish.

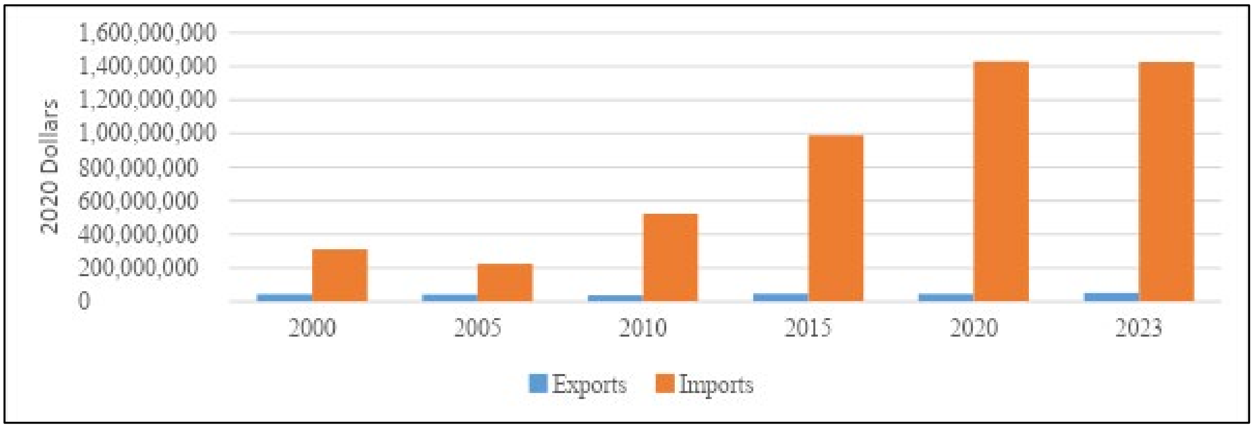

Figure 3.4.1.1-3. Imports and exports (2020 dollars) of seafood into and out of the Gulf Region in 2018. Source: NMFS, USA Trade in Fishery Products, BEA for GDP Implicit Price Deflator.

In 2010 and 2015, imports of fresh/frozen filets of tilapia and pangasius catfish ranked first and second by value; together they represented about 60% of seafood imports into the Gulf Region. In 2010, about 50 mt (110,231 lbs) of fresh/frozen pangasius catfish were imported into the Region (Upton 2015). Although catfish production (~214 mt [471,789 lbs.] in 2010) in the United States exceeded imports, the average price of imported pangasius catfish was about half the average price of domestic catfish. The lower price made imported pangasius catfish competitive in the domestic market for several countries, such as Vietnam.

Canned tuna currently and more often ranks first among imports into the Gulf Region. Information on tuna and other HMS imports, exports, and re-exports are summarized by product disposition in the most recent Highly Migratory Species Stock Assessment and Fishery

[13] Imports into Florida's west coast are included, but not imports into its east coast.

Evaluation Report[14]. Other popular imports are fresh/frozen mahi mahi, canned crabmeat, and salmon.

3.4.1.2 Texas Wild-Caught Fisheries and Aquaculture Production Overview

Wild-caught fisheries in Texas averaged 33,805 mt (74.5 million lbs.) with a value around $201.36 million (2020) during 2018 through 2022 (Table 3.4.1.2-1). The total landings represented 5.6% and 23.9% of the commercial landings by weight and value, respectively.

Table 3.4.1.2-1. Commercial landings in Texas by volume (pounds/metric tons) and ex-vessel (dockside) value ($1,000s in 2020 dollars) (2018 – 2022).

Year	Pounds	Metric Tons	Value ($1,000s)
2018	84,383,771	38,276	$218,301
2019	74,909,488	33,979	$212,064
2020	71,533,724	32,447	$195,628
2021	78,909,305	35,793	$229,261
2022	62,902,552	28,532	$151,562
Average	**74,527,768**	**33,805**	**$201,363**

Source: NMFS Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, Accessed 01/31/2024, BEA for GDP Implicit Price Deflator.

Shrimp (northern white and northern pink) ranked first in landings by weight and value from 2018 to 2022. The other top five species by both weight and value were red snapper, blue crab, eastern oyster, and bait shrimp.[15] The annual landings for the top five wild-caught species have been relatively consistent over the years, except eastern oyster landings which decreased dramatically from 2,667 mt (5.9 million lbs) in 2021 to 730 mt (1.6 million lbs) in 2022 (NMFS Office of Science and Technology, commercial landings query, available at: www.fisheries.noaa.gov/foss, accessed 01/31/2024).

Oysters are an important harvested species in Texas, with 90% of the public reef areas in Galveston Bay, Matagorda Bay, and San Antonio Bay used by commercial fishermen. Over the years, Texas oyster reefs have been severely impacted by storms, droughts, and overharvesting. According to the Texas Tribune (3 November 2023),[16] Hurricane Ike in 2008 buried 8,000 acres (3237 hectares) of public reefs in sediment, and in 2017, Hurricane Harvey dumped a record rainfall that inundated Galveston Bay with freshwater, which reduced the bay's salinity killing

[14] https://www.fisheries.noaa.gov/atlantic-highly-migratory-species/atlantic-highly-migratory-species-stock-assessment-and-fisheries-evaluation-reports

[15] Black drum is closely behind.

[16] See https://www.texastribune.org/2023/11/03/texas-oyster-fishing-season/.

many oyster beds. As such, the state has increasingly closed public harvest areas where it considers oysters too small or too scarce in an effort to protect them. In 2022, the state reopened only a small portion of the public reefs, which accounts for the lowest harvest numbers for that year.

To help supplement Texas' wild harvest of oysters, the state passed legislation to authorize off-bottom (water column) production of oysters in 2019. The first oyster farms in the state were authorized in Galveston Bay. Since then however, the industry has grown and operations have expanded into West Galveston Bay, Matagorda Bay, Aransas Bay, and Copano Bay. As of August 2024, the state has issued 11 Grow-Out Permits and 9 Conditional Grow-Out Permits. Work is also underway to authorize a 60 acre (24 hectares) grow-out area, composed of 2-4 acre (0.81-1.62 hectare) sites, that will be used by a co-op of growers in Keller Bay (Dr .Lindsay Glass Campbell, personal communication, August 28, 2024).

Texas aquaculture farms produce both freshwater and saltwater species of food fish; however, most of their production is freshwater species, especially catfish; Texas is one of the nation's top four producers of farmed catfish. The state's combined catfish farms produced 7.58 million food size catfish in 2018 and 7.36 million in 2023 (USDA NASS Agricultural Statistics Board). In 2018, Texas catfish farms reported sales of about $21.50 million (in 2020 dollars) (Table 3.4.1.2-2). Tilapia has also been a popular farmed species in the state; the number of tilapia farms with reported sales grew from nine in 2013 to 12 in 2018 (USDA Census of Aquaculture 2018).

Table 3.4.1.2-2. Number of aquaculture farms and species grown,reported in Texas, with reported sales and combined sales ($1,000s in 2020 dollars) (2013 and 2018).

Species	Number of Farms (2013)	Number of Farms (2018)	Sales ($1,000s) (2013)	Sales ($1,000s) (2018)
Hybrid Striped Bass	10	1	$28,551	D[1]
Carp	7	4	D	$16
Catfish	54	37	$23,932	$21,498
Red Drum	6	8	D	$19,994
Sturgeon	1	0	D	$0
Tilapia	9	12	$889	D
Trout	1	1	D	D
Total[2]	**72**	**52**	**$64,989**	**$53,550**

1. Undisclosed. 2. Some of these farms produce multiple species of food fish. Source: USDA Census of Aquaculture 2018, BEA for GDP Implicit Price Deflator.

Red drum is another popular species to raise in Texas. The number of red drum farms with reported sales increased from 2013 to 2018. In 2018, the eight red drum farms in Texas reported combined sales of about $19.99 million (2020 dollars), representing 99.8 % of all U.S. farmed red drum sales (USDA Census of Aquaculture 2018).[17] However, the severe freezing weather caused by Winter Storm Uri in February 2021, caused large mortalities and eventually led many producers in the four county area around Matagorda Bay to go out of business given severe or complete mortality of fish inventories in outdoor ponds.[18] According to the Texas Farm Bureau, 99% of the nation's farmed red drum supply was lost that month[19] . Estimates provided to the Texas Farm Bureau by the redfish farmers indicated a loss of redfish and fingerlings of about $50 million (2021 dollars). One farm lost about 700,000 fish with a market value of about $5.5 million (2021 dollars) (Rosenberg 2021).[20] Prior to the COVID pandemic and the freeze impacts in 2021, red drum producers in Texas were increasing production and receiving roughly $3.50 per pound of live weight fish. More recent reports indicate Texas's red drum farms are recovering. Texas operators also produce hybrid striped bass, carp and trout.

Besides food fish, Texas ranks second in the country by both number of crustacean farms with reported sales and third by reported sales of its crustacean farms. In 2018, there were 20 crustacean farms that reported combined sales of about $7.97 million; most produced crawfish and saltwater shrimp. In the 1990s, there were shrimp farms along the Texas Gulf coast, but many of them eventually shut down because of problems with poor quality larvae making them unprofitable. In 2013, there were nine saltwater shrimp farms that reported sales, but there were only four by 2018. Breeding facilities have improved and the price of shrimp has increased, which has regenerated interest in both pond[21] and RAS farming shrimp in the state (San Antonio Report May 19, 2023).[22]

Similar to Louisiana, Texas's crawfish farms have been adversely affected by drought.[23] The 2024 harvest is expected to be no more than a tenth of what it was the previous year. Although the number of aquaculture farms with reported sales in the state declined from 2013 to 2018 (Table 3.4.1.2-3), it is expected that the 2023 Census of Aquaculture will indicate a growth in that number.

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[17] Production of farmed red drum dwarfs commercial (wild-caught) landings of red drum.

[18] https://www.agmrc.org/commodities-products/aquaculture/aquaculture-fin-fish-species/red-drum-or-redfish

[19] https://texasfarmbureau.org/redfish-farmers-industry-suffer-losses-after-freeze/

[20] Because of a former definition in the USDA's Emergency Assistance for Livestock, Honey Bees and Farm-raised Fish (ELAP), redfish was not considered an eligible commodity for disaster assistance at the time. USDA classified redfish as a finfish, which excluded it from the program. At the time only game fish and bait fish were eligible commodities. However, in May 2021, USDA changed its definition of eligible commodities to include food fish, such a red drum.

[21] These are saltwater ponds.

[22] https://sanantonioreport.org/texas-shrimp-farming-inland-aquaculture-techniques/.

[23] And just like in Louisiana, crawfish are a secondary crop and grown in rice fields.

Table 3.4.1.2-3. Number of aquaculture operations/farms in Texas with reported sales and combined sales ($1000s in 2020 dollars) (2005, 2013, and 2018).

TX aquaculture farms in 2005	TX aquaculture farms in 2013	TX aquaculture farms in 2018	2005 Sales ($1,000s)	2013 Sales ($1,000s)	2018 Sales ($1,000s)
95	98	96	$45,710	$77,588	$64,501

Source: USDA Census of Aquaculture 2005, 2013 and 2018, BEA for GDP Implicit Price Deflator.

3.4.1.3 Louisiana Wild-Caught Fisheries and Aquaculture Production Overview

Louisiana's capture fisheries harvested about 869.47 million pounds (394,388 metric tons) of product with a value of about $345.6 million (2020 dollars) during 2018 through 2022 (Table 3.4.1.3-1). Total landings account for 64.9% of the Gulf Region's landings by weight and 41.0% value.

Table 3.4.1.3-1. Commercial landings in Louisiana by volume (pounds, metric tons) and ex-vessel (dockside) value (2020 dollars) (2018 – 2022).

Year	Pounds	Metric Tons	Value ($1,000s)
2018	1,031,984,731	468,105	$387,384
2019	904,686,471	410,363	$333,651
2020	751,548,326	340,900	$283,823
2021	746,778,049	338,736	$351,093
2022	912,343,648	413,836	$372,049
Average	**869,468,245**	**394,388**	**$345,600**

Source: NMFS Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, Accessed 01/31/2024, BEA GDP deflator.

In 2018, Gulf menhaden (*Brevoortia patronus*) landings accounted for 82.9% of the total commercial landings in the state by weight and about 24% by value.[24] The other top five commercial species or species groups by weight were shrimp (northern white and brown), blue crab, eastern oyster, and crawfish. Shrimp (northern white and brown) were the most valuable commercial species. The population of wild oysters has been adversely affected by fluctuating salinity, and caused oyster capture landings to decline during 2018 through 2020; the population slightly recovered in 2021 and 2022. Similar to Texas, Louisiana has begun transitioning from

[24] In 2018 and 2020, the average price of menhadens was about $0.11 per pound (2020$).

the oyster capture fishery to private aquaculture production by enacting legislation to support aquaculture as an alternative method.

In 2013, Louisiana ranked fourth, and in 2018 ranked third, in the nation for sales of aquaculture products; Louisiana ranked first in the number of aquaculture farms with reported sales. Most of Louisiana's aquaculture operations produce freshwater species, which is dominated by crawfish. The state's crawfish farms typically produce from 100 million to 120 million pounds of crawfish annually.[25] Louisiana accounted for about 92% of the nation's crawfish farms (not including the farms that only produce crawfish as bait) and about 97% of farmed crawfish sales (not including sales of crawfish as bait) during 2005 through 2017. Although the number of crawfish farms has declined since 2004, sales continue to be in the millions. In 2004, Louisiana farms sold about $37.7 million of crawfish and in 2017 sales were around $47.4 million (2020 dollars). However, the 2024 crawfish season is forecast to be one of the worst ever because of the persistent drought, which adversely affects crawfish productivity (National Fisherman January 23, 2024).

Louisiana is also one of the Nation's leading producers of oysters. Since 1952, Louisiana has been in the top three states for oyster harvest, and the top producer for 35 years (Petrolia 2023). In 2013 oyster sales were valued at $14.9 million (2020 dollars), and in 2018, the state's oyster farms sold $29.9 million of product.[26] In 2021, Louisiana once again led the nation with 5.9 million pounds of oysters harvested, accounting for one-quarter of all oysters harvested in the U.S (NMFSe 2023). The state's oyster production consists of wild harvest from public oyster reefs, "traditional oyster culture", which involves the transfer of naturally recruited oysters (typically on planted culch consisting of shell, limestone, concrete or another substrate that oyster spat can attach to) to a managed lease for grow-out and "alternative oyster culture", which uses the methods typically associated with oyster aquaculture (e.g., on-bottom racks and cages, and off-bottom floating gear, flip bags and longlines). Oyster farming in Louisiana uses both "traditional" and alternative culture, with alternative oyster culture playing only a relatively minor role in overall production of the state. As of October 2024, there are 10 active permits for alternative oyster culture, on 169 leased acres (LDWF 2024).

Louisiana aquaculture operators do not grow many food fish species. In 2012, there were only eight operations that reported sales of food fish, and in 2017, there were nine operations.[27] Of the nine in 2018, six sold market-size catfish and two sold tilapia. Louisiana ranked second in the country for the number of aquaculture farms with sales of miscellaneous aquaculture; in 2013 and 2018, and those sales were alligators and turtles.

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[25] See https://www.wlf.louisiana.gov/subhome/commercial-crawfish. It is also estimated that those sales generate more than $300 million to the state's economy annually.

[26] Census of Aquaculture 2018.

[27] These food fish are not all market-size.

The number of aquaculture farms declined during 2004 through 2012, but slightly increased thereafter according to the Census of Aquaculture (Table 3.4.1.3-2). A large number of those losses were catfish farms.

Table 3.4.1.3-2. Number of aquaculture operations/farms in Louisiana and combined sales ($1000s in 2020 dollars) (2005, 2013, and 2018).

LA aquaculture farms in 2005	LA aquaculture farms in 2013	LA aquaculture farms in 2018	2005 Sales ($1,000s)	2013 Sales ($1,000s)	2018 Sales ($1,000s)
873	500	522	$130,974	$100,795	$139,847

Source: USDA Census of Aquaculture 2005, 2013 and 2018, BEA for GDP Implicit Price Deflator.

3.4.2 Recreational Fishing

One of the most popular outdoor activities in the Gulf is recreational fishing; it generally represents a large portion of tourism revenue. Fishery managers classify recreational fishing as private and for-hire. The private mode includes anglers fishing from shore (all land-based structures) and private/rental boats, while the for-hire mode includes anglers fishing from charter boats and headboats (also called party boats). Charter boats generally carry fewer passengers and charge a set day fee, whereas headboats carry more passengers and payment is per person. Recreational catch and effort is monitored by NMFS through the Marine Recreational Information Program (MRIP), and is also monitored by individual state programs.

In 2020, the Gulf Coast accounted for 29% of total US marine recreational fishing trips and 30% of the total landings (Figure 3.4.2-1; NMFS 2022b). In 2022, the Gulf region accounted for the highest saltwater recreational fishing trip expenditures (including durable goods equipment) in the U.S., at $5.1 billion (Figure 3.4.2-2; NMFS 2024a).

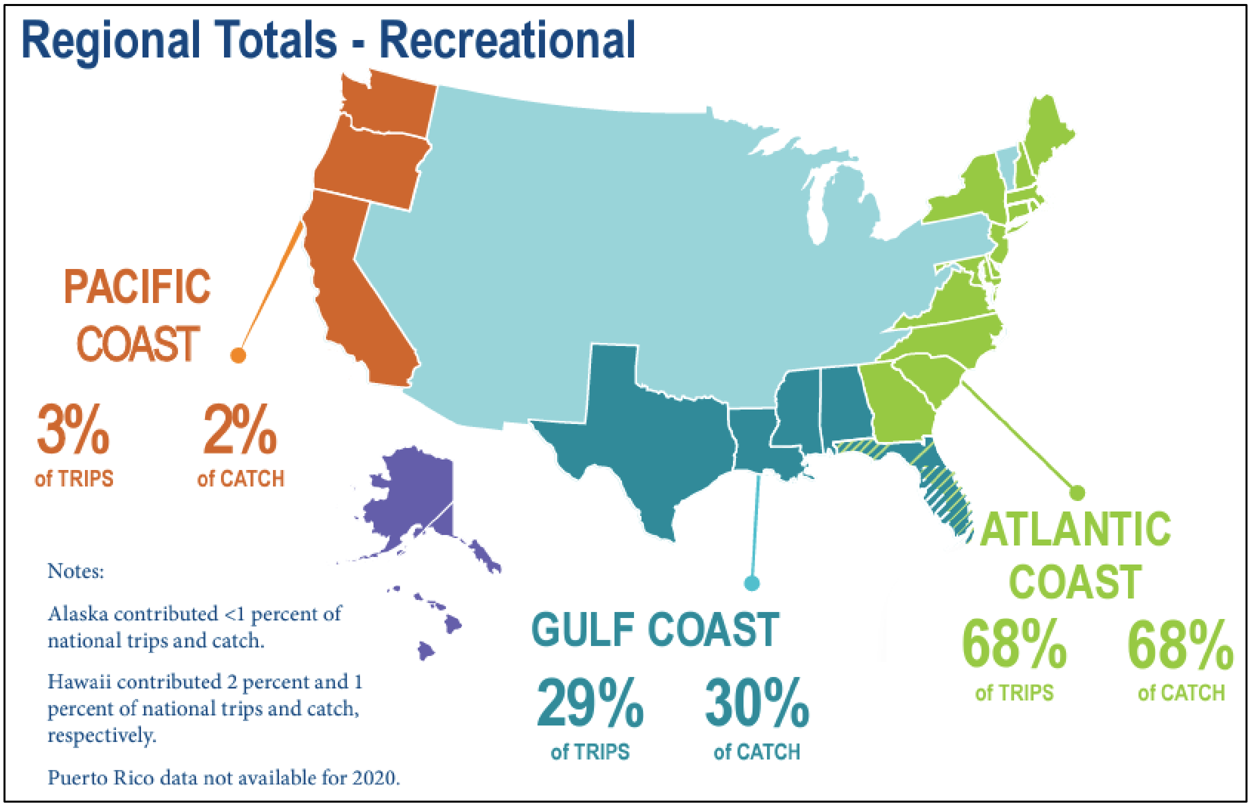

Figure 3.4.2-1. Recreational marine fishing by region in 2020. Source: NMFS 2022

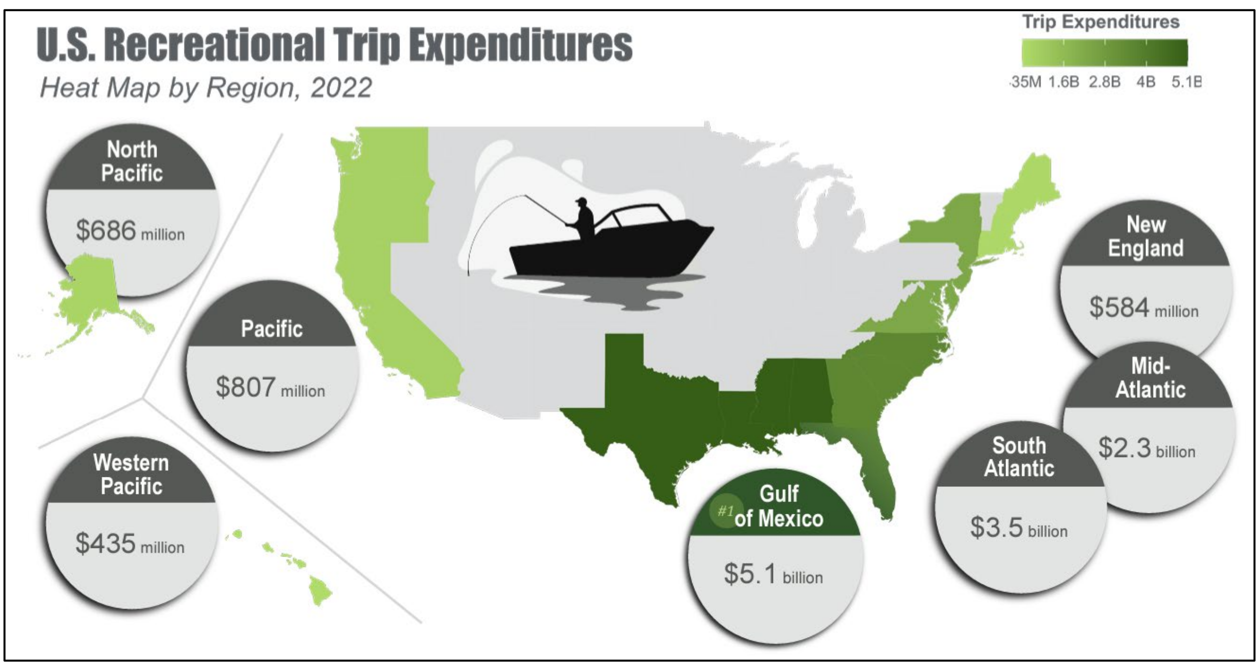

Figure 3.4.2-2. U.S. recreational fishing trip expenditures with regional totals (2022). A logarithmic scale was used to scale expenditures. Note: Eastern Florida is included in the South Atlantic and western Florida is included in the Gulf. Source: NMFS 2024a

The highest expenditures associated with recreational fishing are made by anglers from the Gulf Coast of Florida, followed by Louisiana, Texas, Alabama, and Mississippi (NMFS 2024a). Most recreational anglers are from Florida, with the rest from Louisiana, Texas, Alabama, and Mississippi. Florida accounts for 70% of the fishing trips, followed by Louisiana, Texas, Alabama, and Mississippi. The estimated economic impact of recreational saltwater fishing in Texas for 2006 is described in Table 3.4.2-1.

Table 3.4.2-1. Estimated economic impact of recreational fishing in Texas (2006). Source: adapted from Southwick Associates, Inc. 2007.

—	Retail Sales ($1,000s)	Total Multiplier Effect ($1,000s)	Jobs
All recreational saltwater fishing	$981,293	$1,793,002	18,542
Resident only	$925,499	$1,690,228	17,474
Non-resident only	$55,794	$102,774	1,068
Flounder fishing	$122,790	$225,553	3,313
Redfish fishing	$308,239	$562,883	5,648
Sea Trout fishing	$265,925	$487,309	4,836
Other finfish fishing	$213,751	$391,185	4,066

The estimated economic impact of recreational fishing and recreational boating in Louisiana in 2019 is described in greater detail in Table 3.4.2-2 (adapted from: Southwick Associates 2021). Of note, 'Total Multiplier Effect' represents the total cumulative effect in the economy created by successive rounds of retailer, manufacturer, and others' expenditures, these successive rounds of spending generate additional economic benefits with each round which become smaller and smaller until they can no longer be measured (Southwick Associates 2021).

Table 3.4.2-2. Estimated economic impact of recreational fishing and recreational boating in

All recreational saltwater fishing (freshwater and saltwater)	$2,061,007	$3,167,589	$1,583,349	23,968
Resident only	$1,532,233	$2,315,658	$1,146,075	16,460
Non-resident only	$528,774	$851,931	$437,275	7,508
All Saltwater Fishing	$668,281	$1,027,090	$513,401	7,772
Redfish fishing	$184,126	$282,985	$141,453	2,141
Sea Trout fishing	$116,724	$197,394	$89,672	1,357
All recreational boating	$1,152,338	$2,951,130	$885,273	19,048

Louisiana (2019). Source: adapted from Southwick Associates 2021.

The most common non-bait species landed in the gulf were spotted seatrout, red drum, gray snapper, white grunt, sand seatrout, sheepshead, red snapper, king mackerel, and Spanish mackerel. The top HMS species landed in the gulf were yellowfin and skipjack tunas (NMFS 2022). In 2021, there were also an estimated 28,469 sharks landed, with approximately two-thirds of those shark landings being blacktip sharks.[28]

3.4.3 Seafood Markets and Regional Food Systems

This section highlights some of the market and economic values related to the marine economy, seafood industry, and existing aquaculture industry. Marine resources are a critical part of our food system. Given the numerous possible business scenarios potential aquaculture operations sited in an AOA could employ, it is not possible to identify what markets could be affected by potential aquaculture operations sited in an AOA without specific information about the potential aquaculture industry, so this topic is considered at a regional level. For more alternative-specific information on fisheries and seafood-related infrastructure and businesses, like dealers and processors, see Sections 3.4.1, *Commercial Fishing and Aquaculture Production* and 3.4.4, *Ports and Working Waterfronts*.

[28] See pgs 120-126 of the 2022 Atlantic HMS SAFE Report the most recent year of available data, as of August 2024, https://www.fisheries.noaa.gov/s3/2023-06/SAFE-Report-062223.pdf

In 2022, the seafood industry produced 2.2 mt (4.8 billion pounds) of U.S. processed products and generated $13 billion in revenue (NMFS 2024a). According to the most recent NMFS Status of the Stocks report, the total U.S. seafood industry (wild harvest and aquaculture) generated $183.4 billion in sales impacts, $47.2 billion in income, $74 billion in value-added impacts, and supported 1.6 million full and part-time jobs (NMFS 2023b). It is estimated that U.S. aquaculture farms contributed $4 billion annually at the farm level, which does not include secondary economic impacts, such as processing, distribution, food service, and retail sectors. Thus, the total economic impact of U.S. aquaculture production is likely three to four times greater (Kumar et al. 2024).

Global and nationwide consumer trends show the demand for seafood, and specifically aquacultured-species of seafood, has been steadily increasing over the past few decades (Naylor 2020; Froelich 2021; Rubino 2022). In fact, the FAO estimates that about half of world seafood production comes from aquaculture. Farmed seafood products already make up half of the world's seafood supply, but U.S. production lags behind much of the world; the U.S. seafood trade deficit was around $20.3 billion in 2023. The U.S. ranks 18th in the world in aquaculture production and most (70-85%) of the seafood consumed in the U.S. comes from imports. While aquaculture only accounts for 7% of total domestic seafood production, 24% of the value of seafood products comes from aquaculture.

The growth in aquaculture production has occurred in parallel with global trade (Gephart and Pace 2015). Global trade of fisheries and aquaculture products is described on pp. 82 through 100 of FAO (2024). The U.S. imports more marine species than it exports (Naylor 2020), and was the largest individual importer of aquatic animal products in 2022 (FAO 2024). Aquaculture is helping meet the world's food needs, and recently surpassed wild capture fisheries for the first time in 2024 (FAO 2024). Climate change is a threat to the global food system and a major concern for food security, sustainability, and resilience (Froelich 2022), but researchers indicate aquaculture is essential for reducing and mitigating the effects of climate change (Rubino 2022).

The Gulf economy is summarized on pp. 160-164 of the NMFS Economics of the U.S. 2020 Report (NMFS 2023c) and on pg 18 of the Altas (Riley et al. 2021). Restaurant chains and seafood retailers along the Gulf coast have identified locally-produced fish as a market opportunity that cannot be fully exploited because of constraints in the availability of domestic fish. The natural productivity of domestic waters, seasonality in capture production, limited growth in domestic aquaculture production, and high demand for seafood has caused supply chains driven predominately by imports (Garlock 2020). Species cultured in the region include oysters, clams, shrimp, red drum, almaco jack, spotted seatrout, summer flounder, snook, pompano, black sea bass, and macroalgae. Shellfish aquaculture is a rapidly growing industry and will continue to increase with seafood demand and an increasing human population. The Gulf states are an important producer of farmed bivalves such as hard clams, oysters, bay scallops, and sunray venus clams. In 2019, the Gulf states produced more shellfish by volume than any other region in the nation (NMFS 2022b).

Baseline stressors for markets and regional food systems include variability in the predictability and stability in supply and consumer demands, disruptions to marketing values and practices, and interactions between aquaculture products with wild-caught seafood. Climatic and oceanographic events have also had significant impacts on the economic health of seafood markets.

The interactions of economic demand for seafood products with the conservation of marine resources is an important existing stressor to markets and food systems. Along with all marine resources, the expansion of the aquaculture industry is dependent on the maintenance of clean growing areas, a supportive regulatory environment, aggressive marketing and dependable sources. Market and non-market values can be important when analyzing cost and benefits. Market values may relate to seafood supply, employment, investments, and revenue in both the aquaculture and wild-harvest sectors. Non-market values may relate to public concern and regulations that limit the scale of both sectors (Foelich et al. 2017; Clavelle et al. 2019).

3.4.4 Ports and Working Waterfronts

Working waterfronts are historically and culturally important economic drivers in many coastal communities, especially along the Gulf. Recent NOAA data estimates that the U.S. ocean and Great Lakes economy directly supports over three million jobs and contributes over $350 billion to the national economy (NOAA, *The Economic Contribution of Working Waterfronts*). NOAA's *Economics: National Ocean Watch* (ENOW) dataset covers 47 classes of ocean- and great lakes-dependent economic activities within six sectors: living resources (including aquaculture, fishing, seafood processing and seafood marketing), marine construction, marine transportation, offshore mineral resources, ship and boat building, and tourism and recreation (NOAA, *The Economic Contribution of Working Waterfronts*).

The marine resources in the Gulf support one of the most economically productive regions in the United States. Historically, the Gulf region has various commercial fishing ports that are among the largest in the country. For instance, Empire-Venice, LA, and Intracoastal City, LA, were two of the top ten U.S. Ports in terms of landings (2019-2020); Pascagoula-Moss Point, MS also ranked among the top ports (NMFS 2022). Other top ports (by value) included Port Empire-Venice, LA; Bayou La Batre, AL; Galveston, Texas and Brownsville-Port Isabel, Texas (NMFS 2022).

3.4.5 Tourism

Tourism, recreation, and leisure industries are significant economic contributors in the Gulf region (Riley et al. 2021). Per the Louisiana Department of Culture, Recreation and Tourism, Louisiana hosted 42.6 million domestic and international visitors in 2022, generating $17.1 billion in visitor spending (Louisiana Department of Culture, Recreation and Tourism 2024). Tourism and recreation industries are also major economic drivers in Texas. In 2023, total direct travel spending in Texas (purchases by travelers during their trip, including lodging taxes and other applicable local and state taxes paid by the traveler) was $94.8 billion, and direct employment of 719,600 individuals (Dean Runyan Associates 2024). Natural resource-based activities are substantial components of recreation, leisure, and tourism industries in the Gulf.

Preferred Alternatives 2-4 *(W-1, W-4, W-8) - Off the Coast of Texas*

The Texas Economic Development and Tourism Office highlights various activities and attractions along the Texas Gulf Coast, including recreational boating and fishing, wildlife viewing (e.g., birding, dolphin watching), beaches, seaside towns, historic landmarks and cultural experiences (Texas Economic Development and Tourism Office 2024). In 2006, the total economic effect of fish and wildlife-related recreation in Texas was estimated at $15.8 billion, supporting 139,404 jobs; economic contributions from recreational fishing, hunting, and wildlife watching were estimated at $6.02 billion, $4.63 billion, and $5.12 billion, respectively (Southwick Associates, Inc., 2007).

Preferred Alternative 2 (W-1) is approximately 87 km (47 nm) northeast of Port Isabel and South Padre Island, Texas (Riley et al. 2021). The Texas Travel Research Dashboard (Dean Runyan Associates 2024) reported an estimated $529 million in direct travel spending and around 5,400 supporting jobs in South Padre Island, and another $10 million in direct travel spending and 100 supporting jobs in Port Isabel, Texas in 2023. The Texas Economic Development and Tourism Office lists recreational fishing, wildlife viewing, beaches, and Padre Island National Seashore as some of the notable activities and destinations in the area (Texas Economic Development and Tourism Office 2024). In their 2024 community vulnerability analysis, Michaelis noted communities near **Preferred Alternative 2** (W-1) had generally low scores for fishing reliance and engagement with a few exceptions; Port Mansfield's score for recreational fishing reliance was high and recreational engagement was moderate, and South Padre Island had relatively high scores for both recreational fishing engagement and reliance. Effects from potential disruptions to recreational fishing activity (e.g., given the development of a new industry) could be most impactful to these highly reliant communities; conversely, these communities could benefit from a new working waterfront associated with aquaculture.

Preferred Alternative 3 (W-4) is approximately 91 km (49 nm) from Port Aransas and 78 km (42 nm) from Matagorda Bay, Texas (Riley et al. 2021). The Texas Economic Development and

Tourism Office (2024) highlights Port Aransas as a family-friendly beach town with a variety of recreational fishing opportunities. Competitive and recreational fishing are noted as a highlight for Matagorda Bay, hosting year-round offshore fishing tournaments, with red snapper, wahoo, grouper, and blue marlin noted recreational species of interest (Texas Economic Development and Tourism Office 2024). The Texas Travel Research Dashboard (Dean Runyan Associates 2024) reports an estimated $313.9 million in direct travel and tourism spending and 3,500 jobs supporting travel in Port Aransas in 2023; nearby Texas communities Fulton and Seadrift were reported to have $20.7 million and $4.7 million in direct travel spending in 2023, respectively. In their 2024 community vulnerability analysis, Michaelis noted that some proximal communities to **Preferred Alternative 3** (W-4), Matagorda Bay, Port O'Connor, and Port Aransas, had high scores for recreational fishing reliance, and scores for both Port O'Connor and Port Aransas indicated high recreational fishing engagement. Michaelis (2024) notes that the apparent high reliance on recreational fishing in these communities could warrant further consideration if future aquaculture development were to occur in or near **Preferred Alternative 3** (W-4).

Preferred Alternative 4 (W-8) is located approximately 107 km (58 nm) from Freeport, Texas, an area with nearby beaches and wildlife refuges. The Texas Travel Research Dashboard (Dean Runyan Associates 2024) reports for 2023, an estimated $117.5 million in direct travel spending and 1.6K supporting jobs in the nearby community of Surfside Beach, and $41.9 million in direct travel spending and 570 jobs supported in the nearby community of Clute. In their 2024 community vulnerability analysis, Michaelis noted that Clute had high scores for recreational fishing engagement and moderate scores for reliance; while Surfside Beach and nearby Quintana both had moderate scores for recreational fishing engagement and high recreational fishing reliance, suggesting these communities may be more vulnerable to disruptions to recreational fisheries.

***Preferred Alternative 5** (C-3) and **Alternative 6** (C-13) - Off the Coast of Louisiana*

Per the Louisiana Department of Culture, Recreation and Tourism (2024), the leisure and hospitality industry is the fourth highest employer in the state. The Louisiana Department of Culture, Recreation and Tourism (2024) highlights various recreation activities and attractions along the Louisiana Gulf Coast, including boating, fishing, wildlife viewing and birding, camping, hunting, lakes and beaches, and historic landmarks and cultural experiences. In 2022, direct tourism spending in the state was reported at $13.6 billion, with the recreation category accounting for over $1 billion (Hossain 2022). In 2019, natural-resource based activities (e.g., recreational boating and fishing, hunting, wildlife viewing, etc.) contributed an estimated $9.4 billion to Louisiana's economy and supported over 92,000 jobs; economic contributions from recreational fishing, recreational boating, hunting, and wildlife watching were estimated at approximately $3.16 billion, $2.95 billion, $1.77 billion, and $1.29 billion respectively (Southwick Associates 2021).

Alternative Preferred 5 (C-3) is approximately 133 km (72 nm) south of Pecan Island, LA (Riley et al. 2021). The Louisiana Department of Culture, Recreation and Tourism highlights historic and cultural events and landmarks, agritourism opportunities, hunting, camping, as well as opportunities for birding and other wildlife viewing at various refuges and state and local parks in the communities proximal to **Preferred Alternative 5** (C-3). Direct tourism spending in Louisiana Parishes proximal to **Preferred Alternative 5** (C-3) were reported at $2.86 million (with approximately 30 tourism industry-supporting jobs) in Assumption Parish, $43.26 million (480 supporting jobs) in Iberia Parish, $45.02 million (500 supporting jobs) in St. Mary Parish, and $26 million (290 jobs) in Vermillion Parish (Hossain 2023). In their 2024 community vulnerability analysis, Michaelis reported that communities near **Preferred Alternative 5** (C-3) had relatively low scores for recreational fishing reliance and engagement.

Alternative 6 (C-13) is located south of the Mississippi River and outside of the East Bay area in southern Louisiana (Riley et al. 2021). With the exception of Grand Isle, a barrier island located in southern Jefferson Parish, Louisiana communities in proximity (within 100 km [54 nm]) to **Alternative 6** (C-13) are generally situated along the Mississippi River in southern Plaquemines Parish. In 2022, direct tourism spending in Plaquemines Parish was reported at $49.33 million with approximately 550 industry-supporting jobs (Hossain 2023). The Plaquemines Parish Tourism Commission highlights recreational opportunities including visiting parks and wildlife refuges, birding and wildlife viewing, hunting, coastal and wetland tours, and fishing. Recreational fishing opportunities include inshore and offshore fishing, including deep-sea excursions and fishing offshore structures (e.g., oil rigs). The Plaquemines Parish Tourism Commission (2024) notes inshore recreational species of interest as redfish, speckled trout, flounder, sheepshead, and black drum; offshore species of interest include yellowfin tuna, wahoo, marlin, swordfish, amberjack, cobia, grouper, snapper, tarpon, and triple tail. In their 2024 community vulnerability analysis, Michaelis reported that six of the eight communities analyzed had relatively low scores for recreational fishing; however, both Grand Isle and Venice had high scores for recreational fishing engagement and reliance, which indicates that disruptions to recreational fishing could affect these communities.

3.4.6 Offshore Industrial Activities and Infrastructure

3.4.6.1 Oil and Gas Development

The Gulf region contributes trillions of dollars to the nation's economy and provides millions of jobs through oil and gas exploration and drilling (Riley et al. 2021).The OCS is a significant source of oil and gas for the Nation's energy supply. In FY 2020, offshore federal production reached about 641 million barrels of oil and 882 billion cubic feet of gas, almost all from the Gulf (BOEM 2021). Based on the latest assessment, most of the undiscovered technically and economically recoverable oil is available at water depth between 1,600 and 2,400 m (5249 to 7874 ft) in the Central Gulf planning area followed by the western and eastern planning areas;

gas is available at a water depth between 800 and 1,600 m (BOEM 2021). The offshore oil and gas production in the Gulf dates back to 1938, but it wasn't until the 1950s and 60s that the industry grew rapidly with the advancement of equipment and drilling techniques.

Today, the Gulf is the nation's primary offshore source of oil and gas generating approximately 97% of all Outer Continental Shelf production. To provide a conservative distance estimate for potential aquaculture sites, the spatial planning analyses conducted for the Aquaculture Atlas in the Gulf used a 500 m (1640 ft) setback from existing oil and gas infrastructure (Riley et al. 2021). Riley et al. (2021) found there were no oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes) within 3 km of **Preferred Alternative 2** (W-1), but there were some oil and gas infrastructures located near **Preferred Alternative 3** (W-4) (active lease block [3 pipeline and 2 platform] ~ 3 km), **Preferred Alternative 4** (W-8) (1 pipeline ~ 750 m), **Preferred Alternative 5** (C-3) (3 pipelines [700m, 1.5 km, 2.0 km]; 13 boreholes [3 km]; and 1 platform [2.5 km]), and **Alternative 6** (C-13) (2 pipelines [3 km]; 4 boreholes [3 km], and 1 platform [3 km]).

3.4.6.2 Offshore Wind Energy Development

The development of alternative energy is a relatively new industry in the U.S. In the Gulf, BOEM initially promoted the industry when it published a Request for Interest (RFI) in the *Federal Register* on June 11, 2021, to assess interest in potential offshore wind development in the OCS. The RFI focused on the Western and Central Planning Areas offshore of Louisiana, Texas, Mississippi, and Alabama. On October 31, 2022, BOEM finalized the first final Wind Energy Area (WEA) located approximately 44 km (24 nm) off the coast of Galveston, Texas, and a second final WEA located approximately 104 km (56 nm) off the coast of Lake Charles, LA. On August 29, 2023, BOEM held the first-ever offshore wind energy auction for the Gulf region and RWE Offshore US Gulf, LLC ended up winning the Lake Charles Lease Area. On October 27, 2023, BOEM decided to offer four more WEAs in the Gulf. The first WEA (Option J) is located approximately 76 km (41 nm) off the coast of Texas and the second area (Option K) is located approximately 99 km (62 nm) off the coast of Texas. The third WEA (Option L) is located approximately 52.9 miles off the coast of Texas and the fourth WEA (Option N) is located approximately 82 miles off the coast of Louisiana. BOEM was planning to hold a second offshore wind energy auction for the following areas: WEA I-1 Lease OCS-G37962, WEA I-2 Lease OCS-G37963, WEA J-1 Lease OCS-G37964, and WEA K-1 Lease OCS-G37965, but BOEM canceled this sale given a lack of competitive interest. BOEM received an unsolicited lease request from Hecate Energy Gulf Wind LLC and issued a Request for Competitive Interest in the *Federal Register* (89 FR 60913) on July 26, 2024. BOEM chose these lease areas as the most viable options using suitability modeling, proximity to shore, and stakeholder feedback. None of the AOA Alternatives are in close proximity to these areas. BOEM ultimately decided not to hold the second lease auction (Gulf Wind II) given a lack of competitive interest from qualified, eligible bidders.

In August of 2024, BOEM received an Unsolicited Lease Request from Hecate Energy LLC., to develop OSW in WEAs C and D. Hecate Energy is proposing to install up to 133 fixed-bottom wind turbine generators (WTGs). Each with a capacity of 15-23 MW, with an overall maximum capacity of approximately 3,000 MW. Each turbine deployed on fixed monopile or jacket foundation types. Hecate narrowed its selections to three points of interconnection within Texas and Louisiana and continues to examine 12 potential landfall locations with paths to three designated substations. Export cables may run separately from each of the two lease areas, or the lease areas may be joined offshore with one substation and one central export cable. BOEM is currently considering Hecate's Unsolicited Lease Request and is expected to make a decision regarding the next steps of the process in the coming months.

3.4.6.3 Other Offshore Activities and Infrastructure

Marine Minerals

The OCSLA (43 U.S.C. § 1331 *et seq*.) provides the Secretary of the Interior the authority to manage non-energy minerals on the OCS. The Department of the Interior's (DOI's) jurisdiction over exploration, leasing, and recovery of non-energy marine minerals, or hard minerals, extends to the subsoil and seabed of all submerged lands seaward of state boundaries to the OCS (except where modified by international law or convention or affected by the Presidential Proclamation of March 10, 1983, regarding the Exclusive Economic Zone [EEZ]). Under this authority, BOEM developed the Marine Minerals Program (MMP) to address erosion on coastal beaches, dunes, barrier islands, and wetlands. The MMP identifies large sediment resource areas and then partners with the USACE, states, and local authorities to designate sand borrow areas.

The Agency also responds to commercial requests for valuable OCS minerals, such as gold, manganese, or other hard minerals. Pursuant to Executive Order 13817, the MMP and the U.S. Geological Survey are collaborating to determine which 35 critical minerals are located on the OCS. Outside of U.S. jurisdiction, international companies funded by international countries are proposing to mine nodules in the central Pacific Ocean over the next five to seven years under the governance of the International Seabed Authority. The Deep Seabed Hard Mineral Resources Act (30 U.S.C. Chapter 26 – Deep Seabed Hard Mineral Resources) established an interim domestic licensing and permitting framework for deep seabed hard mineral exploration and mining in international waters pending adoption of an acceptable international regime. The U.S. has two active exploration licenses (USA-1 and USA-4) for international waters in the Pacific Ocean, both are held by Lockheed Martin for five-year terms. Currently, there are no ongoing or proposed mineral mining activities in the Gulf, including within or adjacent to the proposed AOA Alternatives.

Submarine utilities (cables and pipelines)

Submarine cables have been used to transport telecommunications data over great distances for over 150 years. Cables transport information and power (electrical) under the seabed often connecting countries around the world. Despite the importance of satellites, undersea cables are still essential for the internet, global financial markets, and military applications, especially fiber optic cables. Undersea cables are scattered off every coastal state along the east and west coasts of the United States, including the Gulf. Fiber optic cables provide high speed data transmission connecting coastal Gulf States to each other and connecting the U.S. to strategic points in Mexico, such as Mexico City, Cancun, and Queretaro; submarine power cables provide shore-based power to several offshore oil platforms in the Gulf. Undersea cables are buried under the seabed at different depths depending on the location and permitting requirements, but they are usually buried at least one meter below the seabed. Despite the burial depth, some undersea cables are also protected by a layer of rocks because they can become exposed by local oceanographic conditions and offshore activities, such as commercial fishing operations. The laying and placement of submarine cables require coordination, and the installation, maintenance, repair, and removal of cables in certain areas may have an adverse impact on the marine environment and other valuable resources. To help ensure the coordination of cable placement and minimize potential adverse impacts, several federal (NOAA, USACE, BOEM, BSEE, FERC, and FCC) and state agencies (within state waters) have legal authority to regulate the laying and maintenance of cables under various laws, such as the OCSLA.

None of the AOA Alternatives overlap with existing oil and gas infrastructure, and in addition to including this infrastructure to the constraints model of the spatial suitability model used in the Atlas, a 500 m (1,640 ft) buffer was also incorporated to avoid interactions between infrastructure and the anchors that associated with future aquaculture operations that could extend outward within an AOA or farm footprint.

Based on Riley et al. (2021), there is infrastructure on the seafloor within and adjacent to some AOA Alternatives; **Preferred Alternative 4** ((W-8); 1 pipeline [750 m], **Preferred Alternative 5** (C-3); 3 pipelines [3 km], **Alternative 6** (C-13); 2 pipelines [3 km]). Similar to oil platforms, setback was established for potential future aquaculture operations (Riley et al. 2021).

3.4.7 Public Health and Safety

3.4.7.1 Military Readiness and Operations

The military services conduct military readiness activities and operations (e.g., training, research, development, testing, and evaluation activities) throughout the Gulf. Military readiness activities may occur within existing range complexes and testing ranges or on the high seas; however, most military readiness activities occur in designated range complexes and testing ranges (U.S. Navy 2018). An offshore range complex consists of geographic areas that encompass a water component (above and below the surface) and airspace where training and testing of military platforms, tactics, munitions, explosives, and electronic warfare systems occur. Range complexes include established sea and undersea Operating Areas and Special Use Airspace (SUA), which may be further divided to provide better control of the area where particular activities can occur for safety and constraint reasons. SUA can include restricted airspace, military operations areas (MOAs), and warning areas. The terms used to describe different types of controlled airspace and waterspace are defined in Section 2.1 and Section 3.12.2.1 of U.S. Navy 2018, incorporated by reference.

DOD staff in the region and headquarters offices, USCG, NASA and DOD Siting Clearinghouse provided guidance on compatibility of offshore aquaculture operations in the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8 and C-3] and **Alternative 6** [C-13]) with military readiness activities. A description of how national security was incorporated into Atlas development process is described in Riley et al. (2021), and is incorporated by reference:

- Methods section Table 2.9 on p. 64 and Table 2.11 on p. 76;
- Results section pp. 79 through 84;
- Results section Figure 3.11 on p. 102;
- Results section p. 116; and
- Appendix D, p. D-1.

Military operations, training, and testing occur throughout the Gulf region. Nearby training and testing areas include the Key West Range Complex, the Naval Surface Warfare Center Panama City Division Testing Range, the Eglin Gulf Test and Training Range, and Gulf Range Complex, see Figure 2.1-4 in U.S. Navy 2018 and Figure 1-1 in USAF 2018 (incorporated by reference). Most of the AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8 and C-3]) overlap with a controlled airspace, which is generally Warning Areas; warn non-participating aircraft of potential danger. However, none of the AOA Alternatives overlap with controlled waterspace; restricted areas, danger zones, or unexploded ordnance areas because these areas were avoided through the MSP process. Additionally, no military vessel transits occurred in any of the AOA Alternatives areas during the timeframe assessed in the Atlas (Riley et al. 2021).

Military readiness activities varies over time to reflect dynamic requirements, and future project applicants that may potentially overlap with a training and testing area would undergo DOD Siting Clearinghouse Review to ensure current information was applied to permitting decisions and any future environmental review. Future projects may be subject to certain stipulations and final design review intended to reduce potential impacts to military activities (e.g., aquaculture facilities may have height restrictions, lighting requirements and technology restrictions).

The DOD also operates military installations that support specific activities (MMS 2000) These installations not only contribute to ensuring the security of the nation, but also provide significant economic benefits to state and local economies. In Louisiana, other than state government, the first, fourth, and fifth largest employers respectively are Fort Johnson, Barksdale Air Force Base, and the Naval Air Station (NAS) Joint Reserve Base (JRB)-New Orleans (DOD 2024a). In 2020, NAS JRB New Orleans employed more than 1,800 military personnel and civilians and directly contributed more than $171 million in spending to the economy (LED 2021). In Texas, NAS Kingsville and NAS Corpus Christi train nearly half of the U.S. Navy's Strike Pilots (DOD 2024b). In 2023, NAS Kingsville employed approximately 1,800 service members and civilians that contributed more than $1 billion to the Texas economy, while NAS Corpus Christi employed more than 7,100 service members and civilians, who contributed more than $4.6 billion to the state's economy (TCO 2024).

The activities conducted within these designated military use areas vary in mission and duration (MMS 2000). Extensive planning and coordination are necessary to establish and maintain these areas for military use, especially in the highly dynamic environment of the Gulf. The availability of sea and air space, year-round ideal oceanographic and climatic conditions, and proximity to important military infrastructure make the Gulf irreplaceable national assets for military training and operations (DOD 2018). The military installations throughout the region support specific missions that use these spaces for various activities. Development activities that are incompatible with military activities have the potential to delay or disrupt those military operations.

3.4.7.2 Navigational Hazards

According to data from the USACE (2024) on waterborne tonnage at principle U.S. ports, in 2022, Gulf ports accounted for 1,282 million tons (1,163 million mt), or 54%, of the total 2,363 million tons (2,144 million mt) of all cargo (domestic and foreign) handled from waterborne trade in the U.S. The Port of Houston and the Port of South Louisiana led all U.S. Ports for waterborne tonnage, ranked number one and two with 293.8 million tons (265 million mt) and 226.2 million tons (205 million mt) respectively (USACE 2024). The routes and shipping fairways these vessels take to port are vital to our nation's supply chains and any impact or obstruction to shipping activities pose a potential economic impact in addition to the safety of the crew, mariners and others working at-sea.

Vessel traffic in the Gulf takes many forms, and can range from sailing, pleasure craft, recreational and commercial fishing vessels, shipping, oil and natural gas transport, exploration and support vessels, and military vessels. The number of recreational vessels in the Southeastern U.S. and Gulf has been expanding in recent years (Fuentes et al. 2021). While safe navigation around stationary aquaculture structures in offshore can occur, especially when structures use PATONs and are marked on navigational charts, areas of high vessel traffic, such as shipping fairways, deepwater ports and anchorage areas are less compatible with aquaculture activities, posing risks to both vessel traffic and the operation from accidental collisions.

Military, commercial, institutional, and recreational activities take place simultaneously in the Gulf and have coexisted safely for decades. These activities coexist safely because established rules and practices lead to safe use of the waterways. There are existing navigation and vessel regulations and permitting processes in place that are designed to ensure that hazards to navigation and impacts on vessel traffic patterns are minimized to the extent feasible, like requirements for aquaculture gear to be appropriately marked by PATONs (see Section 3.1.1.2.2.), use of Local Notices to Mariners before installation/construction activities, and inclusion of aquaculture operations on nautical charts. Operators of recreational and commercial vessels have a duty to abide by maritime regulations administered by the U.S. Coast Guard. There are a variety of vessel routing measures in the Gulf to ensure safety of navigation that shape existing traffic patterns, including traffic separation schemes, fairways, and corridors. Cargo vessels tend to follow typical routes offshore while passenger and recreational vessel transits are more dispersed. Vessel use of the predetermined routes in the Gulf is high and variable (Riley et al. 2021).

Automatic Identification System (AIS) data were used during the MSP to characterize vessel traffic. AIS transponders are not required on every vessel and requirements for vessels to equip AIS transponders vary over time with changing regulations, but AIS transponders are carried on most self-propelled vessels of 1,600 or more gross tons (3.58 million pounds), vessels of 19.8 m (65 ft) or more in length and engaged in commercial service; towing vessels of 7.9 m (26 ft) or more in length and with more than 600 horsepower; vessels certified to carry more than 150 passengers; vessels supporting dredging operations; and vessels transporting certain dangerous, flammable, or combustible cargo (33 C.F.R. § 164.46). Fishing industry vessels of various lengths and tonnage are also required to carry AIS transponders to support commercial fishing and fish processing (Riley et al. 2021). Smaller vessels that are not required to use AIS (< 65 ft), but it is reasonable to assume vessel traffic would primarily operate in those same areas.

The MSP process for the Atlas and AOA alternatives considered available vessel traffic data, both spatially and temporarily and across numerous sections (e.g. military, shipping, commercial fishing) (Riley et al. 2021). Navigational constraints that were considered to be unsuitable for aquaculture were evaluated, and avoided, and setbacks were applied to aids to navigation, environmental sensors and buoys, and shipping fairways to avoid interactions with either objects themselves or vessel movements in and around the designated areas. The method used to incorporate the industry, transportation and navigation into the Atlas is described in Riley et al. (2021), incorporated by reference:

- Methods section Table 2.7 on p. 60 and Table 2.11 on p. 76;
- Results section p. 91-108

Ocean Research and Monitoring

Various federal, state, and educational organizations regularly conduct scientific research, including aerial-and ship-based scientific surveys, within the geographic analysis area. Marine surveys are conducted from federal and state vessels, chartered fishing vessels, planes, and autonomous vehicles using a variety of techniques and gears. These oceanographic surveys include long-term and seasonal scientific surveys conducted by academic institutions, state and federal agencies. Historically, many research projects have been conducted within and around the FGBNMS. Based on these oceanographic surveys, the AOA Alternatives do not overlap with any known ongoing state, federal, and academic oceanographic research.

3.4.7.4 Seafood Safety

Seafood comprises nearly 20% of animal protein consumed around the world, providing vital nutrition across developing countries and growing middle-class communities (Gephart et al. 2015). Using recommendations from doctors and nutritionists, the USDA and FDA 2020-2025 dietary guidelines encourage Americans to eat more seafood, and include seafood as one of the core elements of a healthy dietary pattern to maintain good health (FDA 2020). Aquaculture's contribution to global seafood production continues to rise to meet demands. The policy drivers of aquaculture described in Section 2 on pp. 2 and 3 of Rubino (2022), incorporated by reference, include public health topics like access to nutrients, access to protein, and climate resilient food systems. Public health concerns that can arise from aquaculture production include the increase in use of formulated food, use of antibiotics, use of antifungals, and use of agrochemicals. These aquaculture practices can potentially lead to elevated levels of antibiotic residuals, antibiotic-resistant bacteria, persistent organic pollutants, metals, parasites, and viruses in aquacultured species. People working in and around aquaculture facilities, populations living near these operations, and consumers may be at potential risk of exposure to these contaminants (Sapkota, et al. 2008). Public health topics related to nutrition and food security are likely to affect seafood consumption, and the drive for aquaculture, in the U.S. (Rubino (ed.) 2008).

The U.S. has a rigorous process for ensuring seafood products are safe for human consumption. There are seafood safety and sanitation programs, as well as therapeutic and drug approval systems established to protect public health and animal health (Section 3.1.1.2.2) The FDA is the regulating body for ensuring food for human consumption is safe and the USDA-APHIS veterinary services oversee the prevention, detection, control, and eradication of animal diseases in aquaculture. A primary food safety hazard of concern in aquaculture products is animal drug residues, and the use of animal drugs in aquaculture is strictly regulated. The FDA Center for Veterinary Medicine regulates the manufacture and distribution of food additives and drugs that may be given to aquatic animals. All FDA approved antibiotics for use in animals require a veterinary feed directive if administered in feed or a veterinary prescription if administered by other routes (80 FR 31708, 2015; Rhodes 2023).

Cultured fish and shellfish are held to the same FDA food safety standards and regulatory requirements as wild-caught seafood, to ensure safe foods are offered to consumers and to protect public health (FDA 2023). Fish and fishery products that enter interstate commerce must meet the requirements of the Seafood Hazard Analysis Critical Control Point (HACCP) regulations or the NSSP for shellfish, see Section 3.1.1.2.4 for more details. The Alabama, Louisiana, Mississippi, and Texas state-level agencies for public health are responsible for implementing their state's shellfish sanitation programs in compliance with the NSSP and for enforcing seafood processing regulations. The FDA has a variety of tools to ensure compliance with seafood safety requirements, including inspections of processing facilities, and examination or sampling of products.

Seafood safety topics surrounding seaweed aquaculture in the U.S. are still developing at state and Federal levels (Janasee 2022). Federally, seaweed is recognized as a raw agricultural commodity, with no Federal oversight during growth or harvest (NSGLC 2023). Typically after harvest, cleaning and fallowing or cleaning and disinfection (e.g., sun-drying) is used to break pathogen transmission between crop cycles (Rhodes et al. 2023a). Once processed, the Food Safety and Modernization Act's Preventive Controls for Human Foods (PCHF), which includes current Good Manufacturing Practices, and the FDA's HACCP regulations are used to regulate seaweed food safety. The PCHF and Seafood HACCP regulations focus on preventive food safety programs that are designed to identify significant hazards and implement controls to prevent those hazards from occurring.

Water quality issues can also interact with public health concerns, e.g., most species that cause HABs are associated with producing poisoning syndromes and HABs can prompt shellfish closures to protect human health. Areas where water quality issues may have posed a concern for public health, like dumping/ocean disposal sites, oil spills, or wastewater treatment plant outfalls, were avoided in the MSP process. See Section 3.4 for more information on the existing water quality conditions in the Gulf and Section 4.2.3 for information on how aquaculture operations may impact water quality. Climate change-induced effects on temperature and ocean chemistry are expected to affect aquatic animal pathogen distribution, abundance, and ability to cause disease, see Rhodes 2023 and Section 4.7 for climate change consideration.

3.4.7.5 Antibiotic Use

In the U.S., there is a robust therapeutic and drug approval system to protect public health and animal health, which is managed by various offices within the FDA Center for Veterinary Medicine (Rhodes et al. 2023b). The FDA's Office of New Animal Drug Evaluation's major responsibility is reviewing information submitted by drug sponsors seeking approval to manufacture and market animal drugs; new animal drugs cannot be legally marketed unless they have been reviewed and approved, conditionally approved, or index-listed (see below) by the

FDA (FDA Office of New Animal Drug Evaluation 2024). To approve and sustain a new animal drug for commercial use, four critical pillars must be met: 1) an animal drug must be safe for the animal, safe for humans consuming food derived from treated animals, and safe for the user or person administering the drug; 2) an animal drug must be effective for its intended uses, which are those prescribed, recommended or suggested in the labeling of the product; 3) an animal drug must be a quality manufactured product, resulting from a validated manufacturing process in accordance with federal regulations; 4) the product must be properly labeled to inform the user how to use the product, safety considerations, residue withdrawal procedures, and storage and handling procedures (FDA Office of New Animal Drug Evaluation 2024). Additionally, the FDA considers the impact of the drug on the environment during the review process (FDA Office of New Animal Drug Evaluation 2024). Once these regulatory standards are met, an animal drug can be approved for marketing; once out on the market, the animal drug is monitored to ensure that these standards are sustained (FDA Office of New Animal Drug Evaluation 2024). Research by the FDA Office of Applied Science assists in ensuring that fish derived from aquaculture production environments are safe for human consumption, and the FDA Office of Surveillance and Compliance is responsible for compliance-related actions, post-approval monitoring, and animal feed safety and medicated feed mill licensing (Rhodes et al. 2023).

During the investigational stages of animal drug development, the Office of New Animal Drug Evaluation may authorize investigational new animal drug exemptions to allow for the use of the drug to generate data to support a final approval (Rhodes et al. 2023). As the market for drugs for aquatic organisms is much smaller than for terrestrial agriculture, the U.S. Fish and Wildlife Service supports the Aquatic Animal Drug Approval Partnership to develop and coordinate safety and effectiveness studies for FDA approval, and oversees the Investigational New animal Drug (INAD) Program (Rhodes et al. 2023). The INAD Program allows for the legal use of specific investigational drugs by participants who are required to collect and submit data to the program (Rhodes et al. 2023). Rhodes et al. (2023) note that while there have been successful efforts to gain approval of drugs for use in aquaculture, these have been primarily focused on freshwater aquaculture species. NOAA has initiated a marine aquaculture medicine cooperative, the Aquatic Animal Drug Approval Partnership, to collaborate with external stakeholders and generate the information necessary to achieve FDA approval of the veterinary drugs needed in marine aquaculture (Rhodes et al. 2023).

The FDA Office of Minor Use and Minor Species Animal Drug Development administers the Index of Legally Marketed Unapproved New Animal Drugs for Minor Species, which makes animal drugs legally available to treat minor species (e.g., ornamental fish) that are not used for food for humans or animals (FDA Office of Minor Use and Minor Species Animal Drug Development 2024).

Concerns related to the use of antibiotics in aquaculture generally include the development of antibiotic-resistant bacteria and elevated levels of antibiotic residues, which is a primary food safety hazard. As described above, the use of animal drugs and antibiotics is strictly regulated and robust processes are established for ensuring the safety of aquaculture products for human consumption. As required, cultured fish and shellfish are held to the same FDA food safety standards and regulatory requirements as wild-caught seafood (FDA 2023). Only medicinal products approved by the FDA may be administered to aquatic animals, and withdrawal periods and testing are enforced to ensure there are no drug residues for animal drugs not approved in the United States and no drug residues for approved drugs exceeding the FDA established tolerance (FDA 2023).

Another concern regarding antibiotic use in aquaculture production is the development of antibiotic resistant bacteria, as antibiotics in unconsumed feed or excreted feces can be accumulated by microorganisms in the surrounding environment (Rhodes et al. 2023). Resistance occurs when exposure to an antibiotic causes selective pressure causing microorganisms to become resistant to antibiotics (Holmes et al. 2016; Rhodes et al. 2023). Studies have documented antimicrobial resistance in benthic bacteria, such as associated with Chilean salmon farms (Buschmann et al. 2012; Shah et al. 2014). While studies have documented antibiotic resistance in fish pathogenic bacteria from the administration of antibiotics at aquaculture operations, these studies should not be interpreted to indicate that similar antibiotic resistance will occur under different environmental conditions and husbandry practices. The occurrence of antibiotic resistant bacteria in association with aquaculture depends on various factors, such as the diversity, frequency, and dosage of antibiotic administration; it depends on environmental conditions of culture, including temperature, dilution of the antibiotics, and the containment of fish and associated bacteria. Accumulation of antibiotics in marine sediments is also a function of the dilution factor (which determines the amount of antibiotic reaching the sediment), biotransformation of the compound in the sediment, oxidation state of the sediment, and water solubility of the antibiotic. The route of administration for antibiotics depends on the rearing system and approved use (Rhodes et al. 2023); various antibiotics and antibiotic administration methods used in aquaculture production in other countries are not approved measures in the United States.

Aquaculture operators and fisheries managers are concerned about the risk of pathogen amplification on operations, transmission of pathogens from cultured to wild fish, and the introduction of nonnative pathogens and parasites when live fish are transported. Aquaculture facilities may use various mitigation measures, such as vaccines, probiotics, limiting culture density, high-quality diets, and antibiotics (where approved), which are effective at preventing and controlling bacterial disease. Actually, antibiotics are a last resort method and managers are using other approaches. In addition to good husbandry practices (e.g., low fish culture density) prudent aquaculture siting (e.g., selecting a location with ample currents and flushing, and environmental conditions conducive to the cultivation of the species) can minimize the need for therapeutant use. When therapeutants are used in aquaculture production, the administration of drugs is performed under the control of a licensed veterinarian. Additionally, U.S. aquaculture operators must adhere to the conditions of all applicable permits, such as NPDES permits for effluent discharge that require all drugs and other chemicals be applied in accordance with label directions, including the use of any medicinal products (e.g., therapeutics, antibiotics, and other treatments).

Potential environmental consequences associated with the use of antibiotics will be specifically evaluated under the permit and agency consultation process. The potential effects related to the use of antibiotics will be assessed on project-specific details for prospective aquaculture operations in the Gulf. NMFS note there are no antibiotics currently approved for use in the open ocean environment for warm water marine species, so the approval of new aquaculture drugs or drug applications would require review and approval by the FDA and require administration under the directions of an accredited veterinarian .

3.4.7.6 Seafood Nutrition

The global human population is around 8.2 billion, and growing at a pace that is exceeding the carrying capacity in various regions and impacting primary food sources (Hopenberg and Pimentel 2001; U.N. 2024). Historically, the human population has been limited and controlled by the availability of natural resources, especially food resources (Pimentel and Pimentel 1996). Today, crop and livestock production continues to increase, but malnutrition, hunger, and human health is still a problem, and it’s a developing concern (Hopenberg and Pimentel 2001). The human population, food availability, and the number of calories per person per day are interconnected. Currently, the main food supply source is agriculture; agriculture supports around 90% of the world’s population (FAO 2003). However, aquatic foods provide 20% of animal protein (Gephart et al. 2017), and the demand for freshwater and marine foods is rising around the world, mainly since seafood contains bioavailable micronutrients, essential fatty acids, and minerals that are not usually found in land-based foods (Kelling et al. 2023). Researchers expect the global demand for fish will double by 2050. The need for seafood is rising as healthy diets become more popular given seafood can lower the risk to various health conditions.

Human health sciences have recognized seafood for its health benefits and ability to optimize human well-being and nutrition (Bang and Dyerberg 1980; Kromhout et al. 1985; Mozaffarian and Rimm 2006; Costello et al. 2020); consuming seafood is linked to improving brain, eye, and heart health (Liu and Ralston 2021). In particular, seafood is an excellent source of high quality proteins and long chain omega-3 fatty acids that can help cardiovascular health, improved cellular function, and overall brain and nervous system functions (Kromhout et al. 1985; Connor 2000; Eliseo et al. 2002; Kris-Etherton et al. 2002; Seierstad et al. 2005). In terms of percent, seafood is high in protein and unsaturated fats, and low in calories, saturated fats, and cholesterol; it's rich in potassium, zinc, iron, and selenium. Some researchers are investigating whether there are any relationships between omega-3 fatty acids and various disorders, such as Alzheimer's disease, arthritis, depression, and asthma (Nelson et al. 2019). The FAO (2010) states pregnant women should consider seafood in their diet to help with brain and neural system development. The current USDA and FDA dietary guidelines (2020-2025) recommends Americans of all ages should eat seafood-at least twice a week, especially pregnant women and young children (Mozaffarian and Rimm 2006; Institute of Medicine 2006; American Heart Association 2016; FDA 2023). NOAA (2020) reports the average American only consumes 16.1 pounds, which is 9.9 pounds below the recommended amount of seafood per capita per year. Based on the average 2,000 calorie daily diet, the guidelines recommend 8 oz per week. Overall, Americans consume less seafood, fruits, vegetables, and more refined grains, meats, poultry, and eggs than the recommended amounts. Also, Americans consume less seafood than most people from developed countries (Liu and Ralston 2021).

3.4.8 Environmental Justice Considerations

Environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, gender, sexual orientation, national origin, tribal affiliation, religion, disability, or income during the development, implementation, and enforcement of environmental laws, regulations, and policies (NMFS 2023f). EJ topics are considered in Federal actions and under NEPA, so people are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change. It is also to protect people from the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and ensure people have equitable access to a healthy, sustainable, and resilient environment to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices.

A series of E.O.s establish federal policy on equity and environmental justice: Executive Order E.O. 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (E.O. 12898) (1994, amended 1995), E.O. 14008, "Tackling the Climate Crisis at Home and Abroad" (E.O. 14008) (2021), and E.O. 13985, "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government" (E.O. 13985, 2021), and E.O. 14096, "Revitalizing our Nation's Commitment to Environmental Justice for All" (E.O. 14096, 2023).

Additional policy mandates for equity and environmental justice are summarized on pages 7-9 of NMFS Equity and Environmental Justice Strategy (NMFS 2023f) and incorporated here by reference. That national strategy, together with NMFS Southeast Equity and Environmental

Justice Implementation Plan[29], aims to advance equity and environmental justice throughout the Southeast by providing a comprehensive framework for current and planned work to address key barriers impeding equitable access to services and opportunities related to our mission-related work.

3.5 Cultural and Historical Environment

3.5.1 Cultural, Historic, and Archaeological Resources

Archaeological resources are defined as any material remains of human life or activities that are at least 50 years of age and can provide a scientific or humanistic understanding of past human behavior, cultural adaptation, and related topics using scientific or scholarly techniques, such as controlled observation, contextual measurement, controlled collection, analysis, interpretation, and explanation. Archaeological resources include any physical evidence of human habitation, occupation, use, or activity, including the site, location, or context (30 C.F.R. § 550.105). In addition, the NHPA of 1966, as amended (54 U.S.C. § 300101) considers "historic properties" as archaeological resources. The regulations define historic properties as any prehistoric or historic district, site, building, structure, or object included on, or eligible for inclusion on, the National Register of Historic Places, which includes artifacts, records, and material remains relating to the district, site, building, structure, or object (54 U.S.C. § 300308). The National Register of Historic Places requires that a historic property typically must be at least 50 years old, retain the integrity of location, design, setting, materials, workmanship, feeling, and association. To qualify, at least one of four significance criteria must be met: (1) be associated with events that have made a significant contribution to the broad patterns of our history; or (2) be associated with the lives of persons significant in our past; or (3) embody the distinctive characteristics of a type, period, or method of construction, or represent the work of a master, or that possess high artistic values, or represent a significant and distinguishable entity whose components may lack individual distinction; or (4) have yielded, or may be likely to yield, information important in prehistory or history (36 C.F.R. § 60.4).

CEI (1977) indicates the sea level was 121 m (397 ft) lower than today and the coastline extended as much as 100 km (62 mi) further into the Gulf in some locations around 18,000 years ago; estimated habitation sites on the Gulf shelf is between 55,000 and 3,500 BP or years before the present, but the time is debatable among scholars. Prehistoric sites probably occurred along the continental shelf out to the 200 m (656 ft) depth contour near desirable landforms: quarry sites, salt domes, springs, valley margins, natural levees, point bars of meandering streams, bay margins, coastal dune lakes and ponds, shell middens, earthen mounds, and terrace margins overlooking an estuary or floodplain (CEI 1977). Based on new techniques, BOEM (2024) indicates ancient landforms were previously located at current depth around 130 m (427 ft).

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[29] https://www.fisheries.noaa.gov/s3/2024-08/SE-EEJ-Implementation-Plan.pdf

Today, the sea level in the Gulf is much higher and rising every year at a rate between 4-10 mm (0.15-0.39 in). In addition, coastal erosion, rivers, and other tributaries in the northern Gulf continue to deposit sediment into the Gulf, which have buried archeological and cultural resources; rates of accumulation are hundreds of feet per century (Frazier 1974). Europeans arrived in the 1500s, but today's sea level is somewhat similar as it was when they established settlements; thus, shipwrecks are somewhat easier to identify than habitation sites (CEI 1977). For instance, BOEM (2023) reports difficulty in confirming when Native Americans settled the coastal regions of the Gulf because archaeological deposits predating 5,500 B.P are buried under as much as 40 m (131 ft) of Holocene sediments or are underwater on the outer continental shelf.

Over the years, BOEM has funded various studies that have identified numerous archaeological resources in the Gulf using a combination of archival research, industry and other Federal agencies' remote-sensing surveys, BOEM-funded environmental studies, consultations, and scientific literature reviews (BOEM 2023). BOEM is the primary agency responsible for identifying, protecting, and conserving archaeological and cultural resources in the Gulf given their regulatory authority and management of offshore activities (e.g., oil and gas exploration and dredging) in the outer continental shelf. The Agency must also meet the regulatory mandates under Sections 106 and 110 of the NHPA. BOEM (2023) indicates historic archaeological resources in the Gulf are shipwrecks, aircraft, and a single lighthouse (Ship Shoal Light); many date back to the post-contact (Europeans arrived in the Gulf in the 1500s). Based on probability-modeling research, BOEM reports two-thirds of the total number of shipwrecks in the northern Gulf are likely within 1.6 km (1 mi) of the shore, and most of the remainder lie between 1.6-10 km (1-6 mi) from shore (CEI 1977). These findings are difficult to prove given problems with the archival record (accurate location, witnesses, and documented records [vessels with treasure were often excluded]). Recent data based on reported and confirmed data indicates there are around 2,240 shipwrecks and probably many more that are undiscovered, especially since they have high levels of preservation and few anthropogenic impacts even though hurricanes can scatter debris a long distance (BOEM 2023). Researchers have estimated that more than 4,000 vessels were lost in the Gulf during 1500 through 1945, and 75% probably occurred nearshore and the others in the outer continental shelf (Garrison et al. 1989). BOEM has documented many shipwrecks[30], including around 40 shipwrecks that are potentially eligible for listing on the NRHP; 13 shipwrecks have been nominated for listing under the NRHP (BOEM 2021). The discovery of shipwrecks has been directly linked to oil and gas exploration. Given only a small portion of the outer continental shelf has been explored, it is highly probable there are more undiscovered shipwrecks (BOEM 2021).

[30] https://www.boem.gov/environment/historic-shipwrecks-gulf-mexico

3.6 Climate Change

Multi-decadal projections of future climate change are estimated by various researchers around the world (IPCC 2023). The Intergovernmental Panel on Climate Change (2023) indicates emissions of greenhouse gasses (i.e., burning fossil fuels that release GHG from their natural reservoirs) have unequivocally caused global warming. GHGs are water vapor, carbon dioxide (CO_2), methane, nitrous oxide, and ozone, which trap heat within the earth's atmosphere (i.e., global warming). Evidence of climate change and its impacts has been detected for at least the past 50 years globally, and these impacts are expected to continue for decades into the future.

Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have been reported around the world. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people. Continued greenhouse gas emissions will lead to increasing global warming, and it is "very likely" that the Earth's atmosphere will warm to at least 1.5°C above pre-industrial temperatures between 2021 and 2040 according to the IPCC CMIP6 climate models. Deep, rapid, and sustained reductions in greenhouse gas emissions could lead to a discernible slowdown in global warming within around two decades, and also to discernible changes in atmospheric composition within a few years; however, current emissions/policies worldwide and modeling fall short of the levels needed to meet climate goals and make it harder to limit warming below 2°C. Every increment of global warming will intensify multiple and concurrent hazards. Risks and projected adverse impacts and related losses and damages from climate change escalate with every increment of global warming. Climatic and non-climatic risks will increasingly interact, creating compound and cascading risks that are more complex and difficult to manage (IPCC 2023). Climate change is occurring over a long period, and although projections become more uncertain farther into the future, the general trend is toward increasing changes as part of the environmental baseline.

Climate change is expected to cause substantial changes in physical characteristics and dynamics within the marine environment, with complex and interacting impacts to marine populations, fisheries, and other ecosystem services (Scavia et al. 2002; Harley et al. 2006; Doney et al. 2012). The IPCC (2023) reports that ocean warming has contributed to an overall decrease in maximum catch potential for some fish stocks, and ocean warming and acidification have adversely affected shellfish aquaculture and fisheries in some oceanic regions. The ocean absorbs approximately one-third of the CO_2 released into the atmosphere every year, changing the chemistry of the ocean by decreasing the pH of seawater, resulting in ocean acidification (Andersson et al. 2015). The combined effects of global warming and ocean acidification drive changes in other physical characteristics, such as sea level, salinity (Cullum et al. 2016), dissolved oxygen (Keeling et al. 2010), wind speed and direction, ocean currents (Howard et al. 2020) precipitation, nutrients (Marinov et al. 2010) and sediment loads. These physical changes, in turn, can cause biological effects, such as changes in species distribution and abundance (Pecl et al. 2017), organism development, and growth (e.g., shell formation in certain invertebrates) (Waldbusser et al. 2015), disease prevalence (Glidden et al. 2022), and occurrence of HABs (Riebesell et al. 2018)

Although oceanic warming is a global phenomenon, its manifestations and consequences differ regionally. The Gulf and Southern Florida climatic conditions are influenced by large-scale atmospheric processes; specifically the tropical Pacific El Niño Southern Oscillation, the Atlantic Multidecadal Oscillation (AMO), and the North Atlantic Oscillation, which drive regional and local environmental conditions in terms of salinity, currents, and precipitation (see Section 3.2.1, Oceanography and Climate for more details on the existing oceanography and climate in the Gulf). The Gulf forms a complex semi-enclosed system with interactions among physical, biogeochemical, socioeconomic, and human activities. Gulf ecosystems are vulnerable to climate change impacts and threatened by habitat degradation, ecosystem fragmentation, and increased population growth along the coast (McKinney et al. 2021). An ocean warming trend is clear in the Gulf (Lawman et al. 2022; Wang et al. 2023). The surface Gulf is warming at a rate approximately twice that of the global ocean. Most regions of the Gulf show a warming trend between 1970 and 2020, except for a subsurface region in the northeastern Gulf (Wang et al. 2023). Sea surface temperature monthly anomalies, which have increased at moderate rates from 1980 - 2011, have seen more dramatic increases in the recent period (2011 – 2016) in the eastern and western subregions (Karnauskas 2017). The northeastern Gulf has been less affected by warming given a weakening Loop Current. The AMO has been increasing steadily from 1980 - 2011 and shifted from a negative (drier) to positive (wetter) state in the mid-1990s (Karnauskas et al. 2017; Binczewska et al. 2023). However, the trend in the AMO index has been slightly decreasing since 2011 suggesting storm intensity (wind speeds) and rainfall will increase, and sea level rise, coupled with increased rainfall, will lead to stronger storm surges and inundation (Lawman et al. 2022).

Biological resources described in Chapter 3 of this DPEIS are being affected by climate change as part of the baseline of the biological environment. Some species may be shifting or will shift their ranges; there may be reductions in suitable habitat; temperature and other physical changes to the environment may be affecting prey or predators in ways that will impact populations and their distributions; and habitats may be changing in ways that also affect populations. Climate change impacts every species and habitat, because changes in temperature, salinity, pH, and other ocean conditions alters distribution of species and habitat use. The availability of suitable alternative habitat, prey, and environmental conditions for feeding, breeding, and other important life history activities will determine the resilience of a species to climate change.

NOAA analyzed several dozen indicators in the Gulf and found that trends in some ecosystem stressors(sea surface temperature, sea level rise, ocean acidification) are now increasing at faster rates in some areas than in the prior three decades (Lindsey 2023). The coverage of natural habitats (e.g., seagrass, wetlands) is generally declining at the same time as the number of artificial habitats (e.g., oil platforms, artificial reefs) is increasing (Peterson et al. 2021). Warming ocean temperatures, sea level rise, and ocean and coastal acidification would be key climate change drivers resulting in biological impacts in the Gulf (Peterson et al. 2021). Sea level rise, ocean acidification, and changing circulation patterns will all have varying degrees of impacts on aquatic species and their habitats. Migratory species will move, sedentary species will disappear, and other species will move deeper and into other areas of the ocean (Seara et al. 2022). High storm surges, wave impacts, and associated floodwaters will further degrade Gulf habitats and increase shoreline erosion and the import of sediments. Lawman et al (2022) report that without substantial mitigation efforts, increasing ocean temperatures and acidification are likely to stress corals and increase bleaching events that will subsequently kill most existing corals in the Gulf and the Caribbean by the end of the 21st century.

4. Environmental Consequences

This chapter describes the direct, indirect, and cumulative effects associated with identifying one or more AOAs in federal waters of the Gulf through this DPEIS and siting offshore aquaculture operations within those areas at a future date. The potential effects of **Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]) are compared relative to one another and to the No Action alternative. The AOA planning effort supported by this DPEIS is expected to directly benefit the administrative environment by informing future siting decisions and the permitting and environmental review process for aquaculture operations proposed within AOA locations. While the No Action alternative would not preclude future projects from being sited within any of the AOAs evaluated here, the potential environmental effects of siting aquaculture operations within the action alternatives are evaluated relative to each other and to siting future projects outside an AOA location. Siting aquaculture operations within an AOA in the future could impact the physical, biological, socioeconomic, cultural and historical environments, and climate change. Specifically, aquaculture operations may impact: the benthic environment, the water column and water quality, wild fish, protected species, commercial and recreational fisheries participants, and other ocean user groups. The geographic distribution and severity of any impacts on these resources depends on where and how aquaculture activities are sited and operated. Science-based siting and environmentally appropriate operational practices of aquaculture facilities can minimize potential adverse impacts.

4.1 Assumptions About Potential Activities in an AOA

To assess the potential impacts of identifying AOAs in Gulf federal waters, this analysis assumes that one or more AOAs would be identified in the Records of Decision (ROD) for this action, and that finfish, shellfish, macroalgae or multi-species offshore aquaculture operations may be sited within an AOA once it has been identified. Although an AOA may be identified as potentially suitable for all types of aquaculture, environmental, regulatory, logistical, and economic considerations related to the AOA's location will probably influence the type of aquaculture operations that may be proposed in the AOA in the future. For example, offshore environments with lower concentrations of planktonic organisms and lower nutrient levels may be less efficient for growing shellfish and macroalgae species than are inshore waters, and culturing higher value aquaculture species, like marine finfish, may be of greater interest to offshore aquaculture operators given the higher capital costs associated with offshore aquaculture infrastructure and operation.

The information on potential impacts discussed in this chapter is intended to inform future permitting and environmental review processes for aquaculture operations proposed for siting within an AOA. While there are no regulatory requirements that would restrict or compel offshore aquaculture operations to be sited within an identified AOA, this planning exercise may influence future applicants to do so. Future offshore aquaculture projects proposed to be sited within an identified AOA may undergo more efficient permitting and environmental review processes because AOAs are identified as potentially suitable for aquaculture based on their potential to avoid or minimize the types of impacts on natural resources and ocean user groups that can create permitting bottlenecks, and federal agencies can incorporate the impact analysis in this programmatic NEPA document into their project-specific reviews to streamline the environmental review process.

4.2 Potential Impacts of Identifying AOAs on Administrative Environment

This action is an administrative planning effort intended to identify potentially suitable locations for offshore aquaculture development and assess the potential impacts associated with siting aquaculture in those areas. This work supports long-term planning for marine aquaculture development in Gulf federal waters in two ways. First, it provides information to help the aquaculture industry determine the best locations to site future offshore operations in the Gulf. Second, it provides regulatory authorities information to support the permitting and environmental review processes for operations proposed to be located within those locations. While identifying AOAs would not change existing regulatory authorities or processes related to permitting offshore aquaculture, siting an offshore aquaculture operation within an AOA could help to avoid conflict with ocean users (e.g., commercial fishing, military operations) and resources (e.g., protected species and sensitive habitats). Additionally, this upfront environmental review of the potential impacts of future aquaculture operations sited within an AOA provides operators with information to design systems and operational practices that avoid or minimize environmental impacts on ocean users and resources.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. NMFS would not identify AOAs in federal waters of the Gulf. This would be inconsistent with the direction in Section 7 of E.O. 13921. However, offshore aquaculture development could still occur in federal waters of the Gulf. Operations sited outside of the areas discussed in this PEIS would not benefit from this preliminary environmental review of potentially suitable sites that will inform the permitting and environmental review process for future aquaculture operations proposed in an AOA. As a result, this alternative is likely to provide the least amount of benefits to the administrative environment of all the AOA Alternatives.

Beneficial effects to the administrative environment would be consistent across **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3), as offshore aquaculture operations proposed to be sited in these locations would be subject to the same (or very similar) federal permitting and environmental review process. The planning effort to deconflict these areas with other ocean users and resources is expected to streamline future efforts to locate aquaculture within AOAs by making permitting and environmental reviews more efficient. This DPEIS evaluates the potential impacts of all potential AOA Alternatives to a similar degree, except in instances where there are data and information gaps. Also, the DPEIS discusses any considerations that could cause the need for additional permits, authorizations, or consultations to site an offshore aquaculture facility within a specific alternative AOA location to the extent these considerations are known. The potential beneficial administrative effects of **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) include support for long-term planning for aquaculture, increased efficiency in permitting and environmental review for offshore aquaculture operations proposed to be sited within their boundaries, and minimization or avoidance of impacts to natural resources and ocean user groups based on a site suitability analysis. **Alternative 6** (C-13) could result in similar administrative benefits, but those benefits would be comparatively less than those expected from **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) because the **Alternative 6** (C-13) location overlaps with other ocean industries, including shipping and navigation (see Section 4.5.8.2) and commercial fishing activities (see Section 4.5.1). While interaction with these other ocean uses would not prohibit aquaculture from occurring in this area, these factors may require additional consideration during the permitting and environmental review process for future aquaculture operations proposed to be sited in that location.

4.3 Potential Impacts of Identifying AOAs on the Physical Environment

This section evaluates how the Proposed Action (identifying AOAs) could potentially impact the physical environment if one or more aquaculture operations were to be sited within an AOA at a future date. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. Resources include: the benthic environment;

protected habitat, marine protected areas and special resources areas, water quality, air quality, and aesthetic quality.

Stressors vary in intensity, frequency, duration, and location. Stressor/resource interactions that were determined to have negligible or no impacts were not carried forward for analysis in the DPEIS. The action of identifying AOAs in federal waters of the Gulf would not have any direct impacts, beneficial or adverse, on the physical environment because this is a planning action that is administrative in nature. The potential impacts of future aquaculture operations that may be sited in AOAs on the physical environment are analyzed to inform future permitting and environmental review processes. No specific aquaculture projects or types of aquaculture are required or certain to occur in an AOA. Should an aquaculture project be proposed within an AOA in the future, potential impacts on the physical environment from those projects would be assessed by the relevant agencies during required permitting and environmental review processes.

4.3.1 Potential Impacts on the Benthic Environment

Benthic environments provide habitat for many valuable species that support recreational and commercial fisheries in the Gulf. Aquaculture operations have the potential to cause impacts on benthic environments and benthic communities, such as bottom disturbance and altering sedimentation within the aquaculture operation footprint. Potential physical impacts are associated with securing aquaculture equipment to the seafloor, which can adversely affect the benthic environment. For example, anchor(s) and associated ground tackle (i.e., chains and cables) can sweep across the seafloor as the equipment moves with the waves and currents which can adversely affect habitat unsuitable for certain benthic organisms to colonize. Sediment could also become resuspended and deposited during anchor and ground tackle installation, gear retrieval, or harvesting activities at the water surface. Moreover, excess feed and waste can accumulate below aquaculture operations depending on the oceanic conditions and other physical factors. For instance, Tan et al. (2024) found that a commercial scale bivalve aquaculture operation can increase biodeposit and alter the seabed within close proximity (~20 m) of a shellfish farm under certain conditions, such as low current. Those impacts temporarily altered the benthic community below the operation, but recovered shortly after harvesting, and at a rate that was quicker than other researchers reported for finfish aquaculture operations. In Tasmania, Keeley et al. (2014) indicated the organic matter was elevated and macrofaunal community was less abundant and diverse below the salmon farm, but was improved and near the background levels and natural conditions within 25 m (82 ft) of the cages and continued to improve with distance. The findings showed the sediment conditions and benthic community below the former salmon farm recovered significantly in the first two years, but it was not fully recovered until around 4-5.5 years. More information about potential benthic impacts from waste and uneaten feed is found in Sections 4.4.1.4, 4.4.2.6 and 4.4.4.6.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and from the potentially more effective permitting and environmental reviews.

The potential effects of siting future aquaculture operations in **Preferred Alternatives 2-5 (**W-1, W-4, W-8, and C-3) and **Alternative** 6 are similar. Riley et al. (2021) considered the known benthic environment and environmental conditions when evaluating the relative suitability of these locations. **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13) have similar water quality characteristics, oceanic conditions, and benthic environments. Therefore, potential effects to the benthic environment associated with siting aquaculture in these areas will be comparable. **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) have sufficient depth and current flow that may allow for rapid dilution of dissolved wastes and broad dispersion of solid wastes discharged from the facility. There are no sensitive benthic habitats (i.e., hardbottom, coral EFH, and HAPC) within the **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13). Harte Bank HAPC is located within 3 km (1.6 nm) southeast of **Preferred Alternative 2** (W-1). However, based on available information, it is unlikely that aquaculture operations would cause benthic impacts that would affect this HAPC because environmental conditions and biological communities are usually at background levels between 25-100 m (82 ft-328 ft) away from a farm (Keely et al. 2014).

The sediment composition varies slightly among the different action Alternatives. Based on Riley et al. (2021), the sediment within **Preferred Alternative 2** (W-1) is 70% mud, but changes to fine sand in the southwest corner, which covers the remaining 30% of the area. Similarly, the sediment in **Preferred Alternative 3** (W-4) is primarily mud and silt (97-99%), and 3% sand in the northeastern corner. The sediment in **Preferred Alternative 4** (W-8) is over 90% sand and mud, with approximately 3% gravel. The sediment in **Preferred Alternative 5** (C-3) is 99% sand and mud, while the northeast corner has a slightly higher % of sand relative to the southwest, where it is more mud. The sediment in **Alternative 6** (C-13) is 99% mud, which is probably sediment from the Mississippi River. Overall, the potential impacts to the benthic environment are unlikely to differ between **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13). There are only slight differences in the substrate composition between the alternatives and they all have similar depth and current flow.

At every **Alternative**, potential adverse effects of future aquaculture operations on the benthic environment could also include physical disturbance of seafloor from gear and anchors, deposition and accumulation of waste, uneaten feed and marine debris around aquaculture operations and changes in composition of benthic organism communities. However, the potential effects could be less or more severe depending on site proximity to sensitive benthic habitats (i.e. hard-bottom, reefs) and physical site conditions (i.e. current, sediment composition).

4.3.2 Potential Impacts on Federally Protected Habitat, Marine Protected Areas, and Special Resource Areas

The siting of future aquaculture operations in an AOA could introduce additional stressors to marine managed areas by affecting water quality, vessel traffic, or the placement and operation of physical structures. Because the action alternatives do not directly overlap with marine managed areas, except EFH for some species (Riley et al. 2021), impacts to managed areas, other than EFH, are not expected to occur. As noted in Section 3.2.2, none of the AOA alternatives overlap with National Marine Sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens and artificial reefs, HAPCs, or areas of known hard-bottom. Future aquaculture operations in any of the AOA Alternatives would be sited over unconsolidated sediments that do not support coral, hardbottom, or artificial reef communities; however, unconsolidated sediments composed of sand, shell, and mud are EFH; as is the water column. Therefore, overlap of the AOA Alternatives with EFH is unavoidable. Impacts could extend to HAPCs outside the AOA Alternative areas. However, site-specific impacts to EFH or other marine managed areas would be evaluated on a project-specific basis. Future aquaculture construction and operations proposed for siting in these areas would require federal authorizations and permits, which would trigger consultation with the NMFS on anticipated EFH impacts. Consultations would be used to identify recommended actions to avoid, minimize, and mitigate adverse impacts to EFH.

Comparison of the Alternatives

Under **Alternative 1 (No Action)**, aquaculture projects could be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and potentially more effective permitting and environmental reviews. Potential adverse effects of future aquaculture operation on sensitive habitats could include potential increase in environmental stressors, including vessel traffic, acoustic and light disturbances, wild species aggregation (i.e., artificially attracting/concentrating marine life), marine debris, disease and pathogen transmission. Effects may be more or less severe from site proximity and type of aquaculture operation proposed.

While the potential effects of siting future aquaculture operations are similar across the Action and No Action alternatives, **Preferred Alternatives 2-5** and **Alternative 6** may be more suitable for aquaculture with respect to impacts on sensitive habitats given spatial modeling efforts to minimize overlap (Riley et al. 2021). The **Preferred Alternative 5** (C-3) and **Alternative 6** (C-13) do not overlap with any national marine sanctuaries, MPAs, marine reserves, deep-sea corals, fish havens, artificial reefs, HAPCs, or mapped hard bottom areas (except for EFH). The AOA Alternatives do however differ in proximity to these resources. **Preferred Alternative 3** (W-4)**, Preferred Alternative 4** (W-8) and **Alternative 6** (C-13) are not located within 3 km (1.6 nautical miles) of these habitats, but **Preferred Alternative 2** (W-1) is located 2.8 km (1.5

nautical miles) northwest of an HAPC (Harte Bank) and 11 artificial reefs about 1.5 km (0.81 nautical miles) from the southeast corner of **Preferred Alternative 5** (C-3).

Given the distance and relatively slow current velocity between the AOA alternatives and known marine managed areas, adverse effects (e.g., sediment accumulation) to sensitive habitats related to operation of a facility or the placement or decommissioning of a facility would probably be minimal and temporary (See Section 4.2.1.3 for a discussion of potential impacts to water quality). <MAP SHOWING DISTANCES TO sensitive areas). Depending upon prevailing currents, siting aquaculture in the AOAs identified in **Preferred Alternative 2** (W-1) and **Preferred Alternative 5** (C-3) has the greatest risk to marine managed areas given their proximity to these areas. However, mitigation measures could be incorporated into proposed projects to minimize any potential impacts. Impacts to marine managed areas from vessel activity associated with aquaculture operations within an AOA would also likely be minimal, as there is minimal overlap between the AOA Alternatives and these managed areas; vessel traffic through managed areas is unlikely.

4.3.3 Potential Impacts on Water Quality

Maintaining suitable water quality is not only important for maintaining a healthy environment and ecosystem, but also important for maintaining the health and welfare of marine organisms grown in aquaculture operations. Future aquaculture operations have the potential to impact surrounding water quality in both adverse and beneficial ways.

Potential localized impacts to water quality from aquaculture operations could include increased nutrient concentrations (i.e. eutrophication) and turbidity levels and reduced dissolved oxygen levels (Prince et al. 2015). A primary concern is the discharge of effluent that may contain higher amounts of nitrogen, phosphorus, organic carbon compounds and solids. Nitrogen and phosphorus are discharged into the water via waste from fish and uneaten or undigested food. Researchers have documented that the amount of nitrogen released from marine fish cages varies among species, but it can be significant for some aquaculture species (Prince et al. 2015). For instance, Alston et al. (2005) reported that 79% of the nitrogen fed to mutton snapper (*Lutjanus analis*) and cobia *(Rachycentron canadum*) was released into the water. In European aquaculture operations, nitrogen loss associated with Atlantic salmon ranged from 52 to 95% (Prince et al. 2015). However, in recent decades, studies have indicated that better feed formulations and improved feeding efficiency have caused decreased nutrient loading (Price and Morris 2013) and substantially reduced water quality impacts (Rust et al. 2014).

Particulate and dissolved compounds associated with aquaculture effluent discharge can alter water quality by changing the physiochemical properties of the water column, such as nutrient concentrations (Price et al. 2015). Water quality impacts from nutrient enrichment are a major concern with finfish farms because they can not only change key water quality parameters, but they can also have compounding water quality effects with other threats, such as ocean acidification and HABS (Price and Morris 2013; Kessouri et al. 2021). Generally, the availability of nitrogen limits primary production so excess nitrogen released from marine fish cages could contribute to phytoplankton blooms, especially in coastal areas (Price et al. 2015). Notably, the AOA Alternatives are located offshore, not in coastal areas.

Low DO can cause various short and long-term impacts, and mortality in fish when DO reaches hypoxia (< 2.0 mg/l). Solid waste (fecal matter and uneaten feed) can also impact water quality because it can remain suspended in the water column and become fragmented by turbulence, which can then increase turbidity and reduce water clarity (Stenton-Dozey et al. 2013). Potential impacts are usually associated with the operation's direct footprint (i.e., near-field), but occasionally they can extend much further (far-field) than the footprint. While the nutrient discharge from aquaculture operations have been detected as far as 1-2 km (0.54 to 1.08 nm) away from marine finfish operations in sheltered environments such as bays and fjords (Price et al. 2015), in high-energy offshore environments, nutrient discharge levels more rapidly assimilate into the environment or are diluted to levels indistinguishable from the surrounding seawater immediately outside the cage or net-pen, causing no discernible impacts to water quality (Welch et al. 2019).

The release of nutrient discharge from aquaculture operations has been linked to increased contractions of chl-*a* in embayments in the Mediterranean Sea (Sarà et al. 2011). Price et al. (2015) also reported scientific evidence showing primary production cannot only be elevated within the farm footprint, but it can be elevated outside the footprint up to 1 km (0.54 nm) away. Although there is concern that aquaculture effluent could cause phytoplankton blooms, researchers have found no direct link between aquaculture effluent and HABs. The formation and persistence of HABs are dynamic processes caused by numerous factors including weather and oceanographic conditions (e.g. salinity, temperature), currents, nutrients composition of algae blooms and sunlight (Anderson et al. 2021). In general, eutrophication or hypoxia is expected to be less of a concern in the offshore than the nearshore environment given offshore oceanographic conditions, including higher water quality, flushing, and nutrient delivery and assimilation (Fujita et al. 2022).

Other potential adverse water quality impacts associated with offshore aquaculture operations are caused by fuel, chemicals, and other pollutants from vessels and equipment. Accidental discharge of hazardous materials, including fuel, oil, and lubricants into waters could adversely affect the environment and aquaculture operation itself. These types of effects are expected to be short-term and limited in their extent. The construction, maintenance and decommissioning of aquaculture operations also could adversely impact water quality in the short term while those activities are occurring. Examples could include an increase in turbidity from sediment resuspension as anchoring systems are first deployed and set for an operation, or an increase in turbidity and nutrient levels, and decrease in DO during antifouling maintenance of aquaculture gear.

Moreover, it's possible that marine debris associated with aquaculture operations may impact water quality. Marine debris is a prevalent issue that threatens the marine environment and coastal communities around the world, including the Gulf and U.S. Caribbean. Marine debris can include a wide variety of objects constructed of different materials (e.g., lost fishing gear, lost vessel cargo, plastics, metal military debris) from multiple sources (e.g., stormwater runoff, landfills, recreational and commercial activities, and military activities). Plastic makes up most marine debris globally and marine debris is composed of multiple chemical compounds, some classified as POPs (Barnes et al., 2009). Marine debris can leach chemicals or microplastics and enter the marine food web (Smith et al. 2018; Andreas et al. 2021; Bennett et al. 2022; Unuofin and Igwaran, 2023) causing various public health and safety concerns, including navigational hazards. Aquaculture operations can potentially impact water quality through marine debris given the materials. Materials used in offshore aquaculture can include plastics, steel, and copper alloy mesh or copper treated nets (Fujita et al. 2022). As such, there is a chance these materials could degrade over time and be a source of marine debris and pollution (Skirtun et al. 2022; Lin et al. 2022). For instance, copper from fish feed or nets could leach into the water (Chow and Schell 1978; Brooks et al. 2003; Kalantzi et al. 2016).

There is growing scientific evidence that some types of non-fed aquaculture operations (e.g., shellfish and seaweed) can benefit local water quality, provide environmental and social benefits (i.e. ecosystem services), and restore ecosystem quality under certain conditions (Gentry et al. 2019). Under practical conditions and scale, shellfish and seaweed aquaculture can create a range of environmental benefits and positive impacts, such as incrementally improving water quality (Alleway et al. 2023). For example, Gentry et al. (2019) indicated various aquaculture species, including macroalgae and oysters, can improve water quality by filtering and assimilating nutrients and improving water clarity. That study also showed bivalves and algae can improve water clarity in the field within and sometimes beyond the farm. Although these studies show promise, additional field studies are needed to examine scale and expectations. In another comprehensive review, Theuerkauf et al. (2019) found that shellfish and seaweed can remove nutrients, but also bioaccumulate various harmful pollutants, such as persistent organic pollutants, mercury, and microplastics, which would benefit water quality, but pose human health risks.

Any potential impacts on water quality could be minimized through effective siting (e.g., water depth and current flow), permit requirements (e.g., NPDES and monitoring), environmental consultations (e.g., EFH and Section 7 ESA), and implementation of BMPs.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action),** aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. The impacts of the No Action Alternative on water quality are uncertain; it depends on where and what types of aquaculture operations are proposed. Potential adverse effects of future aquaculture operations could occur through discharge of pollutants, generation of marine debris, interaction with HABs. Potential beneficial or adverse effects on nutrient levels, turbidity and primary production, could also occur depending on type of aquaculture. Site conditions (i.e. background nutrient levels, current speed and depth) may increase or decrease the severity of effects.

The potential adverse effects of future aquaculture operations on water quality are expected to be similar across **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) given the similarities in site conditions (e.g. depth, current speed and relatively low ambient nutrient levels) in the offshore environment (Riley et al. 2021). Of the AOA Alternatives, **Preferred Alternative 5** (C-3) and **Alternative 6** (C-13) have elevated ambient nutrient levels (e.g. nitrogen and phosphorus) compared to the other AOA Alternatives. **Alternative 6** (C-13) also has been observed to have a greater variability in salinity and lower levels of light transmissivity given the influence of the Mississippi River outflow. While **Preferred Alternative 5** (C-3) and **Alternative 6** (C-13) may differ some from **Preferred Alternatives 2-4** (W-1, W-4, W-8) in terms of ambient water quality, water quality parameters would not prevent aquaculture operations from being sited in either of these locations. HOwever, ambient water quality may influence the types of aquaculture proposed to be sited in a particular AOA in order to best use environmental conditions at the site (e.g. selecting an AOA with elevated nutrient levels to produce macroalgae, or choosing a AOA with oligotrophic conditions for a finish operations).

4.3.4 Potential Impacts on Air Quality

Available information about the potential impacts of aquaculture on air quality is limited. Available information for open-ocean aquaculture finfish operations describe the potential impacts related to emissions into the water (e.g., Bergland et al. 2020) rather than into the air. Open-ocean finfish aquaculture operations could emit pollution into the air because feed pellets distributed by hand or machine can sometimes create a fine dust (Hargrave et al. 2003). There is a potential for air quality to be impacted from vessels associated with an aquaculture operation, which would likely use diesel internal combustion. Marine vessels operating around the world produce a considerable amount of greenhouse gas emissions, especially large ocean-going cargo vessels and harbor craft. Exhaust emissions from marine diesel engines emit nitrogen, oxygen, CO_2, carbon monoxide (CO), SO_x, NO_x, hydrocarbons, water vapor, and smoke. The northern Gulf is a busy area for vessel traffic given the various industrial ports (e.g., Houston/Galveston, Port Arthur, Cameron, Gulf Port, and Mobile) and the active fishing and oil and gas vessel fleets. Port activity-based (ocean-going vessels, harbor craft, rail locomotive, and heavy duty vehicles) emissions (PM, diesel particulate matter [DPM], NO_x, SO_x, HC, CO, and CO2) are a major air pollution source (Starcrest Consulting Group 2023). The primary pollutant produced by ocean-going vessels using the port of Long Beach is NO_x followed by CO, HC, PM_{10}, $PM_{2.5}$, and DPM. To reduce emissions associated with marine vessels, the EPA has adopted exhaust emission standards for marine diesel engines installed in a variety of marine vessels ranging in size and application from small recreational vessels to tugboats and large ocean-going vessels.

Most air pollutant emissions and air quality impacts from aquaculture operations would occur from diesel-fueled vessels traveling to and from the offshore facility and equipment operation (e.g. generators) at the site. Marine vessels will be used to transport personnel, equipment, and cultured species. The magnitude of emissions and the resulting air quality impacts would vary operation to operation and by the number of vessels and frequency of trips. In general, air emissions would vary by vessel size, hull type, vessel age and equipment optimization. Over time, it is likely the technology used to operate and service aquaculture will advance and systems automation will increase. This could help to reduce vessel traffic to and from offshore aquaculture operations, and reduce vessel emissions from that traffic, particularly with the adoption of electric motors for marine vessels. Although marine vessels will be used for transportation, it is likely the number and size of vessels will be minimal and similar in size to fishing vessels operating in the region. Vessels should be properly sized to meet the demands of the operation, but no larger than necessary to safely move equipment and personnel. Potential impacts to air quality associated with marine vessels is likely to be minimal to minor, but that will again be dependent on the needs of an individual project. Given the size of the AOA Alternatives and the proximity to port, it is likely aquaculture operations will use medium size (9.1-22.9 m [30-75 ft]) fishing or work vessels, which produce minimal air emissions. Depending on operational and equipment needs, the vessels could be equipped with electric motors or gasoline-fueled outboard engines rather than diesel engines, which have even lower air emissions, especially new and more efficient 4-stroke engines.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. The potential impacts on air quality from the No Action Alternative are uncertain. Unforeseen impacts on air quality could occur from future aquaculture, depending on the types and locations of operations proposed. Potential adverse or neutral effects of future aquaculture operations could occur from emissions associated with the type farm operation (i.e. finfish, shellfish, macroalgae or multispecies), power generation and vessel use and transit patterns (i.e. distance and frequency), and operational considerations (i.e. type of aquaculture operations, culture systems employed, how vessels or farm systems are powered).

The potential effects of siting future aquaculture operations are similar across all of the **Alternatives** including the **No Action** alternative. Most coastal counties along the northern Gulf are in compliance (attainment) with the NAAQS for the primary air pollutants, with the exception of St. Bernard Parish, LA and the Houston-Galveston-Brazos area in Texas, which are in nonattainment for the criteria pollutants of sulfur dioxide (2010) and Ozone 8-hour (2015) respectively (EPA 2024). **Preferred Alternatives 2-4** (W-1, W-4, W-8) are similar distances from shore and port, between 79 km (43.0 nm) and 107.4 km (58.0 nm) offshore, suggesting transit times and emissions could be similar. **Preferred Alternative 5** (C-3) is the furthest alternative from shore, approximately 133.4 km (72.0 nm) south of Pecan Island, LA, and 137.5 km (74.2 nm) south of Marsh Island, which would require the longest transit times and and potentially causing the greatest level of emissions. **Alternative 6** (C-13) is the closest to shore of all the alternatives, 9.6 km (5.2 nm) from the inlet at South Pass, and although vessels would have to travel 36 km (20 nm) from the nearest port of Venice, LA to reach the AOA, would have the shortest transit distance of all the AOAs and likely the lowest vessel emissions.

4.3.5 Potential Impacts on Aesthetic Quality

4.3.5.1 Potential Impacts on the Visual Environment

Visual impact on the coastal landscape is often a cause for public opposition to aquaculture development, especially in areas with high-value properties, historically important scenic views, or when a project is in the vicinity of a cultural resource. However, the severity and magnitude of impacts are associated with the distance from shore, height of the structure, and the general meteorological conditions in the area. Atmospheric and environmental factors can influence visibility and perception from sensitive viewing locations. Another factor is the public's viewing spot; the higher the viewing spot, the farther the public could potentially spot an aquaculture facility from shore, such as a steep cliff, which is not the coastal topography in the Gulf. Generally, the contrast of the ocean makes surface cages and net pens more obvious from a high viewpoint. However, the human eye can only see about 5 km (3 miles) offshore in clear conditions when standing on the beach. Thus, cage systems sighted far enough from shore will be hidden from view in the vastness of the ocean, especially from low-level spots (Grant 2006). Additionally, aquaculture operations that use submersible cages would likely reduce visual impacts. In Hawaii, cage placement near Keahole point was determined to have no effect on the viewshed of the area (Blue Ocean Mariculture 2014). In previous planning studies conducted by NOAA NOS/NCCOS for viewshed impact in San Diego, California, it was determined through modeling and photo-realistic simulations that offshore fish farms would have minimal impact on the viewshed when aquaculture operations are sited greater than 9 km (5 nm) from the shoreline (Morris et al. 2015).

Another potential impact associated with aesthetics is fixed lighting on the offshore facility. Lights may be used to mark the offshore facility for navigational safety, which could be seen from a great distance at night. The number and type of lights would depend on various factors, including the size of the facility. Surface work lights are often down-shielded to prevent light pollution; however, without shielding, a strong white light is visible for 18 nm (33 km) (Cicin-Sain et al. 2000); most beacon lights are red or green, which are visible for 12 nm (22 km). In sum, the potential impacts associated with artificial light will depend on various factors, including the color, intensity, and duration of the lighting. A short-duration synchronized flashing navigational safety light is likely to have less impact on the human and natural environment than a bright long-duration non-flashing light.

Potential future aquaculture operations that might be located in an AOA will not likely have a measurable visual impact on the seascape given the AOA alternatives are a significant distance from shore. Unlike other regions, visual impacts are not likely to be a contentious issue in the northern Gulf since much of the region is already dominated by industrial development, primarily oil and gas platforms.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. **Alternative 1 (No Action)** could cause unforeseen impacts on the aesthetic environment. Potential adverse or beneficial effects could occur given visibility of aquaculture operation, support vessels, and lighting. Potential effects may be increased or decreased in intensity by proximity to shore, coastal development near the operation site, environmental conditions, and ambient viewscape.

While the potential effects of siting future aquaculture operations are similar across the Action and No Action alternatives, **Preferred Alternatives 2-5 (**W-1, W-4, W-8 and C-3) may be more suitable for aquaculture with respect to impacts on visual impacts given the significant distance from shore. Although **Alternative 6** (C-13) is the closest distance from shore (9 km [5 nm]), there are no residential homes, parks, or any public viewing spots in proximity to this AOA alternative. Adverse visual effects are expected to be minimal and only in the immediate area near any of the Alternatives, in the offshore environment. Further, it is unlikely the addition of low relief aquaculture structures (floating net-pens or shellfish gear) would even be discernible in a viewshed amongst existing oil and gas infrastructure and may even be obscured by it.

4.3.5.2 Potential Impacts on the Acoustic Environment

The acoustic environment of the Gulf is composed of natural and anthropogenic noise sources that emit sounds into the air and water. Sources of natural noise encompass a broad spectrum of frequencies, and include wind and waves, precipitation (e.g., rain, hail, thunder), geological events (e.g., seismic activity, and underwater landslides) and biological sounds (e.g., marine mammals, fishes, and crustaceans) (Sidorovskaia et al. 2016). Natural sounds are somewhat random, but continue over time. In contrast, anthropogenic noise is generated from industrial and recreational activities and equipment, such as transportation (e.g., vessels, aviation), construction and dredging, energy exploration and development, scientific research and explosions (military activities); activities that are specific over time and space.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. The potential impacts on the acoustic environment from **Alternative 1 (No Action)** are uncertain. Unforeseen impacts on the acoustic environment could occur from future aquaculture, depending on the types and locations of operations proposed. Potential adverse effects of future aquaculture operations given acoustic disturbance on the physical environment could occur through construction and maintenance, aquaculture operation, power generation and vessel traffic. Potential effects may be increased or decreased in intensity by proximity to sensitive biological resources, coastal development near the operation site, environmental conditions and ambient soundscape.

While the potential effects of future aquaculture operations sited in an AOA on the acoustic environment are similar across the Action and No Action alternatives, **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) may be more suitable for aquaculture with respect to acoustic impacts on the physical environment given their distance from communities onshore that might be disturbed by sounds generated from aquaculture vessels and operations. In the offshore environment, acoustic disturbances from vessel traffic associated with aquaculture operations are not expected to differ from other vessel traffic, although disturbances could be focused locally around an AOA over time if more operations are sited in one AOA. Site-specific effects related to acoustic disturbance will be assessed once project-specific details (e.g., proposed site location, culture species, production method and gear, and operational details) for prospective aquaculture operations are developed and proposed through the permit and agency consultation process.

4.4 Potential Impacts on the Biological Environment

4.4.1 Potential Impacts on Fish and Invertebrates

This section discusses the potential impacts generally associated with offshore aquaculture, and how those impacts might affect fish and invertebrates. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. ESA-listed fish and invertebrates are additionally discussed in more detail in Section 4. Stressors that may impact fish and invertebrates include the following: acoustic disturbances, light disturbances, wild species aggregations, fish waste and unconsumed food, escapement, introduction of non-native species, antibiotic use, use of forage fish in meal and feed, disease and pathogen transmission, antibiotic use, and marine debris. Stressors vary in intensity, frequency, duration, and location.

The **Proposed Alternatives** overlap with designated EFH and impacts on the physical environment are discussed in Section 4.3. Aquaculture structures, operations and impacts on the physical environment (e.g., potential water and sediment quality impacts) can impact fish and invertebrate use in ways that may be both adverse and beneficial. Siting aquaculture may influence behavior, local biodiversity, and ecosystem functions, especially in the Gulf because suitable habitat is often limited.

4.4.1.1 Water quality

Aquaculture has the potential to adversely or beneficially affected water quality
Water quality degradation associated with aquaculture operations is another potential stressor for marine mammals. Aquaculture operations have the potential to negatively impact water quality in different ways (e.g., increasing turbidity, lowering DO, reducing water clarity, and altering the local hydrodynamics), but a primary concern is the discharge of pollutants (e.g., ammonium, nitrate, phosphate, and organic carbon compounds), especially inorganic nutrients (nitrogen and phosphorus) and particulate matter (Dunne et al. 2021). Poor water quality can directly impact not only marine mammals in various ways (e.g., reduce growth, increase deformities, and decrease reproductive abilities), but it can indirectly impact them via their prey (EPA 2021). Despite these risks, potential impacts will vary significantly depending on the hydrodynamics conditions (i.e., current velocity) and cage placement; submerged cages in deep waters with sufficient water flow will have less impacts than surface cages in shallow waters with no or limited water flow because nutrient concentrates will disperse, especially with distance; inorganic concentrations are higher near the cages (Dunne et al. 2021). Controlling and reducing feed waste can reduce potential water quality issues (Dauda et al. 2019). Generally, nutrient levels and other water quality criteria are elevated at the aquaculture facility, but only extend a short distance downstream (< 100 m) from the facility.

4.4.1.2 Acoustic and Light Disturbances

Acoustic disturbances would be at low levels of noise, temporary, and localized. Potential impacts on fish include temporary and infrequent acoustic masking or behavioral reactions.

Invertebrate sound detection is primarily limited to low-frequency particle motion and water movement that diminishes rapidly with distance from a sound source, therefore the risk of adverse impact is negligible and mostly limited to offshore surface layers of the water column where only zooplankton, squid, and jellyfish are prevalent mostly at night (U.S. Navy 2018). Artificial lights can have adverse implications for a variety of marine life, including corals, sea turtles, and sea birds (Marangoni et al. 2022). For instance, light pollution disrupts the natural orientation cues and may cause sea turtle hatchlings to become disoriented (Marangoni et al. 2022). Light pollution has also been known to attract some marine life and deter others, which can have local biota implications (Marangoni et al. 2022). However, the impacts of lights from offshore aquaculture operations on fish and invertebrates are likely limited to the disruption of diel vertical patterns. Also, mitigation measures could reduce potential impacts, such as requiring a particular color or intensity of light.

4.4.1.3 Wild Species Aggregation

Aquaculture structures have the potential to attract marine life, especially finfish aquaculture, which could lead to beneficial or adverse impacts. Artificial structures, like aquaculture facilities, can attract varied species. Wild fish aggregate around aquaculture facilities globally, regardless of cultivated species (Rhodes et al. 2023a). Invertebrates attach to structures and fish tend to aggregate around structures because they can (1) shelter against currents and predators, (2) increase prey, (3) increase feeding efficiency and (4) provide nursery and recruitment sites (Reubens et al. 2013). Aquaculture structures have the potential to not only attract marine life, but also provide nutrients (i.e. excess fish feed). Visual surveys (pre and post-installation) at one aquaculture site in Puerto Rico showed species richness and abundance of wild species increased after the finfish aquaculture grow-out structures were deployed and secured (Alston et al. 2005). Biomass and fish species density may increase around structures, but effects are species-specific (Mercader et al. 2017). Given aquaculture operations can attract fish, it is possible that some recreational anglers will fish near aquaculture operations like they do at oil and gas platforms, which could increase targeted fishing locally.

Aquaculture structures and aggregation in an AOA would possibly increase the connectivity between man-made structures in the offshore environment. This connectivity could create new dispersal pathways for native and nonnative invertebrates and fishes (Diana 2009; Adams et al. 2014). Gear footprints may also create site-specific eddy effects that may impact egg and larval retention around gear.

Sharks could be attracted to the cultured finfish, dead discards, or the odor or noise generated during feeding (Bath et al. 2022). Sharks are documented to occur in association with offshore aquaculture facilities in Hawaii (Papastamatiou et al. 2010), and may exhibit fidelity around cages (Papastamatiou et al. 2010; Loiseau et al. 2016). The risk of shark damage to cages has spurred research on mitigation techniques (Sclodnick et al. 2011). Planning, management and appropriate husbandry practices could reduce shark interactions with aquaculture infrastructure (Huveneers et al. 2022).

Overall, aquaculture infrastructure (cages and anchor systems) can create artificial habitat for fish and invertebrates. Artificial structures in the Gulf usually provide similar habitat as natural habitat (hard bottom) in terms of species composition and abundance depending on the size, location, and other biological and environmental factors. Changes to habitat use may include exclusion, avoidance, or attraction, and could range from no impact, beneficial (e.g. increased foraging success), to adverse impacts (e.g. increased predation), depending on intra- and inter-specific interactions around a facility.

4.4.1.4 Waste and Unconsumed Feed

Environmental impacts associated with aquaculture operations are often linked to excess nutrient input and the ecosystem's capacity to assimilate the nutrients (Pearson and Rosenberg 1978; Rust et al. 2014). Aquaculture operations may cause excess nutrient inputs. Excess nutrients into a waterbody can lead to an increase in primary productivity which could stimulate excessive algae growth (eutrophication). An increase in algae growth, sometimes called an algal bloom, could reduce DO in the water when dead material decomposes and can cause fish and invertebrates to die. Excess nutrients can also cause an increase in turbidity and a decrease in visibility, which may reduce the ability of some fish to see their prey or predators (Horta et al. 2021). Fish waste and unconsumed feed are the main sources of excess nutrients and solids from finfish operations, which can affect water quality, benthic habitat, and associated biological communities of fish and invertebrates, in ways that may be adverse or beneficial, but many potential environmental impacts can be avoided with prudent farm siting, proper management, and modern technologies. Fish farms in the U.S. must monitor discharges to both the benthic environment and the water column according to the Clean Water Act, and follow effluent limitations set by the Environmental Protection Agency.

Waste from aquaculture operations may enhance the productivity of algae, invertebrates, and fish (Katz et al. 2002; Dempster et al. 2005; Rensel and Forster 2007). A recent assessment by Bøhn et al. (2024) summarized the potential risks of aquaculture feed spillover from Atlantic salmon farms on the wild Atlantic cod populations in Norway, noting behavioral changes in wild fish attracted by excess feed from the farms, potential increased growth and associated maturation and fecundity implications. Bøhn et al. (2024) also described the potential for physiological impacts to wild fish consuming excess aquaculture feeds, which are formulated from terrestrially derived ingredients with different nutritional profiles than marine-derived oils and proteins. Risk mitigation strategies suggested by Bøhn et al. (2024) include locating salmon farms further offshore to reduce interactions with the coastal ecosystem and cod spawning areas.

Environmental monitoring studies of finfish operations in offshore waters of the U.S. and U.S. Caribbean have reported benthic effects relatively localized to finfish enclosures. An environmental monitoring study of offshore finfish culture of mutton snapper (*Lutjanus analis*) and cobia (*Rachycentron canadum*) in waters off Puerto Rico reported no evidence of anaerobic sediments beneath the fish cages, and inorganic nitrogen levels near the cages were similar to background levels (Alston et al. 2005). Alston et al. (2005) noted that effects to the macroinvertebrate community and sediments were only observed directly beneath the finfish cages, just prior to harvest (a period when feeding rates are at their highest). A benthic monitoring study near an aquaculture operation in Hawaii reported a gradual buildup of organic material beneath the fish cages and shift toward anaerobic conditions at sites near the fish culture cages; however, while the eutrophication footprint expanded over the course of the study, effects to the benthic polychaete community remained localized to the immediate area of the fish enclosure (Lee et al. 2006). New Hampshire Sea Grant (2006) also found no measurable environmental impacts associated with its offshore aquaculture demonstration project (Barnaby, 2006).

Degraded water quality has been observed at farms in nearshore areas with limited water exchange. However, when aquaculture farms are sited in well-flushed environments, water quality effects are typically not observed at distances greater than 30 m (98 ft) from the cages (Price and Morris 2013). While nutrient spikes and dissolved oxygen decreases have been observed after feedings, monitoring data collected from marine fish operations (Alston et al. 2005; Lee et al. 2006; Langan 2007) usually show few significant or persistent water quality or benthic issues (Price and Morris 2013; Rust et al. 2014).

Various researchers have reported limited impacts on the benthic community associated with aquaculture; most of the impacts are within the immediate area of the cages (Price and Morris 2013). Benthic impacts may be mitigated by siting operations in areas with ample depth and flushing over erosional seafloors, and by monitoring down-current areas, including any sensitive habitats and biologic communities (Price and Morris 2013). To further minimize risk, aquaculture operators can leverage local currents and natural water flow through strategic gear configurations and orientation, which will help optimize fish growth and waste dispersal (Rust et al. 2014). In recent years, better feed formulations and improved feeding efficiency have led to decreased nutrient loading (Price and Morris 2013) and water quality impacts (Rust et al. 2014). Rust et al. (2014) noted that because feeds typically account for over half of the operating costs, operators closely monitor feeding regimes to minimize feed waste. Modern feed formulations aim to reduce solid waste through improvements in digestibility, ingredient selection, and nutrient balance (Cho and Bureau 2001). In their sustainability guidance for aquaculture feeds, Tacon et al. (2022) reiterated the need for continued improvements to aquaculture feed formulations, recommending feed mills establish dedicated research and development programs for in-house testing of feeds, including digestibility of feed ingredients.

Specific operational practices (e.g., fallowing) can decrease potential benthic environmental impacts from uneaten fish feed and fish wastes. Integrated multi-trophic aquaculture (IMTA), a practice of co-cultivating extractive species (e.g. bivalve mollusks, sea cucumbers, marine worms, macroalgae) with feed-required species (e.g. finfish) may increase retention of aquaculture waste. Nederlof et al. (2021) noted that nutrient removal efficiencies for extractive species vary greatly (2-100%) because of cultivation techniques, waste, measuring methods, production intensity and species cultivated; various biological and environmental parameters may limit the retention efficiencies and affect an IMTA system's bioremediation capability. Nederlof et al. (2021) estimated bioremediation efficiencies of 40-50% could be realistic for open aquaculture systems, demonstrating potential for substantial nutrient retention from fish culture by extractive species in IMTA systems. Buck et al. (2018) and Fujita et al. (2023) noted however that technological advancements are still needed for IMTA to be commercially feasible at a large scale in the offshore environment.

4.4.1.5 Escapement

Escaped organisms and reproductive material from any type of aquaculture could cause the introduction of new individuals and new genes to wild populations. Fish escapes are inevitable in aquaculture and have been reported in almost every country where aquaculture facilities operate (Jackson et al. 2015; Glover et al. 2017; McIntosh et al. 2022; Purcell et al. 2024). Although diligence through technology and management can help mitigate escapes, it is nearly impossible to guarantee that cultivated fish and organic material from macroalgae and shellfish aquaculture would never be released from facilities. The risk of adverse impacts on wild populations from fish escapes may depend on the way in which the escape occurs. In the event of an accidental release, many of the fish may be recovered, but it is likely that a small portion of fish would escape into the natural environment. Types of escapes may include:

- Release of reproductive material or larvae during grow-out;
- Leakage escape during normal operational activities including cleaning, maintenance, inventory, net transfers, or harvest; or given normal wear and tear, such as small tears in a net (~release of 10s to 100s);
- Episodic escape given small- to medium-scale loss of infrastructure and episodic failures of gear, during events like a breach by a predator, collapse of one net pen, grow-out container failure or loss, cage malfunction, bag tearing, damage to mooring lines, vessel collisions, or the impact of waves and currents at the farm site (~release 1,000s to 10,000s);
- Large-scale escape and catastrophic escape given a total system or gear failure across a facility. Loss of a substantial portion of a farm system or even the entire farm, (~release of 10,000s to 100,000s).

The environmental consequences of escaped organisms include potential genetic impacts and/or ecological impacts. Potential adverse ecological impacts from interactions with wild populations include increased competition with wild populations for food and space, predation, and the transmission of disease (Flemming et al. 2000; Green et al. 2012; Rhodes et al. 2023a,b). Risk factors that contribute to the likelihood of escaped or dispersed organisms interacting with wild populations include: rate of survival of larvae or other reproductive material; probability of encounter (with wild counterparts and habitat); and rate of successful recruitment (settlement and survival into sexual maturity). These risk factors will vary for each aquaculture operation. For example, some target species reach market size around the same time they reach maturity, allowing them to be harvested before full maturity, but other species may mature during grow-out, creating potential for release of reproductive material and subsequent free-swimming larvae in the water column originating from the farm.

The magnitude and severity of impact varies depending on the number of cultured organisms escaping, their life stage when they may escape, the culture of non-native or naturalized species and the implications for genetic diversity, the frequency of escape events, cultured population husbandry and genetic management (e.g., reproductive capabilities), proximity to wild habitat, and the size, health, and genetic diversity of wild populations (Lorenzen et al. 2012; Atalah and Sanchez-Jerez 2020; Rust et al. 2014. Ecological interactions may have immediate impacts similar to wildlife aggregations, acting on temporally co-occurring populations. Typically, domesticated fish raised in captivity are poor performers and have low fitness in the wild. Escapees quickly become prey to other predators, lessening their potential for food and habitat competition (NMFS 2022).

As soon as reproductive potential is factored into interactions, the potential impacts become additional genetic considerations. The spawning success of escaped/dispersed organisms could vary from them being entirely sterile to being capable of more successful contribution to the next generation compared to wild fish (Purcell et al. 2023 (draft)). Genetic impacts may include the introduction of maladaptive genes and reduced fitness in wild populations, and the loss of genetic diversity within or between populations (McGinnity et al. 2003; Waples et al. 2016). Cultured populations of shellfish and finfish often show reduced genetic diversity compared to wild populations because broodstock represents a small subset of individuals with a fraction of potential wild diversity and given selective breeding processes used in aquaculture. Genetic diversity provides long-term resilience to wild populations from new and future stressors (e.g., temperature stress associated with climate change) (Waples et al. 2012). Loss of genetic diversity in a population could cause the inability to respond to new selective pressure (e.g., environmental changes and pathogens). However, the extent of diversity loss, and the capacity of wild populations to withstand or recover from a loss of diversity is difficult to quantify and varies greatly. In contrast, the immigration of individuals from another population may also act to rapidly increase genetic diversity in wild populations, which could be a benefit.

If escaped or dispersed organisms survive long enough to interbreed with wild populations, reproductive effects would depend on genetic fitness and the biological characteristics of both the escaped/dispersed organisms and the wild populations with which they interact. Data from other countries on the dispersal abilities of cultivated finfish (examples include tagged and recovered Atlantic salmon, farmed cod, Gilthead Sea Bream, and European seabass) show that escaped fish are highly capable of traveling great distances to find their way to wild populations of the same species. However, domesticated fishes have a low probability of surviving in the wild. Studies also show that both male and female domesticated fishes have much lower reproductive success than wild counterparts, although most of the data is limited to Atlantic salmon. Many shellfish species can disperse great distances, ranging from 13 to 100 km (7.0 nm to 54 nm) from their parental sources (Powers et al. 2023).

Escape risks can be managed through strategic siting, engineering design, gear maintenance, and nursery practices. However, any aquaculture operation must account for the potential risk of unintentional releases given factors such as storm events, wave action, vessel collisions, handling mistakes, predator attraction, and gear malfunctions. Potential mitigation measures include broodstock management, genetic diversity monitoring, seeding time, siting, harvest before maturity, and sterilization. Escaped/dispersed organisms and reproductive material are considered biological material and a pollutant that must be considered in the NPDES permitting process. Overall, the likelihood of escapes is high. However, the likelihood of escaped/dispersed organisms contributing significant genetic change to wild populations is species-dependent and variable, but generally not high. The ability for domesticated fishes to survive, and compete with wild fish stocks for food or habitat is low.

4.4.1.6 Introduction of non-native species

The cultivation of non-native species (species outside of their native range) is an interest and concern to regulators and the public, as non-native species have the potential to affect the ecosystem; escapement is the primary concern. Potential impacts to native species and the environment include competition (e.g., food and space), predation, habitat alteration, reproductive inhibition (e.g., spawning site competition), genetic alteration (if escaped individuals were to successfully produce offspring or hybridize with native conspecifics), and pathogen introduction (i.e. non-native pathogens or parasites) (Hill 2008). The potential introduction and establishment of non-native populations is a conservation concern because non-native species can become invasive, which often changes ecosystem functions, and can lead to habitat degradation or loss, and impacts on native species populations.

There are currently no applicants proposing to cultivate non-native species in federal waters of the Gulf. NOAA’s Marine Aquaculture Policy (2011) supports the culture of only native or naturalized species in federal waters unless best available science demonstrates use of non-native or other species in federal waters would not cause undue harm to wild species, habitats, or ecosystems in the event of an escape (NOAA 2011). The potential effects related to introduction of non-native species will be assessed, if applicable, once project-specific details (e.g., proposed site location, culture species, production method and gear, and operational details) of prospective aquaculture operations are developed and proposed through the permit and environmental review process.

4.4.1.7 Use of forage fish in meal and feed

Fish feeds have traditionally relied on fishmeal and fish oil from wild-caught forage fish and other sources of aquatic animal protein and lipids used to produce aquaculture feeds are shellfish, wild-capture fisheries bycatch, seafood processing by-products (both wild-capture and aquaculture), wild harvested zooplankton and macroinvertebrates, and wild-harvested and cultured marine annelid worms (Tacon and Metian 2008a,b 2015; Tacon et al. 2011). Limited supplies of fishmeal and fish oil derived from wild capture fisheries, paired with persistent demand, has led to concerns about the long-term sustainability and management of global wild capture fisheries targeted for the production of these products (Tacon et al. 2011; FAO 2022). Fishmeal and oil sourced from U.S. fisheries are sustainably managed and responsibly harvested in compliance with U.S. regulations. Forage species, including small fishes and invertebrates (e.g. krill) are an important foundation for marine food webs. Changes to forage species populations can have dramatic effects on other populations (Enticknap 2011; CDFW 2016b; PFMC 2016). Smaller fishes may be subject to increased predation if large predatory fishes, seabirds, or marine mammals are present in wildlife aggregations around any aquaculture gear. The potential of using forage fish in fishmeal and feeds will be assessed once project-specific details (e.g., culture species, production method and fish feeds that may be used) when prospective aquaculture operations are developed and proposed through the permit and environmental review process.

4.4.1.8 Disease and pathogen transmission

Transmission of pathogens and disease between wild and cultured organisms is a prominent concern for aquaculture producers, natural resource managers, and the general public. In fact, the FAO recognizes disease as a major constraint to global aquaculture production (Subasinghe et al. 2023). The proximity of wild species to aquaculture operations presents the opportunity for potential pathogen transmission and transfer (Rhodes et al. 2023). Infectious diseases, a subset of diseases, are ecological interactions involving two or more organisms; these interactions require three elements: (1) a susceptible host, (2) a pathogen capable of infection, and (3) an environment favorable to disease development (Figure 4.4.1.8-1; Rhodes et al. 2023). Biosecurity management is typically directed toward one of these elements to minimize or reduce disease risk (Rhodes et al. 2023).

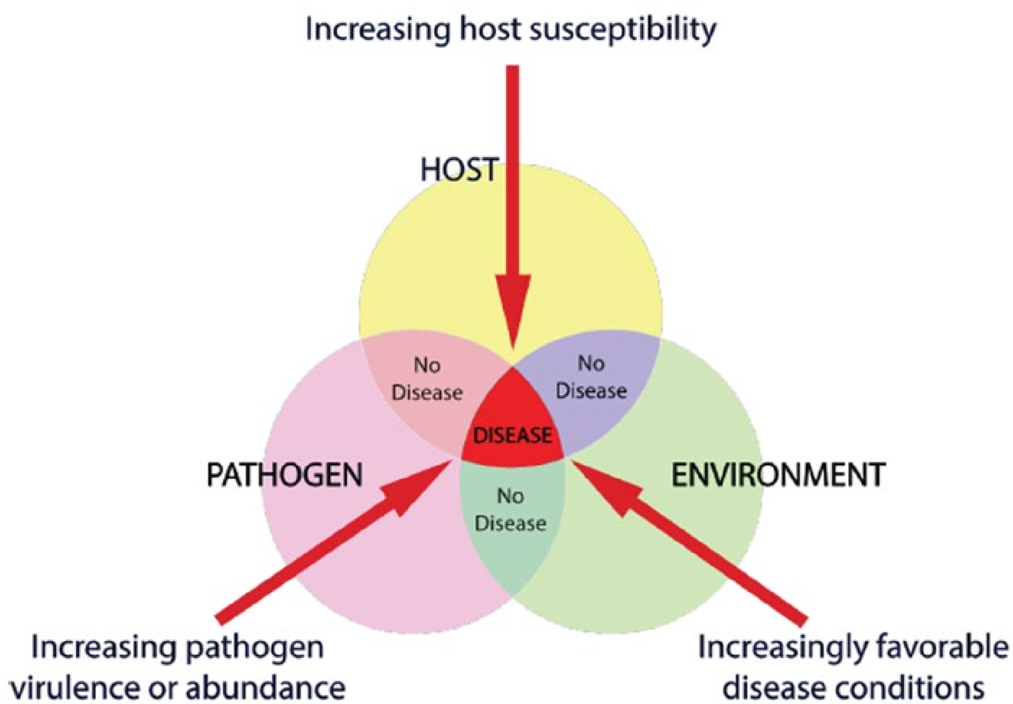

Figure 4.4.1.8-1. Conceptual model of infectious disease development. The three elements required for disease occurrence are represented as circles. Red arrows represent vectors driving elements toward greater likelihood of disease occurrence. *Source: Rhodes et al., 2023; adapted from Snieszko 1974.*

Although some pathogens have a high likelihood of infecting a susceptible host, many pathogens are commonly found on the host or in the environment without causing disease, becoming pathogenic when host susceptibility increases or environmental conditions become conducive to infection. Pathogens are categorized into three groups: viruses, bacteria, and parasites (e.g., protozoans, fungi, and worms) (Rhodes et al. 2023). Viruses are completely dependent upon a host to persist and replicate, whereas bacteria are often capable of survival and replication without a host (Rhodes et al. 2023). The vast majority of identified bacteria are not known to be pathogenic, and many pathogenic bacteria are considered opportunistic - not dependent on a host to survive, but capable of colonizing a host when environmental conditions favor pathogenicity or host susceptibility increases, often given injury, stress, illness, or compromised immune system (Rhodes et al. 2023). Rhodes et al. (2023) indicated opportunistic bacterial infections were a concern for marine aquaculture, since disease vectors are often present in the natural environment and exposure is generally difficult or impossible to avoid. Parasites (the term used in this document to encompass pathogens other than viruses and bacteria) vary in size and complexity, from unicellular microorganisms to metazoans (e.g., sea lice) (Rhodes et al. 2023).

There are two major mechanisms of pathogen transfer and transmission: horizontal transmission occurs between susceptible hosts and vertical transmission occurs between broodstock and their offspring (Rhodes et al. 2023). Vertical transmission is an important consideration during broodstock and seed procurement and spawning; control of vertical transmission relies largely on quarantine, screening for specific pathogens, and surface decontamination (e.g., treatment of eggs) (Rhodes et al. 2023). Horizontal transmission may occur through direct or indirect transfer between susceptible hosts, and is the principal pathway for pathogen spread (Rhodes et al. 2023). Methods to control horizontal transmission of pathogens may include culling or isolation of diseased organisms and treatment with approved therapeutants. Rhodes et al. (2023) reported the common modes of horizontal pathogen transmission include waterborne transmission, direct contact, the associated with organisms that can carry a pathogen, the associated with a pathogen-contaminated inanimate materials, and active pathogen movement from an infected host to a susceptible host:

Waterborne transmission may occur via release from an infected host into water, and subsequent direct uptake from water by a susceptible host. Aquatic organisms may become infected when a pathogen attaches or invades surfaces, such as gills, gastrointestinal tract, or skin. Variables including temperature and water chemistry can affect infection severity and likelihood of disease. As health status of the host organism dictates to some extent the degree of susceptibility to a given level of pathogen of exposure, understanding hydrodynamic transport and residence time of a pathogen can be used to estimate the probabilities of disease transfer between farms and can inform farm siting and spacing.

Potential pathogen transfer routes between wild and aquaculture organisms depends on various factors, including but not limited to the species (wild and cultivated), aquaculture system design, culture setting, and husbandry operations; offshore aquaculture systems generally have free seawater exchange with limited barriers to pathogen flow between the culture system and surrounding environment (Rhodes et al. 2023). Tracing the direction of pathogen transmission can be challenging, and many reports of disease transfer between wild and farmed populations have been based on correlation or coincidence (Lafferty et al. 2015 as cited in Rhodes et al. 2023). Nonetheless, Rhodes et al. (2023) noted the correlative data between infections in net pen salmon and proximal wild fish infestations have supported the likelihood that disease spillover occurs (e.g., Thorstad et al. 2015; Vollset et al. 2018), although it is not clear whether aquaculture operations are the sole contributors to such infestations (DFO 2023; Rhodes et al. 2023). As salmonid production constitutes approximately 60% of global marine finfish aquaculture (Carballeira et al. 2021), much of the research on pathogen transfer between wild and cultured finfish is representative of this particular type of production (Rhodes et al. 2023). However, pathogen transfer dynamics may differ under different environmental conditions (e.g., offshore vs. nearshore environment; water flow dynamics) and husbandry practices (e.g., culture density). Pathogen persistence in the marine environment is influenced by various factors including temperature, salinity, and ultraviolet radiation (i.e., sunlight) exposure, and conditions conducive to persistence vary between organisms (Rhodes et al. 2023); hydrology and water flow dynamics also impact pathogen transport.

Pathogens that are capable of infecting multiple host species can increase the opportunity for pathogen transmission (Kurath and Winton 2011; Rhodes et al. 2023). The potential for direct contact and water-borne pathogen transmission may increase when aquaculture operations attract other fish, marine mammals, or seabirds, which could function as pathogen vectors or reservoirs (Rhodes et al. 2023). Potential pathways for pathogen transfer between cultured and wild populations are presented in Table 4.4.1.8-1.

Table 4.4.1.8-1. Descriptions of pathways for pathogen transfers between aquaculture and wild populations. "Intraspecific" and "interspecific" refer to host organisms. *Source: adapted from Rhodes et al. 2023 and Bouwmeester et al. 2020.*

Intraspecific or interspecific pathogen transfer from introduced to endemic populations (spillover).	Pathogen present in introduced species is transferred to the same host species (intraspecific) or to a different host species (interspecific) in endemic populations.
Intraspecific or interspecific pathogen transfer from endemic to introduced populations (spillback).	Pathogen present in endemic species is transferred to the same host species (intraspecific) or to a different host species (interspecific) in introduced populations. If the introduced species is cultivated at densities higher than endemic densities, infection levels can increase.
Pathogen transmission interference or pathogen dilution.	Presence of cultured species or nearby wild species affects the transmission of wild pathogens, such as a sink for pathogens.

Aquaculture species usually begin life in a hatchery or nursery located either on land or in the nearshore environment, including those cultivated in the offshore environment. Depending on the species, wild broodstock may be captured for breeding or sourced from an established breeding program (Rhodes et al. 2023). Wild-sourced broodstock, gametes, or eggs, and those obtained from other sources external to the facility (e.g., other aquaculture producers), may introduce pathogens to the culture facility; sourcing stocks from verified pathogen-free sources (available for some species/species groups), or quarantining and screening incoming stocks for specific pathogens are effective measures for minimizing risk (Murray et al. 2022). The USDA-

APHIS National Aquaculture Health Plan and Standards states that rearing facilities should be stocked only with organisms of known health status, and requires hatcheries under their purview to participate in health inspection standards (USDA APHIS 2021). The U.S. Fish and Wildlife Service's Handbook of Aquatic Animal Health Procedures and Protocols details procedures for inspecting, testing, and managing incoming broodstock (USFWS 2022). The American Fisheries Society's Fish Health Section (AFS FHS) publishes a fish health manual, the Blue Book[31], which outlines health inspection and diagnostic methods for fish health; this manual, which is developed by the largest organization of fish health professionals in the U.S., is widely adopted by government and industry entities (Rhodes et al. 2023).

Hatchery or nursery water is another potential pathway for pathogens to be introduced into culture systems, and managing this risk can be especially challenging in flow-through facilities; to minimize these risks, some facilities use well water, particularly for rearing the earliest and most sensitive life stages (Rhodes et al. 2023). Filtration and UV irradiation are common but expensive (especially at large scale/water volume) method for treating production water; utilizing recirculating aquaculture system (RAS) technologies may substantially decrease influent water volume need and the associated potential for waterborne pathogen ingress. Pathogen risk reduction through the development of disease-resistant strains of plants and animals to be used in cultivation is well-established in agriculture and aquaculture (Rhodes et al. 2023). In the U.S., there are state- and species-specific regulations and requirements for the interstate movement of marine and aquatic species, including aquaculture stocks. The Regional Shellfish Seed Biosecurity Program (RSSBP) facilitates interstate movement of bivalve seed and larvae sold from East Coast hatcheries through the implementation of a voluntary biosecurity validation and compliance process that streamlines interstate shipment approvals for hatchery facilities enrolled in the program (RSSBP 2024).

Marine offshore aquaculture involves the transportation of species, personnel, equipment, and supplies between land and culture sites, and in some cases between culture sites; this activity increases the risk for the release of pathogens along the route, especially when moving species or harvest product (Rhodes et al. 2023). One transport-related area of particular consideration is the use of well boats to transport fish and equipment; older vessel designs may be more difficult to disinfect between trips compared to newer models, which are generally designed to be conducive to frequent disinfection as routine biosecurity protocol (Rhodes et al. 2023). Ballast water of vessels used to service aquaculture facilities is another area of pathogen transfer consideration; to minimize risks, aquaculture operators may limit the taking or discharging of ballast water within a certain distance from aquaculture operations.

The proximity between cultured and wild organisms presents the potential for pathogen transfer, and facilities that aggregate wild species can increase the risk (Rhode et al. 2023). In addition to

[31] https://units.fisheries.org/fhs/fish-health-section-blue-book-2020/

pathogen transfer considerations, persistent predator presence can heighten stress of cultured animals that may in turn contribute to immunosuppression and increased susceptibility to disease (Ashley 2007). Organic material (for example, from feces or feed) can also function as a supportive environment for certain types of pathogens, causing longer persistence and increased opportunity to infect a host (Gerba and Schaiberger, 1975; Rhodes et al. 2023). Implementing best practices for administering feed (appropriate feed type and formulation, amount, and schedule) can minimize unconsumed feed waste at aquaculture operations, decreasing the risk associated with the potential wildlife attraction factor. Proper management of farmed species mortalities is critical for limiting potential pathogen release and reducing the attraction of predators (Rhodes et al. 2023). Biosecurity measures include securing mortalities in non-leaking containers for transport to shore, disinfection of gear that comes in contact with carcasses, and avoiding transport of mortalities between farm sites (Rhodes et al. 2023). Under the NPDES regulations, disposal of carcasses directly into seawater is not permissible.

Climate change-induced effects on temperature and ocean chemistry are anticipated to affect pathogen distribution, abundance, and ability to cause disease (Rhodes et al. 2023). Poor environmental conditions can cause chronic stresses that can contribute to disease development. The potential effects of climate change on pathogen and disease dynamics is a critical factor for all current and prospective aquaculture operators to consider during planning.

4.4.1.9. Antibiotic Use

Some aquaculture operations may use antibiotics for cultured stocks, depending on the system and approved use. In the U.S., the use of antibiotics in aquaculture production is highly regulated by the FDA under various laws and there are currently no antibiotics approved for use in the open ocean environment for warm water marine species. The FDA Center for Veterinary Medicine maintains a list of approved drugs for aquaculture[32] , which has primarily focused on freshwater aquaculture species to date, (FDA 2024), and regulates the manufacture and distribution of food additives and drugs that may be administered to aquatic animals. All FDA-approved antibiotics for use in animals require a veterinary feed directive if administered in feed, or a veterinary prescription if administered by other routes (FDA, 2023, Rhodes et al. 2023). The administration of antimicrobials, prescription, and veterinary feed directive drugs in the United States requires a valid veterinarian–client–patient relationship (Rhodes et al. 2023; AVMA 2024).

[32] https://www.fda.gov/animal-veterinary/aquaculture/approved-aquaculture-drugs

Shellfish and finfish all may bioaccumulate antibiotic residuals, heavy metals, or other pollutants that may be found in the water column as a result of antibiotics, antimicrobials, antiparasitics medications, vaccines, other medical preventatives, and other husbandry materials. Antibiotic residuals have been shown to occur around marine aquaculture, which can induce changes to water quality and have the potential to be toxic to marine life (Zhang et al. 2023). Disease prevention and response for finfish may include vaccination, probiotics, immunostimulatory molecules, antimicrobial peptides, or antibiotics. However, the use of antibiotics in finfish aquaculture globally is not high, and is expected to be even lower in the offshore environment given improved water quality, fewer interactions with host fish, and less biofouling (Rensel and Forster 2007; Hjeltnes et al. 2018).

4.4.1.10 Marine Debris

Fish and invertebrates may be adversely or beneficially impacted by marine debris generated from aquaculture operations. Beneficial impacts may be similar to the effects of new wildlife aggregations around structures. Adverse impacts of marine debris include entanglement, ingestion, and alteration of habitat. Materials used in offshore aquaculture can include plastics, steel, and copper alloy mesh or copper treated nets (Fujita et al. 2022). Materials could degrade over time and be a source of microplastic pollution (Skirtun et al. 2022; Lin et al. 2022), leach into the water column or organismal tissues (Brooks et al. 2003; Chow and Schell 1978; Kalantzi et al. 2016; Talsness 2009; Barnes et al. 2009; Spykra 2017) or become a source of persistent organic pollutants (Barnes et al. 2009). In particular, aquaculture operations can be a source of plastic pollution in the marine environment (Arantzamendi et al. 2022; Skirtun et al. 2022) given the the materials used to construct and secure the aquaculture equipment (i.e. buoys, plastic pipes, mesh netting). Storms can increase the risk of aquaculture operation components (e.g., cages, nets) from becoming loose or breaking free and entering the marine environment. Marine debris from aquaculture operations can cause various problems for marine life, including becoming a biosecurity risk for the spread of non-native marine species (Campbell et al. 2017). However, mitigation measures and BMPs can reduce the risk to the marine resources. Various mitigation measures have been identified to limit marine debris from aquaculture operations, such as routinely monitoring, maintaining, and replacing gear (Arantzamendi et al. 2022; Skirtun et al. 2022).

Aquaculture operations can be a source of plastic pollution in the marine environment (Arantzamendi et al. 2022; Skirtun et al. 2022) given the various plastics and other materials used to construct and secure the aquaculture gear (i.e. buoys, plastic pipes, mesh netting). In addition to being generally harmful to various fish species and invertebrates, marine debris can impact giant manta rays because it can often pass through and become logged in their large gills during feeding (Germanov et al. 2019). The likelihood that expended items would cause a potential impact on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item.

Accidentally-discarded or lost gear or other supplies from an aquaculture facility could cause marine debris interacting with wild fish stocks. Potential adverse effects of marine debris on EFH is described on pp. 187 through 189 of Kiffney et al. (2022), incorporated by reference. These interactions may not be adverse, but exposes individuals to risks of adverse impacts including entanglement, suffocation, starvation if ingested, smothering/covering, or alteration of the benthic invertebrate community (Katsanevakis et al. 2007; Gregory 2009; EPA 2011; Kuhn et al. 2015; CalOPC 2018; ONMS 2020; Bath et al. 2023). When tangled, animals are more susceptible to other threats including injury, predation, and infections (ONMS 2020). When ingested, marine debris can increase tissue contamination, cellular damage (e.g. tissue erosion or tumors), and reproductive issues (Schiff et al. 2000; USFWS 2005; Komoroske et al. 2011; LA RWQCB 2011; Spyrka 2017). Longer-living species are at higher risk given bioaccumulation of heavy metals and tissue contamination over time and through the food web.

4.4.1.11 Comparison of the Alternatives

Alternative 1 (No Action) serves as the existing baseline against which to compare all of the action alternatives. Under **Alternative 1 (No Action),** aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

The offshore environmental and oceanic conditions are similar within **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13). Therefore, the impacts to fish and invertebrates associated with siting aquaculture operations in any of these areas are expected to be comparable in terms of magnitude and severity. Although Riley et al. (2021) evaluated, scored, and developed the most suitable areas for siting aquaculture given the environmental conditions, and the biological and human environments, it is difficult to distinguish and compare among the AOA Alternatives. The risk of injury caused by noise, and light is expected to be the same across all of the AOA Alternatives and that risk is expected to be low regardless of the area. The number of vessels associated with any facility is expected to be generally low; thus, noise related to the deployment and operations will be limited in area and duration, and potential impacts from lights would be localized. Similarly, potential impacts from fish waste and unconsumed feed, escapement, disease and pathogen transmission, antibiotics, and marine debris are likely to be the same across all of the Alternatives, and impacts (severity and magnitude) will depend on the operations of a specific facility.

The risks related to species aggregations around aquaculture facilities are expected to be low for manta rays, sharks, and fishes. These risks could vary slightly by geographical location given the difference in marine species abundance and distribution between the central and western Gulf. **Alternative 6** (C-13) could potentially attract more inshore species than **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) because it is located closer to shore. For example, there could be more coastal migratory sharks than pelagic sharks at **Alternative 6** (C-13) because coastal migratory sharks (e.g., blacktip and bull sharks) are more likely to be attracted to nearshore aquaculture operations than pelagic sharks (e.g., common thresher shark and shortfin mako shark); pelagic sharks pursue fast-swimming prey (e.g., squid, mackerel, and bluefish) in the open-ocean environment (Wood et al. 2009). Coastal migratory sharks could also be found at the **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) , but their relative abundance would probably be less than **Alternative 6** (C-13).

4.4.2 Potential Impacts on ESA-listed Species

This section discusses the potential impacts generally associated with offshore aquaculture, and how those impacts might affect protected species described in Section 3.3 (ESA-listed corals, sea turtles, the giant manta ray, and Rice's whale). This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. ESA-listed birds are discussed in Section 3.3.5. Stressors that may impact ESA-listed species include: entanglement and entrapment, vessel strikes, acoustic disturbances, light disturbances, wild species aggregations, fish waste and unconsumed food, antibiotic use, and marine debris. Stressors vary in intensity, frequency, duration, and location. There is no overlap between any of the AOA alternatives and any existing critical habitat for ESA-listed species, but there may be overlap with proposed critical habitat for green sea turtles which includes Sargassum habitat (from 10 meters depth to the U.S. EEZ) in the Gulf. The proposed critical habitat for Rice's whale is in close proximity to many of the AOA alternatives. Impacts on critical habitat, if and when finalized, would be considered in future environmental planning and consultation. Generally, known areas of importance for protected species were avoided in the marine spatial planning process, which is expected to minimize impacts on protected species and their habitats.

4.4.2.1 Entanglement and Entrapment

Offshore aquaculture components can potentially cause serious injury or mortality to various marine species, including protected species. Aquaculture operations use lines, nets, buoys, and various anchoring equipment, which can entangle marine species. For example, sea turtles are at risk of entanglement given their migratory behavior, morphology, and feeding habits (Hamelin 2017). Currently, there are few published reports of sea turtles being entangled in aquaculture facilities; however, available information indicates leatherback (*Dermochelys coriacea*) sea turtles have become entangled at shellfish operations in Canada and the Northeastern U.S. (Bath et al. 2023). Leatherback sea turtles may be the most likely to become entangled given their body morphology (i.e., large size, long pectoral flippers, and lack of a hard shell) and attraction to gelatinous organisms and algae that can collect on aquaculture structural components.

Giant manta rays are susceptible to entanglement in commercial and recreational fisheries given their large body and shape. Entanglements may cause injury, and even death. Manta rays are obligate ram ventilators, meaning that they need to swim constantly to "breathe." Therefore, entanglement that prohibits movement will cause asphyxiation. Globally, manta rays are vulnerable to entanglement by various fishing gears, particularly surface drift gillnets and bottom set nets deployed in neritic waters (<50 m [164 ft]) (Andrzejaczek, et. al. 2021). Giant manta rays are at-risk to the netting used in aquaculture since it is similar to fishing nets.

Entanglement is a major threat to large whales. The degree of risk from direct fishery interactions is a function of the degree of spatial overlap between fishing effort and whale habitat, whale size and behavior, and the likelihood that an interaction will cause serious injury or mortality for a specific gear type (Benjamins et al. 2014). Bottom longline fishing gear poses an entanglement threat mainly to cetaceans that feed along the bottom. The mooring lines used in aquaculture could pose a similar risk to cetaceans that feed near the bottom. Relatively little is known about Rice's whales' foraging ecology and diet but limited tagging data suggest they spend the daytime diving near the floor to feed and therefore they may be vulnerable to this type of impact. There have been two historical Rice's whale strandings in the Gulf where they were entangled in fishing gear, but it was unclear whether the gear caused the death; there have been no known serious injuries or mortalities of Rice's whales from interactions with fisheries since 2003. Bryde's whales (closely related to Rice's whales - similar size and body shape), have been entangled in several New Zealand and South African commercial fisheries (Segre et al. 2022). Overall, 17 Bryde's whales were entangled, 10 fatally so, during 2014 through 2021 (Segre et al. 2022). Various other species of large whales (humpback, minke, right, Bryde's, and short-finned pilot whales) have also been entangled in mussel, oyster, and finfish aquaculture gear, though entanglement of whales at aquaculture farms is rare with fewer than 20 whale mortalities reported globally given aquaculture interactions (Bath et al. 2023). The scientific literature shows many whale species are vulnerable to fishing and aquaculture gear. As such, entanglement is a major issue that needs to be fully examined during the individual permit and regulatory review process for an individual aquaculture project.

4.4.2.2 Vessel Strikes

Many marine species are susceptible to vessel collisions or strikes, including species protected under the ESA. Offshore aquaculture operations (i.e. installation, maintenance, and harvesting) will require various types and sizes of vessels and the operation of these vessels could alter the normal behaviors of, or collide with, marine animals, including protected species. Vessel strikes are a major conservation issue for various large whales and other protected species. Injury and mortality of protected species have been directly linked to various types of commercial and recreational vessels and the likelihood of an interaction is generally associated with vessel traffic, and vessel speed and size.

Collisions involving vessels and whales are a major conservation concern around the world given the number of incidents, but the number of injuries and mortalities are probably much higher than reported given underreporting and undetected incidents, especially from large ships traveling at high speeds at night. In the U.S., many vessel strikes with whales are reported along the Atlantic coast and are a major concern for whales that spend a lot of time near the surface (Constantine et al. 2015), like the Rice's whale. In the Gulf, Soldevilla (2017) discovered the Rice's whale spends 70% of its time within 15 m of the surface, making it vulnerable to vessel strikes. At night, it spent even more time (88%) at these shallow depths. In 2009, a vessel strike and subsequent mortality of an adult female Rice's whale was reported near Tampa, FL in 2019, NOAA scientists photographed a free-swimming Rice's whale with a severely deformed spine, which was likely caused by a vessel strike. Rice's whale are vulnerable to ship strikes, especially at night in offshore waters.

Sea turtles may experience stress from being startled by a vessel in transit (to and from the aquaculture operation) or when encountering vessels engaging in aquaculture-related activities at the operation site. Sea turtles are most susceptible to vessel strikes when they surface to breathe, reproduce, feed, bask, mate and orient themselves to their surroundings (Fuentes et. al. 2021) and since sea turtles rely primarily on visual cues to detect vessels (Hazel et al. 2007), they may have limited time and ability to avoid vessel strikes. In the Southeastern U.S. and Gulf, sea turtle vessel strikes are becoming more frequent, given the rise in recreational vessels (Fuentes et al. 2021). In Florida, over 30% of all stranded sea turtles had injuries consistent with a vessel strike (Foley et al. 2019). While sea turtles can survive injuries from vessel strikes, it can often lead to other health issues, such as reduced feeding efficiency.

Giant manta rays are susceptible to vessel strikes because they spend a significant amount of time on the surface foraging, undergoing social interactions, cleaning, and cruising (Burgess 2017). As such, they are susceptible to severe injuries from boat strikes and propellers (McGregor et al. 2019; Stevens and Froman 2019). While manta rays are known to heal rapidly from vessel strike injuries, similar to other elasmobranchs, recovery takes a significant amount of metabolic energy, which may reduce fitness (Strike et al. 2022).

4.4.2.3 Acoustic Disturbances

Anthropogenic noise associated with offshore aquaculture operations may affect the marine environment and marine species, including protected resources. Construction, specifically associated with finfish cage assembly (connecting cage spars or metal posts, i.e. "framing") could cause open ocean underwater noise exceeding the behavioral threshold and/or physiological/injury noise threshold for sea turtles and marine mammals (Bath et al. 2023). Bath et al. (2023) characterizes sound sources as impulsive or non-impulsive and intermittent or continuous. Sound disturbance can also be generated from vessels and the equipment used in aquaculture operations, decommissioning, or during site surveys (i.e. generators, sonar, automatic fish feeders, acoustic deterrents).

Factors that may affect an animal's reaction include the acoustic characteristics of the introduced sound (i.e., frequency, duration, and intensity), the physical characteristics of the habitat; the baseline soundscape, interactions with other sound sources, the animals' use of the habitat and activity at the time of exposure (e.g., feeding, traveling, resting), the animal's physical condition, prior experience with the sound, the context of the exposure (e.g., in a semi-enclosed bay vs open ocean), and proximity to the source of the sound (US Navy 2018). Despite the complexity, researchers have shown that a common response of marine animals to a potentially damaging or disruptive sound pressure level is avoidance. Avoidance can cause or alter behavior, such as displacing species from important foraging grounds and otherwise interfere with key life functions (National Research Council 2003).

Anthropogenic underwater noise can interfere with key life functions of marine mammals (e.g., foraging, mating, nursing, resting, migrating) by impairing hearing sensitivity, masking acoustic signals, altering communication patterns, eliciting behavioral responses, or causing physiological stress; all of which may cause habitat displacement (National Research Council 2023). As noted above, sound sources from aquaculture operations may be generated from vessel activity, construction, or general operations. Vessel noise overlaps with the low-frequency hearing ranges of marine mammals and may affect an animal at some distance from the source given long-range sound propagation at low frequencies (Erbe 2019). The extent of the sound propagation throughout the marine environment is highly project dependent and depends on many factors, such as vessel size, speed, the size, material, the method for pile driving and the equipment and methods used for construction. Similar to other anthropogenic sound sources, the sound levels associated with any aspect of aquaculture operations significantly decrease with increasing distance from the acoustic source. The sound pressure waves spread out under the influence of the surrounding receiving environment, referred to as transmission loss. With increasing distance from a noise source, potential acoustic impacts can range from physiological injury to permanent or temporary hearing loss, behavioral changes, and acoustic masking (i.e., communication interference).

Impulsive sounds may cause injury in fishes and sea turtles. Non-impulsive sound sources have not been known to cause direct injury or mortality to fish or sea turtles under conditions that would be found in the wild (U.S. Navy 2018). Underwater noise impacts to sea turtles are not completely understood (Popper et. al. 2014). In general, sea turtles hear best between 200 to 750 Hz and do not hear well above 1 kHz. Sea turtles are also generally less sensitive to sound than marine mammals, with the most sensitive hearing thresholds at or above 75 dB re 1 µPa (Reese et al. 2023). ESA-listed sea turtles and fish would be more likely to experience masking, physiological stress, and behavioral reactions to any acoustic disturbances, although risk would be low even close to a sound source.

4.4.2.4 Light Disturbances

Although only localized effects are possible based on the small spatial footprint (illuminated area) and the rapid attenuation of light underwater, artificial lights could affect the prey species behavior surrounding the aquaculture structures. Artificial light can concentrate small and medium-size fishes and thereby attract cetaceans, or disrupt the diel vertical patterns of zooplankton or fish, which are often the prey of marine mammals (Orr et al. 2013). Excess lighting in the water column has the potential to disrupt marine mammal foraging behavior. A potential beneficial impact is that artificial lighting around man-made structures may reduce the risk of collision between the man-made structures and marine mammals (Orr et al. 2013). Artificial light is also a conservation concern for nesting sea turtles and sea turtle hatchlings because their vision can become impaired, causing them to be misoriented, disoriented, or both (Yen et al. 2023).

4.4.2.5 Wild Species Aggregation

Artificial structures alter natural habitat, which may influence local biodiversity and ecosystem functions. Artificial structures can attract numerous marine species from small fishes to pelagic species, including marine mammals and sea turtles. Fish tend to aggregate around man-made structures to hide against currents and predators, increase feeding efficiency, and provide nursery and recruitment sites (Reubens et al. 2013). Thus, offshore aquaculture structures (e.g., cages) can attract marine life like an artificial reef or fish aggregating device (FAD); artificial reefs, oil and gas platforms, and wind farm structures support various marine species. Aquaculture structures have the potential to not only attract marine life, but provide nutrients (i.e. excess fish feed) to numerous fishes. For example, visual surveys (pre and post-installation) at one aquaculture site in Puerto Rico showed species richness and abundance of wild species increased after the finfish aquaculture grow-out structures were deployed and secured (Alston et al. 2005).

Aquaculture structures may also potentially attract sea turtles. Sea turtles are commonly reported at artificial reefs (submerged structures) because they can provide various ecological functions, such as foraging and sheltering habitat (Barnette 2017). The increased abundance of species may provide foraging opportunities for sea turtles transiting the region. In areas with minimal hard bottom habitat or structural relief, aquaculture structures may provide important inter-nesting habitat for sea turtles (Barnette 2017). Offshore aquaculture structures may provide beneficial impacts to sea turtles by providing foraging opportunities. Offshore aquaculture structures may also aggregate for the prey for the giant manta ray, such as euphausiids, copepods, mysids, decapod larvae, shrimp, and small pelagic fish species. However, it could also alter normal behavior by causing site fidelity (Pate 2020).

The presence of offshore aquaculture operations could potentially cause behavioral modifications in marine mammals by aggregating prey and providing unnatural foraging opportunities. Bottlenose dolphins are attracted to finfish aquaculture operations around the world, including Australia, Greece, Italy, Hawaii, and throughout the Mediterranean (Harnish et al. 2023). This attraction to finfish operations has caused behavioral modifications in dolphins, such as exhibiting aggression; fighting for prey located within and around the fish cages (Harnish et al. 2023). In the northern Mediterranean, bottlenose dolphins were observed foraging on wild fish species near fish aquaculture cages and feeding on discarded or escaped fish (Diaz 2012;

Bonizzoni et al. 2014). It is unknown how these effects may impact Rice's whales since relatively little is known about their foraging ecology and diet.

As explained in Section 4.4.1.3, aquaculture operations also have the potential to attract large sharks. Thus, it is even possible that protected species co-occurring with offshore finfish aquaculture operations could be at risk from shark predation. Large predatory sharks (e.g., tiger *Galeocerdo cuvier* and bull *Carcharhinus leucas*) and cetaceans (e.g., false killer whales *Pseudorca crassidens* and orca *Orcinus orca*) are known to prey on adult manta rays (Strike et. al. 2022). Even unsuccessful predation attempts can leave permanent injuries ranging from small, quick-healing flesh wounds, with little or no tissue loss, to severe bites, which truncate or disfigure pectoral fins of manta rays (Strike, et. al. 2022). Sharks may also prey on whales, which make up a large portion of the diet for some shark species. Off Brazil, Bornatowski, et al. (2012) found humpback whales (*Megaptera novaeangliae*) had bite scars from large sharks, indicating sharks sometimes target humpback whales in the region.

Given aquaculture operations can attract fish, it is possible that these systems will attract recreational anglers, which could increase protected species and hook and line interactions. Sea turtles could be vulnerable to hook and line gear since sea turtles are known to bite baited hooks.

4.4.2.6 Waste and Unconsumed Feed

Section 4.4.1.4 presents information on the general impacts of waste and unconsumed feed. Water quality issues are linked to increased nutrient (e.g., phosphorus, nitrogen, and carbon), ammonia, and turbidity levels, and decreased dissolved oxygen concentrations. Sediment impacts include total organic carbon, redox potential, free sulfides, abundance and diversity of marine organisms (Rust et al. 2014), and total volatile solids (TVS). Elevated concentrations of sulfides (metabolites of sulfate-reducing bacteria) may occur in areas of organic enrichment beneath aquaculture operations, when conditions are anaerobic (Holmer and Kristensen 1992; Kristensen 2000; Heijs et al. 2000). Redox potential (eH) is an indicator of the sediment's stability and reduction and oxidation attributes; researchers have reported anoxic conditions and negative redox potentials in sediments near aquaculture operations (Wu et al. 1994; Pawar et al. 2001). Other environmental issues include suspended solids, pH, and chlorophyll-a (an indicator of phytoplankton algae presence and abundance). Monitoring environmental indicators can help inform aquaculture management on fallowing, feeding practices, and harvest (Rust et al. 2014). These types of impacts may potentially adversely affect protected corals nearby.

Benthic impacts can occur when the decomposition rate of uneaten fish feed and fish waste is too slow, causing an accumulation of solids and nutrients. Porrello et al. (2005) reports the settlement rate of particulate waste is a function of current speed, with lower-velocity currents causing more waste accumulation than high-velocity currents. Depositional sites tend to accumulate organic matter (Rust et al. 2014), while particulate accumulation is unlikely to occur on erosional seafloors (Kalantzi and Karakassis, 2006) because there is greater material dispersion and subsequent decomposition and assimilation (Holmer et al. 2005; Phillips 2005; Giles 2008).

Sediment quality near aquaculture operations is sometimes determined by the feed composition and size (i.e. pellet feed) (Pawar, Matsuda and Fujisaki 2002). Feed settling rates vary by feed type, with slower sinking feeds causing greater dispersion. Feed quality and feed management are important considerations with respect to potential environmental effects. Hasan and New (2013) indicate the use of feed formulations are insufficient to satisfy nutritional needs and specific life stage feeding efficiencies. Inappropriate feeding practices can cause overfeeding, increased feed waste and nutrients, and risk for environmental impacts (Hasan and New 2013). Hasan and New (2013) found that farmers using commercially compounded feeds are often provided with feeding tables and access to technical support to determine appropriate feed rationing and schedules; however, these procedures are not always followed or used effectively. Hasan and New (2013) note that it is in the feed manufacturer's best interest to ensure their feeds are used properly, as inefficient utilization of their products may cause the perception of poor growth response, causing farmers to change suppliers.

Nash et al. (2008) reported a group of international experts identified increased organic loading and inorganic loading as two major categories of 'observed or perceived' effects associated with marine finfish aquaculture. Identified sources of organic loading include particulate sources (fish fecal material and uneaten fish feed), including soluble organic sources and dissolved components of uneaten feed. Inorganic loading sources include nitrogen and phosphorus from fish excretory products and trace elements and micronutrients from fish fecal matter and uneaten feed (Nash et al. 2008). Fujita et al. (2023) report that at nearshore aquaculture operations, an estimated 45% of the nitrogen and 18% of the phosphorus is excreted, and detections have been reported 1-2 km from aquaculture cages (Weitzman et al. 2019). Fujita et al. (2023) note that while metabolic waste products have sometimes caused eutrophication and low oxygen conditions at some nearshore aquaculture facilities, similar impacts are not expected to occur at offshore facilities given the assumption that increased flushing rates will aid dispersion. However, Fujita et al. (2023) caution that it is still possible for impacts to occur, especially when considering cumulative impacts, and the dynamic nature of nutrient fate. Buck et al. (2018) reiterated the importance of prudent farm siting and monitoring to ensure environmental thresholds are not approached or exceeded.

In terms of evaluating potential impacts associated with future offshore aquaculture operations in the Gulf, the most comparable operations are those off Panama given the location (~ 13 km offshore) and cultured species (cobia [*Rachycentron canadum*]), and method (22 cages). Similar to other researchers, Welch et al. (2019) found no significant difference between water samples taken upstream and downstream of the operation, but did discover some sediment enrichment near the cages. Welch et al. (2019) noted, with cautious optimism, that the study demonstrates that appropriately sited commercial-scale offshore aquaculture operations have minimal water quality impacts.

Degraded water quality has been observed at farms in nearshore areas with limited water exchange. However, when aquaculture farms are sited in well-flushed environments, water quality effects are typically not observed at distances greater than 30 m (98 ft) from the cages (Price and Morris 2013). While nutrient spikes and dissolved oxygen decreases have been observed after feedings, monitoring data collected from marine fish operations (Alston et al. 2005; Lee et al. 2006; Langan 2007) usually show few significant or persistent water quality or benthic issues (Price and Morris 2013; Rust et al. 2014).

Unconsumed fish feed and fish waste from offshore aquaculture operations may affect proximal water quality, sediments, and the marine organisms living within or vicinity. However, proper siting can help avoid important benthic and sensitive habitats, and find areas with sufficient depth and current flow to reduce nutrient concentrations associated with aquaculture operations to levels compatible with the ecological carrying capacity of a region. Technological advancements and studies can inform site selection and best practices for minimizing potential environmental impacts, such as environmental modeling. Effective feeding practices and monitoring can also help mitigate environmental impacts from finfish aquaculture operations. Moreover, continued improvements to fish feed formulations can increase feed efficiencies and minimize waste from unconsumed feeds. Thoughtful and well-informed aquaculture site selection and proper management play key roles in minimizing environmental impacts associated with unconsumed feeds and fish waste from marine finfish aquaculture operations.

4.4.2.7 Antibiotic Use

Section 4.4.1.9 presents general information about the use of antibiotics in aquaculture production. The use of antibiotics may impact protected coral species, depending on scale and overlap. Pharmaceutically active compounds have been detected in reef-building corals in the Red Sea, with elevated concentrations detected in corals from shallow sites and in areas with heavy human activity (Navon 2024). Studies have documented negative effects of antibiotics on coral health and hypothesized that antibiotic suppression of the native microbiota enables the proliferation of potential pathogens (Connelly 2022). However, antibiotics are sometimes used to treat sick corals, as they can be an effective way to stop the spread of diseases like Stony Coral Tissue Loss Disease.

The potential effects related to antibiotic use will be assessed once project-specific details (e.g., proposed site location, culture species, production method and antibiotics that may be used) for prospective aquaculture operations are developed and proposed through the permit and environmental review process.

4.4.2.8 Marine Debris

Protected species may be adversely affected by marine debris generated from aquaculture operations. Marine debris impacts can vary from entanglement to accidentally ingesting materials. A review of the scientific literature found the majority of sea turtle entanglements were associated with lost or discarded fishing gear (Duncan 2017). Sea turtles are particularly vulnerable to ghost nets given their tendency to use floating objects for shelter and foraging; ghost nets with relatively larger mesh and smaller twine size (e.g., pelagic drift nets) had the highest probability of entanglement (Wilcox 2015). Bath et al. (2023) indicates leatherback sea turtles have become entangled at shellfish operations in Canada and the Northeastern U.S. given their body morphology (large size, long pectoral flippers, and lack of a hard shell) and attraction to gelatinous organisms and algae that can collect on aquaculture structural components.

Giant manta rays (i.e. filter-feeding elasmobranchs) are also vulnerable to marine debris because it can often pass through and become logged in their large gills during feeding (Germanov et al. 2018). Marine debris ingestion is a major problem for marine mammals and marine debris from an aquaculture facility located in an AOA could be carried to areas where Rice's whales are present or feeding. In 2019, a Rice's whale washed up in the Florida Everglades with a piece of plastic in its stomach; potentially leading to the stranding and subsequent mortality of the whale.

The nature and extent of those potential impacts is unknown without more information on the location, type and proposed operation of any potential aquaculture facility. However, mitigation measures and BMPs can reduce the risk to the marine resources. Various mitigation measures have been identified to limit marine debris from aquaculture operations, such as routinely monitoring, maintaining, and replacing gear (Arantzamendi et al. 2022; Skirtun et al. 2022).

4.4.2.9 Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

The potential adverse and beneficial effects and severity are the same for all AOA Alternatives. **Preferred Alternative 2** (W-1) does not overlap with, but is closest in proximity (3.0 km [1.6 nm]) to proposed Rice's whale critical habitat of all alternatives. **Preferred Alternative 2** (W-1) does overlap with proposed green sea turtle critical habitat, which covers the majority of Gulf waters, and overlap with high use areas of giant manta rays. The area is also nearby sensitive benthic habitat for ESA-listed coral species (Coral 9 HAPC, Harte Bank), but outside of expected area of effects from aquaculture operations sites in AOA. **Preferred Alternative 3** (W-4) is also in close proximity to proposed Rice's whale critical habitat and overlaps with proposed green sea turtle critical habitat and high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles. **Preferred Alternative 4** (W-8) is also in close proximity to proposed Rice's whale critical habitat and overlaps with proposed green sea turtle critical habitat and high use areas of giant manta rays. **Preferred Alternative 5** (C-3) is the furthest (29.7 km [16.0 nm]) from proposed Rice's whale critical habitat of all alternatives, but still overlaps with the proposed green sea turtle critical habitat and overlaps with high use areas of giant manta rays, loggerhead, Kemp's ridley and leatherback sea turtles. **Alternative 6** (C-13) is in close proximity to proposed Rice's whale critical habitat. The area overlaps and with the proposed green sea turtle critical habitat with high use areas of giant manta rays, loggerhead and Kemp's ridley sea turtles

Risk can be reduced by implementing mitigation measures and BMPs, such as reducing vessel speed, using trained Protected Species Observers, or water quality monitoring. The potential impacts on specific protected resources will be examined and associated mitigation measures developed more thoroughly during the individual permit and agency consultation processes. Given their low genetic diversity, small population size, and restricted range, the loss of any Rice's whale may be particularly significant.

4.4.3 Potential Impacts on Marine Mammals

This section discusses the potential impacts generally associated with offshore aquaculture, and how those impacts might affect marine mammals. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. Existing threats and stressors to marine mammals are generally associated with fishery interactions and vessel strikes. Limited information is available describing the potential impacts on marine mammals associated with aquaculture operations, but the primary risks are related to habitat loss, entanglement, water degradation, and behavioral changes, such as attraction or avoidance (Wursig 2020; Bathe et al. 2023). Habitat or space loss can be an issue for marine mammals pursuing prey, but that depends on the species and location. For instance, aquaculture cages placed in a small shallow water cove could impair prey pursuit, but that would depend on various biological, physical, and equipment factors, such as the marine mammal species, cove size, water depth, and the size and the number of cages. Most marine mammals hunt in packs, so habitat loss could be a problem depending on the location and footprint of the operation. Researchers have shown mussel farms along the coast in Admiralty Bay, Marlborough Sounds, New Zealand have inhibited dusky dolphin movements during prey pursuit (Pearson et al. 2012). Besides limiting mobility, aquaculture equipment could deter daily, seasonal, or annual movements (Bath et al. 2023). Despite these potential issues, impacts could be minimized by placing equipment in deep water and providing adequate spacing so animals can still move freely around the area.

4.4.3.1 Entanglement and Entrapment

Entanglement is a potential issue for marine mammals given most aquaculture operations use nets, cages, bins, and various anchoring components (e.g., vertical or mooring lines, chains, floats, and anchors). Aquaculture equipment has similarities to commercial fishing gear, making it a potential stressor. In fact, marine mammal entanglement in commercial fishing gear is a major cause of injury and mortality (NMFS 2024b). Recent information indicates marine mammals have become entangled in aquaculture equipment. Bath et al. (2023) reported several species of large whales (humpback, minke, right, Bryde's, and short-finned pilot whales) have been entangled in mussel, oyster, and finfish aquaculture gear. The Marine Mammal Commission also reported a young right whale was entangled (February 2015) in aquaculture gear in South Korea. Marine mammals can become entangled with aquaculture equipment when pursuing prey, depredating from the cages, or habituating to fish harvesting operations, such as feeding on discarded fish (Bath et al. 2023). Dolphins are at risk of entanglement from lines, nets, or floating equipment used in aquaculture operations. Entanglements in nets or lines can lead to serious injuries or death. Unfortunately, information on how marine mammals perceive ocean structures is poorly understood (Knowlton et. al. 2012; Benjamins et. al. 2014) and there is limited data on the ages or size classes of dolphins that become entangled in aquaculture gear. Marine mammal interactions with marine aquaculture gear will depend on various factors, including but not limited to marine mammal species, behavior once entangled, and equipment. Potential impacts could be minimized by using rigid netting material and maintaining line tension. The scientific literature shows many whale species are vulnerable to fishing and aquaculture gear. As such, entanglement is an important potential stressor that needs to be fully examined during the permitting and environmental review process for an individual aquaculture operation.

4.4.3.2 Water Quality

Water quality degradation associated with aquaculture operations is another potential stressor for marine mammals. Aquaculture operations have the potential to negatively impact water quality in different ways (e.g., increasing turbidity, lowering DO, reducing water clarity, and altering the local hydrodynamics), but a primary concern is the discharge of pollutants (e.g., ammonium, nitrate, phosphate, and organic carbon compounds), especially inorganic nutrients (nitrogen and phosphorus) and particulate matter (Dunne et al. 2021). Poor water quality can directly impact not only marine mammals in various ways (e.g., reduce growth, increase deformities, and decrease reproductive abilities), but it can indirectly impact them via their prey (EPA 2021). Despite these risks, potential impacts will vary significantly depending on the hydrodynamics conditions (i.e., current velocity) and cage placement; submerged cages in deep waters with sufficient water flow will have less impacts than surface cages in shallow waters with no or limited water flow because nutrient concentrates will disperse, especially with distance; inorganic concentrations are higher near the cages (Dunne et al. 2021). Controlling and reducing feed waste can reduce potential water quality issues (Dauda et al. 2019). Generally, nutrient levels and other water quality criteria are elevated at the aquaculture facility, but only extend a short distance downstream (< 100 m) from the facility.

4.4.3.3 Vessel Strikes

Vessel collisions are a potential source of injury and mortality, but the impact of vessel interactions depends on various factors, such as the marine mammal species and vessel speed. Vessel traffic can pose a risk and also potentially alter behavior; marine mammals could alter their behavior by avoiding a busy vessel traffic area (Bath et al. 2023). Vessel strikes are the second major cause of serious injury and mortality for the North Atlantic right whale (*Eubalaena glacialis*), and source of anthropogenic impact that can inhibit the recovery of the North Atlantic humpback whale (*Megaptera novaeangliae*) (Hill et al. 2017); vessel strikes are a major conservation issue for various large whales. Injury and mortality have been directly linked to various types of commercial and recreational vessels; the likelihood of an interaction is generally associated with vessel traffic, and vessel speed and size. Collisions involving vessels and whales are a major conservation concern around the world given the number of incidents, but the number of injuries and mortalities are probably much higher than predicted given underreporting and undetected incidents, especially from large ships traveling at high speeds at night. In the U.S., many vessel strikes with whales are reported along the Atlantic coast; however, they still occur in the Gulf and are a major concern for whales that spend a lot of time near the surface (Constantine et al. 2015), like the Rice's whale. See section 4.4.2.2 for more information specific to vessels strikes and Rice's whale.

Dolphins are also vulnerable to vessel strikes in areas where they overlap with high vessel traffic. Although dolphins can recover from vessel strike injuries if they affect soft tissue, injuries from blunt force, or to the bone, or those that cause loss of an appendage can lead to death (Wells et. al. 2008). Avoiding a vessel strike depends on the dolphin's ability to hear the vessel and detect the direction and speed it is traveling. Vessel traffic can also alter behavior. Ribeiro et. al. (2007) documented aquaculture vessel traffic significantly altered Chilean dolphin behavioral responses (e.g., swimming orientation and speed) while foraging, which may have reduced foraging efficiency and overall fitness. Offshore aquaculture operations (i.e. installation, maintenance, and harvesting) will require various types and sizes of vessels, so its possible aquaculture vessels could alter normal behaviors or collide with marine animals, but that will depend on various factors like visibility, vessel speed, vessel Captain experience, and marine mammal avoidance behavior.

4.4.3.4 Acoustic Disturbance

Another potential stressor for marine mammals is acoustic disturbance. How anthropogenic noise alters a marine animal's use of its habitat depends on various factors and site-specific variables: the acoustic characteristics of the introduced sound (i.e., frequency, duration, and intensity); the physical characteristics of the habitat; the baseline soundscape; interactions with other sound sources; and the animals' use of that habitat. All of these factors will influence the pervasiveness and dominance of anthropogenic sound sources across the habitat. Despite the complexity, researchers have shown that a common response of marine animals to a potentially damaging or disruptive sound pressure level is avoidance. Avoidance can cause or alter behavior, such as displacing species from important foraging grounds and otherwise interfere with key life functions (National Research Council 2003).

Anthropogenic noise associated with offshore aquaculture operations may affect marine mammals. Although short-term, construction, specifically associated with finfish cage assembly (connecting cage spars or metal posts, i.e. "framing") could cause open ocean underwater noise exceeding the behavioral threshold and/or physiological/injury noise threshold for marine mammals (NMFS 2023). NMFS (2023) characterizes sound sources as impulsive/non-impulsive (which may cause permanent and temporary hearing threshold shifts) and intermittent/continuous (which may cause behavioral disturbance). Sound disturbance can also be generated from vessels and the equipment used in aquaculture operations (i.e., generators and automatic fish feeders). See Section 4.4.2.3 for more information on the impacts to marine mammals from anthropogenic underwater noise.

4.4.3.5. Light Disturbances

Artificial light may impact marine mammals because it can concentrate small and medium-size fishes and thereby attract cetaceans. Although only localized effects are possible based on the small spatial footprint (illuminated area) and the rapid attenuation of light underwater, artificial lights could affect the prey species behavior surrounding the aquaculture structures. This potential impact is associated with prey attraction to light and the underwater structures, including the disruption of diel vertical patterns of zooplankton or fish, which are often the prey of marine mammals (Orr 2013). Excess lighting in the water column has the potential to disrupt marine mammal foraging behavior. For instance, observations at offshore oil rigs in the Gulf showed dolphin species foraging near the surface and remaining around the platforms for longer periods at night when the lights illuminated the area (Cremer et al. 2009). Artificial lighting has the potential to attract marine mammals preying on fish inside and outside of the cages, but those impacts could be minimized by placing lights in ideal locations, such as above the cages rather than submerged.

4.4.3.6 Use of forage fish in meal and feed

The use of forage fish in meal and feed could potentially adversely impact marine mammals via reduced prey abundance, if greater harvest of reduction fishery species (e.g., menhaden) are needed to produce more fishmeal and feed to support aquaculture development. The potential effects given the use of forage fish in fishmeal and feeds would be assessed once project-specific details (e.g., culture species, production method and fish feeds that may be used) are developed and proposed through the permit and environmental review process.

4.4.3.7 Wild Species Aggregation

Aquaculture structures and operations may attract marine mammals, their prey, and predators as described in Sections 4.4.1.3 and 4.4.2.5. Artificial structures alter natural habitat, which may influence local biodiversity and ecosystem function, and impacts may be adverse or beneficial. For example, marine mammals may benefit from aggregating prey and foraging opportunities, while marine mammal aggregations around aquaculture operations may increase the risk of other stressors, like entanglement, shark interactions, or vessel interactions.

4.4.3.8 Marine Debris

Marine debris is another potential health problem for marine mammals because they can accidentally ingest or become entangled with it causing various injuries and even mortality. Section 4.4.1.10 discussed the types of marine debris that can be caused by aquaculture operations and the general risks associated with this debris. Marine debris can also potentially entangle and cause injury and mortality to marine mammals. Marine debris ingestion has been documented in 48 cetacean species, including bottlenose and Atlantic spotted dolphins (Baulch and Perry 2014). Baulch and Perry (2014) reported bottlenose dolphins are the most common cetacean that ingests or becomes entangled in marine debris in the Gulf; 78% of cases in the marine mammal stranding database from 2000 to 2014. Marine debris from aquaculture facilities may also have direct impacts on whales, depending on the project location and environmental conditions. As noted in Section 4.4.2.8, in 2019, a Rice's whale washed up in the Florida Everglades with a piece of plastic in its stomach; potentially leading to the stranding and subsequent mortality of the whale. The nature and extent of the potential impacts of marine debris on marine mammals is unknown without more information on the location, type and proposed operation of any potential aquaculture facility. However, implementing BMPs and using appropriate aquaculture gear should minimize potential impacts to marine mammals associated with marine debris (Arantzamendi et al. 2022; Skirtun et al. 2022).

4.4.3.9 Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1 (No Action)**, aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Marine mammal habitat is somewhat similar within **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13), so it is anticipated the risk of adverse impacts given the stressors described above will generally be comparable in terms of magnitude and severity within each of those areas. Overall, some marine mammal species could be displaced, display avoidance behavior, or be attracted to aquaculture activity sited within any AOA alternative, but that is highly dependent on various biological and aquaculture infrastructure factors, such as the temporal and spatial distribution of prey and the footprint of the aquaculture operations. The

AOA alternatives range in size from 500 to 2,000 acres (0.78 to 3.13 sq mi), which is relatively small in comparison to available and preferred habitat; therefore, size variation between alternatives are improbable to translate into detectably different levels of overall risk. **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3), all overlap with high use areas for Atlantic spotted dolphins. Some nearshore species of marine mammals like bottlenose dolphin could also be attracted to the aquaculture marine finfish cages at **Preferred Alternative 5** (C-3) and **Alternative 6** (C-13) given their close proximity to shore. It's improbable that offshore deep diving marine mammals (e.g., sperm whales) would be impacted given their preferred habitat is along the continental shelf, slope, or basin.

Marine mammals could be exposed to stressors given entanglement and entrapment, water quality, vessel strikes, acoustic and light disturbance, marine debris, new wildlife aggregations, and the use of forage fish in feeds and meal associated with siting aquaculture regardless of geographic location. The risk of adverse impacts can be reduced by implementing mitigation measures and BMPs, such as reducing vessel speed, using trained Protected Species Observers, or water quality monitoring. Marine mammals could get entangled in aquaculture equipment, but the risk can be minimized if cages are constructed with galvanized steel and the anchoring component remains taut. Water quality degradation is possible, but the potential impacts can be minimized if cages are placed below the surface in an area with adequate current velocity; all the AOA Options have average flow (Riley et al. 2021). Aquaculture cages, equipment, and navigational safety lighting could attract marine mammals, but the anticipated impacts are expected to be minor with the implementation of mitigation measures and BMPs developed in consultation with NMFS. Marine debris can sometimes be a stressor for marine mammals, but implementing BMPs should alleviate or reduce the risk. Vessel collisions with marine mammals are a major cause of injury and mortality, but vessel speed restrictions and other BMPs can reduce the risk to marine mammals. Acoustic disturbance risks to marine mammals is expected to be low regardless of the geographical location because noise related to the deployment and operation of aquaculture systems will be limited in area and duration, and the number of vessels associated with any facility is expected to be low.

4.4.4 Potential Impacts on Seabirds

This section discusses the potential impacts generally associated with offshore aquaculture, and how those impacts might affect birds, including birds that may be protected by the ESA or MBTA. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. Stressors that may impact these species include: entanglement and entrapment, vessel strikes, acoustic disturbances, light disturbances, wild species aggregations, fish waste and unconsumed food, disease and pathogen transmission, marine debris, and the use of forage fish in meal and feed. Stressors vary in intensity, frequency, duration, and location. The AOA alternatives do not overlap with any existing critical habitat for

ESA-listed bird species and potential impacts on protected species and designated critical habitat would be considered in future environmental planning and consultation.

4.4.4.1 Entanglement and Entrapment

Seabirds flying around, roosting on, or attempting to feed at an aquaculture site may become entangled in lines or nets, including containment nets and predator exclusion nets (Price and Morris 2013). Many seabird species may be attracted to floating aquaculture gear, as roosting or feeding sites, which can cause them to become entangled and drown, starve, or suffer physical trauma (Barnes 2019; Bath et al. 2023). Entanglement can cause cuts and abrasions and impede mobility, which increases the risk of starvation, predation, and drowning. Bath et al. (2022) found that finfish aquaculture operations pose the greatest risk of entanglement to seabirds. Data on the injury and mortality of seabirds from aquaculture gear is limited; however, some commercial aquaculture producers have begun reporting bird mortalities publicly though company sustainability dashboards (Bath et al. 2022).

NMFS works with the fishing industry and other partners to develop regulations, monitoring plans, engineering studies, and gear modifications to reduce the bycatch of sea turtles, marine mammals, sea birds, and non-target fish (NMFS 2022e). Mitigation measures may include line cutting devices, timed buoy releases, and marked gear; mitigation can include chain link fencing that has shade cloth stretched over it to prevent seabirds from becoming entangled (CDFW 2010). Setting or maintaining gear at night may also help mitigate some predation activity for seabirds (Gladics et al. 2017). These examples and other types of BMPs may avoid or reduce the risk of entanglement and entrapment for birds.

4.4.4.2 Vessel Strikes

Vessel strikes could impact diving seabirds. Impacts from vessel interactions range from behavioral disturbance to injury or death. Disturbance caused by motorboats may also cause behavioral responses in birds, when animals stop foraging or resting activities and move away from what is perceived to be a threat (NPS 2012). Factors that may mediate these effects include vessel speed, the number of vessel trips needed to install and tend to gear, existing volume and density of vessels in the action area, including the density of protected species and their behaviors, especially for the seasonality or timing of vessel operations. These considerations may be incorporated into permit conditions for in-water work. Historically, the risk of vessel strikes in aquaculture projects has been generally considered discountable given mitigation (VPD 2018; Mori and Riley 2021).

4.4.4.3 Acoustic Disturbances

There is potential for diving seabirds to be disturbed by underwater noise and birds that forage near the surface would be exposed to underwater sound for shorter periods of time than those that forage below the surface. However, it is more probable that seabirds may be attracted to an area given overwater noise and activity. There are many established mitigation methods required for marine industries under ESA and MBTA that may be incorporated into project designs and operations plans through the permitting process to avoid or reduce potential adverse impacts.

4.4.4.4 Light Disturbances

Seabirds may be at risk for adverse impacts from artificial light (Marangoni et al. 2022). Seabirds are attracted to artificial lighting, which may be associated with some aquaculture structures and with support vessels that may visit or be moored at an aquaculture site. Artificial lighting has the potential to attract and disorient seabirds which may lead to increased collisions with aquaculture structure and support vessels and elevated entanglement risk (Sagar 2013). Documentation from fisheries shows that lights disorient birds and can cause them to fly into ships, causing injury or death (USFWS 2005). Small fish and other prey items may also be attracted and concentrated around light sources from aquaculture operations, which may influence seabird foraging behaviors and diets (McConnell et al. 2010).

Seabirds that are typically found inland (e.g., songbirds) may be flying in large numbers over the Gulf during annual spring and fall migrations (U.S. Navy 2018). Although the potential is low for any shorebird species to be found in any of the Alternatives, shorebirds can be impacted by artificial light in the coastal environment (Simons et al. 2021) by becoming disoriented by a concentration of lights in an AOA.

4.4.4.5 Wild Species Aggregation

Aggregations of marine mammals, seabirds, predatory fish and schooling fish are observed near marine aquaculture worldwide, regardless of the species farmed (Rensel and Forster 2007; Bath et al. 2023; Rhodes et al. 2023a). Many bird species may be attracted to floating aquaculture gear, as roosting or feeding sites, which increases entanglement risk (Barnes 2019; Bath et al. 2023). Aggregating cues include predation opportunities, physical protection by floating structures, and conditioned responses to sounds, lights, and aquaculture operations (Rhodes et al. 2023a). Prey may use structures to escape predators and alternatively, facility structures may aggregate prey and provide novel foraging opportunities (Duprey et al. 2007; Kramer et al. 2015; Bath et al. 2023). Sea birds may be drawn to aquaculture for opportunistic feeding on schooling fish and seabirds may feed on biofouling organisms on gear as well (Nash et al. 2005). Predation on shellfish operations from both diving and non-diving seabirds has been documented in other areas (CDFW 2010). Diving seabirds are also drawn to finfish aquaculture (Lloyd 2003).

Aggregations around aquaculture facilities offer alternative opportunities for food sources that could become a more attractive option than hunting wild prey over wide spatial ranges (Rhodes et al. 2023a). Aggregations around aquaculture facilities within an AOA may create a predictable, if not reliable, food source that could alter predatory behavior. Changes in behavior and habitat use of seabirds have been documented around finfish operations. While enhanced foraging and opportunistic predation could be considered a beneficial impact for seabirds, there are tradeoffs. Aggressive intra- and inter-specific behavior could increase given aggregations.

4.4.4.6 Waste and Unconsumed Feed

NSSP language mandates that if gear may attract birds or mammals, farms must have an operational plan to deter them so that water quality (and sanitation) are protected from their potentially accumulating feces.

4.4.4.7 Disease and Pathogen transmission

Pathogens that are capable of infecting multiple host species can increase the opportunity for pathogen transmission (Kurath and Winton 2011; Rhodes et al. 2023). Birds may function as pathogen vectors or reservoirs and the potential for direct contact and water-borne pathogen transmission may increase when aquaculture operations attract other fish, marine mammals, or seabirds (Rhodes et al. 2023). given aggregations near facilities and potential increases in intra- and inter-specific interactions, there may be higher potential for the spread of pathogens among seabird and marine mammals populations than between a cultured population and the predators. Birds would likely pose a risk to cultured populations through bacteria or parasitic infections. The presence and active hunting by seabirds and marine mammals could worsen a disease outbreak in fish species by increasing stress levels.

4.4.4.8 Marine Debris

Seabirds may be adversely affected by marine debris generated from aquaculture operations. Adverse impacts of marine debris include entanglement, ingestion, and alteration of nesting habitat. Ingestion of marine debris by seabirds can lead to physical damage and blockage of the digestive tract, absorption of toxic chemicals, and decreased efficiency in the ability to find food. Nesting habitat can also be affected when seabirds use marine debris in nests, which further increases the chances of entanglement and ingestion.

The ingestion of plastics by seabirds (e.g., albatrosses and shearwaters) occurs with high frequency and is of particular concern because of impacts on body condition and the potential transmission of toxic chemicals, which affect mortality and reproduction. The rates of plastic ingestion by seabirds are closely related to the concentration of plastics in different areas of the ocean from waste discharges and ocean currents, which is increasing (Wilcox et al. 2015; Kain et al. 2016). The Gulf has a high concentration of microplastics[33], which may be produced as a by-

[33] The Gulf is of special interest for microplastic pollution because it is home to most plastic manufacturers in the United States, and concentrations of microplastics reported off the coast of Louisiana, in the northern Gulf, are among the highest reported worldwide (Grace et al. 2022).

product of the degradation of larger plastics, and have the potential to be a major ecotoxicological concern for wild birds (Grace et al. 2022).

4.4.4.9 Use of Forage Fish in Meal and Feeds

Forage species, including small fishes and invertebrates (e.g. krill) are an important foundation for the marine food web that feeds seabirds. Changes to forage species populations can have dramatic effects on other populations (Enticknap 2011; CDFW 2016b; PFMC 2016). Forage species are targeted by humans globally to provide fish for aquaculture feed, livestock and poultry feed, and human consumption (OIMB 2011; Enticknap et al. 2011). Smaller fishes may be subject to increased predation if large predatory fishes, seabirds, or marine mammals are present in wildlife aggregations around any aquaculture gear. The potential effects given the use of forage fish in fishmeal and feeds will be assessed once project-specific details (e.g., culture species, production method and fish feeds that may be used) when prospective aquaculture operations are developed and proposed through the permit and environmental review process.

4.4.4.10 Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Aquaculture has the potential to provide beneficial or adverse effects for wild species aggregation and water quality. Aquaculture structures have the potential to provide opportunities for feeding and spots for seabirds to perch or rest. However, these disruption in natural behavior patterns can increase the risk of other adverse effects like entanglement and entrapment and vessel strikes if birds become attracted to an operation. Water quality could be improved or impaired locally by type of aquaculture operation (e.g., finfish, shellfish or macroalgae) and impacts could be further compounded if birds congregate in large numbers at a site, creating health and seafood safety issues. Potential adverse effects of entanglement and entrapment, light disturbances and acoustic disturbance, marine debris, vessel strikes, waste and unconsumed feed, disease and pathogen transmission, and antibiotic use, could cause increased risk of disease, serious injury or death to seabirds. The location, type of aquaculture operation and seabird species present may increase or reduce the severity and risk of effects.

The potential effects do not differ across the **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13), so it is anticipated the risk of adverse impacts given the stressors described above would be similar for all AOA Alternatives. The severity of these potential impacts would likely be reduced for any alternative, given the implementation of best management practices to reduce the risk of injury and mortality of seabirds.

4.5 Potential Impacts on the Socioeconomic Environment

This section evaluates how and to what degree the Proposed Action (identifying AOAs) could potentially impact the socioeconomic environment. This section also includes information on the potential socioeconomic impacts of siting offshore aquaculture facilities within an identified AOA. Stressors and resource area components for the socioeconomic environment include: commercial fishing; seafood markets and regional food systems; recreational fishing; ports and working waterfronts; tourism economies; oil, gas, and wind energy development; other offshore activities and infrastructure; shipping and navigation; military readiness and operations; and environmental justice. The action of identifying AOAs in federal waters of the Gulf would not cause any immediate direct or indirect impacts, beneficial or adverse, on the socioeconomic environment as this action is only a planning action and administrative in nature. No specific aquaculture projects or types of aquaculture are required or certain to occur within an AOA. Should an aquaculture project be proposed within an AOA in the future, potential impacts on the socioeconomic environment would be assessed by the relevant agencies during the permitting and environmental review processes, and could be similar to the potential impacts described in this section.

Michaelis et al. (2024; *In Review*) provides an overview of social vulnerability, natural hazard risk factors, and working waterfront opportunity for communities proximal to the Gulf AOA Alternatives (Figure 4.5-1). Data including Community Social Vulnerability Indicators (CSVIs), developed by NMFS to characterize the well-being of coastal communities engaged in fishing activities (Jepson and Colburn 2013), were analyzed to assess potential vulnerabilities and resilience of communities in proximity to Gulf AOA Alternatives. CSVIs include 14 statistically robust social, economic, and climate change indicators that characterize and evaluate a community's vulnerability and resilience to disturbances (e.g., regulation changes, extreme weather, and sea level rise.) (NMFS OST 2021). In the study, offshore aquaculture development was treated, in a broad sense, as a potential 'disturbance' or change (Michaelis et al. 2024; *In Review*).

As noted by Michaelis et al. (2024; *In review*), the AOA Alternatives are not prescriptive with respect to the types of aquaculture production, operational requirements, or specific details (e.g., species in production, harvest methods, or landing locations); therefore, the specific interactions between aquaculture activities within AOAs and nearby coastal communities are not yet known and challenging to assess. However, considering existing vulnerabilities during the AOA identification process can strengthen an understanding of the human dimensions and potential community impacts for future aquaculture siting in the region (Michaelis 2024; *In review*).

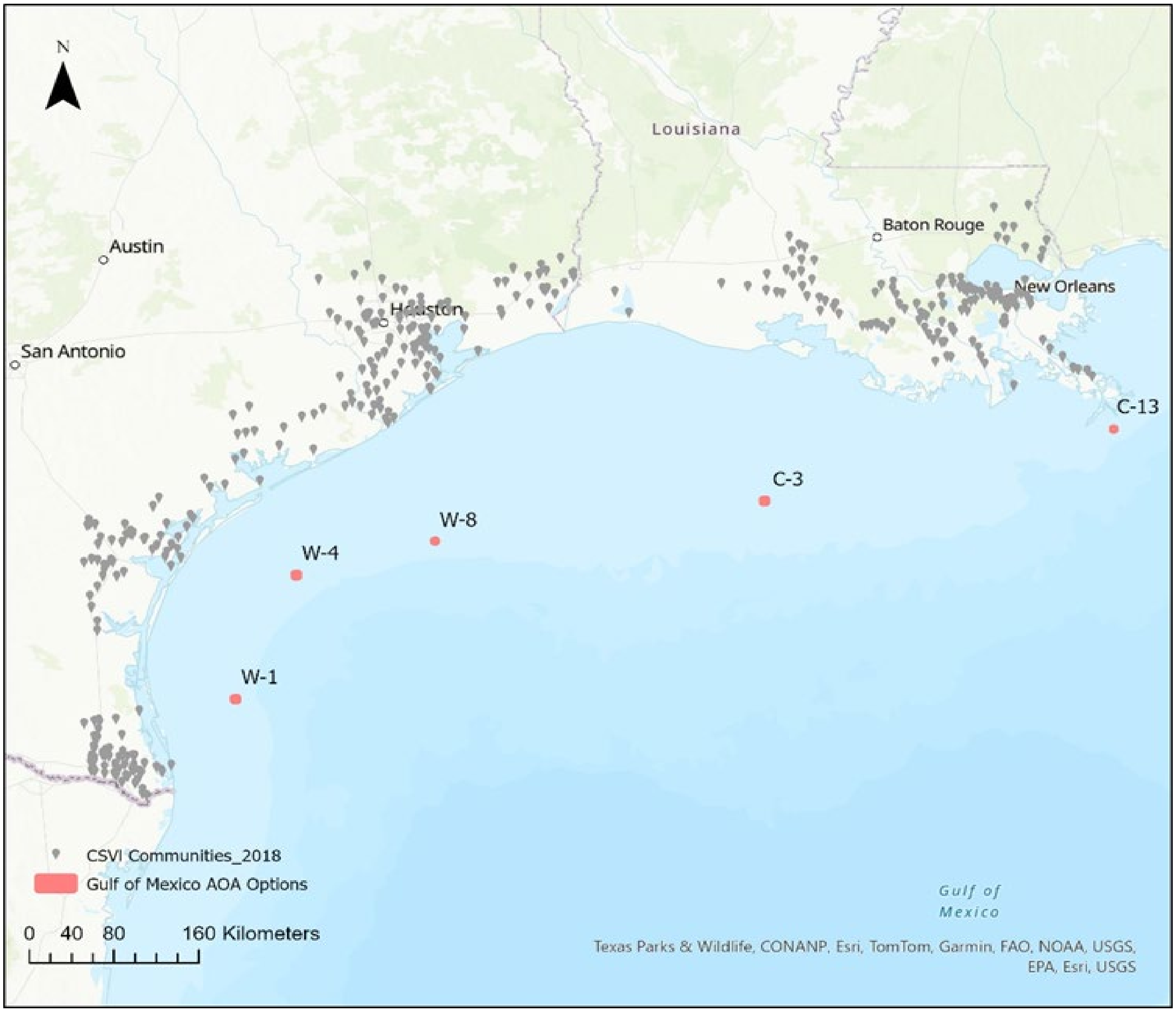

Figure 4.5-1. Coastal communities and AOA Options in the Western and Central Gulf. AOA Options are represented in red with alphanumeric labels. NOAA-identified fishing communities are shown as gray markers. Source: Michaelis 2024 (*In Review*).

4.5.1 Potential Impacts on Commercial Fishing

Commercial fisheries in the Gulf are one of the most valuable natural resource industries in the United States. In 2022, commercial fisheries in the Gulf ranked second behind Alaska in total landings valued at US $912.4 million (NMFS 2024a). Overall, the most valuable commercial fisheries in the Gulf are white and brown shrimp, gulf menhaden, blue crab, and eastern oyster. Offshore aquaculture operations have the potential to interfere with or displace commercial fisheries if not sited appropriately. Riley et al. (2021) acquired commercial fisheries data (e.g., shrimp ELB data [2004-2019]) and performed gridded relative suitability analysis to identify the grid cells with the least overlap with commercial fishing and the highest suitability for aquaculture development; the best available data was used and all data were checked for completeness and quality. The researchers used tracklines created from transmission points from commercial fishing vessels to map fishing activity and identify fishing grounds. Using this information, suitability maps were then developed overlaying commercial fishing activity (low, moderate, and high) within the AOA Alternatives.

Even though the AOA Alternatives are relatively small in size, ranging from 500 to 2,000 acres (0.78 to 3.13 sq mi), the siting aquaculture in the western and central Gulf would result in the displace some commercial fishing activities, creating the potential for navigational hazards with the establishment of fixed structures, increasing the potential for entanglement, and gear loss and economic loss from some fisheries displacement. The loss of productive fishing grounds may cause adverse economic effects to commercial fisheries, and further limit space where fishing can occur in a region where ocean space is limited by oil and gas infrastructure and other industrial activities. BOEM (2024) reports there are 2,360 active leases, 1,452 platforms, 54,176 wells drilled, and 22,467 wells produced in the Gulf. Eighty-one percent of the active leases are in the central planning area (*n* = 1,905; 10,334,327 acres leased), followed by the western (*n* = 442; 2,407,425 acres leased) and eastern (*n* = 12; 74,880 acres leased) planning areas.

Another issue in the northern Gulf that limits space for commercial fisheries are red tide events and the hypoxia zone that typically develop annually and can extend from the nearshore waters off Louisiana to Texas to as far as 50-150 km (27 to 81 nm) offshore (Rabalais and Turner 2019). For instance, Perruso et al. (2023) reported the spatial distribution of monthly fishing effort was significantly affected by red tide events in the Gulf off Florida during 2008 through 2019. Although the findings did not show measurable changes in fleet-level fisheries metrics, there was a significant displacement of the fleet from the red tide impacted area. Displacement can have unpredictable economic and resource consequences in other areas (Gill et al. 2020). As such, it is important to evaluate multiple use options of marine space, especially since some commercial fishing methods (e.g., bottom longline, shrimp trawling) may be incompatible with some industrial activities, such as offshore wind (Gill et al. 2020).

Another potential socioeconomic impact on commercial fisheries associated with aquaculture is market competition. Supply and demand generally controls the price of goods and services, including seafood prices. Dockside value of seafood is also dictated by various direct expenditures, such as fuel, insurance, gear, and other vessel operational and supply chain costs. In addition, marketing campaigns and advertising can sometimes influence seafood prices along with inflation, which causes shoppers to choose lower priced protein sources, such as chicken. Branding, labeling, and certification can influence consumers to pay more for food products that are marketed as sustainable or healthy, such as “100 percent organic, organic, or made with organic…” Traceability and other information that qualifies the product is becoming more important to consumers. Quality is also important to consumers; many consumers are often willing to pay more for a product where quality is guaranteed.

In the Gulf, one of the most significant adverse impacts on commercial fisheries is market competition from imported seafood, especially shrimp; imported shrimp account for the majority of all the shrimp consumed in the United States (Griffith et al. 2023). The main reason imports impact commercial fisheries is because imported seafood prices are usually lower than domestic given labor and operational costs are lower, and environmental restrictions and safety standards can be less stringent outside the U.S. Imported shrimp has had profound impacts on domestic shrimp prices (Griffith et al. 2023). Griffith et al. (2023) highlighted that shrimp prices in the 80s were usually above $2.50 per pound, but dropped to around $1.25 per pound in 2006 because of imports. In 2014, Gulf shrimp dealers were able to sell shrimp for as high as $2.84 per pound, but that is a 40% decline since the early-90s after adjusting for inflation. Although most, if not all, shrimp imported is farm-raised, the other primary species (Gulf menhaden, blue crab, and eastern oyster) landed in the Gulf are not imported from other countries. However, many of the top finfish imported into the U.S. do compete with species from the southeast and Gulf. The main seafood imported into the U.S. are shrimp, salmon, crab (crabmeat and lobster), tuna, and whitefish (tilapia, cod, pollock, catfish, haddock and hake); all of these imports are directly distributed in the southeast region, including the Gulf via retail (food and beverage stores), restaurants, and other hospitality industries (Ferreira et al. 2022).

It is difficult to predict whether domestic aquaculture would compete with domestic capture fisheries in the Gulf, but it is possible depending on the species, production amount, potential limits on foreign imports, marketing and campaigns, price per pound, and other business factors. Market competition (e.g., increase supply) of an aquaculture product that also has a domestic wild-capture fishery, could compete with and lower the price of seafood from domestic capture fisheries, if supplies of particular seafood

However, aquaculture production of species with limited commercial harvest could limit adverse market effect and could even help spur demand

With the right marketing campaign that supplements and supports sustainable capture fisheries in the U.S., domestic aquaculture operations could help increase domestic prices if consumers started buying less imports and more domestic seafood.

Another potential benefit of aquaculture operations in the Gulf is the fish aggregation device (FAD) effect; FADs are man-made floating objects or structures that attract bait fish which then attract commercial and recreational important species like tuna and mahi-mahi. It is possible that floating or subsurface cages could serve as a FAD and benefit local commercial and recreational anglers. Aquaculture cages have been shown to attract and congregate wild fish in various regions (Felsing et al. 2005).

In sum, potential adverse effects of future aquaculture operations could occur due to displacement or disruption of commercial fishing associated with fixed gear and other equipment placement in the water column, surface, and bottom; marine debris; disease transmission from cultivated stocks, and increased vessel traffic in and out of coastal areas. Potential FAD effects may be beneficial or adverse. Potential effects on seafood markets may be adverse (increased domestic competition) or beneficial (increased consumer demand for domestic seafood). Workforce effects may be adverse (competition for limited labor resources) or beneficial (diversification of job opportunities). There is a potential for effects to increase or decrease in magnitude depending on overlap with or proximity to commercial fishing activities or markets.

Comparison of Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

The effects of market competition between seafood produced by offshore aquaculture and domestic wild capture species cannot be determined without project specific information provided (e.g., species to be raised, market and business information), however these effects are expected to be similar across all AOA Alternatives (**Alternative 1** [No Action], **Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]).

Preferred Alternatives 2,3 and 5 (W-1,W-4 and C-3) similarly avoid overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining, and overlap with low levels of bandit gear fishing and shrimp trawling activity. **Preferred Alternative 4 (**W-8) avoids overlap with bandit gear fishing, menhaden fishing, HMS pelagic longlining, but does overlap with low levels of reef fish longline and shrimp trawling activity. **Alternative 6** (C-13) avoids overlap with menhaden fishing, HMS pelagic longlining and reef fish longlining, but does overlap with areas of moderate shrimp trawling activity and low levels of bandit gear fishing.
Riley et al. (2021) indicated **Preferred Alternatives 2, 3 and 5** (W-1, W-4, and C-3) overlap the designated Reef Fish Longline and Buoy Gear Restricted Area; therefore, reef fish longline fishing did not occur during 2007-2019, nor will it be impacted from potential future aquaculture. Relatively low amounts of bandit gear fishing and shrimp trawling also occurred within these AOA Alternatives, so it is possible some commercial fishing operations could be affected from future aquaculture development in these areas. **Preferred Alternative 4** (W-8) overlaps with low levels of reef fish longline fishing, and are expected to have similar **Preferred Alternatives 2, 3 and 5** (W-1, W-4, and C-3) due to fishing activities targeting similar species. **Alternative 6** (C-13) overlap with moderate shrimp trawling activities could affect fishing activities in the area. Vessels would need to plan and navigate trawls around fixed aquaculture structures located in the AOA, resulting in greater displacement than just the farm footprint increasing effects and more severe effects in **Alternative 6** (C-13) than **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3).

4.5.2 Potential Impacts on Seafood Markets and Regional Food Systems

Economic benefits from aquaculture production impact not only those directly involved in the industry, but could benefit the Gulf Region by increasing employment and revenue. Aquaculture can supplement domestic seafood landings, increase seafood production, and provide stability for the seafood industry. The annual economic impact to the Gulf region from a single offshore aquaculture production system consisting of 12 cages was estimated to generate between $9.1-$10.2 million (Posadas 2004). A hypothetical growth in aquaculture production based on DOC targets for 2025 is described on pp. 623 through 627 of Nash (2004). These economic analyses provide examples of the types of information that may be incorporated into future environmental review. In addition, important economic concepts that may be applicable to analyze potential impacts of project-specific production include:

- How new products may apply to the existing reliance on imports;
- Estimating potential future growth via economic production concepts;
- Potential growth margins and interactions with wild-caught fisheries;
- Allocative efficiency measures (measures of yield versus conflict trade-offs);
- Production externalities (perceived and/or realized adverse effects of a project that may affect investment capital);
- A defined scope of affected economies;
- How competitive, substitute, or complementary market interactions may affect demand, volumes of supply, and prices of products;
- Casual interference (a metric to measure the effectiveness of a project to grow the aquaculture industry);
- Economic viability of proposed products; and
- Contribution to maintaining working waterfronts.

The aquaculture products produced in an AOA would be expected to provide an overall positive impact on local, regional, state, and national markets and food systems. The aquaculture potential for most candidate species (see Appendix D) has yet to be demonstrated on a commercial scale, but there are markets (fresh, live and frozen) for aquaculture products. Although offshore aquaculture production would lag land-based operations in its initial development phase, offshore aquaculture could still generate jobs, export earnings, and increase the volume of domestically-produced seafood (CEA 2018; Fujita et al. 2023). Aquaculture not only can increase global seafood supply, it can reduce the uncertainty in supply chains by providing a more consistent delivery and high-quality product, compared to wild-capture fisheries (Rubino (ed.) 2008). Offshore aquaculture production may provide market competition and a substitute for imported seafood products for local, regional, national, and international markets; but the extent of those beneficial impacts would depend on many factors, such as global and regional markets, prices, volumes of local production and imports, and product quality and availability. Predictive modeling has suggested it is more probable that Gulf farmed finfish would compete with imports than with domestic wild-caught fish, given U.S. wholesale buyers have a preference for domestic fish to imported fish, but no significant preference for wild-caught fish over farmed fish (Garlock 2020).

Despite benefitting from a closer proximity to markets, the cost for domestic seafood products are generally higher due to a higher domestic costs of labor, processing and greater regulatory costs (CEA 2018; Ferreira 2024). Current market data should be considered in future environmental reviews to sufficiently analyze the market impacts from species being proposed for cultivation and targeted products. New market demands could also be created with associated marketing strategies. In the Gulf, there is already stakeholder interest in aquaculture production to supply local and domestic markets (Garlock 2020; CEA 2018). The assumed dependency of offshore operations with coastal facilities in regional working waterfronts would likely provide a beneficial contribution to the state's economy and employment (see Section 4.5.4).

Assuming the siting of one or more aquaculture operations within an AOA would increase domestic seafood production and provide an economic benefit at the local or regional scale, operating costs could still be problematic. Offshore aquaculture operations in the U.S. are estimated to be 15-30% higher in cost than nearshore operations, and high start-up costs have historically dissuaded potential aquaculture investors interested in using existing oil and gas platforms in the Gulf (CEA 2018). Operations sited in an AOA should probably focus on high-value products for upscale markets to generate higher revenue to cover operating costs and provide a positive return on investment. Disproportionate negative impacts on existing businesses and employees associated with aquaculture and with fisheries is possible without thoughtful planning (Fujita et al. 2023).

The spatial planning process and environmental review used to identify AOAs may help reduce the start-up costs and overall budget associated with permitting and environmental compliance. However, the high capital investment necessary for operations to start-up, would likely give large, established businesses an advantage over local or regional stakeholders, and could reduce the social and economic benefits associated with the AOA planning process for small-scale. While collaborative or vertical business pathways may occur to achieve economic viability, vertically-integrated pathways may favor the offshore aquaculture industry from a cost perspective. The development of business strategies that leverage local existing infrastructure (e.g., ports, fish houses, processing) or develop that new infrastructure utilizing a local workforce would provide the greatest social and economic benefits for coastal communities.

An increase in aquaculture production may change the revenue, value, and profitability of seafood products, creating new interactions between wild harvest, existing aquaculture, and potentially new aquaculture products. The food security benefits from an expanded aquaculture industry would depend on who consumes the products and what food categories and markets they displace. National price trends show the cost of aquacultured products is decreasing steadily over time (1990-2005), which suggests a beneficial impact for market development and market share (Rubino (ed.) 2008). If the identification of an AOA facilitates the growth of the aquaculture industry, then this could increase the affordability and therefore accessibility of seafood, and may expand products beyond the existing high-end niche markets. This may increase competition with wild-harvested seafood products. If much of the expansion occurs in waters that are far from shore or are subject to high energy conditions, seafood from such farms may become costly relative to other foods, resulting in consumption that is dominated by higher-income consumers who already tend to consume high levels of animal protein (Fujita 2023).

The difference in the cost structure between aquaculture and wild capture fisheries has important implications for how the two sectors may experience price interactions. Wild versus farmed products have unique attributes for biological constraints, competing goods, and sales techniques (Asche et al. 2005; Valderrama and Anderson 2010). In traditional fisheries, the primary costs are labor, fuel and fleet maintenance; and in the aquaculture sector, the primary costs are generally inputs (e.g., feed and energy), labor, land and equipment (Rubino (ed.) 2008). As such, aquaculture may have more opportunities to reduce costs in production and management than wild-caught fisheries. Aquaculture products may also supply seafood that is more consistent than season-dependent wild fisheries. This consistency in the supply of a species may be preferable to seafood processors and distributors, who can make production and marketing decisions throughout the year instead of over a concentrated time period (Rubino (ed.) 2008). Price and consistent supply may be key factors when considering market interactions in future environmental review.

In 2020, the COVID-19 pandemic caused large-scale disruptions to the U.S. economy demonstrating how markets and food systems can change suddenly. Impacts occurred throughout the entire seafood supply chain from harvesters and aquaculture operations to seafood dealers, processors, wholesalers, and retail and food service in the U.S. and globally. U.S. seafood producers were impacted by disruptions to the relationship between imports and exports; international trade and processing facilities shut down for several months. Also, wild-caught seafood products could not be exported. Seafood demand from the foodservice sector declined sharply and seafood retail surged (NMFS 2021). Smaller, community-supported fisheries focused on selling seafood directly to local consumers, while larger businesses (e.g., farmed finfish imports) shifted from restaurant to retail sales (Froelich et al. 2021).

A more competitive U.S. aquaculture industry may support the U.S. economy by combating potential sources of illegal, unreported, and unregulated fishing (IUU fishing) and supporting certification programs in sustainable environmental and social business practices. The U.S. reliance on imports to meet the demand for seafood is complicated by the global concern for IUU fishing, including humanitarian impacts associated with some imports (Diana 2009; NOAA

2022). In increasingly crowded and competitive markets, consumers are starting to demand the values, context, culture and other factors that shape what activities are associated with business practices (Murray and D'Anna 2015). Imported sources are much harder to trace, which increases the likelihood for seafood products to be on the market that lack the same level of environmental and social standards as those produced in the U.S.

Aquaculture is the fastest-growing food-production sector globally, and is expected to continue to grow globally for several decades as the population continues to grow (Lester et al. 2018a,b). Based on over 400 aquaculture studies globally, three possible drivers that indicate marine aquaculture may be the leading solution to close the gap between seafood consumption demand and production are suggested in Fong et al. (2023):

- Marine taxa are often cash crops of high value with substantial infrastructure investment, which may motivate and facilitate higher yield;
- The feed for marine farmed fishes may rely more on external inputs to provide adequate nutrition compared to fresh-water aquaculture (e.g., salmon vs. carp);
- Marine algae may outperform freshwater algae (e.g., spirulina), given a taxonomic focus on large brown seaweeds and rapidly growing reds (e.g., *Laminaria* spp.).

According to some analysts, the future of aquaculture in the United States depends on making permitting more predictable and coordinated and less costly and removing or reducing barriers to entry (Lester et al. 2018a,b; Rubino 2023). Without changes to the social license, the regulatory framework, and economic incentives in support of domestic seafood production, the U.S. is unlikely to increase domestic production of marine aquaculture. And even with these changes, U.S. marine aquaculture production is likely to expand slowly given the long startup lead times (Rubino 2023). Competition in food markets may exist with or without domestic aquaculture, and current trends show the U.S. cannot meet consumer seafood demand solely through wild caught fisheries (NMFS 2023d).

In sum, potential beneficial and adverse effects of future aquaculture operations could occur due to introduction of new domestic products, increase in the supply of domestic products, new or increased interactions with wild-caught seafood products (competition or complimentary), and new or increased interactions with existing interstate or international trade markets. The overall growth in a market may be considered an economic benefit, but local or regionally-scaled costs may occur simultaneously. Effects of offshore aquaculture development on existing aquaculture and fisheries industries could be adverse and/or beneficial. As development of offshore aquaculture can require high capital investment, large, established businesses (domestic or international) could have an advantage over local or regional stakeholders.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

While the potential effects of siting future aquaculture operations are similar across Action and No Action alternatives, **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13) may be more suitable for aquaculture. Potential adverse effects and beneficial effects are the same as those discussed above in Alternative 1, but the type (adverse/beneficial) and magnitude of effects could depend largely on the details of potential future aquaculture operations (e.g., species and volume produced, target markets), and overlap with or proximity to existing aquaculture and or commercial fishing activities and markets. For **Preferred Alternative 2 (W-1)**, nearby Texas coastal communities, including Port Mansfield and South Padre Island, could benefit if offshore aquaculture were to integrate into the existing ocean economy in a complementary way and provide accessible jobs. For **Preferred Alternative 3 (W-4)** nearby Texas coastal communities, including Matagorda, Port Aransas, and Port O'Connor could benefit. For **Preferred Alternative 4 (W-8)** nearby Texas coastal communities, including Clute, Quintana, and Surfside could benefit. For **Preferred Alternative 5 (C-3)**, nearby Louisiana coastal communities could benefit. For **Alternative 6 (C-13)**, nearby Louisiana coastal communities, including Grand Isle and Venice, could benefit.

4.5.3 Potential Impacts on Recreational Fishing

Recreational fisheries could be directly and indirectly affected by aquaculture operations. Potential adverse effects of future aquaculture operations could occur due to displacement or disruption of recreational fishing associated with fixed gear and other equipment placement in the water column, surface and bottom; marine debris; disease transmission from cultured stocks; and increased vessel traffic in and out of coastal areas. Potential FAD effects may be beneficial and/or adverse; recreational fishing opportunities may increase or improve when aquaculture activities act as FADs. Potential effects may increase or decrease in magnitude depending on overlap with or proximity to recreational fishing activities. These impacts could vary slightly among Alternatives. If offshore aquaculture were to develop and if it were to have an adverse effect on recreational fishing, communities with higher recreational engagement and reliance indicator scores may experience greater impacts, highlighting the importance of recognizing and thoughtfully considering social vulnerability characteristics in strategic planning and siting of aquaculture operations (Michaelis 2024; In Review).

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

While the potential effects of siting future aquaculture operations are similar across Action and **No Action** alternatives, **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6 (C-13)** may be more suitable for aquaculture. Potential adverse effects were reduced by minimizing overlap of AOA Alternatives with recreational fishing activities through site suitability analysis that considered(e.g.,headboat survey data and avoiding overlap with artificial reef areas and fish havens). In addition to the potential beneficial and adverse effects discussed above, nearby communities could be impacted through the action alternatives as follows: **Preferred Alternative 2 (W-1)**: Nearby Texas coastal communities, including Port Mansfield and South Padre Island which have moderate to high recreational fishing engagement and reliance, could be impacted (positive or negative) from potential future aquaculture development; **Preferred Alternative 3 (W-4)**: Nearby Texas coastal communities, including Matagorda, Port Aransas, and Port O'Connor which have high recreational fishing reliance could be impacted (positive or negative); **Preferred Alternative 4 (W-8):** Nearby Texas coastal communities, including Clute, Quintana, and Surfside which have moderate to high recreational fishing engagement and/or reliance, could be impacted (positive or negative); **Preferred Alternative 5 (C-3):** Nearby Louisiana coastal communities with low recreational fishing engagement and reliance could be impacted (positive or negative); **Alternative 6** (C-13): Nearby Louisiana coastal communities, including Grand Isle and Venice which have high recreational fishing engagement and reliance, could be impacted (positive or negative).

4.5.4 Potential Impacts on Ports and Working Waterfronts

Potential beneficial and adverse effects of future aquaculture operations could occur due to increased vessel traffic in and out of coastal areas, harvested product moving through coastal facilities, and the need for shoreside industrial-use infrastructure (e.g., boat ramps, marinas, dock space, storage, processing). There is a potential for adverse effects from competition for resources (e.g., labor, workforce housing, markets, etc.), especially in communities highly vulnerable to disruptions caused by natural hazards (hurricanes, extreme weather, etc.) and potential for beneficial effects if aquaculture were able to integrate into existing working waterfronts or collaboratively develop needed infrastructure in communities where it does not yet exist (if there is space and capacity for such development).

Per Michaelis (2024), analysis of working waterfront indicators for the two communities near **Preferred Alternative 2** (W-1) yielded results on the opposite ends of the spectrum (Michaelis 2024; In Review). Cameron County had a high degree of seafood-related infrastructure and businesses, moderate shellfish processing, and moderate presence of boat ramps and marinas, while Willacy County had a low/very low degree of all of these indicators (Michaelis 2024; In Review). Michaelis (2024) suggested it's possible aquaculture could integrate into existing working waterfronts, but integration could prove challenging given the present rapid development of other potentially more lucrative industries like the liquefied natural gas and offshore wind energy sectors. Per Michaelis (2024), a smaller port, Port Isabel, may be a more likely location for potential aquaculture integration in this area. Analysis suggests aquaculture development could be welcomed in communities near **Preferred Alternative 2** (W-1) assuming employment can provide income above the poverty level (Michaelis 2024; In Review). Michaelis (2024) noted communities near **Preferred Alternative 2** (W-1) are highly vulnerable to various natural hazards, so prospective aquaculture operators should ensure their development does not compete for local resources (e.g., labor, facilities, markets, and space) or conflict with existing ocean economy sectors (Michaelis 2024; In Review).

Communities near **Alternative 3** (W-4) have a relatively high degree of seafood-related infrastructure, and although the scores for individual indicators varied among these communities, the majority of the counties in the area had at least a moderate degree of resources supporting a waterfront seafood industry (Michaelis 2024). Per Michaelis (2024), the analysis showed the development of offshore aquaculture could be beneficial to at least a portion of this region (Aransas, Matagorda, and Nueces counties) if it created new and accessible jobs. However, for maximum benefits, development must occur in a way that is complementary to the existing ocean economy, including commercial and recreational fisheries (Michaelis 2024. Michaelis (2024) noted the observed variability in the working waterfront, which suggests impacts could vary differently from offshore aquaculture development. As with the communities near the other AOA Options, natural hazard risks in this area are a prevalent risk, with Nueces County having the highest high-hazard indicator scores in the area (Michaelis 2024).

Analysis for communities near **Preferred Alternative 4** (W-8) suggests a sizable ocean economy within the fisheries component is recreational fisheries (Michaelis 2024). Michaelis (2024) noted prospective aquaculture operators interested in siting in or near **Preferred Alternative 4** (W-8) may need to consider whether the existing commercial working waterfront infrastructure is sufficient, or if additional capacity would need to be developed. Per Michaelis (2024), communities near **Preferred Alternative 4** (W-8) were distinct (from the others analyzed) because they were all located within a single county and had a large highly educated population; these communities had relatively high incomes and high unemployment. Michaelis (2024) noted the socioeconomic data associated with **Preferred Alternative 4** (W-8) may suggest fewer opportunities (relative to the AOA Alternatives analyzed) to benefit the local communities by offshore aquaculture job creation. However, Michaelis (2024) does note that of the areas analyzed, only **Preferred Alternative 4** (W-8) and **Alternative 6** (C-13) had nearby communities that were highly educated with high incomes. Thus, these areas may provide a unique opportunity for prospective aquaculture operators to recruit from within local communities to fill positions requiring higher education. As with the other areas included in the analysis by Michaelis (2024), the communities near **Preferred Alternative 4** (W-8) were also vulnerable to various natural hazards.

Michaelis (2024) studied how working waterfront communities in proximity to Gulf AOA Alternatives might perceive a developing aquaculture industry. The study examined and scored various “working waterfront indicators” that included seafood dealers, seafood-related businesses, shellfish processors, and presence of boat ramps and marinas. Data for communities near **Preferred Alternative 5** (C-3) indicated developing aquaculture could potentially use active working waterfront businesses and infrastructure (Michaelis 2024). However, Michaelis (2024) cautioned, that given climate change and natural hazard risks in the area, measures should be taken to enhance resiliency of these working waterfronts to major events (i.e. hurricanes and other major flooding events), especially for the small fishing waterfronts located below the local levee system. The socioeconomic characteristics data suggested new aquaculture development in communities near **Preferred Alternative 5** (C-3) could be positive, but that is assuming new aquaculture related jobs are desirable, accessible to those in the communities, and if the existing seafood industry has the capacity to take in additional seafood products (Michaelis 2024). Michaelis (2024) noted that while the existing role of the ocean economy in these communities may suggest potential opportunities for aquaculture development and integration, caveats and potential concerns related to competition for space, labor, or other resources, storm readiness for operational infrastructure and workforce housing are important considerations for planning and siting to maximize potential community benefits and help reduce social vulnerability.

Results for communities near **Alternative 6** (C-13) also indicated the presence of existing working waterfront businesses (high scores for commercial and recreational fishing, seafood dealers and seafood-related businesses, boat ramps and marinas) and associated infrastructure could potentially be integrated by new aquaculture operations assuming the region could handle additional seafood products and associated business (Michaelis 2024; In Review). Michaelis (2024) again indicated that climate change and natural hazard risks are important vulnerability considerations for communities in proximity to **Alternative 6** (C-13). Per Michaelis (2024; *In Review*), the data suggested there was a potential to mutually beneficial the local communities and aquaculture; however, further information and analysis would be needed to assess the likelihood. Offshore aquaculture development could potentially provide jobs spanning the notable wide range of skill sets and backgrounds for residents in communities near **Alternative 6** (C-13) (Michaelis, 2024; In Review). Thus, this could reduce the need to seek employees from outside of the community, which could help with the various challenges Michaelis (2024; In Review) pointed out for these communities (e.g., income disparity, unemployment, housing burden, and individuals living below the poverty line). Michaelis (2024; In Review) cautioned that while the active ocean economy in these communities may indicate potential opportunities for aquaculture integration, aquaculture development must be careful not to compete for limited community resources, such as dockside space, and labor.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. Potential beneficial and adverse effects of future aquaculture operations could occur given increased vessel traffic in and out of coastal areas, harvested product moving through coastal facilities, and the need for shoreside industrial-use infrastructure (e.g., boat ramps, marinas, dock space, storage, processing). There is a potential for adverse effects from competition for resources (e.g., labor, workforce housing, markets, etc.), especially in communities highly vulnerable to disruptions caused by natural hazards (hurricanes, extreme weather, etc.) and potential for beneficial effects if aquaculture were able to integrate into existing working waterfronts or collaboratively develop needed infrastructure in communities where it does not yet exist (if there is space and capacity for such development).

The potential effects of siting future aquaculture operations are similar across Action and No Action alternatives, **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13), and would vary depending on type of aquaculture operations proposed and business plans (e.g., utilizing existing working waterfronts, vertically integrating). The potential beneficial effects to nearby communities also vary slightly across AOA Alternatives due to the proximity to coastal communities and their socioeconomic conditions and vulnerabilities. **Preferred Alternative 2** (W-1**)** has the potential to provide accessible jobs to nearby communities that could enable household income above the poverty level. **Preferred Alternatives 3 and 5** (W-4 and C-3) have the potential to provide accessible jobs. **Preferred Alternative 4** (W-8) is uniquely located nearby communities that are characterized by higher education levels and has the potential to provide employment opportunities that require higher educational experience, mutually benefiting aquaculture operations and the community. **Preferred Alternative 6** (C-13) has the potential to provide accessible jobs that span a wide-range of skill sets and backgrounds, benefiting broad portions of the community.

4.5.5 Potential Impacts on Tourism Economies

Tourism, leisure, and recreation are important industries in the Gulf region, and natural resource-based activities are a substantial component of these sectors. As outdoor recreation expenditures are often made in rural or lightly populated areas, the economic contributions of fish and wildlife resources can be particularly important to rural economies (Southwick Associates Inc 2007). Recreation can also contribute to community wellbeing and the maintenance of historic and communal ties. In the Gulf region, recreational fishing is an integral part of life and the culture of many communities and an important economic driver and substantial component of regional tourism and recreation. Residents and non-residential visitors alike who participate in recreational fishing activities support local and regional economies and jobs through purchases of fishing equipment and bait, boat purchases and rentals, paying for charter boat excursions, including purchases at local businesses, such as restaurants and grocery markets, fuel purchases, and hotel stays. A 2024 community vulnerability study by Michaelis identified Texas and Louisiana Gulf Coast communities in proximity to AOA Alternatives with moderate-to-high recreational fishing engagement and or reliance:

- Port Mansfield and South Padre Island, near **Preferred Alternative 2** (W-1);
- Matagorda Bay, Port O'Connor, and Port Aransas, near **Preferred Alternative 3** (W-4);
- Clute, Surfside Beach, and Quintana, near **Preferred Alternative 4** (W-8);
- Grand Isle and Venice, near **Alternative 6** (C-13).

Communities with higher recreational fishing engagement and reliance indicators could be particularly vulnerable to adverse disruptions from the expansion of aquaculture, but it could also represent areas with high potential for collaborative development from existing industry and infrastructure (Michaelis 2024; In Review). Commercial and recreational fishers may have interest in fishing near offshore aquaculture operations, as wild fish often aggregate around aquaculture equipment (Rhodes et al. 2023a). Having new reliable wildlife aggregation locations could create new opportunities for tourism and other recreational activities. For example, snorkel and scuba tours dive near aquaculture facilities in Hawaii to view wildlife (Kona Blue 2007).

Opportunities may exist for new aquaculture activities to be integrated into, and contribute in a complementary way, to local and regional tourism and recreation economies. For example, by contributing to and supporting the local seafood supply chains through cultivated product sales to local restaurants, suppliers, and grocery markets. Some aquaculture operators have also sought to diversify their business by offering agritourism experiences, such as farm tours and offering tastings of their cultivated products. One such example of the blending of aquaculture and tourism are the various regional shellfish and oyster "trails", that provide an interactive guide that invites locals and visitors to explore local aquaculture farms. These shellfish and oyster trails can be found throughout the country, and include the Maine Oyster Trail, Florida's Big Bend Shellfish Trail, the North Carolina Oyster Trail and Virginia Oyster Trail to name a few.

Tourists are increasingly becoming interested in local foods that reflect local livelihood and culture. Thus, aquaculture has become increasingly valuable to coastal communities for assuring consistent supply of local seafood to meet demand and maintaining locally-sourced seafood as a means to differentiate themselves to tourists (Kim et al. 2017). Value-added tourism products can contribute to the local seafood experience, and may include seafood trails, chefs or restaurant staff providing outreach on culinary techniques or harvest methods for local seafood, seafood and maritime events and festivals, interpretive tours or seafood harvesting or processing.

The identification of an AOA would not disqualify tourism or other recreational activities offshore. However, recreational ocean users may experience changes in transit patterns or access from increased vessel traffic or safety restrictions around fixed gear and other equipment placed in the water column or surface from aquaculture operations. Safety buffers may be set up around project sites during survey operations, construction, maintenance, and decommissioning activities. Nuisance impacts may include aesthetics, dust emissions, water quality degradation, and increased traffic that disrupt the recreational experience. Offshore facilities would be identified with appropriate markings for safety of navigation to identify facilities to ocean users in the area and avoid potential conflicts (Section 4.5.8.2). With the exception of permanent restricted access zones that may be established, many of these impacts would likely only affect tourism and other recreational activities temporarily while work was underway. There are disagreements in the literature regarding how the visual impact of aquaculture operations interacts with the tourism sector (Agular-Majarrex et al. 2017); for additional discussion of visual impacts (see Section 4.3.5). Given the size of these facilities in comparison to the available space for offshore recreation, and patterns of historical recreation estimated via vessel movement, the risk of adverse effects that displace, impede, or disrupt tourism and other recreation is low.

If a prospective aquaculture operator were to propose siting an operation within an AOA in the Gulf, the potential socioeconomic impacts, including impacts to tourism, would be assessed at that time and would be dependent on various project-specific details. The socioeconomic impacts would depend on the specific operational details of any new aquaculture operation (e.g., species grown, gear type used, intended market, travel and opportunity costs, disproportionate impacts to small and large business entities, and disproportionate impacts to certain communities, etc). Understanding the regional and local socioeconomic landscape, including the tourism component, can help regulators and prospective aquaculture operators in considering the potential effects associated with new offshore aquaculture activities. The extent to which potential changes patterns of access/transit or nuisance impacts may impact patterns of business or have direct or indirect effects on the economic value associated with tourism and recreation would be considered in future environmental review. The tourism and recreation sector includes a wide range of businesses that attract or support marine-based tourism and recreation, such as eating and drinking establishments, hotels and lodging, scenic or wildlife viewing tours, aquariums, parks, marinas, boat dealers, recreational vehicle parks and campsites, and associated sporting goods manufacturing. Many of the activities associated with this sector, such as hotels and restaurants, are not always directly marine dependent (SeaGrant 2023). Generally, communities where tourism is a significant component of the local economy could be more vulnerable to adverse disruptions (e.g., competition for markets, workforce, etc.), but it could also represent opportunities for potential collaboration to enhance or grow tourism. Early engagement with communities by prospective aquaculture operators can provide insight into how new offshore aquaculture activities may be integrated in a way that is complementary and beneficial to nearshore communities (Michaelis 2024; *In Review*), their tourism sectors and local economies more broadly.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Aquaculture development has the potential to cause adverse effects from the displacement or disruption of recreational activities due to fixed gear and other equipment being placed at the surface or in the water column, increased vessel traffic in and out of coastal areas, or changes in ecosystem services that support recreation and tourism. Aquaculture could create beneficial or adverse effects from wild species aggregation, establishing new opportunities for recreation (e.g., fishing, diving, sightseeing). Wild aggregation effects may also contribute to increased fishing pressure on commercially and recreationally important marine species leading to adverse effects on wild fish stocks.

The coastal communities nearby **Preferred Alternatives 2-4** (W-1, W-4, W-8) and **Alternative 6** (C-13) all have moderate to high levels of recreational fishing engagement and reliance and could benefit from new recreational fishing opportunities from the development of offshore aquaculture operations. Additionally, there are other coastal communities nearby with more traditional tourism economies that could be altered or affected by new aquaculture development nearby. The nearby communities closest to **Preferred Alternative 5** (C-3) have lower recreational fishing engagement and reliance, indicating that they may not benefit as much from increased fishing opportunities.

4.5.6 Potential Impacts on Oil, Gas and Wind Energy Development

4.5.6.1 Oil and Gas Development

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. Also, potential impacts of future aquaculture operations could occur with other industries if sited in high-use areas with other ocean use sectors, such as oil and gas. The severity of effects may be increased or decreased depending on the proximity to industrial activities and industry vessel transit corridors.

The potential effects at **Preferred Alternative 2** (W-1) are the same as discussed in **Alternative 1**. This location does not overlap and is not in close proximity (within 3 km [1.62 nm]) to any oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes). Thus, potential effects on offshore industrial activities are not expected given the geographical distance to the structures and regulatory setbacks from oil and gas infrastructure. The potential effects at **Preferred Alternative 3** (W-4) are the same as discussed in **Alternative 1**. This location does not overlap with any oil and gas infrastructure, but it is located 2.64 km (1.43 nm) east of an active oil and gas lease block with infrastructure. However, potential effects on offshore industrial activities are not expected given the geographical distance to the structure and regulatory setbacks. The potential effects at **Preferred Alternative 4** (W-8) are the same as discussed in **Alternative 1**. Similarly, this location does not overlap with any oil and gas infrastructure, but it is located 750 m from a single oil and gas pipeline. Despite this distance, potential effects on offshore industrial activities are not expected given the regulatory setback, and other likely mitigation measures. The potential effects at **Preferred Alternative 5** (C-3) are the same as discussed in **Alternative 1**. Again, this location does not overlap with any oil and gas infrastructure; however, there is a variety of oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]), including three oil and gas pipelines, one within 700m (2297 ft), two active oil and gas platforms, and 13 boreholes. Despite this infrastructure, potential impacts are not expected given the regulatory setbacks and other likely mitigation measures. The potential effects at **Alternative 6** (C-13) are the same as discussed in **Alternative 1**. Same as the other Alternatives, this location does not overlap with any oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, and boreholes), but there is some oil and gas infrastructure in the vicinity (within 3 km [1.62 nm]), including one oil and gas platform, two oil and gas pipelines and 4 boreholes. Potential impacts are not expected given the regulatory setbacks and likely mitigation measures..

4.5.6.2 Wind Energy Development

In addition to oil and gas lease areas, BOEM has established Wind Energy Areas (WEA) in the Gulf. On August 29, 2023, BOEM held the first-ever offshore wind energy auction for the Gulf region, resulting in one lease area receiving a high bid of $5.6 million[34]. RWE Offshore US Gulf, LLC was the winner of the Lake Charles Lease Area, which has the potential to generate approximately 1.24 gigawatts of offshore wind energy capacity and power nearly 435,400 homes with clean, renewable energy.

On February 16, 2024, BOEM received an unsolicited application from Hecate Energy Gulf Wind LLC (Hecate Energy) for commercial wind energy lease(s) on the Gulf OCS in WEA Options C and D (Figure 4.5.6.2-1). On July 29, 2024, BOEM published a Request for Competitive Interest (RFCI) for Gulf WEA Options C and D because BOEM had received an unsolicited lease request from Hecate Energy for these areas. BOEM is currently reviewing comments received on the RFCI. WEA Options C and D are located off the coast of Southeast Texas. The first, WEA Option C, totals 74,113 acres, and the second, WEA Option D, totals

[34] https://www.boem.gov/renewable-energy/state-activities/gulf-mexico-wind-auction-1

68,239 acres (106.6 sq mi). The entire area comprises approximately 142,352 acres (222.4 sq mi).

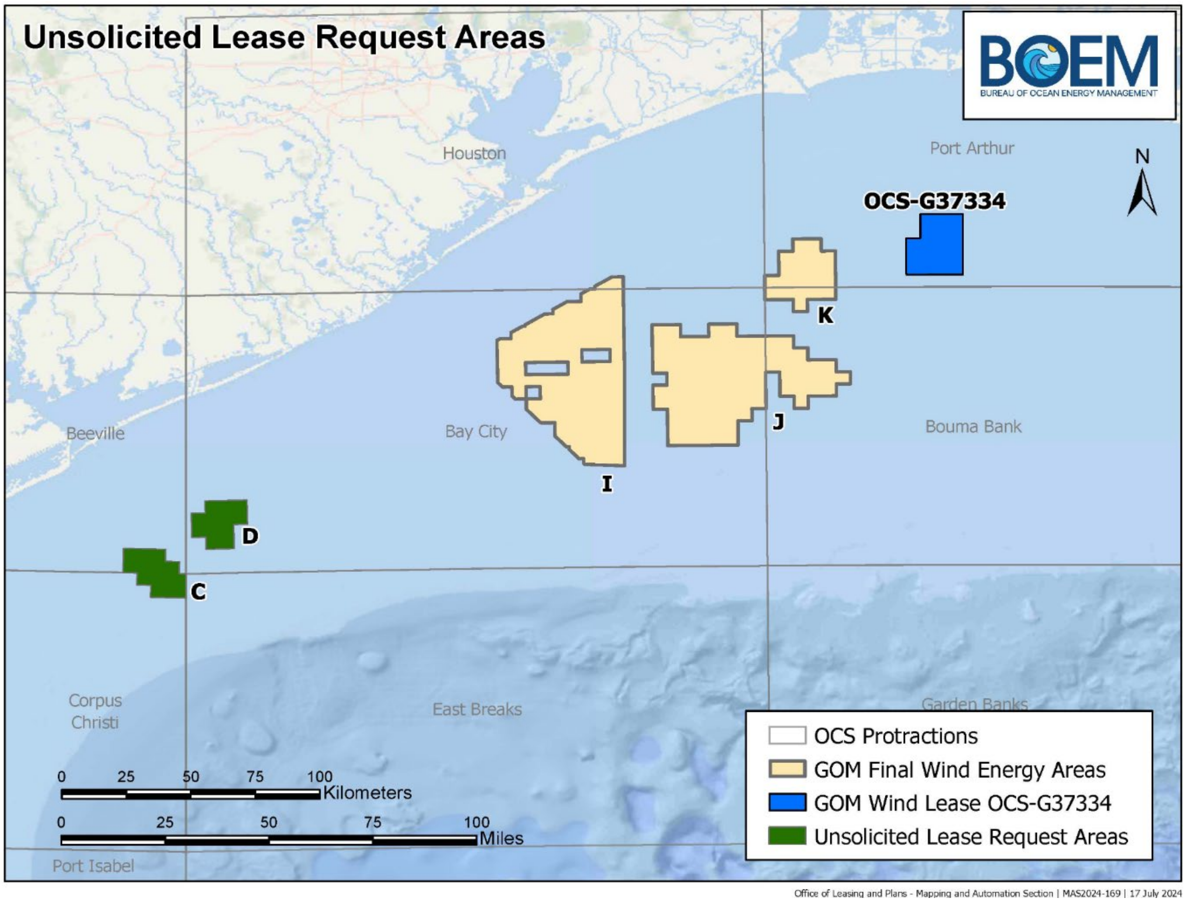

Figure 4.5.6.2-1. Gulf OCS WEA Options C and D, off the coast of Southeast Texas. The proposed location for Hecate Energy's proposed Gulf Wind Offshore Wind Project 2.
Source: BOEM Office of Leasing and Plans, Mapping and Automation Section 2024. Available: https://www.boem.gov/renewable-energy/state-activities/gulf-mexico-activities

Hecate Energy's proposed "Gulf Wind Offshore Wind Project 2" aims to generate up to 2 gigawatts of renewable energy in the Gulf. Hecate Energy proposes multiple potential uses for this renewable energy, including interconnection to the electric grid, sale in power purchase agreements to private off-takers, or use for Wind-to-X technologies through which offshore wind energy is used to produce another energy resource. The proposed project would consist of up to 133 fixed-bottom wind turbine generators, each with a capacity of 15-23 megawatts (MW). This would cause an overall maximum capacity of approximately 3,000 MW.

On March 21, 2024, BOEM issued a Proposed Sale Notice (89 FR 20234, March, 21, 2024) for a second lease sale in the Gulf (Figure 4.5.6.2-2.). BOEM received 25 comments, but only one company was deemed qualified to bid. As a result, BOEM canceled this sale given a lack of competitive interest. BOEM may decide to move forward with a lease sale at a future time, should industry interest warrant one.

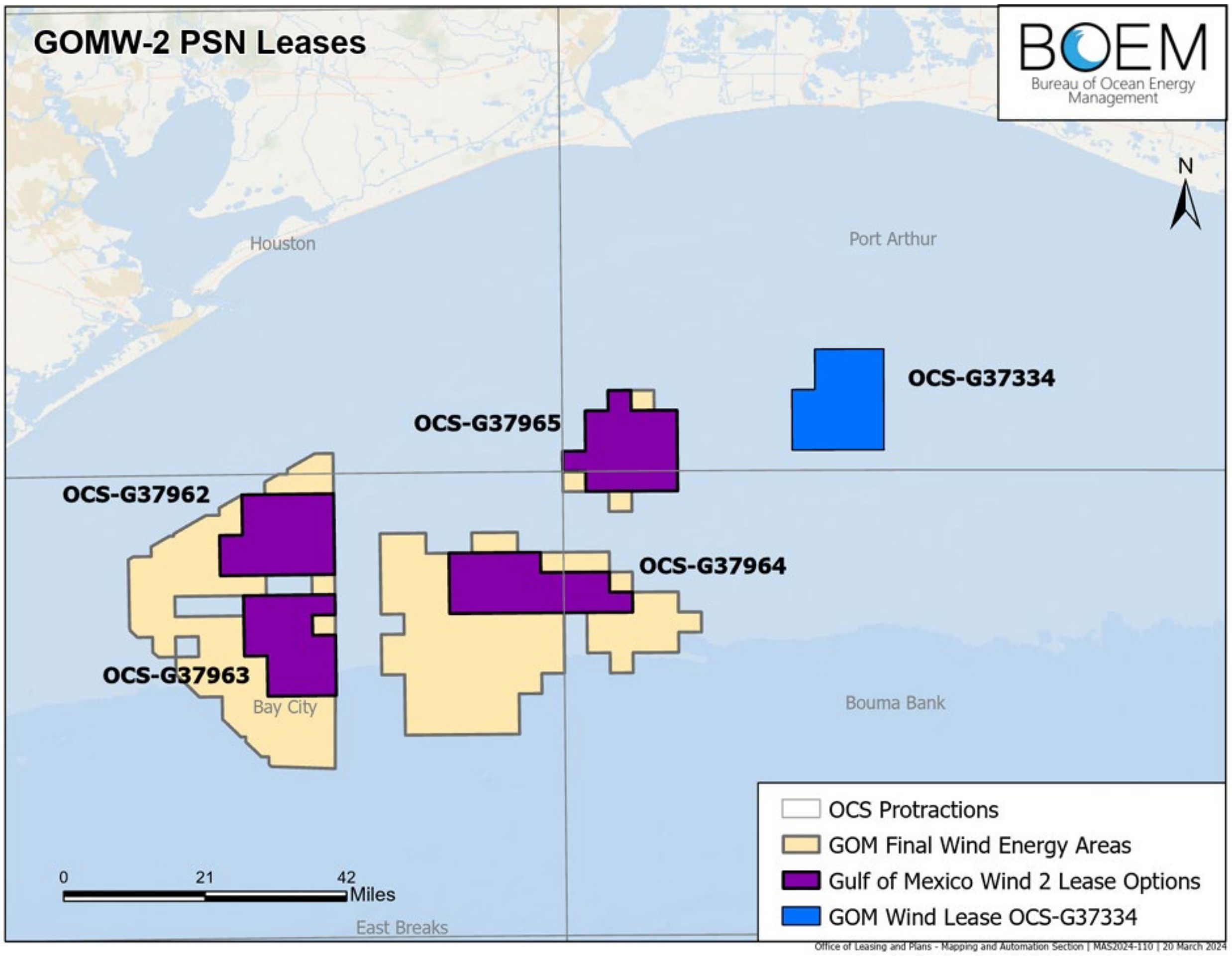

Figure 4.5.6.2-2. Gulf of Mexico Wind 2 Lease Options located off the coasts of Texas and Louisiana. *Source: BOEM Office of Leasing and Plans, Mapping and Automation Section 2024. Available:*https://www.boem.gov/renewable-energy/state-activities/gulf-mexico-wind-auction-2

There is no requirement for aquaculture operations to be sited within an AOA, and unlike energy development (e.g., oil and gas, wind energy) because there is presently no leasing mechanism to 'reserve' areas for aquaculture development in U.S. federal waters. Michaelis (2024; In Review) notes that new aquaculture businesses seeking to integrate into existing working waterfront communities in some coastal Gulf areas could find it challenging given the present rapid development of other potentially more lucrative industries, like liquefied natural and offshore wind energy sectors. Alternatively, prospective offshore aquaculture operators could seek to leverage resources and partner with the energy industries and affiliated supply sectors in these areas (Riley et al. 2021).

The comprehensive marine spatial analysis conducted for the development of the Atlas (Riley et al. 2021) sought to identify areas where conflicts with ocean users could be minimized and adverse interactions mitigated. As energy development in the Gulf is ongoing and dynamic, continued marine spatial planning efforts, interagency coordination, and stakeholder engagement, and prudent siting by prospective offshore aquaculture operators interested in siting in AOAs (or elsewhere in the Gulf), could help minimize conflicts with existing and developing energy uses and maximize benefits to nearshore communities.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. Potential for negative effects of future aquaculture operations could occur if sited in areas of high conflict with other ocean use sectors, such as wind energy development areas.

Preferred Alternatives 2-5 (W-1, W-4, W-8, and C-3) and **Alternative 6 (C-13)**, do not overlap with existing WEAs and all AOA Alternatives are located in deeper waters (>50m [164 ft] of the OCS that WEAs. **Preferred Alternative 2** (W-1) is located 37 km (20 nm) from the closest WEA, WEA Option A. **Preferred Alternative 3** (W-4) is located 14.5 km (7.8 nm) from the closest WEA, WEA Option C. **Preferred Alternative 4** (W-8) is located 21.8 km (11.7 nm) from the closest WEA, WEA Option G. **Preferred Alternative 5** (C-3) is located 103.6 km (55.9 nm) from the closest WEA, WEA Option N. **Preferred Alternative 6** (C-13) is located 340 km (188 nm) from the closest WEA, WEA Option N.

Due to this lack of overlap and distance between WEAs and the AOA Alternatives, and the AOA Alternatives being located in deeper waters and further from shore, aquaculture operations sited in an AOA are expected to have a minimal impact on wind energy development and operations. If both industries were to continue to develop, marine aquaculture operations may create a modest increase in vessel traffic that might travel in and around WEA occupied by wind farms to reach nearby ports. However, navigational safety measures (e.g., PATONs) would mitigate much of the risk of increased vessel traffic by aquaculture.

4.5.7 Potential Impacts on Other Offshore Activities and Infrastructure

Marine minerals, submarine utilities (cables and pipelines), scientific research and surveys, and associated activities and infrastructure could be impacted from the no action, action alternatives, and ongoing and planned activities in the geographic analysis area. The potential impacts could vary in severity and magnitude from overlapping with sand dredging operations to impeding a scientific research survey.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Potential for negative effects of future aquaculture operations could occur if sited in areas of high conflict with other ocean use sectors, such as marine mineral operations, and submarine utilities. **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3) and **Alternative 6** (C-13), do not overlap with mineral mining activity. Overall, marine mineral operations and submarine utilities are not anticipated to be impacted by **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) given the geographical distance to the structures and standard setbacks. However, it is possible that future oceanographic surveys could be impacted by aquaculture operations established in an AOA, but vessel captains operating research vessels in the area could spot and avoid structures, equipment and transiting vessels. Any future offshore aquaculture structure (e.g., submerged cages) will need to use visible floats and lights as required by USCG, which will reduce potential risk. Future oceanographic surveys may need to alter or adjust the sampling locations. Although the risk is low that **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) will impact ongoing offshore activities in the region, there is potential risk that offshore activities could impact aquaculture operations. For instance, a research vessel traversing near the area could collide with the aquaculture equipment destroying it and releasing the harvested species. Overall, the risk is low but the magnitude would be severe. In addition, inclement weather or unexpected aquaculture mooring system failure could cause aquaculture equipment to break away and potentially impact ongoing and planned offshore activities.

4.5.8 Potential Impacts on Health and Public Safety

This section evaluates how and to what degree the Proposed Action (identifying AOAs) could potentially impact navigational safety and military readiness and operations. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. While the seafood safety (including antibiotic use), seafood nutrition and marine debris may affect health and public safety generally, these effects would be the same across all AOA Alternatives, including the no action alternative. Therefore, these issues are not discussed further in this section. The impacts of antibiotic use and marine debris are however discussed in further detail in relation to the physical and biological environments (see Section 4.3 and Section 4.4).

The action of identifying AOAs in federal waters of the Gulf would not cause any immediate direct or indirect impacts, beneficial or adverse, on the public health and safety as this action is only a planning action and administrative in nature. No specific aquaculture projects or types of aquaculture are required or certain to occur within an AOA. Should an aquaculture project be proposed within an AOA in the future, potential impacts on the health and public safety in the socioeconomic environment would be assessed by the competent agencies during the permitting and environmental review processes, and could be similar to the potential impacts described in this section.

4.5.8.1 Potential Impacts on Military Readiness and Operations

The identification of AOAs in U.S. federal waters of the Gulf is not expected to have adverse effects on military readiness and operations, in part given the extensive coordination and consultation with DOD staff in the region and headquarters offices, DAF, USCG, NASA and DOD Siting Clearinghouse in the development of the spatial suitability modeling process for military and national security activities used considered in the Atlas. The AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8 and C-3] and **Alternative 6** [C-13]) analyzed in this DPEIS do not overlap with military Danger Zones and Restricted Areas, or unexploded ordnance points and areas. Additionally, there were no military vessel transits in any of the AOA Alternatives during the 2015-2019 time period considered in the spatial analysis of the Atlas.

This proactive coordination and planning helps to ensure that aquaculture operations in an AOA can occur in the offshore environment with minimal risk to public health and safety, while still maintaining the training and readiness capabilities of the nation's armed forces in the interest of national security. It also allows the military installations that support those missions to remain or even expand operations, employing military personnel and civilians within a region, providing economic benefits to communities of the Gulf.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture operations could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. Additionally, those operations would be at higher risk for proposing sites for aquaculture that may conflict with military activities that are incompatible with aquaculture development, and could cause an inefficient site selection, permitting and environmental review process for proposed offshore aquaculture operations.

Preferred Alternatives 2-5 (W-1, W-4, W-8 and C-3) overlap with SUA Warning Areas, with **Preferred Alternative 2** (W-1) and **Preferred Alternative 3** (W-4) also overlap with MOAs. SUA Warning Areas and MOAs. **Alternative 6** (C-13) is the only AOA Alternative that does not overlap with a SUA Warning Area. Coordination with the DOD has determined aquaculture operations sited within an AOA Alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8 and C-3] and **Alternative 6** [C-13]) are considered to be compatible with military activities. However, aquaculture operations sited in AOAs may still be subject to certain stipulations (e.g., height restrictions, lighting requirements, technology restrictions and hold harmless agreements) and final design review by the DOD Siting Clearinghouse intended to reduce potential impacts to military activities.

4.5.8.2 Potential Impacts on Navigation Safety

If an AOA were identified and aquaculture farms were sited in an AOA, there could be potential adverse impacts associated with the introduction of new structures, obstructions, or hazards to navigation. Interactions with vessels operating in the Gulf could occur due to buoy or marker misinterpretation by mariners, collisions, and entanglement with active or derelict gear that has become loose, separated or is potentially unmarked. Interactions may also occur between vessels operating in the Gulf and vessels providing support to aquaculture operations (e.g. personnel transport or feed and equipment barges) Vessel interactions may lead to damaged gear, localized environmental impacts, loss in revenue, and human health and safety risks.

Moreover, marine debris associated with aquaculture operations could be a navigational safety issue. For instance, marine debris accidentally dispersed from an aquaculture facility can potentially cause navigational hazards and costs to shipping, recreation and tourism, and fishing (Mouat et al. 2010). Interactions with marine debris at an aquaculture facility may not only cause navigational problems and economic losses to offshore industries, but the aquaculture facility can also suffer damage to vessels and equipment, including time and resources (Macfadyen and Cappell 2009). Also, marine debris from land-based or other sources can become entangled with aquaculture gear that may require divers to clear the debris and depending on the sea state, may add safety concerns for divers (Macfadyen and Cappell 2009). Removing marine debris at an aquaculture facility can be costly. In Scotland, Hall (2000) reported that on average one hour per month was spent removing debris and disentangling fouled propellers, which can cost around £1,200 (~$1,500 USD) per incident or € 155,548 ($169,248 USD) per year.

Other potential impacts are possible during construction, operations, and decommissioning, because there may be more fixed gear and vessels in the area, which could increase the risk of entanglement and collision with gear causing marine debris. In general, all types of aquaculture operations may create safety concerns given the gear and cages are often submerged. Risk can be reduced with proper awareness and prevention measures. Aquaculture equipment can include an array of anchors, lines, and moored structures or vessels. Structures may also include submerged pipelines, cables, and water intakes. Potential impacts can include vessel colliding with a structure, vessel collision, structural damage given environmental factors, or exposure to hazardous materials in the case of accidental spills or gear loss, and risk of marine debris. Vessel propellers may get caught in derelict gear, which could pose health and safety risks. Potential impacts could involve commercial or recreational vessels passing through the area. Potential impacts could be minimized during the USCG and USACE permit review; any moored structure, aids to navigation, or other changes to navigable waters, requires a risk assessment report to identify primary threats to waterway safety, and a determination made to assess whether a more extensive, technical risk analysis is necessary before a permit is issued.

Public interest factors that will be considered during the review include reducing the possibility of personnel injury or loss of life; damage or loss of vessels, cargo, or structures in, on, or immediately adjacent to the navigable waters of the United States; and, damage to the marine environment. It is anticipated the potential impacts on the human environment from marine debris will be minimal. It is expected that mitigation associated with authorizations for aquaculture projects will include marine debris awareness and prevention. Requiring and developing a Marine Debris Management and Monitoring Plan could minimize the risk of marine debris. Also, gear marking and reporting lost gear could mitigate impacts from marine debris.

All aquaculture operations in federal waters are required to comply with federal regulations adopted to ensure safe marine vessel movement, including appropriate marking of aquaculture structures with PATONs. As part of the USCG and USACE review of any moored structure, aid to navigation, or other changes to navigable waters, a risk assessment may be conducted to identify primary threats to waterway safety as well as to determine if a more extensive, technical risk analysis is necessary. Offshore aquaculture operations sited in an AOA would be subject to the same or similar conditions designed to minimize impacts (e.g., design stipulations, requirements for gear maintenance, monitoring, response time and recovery). Engineering designs, monitoring and maintenance plans, and response and contingency plans would mitigate public health and safety risks related to gear failures and marine debris and should reflect a range of oceanographic conditions. Fredriksson and Beck-Stimpert (2019), incorporated by reference, developed engineering technical guidance for offshore aquaculture installations in the Gulf intended to reduce the risk of gear becoming derelict. Following these plans and conditions, and conducting routine and proactive monitoring of the aquaculture structures by operators would help to mitigate potential risks of vessel interaction, regardless of AOA alternatives.

Offshore aquaculture development in an AOA could affect navigational patterns of marine vessels and increase vessel traffic volume, both offshore and near ports and harbors. Factors that may influence the extent of impacts vessel traffic associated with operations sited in an AOA may have on transportation and navigation include vessel speed, the number of vessel trips needed to install and tend to gear, distance traveled, existing volume and density of vessels in the area, and seasonality or timing of vessel operations. These factors and the impact they may have on existing transportation and navigation would vary by operation and location relative to ports, processing, and shipping infrastructure, and would likely be considered and minimized in permit conditions for specific aquaculture operations. Local ports are expected to be used for the vast majority of operations, maintenance, and construction/destruction activities, and landing aquaculture products. For additional discussion on individual AOA proximity to and expected impacts on particular ports and working waterfronts, see Section 4.5.4. The growth of aquaculture operations in an AOA could also increase demand on offshore regulation compliance enforcement, and demand on emergency services.

Safety buffers, speed reductions and restricted areas may be enacted by regulatory agencies (i.e. USGC or USACE) in the immediate vicinity of the operations during certain activities or permanently for public safety purposes. Vessels associated with aquaculture operations sited in an AOA would comply with all navigation and vessel regulations, including vessel traffic service/separation schemes for ports, harbors, and other waters subject to congested vessel traffic. Site-specific navigational risk assessments which may be required in the USCG permitting process of future aquaculture operations would consider if the increase in vessel traffic in and out any port/harbor would constitute a meaningful change from baseline conditions or post a significant risk beyond what can be safely handled by the port or harbor.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

The types of adverse impacts future aquaculture operations pose to navigation are consistent across the AOA alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]), including **Alternative 1** (No Action). None of the AOA alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** (C-13) overlap with shipping fairways or anchorage areas. Mitigation measures could be applied consistently across AOA alternatives to reduce risks. There is, however, an increase in the risk of effects based upon the frequency in which vessels transit through the AOA, representing the normal transit patterns of vessels potentially disrupted by new structures or obstructions that could occur in an AOA through future aquaculture development in those locations.

Preferred Alternative 2 (W-1) averaged around 19 AIS tracked vessel transits across the AOA alternative per year (averaged 2015-2020), the majority of which were associated with fishing activities. **Preferred Alternative 3** (W-4) averaged a greater number of vessel transits with 32 transits per year, the majority of which were tankers and uncharacterized vessels likely associated with oil and gas activities. **Preferred Alternative 4** (W-8) had the lowest average vessel transit through any AOA alternative with 12 vessel transits averaged from 2015-2020, mostly from tankers. **Preferred Alternative 5** (C-3) has averaged 106 vessel transits per year, which is greater than **Preferred Alternatives 2-4** (W-1, W-4, W-8). The majority of these vessel transits through **Preferred Alternative 5** (C-3) were from fishing and uncharacterized vessels. **Alternative 6** (C-13) had the greatest average number of vessel transits per year traveling through the AOA alternative out of all AOA alternatives (**Preferred Alternatives 2-5** [W-1, W-

4, W-8, and C-3] and **Alternative 6** (C-13). Averaged over the same 5 year period (2015-2020), **Alternative 6** (C-13) had 1,340 vessel transits through the AOA alternative per year. This large difference in vessel transits is attributed to **Alternative 6** (C-13) likely has a greater number of untracked vessel transits than **Preferred Alternatives 2-5** (W-1, W-4, W-8, and C-3), given its close proximity to shore which would be more accessible to smaller recreational vessels than locations further offshore.

4.5.9 Potential Impacts on Environmental Justice

EJ communities around the Gulf, including minority populations, low-income populations and other underserved communities may have unique human health vulnerabilities (e.g., heightened disease susceptibility, health disparities, and pathways). The types of potential impacts to public health and safety described above are generally not expected to cause any disproportionately high and adverse human health or environmental effects EJ communities, but should be considered in more site-specific detail in future environmental reviews. Aquaculture discharges authorized under the federal permitting process are not expected to adversely impact the quality of the farmed aquaculture species, which should avoid human health risks to minority, low-income populations, or consumers in general.

EJ is defined as equity applied to environmental laws, policies, and practices (NMFS 2023f). The Federal Government recognizes that barriers to equity have caused many communities to be underserved, making them the most vulnerable to socioeconomic and environmental issues, such as climate change. Long standing socioeconomic inequities can make underserved communities, who often have the highest exposure to hazards and the fewest resources to respond, more vulnerable (NMFS 2023f). Per NMFS (2023), fishing communities may be especially vulnerable to sea level rise, increased storm events, displacement, accumulated effects from multiple disasters, loss of catch abundance and diversity, and the resulting impacts to their local economy. Environmental justice ensures minority and low-income populations are not disproportionately impacted by adverse human health or environmental effects.

EJ communities around the Gulf may experience unique socioeconomic conditions (e.g., reliance on a particular resource that may be affected by the proposed action, subsistence fishers, and minority-owned small business owners). The types of potential socioeconomic impacts described above are generally not expected to cause any disproportionately high and adverse effects on EJ communities, but should be considered in more site-specific detail in future environmental reviews. If, in the future, aquaculture operations were proposed to be sited within an identified AOA, environmental justice considerations and potential impacts would be assessed at the time, based upon proposed project information.

Preferred Alternatives 2-5 (W-1, W-4, W-8 and C-3) are located offshore ranging between 79 km (43 nm) and 133.4 km (72.0 nm) from shore. While **Alternative 6** (C-13) is notably closer to shore (9.6 km [5.2 nm]) than the other alternatives, there are no minority or low-income populations in close proximity to any of the Alternatives. While minority or low-income populations may not be impacted from future offshore aquaculture operations sited in an AOA, adjacent shore communities could be impacted from new offshore aquaculture operations (See Sections 4.5.1, *Potential Impacts to Commercial Fishing*; 4.5.3, *Potential Impacts to Recreational Fishing*; 4.5.4, *Potential Impacts to Ports and Working Waterfronts*; 4.5.5, *Potential Impacts to Tourism Economie*s for detailed discussion).

In their publication, Michaelis (2024) describes the social vulnerabilities, risks, and opportunities associated with new offshore aquaculture development for onshore communities located within 100-190 km (54-103 nm) of the Alternatives. Among the CSVIs analyzed by Michaelis (2024) were poverty, population composition, and personal disruption (refer to Table 4.5.9-1 for a list of NMFS CSVIs and their descriptions (Jepson and Colburn 2013).

Indicators of vulnerability associated with environmental justice can include, but are not limited to income, race, ethnicity, household structure, education levels, and age. Directives of E.O. 12898 focus on federal agencies considering, “the disproportionately high and adverse human health or environmental effects of (an agency’s) programs, policies, and activities on minority populations and low-income populations in the United States and its territories…” Some of the indices within the NMFS CSVIs can provide useful insights for understanding communities where environmental justice may be a concern. The low-income element of environmental justice can be measured by using the Poverty, Population Composition Vulnerability, and Personal Disruption indices of the CSVIs. Other options are to simply use the Poverty index alone or the Percent of families below poverty level, though this covers fewer aspects of poverty. The minority status element can be assessed through the Population Composition Index described below. It is also possible to use the percent of individuals who are members of the American Indian or Alaska Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic – per the Decennial Census. Further, some fisheries and fishing-related industries may include individuals of the defined minority or low income populations and these should be mentioned at least qualitatively. More generally, in any case where the use of quantitative or statistical data is problematic, another option would be to hold scoping meetings to discuss levels of minority and low-income populations. Detailed EJ analysis should be completed in future environmental review.

Table 4.5.9-1. NOAA Fisheries Community Social Vulnerability Indicators. *Source: Jepson and Colburn 2013.*

Fishing Engagement and Reliance Indicators	Definition
Commercial Fishing Engagement	Measures the presence of commercial fishing through fishing activity as shown through permits, fish dealers, and vessel landings. A high rank indicates more engagement.
Commercial Fishing Reliance	Measures the presence of commercial fishing in relation to the population size of a community through fishing activity. A high rank indicates more reliance.
Recreational Fishing Engagement	Measures the presence of recreational fishing through fishing activity estimates. A high rank indicates more engagement.
Recreational Fishing Reliance	Measures the presence of recreational fishing in relation to the population size of a community. A high rank indicates increased reliance.

Environmental Justice Indicators	Definition
Poverty	Is expressed as those receiving assistance, families below the poverty line, and individuals older than 65 and younger than 18 in poverty. A high rank indicates a high rate of poverty and a more vulnerable population.
Population Composition	Corresponds to the demographic makeup of a community including race, marital status, age, and ability to speak English. A high rank indicates a more vulnerable population.
Personal Disruption	Captures unemployment status, educational attainment, poverty, and marital status. A high rank indicates less personal capacity to adapt to changes and thus a more vulnerable population.

Climate Change Indicators	Definition
Sea Level Rise	Signifies the overall risk of inundation from projected sea level rise between one to six feet over the next ~90 years. The indicator represents the possibility of inundation based upon the combined projections at each stage of sea level rise and could vary depending upon future circumstances. A high rank indicates a community more vulnerable to sea level rise.
Storm Surge Risk	Refers to the overall flooding risk from hurricane storm surge categories 1-5. It represents the "worst-case" possibility of inundation based on the combined hurricane storm surge categories and could vary depending on future circumstances. A high rank indicates a community more vulnerable to a particular hurricane storm surge.

Climate Change Indicators	Definition
Labor Force Structure	Characterizes the availability of employment including females employed, population in the labor force, self-employment, and social security recipients. A high rank indicates fewer employment opportunities and a more vulnerable population.
Housing Characteristics	A measure of infrastructure vulnerability to coastal hazards including median rent and mortgage, number of rooms, and presence of mobile homes. A high rank means more vulnerable infrastructure and a more vulnerable population. On the other hand, the opposite interpretation might be that more affordable housing could be less vulnerable for some populations.

Gentrification Pressure Indicators	Definition
Housing Disruption	Represents factors that indicate a fluctuating housing market where some displacement may occur given rising home values and rents including change in mortgage value. A high rank means more vulnerability for those in need of affordable housing and a population more vulnerable to gentrification.
Retiree Migration	Characterizes communities with a higher concentration of retirees and elderly people in the population including households with inhabitants over 65 years, population receiving social security or retirement income, and level of participation in the workforce. A high rank indicates a population more vulnerable to gentrification as retirees seek out the amenities of coastal living and move to these communities.
Urban Sprawl	Describes areas experiencing gentrification through increasing population density, proximity to urban centers, home values and the cost of living. A high rank indicates a population more vulnerable to gentrification.

Based on Michaelis (2024), nearly half of the 18 Louisiana communities analyzed within 190 km (103 nm) of **Preferred Alternative 5** (C-3) had relatively high environmental justice vulnerability scores, with all but four of the communities possessing high scores for personal disruption (Table 4.5.10.2). Sixteen of the 18 communities had high scores for at least one of the EJ vulnerability indicators, and six communities had high scores for all three EJ vulnerability indicators (Table 4.5.9-2). These indicator scores suggest that many households in these communities may be resource-limited in various ways (e.g., income, education, and English language skills) and less able to adapt to changes caused by the development of a new industry. However, Michaelis (2024) noted these communities may also present opportunities for thoughtful collaboration and equitable engagement by prospective operations to reduce vulnerabilities.

Table 4.5.9-2. **Preferred Alternative 5** (C-3) indicator scores by community. Categorical ranked scores are presented for 18 communities, listed alphabetically. Refer to Table 4.5.9-1 for indicator definitions. High vulnerability scores of 3 or 4 are emphasized in red; higher scores denote greater vulnerability. A score of 0 indicates no data available. (*Source: Michaelis 2024; In Review)*

Community (Louisiana)	Commercial Fishing Engagement	Commercial Fishing Reliance	Recreational Fishing Engagement	Recreational Fishing Reliance	Poverty	Population Composition	Personal Disruption	Sea Level Rise Risk	Storm Surge Risk	Labor Force	Housing Characteristics	Housing Disruption	Retiree Migration	Urban Sprawl
Abbeville	4	3	1	1	4	3	4	1	2	3	3	1	1	1
Amelia	1	1	1	1	3	4	4	4	3	2	4	1	1	1
Baldwin	1	1	1	1	3	3	4	2	3	2	4	1	1	1
Bayou Vista	1	1	1	1	2	1	3	1	3	2	4	1	1	1
Berwick	2	1	1	1	3	1	3	1	3	3	3	1	1	1
Charenton	1	1	1	1	2	2	1	1	3	2	4	1	1	1
Delcambre	2	1	1	1	3	2	4	3	3	2	4	1	2	1
Erath	2	1	1	1	2	1	3	3	3	1	4	1	1	1
Franklin	2	1	1	1	3	3	4	4	4	2	3	1	2	1
Glencoe	1	1	0	0	1	3	2	0	3	4	0	0	2	0
Jeanerette	2	1	1	1	4	4	4	1	2	2	4	2	1	1
Kaplan	2	1	1	1	3	1	4	1	2	3	3	1	2	1
Lydia	1	2	1	1	4	1	4	1	3	3	0	0	1	0
Morgan City	3	1	1	1	2	2	3	3	4	3	3	1	1	1
New Iberia	3	1	1	1	4	3	4	1	3	2	3	1	1	1
Patterson	2	1	1	1	2	2	2	1	3	1	3	1	1	1
Siracusaville	1	1	1	1	1	4	1	0	3	4	0	0	2	1
Sorrel	1	1	1	1	4	1	3	0	3	4	0	0	2	1

Per the analysis by Michaelis (2024), all eight of the Louisiana communities included in the analysis within 100 km (54 nm) of **Alternative 6** (C-13) had relatively high scores for at least one of the environmental justice vulnerability categories, five out of these had high scores in two of the categories, and two of these communities scored high in all three of the EJ vulnerability categories (Table 4.5.9-3). Michaelis (2024) noted it would be especially important for more vulnerable communities that new operations seeking to develop be mindful of these environmental justice challenges, and develop ways to mitigate impacts.

Michaelis (2024) reported four of the five Texas communities analyzed within 100 km (54 nm) of **Preferred Alternative 2** (W-1) had relatively high scores for at least one of the environmental justice vulnerability categories, and two of these communities (Laguna Heights and Port Isabel) had high scores for all three EJ vulnerability categories (Table 4.5.9-4).

As reported by Michaelis (2024), the EJ vulnerability scores for communities analyzed within 110 km (59 nm) of **Preferred Alternative 3** (W-4) were generally low. Two of the eight communities had relatively high scores for one EJ vulnerability indicator (Holiday Beach and Matagorda), one community (Lamar) had relatively high scores for two of the three indicators, and one community (Seadrift) notably had high scores for all three EJ vulnerability indicators (Table 4.5.9-5). Per Michaelis (2024; In Review) the scores suggest that Holiday Beach, Lamar, and Seadrift may have less ability to adapt to change (such as those brought by new developing industries), depending on the types of changes that occur with aquaculture. High poverty scores may suggest that Matagorda, Lamar, and Seadrift could benefit if new aquaculture development were able to positively affect local and household incomes (Michaelis 2024; In Review).

Per Michaelis (2024, all communities analyzed within 125 km (109 nm) of **Preferred Alternative 4** (W-8), except for Surfside Beach, had a high vulnerability score in at least one EJ vulnerability indicator; notably, scores for Freeport suggest very high environmental justice-related vulnerability. Personal disruption was the most common vulnerability concern for communities near **Preferred Alternative** 4 (W-8), suggesting less personal adaptive capacity to readily adjust to changes brought about by new industry development.

Table 4.5.9-3. **Alternative 6** (C-13) indicator scores by community. Categorical ranked scores are presented for 4 communities, listed alphabetically. Refer to Table 4.5.9-1 for indicator definitions. High vulnerability scores of 3 or 4 are emphasized in red; higher scores denote greater vulnerability. A score of 0 indicates no data available. (*Source: Michaelis 2024; In Review).*

Community (Louisiana)	Commercial Fishing Engagement	Commercial Fishing Reliance	Recreational Fishing Engagement	Recreational Fishing Reliance	Poverty	Population Composition	Personal Disruption	Sea Level Rise Risk	Storm Surge Risk	Labor Force	Housing Characteristics	Housing Disruption	Retiree Migration	Urban Sprawl
Boothville	2	3	1	1	4	1	4	1	3	2	0	1	2	0
Buras	3	3	1	2	3	2	3	2	3	3	4	1	1	0
Empire	4	4	1	2	4	4	4	2	4	2	4	1	1	1
Grand Isle	4	4	4	4	2	1	3	4	4	3	3	4	3	1
Pointe a la Hache	1	2	1	2	0	4	4	0	3	1	0	0	1	0
Port Sulphur	4	2	1	1	4	4	4	2	4	3	4	1	1	1
Triumph	1	1	1	1	2	3	2	2	3	2	0	0	1	0
Venice	3	4	4	4	3	1	2	1	3	1	0	1	1	0

Table 4.5.9-4. **Preferred Alternative 2** (W-1) indicator scores by community. Categorical ranked scores are presented for 8 communities, listed alphabetically. Refer to Table 4.5.9-1 for indicator definitions. High vulnerability scores of 3 or 4 are emphasized in red; higher scores denote greater vulnerability. A score of 0 indicates no data available. (*Source: Michaelis 2024; In Review)*.

Community (Texas)	Commercial Fishing Engagement	Commercial Fishing Reliance	Recreational Fishing Engagement	Recreational Fishing Reliance	Poverty	Population Composition	Personal Disruption	Sea Level Rise Risk	Storm Surge Risk	Labor Force	Housing Characteristics	Housing Disruption	Retiree Migration	Urban Sprawl
Laguna Heights	1	1	1	1	4	4	4	1	2	2	4	1	1	1
Laguna Vista	1	1	1	1	3	2	1	1	2	3	2	1	3	1
Port Isabel	4	2	2	1	4	4	3	2	4	3	4	3	2	1
Port Mansfield	1	4	2	4	0	1	3	2	3	1	0	4	2	1
South Padre Island	1	1	3	3	1	1	1	3	3	2	2	1	1	1

Table 4.5.9-5. **Preferred Alternative 3** (W-4) indicator scores by community. Categorical ranked scores are presented for eight communities. High vulnerability scores of 3 or 4 are emphasized in red; higher scores denote greater vulnerability. A score of 0 indicates no data available. (*Source: Michaelis 2024; In Review).*

Community (Texas)	Commercial Fishing Engagement	Commercial Fishing Reliance	Recreational Fishing Engagement	Recreational Fishing Reliance	Poverty	Population Composition	Personal Disruption	Sea Level Rise Risk	Storm Surge Risk	Labor Force	Housing Characteristics	Housing Disruption	Retiree Migration	Urban Sprawl
Austwell	1	1	1	1	1	1	2	1	1	4	0	1	4	1
Fulton	2	2	1	1	1	1	2	1	1	4	4	4	4	1
Holiday Beach	1	1	1	1	1	1	3	0	3	4	0	0	4	1
Lamar	1	1	1	1	4	2	3	0	2	4	2	0	4	1
Matagorda	2	3	2	4	3	1	1	0	3	3	0	0	3	1
Port Aransas	2	1	4	4	1	1	1	4	2	1	2	4	1	1
Port O'Connor	2	2	3	4	1	2	2	0	3	3	4	0	3	0
Seadrift	2	2	1	1	4	3	4	1	2	3	4	4	1	1

Table 4.4.9-6. **Preferred Alternative 4** (W-8) indicator scores by community. Categorical ranked scores are presented for 6 communities, listed alphabetically. Refer to Table 4.5.9-1 for indicator definitions. High vulnerability scores of 3 or 4 are emphasized in red; higher scores denote greater vulnerability. A score of 0 indicates no data available. (*Source: Michaelis 2024; In Review).*

Community (Texas)	Commercial Fishing Engagement	Commercial Fishing Reliance	Recreational Fishing Engagement	Recreational Fishing Reliance	Poverty	Population Composition	Personal Disruption	Sea Level Rise Risk	Storm Surge Risk	Labor Force	Housing Characteristics	Housing Disruption	Retiree Migration	Urban Sprawl
Austwell	1	1	1	1	1	1	2	1	1	4	0	1	4	1
Fulton	2	2	1	1	1	1	2	1	1	4	4	4	4	1
Holiday Beach	1	1	1	1	1	1	3	0	3	4	0	0	4	1
Lamar	1	1	1	1	4	2	3	0	2	4	2	0	4	1
Matagorda	2	3	2	4	3	1	1	0	3	3	0	0	3	1
Port Aransas	2	1	4	4	1	1	1	4	2	1	2	4	1	1
Port O'Connor	2	2	3	4	1	2	2	0	3	3	4	0	3	0
Seadrift	2	2	1	1	4	3	4	1	2	3	4	4	1	1

The analysis by Michaelis (2024) provides an overview of community characteristics related to social vulnerability, including environmental justice considerations, which should be recognized and thoughtfully considered in strategic planning during the siting of future aquaculture operations. If aquaculture operations are proposed for siting within an AOA, more detailed analysis of how communities may be impacted could tier from this work (See 5.1 *Tiered NEPA Analyses from the DPEIS)*, once project details and operational specifics are known. Per Michaelis (2024; In Review), depending on the approach, offshore aquaculture development has the potential to both exacerbate existing community vulnerabilities or contribute potential solutions, highlighting the importance for planners and prospective operators to consider how new aquaculture activities can be integrated in a way that is beneficial to nearby communities. Best practices for project planning (e.g., early community engagement by prospective aquaculture operators) can increase the likelihood of success for offshore aquaculture to have the most beneficial impact on local communities (Michaelis 2024)

Economic Characteristics of Community Vulnerability

As with impacts considered in this analysis, economic resources will need to be assessed on a case by case basis from siting to decommissioning, taking into account the species grown, method and volume of production, farm location, local ecological, oceanographic, and environmental factors, and other upstream and downstream processes as discussed above. The location of a farm relative to ports, processing, and shipping infrastructure can impact protected resources. Permitting agencies can also consider beneficial ecosystem services provided from an operation, such as from bivalve aquaculture (e.g., van der Schatte Olivier et al. 2020), or mitigation measures that may be implemented for operations.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews. Also, future aquaculture siting outside any of the proposed Alternatives could cause adverse effects on EJ communities without the fair treatment and meaningful involvement of all people, regardless of race, color, gender, sexual orientation, national origin, tribal affiliation, religion, disability, or income. The potential impacts (adverse or beneficial) on human health and the environmental effects on minority, low-income populations, or EJ communities are described in Table 2.9-1.

As discussed above, the types of potential impacts associated with future aquaculture on EJ communities are somewhat similar, but do vary slightly across the AOA alternatives (**Preferred Alternatives 2-5** [W-1, W-4, W-8, and C-3] and **Alternative 6** [C-13]), including **Alternative 1** (No Action). **Preferred Alternative 2** (W-1) is located outside and away from any coastal community given it is in federal waters. Although the closest communities are 79 km (42.7 nm) from Port Mansfield, TX, and 90 km (48.6 nm) from Port Isabel, TX, to the site, there still could be adverse or beneficial effects on human health and environmental effects on minority, low-income populations, or EJ communities. **Preferred Alternative 3** (W-4) is the closest port and associated community is 89.8 km (48.5 nm) from Port Aransas, to the site. Potential effects are the same as discussed as **Preferred Alternatives 2**. Preferred Alternative 4 (W-8) is the closest port and associated community is 107.4 km (58 nm) from Freeport, TX, to the site. Potential effects are the same as discussed as **Preferred Alternatives 2-3**. Preferred Alternative 5 (C-3) is the closest port and associated community is 133 km (71.8 nm) from Morgan City, to the site. Potential effects are the same as discussed for **Preferred Alternatives 2-4**. **Alternative 6** (C-13) is the closest port and associated community is 9.6 km (5.18 nm) from South Pass, LA to the site, and the potential effects are the same as discussed as **Preferred Alternatives 2-5**.

4.6 Potential Impacts on Cultural and Historical Environment

This section evaluates how and to what degree the Proposed Action (identifying AOAs) could potentially impact the cultural and historical environment. This section also discusses how these potential impacts may differ between alternatives under consideration in this DPEIS. Stressors and resource area components for the cultural and historical environment include: cultural, historic and archaeological resources; and environmental justice. Stressors vary in intensity, frequency, duration, and location. Stressor/resource interactions that were determined to have negligible or no impacts were not carried forward for analysis in the DPEIS.

4.6.1 Potential Impacts on Cultural, Historic, and Archaeological Resources

Researchers have estimated that more than 4,000 vessels were lost in the Gulf during 1500 through 1945, and 75% probably occurred nearshore and the others in the outer continental shelf (Garrison et al. 1989). Recent data based on reported and confirmed data indicates there are around 2,240 shipwrecks and probably many more that are undiscovered, especially since they have high levels of preservation and few anthropogenic impacts even though hurricanes can scatter debris a long distance (BOEM 2023). BOEM has documented many shipwrecks, including around 40 shipwrecks that are potentially eligible for listing on the NRHP; 13 shipwrecks have been nominated for listing under the NRHP (BOEM 2021a). Given only a small portion of the outer continental shelf has been explored, it is highly probable there are more undiscovered shipwrecks (BOEM 2021a).

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Riley et al. (2021) evaluated relative suitability for siting aquaculture given cultural, historic, and archeological resources. **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) do not overlap with any known cultural, historical or archaeological resources. **Alternative 6** (C-13) is located approximately 2.5 km (2.17 nm) from known shipwreck, however, the AOA location is far enough away from the shipwreck that aquaculture operations that may be sited within that AOA are not expected to cause any impacts to it.

Additionally, permitting agencies for aquaculture operations proposed in an AOA are required to comply with the National Historic Preservation Act (see Section 3.1.1.2.3) and to ensure that valuable cultural, historic, and archeological resources are not incidentally impacted by permitted activities. Ensuring this typically includes proponents of aquaculture operations conducting benthic surveys to ensure there are no cultural, historical and archaeological resources at a proposed site of operation and coordination with State Historic Preservation Offices to confirm that surveys employed the appropriate survey techniques and that there are not any known records of resources found at a site.

4.7 Potential Climate Change Impacts

While the action of identifying AOAs would not have climate impacts, the siting of aquaculture facilities in an AOA may have impacts to climate. Climate analyses must consider both the potential effects of future aquaculture operations on climate and the effects of climate change on future aquaculture operations and its environmental impacts. The CEQ issued interim guidance in 2023 (88 FR 1196, 2023) related to the consideration of greenhouse gas emissions and climate change in NEPA reviews. The guidance states that NEPA reviews should quantify the proposed actions' GHG emissions, place GHG emissions in appropriate context and disclose relevant GHG emissions and relevant climate impacts, and identify alternatives and mitigation measures to avoid or reduce GHG emissions.

The analysis presented here is qualitative given the programmatic nature of this review and the unknown number of farms or types of operations that may eventually be sited within an AOA. Project-level NEPA reviews would consider impacts on climate and may provide estimates of GHG emissions or reductions in emissions and those analyses would be quantitative to the extent possible. Total emissions calculations should consider all increases and decreases that are reasonably foreseeable and are possibly controllable through permitting agencies' continuing program responsibilities to affect emissions. Many global climate models contain cold temperature biases in the Gulf when compared to observed temperatures and the simulated temperature changes by the end of the 21st century may be underestimated, therefore regional models may be preferable for use in tiered NEPA reviews (Lawman et al. 2022). In support of its Climate Science Strategy, NMFS has developed a series of useful products and tools, such as Regional Action Plans, Ecosystem Status Reports, and Climate Vulnerability Assessments that may be considered in future environmental review. See Quilan et al. (2023), Seara et al. (2022), and Karnauskas et al. (2017) for the current regional products, which may be updated periodically in the future.

Research on GHG emissions from aquaculture is a growing area of study. MacLeod et al. (2020), found that global aquaculture production for nine major culture groups of bivalves, shrimps/prawns, and finfish (which accounted for 93% of global aquaculture production) accounted for approximately 0.49% of anthropogenic GHG emissions (263 Mt carbon dioxide equivalents or CO2e[35]) in 2017. Raul et al. (2020) estimate that global aquaculture production emissions will increase to 3.83×10^{11} g CO_2e by 2030. Still, the proportion of GHG emissions from aquaculture is significantly less than emissions from land-based production of livestock and crops or those produced by wild-capture fisheries, and aquaculture may even offer opportunities for carbon storage (Jones 2022; Halpern et al. 2022).

Differences and variability in GHG emissions from aquaculture are greatly influenced by the type and volume of species reared, farm location, type of production system, and associated environmental factors (Jones et al. 2022; Zhang et al. 2022; Chen et al. 2023). Typically, emissions of GHG are closely linked to the level of production, except in some cases where there is an inverse relationship, like bivalve farms (MacLeod et al. 2020). GHG emissions in the aquaculture production cycle come from sources including feed processing, production and supply of eggs, larvae, or other propagules, on-farm energy use, processing, storage, and shipment, among others. Jones et al. (2022) note that upstream and downstream processes contribute a significant proportion of overall GHG emissions from aquaculture, often more than on-farm operations themselves. However, differences in these processes (particularly in downstream shipping methods), make it difficult to estimate emissions from any one “typical farm”. In addition, many estimates of GHG emissions in the literature are regional in scope or from countries outside of the U.S., where differences in production practices, policy, and regulatory frameworks make it difficult to assess what may be expected from offshore aquaculture operations located in a Gulf AOA in the future (Robb et al. 2017; Raul et al. 2020; Zhang et al. 2022; Chen et al. 2023).

Nevertheless, there are some general patterns and estimates of GHG emissions from different types of operations that may be used to infer impacts. Finfish produce greater emissions in large part from the feed conversion ratio (amount of food needed to produce live weight gain), energy use in onshore systems, feed transfer, and product delivery. Bivalves (oysters, mussels, and clams) have lower emissions given the fact that they are filter feeders and no energy is used for feed production once they leave the hatchery and enter the growing environment. Bivalves can

[35]Other GHGs are often reported by their carbon dioxide equivalent for global warming potential. These conversion rates change over time, based on best available science and atmospheric composition. Future environmental review should ensure that consistent metrics are used, or that conversions are applied when comparing emissions metrics that may use different CO_2e bases (e.g., comparing historical data to a newer emissions goal). The most recent IPCC report will have the most recent CO_2e metrics.

also act as carbon sinks through sequestration in their shells. Seaweed has the lowest emissions compared to finfish and bivalves, stemming from the hatchery and processing stages as well as shipping. Seaweeds can also serve as carbon sinks through export and sequestration of seaweed biomass in both coastal and deep water habitats (Jones 2022).

Median estimates of total GHG emissions (in kg of CO_2e per metric ton live weight harvested) across the supply chain (excluding post-farm transport) from Jones et al. (2022), based on a systematic review of 50 studies in the literature, are as follows:

- Fed finfish: 3,271 kg of CO_2e/ton wet weight produced. Variability comes mainly from the type of production system (coastal net pens vs. closed or recirculating systems), and ranged from 1,382–44,400 kg of CO_2e/ton wet weight.
- Bivalves: 392 kg of CO_2e/ton wet weight produced. Variability is driven by the diverse production systems used in this sector, and ranged from –5 (i.e., bivalves were a net sink of carbon) to 1,874 kg of CO_2e/ton wet weight. Including post-harvest transport, which increased the maximum emissions to around 2,744 kg of CO_2e/ton wet weight; this estimate is below the median emissions estimate for finfish.
- Seaweeds: 22 kg of CO_2e/ton of seaweed produced, with a range from 11.4-28.2 kg of CO_2e. Including post-harvest transport, which increased the maximum emissions estimate to 231 kg of CO_2e/ton of seaweed.

Seaweed and shellfish farms have the ability to sequester some carbon amounts, denitrify water and stabilize environments (Gentry et al. 2020). Increasing the overall carbon sink for an aquaculture operation could help mitigate the GHG emissions. Integrated multi-trophic farming operations offer a mechanism for adaptation to stressors of climate change, whereby production and transport emissions and cost can be consolidated for multispecies production. The potential effects of proposed greenhouse gas emissions are by nature global and may cause cumulative impacts because most individual sources of greenhouse gas emissions are not large enough to have any noticeable effect on climate change.

Climate change already affects aquaculture and the impacts are likely to increase, especially in the absence of proactive interventions (Froelich, 2022). Changing temperatures, sea level, salinity, dissolved oxygen levels, and associated biological and physical characteristics will impact marine aquaculture for the next several decades (Rub et al., in press). Based on Lorenzen (2020), drivers of climate change with impacts on regional fisheries and aquaculture sectors include the following:

- Temperature increases;
- Increases in average rainfall and increases in variability;

- Altered hydrology with an increase in average and variability of river flows, and freshwater outflow into coastal systems;
- Changes in large- and meso-scale circulation features in the Gulf like the Atlantic Multidecadal Oscillation and the Loop Current;
- Changes in ocean stratification;
- Changes in the frequency and intensity of harmful algal blooms;
- Greater frequency and severity of storms;
- Sea level rise;
- Ocean acidification;
- Changes in coastal and riparian geomorphology;
- Changes in infrastructure (e.g., boat ramps, docks, roads); and
- Mitigation policies (e.g., a carbon tax on fuel or carbon credits for sequestration in shellfish farming).

Extreme weather and flooding can directly affect aquaculture structures, creating the possibility of fish escapement (Adhikari et al. 2018; Kais and Islam 2018), and increase sediment load, which affects the filtration rate of shellfish (Rosa et al. 2012). Extreme weather can also create fluctuations in salinity, temperature, and dissolved oxygen which can directly stress or alter the physiology of cultured species. High storm surges, wave impacts, and associated floodwaters will further degrade Gulf habitats and increase shoreline erosion and the import of sediments, compounding temperature and acidification risks to sensitive species like corals (Lawman 2022). More indirectly, increased flooding and coastal inundation threatens coastal wastewater infrastructure, which can have implications for water quality, sanitation, and human health and safety in coastal growing areas, particularly for shellfish. Increased water temperature could adversely affect feed conversion rates in finfish, growth rates in many species, or make disease more prevalent (Reid et al. 2019). Ocean acidification can impinge development in larval shellfish by causing the dissolution of the shell (Gazeau et al. 2013).

Changes related to climate are likely to affect aquatic species' distributions, abundances, interactions with other species, and community structures. Suitable habitat location, quality, timing, and use may also change as climate changes. NMFS conducted a climate vulnerability analysis for fishes and invertebrates in the Gulf and found that all assessed species are projected to face significant exposure to climate-driven environmental changes, but which species are expected to be susceptible or resilient to these changes would vary depending on life-history traits (Quinlan et al. 2023). Key findings include:

- All species in the Gulf are projected to experience high or very high exposure to climate-driven change in environmental variables;
- The primary environmental factors of concern include temperature, salinity, ocean acidification, and dissolved oxygen;
- Biological sensitivities are variable and range from low to very high, with most species (~63%) falling into the low sensitivity category;
- The dominant biological aspects include population growth rate, other stressors, early life stage survival and settlement, spawning cycle, complexity in reproductive strategy, and spawning stock size/status; and
- Twenty percent (20%) of the species, representing groupers, elasmobranchs, snappers, diadromous fishes, invertebrates, and coastal species, had high or very high overall vulnerability to climate change. Twenty-eight percent (28%) of all species were moderately vulnerable, and 52% were low-vulnerability species.

E.O. 14030 on Climate-Related Financial Risk identified risks that climate change poses to assets and investments, including the risks associated with decarbonization. Climate change impacts may exacerbate existing public health issues and create new health hazards like heat-related morbidity and mortality, drought-related malnutrition, flood-related injuries and death, increases in vector-borne diseases, and large-scale migrations (Petkova et al. 2015). Thermal stress has been linked to observed disease outbreaks in some aquatic species and this may intensify under future warming; therefore, the intersection between climate change and disease will be an important feature to include in future risk assessments (Lawman et al. 2022). In addition, food security is an issue that may be exacerbated or brought on by climate change impacts to food resources. A diverse and vibrant aquaculture industry can add resilience to U.S. food systems via select species propagation and responsive production control (Troell et al. 2014).

E.O. 13990 states that the administration has a policy of bolstering resilience to the impacts of climate change and advancing environmental justice. Section 4.5.9 provides further discussion of Environmental Justice considerations that also apply to the context of climate change. Climate change can have a disproportionate adverse impact on environmental justice communities, and vulnerable coastal communities have increased risk from climate change because of pre-existing socioeconomic inequities that can increase harm or cause displacement (Sievanen et al. 2018).

4.7.1 Vulnerable Communities and Climate Change

NMFS developed CSVIs for coastal communities engaged in fishing to characterize community well-being (Jepson and Colburn 2013). These CSVIs include social, economic, and climate change indicators which characterize and evaluate community vulnerability and resilience to ‘disturbances’, such as fishing regulation changes, extreme weather events and other major events (e.g., oil spills), and climate change impacts (Jepson and Colburn 2013). CSVIs within the climate change category include sea level rise and storm surge risk, which are defined in Table 4.7.1-1 below.

Table 4.7.1-1. NMFS CSVIs - climate change indicators. (Source: Table modified from Michaelis, 2024 In Review; definitions also available from NMFS Office of Science and Technology 2021).

Climate Change Indicator	Definition
Sea level rise	The overall risk of inundation from projected sea level rise between one to six feet over the next ~90 years. The indicator represents the possibility of inundation based upon the combined projections at each stage of sea level rise and could vary depending upon future circumstances. A high rank indicates a community more vulnerable to sea level rise.
Storm surge risk	Overall risk of flooding from hurricane storm surge categories 1-5. The indicator represents the "worst-case" possibility of inundation based on the combined hurricane storm surge categories and could vary depending on future circumstances. A high rank indicates a community more vulnerable to a particular hurricane storm surge.

The 2024 social vulnerability study by Michaelis (in review) analyzed CSVI data for communities near central and western Gulf AOA Alternatives. That analysis found communities within 100 km (59 nm) of **Preferred Alternative 2** (W-1) to be highly vulnerable to storm surge, and South Padre Island, highly vulnerable to sea level rise. Economic indicator scores for Laguna Heights and Port Isabel may indicate that housing in these areas is ill-equipped to handle coastal hazards, a relevant consideration with respect to workforce housing needs (see Table 15 in Michaelis 2024; In Review). Per Michaelis (2024; In Review), the relatively high risk associated with various natural hazards (e.g., hurricanes, riverine and coastal flooding, heat and cold waves) amplifies the vulnerability identified in the CSVIs for communities near **Preferred Alternative 2** (W-1).

Of the communities studied within 110 km (59 nm) of **Preferred Alternative 3** (W-4), Port Aransas, had a high vulnerability score for sea level rise; however, Michaelis notes that data were not available for four out of eight communities for this indicator. Storm surge risk was a more prevalent climate change-related vulnerability; with three of the eight communities possessing high vulnerability scores for this factor (see Table 18 in Michaelis 2024; In Review). Per Michaelis (2024; In Review), although climate change related vulnerabilities should certainly be considered when planning and siting offshore aquaculture, relative to the other AOA

Alternatives, the climate change factors included in their analysis may not be as high a concern for communities near **Preferred Alternative 3** (W-4). Similar to the analysis for the communities near the other AOA Alternatives, economic indicators suggest that housing in several communities near **Preferred Alternative 3** (W-4) (Fulton, Port O'Connor, and Seadrift) may be ill-equipped to handle coastal hazards (see Table 18 in Michaelis 2024; In Review). Also, natural hazard risks were again prevalent and varied among counties, with Nueces County having more high hazard-specific NRI scores than other counties; the relatively high risk associated with various natural hazards (e.g., hurricanes and flooding) may intensify vulnerability associated with the CSVIs for communities near **Preferred Alternative 3** (W-4).

Four of six communities analyzed within 125 km (67 nm) of **Preferred Alternative 4** (W-8) were highly vulnerable to climate change factors of storm surge and sea level rise. Similar to the analysis of communities near other AOA Options, economic indicators suggest that availability of storm-ready housing may be a concern for communities near **Preferred Alternative 4** (W-8). NRI scores for communities near AOA Option W-8 were high given various hazards (e.g., hurricanes, flooding, tornadoes, lightning, cold and winter weather; see table 22 of Michaelis 2024; In Review), highlighting the potential for these factors to amplify vulnerability related to CSVIs for these communities.

Of the nearby (within 190 km (103 nm) of **Preferred Alternative 5** (C-3) Louisiana coastal communities analyzed, most had high vulnerability scores for storm surge; several communities were also highly vulnerable to sea level rise (see Table 9 in Michaelis, 2024; In Review). Michaelis (2024; In Review) notes that in addition community safety considerations related to climate change impacts, infrastructure (e.g., processing facilities, roads, and railways), which could support aquaculture development may also be vulnerable, potentially limiting nearby options for landing product. Michaelis (2024; In Review) notes that all communities near **Preferred Alternative 5** (C-3) (for which data was available) also had high vulnerability scores related to housing, suggesting that housing capable of withstanding major storm events may be limited, and may be an important consideration for prospective aquaculture operations with regard to workforce housing needs. In addition to CSVI analysis, FEMA National Risk Index (NRI) ratings for the Parishes near **Preferred Alternative 5** (C-3) were indicative of relatively high risk from various natural hazards, including hurricanes, flooding, tornados, and drought (Michaelis 2024; In Review).

All eight of the studied communities (located within 100 km (59 nm) of **Alternative 6** (C-13) possessed high vulnerability scores for storm surge, and Grand Isle, was also highly vulnerable to sea level rise. Analysis also suggests that housing capable of withstanding future storm events may be limited in communities near **Alternative 6** (C-13). Michaelis (2024; In Review) notes that the intersection of housing and climate change vulnerability factors suggest storm-ready infrastructure (e.g., workforce residences, transportation and seafood processing) is an especially important consideration in these communities. NRI ratings indicated that these communities were also highly vulnerable to various natural hazards, including hurricanes, flooding, lightning, hail and heatwaves, underscoring the role of climate change and natural hazards in amplifying vulnerabilities in these communities (Michaelis 2024; In Review).

In sum, potential adverse effects of future aquaculture operations on Gulf communities due to climate change could occur due to natural hazards (i.e. hurricanes, flooding, heat and cold waves), storm surge risk, sea level rise, economic indicators and housing characteristics and infrastructure vulnerability. Individual communities within distance from a future aquaculture operation may be more or less affected by climate change effects, which could include effects to supportive shoreside infrastructure and local housing dependent on the location of the aquaculture site and adjacent communities associated with the operation.

Comparison of the Alternatives

Alternative 1 (No Action) would have no effect on baseline conditions. Under **Alternative 1** (No Action), aquaculture projects could still be sited in the Gulf, but may not benefit from the analyses in this DPEIS, and the potentially more efficient permitting and environmental reviews.

Potential adverse effects of future aquaculture operations on Gulf communities given climate change could occur given natural hazards (i.e. hurricanes, flooding, heat and cold waves), storm surge risk, sea level rise, economic indicators and housing characteristics and infrastructure vulnerability. Individual communities within distance from a future aquaculture operation may be more or less affected by climate change effects, which could include effects to supportive shoreside infrastructure and local housing dependent on the location of the aquaculture site and adjacent communities associated with the operation.

Potential adverse effects of future aquaculture operations in the **Preferred Alternatives 2-5** (W-1, W-4, W-8 and C-3) and **Alternative 6** (C-13) are the same as discussed above.

Analysis by Michaelis (2024; In Review) found that communities within 100-190 km (54-103 nm) of Gulf AOA Alternatives had high scores for climate change-related and natural hazard vulnerability indicators (i.e. CSVIs and National Risk Index for Natural Hazards). Michaelis (2024; In Review) noted that relative to other AOA alternatives, communities near **Preferred Alternative 3** (W-4) had comparably lower climate change-related CSVI scores; however, data for these indices (storm surge and sea level rise) was unavailable for some of the communities near **Preferred Alternative 3** (W-4). Michaelis (2024; In Review) notes that while it is not likely that siting of offshore aquaculture would on its own increase climate-related vulnerabilities, jobs and infrastructure created for a new industry would be similarly vulnerable to climate change risks. CSVI and NRI data suggests that the interaction of environmental justice, climate change, and economic vulnerabilities may present challenges for aquaculture development if not approached thoughtfully and in a way that may help reduce these vulnerabilities. For example, in communities where storm-ready housing availability is limited, arrival of new residents (i.e. workforce to support a new offshore aquaculture operation) could further compound housing concerns. Storm-ready infrastructure (e.g., workforce residences and seafood processing facilities and support infrastructure) will be an especially important consideration for communities near Gulf AOA Alternatives (Michaelis 2024; In Review).

4.8 Cumulative Effects

Federal agencies preparing an environmental impact statement must also consider cumulative effects that result from incremental impacts of a Proposed Action when added to other past, present, and reasonably foreseeable future actions (RFFA), regardless of which agency (federal or non-federal) or person undertakes such actions. Cumulative effects can result from individually minor, but collectively significant actions that take place over a period of time (40 C.F.R. § 1508.1(i)(3). Below is a five-step cumulative effects analysis.

4.8.1 The area in which the effects of the proposed action will occur

The affected area of this Proposed Action (identifying AOAs) encompasses federal waters of the Gulf, includes communities of the Gulf located near the AOA Alternatives and other communities interested in aquaculture in the Gulf. Most relevant to this Proposed Action are participants in the marine economy, seafood industry, and existing aquaculture and fishing industries in the Gulf. For more information about the area in which the effects of this Proposed Action will occur, please see Chapter 3, Affected Environment, which describes these important resources and other relevant features of the human environment.

4.8.2 The impacts that are expected in that area from the proposed action

The Proposed Action would identify one or more AOAs using marine spatial planning and an ecosystem approach to aquaculture that balances competing needs and stakeholders, while also protecting the marine environment that supports them; it does not authorize or permit any specific aquaculture-related activities or individual aquaculture projects. The environmental consequences of the Proposed Action are analyzed in detail in Chapter 4. This action is not expected to have significant beneficial or adverse cumulative effects on the physical, biological, cultural and historic environments because the action is a planning action. This action would likely have variable direct and indirect, but generally beneficial effects, on the socioeconomic and administrative environments and public health and safety.

4.8.3 Other past, present and RFFAs that have or are expected to have impacts in the area

There are thousands of actions occurring in the Gulf on an annual basis. It is not possible, nor necessary to list all of them here, but the actions that have the potential to combine with the Proposed Action to cause cumulative effects are discussed below.

Fishery related actions - Ongoing management of commercial and recreational fisheries all have impacts in the area, and could combine to have a cumulative effect. Management of these fisheries determines who, where, and when particular types of fishing activities are allowed to occur. Descriptions of federal fishery management actions can be found on the Council's website[36] and are incorporated here by reference. See Section 1.4.3 for a description of past aquaculture actions in U.S. federal waters of the Gulf.

Non-fishery related actions - Forces affecting the Gulf's human environment have been described in previous cumulative effect analyses (e.g., U.S. Navy 2018; OCS 2022; BOEM 2023). Most relevant to this proposed spatial planning action are maritime traffic, military readiness activities and operations, and offshore industrial activities/infrastructure (including oil, gas and renewable energy development).

There is a large and growing body of literature on past, present, and future impacts of global climate change induced by human activities. Some of the likely effects commonly mentioned are sea level rise, increased frequency of severe weather events, and change in air and water temperatures. The IPCC has numerous reports addressing their assessments of climate change. Global climate changes could affect the human environment in the Gulf as discussed in Section 4.7, *Potential Climate Change Impacts*. However, the extent of these effects cannot be quantified at this time and vary along with the range of global emissions scenarios interacting with global and regional mitigation/adaptation scenarios. Potential future aquaculture operations are not expected to significantly contribute to climate change through the increase or decrease in the carbon footprint because most individual sources of greenhouse gas emissions are not large enough to have any noticeable effect on climate change. As described in Section 4.7, *Potential Climate Change Impacts,* the contribution to greenhouse gas emissions from aquaculture is minor compared to other emission sources (e.g., oil platforms).

4.8.4 The impacts or expected impacts from these other actions

The effects from these other actions have been analyzed in other NEPA documents as listed in part three of this section (U.S. Navy 2018; OCS 2022; BOEM 2023). They include detailed analysis of cumulative effects on the human environment. Many of these actions are expected to increase above the present level and would likely contribute impacts to the administrative

[36] https://gulfcouncil.org/

environment, physical environment, biological environment, socioeconomic environment, climate, and cultural and historic resources. In general, the effects of all these types of actions on the socioeconomic environment are variable and positive, except climate change. In general, the effects of fishery-related actions are positive as they ultimately act to restore/maintain the stocks at a level that will allow the maximum benefits in yield and recreational fishing opportunities to be achieved. In general the effects of military readiness activities/operations, and offshore industrial activities/infrastructure (including oil/gas and renewable energy development) are negligible to moderate on all resources areas considered in this DPEIS.

Other impacts are considered major and thus significant because the cumulative effects of other cumulative actions described above in part 3 (particularly from vessel strikes, climate change, bycatch, entanglement, and reduced prey) are expected to cause relatively high rates of injury and mortality that could cause population declines in some biological resources like marine mammals or ESA-listed species. Therefore, cumulative impacts on biological resources would be significant without consideration of the impacts of the Proposed Action. Climate change is expected to have major and thus significant impacts on all resource areas considered in this DPEIS without consideration of the impacts of the Proposed Action.

4.8.5. The overall impact that can be expected if the individual impacts are allowed to accumulate

This action, combined with other past actions, present actions, and RFFAs, is not expected to have significant beneficial or adverse effects on the physical, biological, and cultural or historical environments, climate change, or public health and safety because this action is an administrative planning action only that aims to reduce ocean user conflicts (see Sections 4.2, *Potential Impacts on the Physical Environment;* 4.3, *Potential Impacts on the Biological Environment* and 4.5, *Potential Impacts to Health and Public Safety*). For the administrative and socioeconomic environments, effects should be variable or positive, (see Section 4.1, *Impacts on the Administrative Environment* and 4.4, *Potential Impacts on the Socioeconomic Environment*). Most effects are likely minimal as the Proposed Action, along with other past actions, present actions, and RFFAs, are not expected to alter existing ocean uses or the ocean economy in the Gulf.

4.8.6 Summary

The Proposed Action (Identifying AOAs) is not expected to have individual significant effects to the administrative, physical, biological, socioeconomic, cultural and historic environments, climate change, or public health and safety. Any effects of the Proposed Action, when combined with other past actions, present actions, and RFFAs are not expected to be significant. The goal of marine spatial planning is to achieve social, economic, and ecological objectives, and protect the environment given the demands for development. The effects of the Proposed Action are, and will continue to be, monitored through the collection of data by NMFS and other Federal and state stakeholders, including biological, economic and social analyses.

5. Conclusion

The identification of one or more AOAs in federal waters of the Gulf of Mexico is a comprehensive planning effort and administrative in nature. It does not create any immediate impacts, beneficial or negative, to the physical, biological, socioeconomic, cultural and historical environments, public health and safety or climate change. No specific aquaculture operation or types of aquaculture are required or certain to occur within an AOA.

The identification of AOAs do have beneficial effects on the administrative environment. Efficiencies created in the siting, permitting and environmental review of future offshore aquaculture operations located within an AOA, are expected to reduce the future administrative burden project proponents and agencies face compiling the information necessary to prepare and analyze siting consideration and permit applications. The efficiency gained through this upfront analysis and review are expected to create efficiencies in those processes, leading to a more timely and predictable permitting and environmental review for offshore aquaculture operations sited in an AOA. While there are some administrative benefits realized for all AOA Alternatives (Preferred Alternatives 2-5 [W-1, W-4, W-8, C-3] and Alternative 6 [C-13]) analyzed in this DPEIS, Preferred Alternatives 2-5 (W-1, W-4, W-8, C-3) offer the greatest administrative benefits and efficiencies. The factors of high vessel traffic and moderate levels of shrimp trawling activity would present challenges for siting aquaculture operations within Alternative (C-13), and compared to Preferred Alternatives 2-5 (W-1, W-4, W-8, C-3) would likely present a more complex and challenging permitting and environmental review process for operations proposed within this area. That's not to say that aquaculture operations could not be proposed in this area, however the potential suitability of this area compared to the other alternatives is lower, and as a result not a Preferred Alternative based on this analysis.

This DPEIS identifies multiple preferred alternatives in direct response to the intent of and directives of E.O. 13921, to increase sustainable domestic seafood production through offshore aquaculture. While each Alternative discussed in this DPEIS has varying degrees of impacts that could be associated with the siting of future aquaculture operations in those locations, identifying multiple AOAs provides the opportunity to support a diversified offshore aquaculture sector, across a broad geographic region. This diffusion of opportunity through the identification of multiple AOAs could help to mitigate potential impacts of this developing aquaculture sector, incentivising development and providing social and economic opportunities across a large portion of the Gulf.

5.1 Tiered NEPA Analyses from the DPEIS

Programmatic NEPA reviews can be an effective measure to generate efficiencies in the environmental review process of future project-specific actions. These initial evaluations establish a broad-level review of environmental impacts that can be used to inform subsequent reviews for site and project specific actions, which is defined as a tiered[37] NEPA review (CEQ 2014).

Programmatic NEPA reviews can facilitate decisions on Agency actions that precede site- or project-specific decisions and actions, such as mitigation alternatives or commitments for subsequent actions, or narrowing of future alternatives. They also provide information and analyses that can be incorporated by reference in future NEPA reviews.

In the case of this DPEIS, subsequent tiered NEPA reviews will be conducted on a site- or proposal-specific basis, and will begin once a project proponent has submitted a complete permit application to one or more federal agencies proposing a new aquaculture operation within an AOA in the Gulf. Agencies relying on the programmatic NEPA review will consider whether its tiered review requires additional analysis that adds to or builds on the programmatic review. Additionally, the tiered review may raise new issues that may need to be addressed through additional agency reviews, authorizations or consultations (e.g., ESA Section 7, NHPA Section 106).

The potential environmental impacts of siting aquaculture operations are generally discussed in this DPEIS, and the programmatic analysis has been limited to the foreseeable effects from the identification of AOAs in the Gulf. The type of aquaculture (e.g., finfish, seaweed, and shellfish), design and exact location of aquaculture operations that may be proposed in an AOA are not known at this time. Thus, all environmental impacts of a site- or proposal-specific aquaculture operations have been deferred until such time as an aquaculture operation has been proposed and complete permit applications have been received by federal permitting agencies. When site- or proposal-specific aquaculture operation is proposed in an AOA, NOAA or another relevant federal agency (e.g., EPA and USACE) will notify all interested parties of the schedule for any subsequent NEPA reviews following the regulations (40 C.F.R. § 1501.9 *et seq*.).

[37] "Tiering" refers to an approach where federal agencies first consider the broad, general impacts of proposed program, plan, policy, or large scope project – or at the early stage of a phased proposal – and then conduct subsequent, narrower, decision focused reviews. (40 C.F.R. § 1502.20 *et seq*. and 40 C.F.R. § 1508.28 *et seq*.)

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APPENDIX A: Executive Order 13921, Promoting American Seafood Competitiveness and Economic Growth (85 FR 28471, May 7, 2020)[38]

Presidential Documents Federal Register / Vol. 85, No. 92 / Tuesday, May 12, 2020 / Presidential Documents 28471 Executive Order 13921 of May 7, 2020, Promoting American Seafood Competitiveness and Economic Growth

By the authority vested in me as President by the Constitution and the laws of the United States of America, and in order to strengthen the American economy; improve the competitiveness of American industry; ensure food security; provide environmentally safe and sustainable seafood; support American workers; ensure coordinated, predictable, and transparent Federal actions; and remove unnecessary regulatory burdens, it is hereby ordered as follows:

Section 1. Purpose.

America needs a vibrant and competitive seafood industry to create and sustain American jobs, put safe and healthy food on American tables, and contribute to the American economy. Despite America's bountiful aquatic resources, by weight our Nation imports over 85 percent of the seafood consumed in the United States. At the same time, illegal, unreported, and unregulated fishing undermines the sustainability of American and global seafood stocks, adversely affects general ecosystem health, and unfairly competes with the products of law-abiding fishermen and seafood industries around the world. More effective permitting related to offshore aquaculture and additional streamlining of fishery regulations have the potential to revolutionize American seafood production, enhance rural prosperity, and improve the quality of American lives. By removing outdated and unnecessarily burdensome regulations; strengthening efforts to combat illegal, unreported, and unregulated fishing; improving the transparency and efficiency of environmental reviews; and renewing our focus on long-term strategic planning to facilitate aquaculture projects, we can protect our aquatic environments; revitalize our Nation's seafood industry; get more Americans back to work; and put healthy, safe food on our families' tables.

Section 2. Policy. It is the policy of the Federal Government to:

(a) identify and remove unnecessary regulatory barriers restricting American fishermen and aquaculture producers;

(b) combat illegal, unreported, and unregulated fishing;

[38]Available:https://www.federalregister.gov/documents/2020/05/12/2020-10315/promoting-american-seafood-competitiveness-and-economic-growth

(c) provide good stewardship of public funds and stakeholder time and resources, and avoid duplicative, wasteful, or inconclusive permitting processes;

(d) facilitate aquaculture projects through regulatory transparency and longterm strategic planning;

(e) safeguard our communities and maintain a healthy aquatic environment;

(f) further fair and reciprocal trade in seafood products; and

(g) continue to hold imported seafood to the same food-safety requirements as domestically produced products.

Section 3. Definitions. For purposes of this order:

(a) ‘‘Aquaculture’’ means the propagation, rearing, and harvesting of aquatic species in controlled or selected environments;

(b) ‘‘Aquaculture facility’’ means any land, structure, or other appurtenance that is used for aquaculture;

(c) ‘‘Aquaculture project’’ means a project to develop the physical assets designed to provide or support services to activities in the aquaculture sector, including projects for the development or construction of an aquaculture facility;

(d) ‘‘Exclusive economic zone of the United States’’ means the zone established in Proclamation 5030 of March 10, 1983 (Exclusive Economic Zone of the United States of America);

(e) ‘‘Lead agency’’ has the meaning given that term in the regulations of the Council on Environmental Quality, contained in title 40, Code of Federal Regulations, that implement the procedural provisions of the National Environmental Policy Act (NEPA) (42 U.S.C. 4321 et seq.);

(f) ‘‘Maritime domain’’ means all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances;

(g) ‘‘Maritime domain awareness’’ means the effective understanding of anything associated with the global maritime domain that could affect the security, safety, economy, or environment of the United States; and

(h) ‘‘Project sponsor’’ means an entity, including any private, public, or public-private entity, that seeks an authorization for an aquaculture project.

Section 4. Removing Barriers to American Fishing.

(a) The Secretary of Commerce shall request each Regional Fishery Management Council to submit, within 180 days of the date of this order, a prioritized list of recommended actions to reduce burdens on domestic fishing and to increase production within sustainable fisheries, including a proposal for initiating each recommended action within 1 year of the date of this order.

> (i) Recommended actions may include changes to regulations, orders, guidance documents, or other similar agency actions.
>
> (ii) Recommended actions shall be consistent with the requirements of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801 et seq.); the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.); the Marine Mammal Protection Act (16 U.S.C. 1361 et seq.); and other applicable laws.
>
> (iii) Consistent with section 302(f) of the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1852(f)), and within existing appropriations, the Secretary of Commerce shall provide administrative and technical support to the Regional Fishery Management Councils to carry out this subsection.

(b) The Secretary of Commerce shall review and, as appropriate and to the extent permitted by law, update the Department of Commerce’s contribution to the Unified Regulatory Agenda based on an evaluation of the lists received pursuant to subsection (a) of this section.

(c) Within 1 year of the date of this order, the Secretary of Commerce shall submit to the Director of the Office of Management and Budget, the Assistant to the President for Economic Policy, the Assistant to the President for Domestic Policy, and the Chair of the Council on Environmental Quality a report evaluating the recommendations described in subsection (a) of this section and describing any actions taken to implement those recommendations. This report shall be updated annually for the following 2 years.

Section 5. Combating Illegal, Unreported, and Unregulated Fishing.

(a) Within 90 days of the date of this order, the Secretary of Commerce, acting through the Administrator of the National Oceanic and Atmospheric Administration (NOAA), shall issue, as appropriate and consistent with applicable law, a notice of proposed rulemaking further implementing the United Nations Food and Agriculture Organization Agreement on Port State

Measures to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated Fishing, which entered into force on June 5, 2016 (the Port State Measures Agreement).

(b) The Secretary of State, the Secretary of Commerce, the Secretary of Homeland Security, and the heads of other appropriate executive departments and agencies (agencies) shall, to the extent permitted by law, encourage public-private partnerships and promote interagency, intergovernmental, and international cooperation in order to improve global maritime domain awareness, cooperation concerning at-sea transshipment activities, and the effectiveness of fisheries law enforcement.

(c) The Secretary of State, the Secretary of Commerce, the Secretary of Health and Human Services, and the Secretary of Homeland Security shall, consistent with applicable law and available appropriations, prioritize training and technical assistance in key geographic areas to promote sustainable fisheries management; to strengthen and enhance existing enforcement capabilities to combat illegal, unreported, and unregulated fishing; and to promote implementation of the Port State Measures Agreement.

Section 6. Removing Barriers to Aquaculture Permitting.

(a) For aquaculture projects that require environmental review or authorization by two or more agencies in order to proceed with the permitting of an aquaculture facility, when the lead agency has determined that it will prepare an environmental impact statement (EIS) under NEPA, the agencies shall undertake to complete all environmental reviews and authorization decisions within 2 years, measured from the date of the publication of a notice of intent to prepare an EIS to the date of issuance of the Record of Decision (ROD), and shall use the ‘‘One Federal Decision’’ process enhancements described in section 5(b) of Executive Order 13807 of August 15, 2017, (Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects), and in subsections (a)(ii) and (iii) of this section. For such projects:

> (i) NOAA is designated as the lead agency for aquaculture projects located outside of the waters of any State or Territory and within the exclusive economic zone of the United States and shall be responsible for navigating the project through the Federal environmental review and authorization process, including the identification of a primary point of contact at each cooperating and participating agency;
>
> (ii) Consistent with the ‘‘One Federal Decision’’ process enhancements, all cooperating and participating agencies shall cooperate with the lead agency and shall respond to requests for information from the lead agency in a timely manner;

(iii) Consistent with the ‘‘One Federal Decision’’ process enhancements, the lead agency and all cooperating and participating agencies shall record all individual agency decisions in one ROD, unless the project sponsor requests that agencies issue separate NEPA documents, the NEPA obligations of a cooperating or participating agency have already been satisfied, or the lead agency determines that a single ROD would not best promote completion of the project's environmental review and authorization process; and

(iv) The lead agency, in consultation with the project sponsor and all cooperating and participating agencies, shall prepare a permitting timetable for the project that includes the completion dates for all federally required environmental reviews and authorizations and for issuance of a ROD, and shall make the permitting timetable publicly available on its website.

(b) Within 90 days of the date of this order, the Secretary of the Army, acting through the Assistant Secretary of the Army for Civil Works, in consultation with the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Homeland Security, the Administrator of the Environmental Protection Agency, other appropriate Federal officials, and appropriate State officials, shall:

(i) develop and propose for public comment, as appropriate and consistent with applicable law, a proposed United States Army Corps of Engineers nationwide permit authorizing finfish aquaculture activities in marine and coastal waters out to the limit of the territorial sea and in ocean waters beyond the territorial sea within the exclusive economic zone of the United States;

(ii) assess whether to develop a United States Army Corps of Engineers nationwide permit authorizing finfish aquaculture activities in other waters of the United States;

(iii) develop and propose for public comment, as appropriate and consistent with applicable law, a proposed United States Army Corps of Engineers nationwide permit authorizing seaweed aquaculture activities in marine and coastal waters out to the limit of the territorial sea and in ocean waters beyond the territorial sea within the exclusive economic zone of the United States;

(iv) assess whether to develop a United States Army Corps of Engineers nationwide permit authorizing seaweed aquaculture activities for other waters of the United States;

(v) develop and propose for public comment, as appropriate and consistent with applicable law, a proposed United States Army Corps of Engineers nationwide permit authorizing multi-species aquaculture activities in marine and coastal waters out to the limit of the territorial sea and in ocean waters beyond the territorial sea within the exclusive economic zone of the United States; and

(vi) assess whether to develop a United States Army Corps of Engineers nationwide permit authorizing multi-species aquaculture activities for other waters of the United States.

Section 7. Aquaculture Opportunity Areas.

(a) The Secretary of Commerce, in consultation with the Secretary of Defense, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Homeland Security, the Administrator of the Environmental Protection Agency, other appropriate Federal officials, and appropriate Regional Fishery Management Councils, and in coordination with appropriate State and tribal governments, shall:

(i) within 1 year of the date of this order, identify at least two geographic areas containing locations suitable for commercial aquaculture and, within 2 years of identifying each area, complete a programmatic EIS for each area to assess the impact of siting aquaculture facilities there; and

(ii) for each of the following 4 years, identify two additional geographic areas containing locations suitable for commercial aquaculture and, within 2 years of identifying each area, complete a programmatic EIS for each area to assess the impact of siting aquaculture facilities there.

(b) A programmatic EIS completed pursuant to subsection (a) of this section may include the identification of suitable species for aquaculture in those particular locations, suitable gear for aquaculture in such locations, and suitable reporting requirements for owners and operators of aquaculture facilities in such locations.

(c) In identifying specific geographic areas under subsection (a) of this section, the Secretary of Commerce shall solicit and consider public comment and seek to minimize unnecessary resource use conflicts as appropriate, including conflicts with military readiness activities or operations; navigation; shipping lanes; commercial and recreational fishing; oil, gas, renewable energy, or other marine mineral exploration and development; essential fish habitats, under the Magnuson-Stevens Fishery Conservation and Management Act; and species protected under the Endangered Species Act of 1973 or the Marine Mammal Protection Act.

Section 8. Improving Regulatory Transparency for Aquaculture.

(a) Within 240 days of the date of this order, the Secretary of Commerce, in consultation with other appropriate Federal and State officials, shall prepare and place prominently on the appropriate NOAA web page a single guidance document that:

> (i) describes the Federal regulatory requirements and relevant Federal and State agencies involved in aquaculture permitting and operations; and
>
> (ii) identifies Federal grant programs applicable to aquaculture siting, research, development, and operations.

(b) The Secretary of Commerce, acting through the Administrator of NOAA, shall update this guidance as appropriate, but not less than once every 18 months.

Section 9. Updating National Aquaculture Development Plan.

(a) Within 180 days of the date of this order, the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce, in consultation with the Joint Subcommittee on Aquaculture, established pursuant to the National Aquaculture Act of 1980 (16 U.S.C. 2801 et seq.), shall assess whether to revise the National Aquaculture Development Plan, consistent with 16 U.S.C. 2803(a)(2) and (d), in order to strengthen our Nation's domestic aquaculture production and improve the efficiency and predictability of aquaculture permitting, including permitting for aquaculture projects located outside of the waters of any State or Territory and within the exclusive economic zone of the United States.

(b) In making any revisions to the National Aquaculture Development Plan as a result of this assessment, the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce shall, as appropriate:

> (i) include the elements described at 16 U.S.C. 2803(b) and (c) and the appropriate determinations described at 16 U.S.C. 2803(d);
>
> (ii) include programs to analyze, and formulate proposed resolutions of, the legal or regulatory constraints that may affect aquaculture, including any impediments to establishing security of tenure—that is, use rights with a specified duration tied to a particular location—for aquaculture operators, owners, and investors; and
>
> (iii) consider whether to include a permitting framework, including a delineation of agency responsibilities for permitting and associated agency operations, consistent with section 6

of this order and with the ''One Federal Decision'' Framework Memorandum issued on March 20, 2018, by the Office of Management and Budget and the Council on Environmental Quality, pursuant to Executive Order 13807.

(c) The Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce, in consultation with the Subcommittee on Aquaculture, shall subsequently assess, not less than once every 3 years, whether to revise the National Aquaculture Development Plan, as appropriate and consistent with 16 U.S.C. 2803(d) and (e). If the Secretary of the Interior, the Secretary of Agriculture, and the Secretary of Commerce decide not to revise the National Aquaculture Development Plan, they shall within 15 days of such decision submit to the Assistant to the President for Economic Policy and the Assistant to the President for Domestic Policy a report explaining their reasoning.

Section 10. Promoting Aquatic Animal Health.

(a) Within 30 days of the date of this order, the Secretary of Agriculture, in consultation with the Secretary of the Interior, the Secretary of Commerce, other appropriate Federal officials, and States, as appropriate, shall consider whether to terminate the 2008 National Aquatic Animal Health Plan and to replace it with a new National Aquatic Animal Health Plan.

(b) Any new National Aquatic Animal Health Plan shall be completed, consistent with applicable law, within 180 days of the date of this order.

(c) Any new National Aquatic Animal Health Plan shall include additional information about aquaculture, including aquaculture projects located outside of the waters of any State or Territory and within the exclusive economic zone of the United States, and shall incorporate risk-based management strategies as appropriate.

(d) If adopted, the Plan described in subsections (b) and (c) of this section shall subsequently be updated, as appropriate, but not less than once every 2 years, by the Secretary of Agriculture, in consultation with the Secretary of the Interior, the Secretary of Commerce, other appropriate Federal officials, and States, as appropriate.

Section 11. International Seafood Trade.

(a) In furtherance of fair and reciprocal trade in seafood products, within 30 days of the date of this order, the Secretary of Commerce shall establish an Interagency Seafood Trade Task Force (Seafood Trade Task Force) to be co-chaired by the Secretary of Commerce and the United States Trade Representative (Co-Chairs), or their designees. The Secretary of Commerce shall, to the extent permitted by law and within existing appropriations, provide administrative support and funding for the Seafood Trade Task Force.

(b) In addition to the Co-Chairs, the Seafood Trade Task Force shall include the following members, or their designees:

(i) the Secretary of State;

(ii) the Secretary of the Interior;

(iii) the Secretary of Agriculture;

(iv) the Secretary of Homeland Security;

(v) the Director of the Office of Management and Budget;

(vi) the Assistant to the President for Economic Policy;

(vii) the Assistant to the President for Domestic Policy;

(viii) the Chairman of the Council of Economic Advisers;

(ix) the Under Secretary of Commerce for International Trade;
(x) the Commissioner of Food and Drugs;

(xi) the Administrator of NOAA; and

(xii) the heads of such other agencies and offices as the Co-Chairs may designate.

(c) Within 90 days of the date of this order, the Seafood Trade Task Force shall provide recommendations to the Office of the United States Trade Representative in the preparation of a comprehensive interagency seafood trade strategy that identifies opportunities to improve access to foreign markets through trade policy and negotiations, resolves technical barriers to United States seafood exports, and otherwise supports fair market access for United States seafood products. (d) Within 90 days of the date on which the Seafood Trade Task Force provides the recommendations described in subsection (c) of this section, the Office of the United States Trade Representative, in consultation with the Trade Policy Staff Committee and the Seafood Trade Task Force, shall submit to the President, through the Assistant to the President for Economic Policy and the Assistant to the President for Domestic Policy, the comprehensive interagency seafood trade strategy described in subsection (c) of this section.

Section 12. General Provisions.

(a) Nothing in this order shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department or agency, or the head thereof;

or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(b) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

APPENDIX B: ESA Listed Bird Species and Bird Species of Biological Concern in Northern Gulf of Mexico

Table B.1. ESA Listed Bird Species in Northern Gulf of Mexico

Common Name	Scientific Name	Listing Status
Mississippi Sandhill Crane	*Antigone canadensis pulla*	Endangered
Rufa Red Knot	*Calidris canutus rufa*	Threatened
Atlantic Coast Piping Plover	*Charadrius melodus melodus*	Threatened
Whooping Crane	*Grus americana*	Endangered
Southeast DPS Wood Stork	*Mycteria americana*	Threatened
Black-capped Petrel	*Pterodroma hasitata*	Endangered

Table B.2. Birds of Conservation Concern (2021) in Northern Gulf of Mexico. Bird of Conservation Concern for Continental USA (CON), Bird of Conservation Concern for continental Bird Conservation Region(s) (BCR), Terrestrial Bird Conservation Region(s)/Marine Bird Conservation Region (BCR/MBCR), Southeastern Coastal Plain (27), Gulf Coastal Prairie (37), Gulf of Mexico (M20), breeding (X) and non-breeding (nb).

Common Name	Scientific Name	Scale	BCR/MBCR	Use
American Golden-Plover	*Pluvialis dominica*	CON	37	nb
American oystercatcher	*Haematopus palliatus*	CON	27, 37	X
Atlantic Band-rumped Storm-Petrel	*Hydrobates castro*	CON	M20	nb
Atlantic Ruddy Turnstone	*Arenaria interpres morinella*	BCR	27, 37	nb
Atlantic Whimbrel	*Numenius phaeopus hudsonicus*	BCR	27, 37	nb
Atlantic/Gulf Seaside Sparrow	*Ammodramus maritima maritima/pennisulae/ macgillivraii/fisheri/sennetti*	CON	27, 37	X
Atlantic/Interior Least Tern	*Sternula antillarum antillarum/athalassos*	CON	27, 37	X
Sargasso Shearwater	*Puffinus lherminieri*	CON	M20	nb
Bachman's sparrow	*Peucaea aestivalis*	CON	27	X
Black Skimmer	*Rynchops niger*	CON	27, 37	X
Black-capped Petrel	*Pterodroma hasitata*	CON	M20	nb
Brown-headed nuthatch	*Sitta pusilla*	BCR	27	X
Buff-breasted Sandpiper	*Calidris subruficollis*	CON	37	nb
Cerulean Warbler	*Setophaga cerulea*	CON	27	X
Chimney Swift	*Chaetura pelagica*	CON	27, 37	X
Chuck-will's Widow	*Antrostomus carolinensis*	BCR	27	X
Cory's Shearwater	*Calonectris diomedea*	CON	M20	nb
Dicksissel	*Spiza americana*	BCR	37	X
Eastern Loggerhead Shrike	*Lanius ludovicianus excubitorides/migrans*	BCR	37	X

Common Name	Scientific Name	Scale	BCR/MBCR	Use
Eastern Whip-poor-will	*Antrostomus vociferus*	CON	27	X
Eastern/Central Semipalmated Sandpiper	*Calidris pusilla*	BCR	27	nb
Forster's Tern	*Sterna forsteri*	BCR	37	X
Gull-billed Tern	*Gelochelidon nilotica*	CON	27, 37	X
Henslow's Sparrow	*Ammodramus henslowii*	CON	27, 37	nb
Hudson Bay Dunlin	*Calidris alpina hudsonia*	BCR	27, 37	nb
Hudsonian Godwit	*Limosa haemastica*	CON	37	nb
Interior/Gulf Coast Snowy Plover	*Charadrius nivosus nivosus*	CON	27, 37	X
Kentucky Warbler	*Geothlypis formosa*	CON	27	X
King Rail	*Rallus elegans*	CON	27, 37	X
LeConte's Sparrow	*Ammodramus leconteii*	CON	27, 37	nb
Lesser Yellowlegs	*Tringa flavipes*	CON	27, 37	nb
Long-billed Curlew	*Numenius americanus*	BCR	37	nb
Magnificent Frigatebird	*Fregata magnificens*	BCR	M20	nb
Marbled Godwit	*Limosa fedoa*	CON	27, 37	nb
Mountain Plover	*Charadrius montanus*	CON	37	nb
Northern Grasshopper Sparrow	*Ammodramus savannarum perpallidus/pratensis*	BCR	27	X
Pacific Red Knot	*Calidris canutus roselaari*	CON	37	nb
Painted Bunting	*Passerina ciris*	BCR	27, 37	X
Pectoral Sandpiper	*Calidris melanotos*	CON	27, 37	nb
Prairie Warbler	*Setophaga discolor*	CON	27	X
Prothonotary Warbler	*Protonotaria citrea*	CON	27, 37	X
Purple Sandpiper	*Calidris maritima*	CON	27	nb
Pyrrhuloxia	*Cardinalis sinuatus*	CON	37	X
Red-headed Woodpecker	*Melanerpes erythrocephalus*	CON	27, 37	X
Reddish Egret	*Egretta rufescens*	CON	37	X
Rusty Blackbird	*Euphagus carolinus*	BCR	27	nb
Saltmarsh Sparrow	*Ammodramus caudacuta*	CON	27	nb
Sandwich Tern	*Thalasseus sandvicensis*	BCR	37	X
Short-billed Dowitcher	*Limnodromus griseus*	CON	27, 37	nb
Southeastern American Kestrel	*Falco sparverius paulus*	BCR	27	X
Sprague's Pipit	*Anthus spragueii*	CON	37	nb
Swallow-tailed Kite	*Elanoides forficatus*	CON	27, 37	X

Common Name	Scientific Name	Scale	BCR/MBCR	Use
Wayne's Black-throated Green Warbler	*Setophaga virens waynei*	BCR	27	X
Willet	*Tringa semipalmata*	CON	27, 37	X
Wilson's Plover	*Charadrius wilsonia*	CON	27, 37	X
Wood Thrush	*Hylocichla mustelina*	CON	27	X
Yellow Rail	*Coturnicops noveboracensis*	CON	27, 37	nb

APPENDIX C: Other Applicable Laws

While the Proposed Action in the DPEIS is a planning action and does not trigger compliance with all the below laws or regulations, any future aquaculture operation sited in an AOA should consider compliance requirements of applicable federal, state, and local laws, regulations, and executive orders. Below is a list of the expected, but not exhaustive, environmental compliance requirements for site specific aquaculture operations that may be applicable, in addition to those described in Section 3.1, *Administrative Environment* of this DPEIS.

Administrative Procedure Act

Administrative Procedure Act All federal rulemaking is governed under the provisions of the Administrative Procedure Act (5 U.S.C. Subchapter II), which establishes a "notice and comment" procedure to enable public participation in the rulemaking process. Under the Act, the National Marine Fisheries Service (NMFS) is required to publish notification of proposed rules in the Federal Register and to solicit, consider, and respond to public comment on those rules before they are finalized. The Act also establishes a 30-day waiting period from the time a final rule is published until it takes effect.

Data Quality Act

The Data Quality Act (Public Law 106-443) effective October 1, 2002, requires the government to set standards for the quality of scientific information and statistics used and disseminated by federal agencies. Information includes any communication or representation of knowledge such as facts or data, in any medium or form, including textual, numerical, cartographic, narrative, or audiovisual forms (includes web dissemination, but not hyperlinks to information that others disseminate; does not include clearly stated opinions). Specifically, the Act directs the Office of Management and Budget to issue government wide guidelines that "provide policy and procedural guidance to federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information disseminated by federal agencies." Such guidelines have been issued, directing all federal agencies to create and disseminate agency-specific standards to:

1. Ensure information quality and develop a pre-dissemination review process;
2. Establish administrative mechanisms allowing affected persons to seek and obtain correction of information; and
3. Report periodically to the Office of Management and Budget on the number and nature of complaints received.

Scientific information and data are key components of environmental review documents. To be consistent with the Act, environmental review documents must be based on the best information available. They should also properly reference all supporting materials and data, and be reviewed by technically competent individuals. With respect to original data generated for environmental review documents, it is important to ensure that the data are collected according to documented procedures or in a manner that reflects standard practices accepted by the relevant scientific and technical communities. Data will also undergo quality control prior to being used by the agency and a pre-dissemination review.

Paperwork Reduction Act

The purpose of the Paperwork Reduction Act is to minimize the paperwork burden on the public resulting from the collection of information by or for the Federal government. It is intended to ensure the information collected under the Proposed Action is needed and is collected in an efficient manner (44 U.S.C. § 3501(1)).

Animal Health Act

The Animal Health Act of 2002 (7 U.S.C. § 8301 et seq.) provides the authority to the Secretary of Agriculture to administer and promulgate animal health regulations for the prevention, control, and management of infectious diseases for all animals, except humans. The focus of the Act is the management of diseases in cultured animals but the scope also includes diseases management in wildlife that have the potential to impact cultured/farmed animals.

International Convention for the Prevention of Pollution by Ships and Act to Prevent Pollution from Ships

The International Maritime Organization adopted the International Convention for the Prevention of Pollution by Ships (MARPOL 73/78) in 1973, subsequently modifying it by Protocol in 1978. Its primary objective is to limit ship-borne pollution by restricting operational pollution and reducing the possibility of accidental pollution. MARPOL 73/78 established standards for stowing, handling, shipping, and transferring pollutant cargoes, as well as standards for discharge of ship-generated operational wastes. The acceptance of the convention by the national government makes the requirements of domestic law. MARPOL 73/78 consists of six separate Annexes, each sets out regulations covering the various sources of ship-generated pollution. Annex I and II are mandatory for all signatory nations, while Annexes III, IV, V and VI are optional. Currently, the U.S. is signatory to Annexes I, II, III, V and VI. Annexes I, II, V and VI have been incorporated into U.S. law by the Act to Prevent Pollution from Ships and implemented within 33 U.S.C. § 1901 and 33 C.F.R. § 151.

Nonindigenous Aquatic Nuisance Prevention and Control Act

The USFWS and NOAA co-chair the Aquatic Nuisance Species Task Force, established under the Nonindigenous Aquatic Nuisance Prevention and Control Act (16 U.S.C. § 4701). The task force coordinates with state and federal management agencies to create a coordinated, unified network that raises awareness and takes action to prevent, monitor, manage and study aquatic nuisance species.

Executive Orders (E.O.)

E.O. 12962: Recreational Fisheries

The Executive Order 12962 (60 FR 30769, June 9, 1995). requires federal agencies, in cooperation with states and tribes, to improve the quantity, function, sustainable productivity, and distribution of U.S. aquatic resources for increased recreational fishing opportunities through a variety of methods including, but not limited to, developing joint partnerships; promoting the restoration of recreational fishing areas that are limited by water quality and habitat degradation; fostering sound aquatic conservation and restoration endeavors; and evaluating the effects of federally-funded, permitted, or authorized actions on aquatic systems and recreational fisheries, and documenting those effects. Additionally, it establishes a seven-member National Recreational Fisheries Coordination Council (NRFCC) responsible for, among other things, ensuring that social and economic values of healthy aquatic systems that support recreational fisheries are considered by federal agencies in the course of their actions, sharing the latest resource information and management technologies, and reducing duplicative and cost-inefficient programs among federal agencies involved in conserving or managing recreational fisheries. The NRFCC also is responsible for developing, in cooperation with federal agencies, States and Tribes, a Recreational Fishery Resource Conservation Plan - to include a five-year agenda. Finally, the E.O. requires NMFS and the USFWS to develop a joint agency policy for administering the ESA.

E.O. 13089: Coral Reef Protection

Executive Order 13089 (63 FR 32701, June 16, 1998) requires federal agencies whose actions may affect U.S. coral reef ecosystems to identify those actions, use their programs and authorities to protect and enhance the conditions of such ecosystems and, to the extent permitted by law, ensure actions that they authorize, fund, or carry out do not degrade the condition of that ecosystem. By definition, a U.S. coral reef ecosystem means those species, habitats, and other national resources associated with coral reefs in all maritime areas and zones subject to the jurisdiction or control of the United States (e.g., federal, state, territorial, or commonwealth waters). Regulations are already in place to limit or reduce habitat impacts within the FGBNMS. Additionally, NMFS approved and implemented Generic Amendment 3 for Essential Fish Habitat (GMFMC 2005a), which established additional habitat areas of particular concern (HAPC) and gear restrictions to protect corals throughout the Gulf. There are no implications to coral reefs by the actions proposed in this amendment.

E.O. 13132: Federalism

Executive Order 13132 (64 FR 43255, August 10, 1999) requires agencies in formulating and implementing policies to be guided by the fundamental Federalism principles. The E.O. serves to guarantee the division of governmental responsibilities between the national government and the states that was intended by the framers of the Constitution. Federalism is rooted in the belief that issues not national in scope or significance are most appropriately addressed by the level of government closest to the people. This E.O. is relevant to AOA identification given the overlapping authorities of NMFS, the states, and local authorities in managing coastal resources, including fisheries, and the need for a clear definition of responsibilities. It is important to recognize those components of the ecosystem over which agencies have no direct control and to develop strategies to address them in conjunction with appropriate state, tribes and local entities (international too).

E.O. 13158: Marine Protected Areas

Executive Order 13158 (65 FR 34909, May 26, 2000) requires federal agencies to consider whether their Proposed Action(s) will affect any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural or cultural resource within the protected area. There are several marine protected areas, HAPCs, and gear-restricted areas in the central and western Gulf. The existing areas are entirely within federal waters of the Gulf. They do not affect any areas reserved by federal, state, territorial, tribal or local jurisdictions.

E.O. 11987 Exotic Organisms

Executive Order 11987 (42 FR 26949, May 25, 1977) requires Federal agencies, to the extent permitted by law, to:

1. Restrict the introduction of exotic species into the natural ecosystems on lands and waters owned or leased by the United States;
2. Encourage states, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the U.S.;
3. Restrict the importation and introduction of exotic species into any natural U.S. ecosystems as a result of activities they undertake, fund, or authorize; and
4. Restrict the use of Federal funds, programs, or authorities to export native species for introduction into ecosystems outside the U.S. where they do not occur naturally.

The order authorizes the Secretaries of Agriculture and Interior to allow exotics import, and native species export if this activity will not adversely affect natural ecosystems.

E.O. 13112 Invasive Species

Executive Order 13112 (64 FR 6183, February 8, 1999) established an Invasive Species Council and specified the duties of Federal agencies whose actions may affect the status of invasive species. The Order requires Federal agencies to use relevant programs and authorities to:

1. Prevent the introduction of invasive species;
2. Detect and respond rapidly to control the spread of such species;
3. Monitor invasive species populations accurately and reliably;
4. Provide for restoration of native species and habitat conditions in ecosystems that have been invaded;
5. Conduct research to prevent introduction; and
6. Promote education on invasive species.

The Invasive Species Council oversees the implementation of the order, has prepared an invasive species management plan, develops guidance to Federal agencies, and encourages planning and action at local, regional, and national levels.

E.O. 12898 Federal Actions to Address Environmental Justice in Minority and Low-Income Populations

Executive Order 12898 (59 FR 7629, February 16, 1994) requires Federal agencies to make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. E.O. 12898 also provides for agencies to collect, maintain, and analyze information on patterns of subsistence consumption of fish, vegetation, or wildlife. That agency action may also affect subsistence patterns of consumption and indicate the potential for disproportionately high and adverse human health or environmental effects on low-income 266 populations, and minority populations. Agencies should also consider environmental justice when conducting NEPA analyses.ch programs related to the development of marine resources.

E.O. 14096 Revitalizing our Nation's Commitment to Environmental Justice for All

Executive Order 14096 (88 FR 25251, April 26, 2023) directs the Federal Government to build upon and strengthen its commitment to deliver environmental justice to all communities across America through an approach that is informed by scientific research, high-quality data, and meaningful Federal engagement with communities with environmental justice concerns.

E.O. 14091 Further Advancing Racial Equity and Support for Underserved Communities Through the Federal Government

Executive Order 14091 (88 FR 10825, February 22, 2023) addresses specific barriers still faced by underserved communities by requiring federal agencies to integrate equity into planning and decision-making. The E.O. builds upon other executive orders and directives concerning equity and environmental justice. E.O. 14091 extends and strengthens equity-advancing requirements for federal agencies with the intent to deliver better outcomes for the American people. The E.O. outlines a multi-pronged approach to advancing equity through the federal government, further defines equity-related terms, including equitable development, community wealth building, equitable data, and algorithmic discrimination.

E.O. 13985 Advancing Racial Equity and Support for Underserved Communities Through the Federal Government

Executive Order 13985 (86 FR 7009, January 25, 2021) called on federal agencies to advance equity by identifying and addressing barriers to equal opportunity that underserved communities may face because of some government policies and programs and develop action plans for addressing any barriers that were identified through an equity assessment.

APPENDIX D: Candidate Species for Offshore Aquaculture in the Gulf

Candidate Finfish Species

Red Drum (*Sciaenops ocellatus*)

Life History Overview

The red drum is an important sport and commercial species classified under the Sciaenidae family (i.e., drums and croakers). The species is found in wide-ranging salinities in nearshore waters from Florida to New England, including the Gulf (GSMFC 2023). Red drum are usually found in shallow water with submerged vegetation or around mud and sand bottom including oyster reefs. They are a demersal species that feeds on fish and crustaceans but will also pursue prey in the water column (Anderson et al. 2023). Red drum are a relatively fast-growing species (28 cm [11] inches and 0.45 kg [1 lb] at age-1) that have a maximum size and weight of 1.5 m (60 inches) and 42.6 kg (94 lb), respectively; it is a long-lived (~37 years) species (Anderson et al. 2023). Red drum are managed as a single stock in the Gulf, with the recreational harvest regulated by individual Gulf States (GSMFC 2023). The Atlantic stock is also state managed, but also federally managed under the Atlantic States Marine Fisheries Commission. In the 80s, the Gulf population was severely overfished so the Gulf of Mexico Fishery Management Council (GMFMC) imposed strict regulatory measures to rebuild the stock, including closing the commercial fishery in federal waters and the EEZ, except for a limited commercial fishery in Mississippi state waters (GSMFC 2023).

Red drum display an ontogenetic shift in preferred habitat. Juveniles and sub-adults are found in lower salinity bays, lagoons, and estuaries (submerged habitat), while mature adults are found in higher salinity nearshore Gulf and bay waters. In the fall, adults congregate in nearshore waters (3-15 km) around passes and inlets to spawn, which is an ideal time to collect broodstock; spawning location can differ by geographical region (Sink 2018; Burnsed et al. 2020; and Anderson et al. 2023). Research shows red drum aggregate (e.g., ~5,000-10,000 individuals in Tampa Bay) in specific nearshore waters to spawn from August to mid-November, with peak spawning occurring during the full and new moon in September and October (Winner et at. 2014; Lowerre-Barbieri et al. 2019). Most red drum reach sexual maturity between three and five years depending on the location and sex; males mature younger than females. Females are batch spawners that can ovulate up to eight times per spawning season. Tringali and Lowerre-Barbieri (2023) reported recruitment variability is a strong adaptive component in the red drum life cycle that contributes to reproductive resilience, stable populations, and high genetic diversity. Mature females are highly fecund, producing 160,000 to 3,270,000 eggs per batch, and up to 60 million eggs annually; fecundity is dependent on size. Red drum produce eggs throughout adulthood and cessation of spawning does not occur in older individuals (Sink 2019).

Gulf and Atlantic red drum populations are genetically somewhat similar (Gold et al. 1993, 1994, 1999; Seyoum et al. 2000). In the northern Gulf, Gold et al. (1999) found evidence of isolation by distance (positive correlation between genetic and geographic distance), which they attributed to sex-specific behaviors. They also suggested a geographic neighborhood size relative to genetic migration of around 500-600 km, which was later supported by Gold and Turner (2002) with a neighborhood size of 700-900 km. Most recently, tagging studies in the Tampa Bay region indicated high spawning site fidelity (~60%) and natal homing, despite some mixing with a population 132 km to the south and another ~30-40% of tagged fish presumably spawned out of the monitoring range (Lowerre-Barbieri et al. 2019; Burnsed et al. 2020). This level of migration outside of the monitored region would generally homogenize allele frequencies across a broader geographic range; thus, the migratory radius is probably between 132 and 260 km.

Aquaculture

Historically, red drum aquaculture in the Gulf has focused on stock enhancement and restoration (GSFMC 2023) using outdoor ponds with recirculating systems (Sink 2019). Broodstock are usually collected from the wild and held in outdoor ponds; individuals can have long production periods, spanning 10 years or more. Spawning is usually initiated through natural or artificial manipulation of photo-thermal periods. Hormonal induction is not typically necessary (Sink 2019). The desired market size is approximately 1.4 kg, which takes between 16 and 24 months depending on the mean temperature. In captivity, red drum are cannibalistic, so they need close attention to size grading and stocking densities (Chiu Liao and Chang 2002). They require cold temperatures (<16°C) for gamete maturation. In the United States, 95% of red drum production is conducted in Texas, primarily near Matagorda Bay (Sink 2019). The species is produced at a large scale throughout Asia, especially in China and Taiwan. However, a large-scale cultured market in the U.S. is still under development (GSFMC 2023). Red drum are generally grown in ponds with recirculating systems, but marine cage culture has been done in China and Israel (Lutz 2022).

Almaco Jack (*Seriola rivoliana*)

Life-History Overview

Almaco jack are an undervalued commercial and recreational species classified under the Carangidae family (jacks, pompanos, jack mackerels, runners, trevallies, and scads). They are a pelagic species commonly found in high saline tropical waters around the world, including the Atlantic Ocean and Gulf. Alamo jack are found in the water column of the open-ocean between 3-35 m and sometimes deeper around artificial reefs, wrecks, and high-relief hard bottom. They are a carnivorous species that preys on various small fish, invertebrates, and crustaceans. Almaco jack are a fast-growing species (2.2 kg [4.9 lb] in 9-12 months) that can attain 96 cm (38 inches) and 25 kg (55 pounds). Fisheries information is limited, but recent catch data for the Gulf estimates 19,061 fish were landed weighing 131,227 lb in 2014 (DeVries et al. 2016). Based on population assessment models, the GMFMC determined overfishing for Almaco jack was occurring in 2020. In the Atlantic, commercial harvest limits are strict (20 in FL and 500 lb trip limit), but in the Gulf there is no minimum size or season limit, and the stock jack complex quota is 312,000 lbs.

Almaco jacks spawn from April to November depending on the water temperature, but it usually occurs at >22°C (UWI 2016; Sims 2019; Blanco 2022). They are pelagic multiple batch spawners aggregating in groups, which has been reported in the Dry Tortugas, Pulley Ridge, and Flower Garden Banks (Gruss et al. 2018). Age-at-maturity is relatively similar between the sexes and early in life with males maturing at 22 months and females at 24 months (UWI 2016). In the spawning season, females can release 300,000 to 1 million eggs per event, which can occur two or three times per week (Sims 2019).

The population genetic structure for almaco jack is unknown. However, genetic information is available for similar species, including Japanese amberjack (*Seriola quinqueradiata*), greater amberjack (*Seriola dumerili*), and yellowtail amberjack (*Seriola lalandi*). Available information shows little to no divergence within water masses, which is similar to other pelagic finfish, such as tuna and billfish. For example, Gold and Richardson (1998) found evidence of two stocks of greater amberjack off the southeastern U.S., one in the northern Gulf and a second along the western Atlantic coast. Based on available information, almaco jack within the Gulf may be a single population.

Aquaculture

Almaco jack is an important aquaculture species with an international market; it's one segment of the Japanese Hamachi market. In Japan, annual aquaculture production of almaco jack, also known as kampachi, is about 2,000 t (4.4 million pounds) (Sims 2019). In the U.S, there are offshore commercial operations in Hawaii, and farming research is being done in Baja California and the Gulf. Almaco jack and other members of the genus *Seriola* can be spawned in captivity using photo-thermal conditioning or hormone induction (Rottman et al. 1991). Broodstock can be conditioned to spawn naturally (26°C; 35 g/L; 12 h light) in an indoor recirculating aquaculture system within 16 weeks of acclimation. Patrick et al. (2019) indicated spawning occurred 3–4 times weekly over three months with an average spawn size of 322,000 eggs and a 58.6% fertilization rate. Roo et al. (2014) reported similar results using hormonal induction methods (GnRHa, 20 µg/kg) administered to male and female broodstock; 10 successful spawns occurred with a mean of 275,000 eggs per spawn and a 92% fertilization rate. In captivity, almaco jack can grow to 1.8 kg in 8 months, and 3 kg in 18 months; growth rates are faster in warmer temperatures, especially above 30°C (Sims 2019). Almaco jack are a hardy species, but parasites and skin flukes can be a problem (UWI 2016; Sims 2019).

Greater Amberjack (*Seriola dumerili*)

Life History Overview

The Greater amberjack, is an important recreational and commercial species classified under the Carangidae family. The species is found in sub-tropical and temperate waters around the world (Patrick et al. 2019). In the western North Atlantic Ocean, greater amberjack are found from Florida to Nova Scotia, including the Caribbean and throughout the Gulf (SEDAR 2014). Greater amberjack are a pelagic species found in open waters that prey on crab, shrimp, and various fish. Greater amberjack are large and relatively fast growing jack with a maximum size and weight around 183 cm (6 ft) and 91 kg (200 lb), respectively. The maximum age is about 15 or 16 years (SEDAR 2014). Similar to other species, females grow faster than males. The species is federally managed as two stocks. The Gulf stock is classified as overfished and overfishing is ongoing, while the South Atlantic stock is not overfished, but overfishing is ongoing. The Gulf population has an estimated spawning stock biomass between 1,000 and 1,800 mt (NMFS 2020).
Greater amberjack habitat varies slightly from juvenile to subadult and adult. Juveniles are found in *Sargassum* spp. mats until about five to six months (Harris et al. 2007), and adults are found in pelagic waters associated with artificial and natural reefs, and hard bottom areas. Greater amberjack spawn near artificial and natural reefs from March to June, with females releasing between 18-59 million eggs in a single season; greater amberjack are broadcast spawners. Most greater amberjack mature between age four and six (Murie and Parkyn 2008) with size-at-maturity varying by region. In the Gulf, females attain 50% maturity around 850-900 mm FL, while in the South Atlantic 50% maturity is slightly shorter at around 719-745 mm FL (Harris et al. 2007). Greater Amberjack are federally managed as two discrete stocks. The GMFMC manages the Gulf stock and the South Atlantic Fishery Management Council manages the Atlantic stock (SEDAR 2014).

Genetic information indicates the Gulf stock is different from the Atlantic stock; there is no evidence of gene flow between any Gulf locations supporting a two-stock hypothesis within U.S. waters (Gold and Richardson 1998). However, Hargrove 2018 found very low statistically significant differentiation among Gulf samples suggesting the possibility of two subpopulations within the region. Research proved the Atlantic population was similar to the Florida Keys population, suggesting recent or regular gene flow between these two regions.

Aquaculture

Greater amberjack has been cultured in the Mediterranean since the 1980s (Sicuro and Luzzana 2016), and the primary producers are China, Korea, and Japan; Japan is the largest producer at around 72,000 t (158 million pounds) annually, as of 2009. In fact, greater amberjack and Japanese amberjack are the main species grown in the country (Nakada et al. 2008). Given the demand, greater amberjack is being explored for further aquaculture expansion throughout Europe and within the United States. Size at harvest is around 3-6 kg, which can be achieved in 24-36 months but that depends on the water temperature and preferred market size.

Controlling reproduction of amberjack in captivity remains challenging. Experiments in the Mediterranean found that females reared in sea cages showed a greater potential for reproductive success than those reared in tanks, which exhibited almost 0% fertilization success. Males reared under both conditions exhibited adequate quality sperm but it was reduced in tanks (Fakriadis 2020). Spontaneous and unpredictable spawning has been observed in Japan (Kawabe et al. 1998) and in the Canary Islands (Sarih et al. 2018). However, spontaneous spawning has never been reported in the Mediterranean (Grau et al. 1996). In Japan, the seed is caught from the wild or imported from other Asian countries that are rearing juveniles.

Florida Pompano (*Trachinotus carolinus*)

Life History Overview

The Florida Pompano, is an important recreational and commercial species classified under the Carangidae family. The species is a warm-water coastal pelagic species that has a broad range from Massachusetts to Brazil (Main et al. 2007; FAO 2016). It is usually found along coastal beaches and inlets. The Florida pompano diet consists of bivalves, crabs, shrimp, and fish; its preferred diet are small clams and sand fleas. It is a small, relatively slow growing jack that has a short life expectancy around three or four years. Maximum size and weight are 66 cm (26 in) and 3.6-4.1 kg (8-9 lb), respectively (Weirich et al. 2021). The species is primarily managed by the individual Gulf States given most of the landings are within state waters and associated with recreational anglers; 73% of recreational landings are in Florida. Commercial landings in Florida vary from 4.8 to 30.2%, and the states does have a designated area in South Florida where special permit holders can commercially harvest pompano with a gillnet. Available stock assessment information indicates the population is stable ranging about 500,000 to 600,000 individuals and abundance exceeds the minimum size threshold for the Atlantic and Gulf stocks (Murphy et al. 2008).

Florida pompano are schooling (Schrandt 2015) species found in high saline nearshore and bay waters including estuarine habitat with lower salinities; juveniles are found in low saline bays and estuaries (Murphy et al. 2008). They can tolerate wide-ranging salinities but prefer warm water temperatures >20°C (Weirich 2021); mortality can occur in cold water. Pompano mature young sometime between 1 and 3 years, which is around 28.5-32.5 cm FL (11.8-12.8 in) (Weirich 2021); males mature slightly younger and smaller than females. Spawning has not been observed in the wild (Weirich 2021), but pompano are possibly multiple batch spawners like other jacks (Sayoum 2017). Florida pompano spawn most of the year from March to October (Weirich 2021), but varies by location, water temperature, and other factors; spawning usually peaks during April through June or July. Spawning sites are unknown but believed to be offshore given some limited field work. Available information suggests fecundity varies from 133,000 to 800,000 eggs per season (Muller et al. 2002). The genetic population structure is unknown and unconfirmed but thought to be a single homogenous randomly mating stock within all coastal U.S. waters (Murphy et al. 2008).

Aquaculture

Researchers have explored raising Florida pompano since the 1950s but initial efforts were not successful. Today, pompano is being raised in offshore net pens in a few locations, including Panama and culture research continues in Florida, Alabama, and Texas (Weirich et al. 2021). Broodstock can easily be obtained from the wild and survive in live wells until transferred to pens or tanks. Viable broodstock also can be obtained from hatchery-reared pompano. Pompano have been induced to spawn year-round using hormone injections coupled with photoperiod and temperature manipulation. Researchers have also used photoperiod and temperature manipulations, followed by abrupt temperature shifts to trigger gonadal maturation and successful spawning. Hormone-induced spawning has been successful using voluntary and strip spawning methods. Juveniles can be grown in large densities, stocked at around 100-200 grams. Growout has been done in recirculating systems, net cages, and ponds. Pompano have a high survival rate in captivity and a harvest size (0.7 kg) can be reached in 6 months (Weirich et al. 2019). The Florida pompano is ready for commercial aquaculture, but there are still significant challenges to commercial feasibility, given unavailable culture information, such as growth rate, feed conversion, and maturation timing. Also, market demand and economics needs to be examined, but the commercial dockside price for pompano in Florida is generally higher than other species so an aquaculture reared product is promising (Weirich et al. 2021).

Cobia (*Rachycentron canadum*)

Life-History Overview

Cobia is a valuable recreational and commercial species categorized under the Rachycentridae family. This coastal migratory species is found in tropical and subtropical waters, with a nearly worldwide distribution (Benetti et al. 2019). In the western North Atlantic Ocean, cobia are mostly found from Florida to Virginia and throughout the Gulf and Caribbean. Cobia are generally found associated with in the water (buoys, debris, shipwrecks, and artificial reefs), and sometimes large marine animals, such as sharks and manta rays. They are a warm-water species preferring water temperatures between 20°-30°C (68°-86°F). Their diet is crustaceans, squid, and fish. Cobia are a fast-growing (~ 38.1 cm [15 in] age-1) species that can reach 2.0 m (79 in) and 68 kg (150 lb); it has a moderate lifespan, which is about 15 years. Females grow faster and longer than males (Franks et al. 1999). The species is managed as two separate stocks with the GMFMC managing the Gulf stock and the Atlantic States Marine Fisheries Commission managing the Atlantic stock. The current stock assessment indicates the species is not overfished but is subject to overfishing.

Cobia habitat varies somewhat by life-stage. Juveniles prefer inshore and nearshore waters (estuaries, bays, sounds, and inlets), while adults prefer nearshore offshore waters associated with artificial and natural reefs, including hard bottom habitat. Cobia are a coastal migratory species that migrates seasonally along the Atlantic coast and throughout the northern and southern regions of the Gulf depending on the water temperature; they migrate in an alternating north-south pattern, toward cooler waters in the spring and warmer waters in the fall (Franks et al. 1999). Cobia have an extended spawning season that begins in April and ends in September, but it varies slightly by region (Brown-Peterson et al. 2001). Similar to other species, cobia aggregate into large schools near coastal bays and estuaries to spawn. Cobia are a pelagic, broadcast spawning species with a 9-12 days spawning frequency; they may spawn 15-20 times during the season (Brown-Peterson et al. 2001). Mean batch fecundity ranges from 377,000 ±64,500 eggs to 1,980,500 ±1,598,500 eggs depending on the method (Brown-Peterson et al. 2001). Annual fecundity in the Gulf is estimated to be 8,730,000-38,232,000 eggs per year (Brown-Peterson et al. 2001; GSMFC 2019).

Research indicates cobia constitute a single homogeneous population in the Gulf (Perkinson et al. 2019). Given the species is pelagic and distributed across the ocean, it is probable there is gene flow and movement over long distances; however, spawning aggregations in the Florida Keys and Northern Gulf may indicate localized genetic structure (Perkinson et al. 2019). Additional research is needed to understand the migration patterns of populations from around the Georgia-Florida boundary line and the segment of that population that migrates south along eastern Florida to the Gulf (GSMFC 2019).

Aquaculture

Cobia are a potential candidate species for aquaculture because they are fast growing, amenable to culture conditions, broad environmental (temperature and salinity) tolerances, and have high-quality filets (Dutney et al. 2017). Aquaculture research with cobia has been going on in the United States since the mid-1970s, and in Taiwan since the 1990s. By the late-90s, Taiwan was able to rear fry and juveniles for grow-out, mostly in nearshore cages. In the early 2000s, aquaculture facilities in Virginia, Texas, South Carolina, and Florida were successful at spawning cobia by using wild gravid females, administering hormone injection/implants, or modifying photoperiod/water temperatures. Outside of the United States, cobia have been commercially cultured in many regions around the world, including Taiwan, China, Vietnam, Belize, Mexico, Bahamas, Philippines, and Panama (FAO 2007); it is being evaluated in the U.S. (Benetti et al. 2019). Cobia are typically grown in nearshore and offshore cages in warm flowing waters with adequate water quality. Given market demand, target product uncertainty, and cost of operations, commercial operators have switched to other species and production has slowed since peaking in 2012-2013 (Seafood Source 2013). The offshore cage culture continues with fewer producers focusing on a higher-value market. As of 2019, the only commercial-scale producer in the Americas is located in Panama (Benetti et al. 2019).

Cobia are fast-growing reaching a harvest size of up to 6 kg in about 10.5 months, but growth rates vary widely by individual. Growth is faster at lower stocking densities and higher water temperatures. Cobia have high nutritional and environmental requirements, which makes production cost high. Broodstock selection for traits and management is done continuously since Cobia spawn year-round. The survival rate in pens is unreported but it is presumed to be low compared to other species given environmental requirements and disease susceptibility. Similar to other warm water species, Cobia are susceptible to many viruses, bacteria, and parasites.

Candidate Macroalgae Species

Sea Lettuce (*Ulva Spp.*)

Biological Overview

Ulva species is an abundant green macroalgae found throughout tropical and temperate coastal waters (Hiraoka 2021; Simon et al. 2022). Their extensive global distribution is facilitated by rapid proliferation, high growth rates, and broad environmental tolerances, including temperature, salinity, and eutrophication (Steinhagen et al. 2019; Simon et al. 2022); it can also survive in freshwater (Melton III and Lopez-Bautista 2021). The *Ulva* genus comprises over 400 described species, with only 129 currently accepted and approximately 40 taxonomically recognized using genetic information (Melton III and Lopez-Bautista 2021; Simon et al. 2022). Several *Ulva* species are found throughout the U.S. East Coast and Gulf (*U. aragoensis, U. compressa, and U. torta*); some are endemic to the Gulf (e.g., *U. californica, U. flexuosa subsp. paradoxa, U. lactuca, U. meridionalis, U. ohnoi, U. tepida, and Ulva sp*. 1 and 2). Overall, there are two morphological forms. The benthic form is found attached to rocks, mollusks, wood, and other algae in intertidal and subtidal areas, while the unattached free-floating thalli is found in intertidal to mesophotic zones (Melton III and Lopez-Bautista 2021). The thallus of various *Ulva* species are either uniform foliose distromatic sheets consisting of two cell layers or a tubular, monostromatic blade form (Hiraoka 2021; Simon et al. 2022). Some species can display both forms, such as *U. compressa* (Simon et al. 2022). The foliose sheet form is commonly known as 'sea lettuce,' while the tubular form is referred to as 'gut weed' (Melton III and Lopez-Bautista 2021). These distinct species evolved from genetic variability and from morphological plasticity, which was influenced by environmental conditions and the associated microbiome (Simon et al. 2022). Their ability to float allows these species to quickly boost their biomass by enlarging their thalli, reaching new areas with fresh nutrient supplies, and avoiding competition and grazers faced by benthic species (Hiraoka 2021). The small size and high motility of *Ulva* propagules facilitates colonization at distances around 24 to 35 km from the nearest population (Coleman and Brawley 2005; Romero 2018). As such, free-floating *Ulva* species have caused 'green tides' events causing nuisances, and environmental and economic impacts (Fort et al. 2021; Melton III and Lopez-Bautista 2021).

Ulva are a heterothallic and isogamous algae that alternate generations with a diploid sporophyte stage and a haploid gametophyte stage. Both stages are macroscopic and morphologically indistinguishable (Smith 1947; Wichard et al. 2015). Haploid gametophytes, either male or female, are generated from recombinant haploid zoospores (i.e., zoids) produced by sporophytes, or clonally from parthenogenic biflagellate gametes, and occasionally from zoids of parthenosporophytes (Wichard et al. 2015). Gametes produced by gametophytes are biflagellate, positively phototactic, and can engage in sexual reproduction with a gamete of the opposite mating type. In the absence of a mate, they can undergo parthenogenic development (developing into a gametophyte, as mentioned above). Zoospores originating from sporophytes are quadriflagellate and negatively phototactic. Equal numbers of zoospores of both mating types are released, and these develop into male and female gametophytes. The generation time of *Ulva* is short; the species can produce spores in just 2 or 3 weeks (Hiraoka 2021).

In most foliose *Ulva* species, fertile tissue develops along the thallus edges (Hiraoka 2021), and changes to color from yellow to brown along the edges of the thallus after development (Smith 1947; Wichard et al. 2015). In the laboratory, male gametes remain motile for less than 24 hours, but female gametes may last a few additional hours. Zoospore swarming typically lasts around 4 or 5 hours, occasionally extending to 24 hours after release (Smith 1947). However, these spores may last for months, which helps the species 'overwinter,' and tolerate periods of being buried in sediment in temperature regions (Romero 2018). Reproduction can occur during warmer seasons or year-round depending on the location (Romero 2018). In temperate areas, *Ulva* biomass increases from winter to spring, and decreases from summer to fall (Hiraoka 2021).

Information describing genetic diversity in *Ulva* is limited, but available information indicates high inter-specific genetic variation with low intra-specific genetic diversity in Europe and the UK (Fort et al. 2021). However, Coleman and Brawley (2005) found *U. linza* displayed highly differentiated populations over small spatial scales, possibly given local adaptations to salinity and intertidal positions. Patterns of population connectivity likely vary by species, especially between benthic and free-floating species. Additionally, understanding the interactions between genetics and responses to environmental conditions is crucial for *Ulva* aquaculture development and strain selection (Melton III and Lopez-Bautista 2021; Simon et al. 2022). Genetic variation can lead to a fivefold difference in the major compound levels (Melton III and Lopez-Bautista 2021). Given the species diversity, regional information is important to confirm relevant species and investigate population genetic structure for aquaculture development. In the Gulf, some genetic sequencing has been conducted on *Ulva ohnoi* and *Ulva lactuca* for taxonomic purposes (Melton III and Lopez-Bautista 2021), but overall population genetic information is lacking in this region. Genetic sequencing can help identify species with a higher risk of overgrowth or bloom development in aquaculture-targeted regions. For instance, Melton III et al. (2016) identified *U. ohnoi* in the Gulf of Mexico and along the Atlantic coast of Florida is prone to overgrowth.

Aquaculture

Despite constituting a small fraction of total seaweed biomass production (less than 0.1%), there is a growing interest in cultivating Ulva given its high productivity and environmental resilience (Steinhagen et al. 2019). Ulva holds potential applications in the food, pharmaceutical, nutraceutical, and cosmetic industries, as well as in biofuels and bioremediation (Simon et al. 2022; Steinhagen et al. 2022). Additionally, these species can be used in their fresh form for culinary purposes, such as in seaweed salads and soups (Ladner et al. 2018).The feasibility of large-scale *Ulva* cultivation in an offshore farm using rope cultivation on longlines was demonstrated in Sweden (Steinhagen et al. 2021). While some *Ulva* species can be propagated vegetatively in an unattached form (e.g., in tank culture), when grow-out occurs offshore, spores are seeded onto nets or seed lines in a hatchery (Ladner et al. 2018). To achieve appropriate seeding concentrations, methods involving fragmentation and a culturing protocol to induce sporulation from thallus tissues independent of seasonal reproduction patterns may be employed (Hiraoka 2021; Steinhagen et al. 2021). Steinhagen et al. (2022) found that high seeding densities (10,000 gametes per mL) increased mean biomass yield by almost 84% compared to low seeding densities (500 gametes per mL). Solutions of 'swarmers' (gametes and spores) are applied to spools, and after propagules are allowed to settle, the spools are kept in the hatchery for 6 weeks to allow growth. Steinhagen et al. (2022) reported that increased contact time in the nursery period was found to minimize detachment and seedling loss caused by wave forces given more vigorous rhizoidal attachment prior to outplanting.

Juvenile plants are gradually acclimatized to natural conditions and can then be deployed to an offshore farm (Steinhagen et al. 2021). In the Steinhagen et al. (2021) study, the growout duration was 6 months. Zollman et al. (2023) reported that cultivation at depths of 3 to 10 m (in their study - 5 m) has been shown to be better than depths of 1 m, given lower growth rates caused by mechanical stress from surface waves. In Sweden, the highest biomass yields were observed in late spring, but beyond this point, the number and size of holes in the thalli, as well as the amount of fertile and fouled tissue, increased, leading to decreased biomass yields and quality (Steinhagen et al. 2022b). The timing and seasonality for grow-out and harvest will vary by location, and for warmer regions like the Gulf, the most appropriate months for grow-out and harvest will likely be different.

Additional considerations include reports of the recombinant gametophyte having faster ontogenetic development and higher growth rates compared to clonally produced gametophytes in *U. fenestrata*, indicating that the selection of the life-history phase may be crucial in developing cultivation approaches for *Ulva* species (Steinhagen et al. 2022). The authors also emphasized the importance of molecular species identification to disentangle the effects of genetic or environmental factors on biomass yield and biochemical composition, enabling site-specific selections of suitable *Ulva* species and strains. Development of sterile strains is also of interest for *Ulva* species that exhibit unpredictable fertility intervals; these species may synchronously develop reproductive tissue, and significant biomass losses can result given the reduced quality of thallus tissue following reproduction (Steinhagen et al. 2022b). This occurrence has limited the commercial potential for large-scale cultivation in *Ulva* species where this occurs.

Dead Man's Fingers (*Codium* spp.)

Biological Overview

Codium are siphonous green algae encompassing over 80 species that are distributed across tropical to temperate regions (Trowbridge 1996; Chang et al. 2003; Kang et al. 2008). In the Gulf, *C. isthmocladum* has been identified off the Yucatan coast (Robledo et al. 2003), and *C. taylorii* has been discovered along the coast of Texas in the lower Laguna Madre, East Flower Garden Bank in the northwestern Gulf, and Veracruz, Mexico (DeYoe and Hockaday 2001). *Codium* species are found in sheltered bays, estuaries, and semi-exposed coastal areas within the intertidal and subtidal zones, extending to depths of 15 meters. Some species thrive at deep depths between 42 and 53 m (Robledo et al. 2003; Neill et al. 2006). These algae attach themselves to various hard substrates, including rocks, shells, and artificial structures (e.g., ropes and plastic); *codium* prefers sandy or muddy bottoms (Neill et al. 2006). Codium can grow up to 30 cm and have two distinct thallus forms—spongy and filamentous. The filamentous forms are finely branched filaments that are formed initially, while the spongy form (preferred for cultivation) develops from the filamentous form under optimal conditions, including higher current flow and irradiance levels (Silva 1955; Trowbridge 1996). Notably, *Codium* can tolerate fluctuating temperature, salinity, light, and nutrients. As such, *Codium* thrives in areas influenced by anthropogenic activities, or in areas with artificial marine structures and/or aquaculture equipment (Neill et al. 2006). Certain *Codium* species can be invasive in marine ecosystems globally, such as *C. fragile*; *C. fragile* has invaded U.S., Europe, Mediterranean, Australia, New Zealand, and Chile coastal waters (Neill et al. 2006; Muha et al. 2019).

Different from other macroalgal species, *Codium spp*. tend to thrive in the warmest water temperatures (Neill et al. 2006). These species are perennial, with spores and thalli capable of surviving in winter and reinitiating growth in spring. The most rapid growth occurs in summer and early fall (Hanisak 1979; Neill et al. 2006). Plant abundance declines during winter and early spring (Churchill and Moeller 1972) but this pattern may vary by location (Chang et al. 2003). Reproductive development is believed to be influenced by water temperature (Churchill and

Moeller 1972), leading to the emergence of reproductive fronds in summer and early fall (Hanisak 1979; Kang et al. 2008).

The sexual reproduction process in *Codium* species is relatively straightforward, involving the production of gametes on gametangia found on mature thalli. Similar to other green algae, these gametes possess two flagella and undergo fusion to form a zygote. This zygote then goes through a siphonous filament phase before developing into the fleshy thalli characteristic of these species, contingent upon specific environmental conditions, such as adequate water current and irradiance levels (Churchill and Moeller 1972). Asexual reproduction has also been documented in these species, including the parthenogenic development of haploid gametes, vegetative fragmentation, development of propagation buds, and the formation and growth of filamentous thalli from isolated utricles with medullary filaments (Churchill and Moeller 1972; Chang et al. 2003). While the gametes have flagella and are mobile upon release, it ceases in 30 minutes (Churchill and Moeller 1972). Nonetheless, these gametes may remain viable and can go through parthenogenic development in the absence of other gametes (Churchill and Moeller 1972). The dispersal of *C. fragile* can also by drifting of the entire plant or plant fragments. These fragments have the capacity for vegetative growth and may also release gametes if fertile (Churchill and Moeller 1972).

Similar to other species, the population structure of *Codium* in the Gulf is unknown, with limited genetic information describing taxonomy (e.g., Schneider et al. 2020). Recent research has explored using environmental DNA (eDNA) for early detection and monitoring of *C. fragile* (Muha et al. 2019). Other research has investigated genetic variation in populations of *Codium fragile ssp. Tomentosoides*. Researchers have found there is low genetic diversity among populations of *C. fragile* and suggested factors associated with colonization processes played a role, but low fecundity and asexual modes of reproduction might contribute to this phenomenon (Provan et al. 2005). Interestingly, this pattern was not observed in other *Codium* species (Provan et al. 2005).

Aquaculture

Green macroalgae constitute a relatively small portion of the global seaweed biomass production, but there is an interest in cultivating *Codium* species (Moreira et al. 2022). Despite the cultivation of *C. fragile* in Korea since the 1980s through small-scale practices, the global production is currently only around 4000 t in fresh weight, with an approximate value of $2 million USD (Moreira et al. 2022). *Codium* is primarily consumed in Korea, China, Japan, and the Philippines in various forms, such as fresh, dried, or salt-cured, and commonly used in dishes like kimchi (Trowbridge 1996; Hwang and Park 2020; Moreira et al. 2022). There is also a pharmacological interest in *Codium* species given their potential anti-inflammatory and anti-tumor properties. Also, there is some interest with their application in bioremediation, particularly in Integrated Multi-Trophic Aquaculture (IMTA) systems (Moreira et al. 2022; Kang et al. 2021).

Small-scale cultivation from natural blooming zygotes has been ongoing in Korea since 1987, using the settlement of wild zygotes (Hwang and Park 2020). However, production has been subject to variations based on recruitment success. Conversely, cultivation methods employing vegetative propagation were developed for *C. fragile*, proving successful in achieving higher production levels (Moriera et al. 2022). Hwang et al. (2020) pioneered cultivation techniques for generating seed stock in 2005. This method includes blending vegetative thalli and seeding lines with the mixture; utricles and medullary filaments remain on these lines, and seed frames are placed in a nursery tank for a month to grow. Afterward, the seed frames are transferred to the sea, where, aided by natural water currents, medullary filaments grow and begin to form fleshy thalli after 40 days. Subsequently, seed lines are removed from the frames and wound around long lines. The thalli undergo approximately 7 months of growth before reaching the harvest stage (Hwang et al. 2009). This cultivation approach has significantly enhanced production, increasing from less than 1 kg-fresh weight to 7 kg-fresh weight per 1 m culture rope (Hwang and Park 2020).

While vegetative fragmentation is simpler given the absence of manipulation in the sexual life cycle, it carries a higher risk of adverse effects related to the loss of genetic diversity. This may cause increased vulnerability to diseases and reduced overall production (Moriera et al. 2022).

***Gracilaria* spp.**

Biological Overview

Gracilaria are a diverse group of red algae that has worldwide distribution, economically important, and includes more than 110 species (Gurgel et al. 2004; Lipinska et al. 2023). These species support a thriving agar industry that includes cultivated and wild plants (Lopez-Bautista and Kapraun 1995). Given their commercial uses and associated value, some *Gracilaria* populations have declined in their natural habitat because of overharvesting (Pereira and Yarish 2008). Other *Gracilaria* populations have exploded and become invasive (Lipinska et al. 2023). *Gracilaria* can swiftly colonize new environments, given their resilience to various stressors, including fluctuations in nutrient levels, salinity, and temperature (van Ginneken and de Vries 2018; Lipinska et al. 2023). They can adapt to a wide-range of environmental conditions and easily become invasive (van Ginneken and de Vries 2018).

Gracilaria tikvahiae is among the most prevalent benthic species in the Gulf because it can grow in diverse habitats, such as bays, inlets, and estuarine environments (Gurgel et al. 2004). It is an important commercial species (i.e., agar production) that can adapt to broad environmental parameters, including temperature and salinity levels (10-40 ppt); prime growth is between 25 and 33 ppt (Gurgel et al. 2004) Moreover, it can survive in broad water temperatures (0°-35°C); optimal growth is between 20° and 28°C (Gurgel et al. 2004). Some researchers suggest the northeast variation, surviving the winter, and the southern variation in tropical waters are the same species (Gurgel et al. 2004). Morphologically, *G. tikvahiae* varies slightly depending on the specific strain and prevailing growing conditions, but it generally has a bushy, branching form, rounded branches that irregularly extend, and thalli that may be terete or flat (Gurgel et al. 2004). The coloration of its blades typically varies from red to brown, green, or nearly black; the color varies by light exposure and nutrient availability (Gurgel et al. 2004). The blades originate from a flattened disc, serving as the holdfast for attached species. Growth is driven by an apical meristem, located at the tip of each branch (Gurgel et al. 2004).

Members of the red algal family Gracilariaceae, known as Gracilaroids, feature a triphasic life history characterized by isomorphic diplohaplonty. This term implies that the gametophyte and tetrasporophyte phases share identical appearances, as erect branched thalli growing from a perennial holdfast (Guillemin et al. 2008). Visual differentiation between these phases is impossible to the naked eye, with the exception of the fertilized female gametophyte bearing cystocarps (the carposporophyte phase), which can be distinguished (Valero et al. 2017). These two phases often spatially and temporally overlap, seemingly occupying similar biological niches (Wehrenberg 2011).

In the triphasic life cycle of *Gracilaria*, meiosis occurs on the reproductive diploid tetrasporophytes, giving rise to haploid tetraspores (Guillemin et al. 2008). After release, these tetraspores attach to the substrate, forming perennial holdfasts and developing into haploid male and female gametophytes. Male gametes, lacking flagella in red algae, are released from male gametophytes into the water, seeking eggs on the female gametophyte thallus (Wehrenberg 2011). Fertilization takes place on the female gametophyte, leading to the development of a cystocarp—a third stage that grows directly on the female gametophyte thallus as small bumps. Through mitotic division, thousands of diploid carpospores are produced in this stage. Upon release, these carpospores attach to the substrate, developing into perennial holdfasts that eventually grow into tetrasporophytes (Guillemin et al. 2008). Reproduction peaks in late summer at high latitudes, and it may occur throughout the year in the tropics. In temperate regions, the fastest growth rate and highest biomass occur in late summer, and peaks in winter in the tropics (Kain and Destombe 1995).

Gracilaria species can also propagate through vegetative fragmentation, occurring when thalli of either the diploid tetrasporophytes or haploid gametophytes break (Guillemin et al. 2008; Valero et al. 2017). Fragments of any size and at any location along the thallus can grow into new thalli, and the process may stimulate further growth, branching in the parent plant (Wehrenberg 2011). In sediment habitats, underground thalli may enable the species to over-winter during harsh periods, and studies have shown the resumption of growth after burial for up to four months

(Wehrenberg 2011). Gracilaria can also propagate from free-floating thalli, where plants detached from the holdfast can grow and propagate vegetatively indefinitely, potentially forming large beds (Guillemin et al. 2008).

Gracilaroid can propagate via sexual (carpospores), asexual (release of tetraspores) and vegetative fragmentation from either the diploid or haploid phase (Guillemin et al. 2008; Wehrenberg 2011), which varies on water velocity, plant density, geographic location, available substrate, and fragmentation frequency (Wehrenberg 2011). For instance, Wehrenberg (2011) reported *G. andersonii* exhibited year-round sexual fertilization at one California site, and vegetative fragmentation at another California site. Limited information is available regarding spore dispersal in *Gracilaria* species, with both tetraspores and carpospores considered significant dispersal mechanisms (Destombe et al. 1992). Destombe et al. (1992) found *G. verrucosa* had a relatively short dispersal phase, and spores were not dispersed far from parent plants. While it has been suggested that haploid spores may have longer dispersal capabilities compared to diploid spores, both spore types can survive for weeks and endure days of desiccation. Seasonal changes may influence the germination rate of these spores (Kain and Destombe 1995). In terms of gamete dispersal, non-motile male gametes are estimated to have a lifespan of six hours, with a limited dispersal distance of a few meters for the male gametophytes (Destombe et al. 1992; Kain and Destombe 1995). Despite their short lifespan, Kain and Destombe (1995) reported fertilization in *G. verrucosa* was over an 80 m distance. *Gracilaria* species tend to disperse via fragmentation. In San Francisco, Albright (2021) discovered that *G. andersonii* are more prone to fragmentation than other species in the same region. Albright (2021) observed the tensile strength of thalli may vary based on the reproductive method and habitat (rocky substrate vs sediment). In the San Francisco estuary, the population relies on vegetative fragmentation as its primary mode of reproduction, and its lower tensile strength may contribute to more frequent fragmentation and subsequent population growth (Albright 2021).

Research on the genetic structure of *Gracilaria* has focused on resolving the taxonomic identification of *Gracilaria* species worldwide. Researchers are interested in the genus because of the intriguing life-cycle and ability to reproduce via sexual and asexual methods (Lipinska et al. 2023). Wehrenberg's (2011) revealed populations displaying differences in reproductive modes could still be classified as the same species. As such, determining the genetic population structure among populations with varying life-cycle phases and modes of reproduction may not be straightforward. For any forthcoming genetic research, there are available genomic resources, including genome assemblies (with differing levels of completeness) for *Gracilaria chilensis*, *G. gracilis*, *G. caudata*, and *G. vermiculophylla*, accessible at https://rhodoexplorer.sb-roscoff.fr (Lipinska et al. 2023). Moreover, sequences of chloroplasts and mitochondrial genomes are accessible for numerous *Gracilaria* species (Iha et al. 2018).

Available information indicates reproducing G. *gracilis* populations displayed only weak, but significant structuring, with a low degree of inbreeding observed in locations separated by 2.5 to 12 km. However, substantial genetic differentiation was detected among locations that were separated by a longer distance (500-1,200 km). The study suggested an overarching pattern of isolation at distances greater than 1 km, while gene flow prevented strong genetic differentiation at shorter distances (Engel et al. 1999). The researchers concluded that *G. gracilis* populations had the potential for local adaptation within ranges of a few hundred meters to several kilometers. Within a given site, there may be genetic heterogeneity among individuals across the habitat. However, wave action and other fine-scale processes cause more frequent gene flow (Engel et al. 2002). In macroalgal species with both sexual and asexual reproduction, the genetic effects of selection differ between these reproductive modes. During sexual reproduction, selection targets specific genomic regions but over generations, genetic diversity is reduces in these regions and neighboring regions linked physically to the selected targets. In contrast, asexual clonal reproduction mimics complete physical linkage across the entire genome causing more rapid fixation of single genotypes and loss of genetic diversity. The decrease in genetic diversity not only limits the available genetic pool for trait improvement but also hinders a population's ability to adapt to new environmental conditions (Guillemin et al., 2008). Guillemin et al. (2008) found that cultivated *G. chilensis* populations had lower diversity than wild populations given clonal propagation practices. However, asexual fragmentation preserved heterozygosity given the lack of segregation in this mode of reproduction (Guillemin et al. 2008). Guillemin et al. (2008) also observed that cultivated genotypes had spread into wild populations.

Gurgel et al. (2004) attempted to identify genetic variability in *G. tikvahiae* from Canada/NE U.S. through the western Gulf of Mexico but wasn't able to determine the geographic location in the northern Gulf that separates the western and eastern Gulf lineages despite identifying four lineages corresponding to distinct regions. These include the Canadian/north east U.S., south east Florida, eastern Gulf of Mexico, and the Western Gulf of Mexico lineages. The authors suggested the genetic differentiation may occur near the mouth of the Mississippi River and/or the Chenier Plain, which is a marsh/estuarine system characterized by shallow muddy substrata extending from southeastern Louisiana to northeastern Texas (Gurgel et al. 2004). These findings suggest the presence of dispersal barriers among some populations in the region. Future genetic research should strive to pinpoint the specific location of this lineage break and determine if there is finer-scale genetic structuring among populations within both the western and eastern portions of the Gulf.

Aquaculture

Commercial cultivation of *Gracilaria* has been established in regions like Chile since the 1980s (Abreu et al. 2009). The algae's properties extend to antiviral, anti-inflammatory, and anti-hypertensive attributes, along with other uses in pharmaceutical and industrial sectors (Gurgel et al. 2004; Iha et al. 2018; van Ginneken and de Vries 2018; Lipinska et al. 2023). *Gracilaria* species can also potentially be used in waste recycling, particularly within multi-trophic aquaculture systems (Halling et al. 2013; Samocha et al. 2015). Beyond their industrial applications, *Gracilaria* species have culinary value often used in salads (Klinkenberg 2020).

With their warm-water growing seasons, ease of propagation, rapid growth rates, and high tolerance to diverse environmental conditions, *Gracilaria* species are a potential aquaculture species (Gurgel et al. 2004). The predominant and straightforward cultivation method for *Gracilaria* species involves asexual propagation, wherein growers use thallus tips to clonally generate new plants (Pereira and Yarish 2008). Observations at farm sites suggest the selection for vegetative propagation may favor sterility (Wehrenberg 2011). Guillemin et al. (2008) noted that 40% of cultivated *G. chilensis* produced reproductive structures, but sexual reproduction was rare, indicating an incomplete life cycle under culture conditions. Domestic cultivation through asexual fragmentation may also unintentionally select for diploidy, possibly from heterosis in heterozygotes causing an excess of heterozygotes in asexually propagated populations (Guillemin et al. 2008; Valero et al. 2017). Debate exists regarding whether the observed heterozygote excess indicates selection for heterozygous diploids or if clonal propagation itself leads to the accumulation of mutations, resulting in a heterozygote excess. Mutational models for clonally reproduced organisms predict the accumulation of a large number of mutations over many generations. However, the extensive production of clonally reproduced individuals for commercial purposes may also contribute to a substantial number of mutations (Guillemin et al. 2008).

Clonal reproduction has consistent production given genetically identical individuals (Redmond et al. 2014), ease of selection and maintenance of desired phenotypes without the risk of loss from recombination in sexual reproduction (Valero et al. 2017). Also, there is potentially higher growth and survival rates (Valero et al. 2017), and reduced risk of cultivated strains mixing with wild conspecifics (Valero et al. 2017). However, drawbacks include reduced genetic diversity in the propagated populations compared to wild populations (Halling et al. 2013; Hurtado et al. 2015). Guillemin et al. (2008) found that cultivated populations of *G. chilensis* contained a third of the genetic diversity as nearby wild populations, potentially diminishing resilience to novel challenges (Valero et al. 2017). Higher rates of sterility in these populations may also limit opportunities for breeding improvements (Valero et al. 2017). Spore seeding provides an alternative method for *Gracilaria* propagation, involving the seeding of spores from mature carposporophytes or tetrasporophytes onto a substratum (Redmond et al. 2014). This process allows the spores to develop into juvenile plants, which are then placed at the farm site. As described by Redmond et al. (2014), the spores are released over the desired substrata (e.g., seed lines) by placing spore-bearing thalli on a screen suspended in water. After a 24-hour period at 20°C, the spores settle undisturbed for 24 to 42 hours in dim light. The seeded lines are maintained at 20°C under low light for 2 months until visible juvenile plants develop, and then outplanted to the culture site. The seeding method offers the convenience of plants attached to lines, eliminating the need to tie individual plants. Additionally, a significant advantage is the minimal volume of material required to establish a commercial farm; only 30 to 40 kg of cystocarpic plants may serve as spore stock, compared to the 10,000 kg needed for a 1 ha farm using the tying method (Alveal et al. 1997). Another notable benefit is the introduction of recombination through sexual reproduction, aiding in the maintenance of genetic diversity crucial for population adaptation to new challenges and the development of high-quality cultivated lines in the long run (Halling et al. 2005; Redmond et al. 2014). However, drawbacks include a two-month incubation period in the nursery before outplanting, and higher levels of phenotypic variation in cultivated individuals (Redmond et al. 2014).

Aquaculture operations cultivate *Gracilaria* using a suspended rope system, where a floating longline is anchored in place with buoys. *Gracilaria* plants are then attached to the line by tying with smaller twine and are allowed to grow further once outplanted; outplanting occurs above 15°C. This approach can also be used for seeding, where lines are outplanted when plants are approximately 13 cm in height. Harvesting methods vary, with options including trimming outer growth every 2 to 4 weeks or harvesting the entire plant (Redmond et al. 2014). This longline approach has been successfully adopted in the Republic of Korea and India (Mantri et al. 2023). Other cultivation systems include using net tubes or floating cages stocked with unattached fronds, are also possible (Redmond et al. 2014). In warmer climates, bottom culture is a popular technique, involving seeding plants onto rocks spread on the bottom in shallow areas or attaching plants to lines suspended just above the bottom, similar to suspended line culture but less flexible for depth adjustment (Redmond et al. 2014).

Common challenges in *Gracilaria* cultivation include grazing, fouling, and environmental stress, especially in warmer regions. Effective control measures involve managing the depth of grow-out lines (deeper leads to less settlement), optimizing stocking density (higher is preferable), and strategically timing outplanting and harvest, particularly in regions with seasonal shifts in water temperatures and other conditions (more critical in temperate climates than in tropical regions) (Redmond et al. 2014). While *Gracilaria* is relatively stress-tolerant, variations in light, salinity, and temperature can impact growth (Redmond et al. 2014). Mitigating risks from extreme weather events is crucial, and protective measures include bringing lines into storage tanks during storms or adjusting the depth of lines to avoid damage from extreme wave action or runoff events (Redmond et al. 2014).

***Eucheuma* Spp.**

Biological Overview

Eucheuma, commonly known as sea moss, are a commercially important pantropical marine red algae that accounts for over 80% of world's carrageenan production. This red algae is found in sandy and rocky substrates with moderate to strong water currents (Dawes 1974). They can have thalli ranging from 35 to 75 cm in length, with main branches extending 7 to 9 cm. The plants exhibit color variation (green, brown, or red), and display differences in branch flexibility, ranging from brittle to cartilaginous (Freile-Pelegrin and Robledo 2008).

Among the 30 known *Eucheuma* species, only two are extensively cultivated for commercial purposes: *Eucheuma isiforme* and *E. denticulatum*. While *E. denticulatum* is native to the Indian and Western Pacific Oceans, E. *isiforme* is indigenous to the Caribbean and Gulf (Zemke-White and Smith 2006; Kim et al. 2017); it's found in the intertidal to subtidal zones (Fredericq et al. 2009). Notably, various *Eucheuma* species, including *E. gelidium*, *E. acanthocladum*, and *E. nudum*, are found off the west coast of Florida (Dawes 1974; Hayashi et al. 2017). In the Yucatan peninsula, the largest standing stock of *E. isiforme* is found from November to December), with peak growth from October to April (Robledo and Freile-Pelegrin 2011). In contrast, the highest growth rates in the Gulf occur in spring, summer, and early fall (Dawes 1974), in contrast with observations from Yucatan peninsula. In the Gulf, near the Florida Keys, *E. isiforme* thrives in exposed marine waters with tidal currents of up to 0.5 knots and at sites with a continuous limestone substrate. They are typically found at depths between 0.5 and 3 m during low tide in areas with high water visibility, this species favors between 20° and 31°C (Dawes 1974); high-density areas may have 10 plants per square meter (Dawes 1974). Abundance is seasonal, and storms can impact natural populations (Dawes 1974). Similar dynamics elsewhere in the world have prompted the introduction of non-native species in various regions when local species' biomass production proved insufficient (Hayashi et al. 2017). The genus is vulnerable to over exploitation and depletion given their commercial value (Dawes 1974).

Similar to other red algae, *Eucheuma* have a triphasic alternation of generations life cycle. This species is isomorphic, having morphemically similar tetrasporophyte and gametophyte stages. The diploid tetrasporophytes generate haploid tetraspores through meiosis, which, upon settling, develop into haploid male and female gametophytes. Sperm are produced on the male gametophytes and eggs are produced on the female gametophytes. The released sperm fertilizes the egg on the female gametophyte's carpogonial branches. The fertilized embryo then matures into a diploid carposporophyte, residing on the thallus of the female gametophyte. The carposporophyte produces diploid carpospores, which upon release then develop into diploid tetrasporophytes (Dawes 1974; Zemke-White and Smith 2006). Dawes (1974) reported vegetatively-produced plants or tetrasporophytes (constituting up to 60% of the plants) are more prevalent in fall and winter. The thallus of *Eucheuma* species is brittle, and when fragmented, these pieces can regenerate vegetatively. However, given their weight, these thalli have a tendency to settle quickly (Dawes 1974). Azanza-Corrales et al. (1992) discovered that through vegetative regeneration, the same life-cycle phase of the plants persists. Consequently, sites may differ in their proportions of male/female gametophytes and tetrasporophytes, depending on the original introduction or colonization in a given location.

Researchers have described taxonomy and explored genetics. Recent taxonomic reclassifications have categorized all kappa-carrageenan producing species under the genus Kappaphycus, iota-carrageenan producing species under the genus *Eucheuma*, and beta-carrageenan producing species under Betaphycus (Azanza 2023). Few researchers have examined the population genetic structure of eucheumatoid species, but some progress has been made in developing genetic markers for identifying color and morphological variants (Neish et al. 2017). This is particularly crucial as the plastic morphology of these species poses challenges in characterizing both inter- and intraspecific variability (Tan et al. 2022). Recognizing the importance of genetic resources for sustained carrageenan production, recent emphasis has been placed on genetic characterization of these species, which helps with identifying threats to wild stocks and developing conservation policies (Tan et al. 2022).

In general, cultivated eucheumatoids originating from a few individuals or broken thalli of farmed cultivars are genetically nearly identical at or around a farm (Neish et al. 2017). Consequently, the genetic diversity within these species has been underestimated, highlighting the need for sampling efforts that accurately assess diversity or aim to identify new cultivars (Neish et al. 2017). In Malaysia, where cultivation has been ongoing for the past five decades, Tan et al. (2022) identified four species across the Eastern Sabah region, with up to three species coexisting in single sites. The sequencing of the cox2-3 spacer and cox1 revealed 17 novel haplotypes across these species, indicating diversity in the wild sampled regions (Tan et al. 2022). However, the authors also observed farmed haplotypes in wild populations, suggesting a potential competition with indigenous eucheumatoid populations in East Malaysia (Tan et al. 2022). The study further highlighted that documenting the displacement of native populations by cultivated eucheumatoids may take decades. Consequently, the authors recommended periodic sampling of wild beds and cautioned against culturing non-native species, which could overgrow and displace local strains and species, disrupting the local ecosystem (Tan et al. 2022).

Aquaculture

Kappaphycus and *Eucheuma* are valuable red algae contributing over 80% of global carrageenan production, with *Eucheuma* species specifically known for producing iota carrageenan (Neish et al. 2017). Cultivation of these species is primarily conducted in Southeast Asia, including Indonesia, the Philippines, Malaysia, China, and Vietnam (Kim et al. 2017; Tan et al. 2022). Cultivation also occurs in Belize, Antigua and Barbuda, Brazil, and Tanzania (Freile-Pelegrin and Robledo 2008; Kim et al. 2017; Eggertsen et al. 2021). Some operators are evaluating whether to cultivate *Eucheuma* in the Gulf. (Racine et al. 2021). Extensive studies on the cultivation and carrageenan production of *Eucheuma* species have been conducted across its global range, including in Mexico, Belize, and the Caribbean (Robledo and Freile-Pelegrin 2011; Hayashi et al. 2017); there are some variations in carrageenan content, properties, and biochemical composition among populations (Freile-Pelegrin and Robledo 2008).

Carrageenan has a wide-ranging market. It is used in the food and pharmaceutical industries, along with other derivatives derived from seaweeds. It is consumed as food or vegetable, and as a carrageenan source for thickening, stabilizing, or emulsifying purposes in dairy products like chocolate milk and ice cream, including reprocessed meats, toothpaste, puddings, salad dressings, and more (Azanza 2023). Additionally, carrageenan is used in animal feed, pet food, fertilizer, and various industrial products and processes, spanning applications like air fresheners, cosmetic product binders, horticulture laboratory culture mediums, soil conditioners, insect repellents, and cough medicines (Trono and Valdestamon 1994; Azanza 2023).

The cultivation of *Eucheuma* relies on vegetative propagation, where 'seedlings' are cuttings obtained from the best mature plants during harvest, serving as seedling material for subsequent crops (Ask et al. 2003). Despite variations in color and branching morphology (Ask and Azanza 2002), farmed material is consistently generated through clonal propagation, a practice unchanged as the industry has expanded (Hayashi et al. 2017; Neish et al. 2017). Dawes et al. (1993) explored micropropagation in eucheumatoids and discovered that even fragments as small as 0.5 cm exhibited almost 100% new branch production. While controlling the sexual reproductive cycle in these species poses significant challenges (Tan et al. 2022), Ask and Azanza (2002) note successful development of *in vitro* cystocarp formation, carpospore release, and germination in eucheumatoids. They indicated sexual reproductive cycles could potentially offer greater flexibility in breeding manipulations.

Despite the time-intensive effort, cultivating *Eucheuma* is primarily done using the "tie-tie" method, which involves securing 50 to 100 cuttings with soft plastic materials at intervals of 20 to 25 cm to monofilament lines submerged in the sea (Dawes et al. 1993). With *Eucheuma* thalli having diameters exceeding 2cm, the tying process to monofilament lines is relatively straightforward, and the fragments are loosely tied to permit movement and orientation with the water current (Ask and Azanza 2002). Cultivation parameters (stocking density, propagule or 'seedling' size, line spacing, maintenance frequency, and planting depth) are all site- and season-specific factors that must be determined for each farm location (Ask and Azanza 2002; Azanza and Ask 2017). The lines are deployed as either shallow or deep set and connected to fixed-off bottom rigs, floating rafts, long lines, and more intricate rafting arrays and long-line configurations (Hayashi et al. 2017). In its simplest form, wooden stakes are used to anchor the ends of cultivation lines into the substrate (Hayashi et al. 2017), which is used in East Africa (Eggertsen et al. 2021). Some regions use basket cultivation to mitigate herbivore grazing, although the labor required for biofouling cleaning and clearance is high (Hayashi et al. 2017). Regardless of the method, these species are cultured between 0.5 and 3 m, with at least 20% light penetration, and adequate water flow (Dawes 1974). Generally, crops are ready for harvest within 6 to 8 weeks (Goh and Lee 2010).

Operators are gradually replacing the "tie-tie" method with tubular netting cultivation, which has demonstrated increased productivity given simplified planting and harvesting periods. Some producers are using large nylon netting supported by stainless steel rings with a diameter of 1 m (Hayashi et al. 2017), and can simply detach the tubular nets and transport them to drying facilities for further processing; this approach is being used in Brazil (Hayashi et al. 2017). Also, efforts are underway to develop mechanized harvesting methods, to alleviate the labor-intensive processes associated with farming these species, including using lower-tech solutions like line strippers (Ask et al. 2003; Neish et al. 2017). Despite the potential advantages of alternative methods, the industry has been slow to adopt them given reported slower growth, higher capital investment, or increased incidences of pest species associated with newer approaches (Ask and Azanza 2002). Selective breeding has been conducted on cultivars in various locations, targeting phenotypes linked to growth and carrageenan content (Dawes et al. 1993). While breeding experiments using tetraspores have been conducted, they are not yet regularly used by the commercial industry (Ask and Azanza 2002).

Common challenges in eucheumatoid culture include herbivore grazing, storm-induced biomass removal, and fouling by other seaweeds (Dawes 1974). Given their brittleness, they are susceptible to damage and breakage from various environmental stressors (Dawes 1974). The removal of epiphytes is a labor-intensive process, often requiring multiple interventions each week (Hurtado et al. 2006). However, neglecting to address epiphyte growth can increase drag on lines and plants, resulting in breakages and plant loss (Ask et al. 2003). Another significant concern for eucheumatoid farmers is the outbreak of a disease known as "ice-ice," which causes pigment loss in thalli tissue and branches breaking (Ask and Azanza 2002); the vector of this disease is unknown (Kim et al. 2017). Another concern is the limited genetic diversity observed in current cultivars. In certain regions, seedlings have begun to exhibit signs of diminished strain vigor and reduced production from continuous clonal vegetative propagation (Hayashi et al. 2017). For instance, Tan et al. (2021) noted low genetic diversity in Malaysian cultivars over a decade. This loss of diversity could potentially impede the cultivars' capacity for environmental adaptation and disease resistance, which may make them susceptible to outbreaks of "ice-ice" or epiphyte infestations. The authors emphasized the need for local biobanks, where farmers can access seedlings and genetically distinct germplasm from cultivars and natural populations, ensuring a sustainable seedstock supply. Incorporating sexual reproduction to introduce new genotypes may also aid in identifying thermally tolerant and disease-resistant cultivars (Kim et al. 2017).

Shellfish Candidate Species for Marine Aquaculture

Bay Scallop (*Argopecten irradians*)

Biological Overview

Bay scallops, native to the Northwest Atlantic, are found in shallow coastal waters from the Gulf to southern Massachusetts Bay (Gosner 1979). There are three subspecies of *Argopecten irradians. Argopecten i. irradians* (Lamarck 1819) is primarily located along the Atlantic coast, extending from New Jersey to New Hampshire. South of this region, *A. i. concentricus* (Say, 1822) is found from New Jersey to North Carolina; the species is also found in Florida and the eastern coastal Gulf. *A. i. amplicostatus* (Dall 1898) is found from Louisiana to Galveston, Texas, and potentially further south.

In 1994, commercial and recreational fisheries for Florida Gulf Bay scallops were closed from overfishing, which prompted abundance surveys. Research revealed population fluctuations occurring on broad 5 to 7 year cycles, characterized by shifts from low to high abundance and vice versa over just one or two seasons (FWC 2023). These population dynamics were closely linked to natural and environmental conditions, such as seagrass abundance, salinity levels, and the number of red tides, hurricanes, and other factors. Additionally, anthropogenic influences such as impact of fishing efforts greatly affect these scallop populations. The bay scallop's short lifespan and variable abundance make stock assessments challenging compared to longer-lived species.

In the northwest Gulf, bay scallop abundance and distribution is lacking for Alabama, Mississippi, and Louisiana. However, it's likely associated with the lack of seagrass beds in these regions. In Texas, A. i. amplicostatus has low densities and follows "boom and bust" cycles approximately every 10-15 years (Withers and Hubner 2009). Notably, Laguna Madres in Texas stands out as the only location with notably high relative abundance, which can be attributed to the presence of extensive seagrass coverage and favorable salinity levels.

Bay scallops are simultaneous hermaphrodite broadcast spawners. Each individual releases eggs and sperm in separate pulses, with the possibility of self-fertilization and viable offspring (Wilbur 1995; Arnold et al. 2005). The viability of gametes is limited to a short time frame, lasting from minutes to hours (Levitan and Petersen 1995). After spawning, the larvae remain in a planktonic phase for one to two weeks (Castagna and Duggan 1971). Afterwards, they attach to seagrass blades until they reach approximately 20 mm before transitioning to the sand within the grass beds (Geiger et al. 2010). Adults and juveniles can move by clapping their shells together to create a "water jet" propulsion, but their mobility is restricted to short distances; they do not venture beyond seagrass beds (Barber and Blake 1983). Florida Gulf Scallops (A. i. concentricus) spawn between September and January, peaking in October, sporadic spawning occurs in spring or early summer (Arnold et al. 1997; Geiger et al. 2010). They aggregate and spawn simultaneously during a single reproductive season; they only live around 2 years (Castagna and Duggins 1971; Barber and Blake 1983; Marelli and Bray et al. 1999).

Atlantic Ocean Bay scallop populations are mainly comprised of A. I. irradians individuals, with some genetic interchange from *A. I. concentricus*. These populations have greater genetic differentiation than the Florida Gulf Bay scallop populations, which exclusively comprise A. I. concentricus individuals (Bert et al. 2011). Atlantic and Gulf scallops are genetically separate populations (Hemond and Wilbur 2011). Bay scallops (*A. i. concentricus*) in Florida have a complex metapopulation genetic structure. This structure reflects characteristics of both source-sink populations, with gene flow originating from donor populations to sink populations, and classic metapopulation dynamics, where all populations have the potential to contribute recruits (Bert et al. 2014). Within this framework, the populations at Steinhatchee and Homosassa emerge as the primary source for the Gulf side of Florida. While there is also gene flow between these sink populations, it is the source populations that make the most substantial contribution to the genetic diversity in this intricate ecosystem. In Florida, bay scallops are managed at the County level, typically focused on establishing season and bag limits for recreational harvest.

Aquaculture

Supplementation programs along the east coast of the United States were initiated in 1998 (Arnold et al. 2005; Wilber et al. 2005). Presently, bay scallops are cultivated for stock enhancement and commercial markets worldwide (Milke et al. 2006; MacKenzie 2008; Tettelbach et al. 2011). They can attain a marketable size (4-7 cm) in just one year, which also happens to coincide with their sexual maturity (Shumway 1991; Milke et al. 2006). In China, aquaculture-raised adults are harvested before reaching sexual maturity, which reduces the likelihood of gamete release from cultured individuals (Zheng et al. 2006).

Eastern Oyster (*Crassostrea virginica*)

Biological Overview

Eastern Oysters are native to the East Coast of North and South America from the Gulf of Lawrence, Canada to Venezuela, South America (Morris 1975). They are found in shallow estuaries and intertidal zones. Eastern oysters are hermaphrodites, initially maturing as males and subsequently transitioning to females. There is evidence indicating this process may be reversible, with oysters' potentially changing sex annually depending on the environmental conditions, nutrition, and physiological stresses (Bahr and Hillman 1967; Ford et al. 1990; Thompson et al. 1996). Eastern oysters can survive in wide-ranging environmental conditions, including temperatures from -1.8° to 36°C. In the southern range, spawning takes place in every month except in winter, while in the northern range, spawning is seasonal, occurring primarily in summer (Berrigan et al. 1991). Fecundity in oysters is challenging to pinpoint given their extended spawning season and intermittent reproduction throughout the year. Nonetheless, estimates suggest a range between 2 and 115 million eggs per female, which varies depending on the oyster's size and geographic location (Davis and Chanley 1956; Cox and Mann 1992; Thompson et al. 1996). Larval development, and the pelagic larval phase, are significantly influenced by temperature, with this dispersal phase lasting anywhere from 11 to 30 days (Kennedy 1996; Shumway 1996). The initiation of larval settlement is driven by salinity and chemical cues released by other live oysters and biofilms suitable for settlement (Hidu and Haskin 1971; Kennedy 1996). Growth is highly dependent on food and temperature; oysters can reach sexual maturity within 4 months in southern waters (Wallace 2001). In the Gulf, oysters can reach a harvestable size (76 to 90 mm) within 18 to 25 months. However, in colder waters like those around Long Island, harvest size can take 4 or 5 years. Fully grown adult Eastern Oysters can typically reach 250 mm (Abbott 1974; Morris 1975), and in the Gulf they reach 300 mm and live 25-30 years (Carriker 1996).

Information gathered from a Biological Review Team suggests that overfishing isn't a significant threat to this species, and recruitment is generally adequate to sustain Eastern oyster populations throughout their range, except for certain areas in the mid-Atlantic. In estuaries where enhancement programs are taking place, these initiatives are deemed necessary to sustain the populations, which applies to roughly half of the estuaries in the mid and south Atlantic regions because of declining populations.

Researchers have investigated the genetic population structure of Eastern oysters in the Atlantic and Gulf. Findings suggest there is a distinct Atlantic population and Gulf population with a transition zone somewhere along the East coast of Florida (Reeb and Avis 1990; Karl and Avis 1992; Hare and Avis 1996; Hoover and Gaffney 2005; Thongda et al. 2018). Additional sampling in the Laguna Madre, Texas found this area is genetically distinct (King et al. 1994; Thongda et al. 2018). Researchers suggest this genetic differentiation could be from adaptation to hypersaline conditions or genetic isolation from other oyster populations (King et al. 1994).

Aquaculture

Enhancement programs have been implemented throughout most of the Eastern oyster's range (NMFS 2007). In these programs, wild oysters are relocated from regions with high spat settlement or contaminated areas. These oysters are moved to areas that are optimized for productivity. In these cultivated habitats, target population densities are maintained to minimize competition for phytoplankton, and deter potential predators, such as crabs and sea stars. Commercial aquaculture production of Eastern oysters, achieved through the selection and breeding of fully captive specimens is rapidly increasing, particularly along the mid-Atlantic coast (Allen et al. 2021). In controlled environments, larval settlement occurs within 11-30 days at around 19° to 33°C (Shumway 1996). In the Gulf, Eastern oysters achieve sexual maturity in 4 months, and they reach a harvestable size (76 to 90 mm) within 12-24 months (Berrigan et al.

1991; Wallace 2001). Given the rapid maturation of Eastern oysters in the Gulf, they have the capacity to reproduce before reaching market size, potentially releasing gametes into the natural environment.

Variegated Sea Urchin (*Lytechinus variegatus*)

Biological Overview

Variegated sea urchins (urchins), *Lytechinus variegatus*, are found from Florida to North Carolina and throughout the GPM, including the Caribbean (Hendler et al. 1995). Urchins are usually found in calm, clear water, such as seagrass beds, rocks, or sand. They have a low tolerance for turbid water with suspended sediment (Moore et al. 1963). Overfishing is a common problem around the world. In the U.S, commercial landings were around 10 or 16 mt in the Gulf during 2010 through 2022 (NMFS 2023e).

Sea urchins are common through the Gulf and can be found in high densities (40 individuals per square meter). Urchins can also aggregate at very high densities of 250 to 600 per square meter, forming what are called urchin fronts. These fronts move through seagrass beds and can denude large areas. Sea urchins feed primarily on seagrass, but they are omnivores, consuming everything they encounter, from phytoplankton to plastic and Styrofoam (Hammer 2013). Urchins reach sexual maturity between 1 and 3 years. They show separate sex broadcast spawning (Pechenik 2000) and spawning occurs at different times depending on the location; spawning is usually from May to late summer during full moon. Urchins can reproduce throughout its life (Tennent 1910; Moore et al. 1963; McCarthy and Young 2002).

Sea urchins, in particular *L. variegatus*, are a popular research species to examine evolution and development (Davidson 2020). Despite the numerous studies, little is known about the population structure in the Gulf. Limited information indicates the highest heterogeneous composition of phenotypic traits is in the Florida Keys. Also, research indicates there are two distinct clades in the Gulf; one clade is composed entirely of Florida Keys urchins, and a second clade is composed of the Gulf, Florida Keys, and eastern Atlantic urchins. The first clade was extremely differentiated from the second clade, suggesting a cryptic species. Within the second clade there was negligible difference, suggesting Clade 2 urchins are similar within these regions (Wise 2011).

Aquaculture

Given their rapid growth rate, high fecundity, and disease resistance, sea urchins are considered an ideal candidate species for aquaculture (Hammer 2013). Urchin enhancement culture has been ongoing in Japan for several decades, but cultivation outside of Japan has only been recent (Hammer 2013). To produce commercially desirable gonads, culture conditions (temperature, salinity, oxygen, lighting and diet formulations) must be highly controlled (Hammer 2013).

Females can produce over 6 million eggs in a single spawning period. Harvestable size can be achieved in one year (Hammer 2013).

APPENDIX E: Possible Mitigation Measures for Offshore Aquaculture Operations

While this PEIS analyzes the impacts of siting aquaculture facilities in AOAs, it does not propose any avoidance, minimization, mitigation, and monitoring measures, however, possible mitigation that could be considered for aquaculture facility development are discussed below. Additional measures, not detailed here, could include measures to mitigate effects to other resources explored in the DPEIS, particularly socioeconomic and cultural and historical resources, environmental justice, and climate change. Provided below are examples for certain stressors and resources.

Compliance with any and all consultation requirements in accordance with ESA Section 7, MBTA, FWCA, and MMPA may be required to minimize adverse impacts on protected species and their habitat. Implementation of EFH conservation recommendations pursuant to Section 305(b)(2) of MSA may help avoid, minimize, mitigate, or otherwise offset adverse impacts on wild fish habitat. Compliance with USDA Animal and Plant Health Inspection Service (APHIS) rules and guidance would also be expected to minimize potential adverse impacts to wild fish stocks.

Future offshore aquaculture operations proposed and sited in an AOA would be subject to permitting and environmental review processes that are designed to minimize potential impacts to different resources. Numerous publicly available tools and reference documents exist to support various aspects of these processes, including the siting, design, operation and management of these facilities. Several of these documents also provide comprehensive overviews of the complex permitting and environmental review process for aquaculture (finfish, shellfish and seaweed) operations sited in federal waters. These references provide useful information for project proponents.

- Guide to Permitting Marine Aquaculture in the United States (NMFS 2022c)
- A Guide to the Permitting and Authorization Process for Aquaculture in U.S. Federal Waters of the Gulf of Mexico (2019)
- An Aquaculture Opportunity Atlas for the U.S. Gulf of Mexico (Riley et al. 2021)
- OceanReports Tool
- Southeast Region ESA Section 7 Mapper
- Essential Fish Habitat Mapper
- Basis-of-Design Technical Guidance for Offshore Aquaculture Installations In the Gulf of Mexico (Fredriksson and Beck-Stimpert 2019)
- National Aquaculture Health Plan and Standards, 2021-2023 (USDA 2021)
- Marine Cage Culture and the Environment: Twenty-first Century Science Informing a Sustainable Industry (Price and Morris 2013)
- Guide to Federal Aquaculture Grant and Financial Assistance Services (NMFS 2021b)

Minimizing Potential Impacts to Oceanography, Marine Protected and Managed Areas

Pre-construction sampling, ongoing monitoring within and around farm sites, and modeling as part of permitting could assist in predicting potential impacts of individual operations. This information could be combined with a gradual expansion of farm sites based on adaptive management frameworks to prevent development of high-density aquaculture that could affect hydrodynamic circulation patterns. Environmental models (e.g. deposition, water quality) can be used to forecast impacts. Ecological Carrying Capacity (ECC) models could be developed to predict upper limits of expansion in a given area. Hydrodynamic models used to examine water quality and biosecurity (reviewed in Rhodes et al. 2023a) can be used to better predict impacts. Hydrodynamic modeling could assist in predicting impacts to marine managed areas. These predictions could inform project-specific planning or potential mitigation, e.g., design modifications or monitoring protocols.

Minimizing Potential Benthic Impacts

Siting and designing facilities using baseline environmental survey results and depositional modeling could minimize potential impacts to sensitive seafloor characteristics. Mitigation measures for impacts to the seafloor may be defined at permitting by the USACE and by the EPA. Potential mitigation measures or BMPs/SOPs adopted to minimize impacts, based on similar aquaculture projects and comments received during scoping, include: visual survey of the ocean floor prior to anchor placement; visual monitoring during and after project; antifouling treatment limitations and onsite use restrictions for gear and anchors; and site-specific modeling and monitoring, e.g., depositional modeling; sediment monitoring for dissolved oxygen Carbon, Total Organic (TOC), Hydrogen sulfide, Sediment Oxygen Demand, Nitrogen, Particle size distribution, Phosphorus, Solids, and Total volatile solids at and around the site; monitoring before construction to obtain baseline information, throughout the project operation and following removal.

Minimizing Potential Water Quality Impacts

Avoiding and minimizing impacts are an important first step for reducing water quality related impacts associated with marine aquaculture. Proper site selection and implementing best management practices (BMPs) can minimize water quality impacts.

Spatial planning and siting are essential management tools for reducing potential water quality impacts associated with aquaculture (Tlusty et al. 2005; Stenton-Dozey et al. 2013; Price et al. 2015). In recent years, federal agencies have relied upon spatial planning for minimizing environmental impacts and user conflicts when siting industrial activities, such as leasing wind energy areas. This same approach is being used here. Siting is important for determining productivity, environmental impact, and interactions with the marine environment (Gentry et al. 2017). Proactive spatial planning is essential for successful and sustainable aquaculture development because biological interactions, human use, and environmental impacts (e.g., water quality) vary significantly with location (Gentry et al. 2017). Proper cage design and farm layout, and spacing can also reduce water quality related impacts.

In addition to site selection, the most effective and practicable means for maintaining and/or improving water quality is implementing BMPs, or combinations of practices that are based on research, field-testing, and expert knowledge. The magnitude and severity of water quality related impacts are associated with physical environmental parameters (e.g., mean temperature, current velocity, and depth) of the site and farm operations (e.g., stocking density, feed conversion ratio, cage design and orientation) (Stenton-Dozey et al. 2013). Understanding and applying BMPs for farm operations minimizes many potential water quality related impacts. Various documents describing BMPs, standards, and procedures for sustainable aquaculture have been developed by industry and government agencies.

As required under the Clean Water Act (CWA), the EPA establishes, monitors, and enforces the NPDES permit associated with aquaculture discharge to ensure pollutants of concern do not exceed regulatory national standards. The NPDES program has specific regulations that apply to discharges from animal aquaculture that includes monitoring for pollutants of concern: total suspended solids, settleable solids, biological wastes (metabolic waste, unconsumed feed), floating and submerged matter, five-day biochemical oxygen demand, low dissolved oxygen, nutrients (phosphorus and nitrogen), ammonia, drugs that are unconsumed or unmetabolized, and chemicals, such as antifouling agents. Establishing a routine monitoring program will help minimize potential impacts because it will help identify any water quality related issues.

The aquaculture industry continues to improve fish farming technology, management practices and performance standards, and explore management strategies focused on reducing the environmental footprint (Rust et al. 2014). Given low feed conversion ratios (less efficient at converting feed to animal biomass) are associated with poor quality feeds and increased nutrient loadings, optimizing feed formulation, quality and feed management practices are essential operational measures for reducing water quality impacts. Over the years, innovative aquaculture farmers have experimented with different feeds, feed strategies, and feed deployment methods to optimize harvest and profit while reducing waste (Shipton and Hasan 2013). Water quality impacts have been reduced at aquaculture farms by making changes in fish feed ingredients (Rust et al. 2014).

BMPs could also include emergency response plans (ERPs) to minimize water quality impacts during unexpected hazards, disasters, and emergencies. For instance, HABs can suddenly develop over the course of a few days or a week, so future aquaculture operators need to have a plan if they need to temporarily relocate their operations (i.e., cages) away from a HAB event. Another way to minimize the impacts associated with an uncontrollable event is through constant monitoring of the water quality conditions within and outside the aquaculture operations. ERPs need to be reviewed and updated, and aquaculture operators should train and practice procedures with staff so they are well prepared and ready to respond to a situation.

Minimizing Potential Air Quality Impacts

Given the relatively small volume of emissions from future aquaculture operations, it is unlikely mitigation measures for reducing impacts on air quality would be necessary. However, as required, all potential aquaculture projects would comply with the EPA's National Ambient Air Quality Standards (NAAQS) (42 U.S.C. § 7403, 78 FR 3086) and local air district emission significance thresholds regardless of their siting location. Despite the low risk of impacting air quality, random air monitoring or fixed station daily monitoring at the aquaculture facility could be implemented to ensure the NAAQS are within limits. Other types of potential mitigation measures could be implemented should the standards be exceeded, such as modifying the feed, vessel, and engine types. Also, other potential mitigation measures could be imposed like restricting the type of operation (finfish vs bivalves or algae), structure (e.g., submerged cages and longlines), and lights (number, type, duration, and shield-use).

Authorizing future aquaculture operations may cause minimal air quality impacts associated with the feed (fine dust), combustion-related stationary or mobile emission sources (e.g., generators and support vessels), and non-combustion-related sources (e.g., leaks from tanks). It is anticipated most air emissions would occur from the diesel-fueled equipment and vessels. Overall, potential air quality impacts to human populations are expected to be negligible because the aquaculture operations would not only be limited in magnitude, but the operations would be located a significant distance from shore. Also, it is unlikely any air emissions associated with the feed or equipment would reach shore, especially since the wind velocity rarely exceeds 7.15 m/s in each AOA Alternative (Riley et al. 2021). It is doubtful air emissions from the vessel fleet (marine engines) would impact air quality in coastal counties near the AOA Alternatives because the number of vessels would be limited given the size of the proposed area (500-2000 acres). It is difficult to anticipate the size of the fleet, but in comparison, the fishing, and oil and gas fleet is significantly larger and there is no evidence to suggest these industries are degrading the air quality.

Minimizing Pathogen and Disease Impacts

Various biosecurity measures and best practices can be implemented to reduce the risk for pathogen transfer from aquacultured stocks to wild species. Proper farm siting, in an area conducive to the species-specific needs of the cultivated organism (e.g., temperature, light, water quality and flow) is critical to reduce disease. Sourcing disease-free broodstock and seed and rearing robust and healthy stocks, maintaining appropriate cultivation densities, and minimizing handling and physiological stress can all help reduce disease risk (Rhodes et al. 2023). The FAO (2020) recommends daily health checks can facilitate finding an outbreak, and although potentially costly to implement, cost-benefit analysis for biosecurity preparedness can help establish effective surveillance measures. The development of operational practices and technologies to reduce the attractiveness of aquaculture operations to wild species are continuously being developed like predator exclusion plans and devices, such as above and below water mesh or net barriers; depending on the barrier characteristics it can be coupled with frequent monitoring for wild species interactions (Rhodes et al. 2023). Visual deterrence methods can also be used for spotting wild species, such as flashing lights. Advancements in technology now allow for video surveillance to monitor culture systems for excess feeding mortalities of cultured stock, which could be coupled with artificial intelligence (AI). Hydrodynamic-biological coupled dispersion models now provide a better understanding of pathogen transfer dynamics and can inform risk management strategies and farm siting (Taranger et al. 2014; Rhodes et al. 2023).

Biofouling (the accumulation of microorganisms and macroorganisms on surfaces) is a common issue for all types of aquaculture operations that can contribute to stress and disease from reduced water flow, growth, and survival; biofouling may harbor pathogens (Rhodes et al. 2023). Desiccation or periodic air-drying of aquaculture infrastructure is a common practice employed by aquaculture producers to manage biofouling. This practice is especially common among oyster farms.

Cultivated seaweed/macroalgae is susceptible to vibrio pathogens, including bacteria, protists, and viruses. Biosecurity measures that have proven effective in the cultivation of seaweed in Asia include using uninfected propagules, removing biofouling from seaweed and cultivation ropes, and early identification of infected stock (Cottier-Cook et al. 2022). Rhodes et al. (2023) noted that disease transmission between cultured and wild macroalgae is still poorly understood and requires additional research, but highlighted the importance of thoughtful siting and monitoring of water quality and environmental conditions, such as sufficient nutrients, adequate light, appropriate temperatures and salinities; local hydrodynamics are the main determinant in cultivated seaweed health and a major factor in disease prevention.