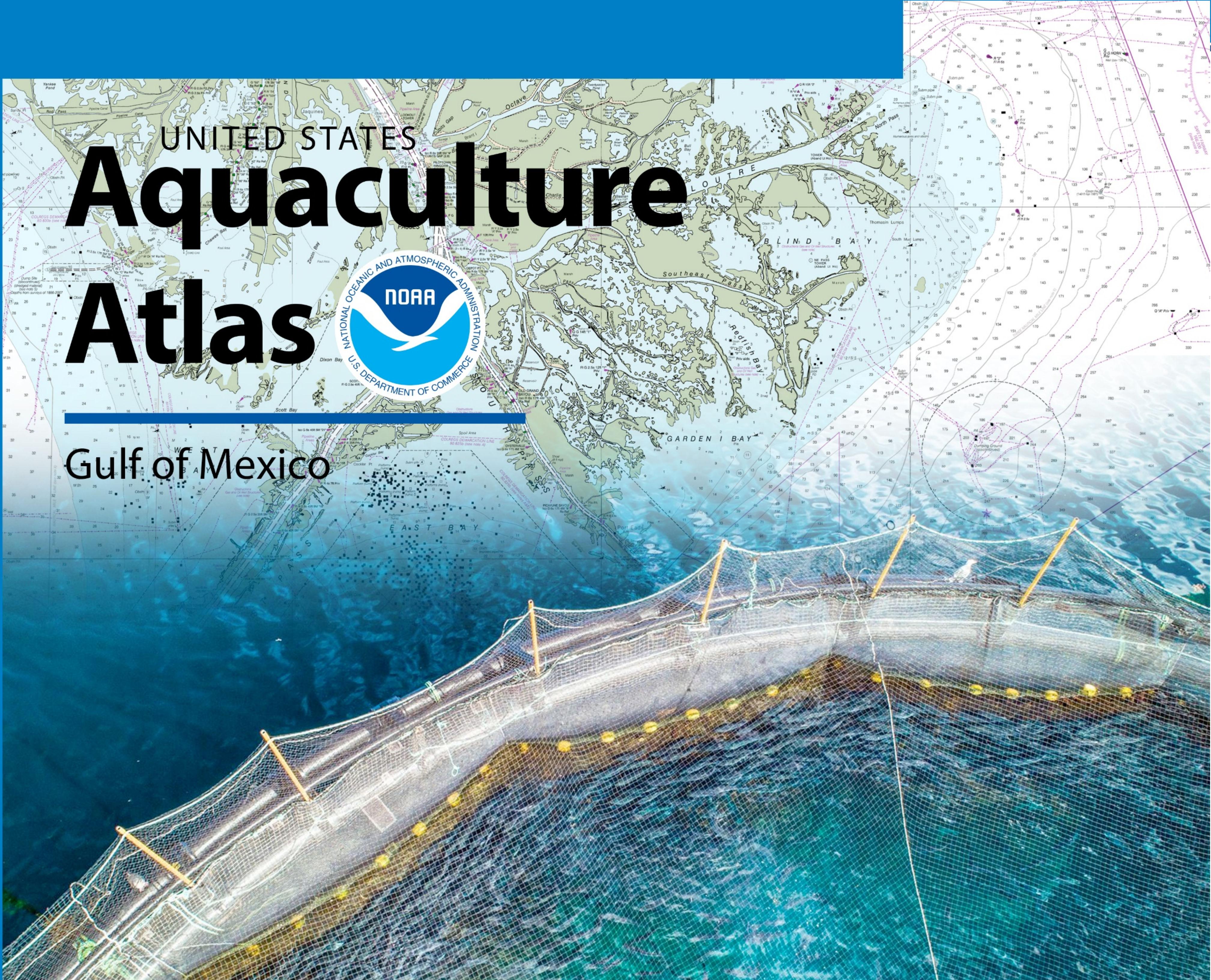
UNITED STATES

Aquaculture Atlas

Gulf of Mexico



An Aquaculture Opportunity Area Atlas for the U.S. Gulf of Mexico

Kenneth L Riley,[1] Lisa C Wickliffe,[2] Jonathan A Jossart,[2] Jonathan K MacKay,[2] Alyssa L Randall,[2] Gretchen E Bath,[2] Meghan B Balling,[2] Brandon M Jensen,[2] and James A Morris, Jr[1]

[1] Marine Spatial Ecology Division, National Centers for Coastal Ocean Science, National Ocean Service, NOAA, 101 Pivers Island Rd., Beaufort, North Carolina 28516

[2] CSS, Inc. under contract to the National Centers for Coastal Ocean Science, National Ocean Service, NOAA, 101 Pivers Island Rd., Beaufort, North Carolina 28516

For further information, direct inquiries to:

Kenneth L Riley, PhD
National Centers for Coastal Ocean Science, National Ocean Service
National Oceanic and Atmospheric Administration,
101 Pivers Island Rd, Beaufort, NC 28516
Ken.Riley@noaa.gov
or visit: http://coastalscience.noaa.gov/

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About this Document

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in the Earth's environment and to conserve and manage coastal and oceanic marine resources and habitats to help meet our Nation's economic, social, and environmental need. As a component of NOAA, the National Ocean Service (NOS) provides data, tools, and services that support coastal economies and their contribution to the national economy. The NOS is dedicated to advancing safe and efficient transportation and commerce, preparedness and risk reduction, stewardship, recreation, and tourism.

The National Centers for Coastal Ocean Science (NCCOS) is located within the NOS and works to help NOAA meet its coastal stewardship and management responsibilities. The NOAA Technical Memorandum NOS series works to achieve timely dissemination of scientific and technical information that is of high quality. The contents are of broad scope, including technical workshop proceedings, large data compilations, status reports and reviews, lengthy scientific or statistical monographs, and more. NOAA Technical Memoranda published by the NCCOS are subjected to extensive review and editing, and reflect sound professional work.

This Atlas includes technical information that may be used to assist agency decision makers in identifying areas that may be suitable for locating Aquaculture Opportunity Areas (AOAs) as mandated by Executive Order 13921 (E.O.), Promoting American Seafood Competitiveness and Economic Growth (May 7, 2020). The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors, and do not necessarily reflect the views of NOAA or the Department of Commerce. It does not reflect any agency decision on the location of an AOA or foreclose the agency's ability to evaluate alternate locations. The information within this Atlas will be used as one source of information to assist the agency in identifying AOAs. The decision to identify an AOA will only be made after completion of the National Environmental Policy Act (NEPA) process and consideration of the information presented in a Programmatic Environmental Impact Statement (PEIS), as required by the E.O. Each PEIS will assess the environmental impacts of siting aquaculture facilities in different potential AOA locations, as informed by this Atlas and other relevant sources of information. The PEIS will, therefore, evaluate alternatives, and provide robust environmental information to support agency decision making to identify a location as an AOA. The PEIS will be developed with multiple opportunities for public comment and in coordination with interested parties, organizations, and agencies, including federal, state, and local agencies, and tribal governments. This Atlas was developed for the specific purpose of preliminarily identifying locations that might be suitable for locating AOAs and includes limitations specific to that purpose. Caution should be exercised when using the Atlas for other purposes.

This Atlas was developed simultaneously with the Morris et al. (2021) Atlas for the Southern California Bight. As such, both Atlases share common authorship, methodologies, and text. Some sections are intentionally identical given the relevance to both regions.

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Executive Summary

Aquaculture has been among the fastest growing global food production sectors for decades. Most recently, growth across the world's aquaculture industries has been dominated by land-based freshwater systems outcompeting nearshore and offshore development. Technological innovations in the aquaculture field have made it possible to culture protein-rich, nutritious seafood in the coastal and offshore environments. The increasing demand for American grown seafood and improved technology to farm in open ocean sites, provides space for aquaculture expansion, increased protein production, reduced social conflict, and lower exposure to land-based sources of pollution. Consumer pressure on the industry to adopt sustainability metrics has not only improved technology, but also governance, management, and responsible siting using innovative spatial modeling. Aquaculture siting analysis requires Geographic Information Systems (GIS) to integrate pertinent spatial data, perform analyses, and generate map-based products to inform policy and permitting decisions regarding where and when aquaculture operations may be located within a given Area of Interest (AOI). Further, an ecosystem approach to aquaculture requires the application of marine spatial planning techniques to ensure equitable shared use of resources and environmental considerations are addressed at the onset.

Presidential Executive Order 13921, Promoting American Seafood Competitiveness and Economic Growth (May 7, 2020), called for the expansion of sustainable seafood production in the United States (U.S.) to ensure food security; provide environmentally safe and sustainable seafood; support American workers; establish coordinated, predictable, and transparent federal actions; and remove unnecessary regulatory burdens. The directive requires the Secretary of Commerce, in consultation with relevant federal agencies, to identify Aquaculture Opportunity Areas (AOA) suitable for commercial offshore aquaculture development. AOAs are identified based on the best available science and through public engagement, to facilitate aquaculture production; support environmental, economic, and social sustainability; and minimize unnecessary resource use conflicts.

To support the Executive Order requirement to identify AOAs, NOAA National Centers for Coastal Ocean Science (NCCOS) collaborated with NOAA National Marine Fisheries Service (NMFS) to initiate a marine spatial planning study to identify potential AOA options in the federal waters of the U.S. Gulf of Mexico. Areas of Interest were identified using a series of public engagement approaches including a Request for Information (RFI) published in the Federal Register (85 FR 67519; October 23, 2020) and one-on-one meetings with stakeholders. These AOIs were delineated based on bathymetric data for depths ranging between 50 m (164 ft) and 150 m (492 ft), political boundaries associated with offshore policies and regulation of submerged lands, outer continental shelf boundary, state and federal water demarcations, and marine protected areas. Due to the spatial scope and large geographical

extent of ecosystems within the preliminary AOI, biogeographical breaks were included using the marine ecoregion approach. Once the biogeographical breaks were applied, four distinct study areas were identified: West, Central, East, and Southeast. Geospatial analysis for identification of AOA options was based on a categorical framework to ensure relevant, comprehensive data acquisition and characterization for spatial suitability modeling. An authoritative spatial data inventory was developed that included data layers relevant to administrative boundaries, national security (i.e., military), navigation and transportation, energy and industry infrastructure, commercial and recreational fishing, natural and cultural resources, and oceanography. With over 200 data layers included in this analysis, the maps, models, and descriptions provide the most comprehensive marine spatial modeling in the U.S. Gulf of Mexico to date.

This spatial modeling approach was specific to the planning goal of identifying discrete areas ranging from 500 to 2,000 ac (202 - 809 ha) in the U.S. Gulf of Mexico that met the industry and engineering requirements of depth and distance from shore and are the most suitable for all types of aquaculture development including the cultivation of finfish, macroalgae, shellfish, or a combination of species. The nine AOA options identified (Figure 3.30 reprinted from the Results below) were selected from 29,839 possibilities of the highest scoring ocean spaces from the West, Central, and East study areas. Spatial modeling was performed at 10-ac (4.05-ha) grid cell resolution providing high contrast of suitability. Modeling results identified three AOA options from each study area, with the exception of the Southeast study area. Major constraints in the Southeast study area included interactions with military activities, a national marine sanctuary, and sensitive biological resources (e.g., corals, submerged aquatic vegetation). A combination of constraints analysis and consultation with the Department of Defense (DOD) removed 100% of the Southeast study area. Any aquaculture development within this region will have to contend with these constraints, which may continue to affect siting and permitting efficiency.

As the U.S. embarks on the identification of AOAs, offshore siting decisions must be based on rigorous MSP science to drive an informed, forward-looking, and sustainable industry to maximize production efficiency and limit adverse interactions with other industries or natural resources. The planning and siting of AOAs is the first ever application of MSP in offshore U.S. waters for the development of offshore aquaculture at this scale. The results of this analysis provide compelling evidence for the opportunities as well as challenges of siting offshore aquaculture in the coastal ocean within reasonable range of the waterfront. Further, this analysis demonstrates the inherent value of advanced regional-scale planning before permitting actions begin. Advancements in marine planning for aquaculture, prior to embarking on permitting, can support effective permitting processes, avoid space-use conflicts, address public concerns, and support business planning practices. Our methods and models could significantly improve the next generation of marine spatial planning contributing support far beyond aquaculture development by unleashing the power of big data and spatial analytics for shipping and navigation, national security and military strategy, offshore energy exploration, identification of marine protected areas, and burgeoning sectors of the ocean economy.

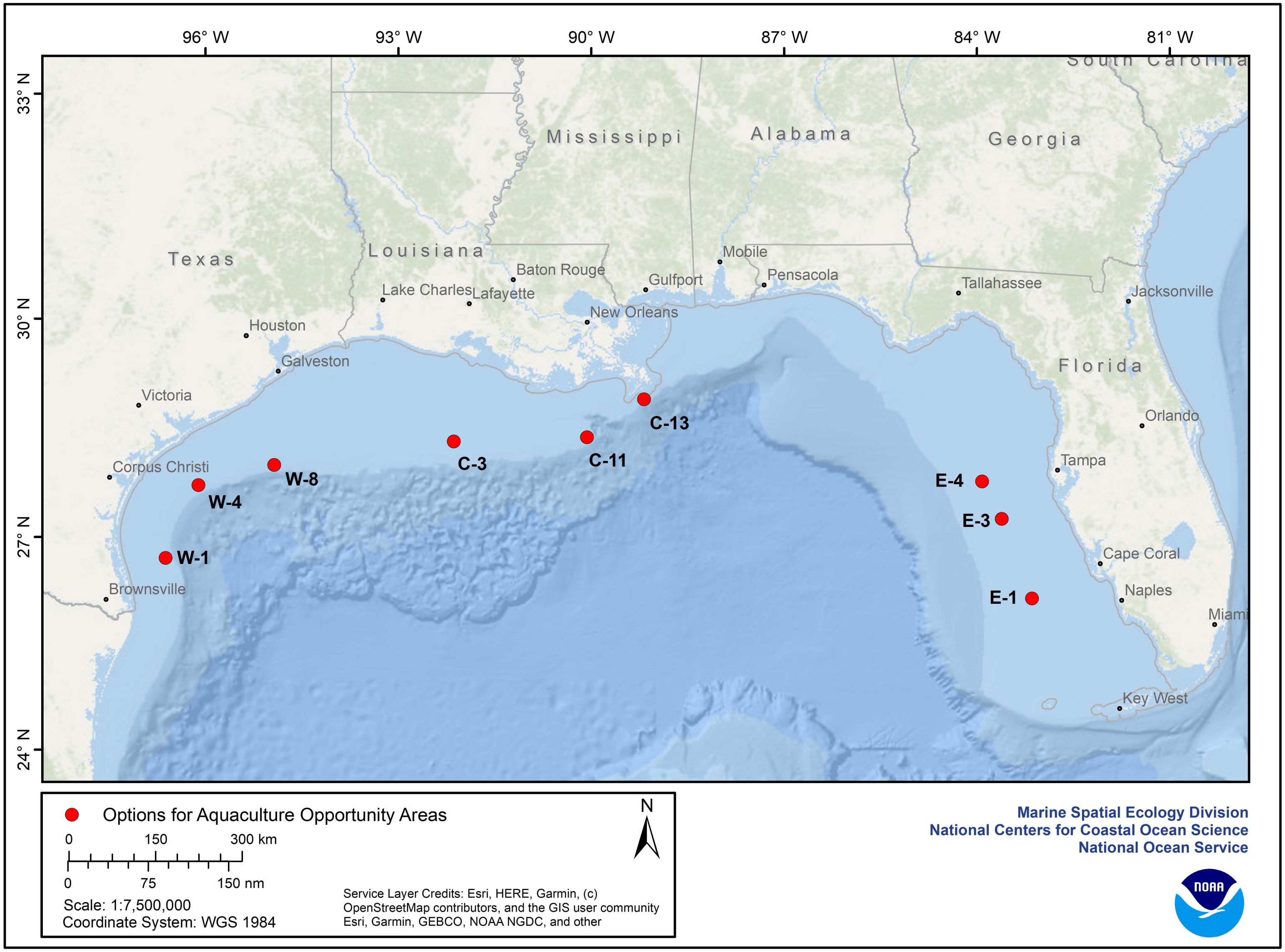

Figure 3.30. (reprinted from Results) Distribution of options for Aquaculture Opportunity Areas in the U.S. federal waters of the Gulf of Mexico. The red circles represent the options, but do not reflect the size of the options.

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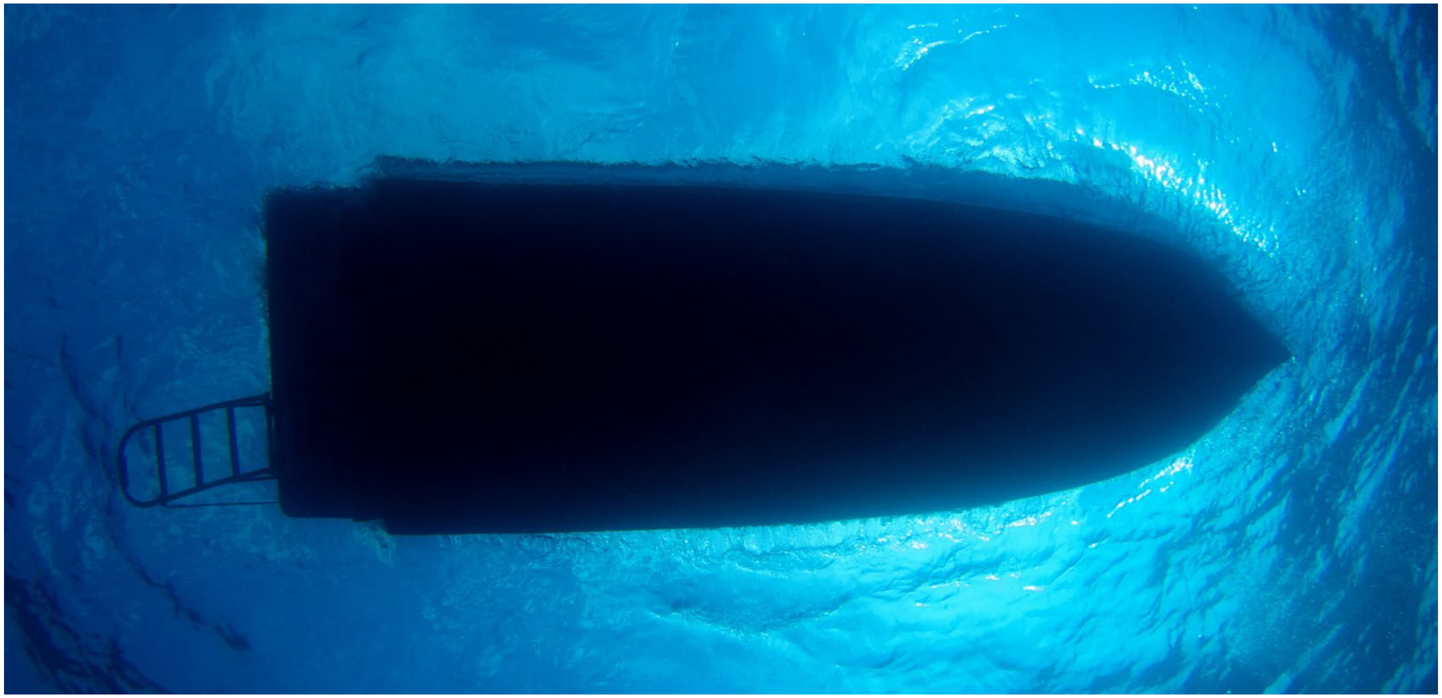

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Acronyms and Abbreviations

ac	acre
AIS	Automated Identification System
AOA	Aquaculture Opportunity Area
AOI	Area of Interest
ARPA-E	Advanced Research Projects Agency-Energy
ATCAA	Air Traffic Control Assigned Airspace
AWOIS	Automated Wreck and Obstruction Information System
BIA	Biologically Important Area
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
C	Central
Cs	Current Speed
CFR	Code of Federal Regulations
Chl-*a*	chlorophyll-*a*
COLREGs	Convention on International Regulations for Preventing Collisions at Sea
COVID-19	Coronavirus Disease 2019
CRM	Coastal Relief Model
CTD	Conductivity, Temperature, and Depth
CUI	Controlled Unclassified Information
CUDEM	Continuously Updated Digital Elevation Model
CWA	Critical Wildlife Area
CWN	Commercial Waterway Network
DCNR	Department of Conservation and Natural Resources
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DPS	Distinct Population Segment
DSCRTP	Deep-Sea Coral Research and Technology Program
E	East
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EGTTR	Eglin Gulf Test and Training Range
EIA	Energy Information Administration
ELB	Electronic Logbook
ENC	Electronic Navigational Chart
E.O.	Executive Order
ESA	Endangered Species Act
EWTA	Eglin Water Test Area
FAA	Federal Aviation Administration
FACSFAC	Fleet Area Control and Surveillance Facility
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FDEP	Florida Department of Environmental Protection
FMA	Federally Managed Area
FMP	Fishery Management Plan
FR	Federal Register

ft	feet
FUDS	Formerly Used Defense Sites
FWC	Florida Fish and Wildlife Conservation Commission
FWRI	Fish and Wildlife Research Institute
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographic Information System
GOM	Gulf of Mexico
ha	hectare
HAB	harmful algal bloom
HABSOS	Harmful Algal Blooms Observing System
HAPC	Habitat Areas of Particular Concern
HMS	Highly Migratory Species
H_s	Significant Wave Height
HUA	High Use Area
IFQ	Individual Fishing Quota
IUCN	International Union for Conservation of Nature
Kd	diffuse light attenuation coefficient
km	kilometer
kt	knots
L	liter
DWF	Louisiana Department of Wildlife and Fisheries
LISA	Local Index of Spatial Association
m	meter
mg/m^3	milligrams per meter cubed
MAIASC	Military Aviation and Installation Assurance Siting Clearinghouse (DOD Siting Clearinghouse)
µmol/L	micromoles per liter
MC	MarineCadastre (https://marinecadastre.gov/)
MCDA	Multi-Criteria Decision Analysis
MDMR	Mississippi Department of Marine Resources
mi	statute mile
MMPA	Marine Mammal Protection Act
MOA	Military Operating Area
MPA	Marine Protected Area
MSP	Marine Spatial Plan/Planning
MSU	Mississippi State University
MT	metric ton
MTR	Military Training Routes
NAA	National Aquaculture Act
NASA	National Aeronautics and Space Administration
NBDC	National Data Buoy Center
NCCOS	National Centers for Coastal Ocean Science
NCEI	National Centers for Environmental Information
NEPA	National Environmental Policy Act
NERRS	National Estuarine Research Reserve System
NCOM	American Seas Navy Coastal Ocean Model
NMFS	National Marine Fisheries Service
nm	nanometer (Kd light attenuation)
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration

N	North
NOS	National Ocean Service
NPDES	National Pollutant Discharge Elimination System
NWGISDC	National Waterway GIS Design Committee
NWN	Navigable Waterway Network
NWS	National Weather Service
OATP	Offshore Aquaculture Technology Platforms
OBIS	Ocean Biodiversity Information System
OCM	Office for Coastal Management
OCS	Outer Continental Shelf
ONMS	Office of National Marine Sanctuaries
PAR	Photosynthetically Active Radiation
PEIS	Programmatic Environmental Impact Statement
PRD	Protected Resources Division
PSU	Practical Salinity Units
RFI	Request for Information
ROSSI	Regional Offshore Sand Source Inventory
RULET	Remediation of Underwater Legacy Environmental Threats
S	South
s	second
SAFMC	South Atlantic Fishery Management Council
SDM	Species Distribution Model
SE	Southeast
SEFSC	Southeast Fisheries Science Center
SERO	Southeast Regional Office
SRHS	Southeast Region Headboat Survey
SUA	Special Use Airspace
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TPWD	Texas Parks and Wildlife Department
TWFD	Texas Wildlife and Fisheries Department
UN	United Nations
U.S.	United States of America
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USM	University of Southern Mississippi
UXO	Unexploded Ordnance
VHF	Very High Frequency
VIIRS	Visible Infrared Imaging Radiometer
W	West
WGS	World Geodetic System

Species List

Common name	*Scientific name*
albacore	*Thunnus alalunga*
almaco jack	*Seriola rivoliana*
Atlantic angel shark	*Squatina dumeril*
Atlantic seabob	*Xiphopenaeus kroyeri*
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Atlantic spotted dolphin	*Stenella frontalis*
bigeye thresher	*Alopias superciliosus*
bigeye tuna	*Thunnus obesus*
blacknose shark	*Carcharhinus acronotus*
blacktip shark	*Carcharhinus limbatus*
Blainville's beaked whale	*Mesoplodon densirostris*
blue marlin	*Makaira nigricans*
bluefin tuna	*Thunnus thynnus*
bonnethead	*Sphyrna tiburo*

Common name	*Scientific name*
broad-leaf gulfweed	*Sargassum fluitans*
brown rock shrimp	*Sicyonia brevirostris*
brown shrimp	*Farfantepenaeus aztecus*
bull shark	*Carcharhinus leucas*
Caribbean spiny lobster	*Panulirus argus*
clymene dolphin	*Stenella clymene*
cobia	*Rachycentron canadium*
common bottlenose dolphin	*Tursiops truncatus*
Cuvier's beaked whale	*Ziphius cavirostris*
dusky shark	*Carcharhinus obscurus*
dwarf sperm whale	*Kogia sima*
elkhorn coral	*Acropora palmata*
false killer whale	*Pseudorca crassidens*
finetooth shark	*Carcharhinus isodon*

Common name	Scientific name
fin whale	*Balaenoptera physalus*
Florida stone crab	*Menippe mercenaria*
Fraser's dolphin	*Lagenodelphis hosei*
Gervais' beaked whale	*Mesoplodon europaeus*
giant manta	*Mobula birostris*
greater amberjack	*Seriola dumerili*
great hammerhead	*Sphyrna mokarran*
green turtle	*Chelonia mydas*
Gulf smoothhound	*Mustelus sinusmexicanus*
Gulf sturgeon	*Acipenser oxyrhynchus desotoi*
hawksbill turtle	*Eretmochelys imbricata*
hogfish	*Lachnolaimus maximus*
Kemp's ridley turtle	*Lepidochelys kempii*
killer whale	*Orcinus orca*
king mackerel	*Scomberomorus cavalla*
pygmy sperm whales	*Kogia breviceps*
leatherback turtle	*Dermochelys coriacea*
lemon shark	*Negaprion brevirostris*
loggerhead turtle	*Caretta caretta*
longbill spearfish	*Tetrapturus pfluegeri*
longfin mako	*Isurus paucus*
melon-headed whale	*Peponocephala electra*
narrowleaf	*Sargassum natans*
Nassau grouper	*Epinephelus striatus*
night shark	*Carcharhinus signatus*
nurse shark	*Ginglymostoma cirratum*
oceanic whitetip shark	*Carcharhinus longimanus*
pantropical spotted dolphin	*Stenella attenuata*
pink shrimp	*Farfantepenaeus duorarum*
pygmy killer whale	*Feresa attenuata*
pygmy sperm whale	*Kogia breviceps*
red drum	*Sciaenops ocellatus*

Common name	Scientific name
red grouper	*Epinephelus morio*
red snapper	*Lutjanus campechanus*
reef shark	*Carcharhinus perezii*
Rice’s whale	*Balaenoptera ricei*
Risso's dolphin	*Grampus griseus*
rough-toothed dolphin	*Steno bredanensis*
royal red shrimp	*Pleoticus robustus*
sailfish	*Istiophorus platypterus*
sandbar shark	*Carcharhinus plumbeus*
scalloped hammerhead	*Sphyrna lewini*
shortfin mako	*Isurus oxyrinchus*
short-finned pilot whale	*Globicephala macrohynchus*
silky shark	*Carcharhinus falciformis*
skipjack tuna	*Katsuwonus pelamis*
smalltooth sawfish	*Pristis pectinata*
Sowerby's beaked whale	*Mesoplodon bidens*
Spanish mackerel	*Scomberomorus maculatus*
sperm whale	*Physeter macrocephalus*
spinner dolphin	*Stenella longirostris*
spinner shark	*Carcharhinus brevipinna*
staghorn coral	*Acropora cervicornis*
striped bass	*Morone saxatilis*
striped dolphin	*Stenella longirostris*
swordfish	*Xiphias gladius*
tiger shark	*Galeocerdo cuvier*
whale shark	*Rhincodon typus*
white marlin	*Kajikia albida*
white shrimp	*Litopenaeus setiferus*
yellowedge grouper	*Hyporthodus flavolimbatus*
yellowfin tuna	*Thunnus albacares*

Unit Conversions

Common units of measure utilized within this publication. Units are listed as imperial units with the metric equivalent. Units are reported in the format used in regulation or policy when possible.

Length	
Imperial	*Metric*
1.00 inch	2.54 centimeters
1.00 foot	30.48 centimeters
1.00 statute mile	1.61 kilometers
1.00 nautical mile	1.85 kilometers
Volume	
1.00 gallon	3.78 liters
1.00 cubic inch	16.39 cubic centimeters
1.00 cubic foot	0.03 cubic meters
1.00 barrel	158.99 liters
Temperature	
32° Fahrenheit	0° Celsius

Area	
Imperial	*Metric*
1.00 square foot	0.09 square meters
1.00 square statute mile	2.59 square kilometers
1.00 square nautical mile	3.43 square kilometers
1.00 acre	0.40 hectare
Mass	
1.00 pound	0.45 kilograms
2,205.00 pounds	1.00 metric ton
Velocity	
1.00 knot	0.51 meters per second
1.00 mile per hour	0.45 meters per second
2.24 miles per hour	1.00 meter per second

INTRODUCTION

Background

The global human population is currently estimated at 7.9 billion people and that number is expected to steadily climb to 8.5 billion by 2030 (U.N. 2019). 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. 2017). Modern human health sciences have recognized seafood for a myriad of health benefits to sustain and optimize human well-being and nutrition (Bang and Dyerberg 1980; Kromhout et al. 1985; Mozaffarian and Rimm 2006; Costello et al. 2020). This recognition has added to the increase in demand for sustainable seafood products, making fish and shellfish the most heavily traded food commodity globally (Gephart et al. 2017; Guillen et al. 2019; Costello et al. 2020).

Already, the increasing consumer demand for seafood has contributed to an escalated rate of fisheries exploitation resulting in overharvests of many fish stocks (Godfray et al. 2010; Costello et al. 2020; Froehlich et al. 2021). Global capture fisheries production has remained relatively stable since the 1980s varying between 86 and 93 million MT harvested annually (FAO 2020). Since the 1990s, a growing demand for seafood has led to exponential growth in the aquaculture industry worldwide (Costello et al. 2020; FAO 2020). Marine aquaculture production increased by 600% from nearly 20 million MT in 1990 to just under 120 million MT at present (FAO

2020). While global aquaculture production is valued at $275 billion annually, the United States contributes a small fraction (less than 0.5%) valued at $1.3 billion (FAO 2021). Stressed ocean ecosystems and a decline in fisheries from overfishing, harmful fishing practices, ocean temperature changes, ocean acidification, land-based sources of pollution, and other threats has increased global awareness of the need to responsibly manage fisheries and aquaculture to meet the surging demand for sustainable seafood.

Global Offshore Aquaculture Development

Aquaculture has been among the fastest growing global food production sectors for decades (FAO 2020). Most recently, growth across the world's aquaculture industries has been dominated by land-based freshwater systems outcompeting nearshore and offshore development (FAO 2020; Naylor et al. 2021); however, technological innovations in the aquaculture field have made it possible to culture protein-rich, nutritious seafood in coastal and offshore environments (Froehlich et al. 2017; Kumar et al. 2018). Offshore, open ocean waters are a new frontier providing space for aquaculture expansion, increased protein production, reduced social conflict, and lower exposure to land-based sources of pollution (Helsley and Kim 2005; Halwart et al. 2007; Langan 2007; Holm et al. 2017). The water depth, currents, and ocean circulation provide optimal environmental conditions for growing diverse marine species and the potential to reduce some of the negative environmental impacts of offshore aquaculture (Pearson and Black 2001; Hargrave 2003; Langan and Horton 2003; Ostrowski and Helsley 2003; Langan 2012; Price and Morris 2013; Holm et al. 2017). Aquaculture farm design and engineering have advanced the capability to withstand dynamic offshore environments and increase production capacity (Fredriksson et al. 2003; Fredheim and Langan 2009; Goudey 2009; Lekang 2013; Holm et al. 2017). China and Norway have made significant investments and are

advancing aquaculture offshore as a means to expand protein production while reducing environmental interactions and limiting other spatial use conflicts (Kapetsky et al. 2013; Froehlich et al. 2021). As aquaculture has expanded over the last twenty years, pressure on the industry to adopt sustainability metrics has not only improved technology, but also governance, management, and responsible siting using advanced spatial tools (Naylor et al. 2021).

U.S. Aquaculture Policies

The National Aquaculture Act 1980

In 1980, Congress enacted 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 fisheries, produce renewable resources, and therefore meet future domestic food needs and contribute to the global seafood supply. Under this law, the Secretary of Agriculture was designated to lead the coordinating committee, established by Executive Order in 1978 (E.O. 12039) as the Joint Subcommittee on Aquaculture within the Office of Science and Technology Policy, charged with creating an Aquaculture Development Plan.

U.S. Department of Commerce and NOAA Aquaculture Policies

After the NAA was authorized 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). To expedite aquaculture development, two corresponding federal policies were enacted. Consistent with the NAA, the U.S. Department of Commerce (DOC) developed an Aquaculture Policy (2011)[1] to specify the goals, objectives, and priorities for all DOC Bureaus, including NOAA, in the context of the Department's overarching emphasis on jobs, the economy, innovation, and international competitiveness. 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)[2] reaffirmed aquaculture as an important component of NOAA's marine stewardship mission and strategic goals for healthy oceans and resilient coastal communities and economies. By statutory authority, NOAA National Marine Fisheries Service (NMFS) is also responsible 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 Executive Order 13921, *Promoting American Seafood Competitiveness and Economic Growth*[3] (May 7, 2020), called for the expansion of sustainable seafood production in the U.S. to

[1] https://media.fisheries.noaa.gov/2021-01/doc-aquaculture-policy-2011.pdf?null
[2] https://media.fisheries.noaa.gov/2021-01/2011-noaa-marine-aquaculture-policy.pdf?null
[3] https://www.federalregister.gov/documents/2020/05/12/2020-10315/promoting-american-seafood-competitiveness-and-economic-growth

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 Aquaculture Opportunity Areas (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 1 year of the E.O., identify at least two geographic areas containing locations suitable for commercial aquaculture.
- [Phase 2] Within 2 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 4 years, identify two additional geographic areas containing locations suitable for commercial aquaculture and complete a PEIS for each within 2 years.
- The establishment of AOAs will not occur until after the PEIS is complete.

State of U.S. Aquaculture

National Food Security

The United Nations World Food Summit of 1996[4] first defined food security as existing "when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food to meet dietary needs for a productive and healthy life." This definition has also been adopted by the USDA Economic Research Service (ERS),[5] which leads research on food security and reporting metrics across U.S. households and communities. Food scarcity can have both local and far-reaching repercussions that threaten individual health, jobs, economies, and the security of entire nations (Allison et al. 2009; Love et al. 2021; White et al.

[4] http://www.fao.org/3/w3548e/w3548e00.htm
[5] https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/definitions-of-food-security.aspx

2021). As of December 2019, before the COVID-19 pandemic,[6] USDA ERS reported that 89.5% of U.S. households were food secure; the remaining 10.5% represents 13.7 million food insecure households (Coleman-Jensen et al. 2020). Compared to the rest of the world, the U.S. maintains a high level of nutrition security (NRC 2006). However, climate change, loss of biodiversity, and the continued degradation of land, soil, and freshwater threaten the nation's food availability, access, utilization, and stability (Galanakis 2020; Laborde et al. 2020).

Food production disturbances, or shocks, temporarily limit the availability of essential nutrition, exacerbating food security issues (Godfray et al. 2010). During the height of the COVID-19 pandemic, the U.S. experienced food shocks and supply chain issues across a multitude of food systems (Galanakis 2020; Laborde et al. 2020; Love et al. 2021). Increased food resilience, defined as the "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" can buffer against future shocks (Love et al. 2021). 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).

[6] https://www.who.int/emergencies/diseases/novel-coronavirus-2019

U.S. Offshore Aquaculture Opportunity

A study by the United Nations (U.N.) Food and Agriculture Organization (FAO) identified the U.S. as having significant marine aquaculture potential (Kapetsky et al. 2013) extending into the Exclusive Economic Zone (EEZ) which covers 9 million km², 20% more than U.S. lands. Although all the space in the EEZ cannot be used for aquaculture, conservative estimates show less than 500 km² (0.01% of the EEZ) would be enough to produce up to 600,000 MT or more of additional farmed seafood per year (Nash 2004). In addition, the U.S. has vast coastlines with suitable depths, current speeds, and temperatures; available gear technology and feeds; access to ports; a stable legal and economic system; skilled labor; and substantial seafood market demand (Nash 2004; Rubino 2008; Kapetsky et al. 2013; Kite-Powell et al. 2013; Knapp and Rubino 2016; Lester et al. 2018). The U.S. EEZ also comprises polar, temperate, and tropical ecosystems providing the ability to develop aquaculture industries that are diverse in species and cultivation practices. To date, a growing U.S. marine aquaculture industry has capitalized on these advantages. In particular, the half-shell oyster market is expanding, salmon production in Washington State and Maine are at historic levels, and new permit applications and plans for farm expansion for offshore operations are proposed for Hawaii, southern California, the Gulf of Mexico, and the northeast U.S. (Knapp and Rubino 2016).

The increasing demand for domestically grown seafood and improved technology to farm in open ocean sites provide the opportunity for marine aquaculture to expand offshore in U.S. federal waters (Kapetsky et al. 2013; Kite-Powell et al. 2013; Rust et al. 2014; Costello et al. 2016; FAO 2020; Holm et al. 2017; Lester et al. 2018). The U.S. imports between 70% and 85% (by edible weight) of its seafood, resulting in a $16.9 billion trade deficit (NMFS 2021a). A significant portion of this imported seafood is farmed overseas or harvested by American fishermen, exported overseas for processing, and then imported to the U.S. (NMFS 2021a). For decades, the U.S. has relied on seafood imports, largely from aquaculture in Asia and Central and South America, to satisfy demand. Americans are the second largest consumer of the world's seafood supply, yet the U.S. only contributes to 9% of the global capture fisheries and aquaculture production combined (FAO 2020; NMFS 2021a). The U.S. aquaculture industry accounts for less than 1% of farmed seafood production globally and is ranked 17th as a minor aquaculture producer (NMFS 2021a). According to the most recent data available (2019), the U.S. marine aquaculture sector was valued at $430 million and produced nearly 44,000 MT of seafood. Approximately 59% of U.S. aquaculture production came from shellfish (oysters, clams, and mussels); the remaining 41% came from salmon (37%) and shrimp (4%) (NMFS 2021a). In the U.S., the Atlantic region represents 41%, the Gulf of Mexico 23%, and the Pacific 36% of total marine aquaculture production. In addition to shellfish and finfish, seaweed farming is the fastest growing sector in U.S. waters with dozens of farms in New England, the Pacific Northwest, and Alaska (NMFS 2021a). Domestic production of seaweeds is estimated to exceed 1,000 MT; however, 10,000 MT are imported annually for the food and colloid markets (Kim et al. 2019). While the growth in global aquaculture is leaving the U.S. behind, American companies and investors are driving technological innovation and funding growth abroad (Rubino 2008; Knapp and Rubino 2016; Lester et al. 2018).

The growth and development of the offshore aquaculture industry in the U.S. has been constrained by uncertain regulatory policies, lack of social acceptance due in part to propagation of misinformation, and concerns about harmful environmental impacts (Rubino 2008; Environmental Law Institute 2015; Knapp and Rubino 2016; Lester et al. 2018). Americans consistently debate about foreign seafood and aquaculture imports regarding food safety and traceability, environmental sustainability, and competition for resources. The growing concern about human rights within the foreign seafood trade also has consumers tending toward caution on the ethics of U.S. reliance on seafood imports (Teh et al. 2019).

Marine aquaculture has an important role in sustainable seafood production. In the U.S., it has the potential to diversify and stabilize seafood production in the face of environmental change and economic uncertainty. Growing more seafood in the U.S. — where there is a high environmental ethic, strict regulations, and health and safety standards — can ensure secure and sustainable seafood production. Farming seafood can also create jobs, reduce reliance on unsustainable imports, and improve the domestic Blue Economy. The U.S. has stewardship practices and technological expertise that have made it a trusted global leader in seafood sustainability.

History and Current Status of Offshore Aquaculture in the U.S. Gulf of Mexico

The U.S. Gulf of Mexico is one of the most economically viable and biologically productive ocean regions in the world, supporting a wide variety of industries including highly productive fisheries (NOAA 2021a). Working waterfronts supporting wild fisheries provide established infrastructure for seafood processing and distribution channels for a wide variety of species. Coastal infrastructure for shipping, port development, and energy production also provide considerable infrastructure to support offshore aquaculture development. Opportunities for open ocean aquaculture in the Gulf of Mexico have been the subject of intense discussion and research since the early 1990s and have included consideration of live rock (i.e., corals and sponges), molluscan shellfish, macroalgae (i.e., seaweed), food fish, and bait fish.

Policies and regulations to support offshore aquaculture in the Gulf of Mexico have been in development over the past twenty years. In 2003, the Gulf of Mexico Fishery Management Council (GMFMC) adopted an open ocean aquaculture policy for federal waters of the Gulf (GMFMC and NOAA 2009). The policy consisted of guidelines to encourage environmentally responsible aquaculture. The Council provided recommendations for six key areas: 1) allowable species, 2) habitat protection, 3) research, 4) location and design, 5) water quality, and 6) health management and disease control. In 2009, the GMFMC developed a Fishery Management Plan (FMP) for establishing a permit for regulating aquaculture in federal waters (GMFMC and NOAA 2009). NMFS proposed regulations in 2014 to implement the FMP as prepared by the GMFMC, which would require a NMFS Gulf Aquaculture Permit to authorize a person to deploy or operate an offshore aquaculture facility and sell allowable aquaculture species cultured at such a facility. The FMP for regulating offshore aquaculture in the Gulf of Mexico final rule was published in the Federal Register (FR) and became effective in 2016[7]. In a lawsuit and court ruling in 2018, which was upheld on appeal in 2020, a federal court sided with plaintiffs and struck down the FMP, concluding NMFS had acted outside of its statutory authority in promulgating its rule for aquaculture under the Magnuson-Stevens Fishery Conservation and Management Act (Nichols 2018).

[7] https://www.federalregister.gov/documents/2016/01/13/2016-00147/fisheries-of-the-caribbean-gulf-and-south-atlantic-aquaculture

One of the earliest forms of offshore aquaculture in the Gulf of Mexico is the culture of live rock for aquarium trade. It developed as a result of the prohibition of wild harvests of live rock in Florida state waters in 1989 and federal waters in 1997. Following the ban on wild harvest, the state and federal governments developed permitting programs that allow deposition of geologically distinct substrate placed on the seabed to attract colonizing plants and invertebrates. The rock is cultured according to NMFS permit specifications at a specific geographic location in waters off the Gulf coast of Florida. In 2020, there were 68 live rock operations permitted by NMFS in federal waters of the Gulf of Mexico.

Shellfish aquaculture has grown rapidly along the Gulf Coast, but not within the offshore environment. Shellfish such as oysters, clams, and scallops are farmed within Gulf Coast estuaries. In 2018, the Gulf states produced more shellfish by volume than any other region in the nation (NMFS 2021a). Louisiana leads the region with over 141,000 ac in farm production (USDA 2019). The Gulf Coast boasts an extensive network of Sea Grant extension professionals that has grown to become a powerful resource for the shellfish aquaculture industry. These professionals are well positioned with an unprecedented reach to help the offshore aquaculture industry achieve success by providing access to cutting-edge research and translating science to those who can put knowledge into practice. Macroalgae farming in the U.S. has taken off in recent years, with rapid growth in offshore waters in New England, the Pacific Northwest, and Alaska. A number of demonstration projects are in development for the Gulf of Mexico including a pilot project off Florida and plans for an integrated multi-trophic research project in state waters of the Gulf of Mexico. 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 use in cosmetics, animal feed, and fertilizer, macroalgae production for biofuels is a topic of significant 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 of Mexico.[8]

Several commercial finfish projects and federally sponsored demonstration projects have occurred in state and federal waters of the Gulf of Mexico (Stickney 1998). SeaFish Mariculture was the first applicant to pursue development of an experimental offshore aquaculture operation in the Gulf of Mexico in association with oil and gas platforms operated by Shell Offshore Services, Inc. and located approximately 89 km (48 nm) south-southwest of Freeport,

[8] U.S. Department of Energy, MARINER ARPA-E Program (https://arpa-e.energy.gov/technologies/programs/mariner)

TX (GMFMC and NOAA 2009). For this project, three net pens were permitted by the U.S. Army Corps of Engineers (USACE) Galveston District in 1997. NMFS issued 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 of Mexico, 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 was fairly streamlined given the location in association with an existing offshore platform, and the operation did not significantly interfere with navigation, fishing, or other uses. 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.

Waldemar S. Nelson and Co., Inc. was contracted by NOAA in 1997 to lead a planning effort to assess the feasibility of establishing offshore aquaculture operations in the northern Gulf of Mexico (Waldemar 1998). The study included extensive literature reviews and state-of-science assessment on site selection, aquaculture systems, engineering, candidate species, regulatory requirements, economic analysis, and market analysis. Experts from across the region contributed to planning for a scenario where an offshore industry could develop with no significant federal or state subsidies. The study concluded that offshore aquaculture holds great attention and potential for public and private entities, but its feasibility remains untested. A major hindrance to such development is the lack of easily accessible information about the environment in the Gulf of Mexico 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.

In 1998, the Gulf Marine Institute of Technology, in partnership with BioMarine Technologies Inc., received approval from Texas state agencies to grow finfish in net pens alongside operational oil and gas platforms using a 2-km^2 (500-ac) site in state waters, 16 km (10 mi) southwest of Matagorda. The applicants secured permits from the USACE and EPA in Texas, but moved their operations with plans to grow greater amberjack and cobia (*Rachycentron canadium*) in federal waters located off Florida. The applicants proposed a 0.1-km^2 (27.5-ac) operation that would include a 1500-m^2 (16,146-ft^2) work platform, forty-eight 30-m (100-ft) diameter net pens, and eight 15-m (50-ft) diameter net pens for nursery production. The project aimed to produce 6.4 million pounds per year once in full operation. Permits were issued in 2003 and renewed in 2008 and 2013;[9] however, the applicants never conducted the required environmental surveys or initiated construction of the farm. In 2018, the USACE and EPA denied renewal citing lack of information for permit approval.

The NOAA Office of Oceanic and Atmospheric Research, National Sea Grant College program and NMFS Office of Aquaculture in partnership with the Gulf States Marine Fisheries Commission (GSMFC) have supported several research and demonstration projects for offshore aquaculture in the Gulf of Mexico. In 2000, Sea Grant funded a demonstration project in association with the University of Southern Mississippi (USM) to evaluate use of

[9] Federal NPDES Permit No. AL0067237; USACE Permit No. SAM-2002-02232-MBM

emerging technology with submersible net pens to assess fish production and survivability of net pens in tropical storm and hurricane conditions. The project secured permitting from the USACE to deploy a net pen approximately 35 km (22 mi) south of Pascagoula, MS (Bridger and Costa-Pierce 2002). The work 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, Waldemar S. Nelson and Co., Inc. was contracted by NOAA through the GSMFC and USM to participate in a planning effort for a demonstration-scale aquaculture project in the Gulf of Mexico. 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 m^3. 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.

Currently, there are several aquaculture projects in development across the Gulf of Mexico. NOAA Office of Oceanic and Atmospheric Research, National Sea Grant College program and the GSMFC, through competitive grants funded by NMFS Office of Aquaculture, are supporting research and demonstration projects leading to commercial development off Florida and Texas. Ocean Era, Inc. was recently permitted[10] to develop a temporary, small-scale demonstration net pen operation to produce almaco jack (*Seriola rivoliana*) at a fixed mooring located on the West Florida Shelf, approximately 73 km (39 nm) offshore of Sarasota, FL. Manna Fish Farms, Inc. is currently conducting environmental surveys for a large-scale commercial operation to produce red drum, striped bass (*Morone saxatilis*) and other species at a 105-ac site located approximately 30 km (16 nm) offshore of Pensacola, FL (Lucas et al. 2021). The Gulf Offshore Research Institute, a not-for-profit corporation, recently completed a feasibility assessment of two offshore platforms that could potentially support aquaculture development co-sited with energy production (Satterlee et al. 2021). The platforms are located approximately 56 km (30 nm) northeast of Port Mansfield, TX. Study results indicate the economics of an offshore platform-based aquaculture system could be cost competitive under a range of assumptions. Geospatial

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

analysis and site characterization revealed favorable conditions for an offshore aquaculture farm, and the study did not identify conflicts that would preclude farm development.

Marine Aquaculture Planning Process

Marine Spatial Planning

Marine spatial planning (MSP) arose out of the necessity to develop planning resources to better understand and spatially manage space in the world's oceans (Douvere 2008). At a basic level, the MSP process is applied to minimize conflicts in ocean space as well as mitigate interactions with other users and minimize adverse interactions with the environment (Ehler 2018). MSP has been applied in an effort to manage a wide range of renewable and non-renewable ocean resources (Ehler and Douvere 2009). In U.S. waters, MSP has been applied in the planning of marine protected areas (MPA), navigation and transportation management, and in energy development. For example, Wind Energy Areas (WEA) and oil and gas planning areas have been established by the Bureau of Ocean Energy Management (BOEM) to plan and define potential lease sales on the Outer Continental Shelf (Kaiser et al. 2011; DOE 2015). Another example, the recent proposal known as the 30 by 30 Initiative, challenges Americans to protect 30% of U.S. land and water resources by 2030 (DOI 2021). This Initiative will require a broad application of spatial planning across our terrestrial, aquatic, and marine resources for improved conservation and management actions.

Aquaculture Planning

Planning and siting for marine aquaculture operations requires thorough synthesis and spatial analyses of critical environmental data and ocean space use conflicts (Kapetsky et al. 2013). Aquaculture siting analysis requires GIS to integrate pertinent spatial data, perform analyses, and generate map-based products to inform policy and permitting decisions regarding where and when aquaculture operations may be located within a given Area of Interest (AOI). The application of MSP is central to an ecosystem approach to aquaculture (EAA) to ensure accountability and equitable shared use of resources (Stelzenmüller et al. 2017; Gimpel et al. 2018). EAA is a strategy for integration of aquaculture activities within the wider ecosystem that promotes sustainable development, equity, and resilience of interlinked social-ecological systems (Brugere et al. 2019). An investment in long-term sustainability requires adequate and consistent environmental conditions and compatible interactions with other natural resources and users over both space and time. Spatiotemporal planning for different types of aquaculture under various scenarios must also balance tradeoffs among environmental, social, economic, cultural, and management considerations (Couture et al. 2021). Incorporating spatial and temporal planning strategies into the aquaculture planning process allows initial compatibility to be assessed, while also increasing efficiency of meaningful communications within and among permitting agencies, and potentially with those seeking permits.

Regardless of the complexity or scale of the aquaculture objective, sustainable planning for offshore aquaculture requires spatially explicit information about suitable areas and data from overlapping human activities to best characterize the dynamics of the marine environment (Kelly et al. 2014; Wever et al. 2015). Spatial planning processes often follow a standard workflow by 1) identification of the planning objective, 2) inventory of data, 3) geospatial analysis of data, 4) interpretation of results, and 5) delivery of map products and reports to coastal managers and other end users. This guiding framework informs site-specific aquaculture infrastructure management challenges while strengthening community resiliency and works to site different types of aquaculture in optimal conditions. Marine spatial planning incorporates and thereby mitigates many potential deleterious ecosystem-level impacts of aquaculture. Spatial data are utilized to represent critical or potential environmental and ocean space use conflicts that could constrain, or conditionally constrain, the siting of aquaculture in federal waters. Using a multi-criteria decision approach (MCDA) allows for evaluation of numerous spatial data types for a location and provides a relative comparison of how suitable the areas in a location are for marine aquaculture (Longdill et al. 2008). Additionally, protected species, habitat descriptions, various fishing activities and management areas, and oceanographic and biophysical characteristics are described and identified in the aquaculture site suitability analysis.

AOA Identification Process

Executive Order 13921 called for the identification of AOAs (Figure 1.1) which are discrete geographic areas suitable for a variety of offshore aquaculture types including finfish, shellfish, and seaweeds as well as integrated multi-trophic aquaculture. Identifying these opportunity areas will require the best available science to facilitate aquaculture production while supporting environmental, economic, and social sustainability. As the U.S. embarks on the identification of AOAs, MSP science will provide 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. 2018). The planning and siting of AOAs is the first ever application of MSP in offshore U.S. waters for the development of aquaculture. A well-developed, comprehensive spatial 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). Additionally, and importantly, proper site selection informed through MSP is essential to minimizing adverse environmental, social, and existing user interactions (Kapetsky et al. 2013; Froehlich et al. 2021). A marine spatial planning study was initiated by NOAA's National Centers for Coastal Ocean Science (NCCOS) in collaboration with NOAA NMFS to identify potential AOA options distributed across the Gulf of Mexico that could support offshore aquaculture development in the region. NCCOS used the best available data to account for key environmental, economic, social, and cultural considerations to identify areas that may support sustainable offshore aquaculture development. Input from other federal agencies, Fishery Management Councils, Marine Fisheries Commissions, states and tribes, and the public was obtained to inform the process. Locations that show promise and have potential to be suitable for developing offshore AOAs in the Gulf of Mexico are presented in this Atlas, which documents the science and results of this effort. The potential AOA options resulting from this analysis will be used by NMFS to inform the development of preliminary alternatives for consideration in a PEIS.

Through spatial modeling, NOAA expects to identify areas that may support approximately three to five commercial-scale aquaculture operations to be considered in the AOA identification process. Areas identified as AOAs will have characteristics that are expected to be able to support multiple aquaculture farm sites of varying types, but all portions of the AOA may not be appropriate for every type of aquaculture. Individual locations for farm operations and types would require further precision siting within the AOA. The size of AOAs may differ based on oceanographic conditions, other uses (e.g., fishing), and potential impacts to protected species, essential fish habitat (EFH), and MPAs, among other considerations. The final proposed aquaculture size and configuration of aquaculture operations as well as species cultivated would require extensive scoping and project planning, permitting, and environmental review including all associated consultations.

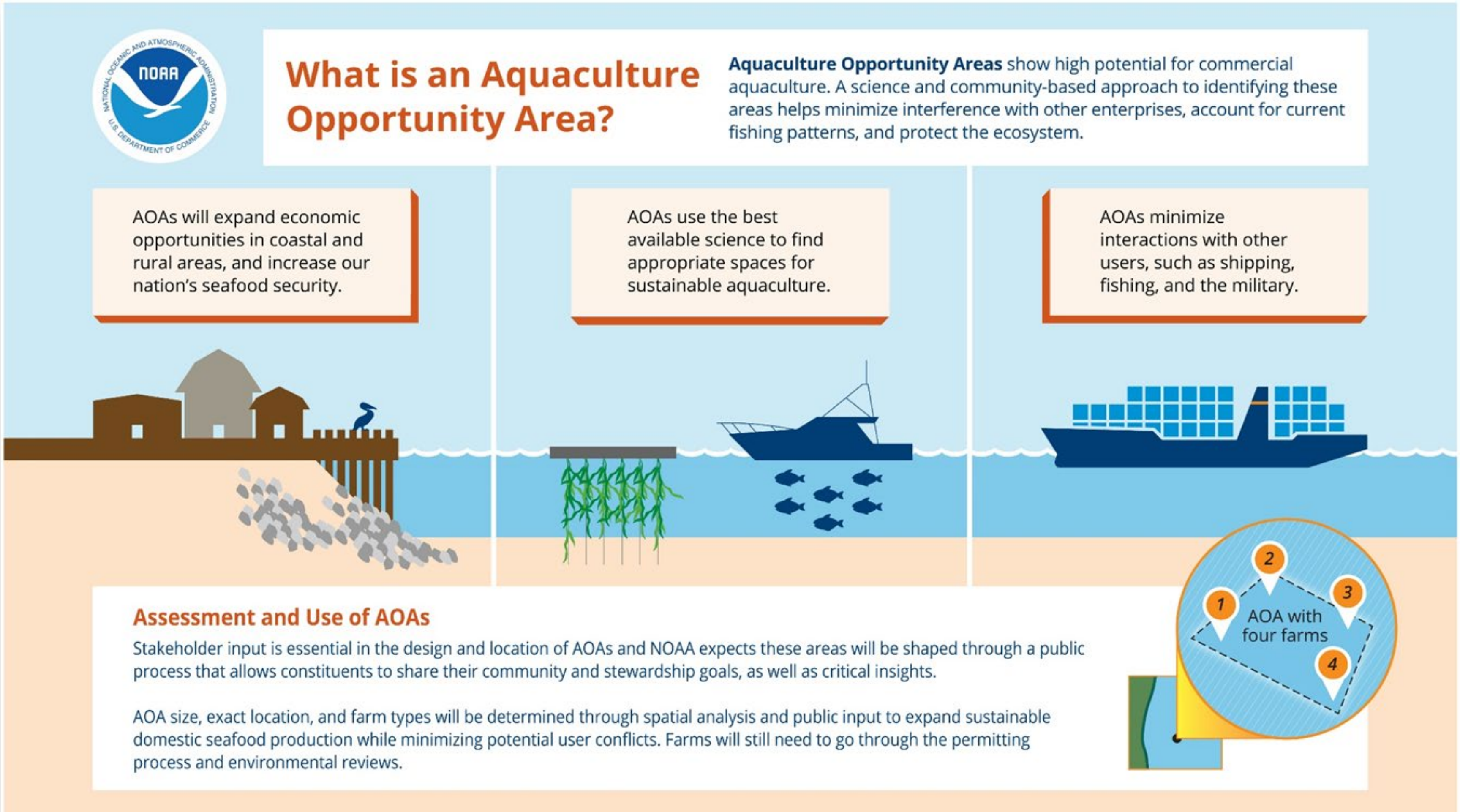


Figure 1.1. Infographic explaining how Aquaculture Opportunity Areas show high potential for commercial aquaculture.

Gulf of Mexico Study Region

Area of Interest

Federal waters off the Gulf Coast states, from Brownsville, TX, to the Florida Keys, were selected as one of the first regions for AOA evaluation because of preexisting spatial data availability, previous analyses in the region, and the industry interest in developing sustainable offshore aquaculture operations there. NOAA further narrowed the criteria for aquaculture planing in the Gulf of Mexico using a combination of spatial mapping approaches, scientific review, and stakeholder input. As described above, the Gulf of Mexico AOA AOI includes federal waters within the EEZ at depths ranging between 50 m (164 ft) and 150 m (492 ft).

Physical Description and Scale

The Gulf of Mexico is the ninth largest body of water in the world (NOAA 2011). The U.S. Gulf Coast shoreline extends 75,640 km (47,000 mi) from the southern tip of Texas east through Louisiana, Mississippi, Alabama, and the Florida Keys. The Gulf of Mexico is a 564,600 km^2 (218,000 mi^2) semi-closed, oceanic basin connected to the Atlantic Ocean via the Straits of Florida and to the Caribbean Sea by the Yucatan Channel (Mendelssohn et al. 2017). Watersheds from 33 of the 48 contiguous states drain into the Gulf regional ocean waters (NOAA 2021a). Shoreline features of the region include barrier islands, wetlands, and more than 750 bays, estuaries, and sub-estuary systems that are associated with larger estuaries (USEPA 2012). Physical oceanographic processes in the Northern Gulf ecoregion include the Loop Current and its eddies, which transport warm saline waters into the Gulf year-round. Bathymetric features of the Gulf of Mexico AOI region include the continental shelf, which extends from the coastline to water depths of approximately 200 m (660 ft).

Marine Ecoregion and Habitats

The Gulf of Mexico AOI occurs within the Northern Gulf of Mexico Level I ecoregion (Spalding et al. 2007; Wilkinson et al. 2009; Mendelssohn et al. 2017). The region is semi-tropical as the temperature regime is influenced by tropical marine currents in the summer and continental air temperatures in the winter (Wilkinson et al. 2009). The Northern Gulf ecoregion is affected by strong tropical cyclones during summer months; severe weather events including thunderstorms and tornadoes are typical for the region as well (Mendelssohn et al. 2017).

The Gulf of Mexico teems with sea life, from shrimp in the coastal estuaries to deep-water corals living thousands of feet below the surface. Coastal areas are home to a wide variety of living resources, including waterfowl, estuarine shellfish, marine mammals, sea turtles, and fish. Freshwater inputs from 37 major rivers, but particularly from the Mississippi and Atchafalaya Rivers, supply the shelf with nutrients (Wilkinson et al. 2009). Turbid coastal river inputs result in low light penetration nearshore; however, light penetration increases as a function of distance from shore (Cardona et al. 2016). Phytoplankton, cyanobacteria, diatoms, dinoflagellates, and photosynthetic microbes form the base of the Gulf pelagic food webs (Biggs and Ressler 2001; Muller-Karger et al. 2015; Cardona et al. 2016). High biological productivity provides resources and habitat for hundreds of economically and ecologically important marine species (Wilkinson et al. 2009). Marine benthic communities in the northern Gulf inhabit continental shelf and slope deep-sea environments including soft sediment, hardbottom areas, coral reefs, deep water coral areas, and chemosynthetic communities. The muddy and sandy continental slope is a complex transitional zone that includes varying ranges of productivity and faunal assemblages (Mendelssohn et al. 2017).

Prehistory and Archaeological Resources

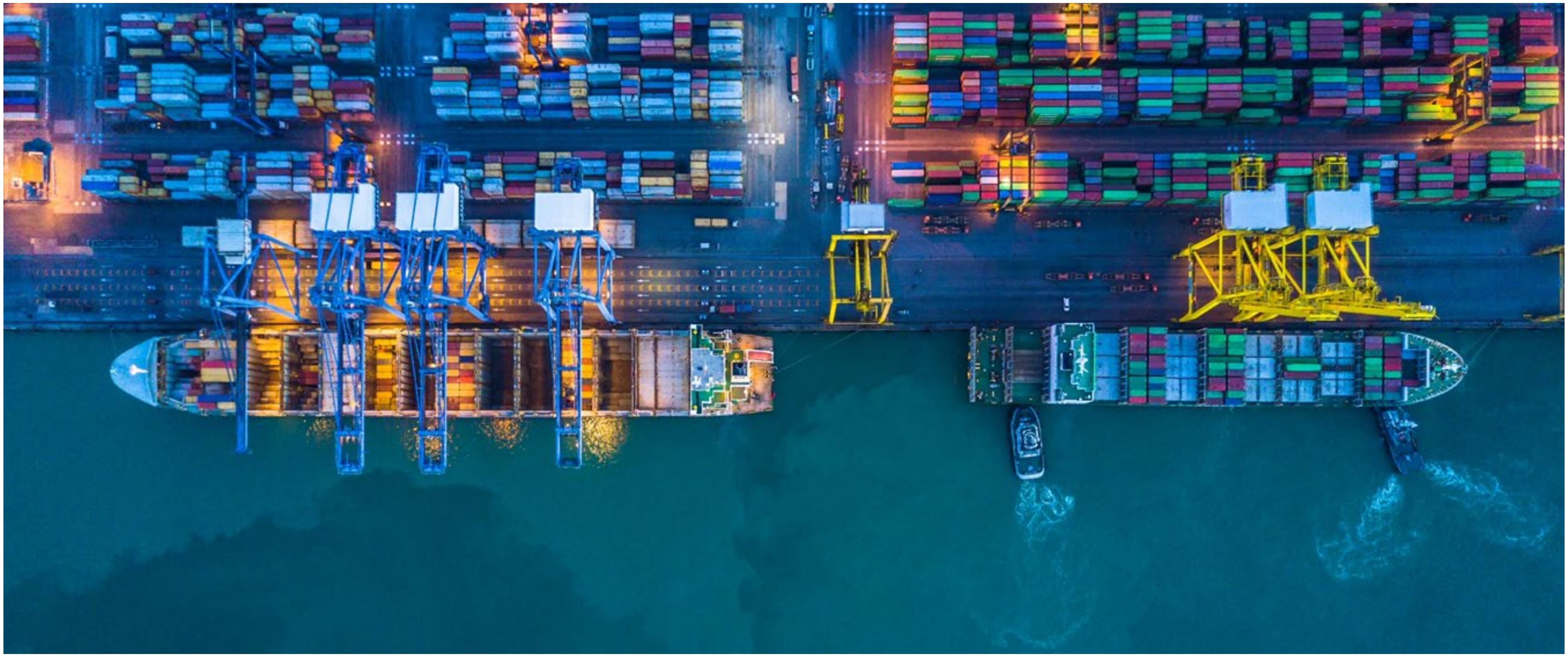
Within this Atlas, we have included many resources and data that are of archaeological interest and may be used in planning for conservation of historic properties. Given the location of the study areas, archaeological sites are most likely to be either pre-contact Native American sites dating from the time at the end of the last ice age when sea levels were significantly lower, or historic shipwrecks dating from the 16th century (BOEM 2017). These archaeological resources, which are included in the definition of historic properties, are defined as any material remains of human life or activities that are at least 50 years of age and that are capable of providing scientific or humanistic understanding of past human behavior or cultural adaptation.

Coastal communities occupied the now-submerged continental shelf of the northern Gulf of Mexico toward the end of the Pleistocene, 20,000 - 17,000 years ago (Evans and Keith 2011). Exact locations of prehistoric sites are sparse and submerged or covered with up to 40 m (131 ft) of sediments on the outer continental shelf (Rees 2010). Hundreds of artifacts discovered along the shore at the McFaddin Beach Site east of Galveston, TX, document the presence of Paleocoastal Native Americans more than 8,000 years ago (Stright 1999). Human occupation from the late Pleistocene through the mid-Holocene has also been documented in Apalachee Bay, in Florida's Big Bend (Faught 2004). European exploration and contact with Gulf Coast Native Americans occurred in the early 1500s with the oldest known shipwreck discovered off the Texas coast that dates back to 1528 (Francaviglia 1998).

Evidence of the nation's rich maritime and economic history is represented by over 1,300 named shipwrecks representative of each time period from the 16th to the 20th centuries. The Gulf of Mexico was an active theater of war with shipwrecks representative of both the U.S. Civil War and World War II (Evans et al. 2013). Modern shipwrecks include commercial fishing vessels, specialized industrial boats and equipment for oil and gas exploration, recreational vessels, and other small craft. Additionally, many artificial reefs now comprise decommissioned ships (i.e., Navy Ships-to-Reef program) and oil and gas platforms (i.e., BOEM Rigs-to-Reef program). The Gulf of Mexico boasts the world's largest artificial reef, the aircraft carrier USS Oriskany, which rests on the seafloor approximately 37 km (20 nm) south of Pensacola, FL, and serves to benefit marine life, commercial and recreational fishing, and recreational diving.

Maritime Economy

The vibrant Gulf of Mexico region supplies trillions of dollars to the nation's economy and provides jobs for millions of people. Over 90% of U.S. oil and gas production occurs in the Gulf of Mexico, which provides billions of dollars to the region's economy (Humphries 2018). Houston and New Orleans are two of the largest ports worldwide, where shipping and ship building are multibillion-dollar industries. The region is one of the most productive areas for natural resources in the country. In 2019, U.S. commercial fish landings in the Gulf of Mexico accounted for 633,664 MT (1.40 billion lbs) of seafood with a value of $796 million (NMFS 2021a). Recreation, leisure, and tourism industries have also become increasingly significant contributors to the Gulf economy. The Gulf of Mexico supports the largest recreational fisheries in the nation (NMFS 2021a). Aquaculture also contributes to the region's maritime economy through the production of finfish, shellfish, seaweeds, and live rock. As of 2018, the Gulf states accounted for 23%, or $345 million, of aquaculture production in the U.S. (NMFS 2021a).



METHODS

Study Areas

At the onset of spatial modeling for ocean planning, it is important to establish an AOI to determine the geographical scope of a project and conduct preliminary assessments through visualization of descriptive characteristics. One unique aspect of ocean planning data is that spatial components are not only based on two continuous spatial dimensions (x and y) (e.g., latitude, longitude), but occasionally also a third (z) (e.g., depth), and fourth dimension (e.g., time) (Wickliffe et al. 2020). Information to determine initial requirements for AOAs was collected from a series of meetings with experts and stakeholders to identify project requirements for offshore aquaculture (finfish, macroalgae, shellfish, or a combination of species) (Table 2.1). Supplemental information was also collected via listening sessions initiated through a NOAA RFI in the Federal Register (85 FR 67519; October 23, 2020). Based on all the information collected through engagement and outreach, study areas were identified and delineated from the AOI for spatial modeling for potential AOAs in federal waters of the Gulf of Mexico. Data needs were identified to formulate study areas and included bathymetric data; political boundaries associated with offshore policies and regulation of submerged lands; Outer Continental Shelf (OCS) boundary, state and federal water demarcations; and MPAs. Within the Gulf of Mexico and under certain U.S. fisheries laws such as the Magnuson-Stevens Fishery Conservation and Management Act, U.S. federal waters (i.e., U.S. EEZ) are defined as having an inner boundary coterminous with the seaward (or outer) boundary of each of the coastal states. This is coterminous with the boundary of coastal states at 5.6 km (3.0 nm), except for Texas and western Florida, which claim 16.7 km (9.0 nm). The outer boundary, established by Presidential Proclamation 5030[11] and consistent with the U.N. Convention of the Law of the Sea, extends out to the 370-km (200-nm) limit (Reed 2000).

NOAA's planning goal for this study was to identify AOA options for the waters of the U.S. Gulf of Mexico with a minimum AOA size of 202 ha (500 ac) and a maximum AOA size of 809 ha (2,000 ac) which would be capable of supporting three to five aquaculture operations. The water depth and distance from shore requirements used to determine the AOI were based on input from industry and previous permit applications and are expected to support all types of aquaculture within federal waters. Stakeholder recommendations

[11] Presidential Proclamation 5030, Exclusive Economic Zone of the United States of America, 48 Fed. Reg. 10605 (1983). https://www.archives.gov/federal-register/codification/proclamations/05030.html

(Table 2.1) suggested the study areas focus on aquaculture development in the Gulf of Mexico at water depths from 50 to 150 m (164 ft to 492 ft). Study area depths were constrained to a maximum of 150 m (492 ft), as siting aquaculture operations in deeper waters would require significantly more space for anchorage. Water depths were extracted using the NOAA U.S. Coastal Relief Model, which provides comprehensive bathymetric data at 3 arc-second horizontal resolution (~90 x 90 m pixels) for the Gulf of Mexico. After the suitable depths were extracted, the AOI was further delineated into study areas using boundaries for U.S. federal waters (Figure 2.1) and the boundaries for the GMFMC (Figure 2.2).

The study area was further refined using the biogeographical divisions from the level III marine ecoregions for the Gulf of Mexico, due to the large geographical extent of the preliminary study area (Spalding et al. 2007; Wilkinson et al. 2009; Ward 2017). Level III ecoregions were utilized and are limited to the OCS and based on differences within the neritic zone as determined by local water mass characteristics, regional landforms, and biological community type (Yáñez-Arancibia and Day 2004; Spalding et al. 2007; Wilkinson et al. 2009; Yáñez-Arancibia et al. 2009; Mendelssohn et al. 2017; Galparsoro et al. 2020) (Figure 2.3). Once the biogeographical breaks were applied, four distinct study areas were identified. The final study areas for spatial analysis included the West (W) study area estimated at 27,421 km² (10,587 mi²), Central (C) study area estimated at 17,671 km² (6,823 mi²), East (E) study area estimated at 35,888 km² (13,857 mi²), and the Southeast (SE) study area estimated at 13,766 km² (5,315 mi²) (Figure 2.4).

Table 2.1. Aquaculture Opportunity Area and boundary rules for study areas.

AOA Boundary Rules	Description
Depth Range	50 - 150 m (164 ft - 492 ft)
Size Range	500 - 2,000 ac (202 - 809 ha)
Polygon Shape	Each AOA polygon will have four corner points for ease in computation, for boundary establishment, and to maintain position to the cardinal directions
Location	U.S. Exclusive Economic Zone
Fishery Management Council Boundaries	Gulf of Mexico Fishery Management Council

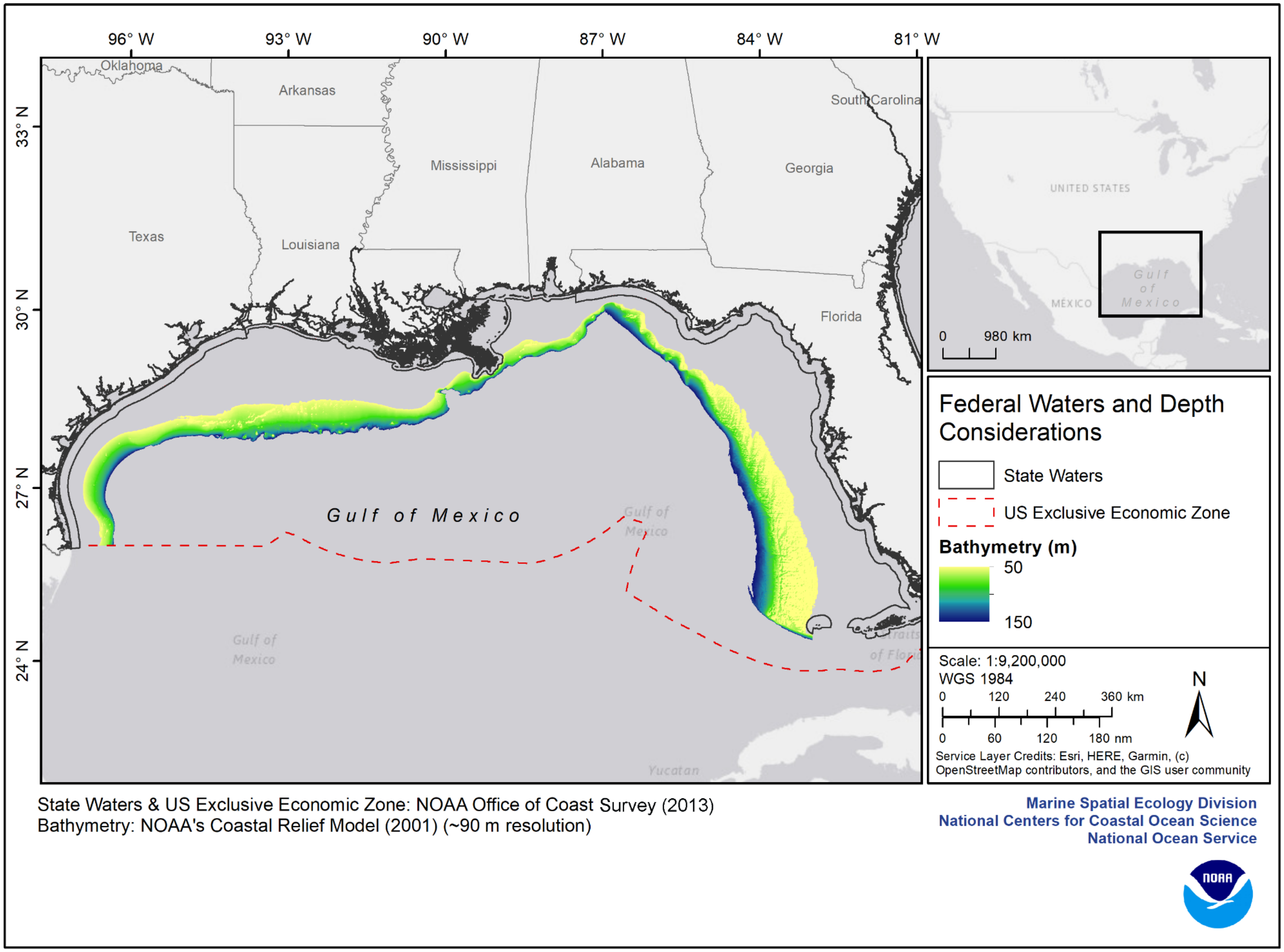


Figure 2.1. Depths from 50 to 150 m (164 to 492 ft) in the U.S. Gulf of Mexico federal waters.

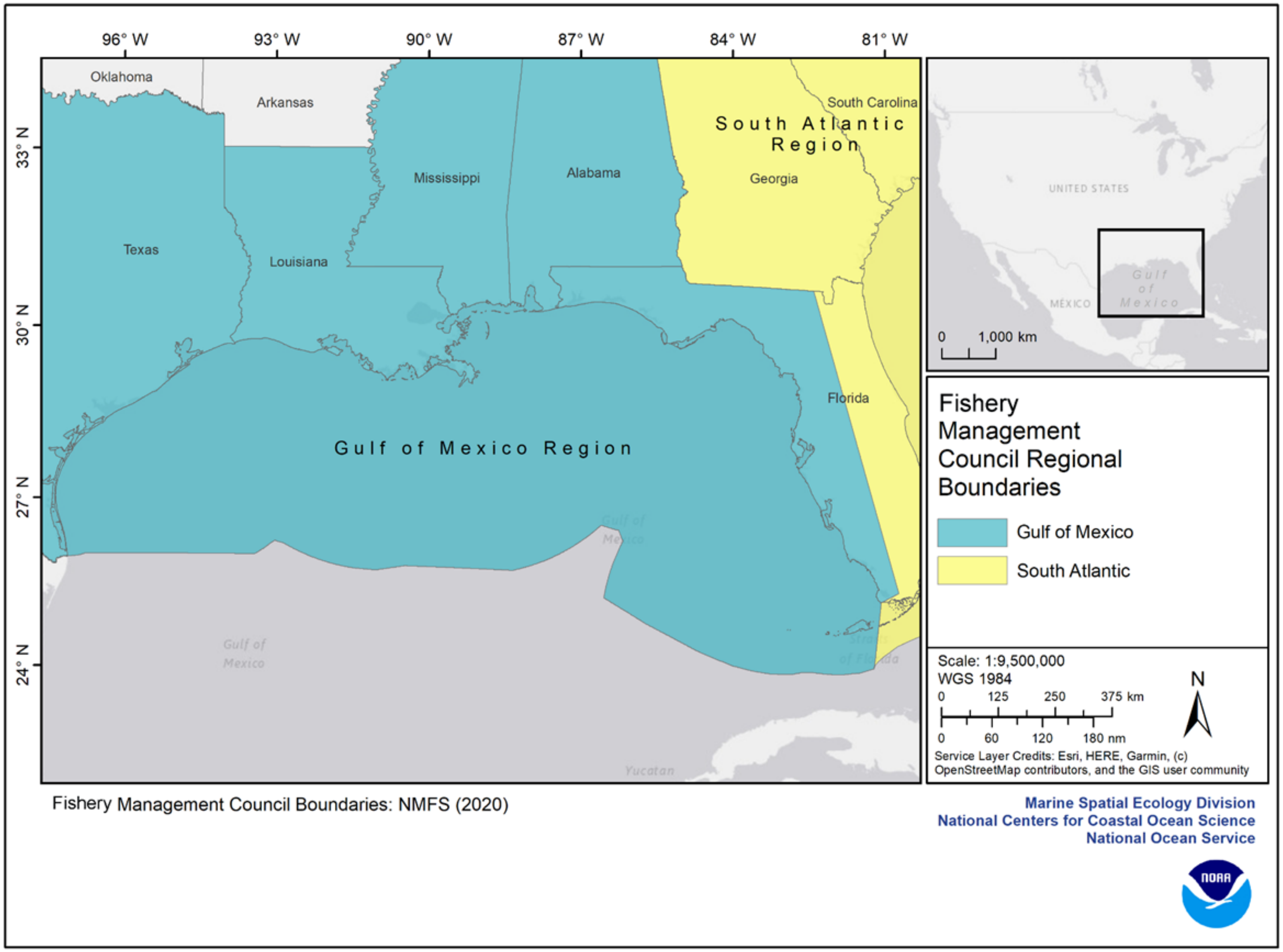


Figure 2.2. Fishery Management Council boundaries defined by the Gulf of Mexico Fishery Management Council and the South Atlantic Fishery Management Council. Study areas were limited to boundaries for the Gulf of Mexico Fishery Management Council.

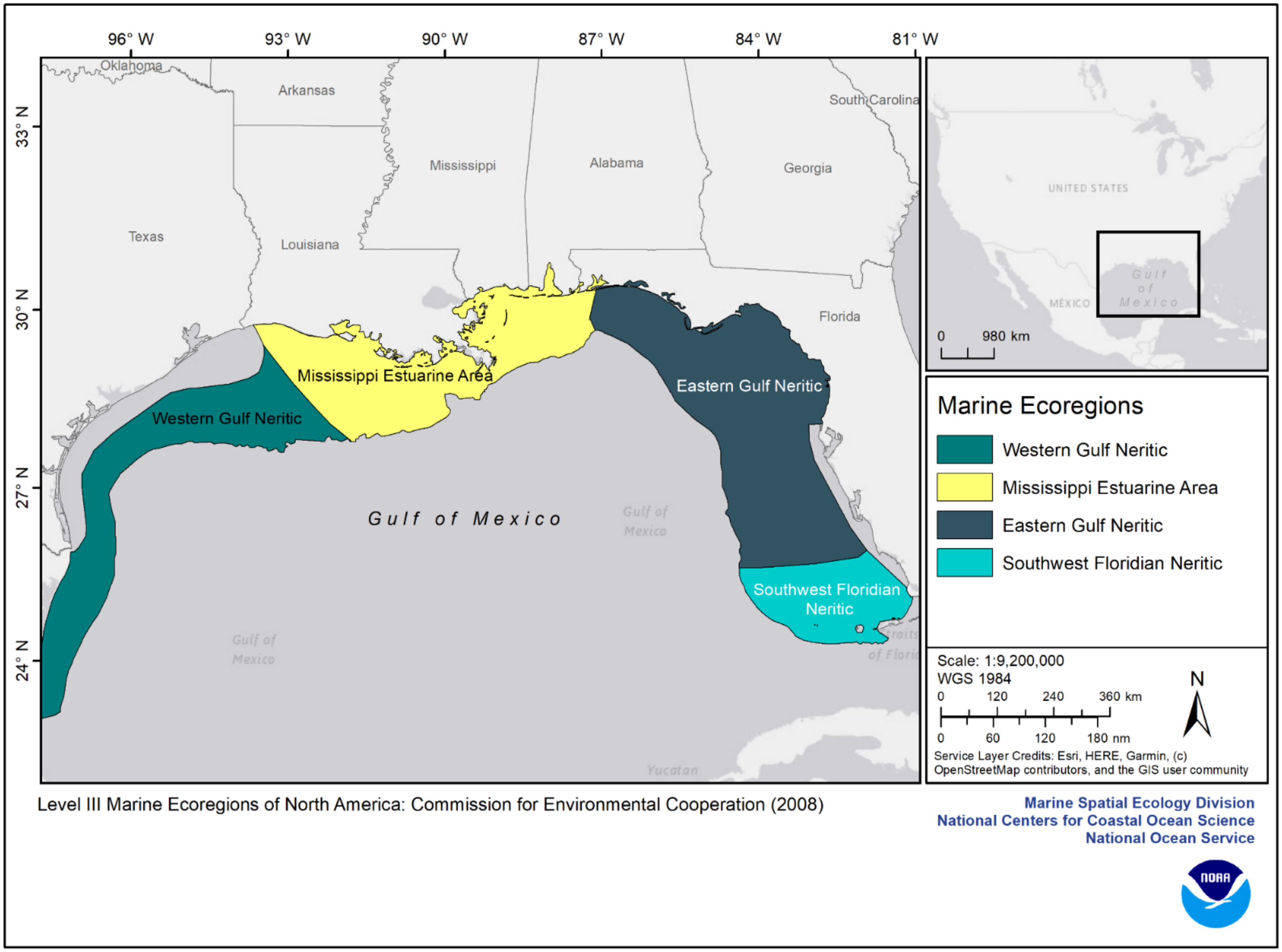


Figure 2.3. The Marine Ecoregions of the World system was used to define the study areas. Level III ecoregions were used to establish biogeographical breaks within the Gulf of Mexico. Ecoregions were defined based on Spalding et al. (2007), Wilkinson et al. (2009), and Ward (2017).

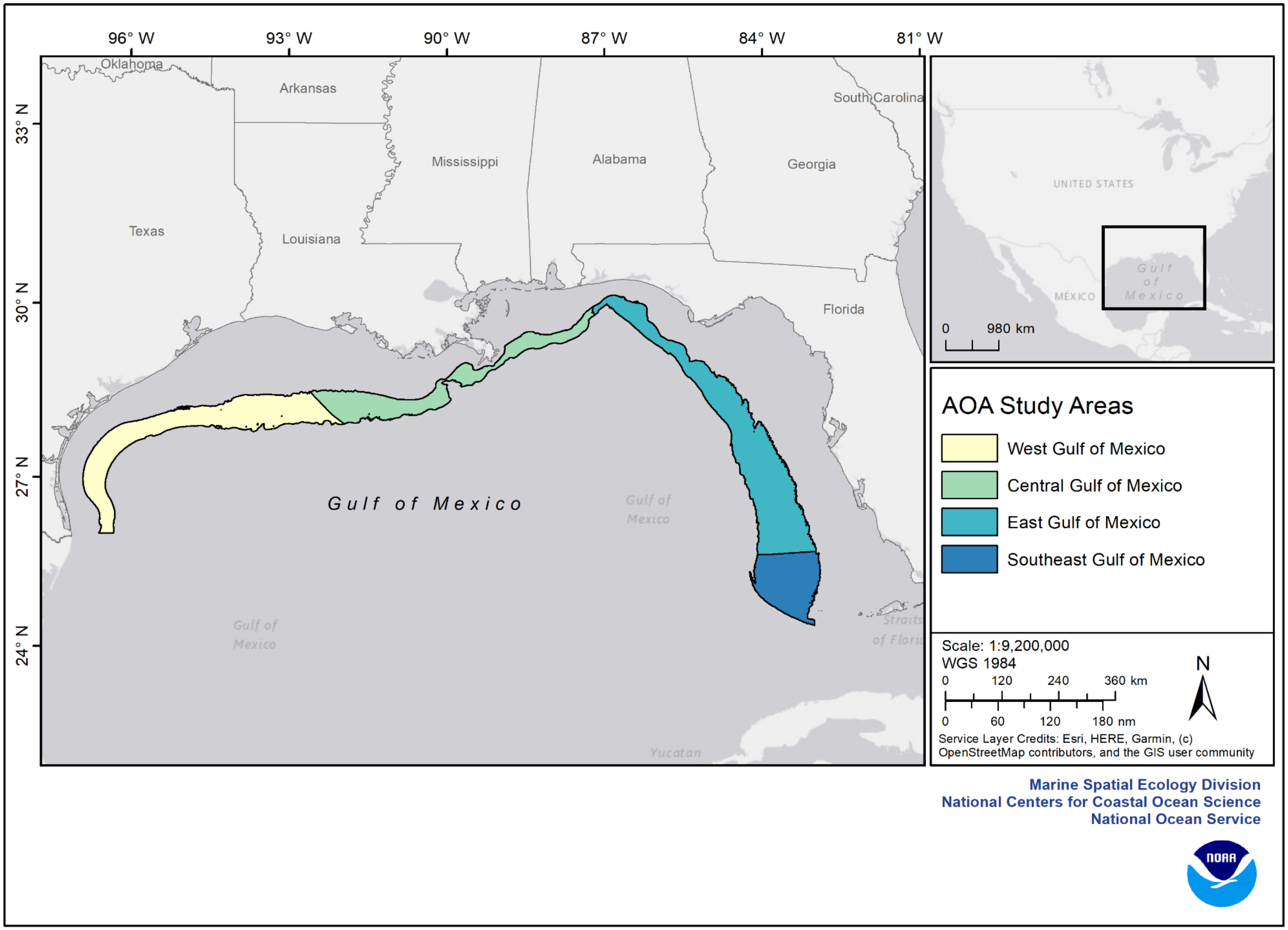


Figure 2.4. Study areas for identification of Aquaculture Opportunity Areas (AOAs) include the West (yellow polygon), Central (green polygon), East (light blue polygon), and Southeast (dark blue polygon).

Spatial Planning: Step-by-Step Approach

Spatial planning and analysis for a potential AOA requires a deep understanding of the relationship between different elements of the environment and ocean use as well as the practical requirements for aquaculture development. By any measure, developing an atlas for an expansive region like the Gulf of Mexico requires compilation and analysis of best-available data. We developed a step-by-step approach for spatial planning using a logical workflow that began with framing the research questions (i.e., project requirements) and data collection and inventory, then continued with spatial suitability modeling, identifying potential AOA options using a unique precision siting modeling strategy, further characterization of options, and finally, interpretation of results. Each step of the workflow diagram corresponds to an essential step of the study, with corresponding methods detailed herein (Figure 2.5).

Geospatial Overlay

Grids are commonly applied for spatial analysis, scientific observations, experiments, and simulations; when used in arrays, they are the most efficient means for mapping spatial variation and establishing a common framework for spatial models (Olea 1984; Dale 1998; Birch et al. 2007). In spatial science, grids are regular polygons that can be repeated over a surface to cover any space without overlaps or gaps. All spatial modeling using a gridded overlay was conducted using ArcGIS™ Pro v. 2.8.0 (Esri 2021a). The grid cell size was determined by a number of factors, including the extent of the analysis, minimum AOA size, processing time, and spatial resolution of data within the model (Hengl 2006). Grid resolution must strike a balance between the coarsest (e.g., bathymetry, oceanographic) and finest (vector data with associated precision and accuracy errors) data in the model. Hengl (2006) and Liang et al. (2004) both acknowledge that grid-cell size selection can be optimized, but at a certain point, increased resolution only provides minor improvements. Moreover, there is no ideal grid cell or pixel size, but it is recommended to avoid using resolutions that do not comply with the inherent properties of input datasets (Hengl 2006). Given these considerations and the aim to identify areas ranging from 500 - 2,000 ac (202 - 809 ha), a gridded overlay with 10-ac (4.05-ha) grid cell size was used for each study area (Figure 2.6).

A hexagonal tessellation was used as hexagonal grids fit natural curves and organic shapes better than square grids, which is an important consideration when determining a relative comparison of complex ocean areas (Tsatcha et al. 2014). Groups of hexagons tend to form less rectilinear shapes because of the hexagonal grid's three non-orthogonal axes (Birch et al. 2007). Hexagons were also of interest for use in this model because they are the closest tessellating shape to a circle, which is a unique shape because it has the smallest perimeter to area ratio, thereby reducing bias and edge effects and providing optimal sampling within a cell (Birch et al. 2007) (Figure 2.6).

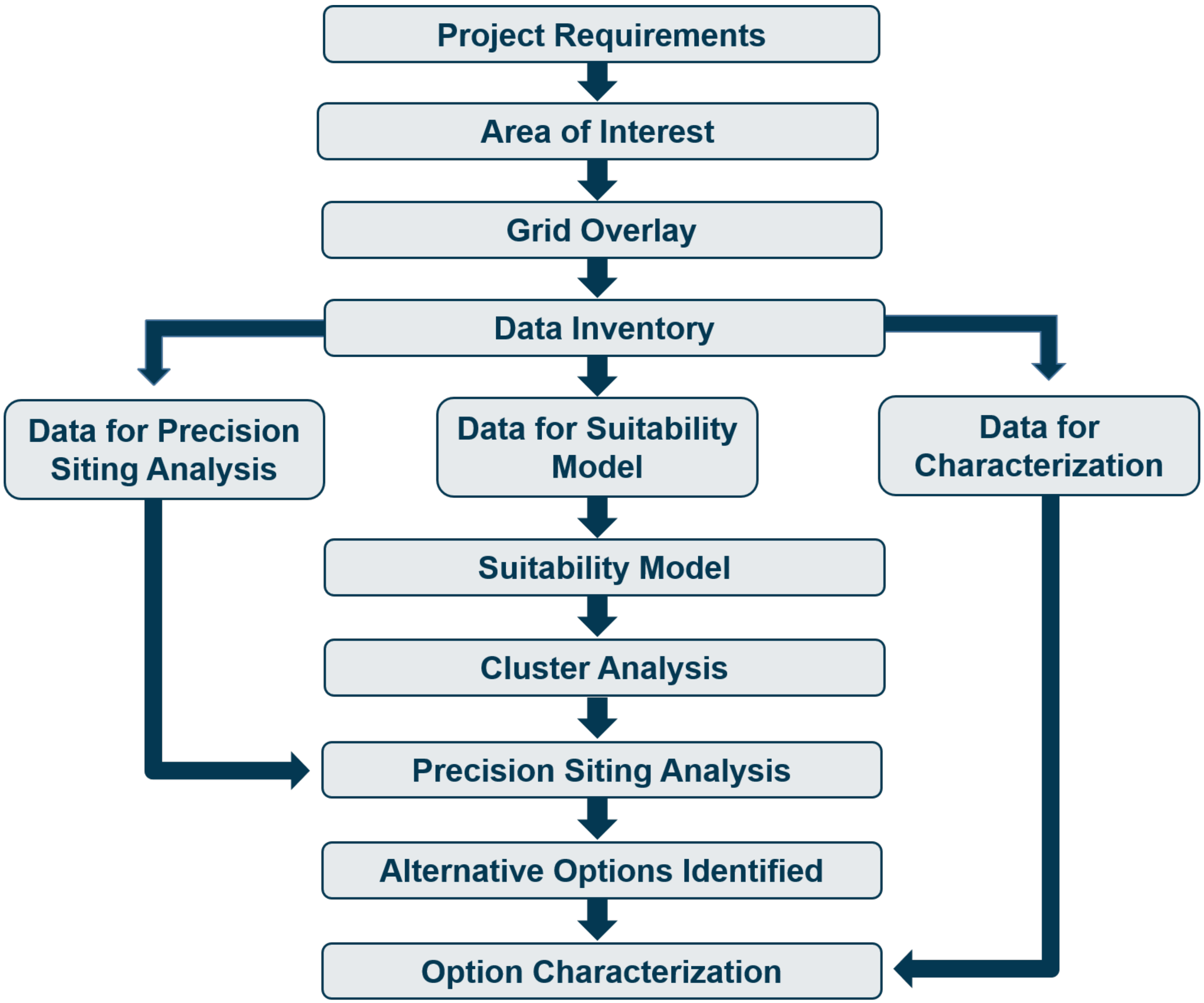


Figure 2.5. Workflow overview for the Aquaculture Opportunity Area study within the U.S. Gulf of Mexico federal waters.

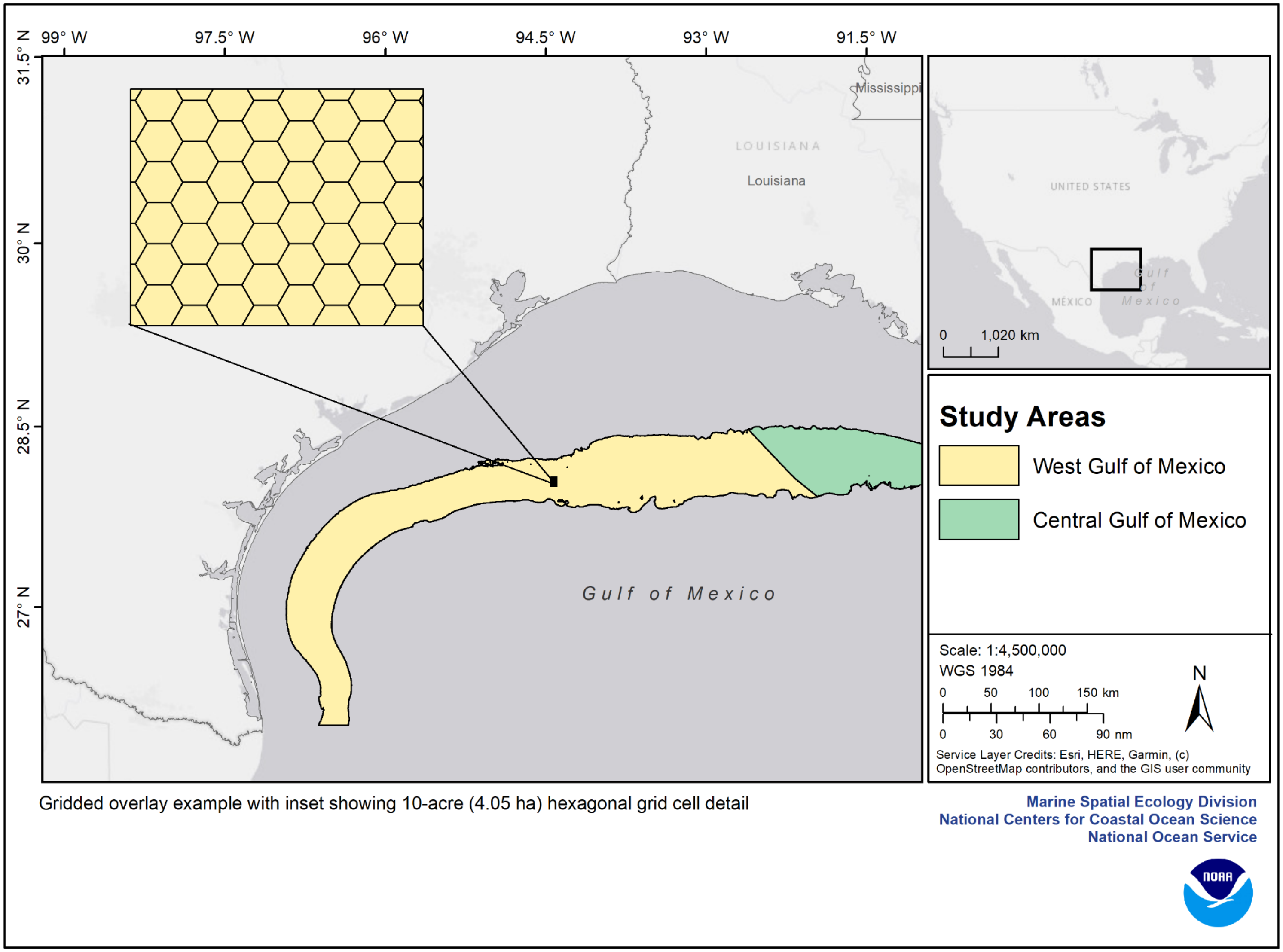


Figure 2.6. An example of the grid cells formulated for each study area. Each cell is a 10-ac or 4.05-ha hexagon.

Data Acquisition, Categorization, and Inventory

Geospatial analysis and marine spatial planning require the consideration of multiple, seemingly incompatible datasets (Longdill et al. 2008) that require substantial data acquisition to properly understand and implement within ocean planning suitability models. Data categorization is needed to describe the relationships among the data input into the models and to organize information into appropriate submodels for suitability modeling. Data categorization was based on schema provided in Lightsom et al. (2015) because the intent of the categorical structure is for ocean planning. The structure intends to bring transparency and a consistent framework for organizing complex and dynamic ocean systems (Lightsom et al. 2015). The categorical framework included herein ensures all necessary data needed for AOA site suitability analysis, a specific type of ocean planning, were included.

Acquisition of spatial data is a key factor in model success because it is the base for further calculations and analysis (Molina et al. 2013). An initial literature review was completed to determine the broad suite of data and categories needed to properly support this ocean planning process. A comprehensive, authoritative spatial data inventory was developed including data layers relevant to administrative boundaries, national security (i.e., military), navigation and transportation, energy and industry infrastructure, commercial and recreational fishing, natural and cultural resources, and oceanography. The data holdings were developed through engagement with non-governmental organizations and U.S. federal and state agencies representing a diverse array of stakeholders. To identify, obtain, and interpret data resources, stakeholders were engaged one-on-one and through Federal Register notice (85 FR 67519; October 23, 2020) and suggestions for data relevant to this study were requested. A total of 192 engagements related to data acquisition and interpretation occurred during 2020 and 2021, encompassing stakeholder interest related to military (15), natural resources (89), regional planning and regulatory (11), industry (21), navigation (5), governance and boundaries (30), social and cultural (6), research (4), environmental non-governmental organizations (2), and human health (9). More than 860 persons participated in these engagements. For all cases, data were selected that represent the most authoritative and highest resolution available.

Data were checked for completeness and quality, and the most authoritative, up-to-date sources were used. All data were projected and calculations performed using an Albers equal area projection for the Gulf of Mexico (Projection: Albers, False Easting: 1,200,000.0, False Northing: 0.0, Central Meridian: -88.0, Standard Parallel 1: 23.0, Standard Parallel 2: 28.0, Latitude of Origin: 16.0) with the World Geodetic System (WGS) 1984 coordinate system. (See Appendix A for the complete data inventory generated for the spatial planning analysis).

Data Processing Steps

Many datasets required processing prior to use in the suitability model, subsequent cluster analysis, precision siting model, or final option characterization. Methods were provided for all data that required some level of processing; many data were received in a ready-to-use format and processing notes can be found in metadata provided by the data originator). Setbacks (i.e., buffers) were applied when required by governance, policy, and regulations. An exception to this rule for setbacks was for point data such as aids to navigation and ocean observing buoys in which a setback was established for the estimated radius of buoy movement (i.e., watch circle) within the study area. In cases where an established setback requirement was not available from an authoritative source, conservative professional judgement was used when assigning setback distances.

NMFS Protected Resources

To holistically consider protected species in the region, a novel combined data layer providing the overall score for select protected species was developed through collaboration with NMFS Southeast Regional Office (SERO) and NMFS Office of Protected Resources (Appendix B). A scoring table was developed to assign relative suitability scores to protected species data based on species status, population size, and trajectory (Table 2.2). Protected species include those listed under the Endangered Species Act (ESA) and/or protected under the Marine Mammal Protection Act (MMPA). This approach was preferred given that this spatial planning process does not consider gear-specific aquaculture or other secondary interactions with protected species. This combined data layer contains only highly vulnerable protected species; as a result, a number of protected species, especially marine mammals, were excluded from this analysis. Those species will need to be considered during the PEIS stage to determine overall suitability of potential AOA sites. The scores provided in Table 2.2 for MMPA and ESA-listed species range from 0.1 (most vulnerable species, based on their biological status) to 0.8 (least vulnerable species) using best-available data for each region (Appendix B). This ranking was developed for each species/stock using factors that are more or less likely to affect their ability to withstand mortality, serious injury, or other impacts that could affect the species' ability to survive and recover.

Table 2.2. Scoring system from the National Marine Fisheries Service for protected resources in the U.S. Gulf of Mexico Aquaculture Opportunity Area study areas.

Status	Status and Trend	Score
Endangered	Declining, small population* or both	0.1
Endangered	Stable or unknown	0.2
Endangered	Increasing	0.3
Threatened	Declining or unknown	0.4
Threatened	Stable or increasing	0.5
MMPA Strategic	Declining or unknown	0.6
MMPA Listed	Small population	0.7
MMPA Listed	Large population	0.8

*Small population equates to populations of 500 or fewer individuals (Franklin 1980).

The combined data layer was developed from a total of eight data layers for the Gulf of Mexico region including Rice's whale, leatherback sea turtle, Kemp's ridley sea turtle, hawksbill sea turtle, smalltooth sawfish (U.S. Distinct Population Segment (DPS)), giant manta ray, loggerhead sea turtle (Northwest Atlantic Ocean DPS), and green sea turtle (North Atlantic DPS). Table 2.3 provides the species, status and trend, and score used when creating the combined data layer for use within the AOA relative suitability model. The eight data layers developed for these species provide the greatest resolution and contrast allowing for meaningful comparisons between grid cells, and correctly attributing increasing levels of concern for areas with multiple overlapping protected species data layers (Figures 2.7 - 2.14). Table 2.4 lists species (including their population status and trend and suitability score) which have limited distribution or are too widely distributed to influence cell scores within the study area during suitability modeling. Additionally, the Gulf of Mexico supports many ESA-listed species of corals. Corals were not included with the protected resources submodel because areas containing corals were scored as 0 (generally not suitable) and were included in the constraints submodel.

NMFS used the product method to combine these data layers, which assumes that a lower scoring variable cannot be compensated by a higher scoring variable (Equation 2.1). For example, a grid cell overlapping with the Rice's whale high use area (HUA) would never have a score higher than 0.1 with the product method, whereas use of a geometric or arithmetic mean would result in scores above 0.1 when combining multiple data layers. Each input data layer in Table 2.3 is displayed in Figures 2.7 - 2.14.

Equation 2.1 Product method equation used to calculate the final protected resource layer score used in the Aquaculture Opportunity Area suitability analysis.

$$p = x_1 \cdot x_2 \cdot \ldots \cdot x_i$$

$x_1 =$ *variable 1*

$x_2 =$ *variable 2*

$x_i =$ *additional variables*

Table 2.3. Score and justification for Endangered Species Act-listed species for Gulf of Mexico distributions known to overlap with Aquaculture Opportunity Area study areas. These scores were used with the product method to develop the final protected species data layer.

Species	Status and Trend	Score
Rice's Whale	Endangered, small and declining	0.1
Leatherback Sea Turtle	Endangered, declining	0.1
Kemp's Ridley Sea Turtle	Endangered, unknown	0.2
Hawksbill Sea Turtle	Endangered, unknown	0.2
Smalltooth Sawfish, U.S. DPS	Endangered, increasing	0.3
Giant Manta Ray	Threatened, declining	0.4
Loggerhead Sea Turtle, North Atlantic Ocean DPS	Threatened, unknown	0.4
Green Sea Turtle	Threatened, increasing	0.5

Table 2.4. Species, distribution overlap with Aquaculture Opportunity Area (AOA) study areas, and status and population trend for Endangered Species Act (ESA) and Marine Mammal Protection Act (MMPA) listed species (NMFS 2021b). These U.S. Gulf of Mexico (GOM) species were not used in suitability modeling. It is recommended each species is given consideration for aquaculture development.

Species	Distribution Overlaps AOA Study Areas	Status and Trend	Reference
Oceanic Whitetip Shark	Yes	ESA Threatened, stable or increasing	-
Nassau Grouper	Yes	ESA Threatened, declining or unknown	-
Atlantic Spotted Dolphin - Northern GOM Stock	Yes	MMPA Listed, unknown	NMFS 2021c
Common Bottlenose Dolphin - Continental Shelf Stock	Yes	MMPA Listed, unknown	NMFS 2015
Rough Toothed Dolphin - Northern GOM Stock	Yes	MMPA Listed, unknown	NMFS 2020
Gulf Sturgeon, Critical Habitat	No	ESA Threatened, stable or increasing	-
Common Bottlenose Dolphin - GOM Eastern Coastal Stock	No	MMPA Listed, unknown	NMFS 2015
Common Bottlenose Dolphin - GOM Northern Coastal Stock	No	MMPA Listed, unknown	NMFS 2015
Common Bottlenose Dolphin - GOM Western Coastal Stock	No	MMPA Listed, unknown	NMFS 2015
Common Bottlenose Dolphin – Northern GOM Oceanic Stock	No	MMPA Listed, unknown	NMFS 2020
Clymene Dolphin - Northern GOM Stock	No	MMPA Strategic, unknown	NMFS 2020
Striped Dolphin - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Fraser's Dolphin - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Pantropical Spotted Dolphin - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
False Killer Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Killer Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Pygmy Killer Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Blainville's Beaked Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Gervais' Beaked Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Cuvier's Beaked Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Dwarf Sperm Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Pygmy Sperm Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Sperm Whale - Northern GOM Stock	No	ESA Endangered, unknown	NMFS 2020
Spinner Dolphin - Northern GOM Stock	No	MMPA Strategic, declining or unknown	NMFS 2020
Melon-headed Whale - Northern GOM Stock	No	MMPA Listed, unknown	NMFS 2020
Risso's Dolphin - Northern GOM Stock	No	MMPA Listed, unknown	-
Short-finned Pilot Whale - Northern GOM Stock	No	MMPA Listed, unknown	-

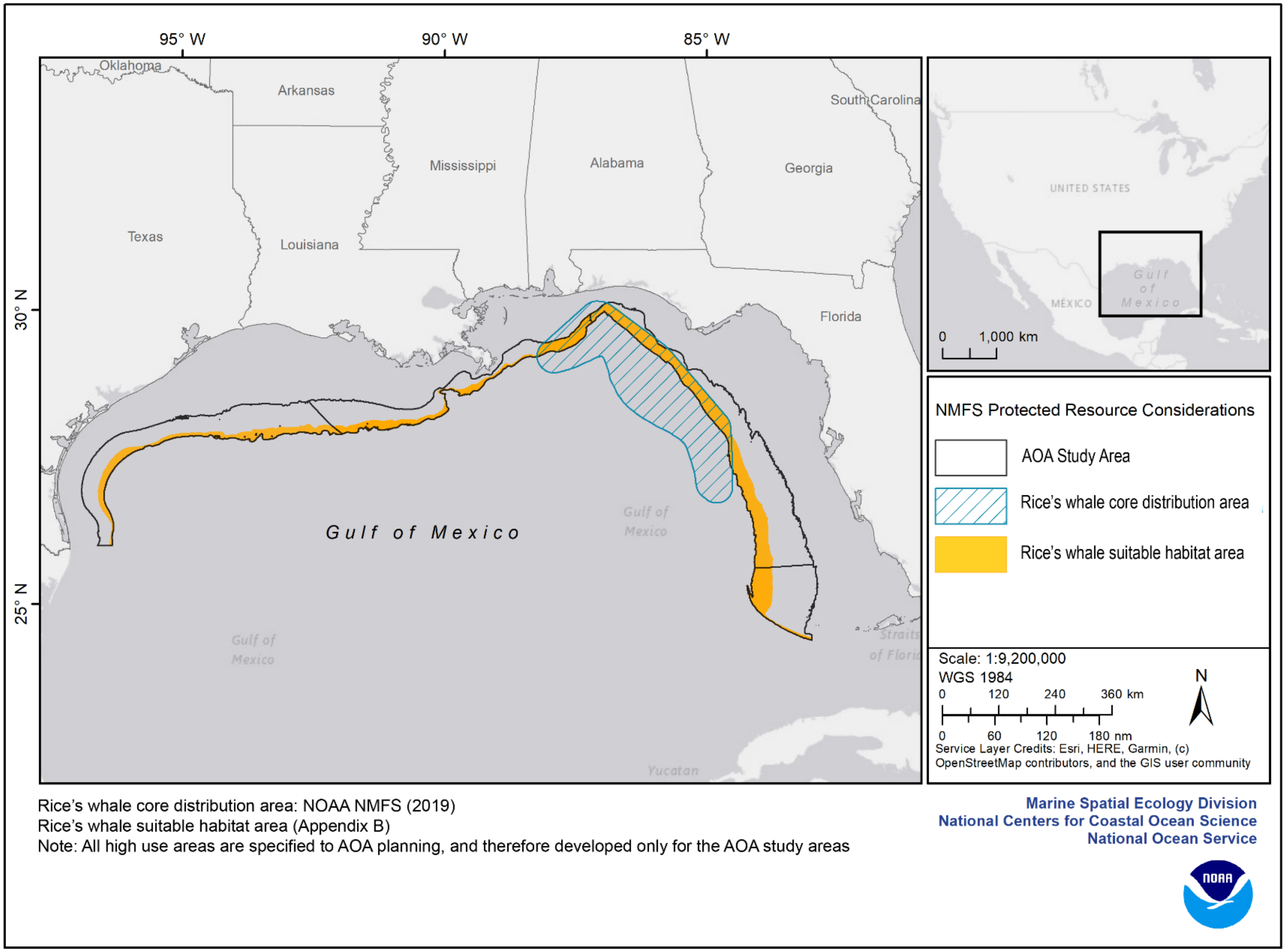


Figure 2.7. Rice's whale suitable habitat (orange area) and core distribution area (blue hatched area) used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

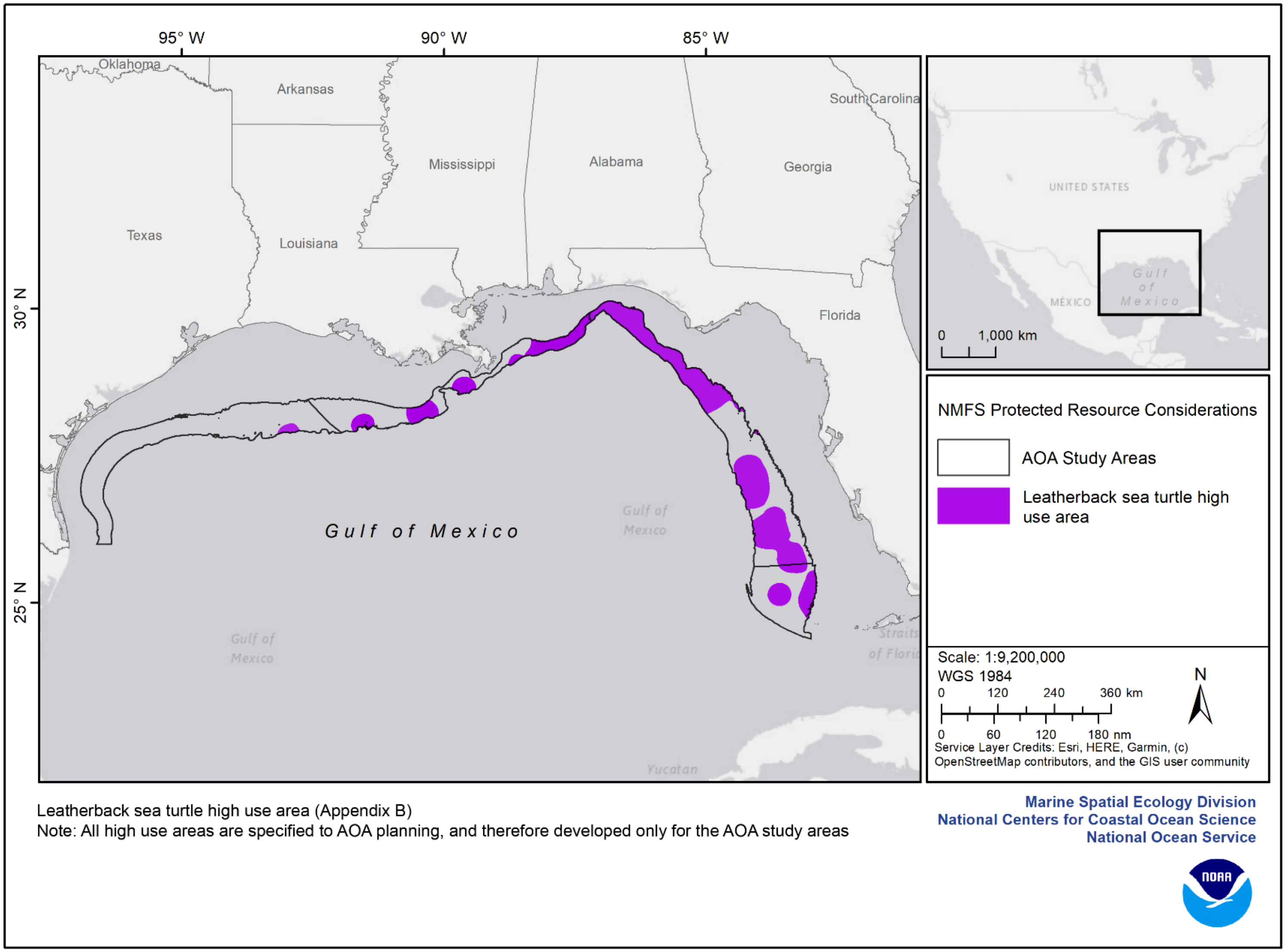


Figure 2.8. Leatherback sea turtle data layer used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

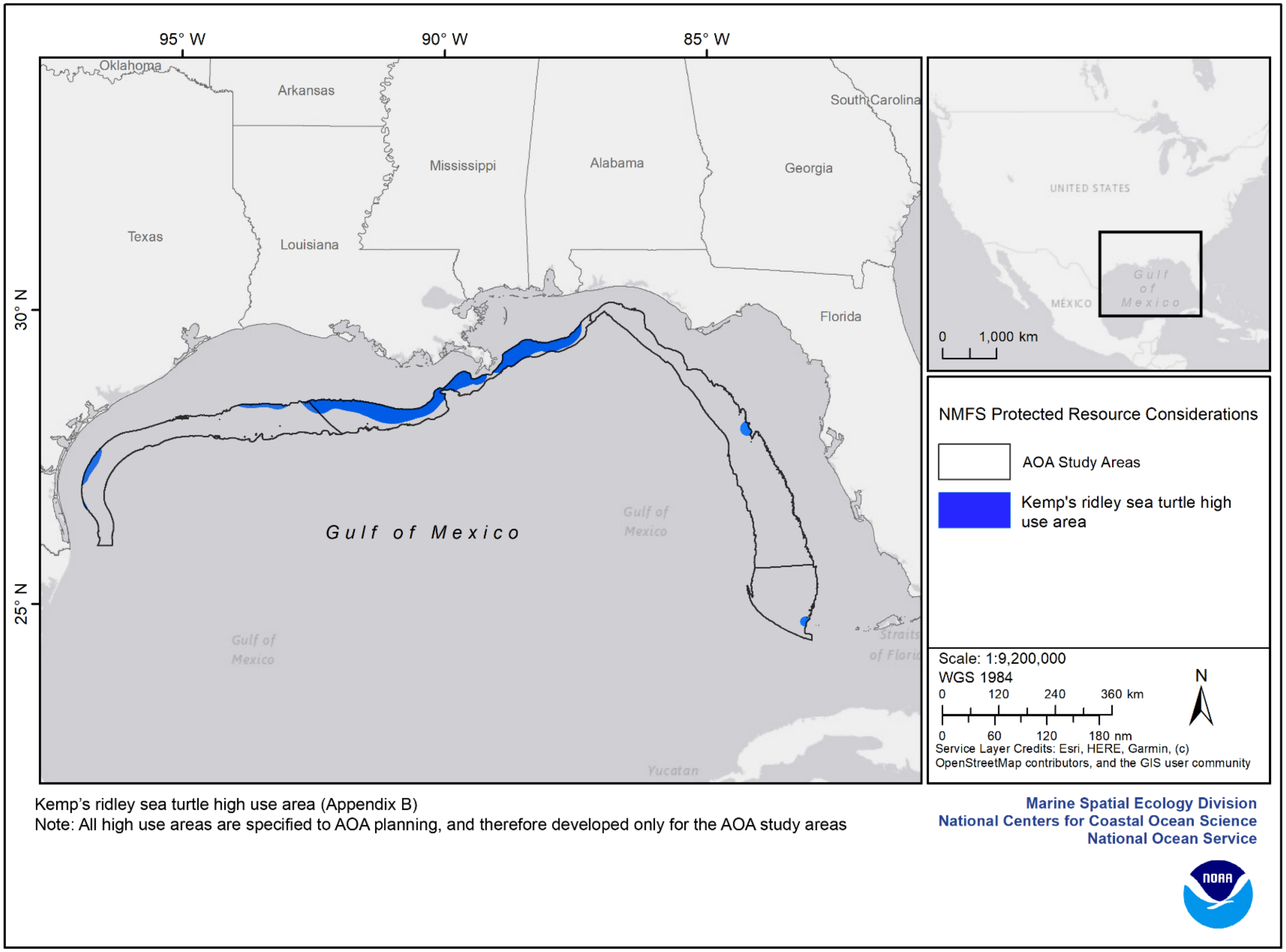


Figure 2.9. Kemp's ridley sea turtle data layer used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

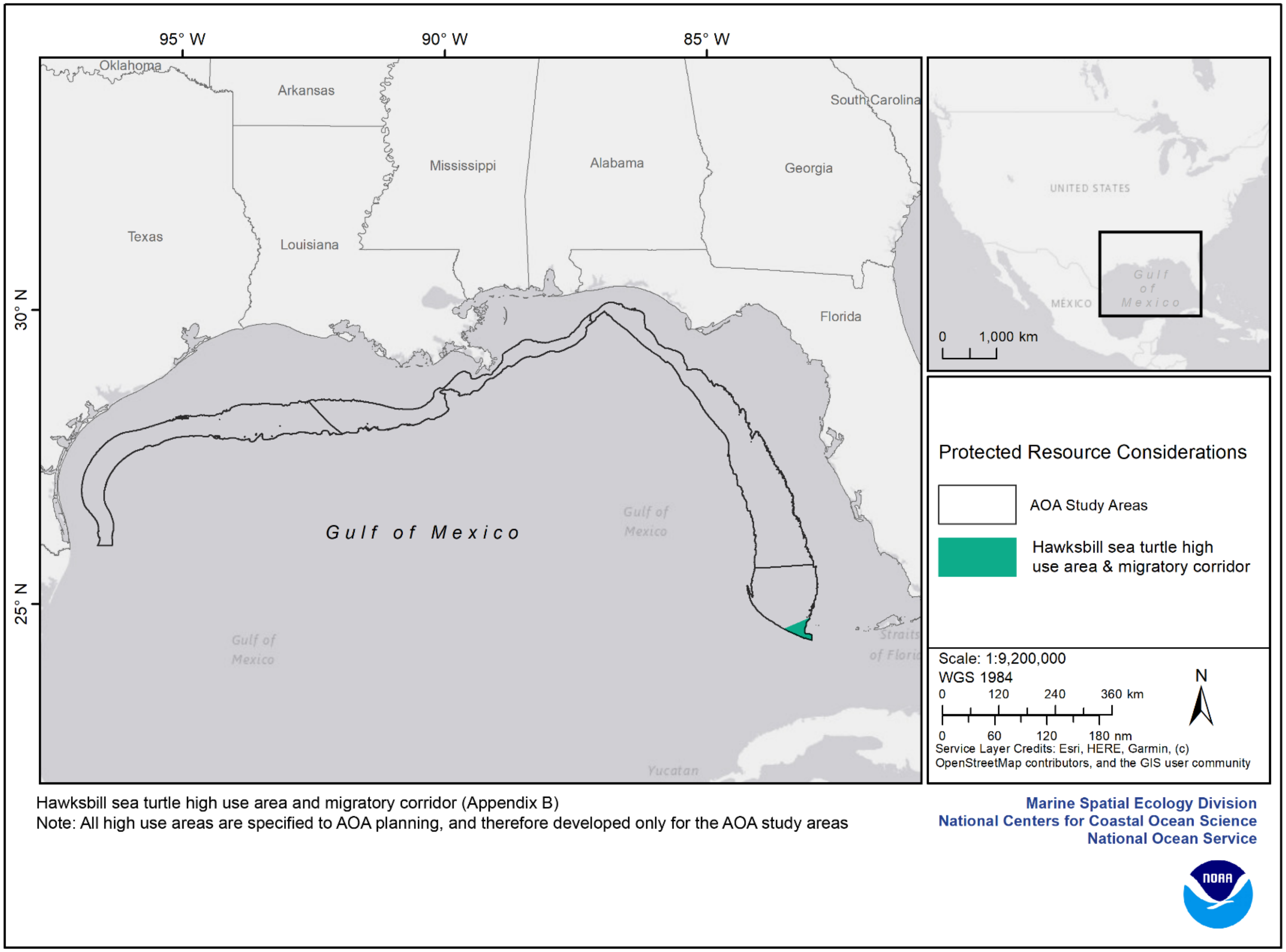


Figure 2.10. Hawksbill sea turtle high use area and migratory corridor used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

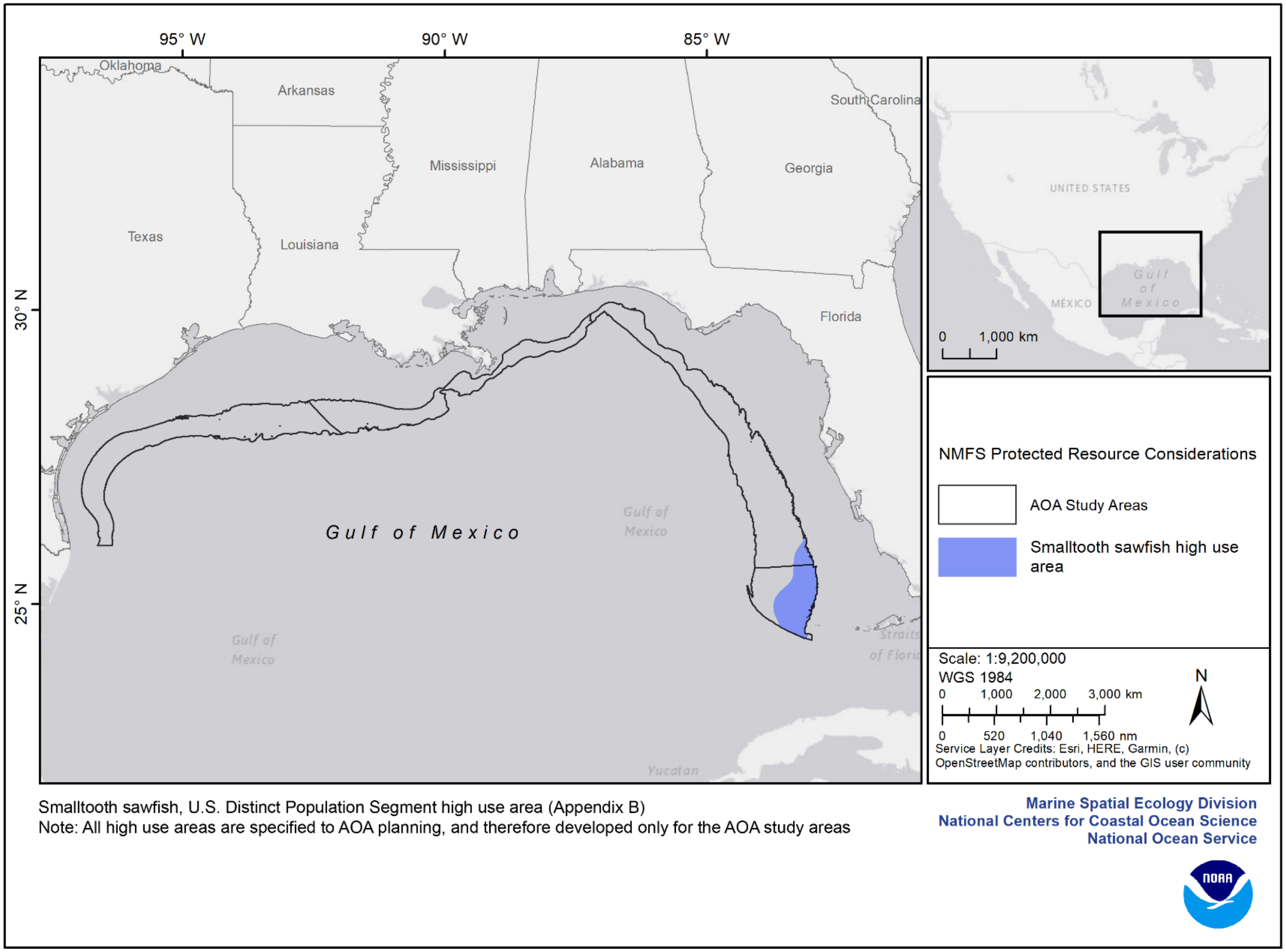


Figure 2.11. Smalltooth sawfish high use area used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

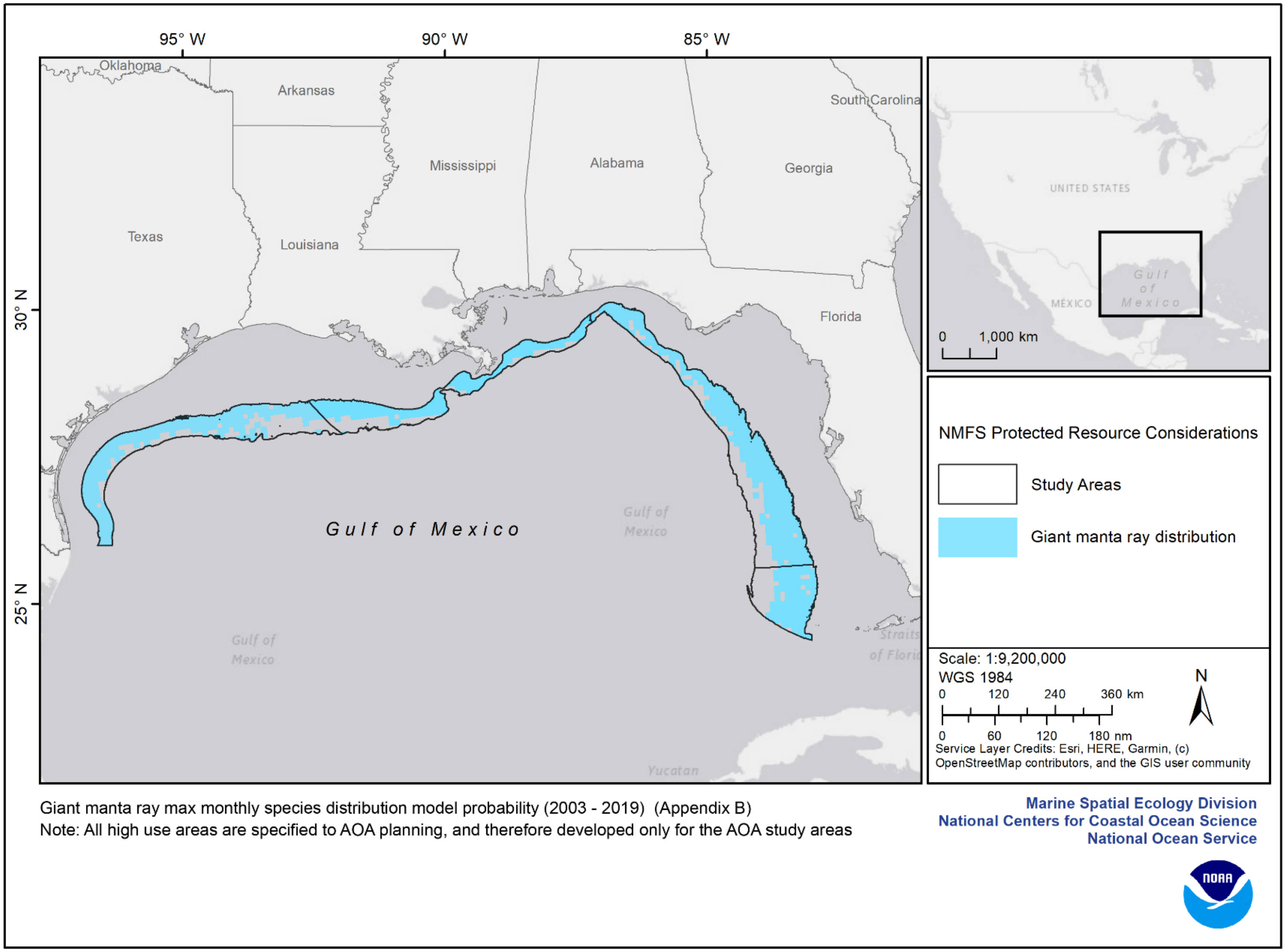


Figure 2.12. Giant manta ray area above the median maximum monthly species distribution model probability (2003 - 2019) used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

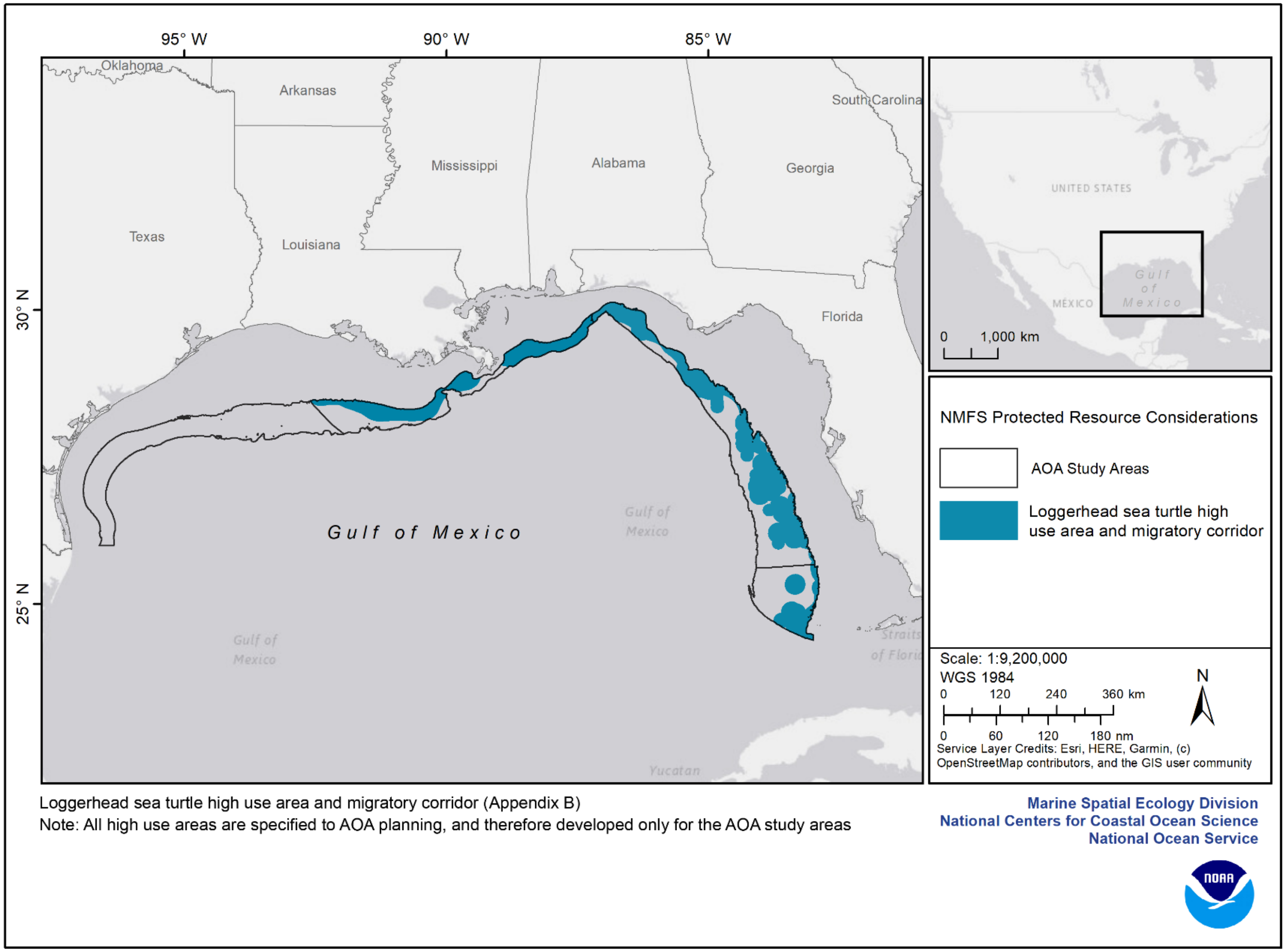


Figure 2.13. Loggerhead sea turtle (Northwest Atlantic Ocean Distinct Population Segment) high use areas used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

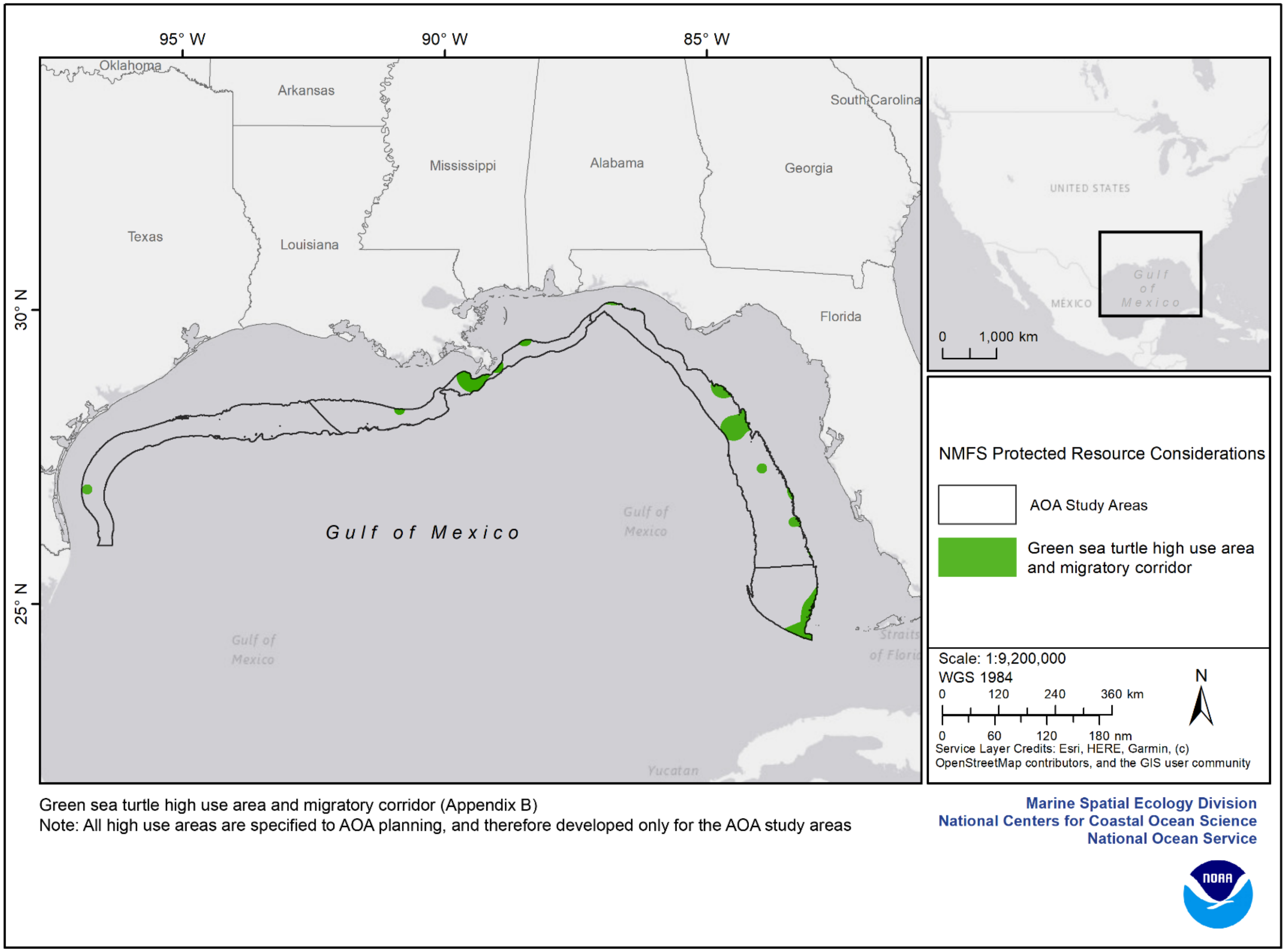


Figure 2.14. Green sea turtle (North Atlantic Distinct Population Segment) (Brugere et al. 2019) high use area used within the combined composite National Marine Fisheries Service Protected Resources data layer implemented within the Aquaculture Opportunity Area suitability analysis.

Bathymetry

The U.S. Coastal Relief Model (CRM) provides comprehensive bathymetric data at 3 arc-second horizontal resolution (~90 x 90 m pixels) for the Gulf of Mexico. For full bathymetric coverage for the Gulf of Mexico waters, the CRM requires download of (from east to west) the Florida and Eastern Gulf of Mexico, Volume 3 CRM (2001); Central Gulf of Mexico, Volume 4 CRM (2001); and Western Gulf of Mexico, Volume 5 CRM (2001).[12] Bathymetry data were clipped (i.e., data not overlapping the study areas were removed) to the study areas for ease of processing.

Vessel Traffic

Automatic Identification System (AIS) vessel traffic data are collected by the U.S. Coast Guard (USCG) to monitor real-time vessel information to improve navigation safety and support homeland security. Data such as ship name, purpose, course, and speed are acquired continuously from vessels through transmissions to 134 fixed stations associated with the Nationwide Automatic Identification System. AIS transponders are not required on every vessel, but are carried on most self-propelled vessels of 1,600 or more gross tons. AIS transponders are also required on

[12] https://w ww.ngdc.noaa.gov/mgg/coastal/crm.htm

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. Additionally, fishing industry vessels of various size and tonnage are required to carry AIS transponders to support commercial fishing and fish processing.[13]

Vessel traffic data from 2015 through 2020 were acquired and processed for the AOI.[14] Tracklines for each vessel were created from the transmission points, with points not being connected if greater than 1.6 km (1 mi) apart or longer than 30 minutes apart in time. The vessel traffic tracklines were categorized by vessel type (cargo, fishing, military, other, passenger, pleasure and sailing, tanker, tug and tow).[15] The 2019 vessel traffic data were used in the suitability model, with the number of vessels transiting a grid cell being counted for the entire year. Vessel traffic was displayed on maps using categories created with quantiles to maximize contrast and ease interpretation of high and low traffic areas. For the within- and among-precision siting models, mean vessel traffic from 2015 through 2019 for transits through the option were utilized. The COVID-19 pandemic, beginning in late February/early March 2020, resulted in impacts to global and regional vessel traffic patterns. Therefore, 2020 vessel traffic data were not used in the suitability model or the precision siting model as they do not necessarily reflect regular traffic patterns over time; however, data were used for reference within characterization for AOA options, as deviations that occurred are important for future aquaculture planning.

Limitations exist when utilizing AIS vessel data. For instance, certain vessels are not required by regulations to carry AIS transponders (e.g., smaller recreational vessels); therefore, not all vessel traffic is represented within the dataset. Additionally, an important caveat to the multi-year AIS mean transit data used in precision siting is that requirements for vessels to equip AIS transponders vary over time with changing regulations. In general, requirements have increased for the type and number of vessels in the dataset making it difficult to ascertain the absolute change in traffic over time within a given area.

[13] https://www.navcen.uscg.gov/?pageName=AISRequirementsRev#Operations
[14] https://marinecadastre.gov/ais/
[15] https://api.vtexplorer.com/docs/ref-aistypes.html

Deep-sea Coral Observational Data

Deep-sea coral observations for the Gulf of Mexico were obtained from the NOAA Deep-sea Coral Data Portal.[16] NOAA Deep-sea Coral Research and Technology Program (DSCRTP) recommended use of the post-1985 presence data on a select group of corals (gorgonians; stony branching, black, and lace corals; and *Hexactinellid* sponges), as this subset represent the most ecologically relevant benthic epifauna. A setback of 1,000 m was applied because deep-sea corals are associated with ecologically-sensitive habitats.

[16] https://deepseacoraldata.noaa.gov/metadata-records/iso-dscrtp-national-db

Fish Havens

Fish havens are defined as artificial reefs 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). Fish haven boundary data were extracted from the NOAA electronic navigational chart (ENC) using the ENC Direct to GIS tool. The extracted features were quality assured by overlaying the features onto the ENC within ArcGIS Pro and performing manual checks to ensure polygons lined up with those on navigation charts. As recommended by the USACE, a setback of 500 ft (152 m) was applied to preserve ecosystems associated with fish havens and artificial reefs, and to avoid recreational user activity for AOA planning.

Oceanographic Data

For each option at the surface, 10 m (33 ft), and near bottom depths, the water temperature, salinity, and oceanographic currents were evaluated using the Navy Coupled Oceanographic Model (NCOM) regional American Seas model at 3-hr intervals from January 2016 through December 2020. The daily mean water temperature and salinity were calculated and assessed as a time series for the period available. Oceanographic current magnitude and direction were examined using the percent occurrence the current was moving in a given direction. In addition, the percent occurrence of wind speed and wind direction was evaluated for all options, using wind data from the North American Regional Reanalysis (NARR) at 3-hr intervals from January 1979 through December 2008. Data were evaluated for the frequency of occurrence when wind speed exceeded the threshold for small craft advisory (10.28 m/s, 20 kt). Percent occurrence of significant wave height (Hs) (the average wave height, from trough to crest, of the highest one-third of the waves) and direction was also evaluated, using wave data output from the MIKE 21 model for the Gulf of Mexico at 3-hr intervals from January 1979 through December 2008.

Water Quality Data

Water quality at each AOA option was assessed by examining nutrient concentration, chlorophyll-*a*, water clarity, and solar energy availability. The Esri Ecological Marine Units (EMU) data set was used to examine mean dissolved nutrient and oxygen levels at the surface for nitrate, phosphate, and silicate (Sayre et al. 2017). The EMU data have excellent vertical resolution (i.e., 102 depth levels), however the horizontal resolution was relatively coarse at 0.25 arc degrees. Although these were the best available data from a water column perspective for this planning exercise, additional in situ data will be necessary for further detail and verification. Chlorophyll-*a* is a specific chlorophyll pigment observed in photosynthesizing organisms such as phytoplankton. Measurements of Chl-*a* concentration are a common approximation for phytoplankton presence. Monthly climatological means of Chl-*a* from 2016 to 2020 were estimated using satellite data from the Suomi-NPP visible infrared imaging radiometer (VIIRS) sensor and were evaluated for seasonal variance. Similarly, satellite data were used to assess spatial light attenuation and water clarity. The diffuse light attenuation coefficient at wavelength 490 nm, Kd(490), is a useful indicator of inorganic and organic turbidity in the water column (Tomlinson et al. 2019). High Kd(490) values indicate shallow attenuation depth and lower clarity of ocean water. The diffuse light attenuation coefficient of photosynthetic active radiation (PAR) at wavelengths 400 to 700 nm, Kd(PAR), is useful for determining the amount of light available for photosynthesis. Here we represent Kd(PAR) as percent light transmissivity (0 – 100%) at 1 m water depth. To calculate the percentage, raw data from 2010 to 2018 for Kd(PAR) were downloaded from National Aeronautics and Space Administration (NASA)[17] and the ratio of radiance at 1 m to solar radiance was calculated.

Commercial and Recreational Fishing Data

Commercial and recreational fishing are important economic drivers for the Gulf of Mexico region (NMFS 2021a), and considerations of use patterns are important for ocean planning and conflict reduction with this established and socio-economically important industry. Data were predominantly received as point data from cooperating programs across NOAA. Fishing data are considered Controlled Unclassified Information (CUI) requiring specific measures for handling, safeguarding, and controlled protection of confidential data components. Under NOAA dissemination. Data and maps within this technical report reflect

[17] https://oceancolor.gsfc.nasa.gov/data/viirs-snpp/

the resolution at which data can be displayed to the public to ensure Administrative Order 216-100[18] to protect confidential fisheries statistics, NMFS uses a rule of three or more submitters in a given stratum before it is considered suitable for public display. This process prevents any data identified with any individual or operation from being disclosed. Data not meeting these criteria were removed from map visualizations. To further maintain confidentiality, all maps containing fishing data were categorized by quantiles into descriptive categories, "Low," "Moderately Low," "Moderate," "Moderately High," or "High" for map visualization (i.e., the descriptive "Low" category would contain the lower quantile, while the "High" category would contain the upper quantile). Within the maps, standardized colors were used to depict categories, with blue representing "Low," light blue "Moderately Low," yellow "Moderate," orange "Moderately High," and red "High." NMFS data were used at the resolution received from the data provider for the suitability model and displayed at the appropriate resolution for public disclosure. Data processing steps for data used in the AOA suitability model were summarized for each fishery dataset received.

Commercial Shrimp Electronic Logbook Data

NMFS Southeast Fisheries Science Center (SEFSC) provided shrimp industry data collected from vessels operating with a NMFS Gulf of Mexico Shrimp Commercial Fishing Permit and participating in the vessel monitoring program. Vessel data (i.e., trawl vessels) were collected from electronic logbook (ELB) records from 2004 to 2019. Approximately 50 to 60% of vessels are required to participate in the ELB program; however, participation has been variable over the years since inception. The ELB records a signal

[18] https://www.st.nmfs.noaa.gov/Assets/intranet2015/pdf/NOAA_216-100_Form.pdf

at 10-minute intervals indicating vessel location and speed over ground. For trawl fisheries, data were categorized into an assumed activity, where 1.0 to 2.0 m/s (1.9 to 3.9 knots) was the speed over ground when trawling is assumed to be occurring. All vessel transmissions where trawling was assumed to be occurring were extracted from the full dataset. Tracklines were then created from the transmission points, with points not being connected if greater than 1.6 km (1.0 mi) apart or if the time difference was greater than 30 minutes. Additionally, tracklines that crossed land features were removed. The sum of vessel transits through each grid cell was calculated for each year, and the total sum of all years used in the suitability model.

Reef Fish Bandit Gear Fishing Data

Vessels targeting reef fish in the Gulf of Mexico often employ bandit reels and handlines for the vertical line fishery. Bandit reels are a preferred gear based on their use in the industry and efficiency in operation. Although many reef fish species are retained, the predominant target species are groupers and snappers (Scott-Denton et al. 2011). NMFS SEFSC with support from NMFS Office of Law Enforcement (OLE) provided gridded point data with predicted fishing locations from 2007 to 2019. The sum values for each of the points were aggregated to a grid (1 km x 1 km) for modeling purposes.

Reef Fish Longline Gear Fishing Data

In contrast to the vertical line fishery for reef fish, some vessels utilize bottom longlines to target the species among the same reef fish complex. For example, longliners off the coast of Florida generally target red grouper in shallow waters, and yellowedge grouper, tilefish, and sharks in deeper waters (Scott-Denton et al. 2011). NMFS SEFSC with support from NMFS OLE provided gridded point data with predicted fishing locations for 2007 to 2019. The sum values for each of the points were aggregated to a new grid (1 km x 1 km) for modeling purposes.

Southeast Region Headboat Survey Data

The NMFS Southeast Region Headboat Survey (SRHS) samples recreational headboats, where anglers pay a per-head fee to target reef fish and coastal migratory pelagic species (Fitzpatrick et al. 2017). Boats typically carry more than six passengers, ranging as high as 100 passengers. Data consist of trip-level logbook records submitted by captains. NMFS has collected the data since 1986 in the Gulf of Mexico. The SRHS ELB was implemented in 2013 to improve data collection. In addition to information on the catch and operations, captains are required to report the geographic location of fishing activity in latitude and longitude degrees and minutes. The NMFS SEFSC provided gridded point data with degrees and minutes of positional data representing where boats were fishing. The point dataset was converted to a grid (0.0083333° x 0.0083333°). The sum of the points within each grid cell was calculated for each year and a sum for all years (2014 to 2020) was calculated and used in the suitability model.

Highly Migratory Species Pelagic Longline Gear Observer Data

NMFS SEFSC with support from NMFS OLE provided raw data from Highly Migratory Species (HMS) Observers with a temporal range from 1993 to 2019, and latitude and longitude in degrees and minutes. These data are a subset of information of HMS fishing vessels (approximately 20% of the industry) in the U.S. Gulf of Mexico and do not reflect the entire industry. Using GIS, a .csv file was converted into a point shapefile, with the "begin haul" location used to represent fishing trips. Overlapping points were dissolved into a single layer and the count was calculated for each point (i.e., one point = 1 fishing trip, five overlapping points = 5 fishing trips). A setback (i.e., buffer) of 0.0083333° was used for each of the points. The setback was set at 820-m (1,260-ft) as a grid cell equivalent for a more conservative approach. The Minimum Bounding Geometry tool was run on the layer, using the "Envelope" Geometry type to turn the circle buffer into a square. Observer data are not displayed in map visualizations because they do not meet data confidentiality requirements for publication.

Menhaden Fishery Data

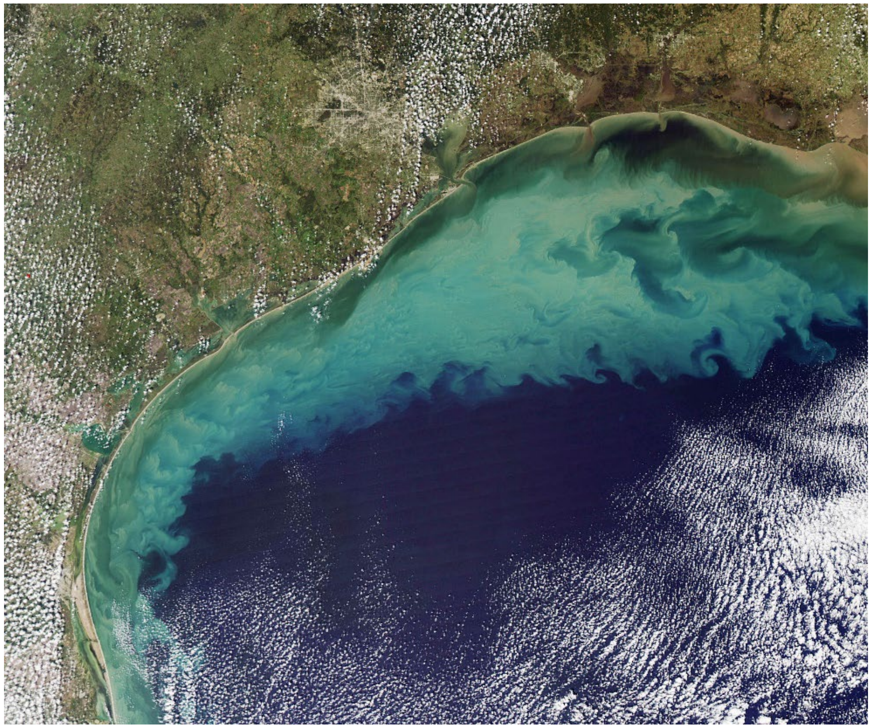
NMFS SEFSC provided point data on the menhaden fishery. Each set had an associated 5-digit code for location. This corresponded with a latitude/longitude that was the centroid of the 10-minute x 10-minute grid cell in which the set occurred. These data were plotted for the years 2000 to 2016. We re-created the 10-minute x 10-minute grid and estimated the total number of sets occurring in each grid cell for the given time period.

Live Rock Aquaculture

NMFS SERO provided point data on live rock permitted operations in U.S. federal waters for 2021. A setback of 1,000-m (3,280-ft) was applied, as live rock farms were treated similarly to hardbottom habitat with potentially sensitive ecosystems.

Harmful Algal Blooms

Observational point data were compiled to demonstrate the historical distribution of *Karenia brevis* in the Gulf of Mexico. Consistent sampling occurred from 2000 to 2018, and therefore, this data period was used to determine areas of consistent annual bloom levels above cellular concentrations lethal to fish (100,000 cells per L) (Quick and Henderson 1974; Gannon et al. 2009). Frequency of blooms (number of years with lethal-to-fish blooms) were visualized to indicate areas of potential concern for current and future impacts to fish species occupying these areas. Data were processed to show patterns and trends over time for an ocean area. Areas with no hexagons represent areas where samples were not collected, whereas hollow hexagons depict areas with sampling where no *K. brevis* was detected (Figure 2.15). Importantly, areas with no bloom occurrence in these data should not be interpreted as if no bloom has or will occur.



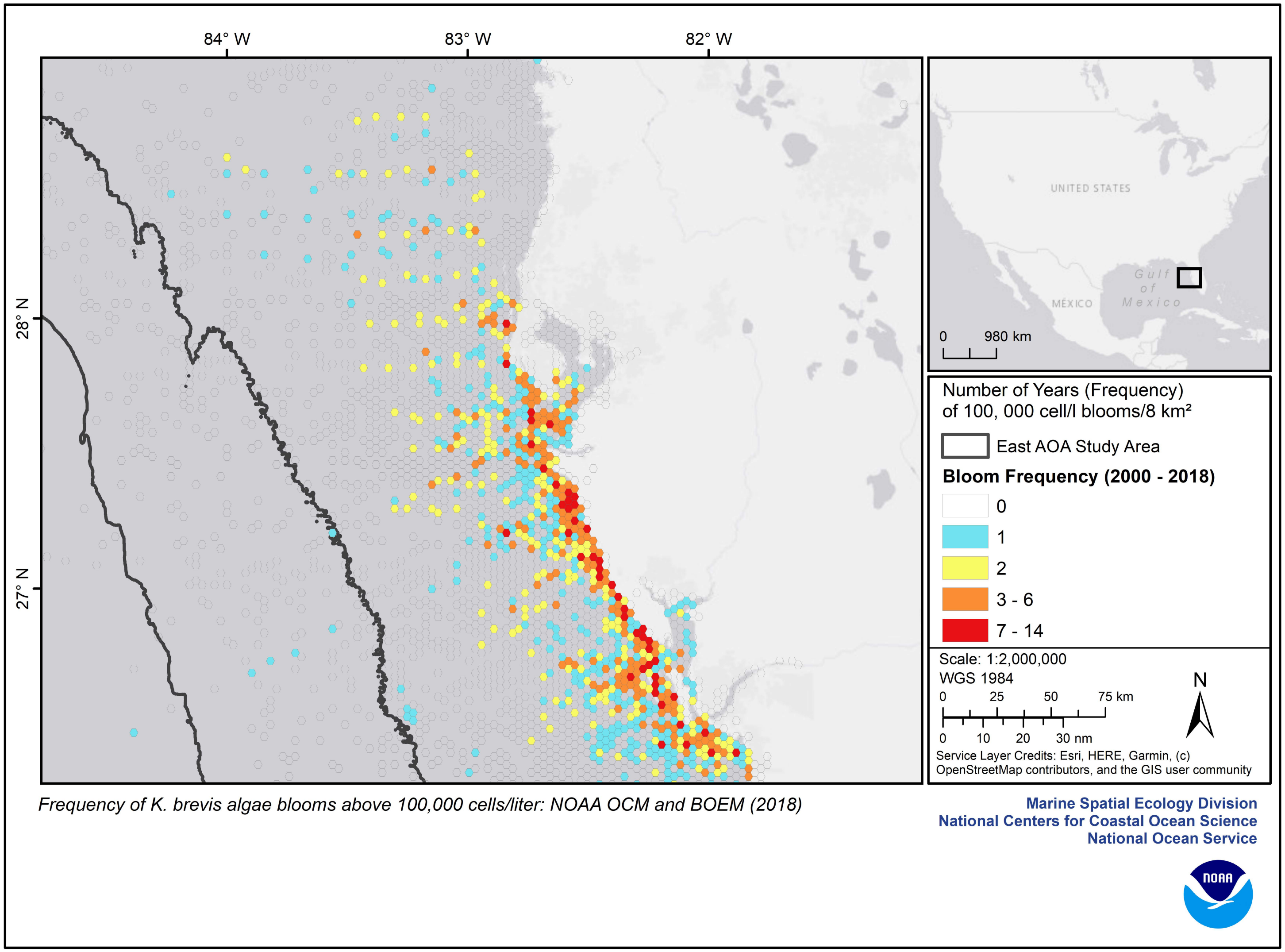
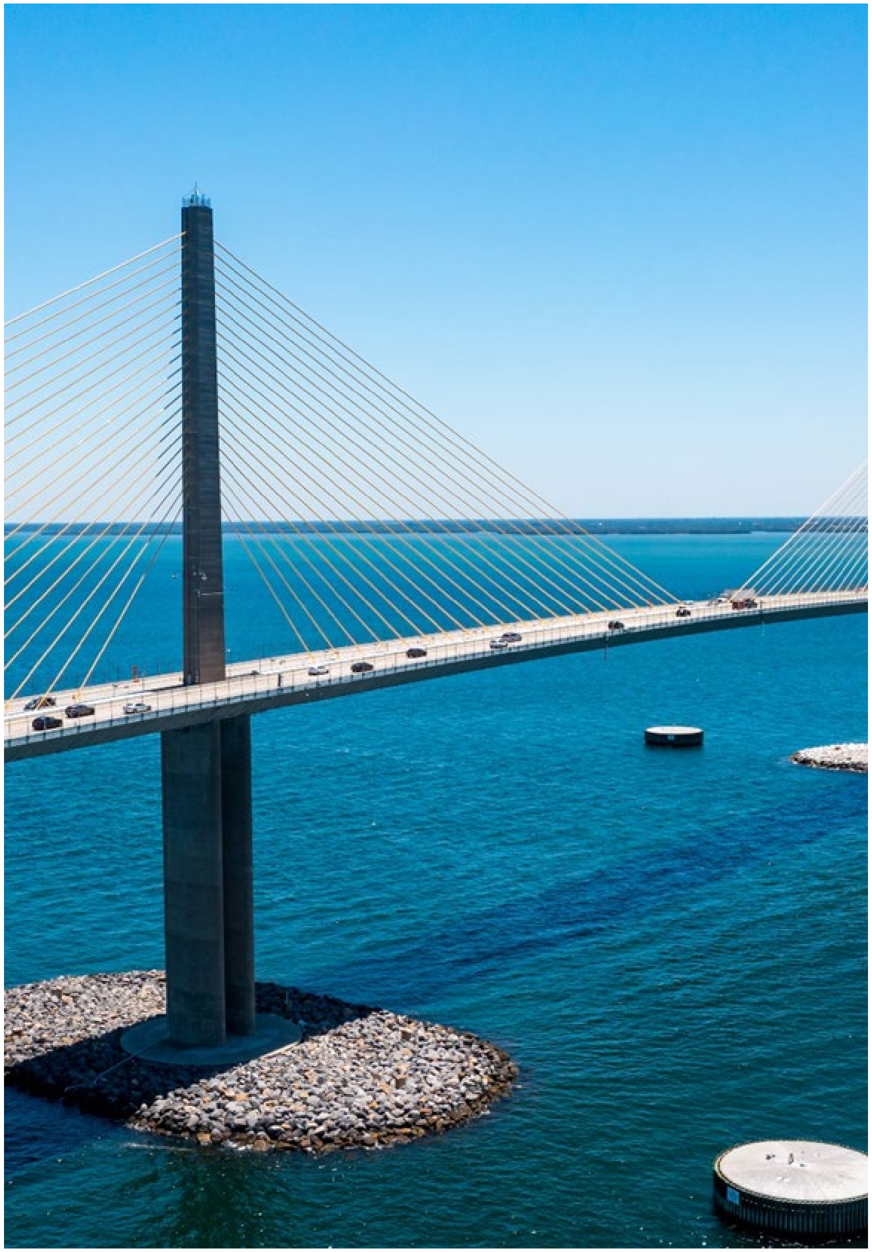


Figure 2.15. Example of data processing outputs for frequency (number of years per 8-km² (2.3 nm²) hexagonal area) of *Karenia brevis* concentrations lethal to fish (100,000 cells per L). Frequency of blooms (number of observations per hexagon) over time aids in visualization of patterns and trends of lethal blooms over a discrete area and time.



Suitability Analysis

A gridded relative suitability analysis, commonly used in a Multi-Criteria Decision Analysis, was performed to identify the grid cells with the highest suitability for aquaculture development in the study areas (Longdill et al. 2008; Radiarta et al. 2008; Gimpel et al. 2015; Bwadi et al. 2019). Spatial data layers included in the suitability analysis identify space-use conflicts and environmental constraints such as active national security areas, maritime navigation, ocean industries, and natural resource management. We utilized a submodel structure to capture ocean use and conservation concerns including national security, natural and cultural resources, industry, navigation, and transportation, and aquaculture and fishing. Data layers with no compatibility with aquaculture development (e.g., shipping fairways) were captured in the list of incompatible constraints and removed from further analysis due to known incompatibility with aquaculture (Figure 2.16). This model structure ensures that each submodel is given equal weight in the final suitability model regardless of how many data layers are present in each submodel.

Final suitability scores are presented within maps as categories (“Unsuitable,” “Low,” “Moderate,” “High”) grouped by quantiles of the final scores, with all scores of 0 being in the “Unsuitable” category and represented by the color red. Within the suitability submodel and final model maps, standardized colors were used to depict categories, with orange representing “Low,” yellow “Moderate,” and blue “High” suitability and coinciding with each proportion of quantile values. With all suitability maps, relative categories still represent values ranging from 0 to 1, with the “Low” category representing the lowest quantile of the data, “Moderate” the middle quantile, and “High” the upper quantile. Presenting categories rather than actual suitability scores simplifies interpretation of results and provides optimal contrast among categories. Further, distribution of scores varies among the suitability submodels (e.g. number of data layers, score range of data distribution depicted); for example, in one submodel a score of 0.5 could be classified as “High,” while in another submodel or region a score of 0.5 could be “Low” because the scores are relative. Thus, suitability scores among the different study areas and different submodels should not be compared, as the score is unique to each study area and submodel.

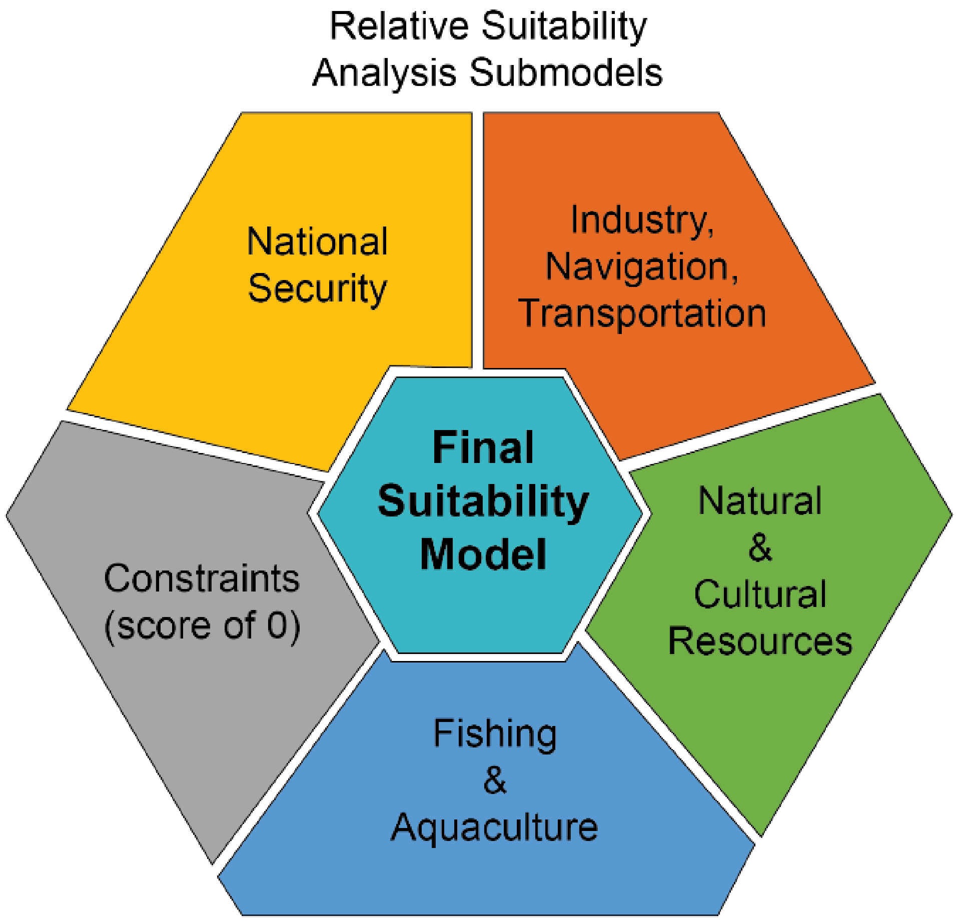


Figure 2.16. Overview of relative suitability model design and the submodel components. The constraints submodel includes all data layers with a score of 0; these data layers were removed before the remaining submodel scores were calculated.

Scoring Categorical Data

Categorical datasets (i.e., in which data are distinct and separate groups) were evaluated to determine if a constraining feature was present or absent in each grid cell. If a feature was absent, a score of 1 was given, otherwise a score of 0 or 0.5 was assigned (0 = unsuitable for aquaculture; 0.5 = potentially unsuitable for aquaculture), which was determined by the feature's relative certainty of compatibility with aquaculture. For example, a regulated shipping lane that experiences regular traffic would be deemed unsuitable for aquaculture and thus receive a score of 0. On the other hand, within certain military operating areas uncertainty exists, and even if a suitable location is found, additional communications and resources may be required; thus, a score of 0.5 would be given.

After all data were gathered and integrated into the greater data inventory, certain data layers with constraints also required, either by agency action or for safety and security reasons, setbacks from the discrete/categorical layer. If a setback was established by a permitting authority as a "no-go" area, a score of 0 was applied as a setback (e.g., fish haven and a 500-ft setback from the outer boundary, all scored as 0). Setbacks were also established based on governance, policy, and regulations, and taking the most conservative setback distance (i.e., buffer) to avoid interactions with other ocean activities. If there was potential for interaction with a transient resource, but uncertainty remains as to what that interaction would be with aquaculture infrastructure, then a score of 0.5 was assigned.

Scoring Numerical Data

Numerical data (i.e., data that can represent any value within a given range) (e.g. continuous data) were reclassified to a 0 to 1 scale using a linear function or fuzzy logic membership functions (Vincenzi et al. 2006; Vafaie et al. 2015; Theuerkauf et al. 2019b; Landuci et al. 2020). Fuzzy logic membership functions are similar to a linear or non-linear functional approach; however, use of fuzzy logic membership functions accounts for additional uncertainty when assigning scores to the data (Kapetsky and Aguilar-Manjarrez 2013). The function used for each numerical dataset was chosen to reflect that dataset's known association or compatibility with aquaculture. The range of the numerical dataset (i.e., the minimum and maximum values) were used as the inputs for creating the function, and were modified to ensure no output value would equal 0. No 0 values were allowed because no observed value in any numerical dataset used was known to be completely incompatible with aquaculture.

The distance to shore parameter is the only dataset where a standard linear function was used, because of high certainty that the closer a location is to shore the more suitable an aquaculture operation is regarding logistics and cost (Gentry et al. 2017). All other numerical datasets, except the wave period, were reclassified using the Z-shaped membership function from the Scikit-Fuzzy (Version 0.4.2) Python library, where the higher the observed value (vessel traffic, fishing effort) the lower the compatibility with aquaculture, and thus the lower the suitability score (Warner et al. 2019; Equation 2.2; Figure 2.17). The wave period dataset was reclassified with the S-shaped membership function from the Scikit-Fuzzy (Version 0.4.2) Python library. Shorter wave periods are less desirable than longer wave periods; therefore, the shorter the wave period the lower the suitability score, and the longer the wave period the higher the suitability score (Warner et al. 2019; Equation 2.3; Figure 2.18).

Categorical and numerical datasets used in scoring for the relative suitability analysis are in Tables 2.5 through 2.8, with a detailed list and rationale for each score found in Appendix C.

Equation 2.2. The Z-shaped membership function from the Scikit-Fuzzy (Version 0.4.2) python library used to rescale numerical data to a 0 to 1 range, with input values modified to ensure no 0 values in the output (Warner et al. 2019). Equation of Z-shaped membership function is based on the MathWorks documentation example (MathWorks 2021)

.

$$zmf(x;a,b) = \begin{Bmatrix} 1, & x \leq a \\ 1 - 2\left(\frac{x-a}{b-a}\right)^2, & a \leq x \leq \frac{a+b}{2} \\ 2\left(\frac{x-b}{b-a}\right)^2, & \frac{a+b}{2} \leq x \leq b \\ 0, & x \geq b \end{Bmatrix}$$

$x =$ *Input value to be rescaled*

$a =$ *Function begins falling from 1 (Minimum value of dataset)*

$b =$ *Function attains 0 (Maximum value of dataset +1 to ensure no 0 values in output)*

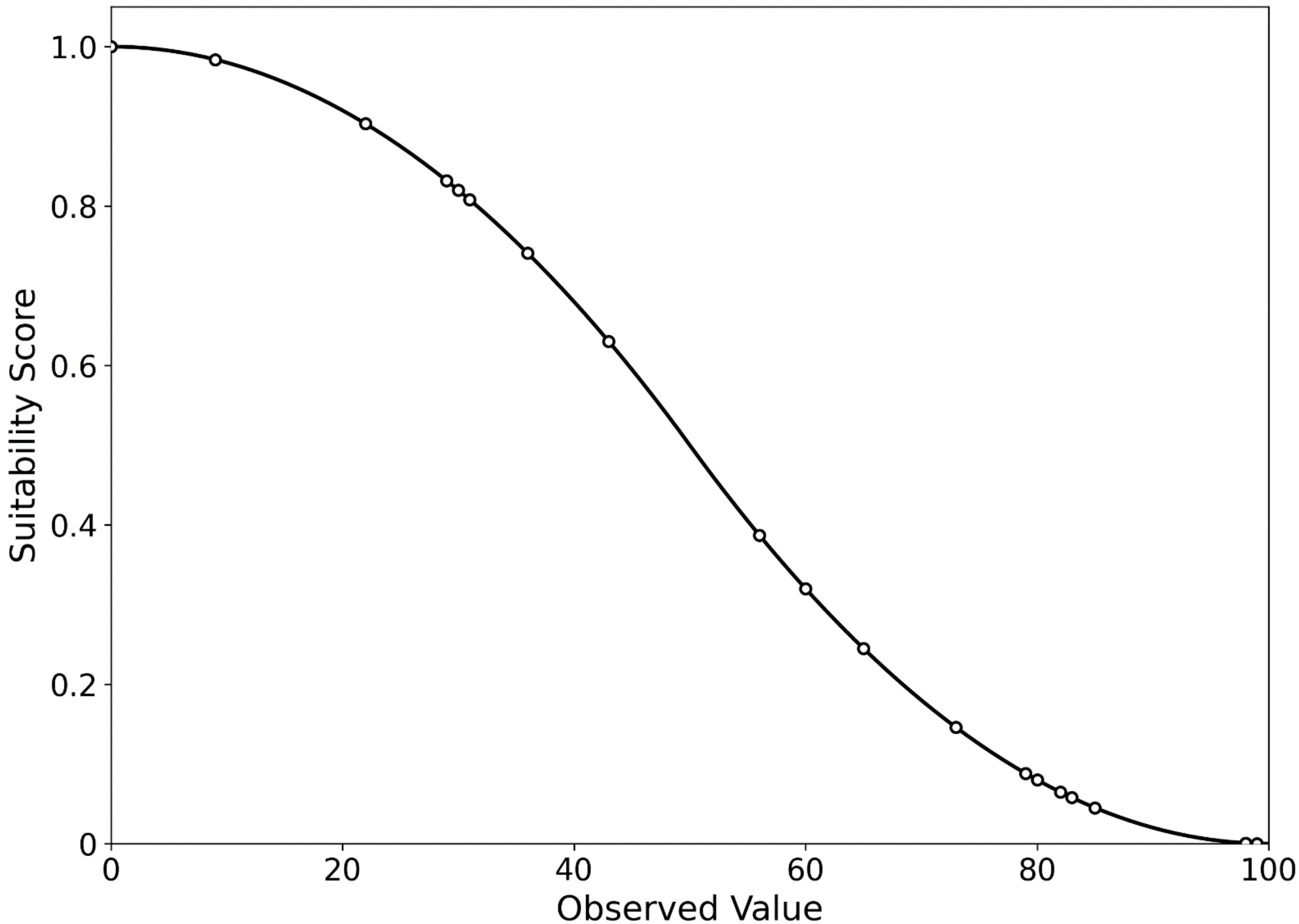


Figure 2.17. Example of a hypothetical Z-shaped membership function, with the minimum observed value being 0 and the maximum observed value being 99. However, the total range of the function goes to 100, as 1 was added to 99 when creating the function to ensure no observed values would be rescaled to 0. For example, the points on the line indicate the intersection of an observed value (e.g., vessel traffic) and the corresponding score to which it would be rescaled from the function.

Equation 2.3. The S-shaped membership function from the Scikit-Fuzzy (Version 0.4.2) python library were used to rescale numerical data to a 0 to 1 range, with input values modified to ensure no 0 values in the output (Warner et al. 2019). Equation of S-shaped membership function is based on the MathWorks documentation example (MathWorks 2021).

$$smf(x;a,b) = \left\{ \begin{array}{ll} 0, & x \leq a \\ 2\left(\dfrac{x-a}{b-a}\right)^2, & a \leq x \leq \dfrac{a+b}{2} \\ 1-2\left(\dfrac{x-b}{b-a}\right)^2, & \dfrac{a+b}{2} \leq x \leq b \\ 1, & x \geq b \end{array} \right\}$$

$x =$ *Input value to be rescaled*

$a =$ *Function rises from 0 (Minimum value of dataset -1 to ensure no 0 values in output)*

$b =$ *Function reaches value of 1 (Maximum value of dataset)*

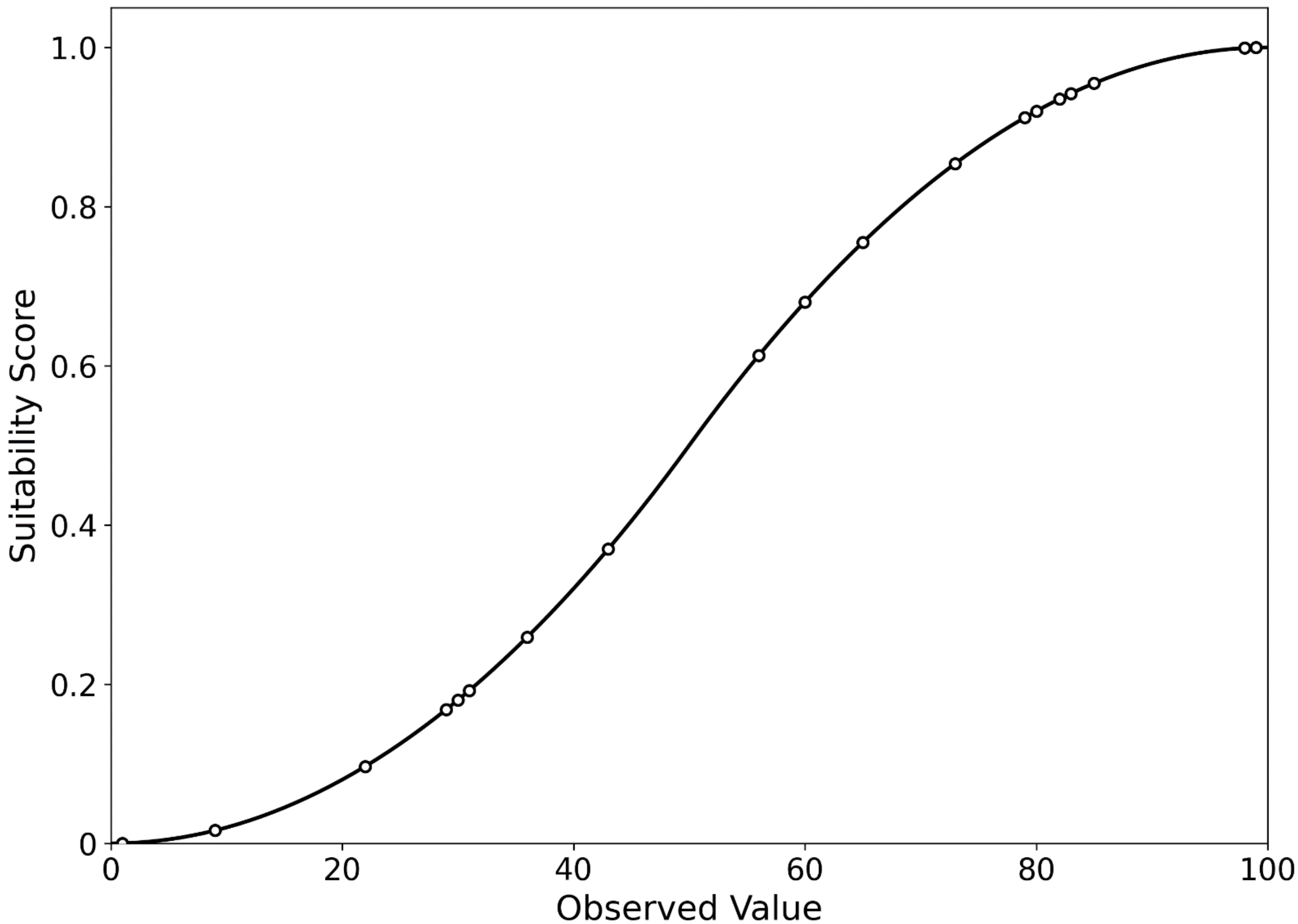


Figure 2.18. Example of a hypothetical S-shaped membership function, with the minimum observed value being 1 and the maximum observed value being 99. In this case, the total range of the function goes from 0 to 99, as 1 was subtracted from 1 when creating the function to ensure no observed values would be rescaled to 0. For example, the points on the line indicate the intersection of an observed value (e.g., vessel traffic) and the corresponding score to which it would be rescaled from the function.

Table 2.5. National Security data layers included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with an 'x' denoting whether it occurred in the West (W), Central (C), East (E), or Southeast (SE) study area. All zero values were included in the constraints submodel. A dash denotes when a dataset did not overlap or intersect a specific study area. Guidance on compatibility with military activities was provided through consultations with the Department of Defense (see Appendix D).

National Security Dataset	Score	W	C	E	SE
Military Operating Area - Corpus Christi	0.5	x	-	-	-
Military Operating Area - Eglin Gulf Test and Training Range	0.5	-	x	x	x
Military Operating Area - Key West	0.5	-	-	-	x
Military Operating Area - New Orleans	0.5	-	x	-	-
Military Operating Area - Pensacola	0.5	-	x	x	-
Military Training Routes (MTR) - Flight Corridors with 12-nm setback	0.5	-	x	-	-
Special Use Airspace - A381	0.5	-	x	-	-
Special Use Airspace - EWTA-2A	0.5	-	-	x	-
Special Use Airspace - EWTA-2B	0.5	-	-	x	-
Special Use Airspace - EWTA-5	0.5	-	-	x	-
Special Use Airspace - MOA US 02174	0.5	-	-	-	x
Special Use Airspace - MOA US 02416 and 02417	0.5	-	x	-	-
Special Use Airspace - W147A and W147B	0.5	x	-	-	-
Special Use Airspace - W147C	0.5	x	-	-	-
Special Use Airspace - W147D	0.5	x	-	-	-
Special Use Airspace - W148A and W148B	0.5	-	x	-	-
Special Use Airspace - W155A	0.5	-	x	x	-
Special Use Airspace - W155B	0.5	-	x	-	-
Special Use Airspace - W228A	0.5	x	-	-	-
Special Use Airspace - W228B	0.5	x	-	-	-
Special Use Airspace - W228C	0.5	x	-	-	-
Special Use Airspace - W228D	0.5	x	-	-	-

National Security Dataset	Score	W	C	E	SE
Special Use Airspace - W54A	0.5	-	x	-	-
Special Use Airspace - W54B and W54C	0.5	-	x	-	-
Special Use Airspace - W59A	0.5	x	x	-	-
Special Use Airspace - W59B	0.5	x	x	-	-
Special Use Airspace - W92	0.5	-	x	-	-
Danger Zones and Restricted Areas (33 CFR § 334.2)	0	-	-	x	x
Military Operating Area - Panama City	0	-	-	x	-
Special Use Airspace - W151A	0	-	-	x	-
Special Use Airspace - W151B	0	-	-	x	-
Special Use Airspace - W151D	0	-	-	x	-
Special Use Airspace - W168	0	-	-	x	-
Special Use Airspace - W174A	0	-	-	x	x
Special Use Airspace - W174B(A)	0	-	-	-	x
Special Use Airspace - W470B	0	-	-	x	-
Special Use Airspace - W470C	0	-	-	x	-
Special Use Airspace - W470E	0	-	-	x	-
Special Use Airspace - W470F	0	-	-	x	-
Unexploded Ordnance (UXO) Points with 500-m setback	0	-	-	x	-
Unexploded Ordnance (UXO) Polygon	0	x	-	x	-

Table 2.6. Natural and Cultural Resources data layers included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with an 'x' denoting whether it occurred in the West (W), Central (C), East (E), or Southeast (SE) study area. All zero values were included in the constraints submodel. A dash denotes when a dataset did not overlap or intersect a specific study area. A guide for abbreviations and acronyms is provided in the front material.

Natural and Cultural Resources Dataset	Score	W	C	E	SE
Florida Keys National Marine Sanctuary	0.5	-	-	-	x
Flower Garden Banks National Marine Sanctuary	0.5	x	-	-	-
Protected Resource Consideration Combined Species Layer	0 - 1	x	x	x	x
Archaeologically Sensitive Areas	0	-	-	x	-
Artificial Reefs with 500-ft setback	0	x	x	x	-
AWOIS Wrecks Polluting, RULET Wrecks, ENC Wrecks and Obstructions, ENC Danger Wrecks with 500-ft setback	0	x	x	x	x
BOEM No Activity Zones with 1000-m setback	0	x	x	-	-
Coral 9 HAPC	0	x	x	-	-
Coral 9 HAPC (Regulated Areas)	0	x	x	-	x
Coral, Coral Reefs, Live or Hardbottom EFH HAPC	0	-	-	-	x
Deep-sea Coral and Sponge Observations (1985 to present) with 1000-m setback	0	x	x	x	x
Federally Managed Area Flower Garden Banks EFH HAPC	0	x	-	-	-
Federally Managed Areas Madison-Swanson, The Edges, and Steamboat Lumps	0	-	-	x	-
Federally Managed Area Pulley Ridge EFH HAPC	0	-	-	x	x
Federally Managed Area Tortugas Marine Reserve EFH HAPC	0	-	-	-	x
Low Relief Structures with 1000-m setback	0	x	x	-	-
Natural Reefs (e.g., Escarpments, Pinnacles) with 1000-m setback	0	x	x	x	x
NOAA Fish Havens with 500-ft setback	0	x	x	x	-
Potentially Sensitive Biological Features	0	x	x	-	-

Table 2.7. Industry and Transportation parameters included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with an 'x' denoting whether it occurred in the West (W), Central (C), East (E), or Southeast (SE) study area. All zero values were included in the constraints submodel. "Cont." denotes continuous data (0 – 1). A dash denotes when a dataset did not overlap or intersect a specific study area.

Industry, Navigation, and Transportation Parameter	Score	W	C	E	SE
Federal Lightering (Rendezvous Areas)	0.5	x	x	-	-
AIS Vessel Traffic 2019 – Cargo	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Fishing	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Military	Cont.	-	x	x	-
AIS Vessel Traffic 2019 – Other	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Passenger	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Pleasure and Sailing	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Tanker	Cont.	x	x	x	x
AIS Vessel Traffic 2019 – Tug and Tow	Cont.	x	x	x	x
Aids to Navigation (Beacons and Buoys) with 500-m setback	0	x	x	x	-
Anchorage Areas (Used/Disused)	0	-	x	-	-
Environmental Sensors and Buoys with 500-m setback	0	x	x	x	x
Lease Blocks with Significant Sediment Resources	0	-	x	-	-
Ocean Disposal Sites	0	-	x	-	-
Oil and Gas Active Leases	0	x	x	x	-
Oil and Gas Boreholes, Test Wells, and Wells with 500-m setback	0	x	x	x	-
Oil and Gas Drilling Platforms with 500-m setback	0	x	x	-	-
Oil and Gas Pipelines with 500-m setback	0	x	x	x	-
Shipping Fairways and Regulations with 500-m setback	0	x	x	x	-
Submarine Cables with 500-m setback	0	x	x	-	-

Table 2.8. Fishing and Aquaculture parameters included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with an 'x' denoting whether it occurred in the West (W), Central (C), East (E), or the Southeast (SE) study area. All zero values were included in the constraints submodel. "Cont." denotes continuous data (0 – 1). A dash denotes when a dataset did not overlap or intersect a specific study area.

Fishing and Aquaculture Datasets	Score	W	C	E	SE
Commercial Shrimp Electronic Logbook Data (2004 - 2019)	Cont.	x	x	x	x
Highly Migratory Species Pelagic Longline Gear Observer Data (1993 - 2019)	Cont.	x	x	-	x
Menhaden Fishery Data (2000 - 2016)	Cont.	-	x	-	-
Reef Fish Bandit Gear Fishing Data (2007 - 2019)	Cont.	x	x	x	x
Reef Fish Longline Gear Fishing Data (2007 - 2019)	Cont.	x	x	x	x
Southeast Region Headboat Survey Data (2014 - 2020)	Cont.	x	x	x	x
Live Rock Aquaculture with 500-m setback	0	-	-	x	-

Calculation of Suitability Scores

Each data layer was scored on a 0 to 1 scale, with scores approaching 0 representing low suitability and 1 representing high suitability relative to the other grid cells for aquaculture. Any grid that contained a data layer with a 0 score (i.e., constraints data layer) was deemed unsuitable for aquaculture, and not considered further in the analysis. Next, a final suitability score was calculated for each submodel by taking the geometric mean of all scores within each grid cell. The geometric mean of the four submodels was used to calculate a final overall suitability score. The geometric mean (Equation 2.4) was chosen because it grants equal importance to each variable (Bovee 1986; Longdill et al. 2008; Silva et al. 2011; Muñoz-Mas et al. 2012). Furthermore, all data layers and submodels had equal weight within the suitability model.

Equation 2.4 Geometric mean equation implemented for final suitability model scoring, after 0 values (constraints submodel) were removed.

$$\textit{geometric mean AOA suitability model} = \sqrt[4]{x_1 \cdot x_2 \cdot x_3 \cdot x_4}$$

$$x_1 = \textit{national security submodel}$$
$$x_2 = \textit{natural and cultural resources submodel}$$
$$x_3 = \textit{industry, navigation, and transportation submodel}$$
$$x_4 = \textit{fishing and aquaculture submodel}$$

Suitability Model Data and Submodel Constraints

After the suitability model was run for each study area, an analysis was performed to describe the data most influential (i.e., area removed by constraints) in removing or impacting the area for each submodel. A simple percentage of how many cells or how much area a particular variable was present in was calculated for each study area. This provides a general idea of how much area was constrained within the submodels and final suitability model outcome.

Local Index of Spatial Association

A Local Index of Spatial Association (LISA) analysis, which identifies statistically significant clusters and outliers, was performed on the final relative suitability modeling results (Anselin 1995). All grid cells with a score of 0 were not included in the cluster analysis, as these areas are unsuitable for aquaculture and are not considered further (Figure 2.16). The ArcGIS Pro Cluster and Outlier Analysis tool was used to implement the LISA analysis (Esri 2021a). The fixed distance spatial conceptualization was utilized within this analysis as it allows for the identification of localized clusters. The function inputs were a 250-m search distance and 9,999 iterations with row standardization and a false discovery rate correction applied to allow for more conservative results by estimating the number of false positives for a given confidence level, adjusting the critical *p*-value accordingly (Esri 2021b). Statistically significant clusters ($p < 0.05$) of the highest suitability scores (i.e., high-high clusters) were identified, with any clusters smaller than 202 ha (500 ac) excluded, as this was the minimum AOA target size.

Data Included in the Suitability Model

All data layers utilized in the suitability model were considered authoritative and were from federal or state agencies, or oceanographic or biophysical models that had been calibrated and validated (Tables 2.5 - 2.8; Appendix C). Before data were selected for use in modeling, data were evaluated for spatial accuracy and temporal and spatial completeness to ensure quality control. Data layers that did not meet these specifications, or did not overlap with study areas, were not included in the suitability model. Some data were included in the characterization data inventory only to provide supplemental information beyond the scope of this study, but those data may be useful during the PEIS process.

Data Not Included in the Suitability Model

Some data layers were not appropriate to include in the suitability and subsequent cluster analysis. Certain data layers did not have the quality or validation, temporal scale, or spatial resolution needed for inclusion in the model. Additionally, some layers were shared at a resolution unsuitable for inclusion in the suitability model without a downscaling algorithm being applied, which can lead to several issues, influencing the accuracy, output resolution, and robustness of the data (Ramírez Villegas and Jarvis 2010; Porporato et al. 2020). Lastly, some data layers were considered, but simply did not overlap or intersect the study area. Table 2.9 lists data layers that were reviewed, but were not included in the suitability model.

Table 2.9. Parameters considered for inclusion in the Aquaculture Opportunity Area suitability model, but had no or uncertain interactions with the planning areas, and therefore were not included. Although these variables were not used in the suitability model, if relevant, they were considered in the characterization of Aquaculture Opportunity Area options.

National Security Datasets		
Military Mission Line (125 mi)	Military Testing and Training Area EWTA-3	SUA 174F
Military Testing and Training Area EWTA-2C	Military Testing and Training Area EWTA-4	SUA 174E
Military Installations	Military Testing and Training Area EWTA-6	SUA W470B
Military Ship Shock Boxes	SUA 155C	SUA W470A
SUA 174G	SUA W453B	SUA MOA US 02214
Regulated Airspace	SUA MUD 14	SUA W151E
SUA MOA US 02208	SUA MUD 8	SUA W151C
SUA W602	SUA W174C(A)	SUA W174H(B)
SUA W174C(B)	SUA W174D	Military Testing and Training Area EWTA-1
Natural and Cultural Resources Datasets		
Manatee Protection Zones (FL)	Spring GOM Monitoring Area for Pelagic Longline Bluefin Interactions	Cetacean Biologically Important Areas (BIAs)
Gulf Sturgeon Critical Habitat	Audubon Important Bird Areas	USFWS Coastal Barrier Resource System
Seagrasses in the United States	Bluefin Tuna HAPC	USFWS Threatened and Endangered Species Act Critical Habitat
Industry, Navigation, and Transportation Datasets		
Coastal Energy Facilities	Marine Hydrokinetic Projects	Pilot Boarding Stations
U.S. Ferry Routes	Wind Energy Areas/Wind Planning Areas	Coastal Maintained Channels
Federal Sand and Gravel Borrow Areas	Wind Planning Areas	
Fishing and Aquaculture Datasets		
Fish Aggregating Devices		

Suitability Modeling Approach, Assumptions, and Limitations

Models, in general, can optimize planning choices and improve the decision-making process by avoiding common biases, offering objective results with limited subjectivity (i.e., equally-weighted approach). However, assumptions must be made within a modeling framework. For instance, we assume multiple overlapping activities in the same space result in greater conflict and are less suitable with aquaculture, which may not necessarily be the case depending on the activities.

Spatial data were used within a GIS framework to develop workflows with a series of interconnected steps (Stelzenmüller et al. 2012; 2017). A flexible, integrated GIS-based suitability model was implemented to consider complex interactions (i.e., equally weighted relative suitability model in an ocean environment) while also aiming for long-term sustainability (Perez et al. 2003; Cho et al. 2012; Pınarbaşı et al. 2017, 2019; Stelzenmüller et al. 2017) (Figure 2.19). An attempt was made to minimize bias among submodels and data layers through the implemented equally weighted approach. Moreover, threshold values assigned for depth and size of AOAs were guided by stakeholder engagement, as initial decisions often are in aquaculture planning (Vincenzi et al. 2006). Models do have limitations (e.g., statistical assumptions, best-available data, modeling approach). For example, in the relative suitability spatial workflow approach used, scoring of categorical and numerical data, reporting statistics used, variability in data temporal and spatial coverage, years and number of years of AIS data used, the shape of the options modeled, *p*-value for LISA cluster and outlier analysis, variables in the suitability and precision siting model, consideration of model error, and oceanographic information included, could, if approached differently, impact or change the final AOA options reported. Other limitations include spatial and horizontal resolution of model data, the accuracy and precision of model data, and primary socio-economic data available. Further, we consistently chose the most conservative approach for scoring assignments and other judgements to increase confidence for aquaculture compatibility within the constraints of the data and model.

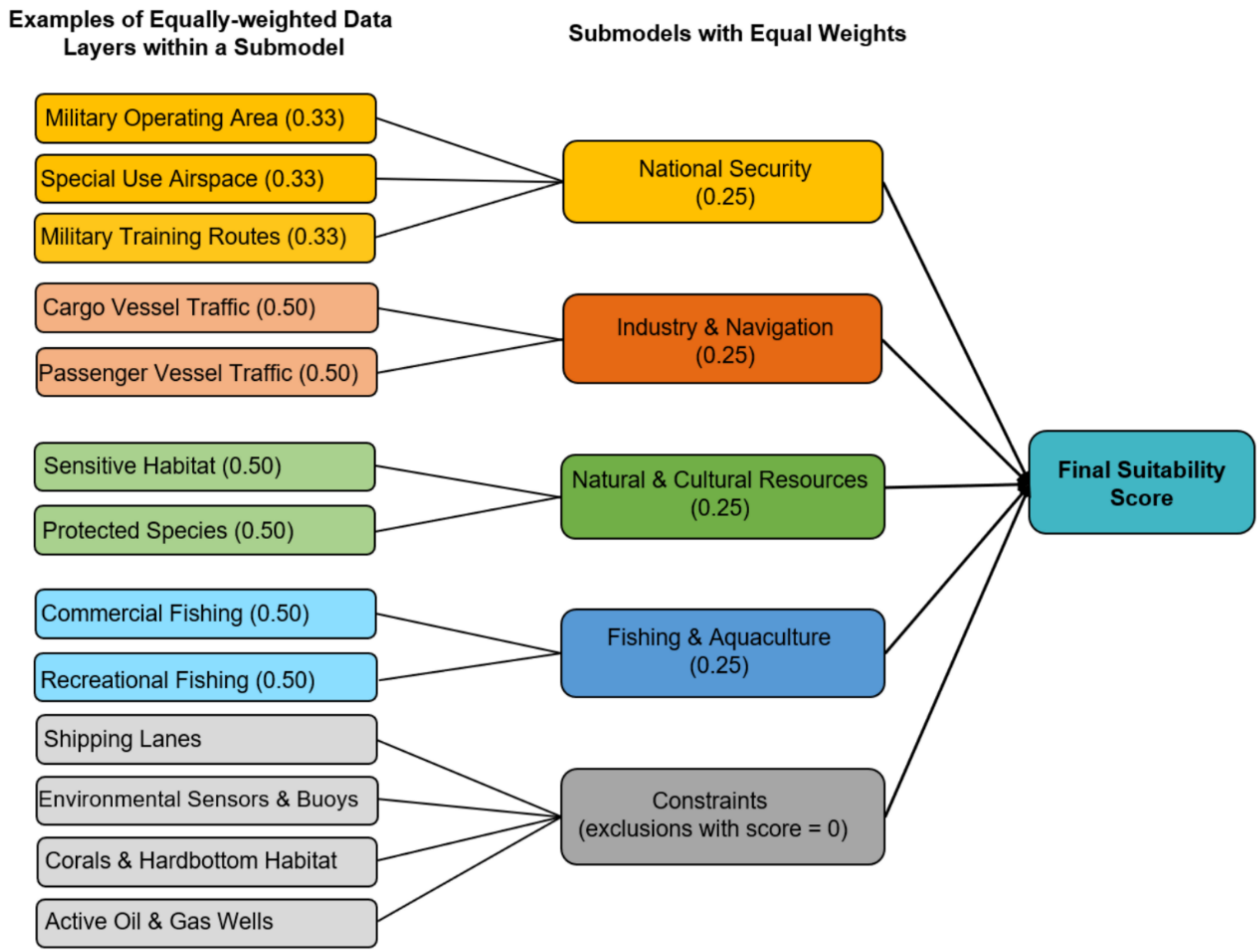


Figure 2.19. A generalized approach to a Multi-Criteria Decision Analysis suitability model with equally-weighted data layers in the submodels and final suitability model.

AOA Suitability Approach and Alternative Suitability Approaches

There are multiple approaches for determining aquaculture suitability based on the planning objective. Predominant methods for suitability modeling approaches for aquaculture planning include a weighted linear combination method with a pairwise comparison (Perez et al. 2003, 2005; Radiarta et al. 2008; Halide et al. 2009; Hossain et al. 2009), while others use parameter specific suitability functions (Vincenzi et al. 2006; Longdill et al. 2008; Cho et al. 2012), as was performed in this analysis. A cumulative effects assessment could be used to assess multiple synergistic or conflicting activities occurring in an area (Menegon et al. 2018). Weighted suitability model approaches may allow for more representative results; however, these approaches rely on expert opinion, which even among experts with similar backgrounds, may be inconsistent in the assignment of weights or ranking of importance (i.e., scoring) (Aguilar- Manjarrez 1996; Silva et al. 2011), resulting in a range of outcomes (Nath et al. 2000; Longdill et al. 2008). Although expert panels can successfully be used in assigning weights in some cases (e.g., Vincenzi et al. 2006; Theuerkauf et al. 2019a, 2019b), in this analysis we attempt to limit bias (e.g., agency or industry sector) to the extent possible, which is why equal weights were given to all data layers and to each of the submodels. Many approaches include constraints (i.e., anthropogenic or natural limitations imposed that do not allow certain actions to occur or overlap), distance to shore or port, and oceanographic forcing factors of the marine environment (e.g., current speed (Cs), significant wave height (Hs) (Brown 1986; Kapetsky et al. 2013; Porporato et al. 2020). Importantly, when adopting the final modeling approach for AOA options identification, the dynamic marine environment was considered relative to those modeling approaches addressing terrestrial environments (Sears 1940; Duck 2012; Maxwell et al. 2015). Favorably to the AOA planning process, NMFS dependent data were used throughout the planning process, capturing some of the social and cultural (e.g., commercial fishing) and economics (e.g., value) of the Gulf of Mexico region.

Precision Siting Model

A precision siting model was developed using custom rules and an adapted version of Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to identify the most suitable potential AOA options in each study area. Generally, the TOPSIS method works by identifying and ranking locations closest to an ideal solution based on distances. We use a submodel structure that produces scores and ranks potential options determined by distance to ideal criteria (e.g., distance to inlet), while avoiding less than ideal criteria (e.g., increased vessel traffic, increased fishing effort). The TOPSIS method and similar ordering techniques (e.g., Analytical Hierarchy Process) have been extensively used within spatial planning frameworks, especially for land and ocean-based renewable energy site selection (Hsu-Shih et al. 2007; Singh et al. 2017; Díaz and Soares 2021). Often, after suitable areas within an MCDA framework are determined, the TOPSIS method or other ranking method is implemented to further refine and rank the results to identify the most suitable location (Sindhu et al. 2017; Konstantinos et al. 2019).

The first step in the precision siting model evaluated the final high-high cluster output (i.e., most suitable areas) derived from the LISA cluster analysis; clusters were then further refined to just those that could accommodate at minimum, a square option that is 500 ac (i.e., the minimum AOA size requirement) (Figure 2.20). For each of the refined clusters, an iterative process was developed, where the first iteration was to identify every possible location accommodating a square that is 2,000 ac (Figure 2.20). Next, all remaining areas within that cluster were examined to determine if additional square options less than 2,000 ac could be placed. Using 500-ac increments, three further iterations were run using 1,500 ac, 1,000 ac, and 500 ac to identify any additional areas within each cluster. Larger size options were prioritized over smaller options during the creation of potential options, as increased size would support more farms, space to optimally configure farming locations, and maximum flexibility in mooring configurations. However, it is important to note that size was not considered when ranking the options in the next steps of the precision siting model.

Within-Cluster Model

All potential options identified within a single high-high cluster were ranked using the within-cluster model, which is structured to identify the highest suitable option according to closest proximity to an inlet, lowest relative fishing effort, and lowest relative vessel traffic (Figures 2.20, 2.21). The data within these three submodels of the within-cluster model were rescaled using a 0 to 1 range, with 0 being less suitable for aquaculture and 1 being more suitable for aquaculture. This is the same method used in the suitability model; however, it is important to note that the rescaling is performed for the data in each individual cluster in the within-cluster model. The logistics submodel contains the single variable of distance to inlet to account for potential economic impacts related to travel distance. Inlets were identified from the Navigable Waterway Network (NWN) lines,[19] with a point shapefile created within navigable inlets for the entire Gulf of Mexico. The distance from a potential AOA to the nearest inlet was calculated for all options. Distance to inlet was rescaled using the minimum and maximum distance values from all options within a single cluster to create a linear function to rescale the values to a 0 to 1 range (Table 2.10). Therefore, the closer an option is to an inlet the higher the score it will receive, while lower scores are given to options farther from the inlet. The commercial fishing submodel in the within-cluster model contains four variables, each representing a different fishing sector, as these comparisons provide greater contrast when looking at the potential options within a single cluster. The four variables, sum of shrimp vessels that had trawled through a potential option, the sum of bandit gear reef fishing, reef longline gear fishing, and headboat survey activity, were calculated for each option. The fuzzy logic Z-shaped membership function was used to rescale each variable to the 0 to 1 range (Table 2.10), meaning that options where fishing effort across a range of fishing sectors was lowest would be scored higher.

The vessel transit submodel in the within-cluster model contains eight variables, one for each type of vessel. A 5-year mean (2015 through 2019) of vessel transits for each vessel type was calculated for potential options. This is different from the suitability model where 2019 was used as the most representative year, as a result of processing time limitations. The 5-year mean provides additional information regarding trends in vessel traffic. Again, the fuzzy logic Z-shaped membership function was used to rescale each of the variables to the 0 to 1 range, meaning that areas of low vessel traffic will receive higher scores than areas of high vessel traffic (Table 2.10).

After all data in the respective submodels were rescaled to the 0 to 1 range, a final score for each submodel was calculated by taking the geometric mean of the variables in each submodel. For the cumulative within-cluster model score, the geometric mean of the three submodels was used to produce the final score for each option in a cluster. The potential option with the highest score was

[19] https://hifld-geoplatform.opendata.arcgis.com/datasets/6bdd4d6080724d3abfb390337d685d41_0/explore?location=7.131116%2C-0.088450%2C3.14

then considered to be the optimal option for that cluster. This operation was performed for each individual high-high cluster.

Among-Cluster Model

The optimal or highest scoring options from the within-cluster model (ranging from 500 to 2000 ac in size) from each cluster were then assessed using the among-cluster model, which further examines and ranks these options (Figures 2.20, 2.22). The among-cluster model ranks and scores AOA options by assuming that those with the best logistical conditions, lowest overall fishing effort, lowest AIS vessel traffic, and most optimal oceanographic conditions are the most suitable for aquaculture. Four submodels were used, with the logistics, commercial fishing, and vessel traffic submodels using the same variables and rescaling techniques as used in the within-cluster submodel. The only difference is that now all data are rescaled from the best option among all the clusters in a study area. In addition, a Metocean (meteorological and oceanographic) submodel was added because the options evaluated are now separated enough to provide contrast with oceanographic variables.

The Metocean submodel in the among-cluster analysis examines four oceanographic variables known to be important considerations for offshore aquaculture (Longdill et al. 2008; Halide et al. 2009; Kapetsky et al. 2013, Landuci et al. 2020). Hindcast Wave Watch III data from 2016 through 2018 were averaged for significant wave height and wave period. Wave period was only considered when significant wave height exceeded 0.75 m (2.5 ft). The mean NCOM American Seas surface current speed and direction were also calculated from 2018 through 2020. Frequency of storm events with wind speeds exceeding 17.5 m/s (34 knots) were also summed for each option. The fuzzy logic Z-shaped membership function was used to rescale the significant wave height, current speed, and storm frequency on the 0 to 1 range (Table 2.11; Equation 2.2; Figure 2.9). The fuzzy logic S-shaped membership function was used to rescale the wave period data to the 0 to 1 range, as longer wave periods are preferred over shorter wave periods when significant wave height exceeds the 0.75-m (2.5-ft) threshold (Table 2.10).

The geometric mean of each submodel was calculated, and the resultant geometric mean of the four submodels was calculated to produce the final score for each option in the among-cluster model. AOA options were ranked by highest to lowest score, with the highest scoring options considered relatively more suitable for aquaculture than the lower scoring options. The three highest scoring options were selected for additional characterization; however, an additional spatial dispersion rule was applied for each study area. This rule applied a 30-nm (56-km) setback from each AOA option within a study area to ensure dispersion of options throughout the geographical scope of the Gulf of Mexico. Therefore,

if the second highest scoring option was within 30 nm (56 km) of the first ranked option, the next highest scoring option was then selected, and so on. In addition, the spatial dispersion rule further justifies evaluating one option per cluster, as the best option will always be put forward among all the clusters evaluated in a study area. One limitation of this method, though rare and only occurring in the East study area clusters 3 and 4 (clusters greater than 30 nm (56 km in length), is the possibility that one cluster could contain the two highest ranked options in a study area. Regardless, the best option from each cluster was put forward and evaluated. A list of data analyzed by the precision siting model is provided in Table 2.10.

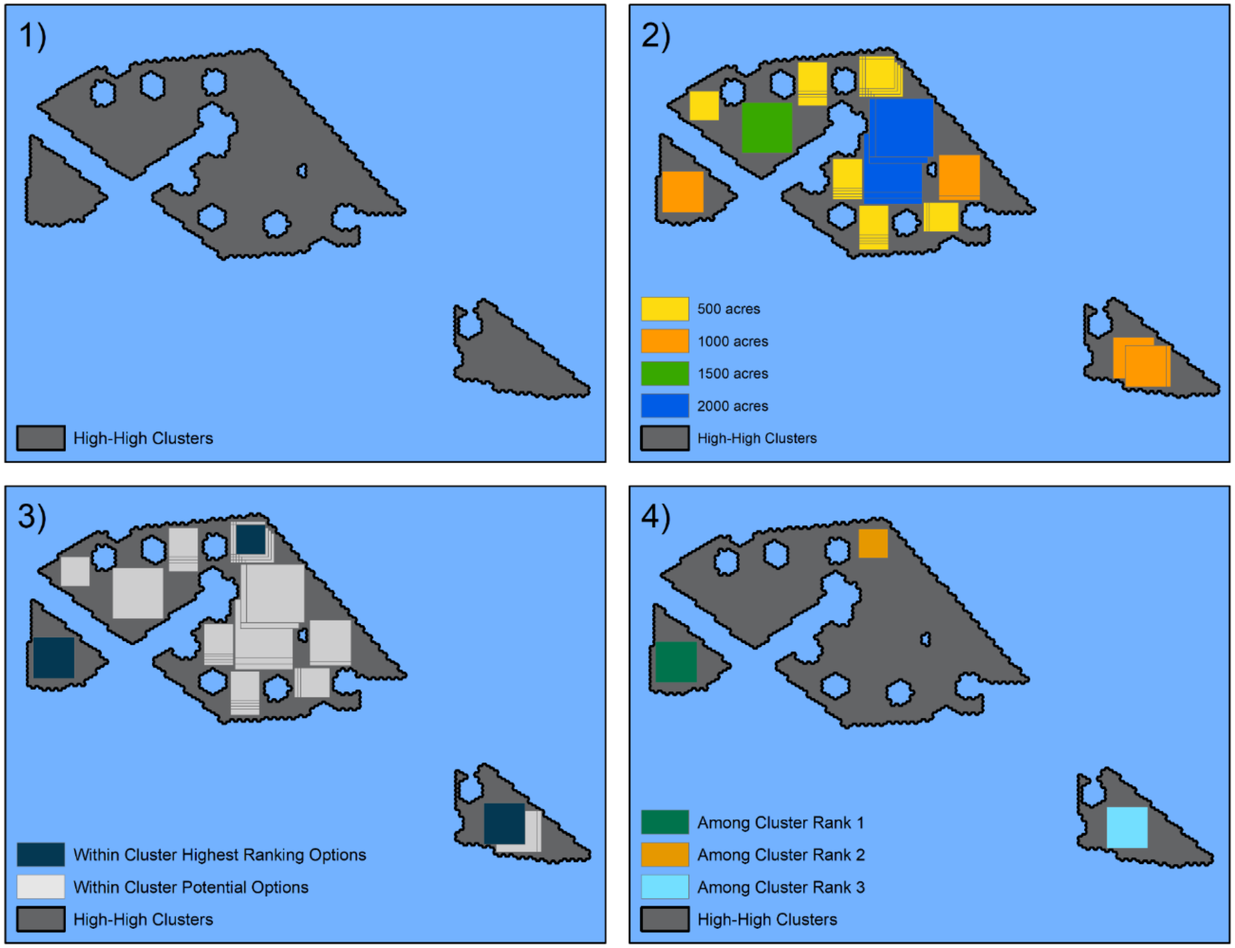


Figure 2.20. Precision siting model workflow steps illustrated within a spatial context. Step 1) illustrates three high-high clusters (dark gray polygon with black outline) determined from the Aquaculture Opportunity Area suitability model and subsequent Local Indicators of Spatial Association Cluster Analysis. Step 2) illustrates how within each high-high cluster, options were identified of 500 ac (yellow boxes), 1,000 ac (orange boxes), 1,500 ac (green boxes), and 2,000 ac (blue boxes) in size (options of the same size could overlap). Step 3) shows all potential options (light gray boxes) within each cluster and scored using the within-cluster model. Once the within-cluster model identified the most suitable option (blue boxes) for each high-high cluster, Step 4) indicates how the highest scoring option from each of the high-high clusters was used to determine the top 3 ranked options among clusters (i.e., among-cluster model) within each study area (i.e., among-cluster Rank 1, 2, and 3).

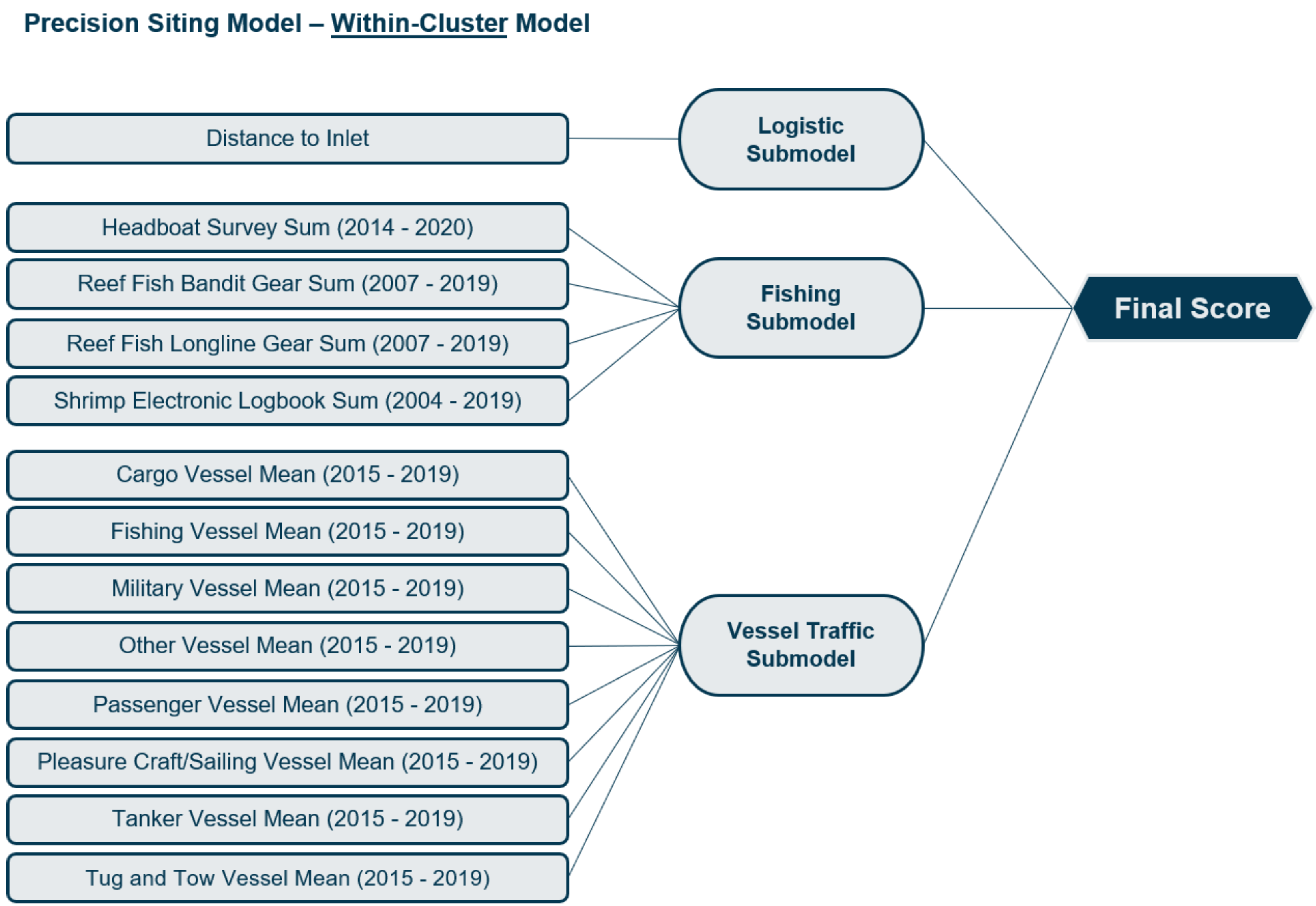


Figure 2.21. Precision siting model workflow for within-cluster comparisons.

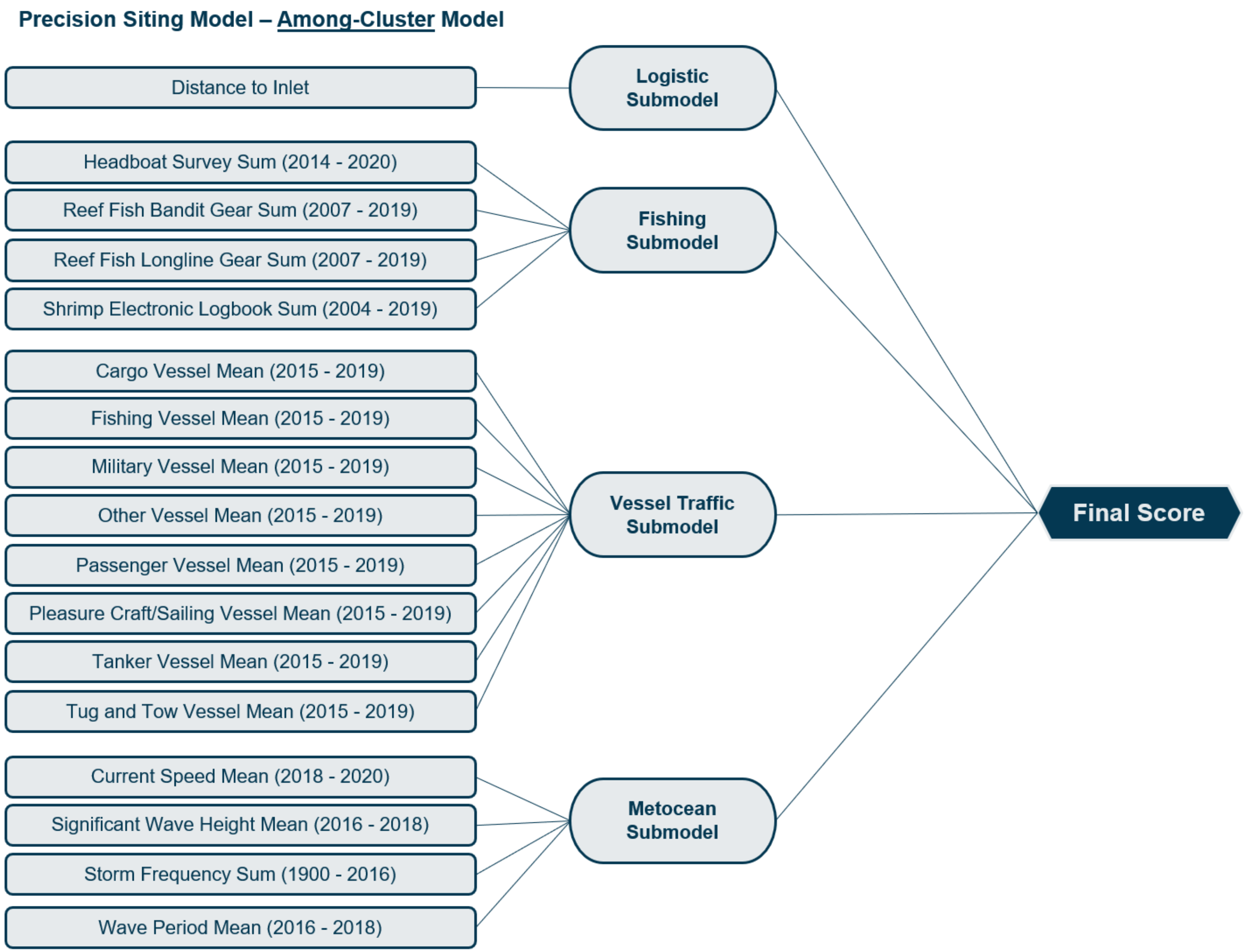


Figure 2.22. Precision siting model workflow for among-cluster model.

Table 2.10. Submodel datasets and data layers used in the precision siting model scaled using linear, Z-shaped, or S-shaped functions.

Submodel	Data Layer	Rescale Function
Logistic	Distance to Inlet	Linear
Fishing	Headboat Survey Sum (2014 - 2020)	Z-shaped membership function
Fishing	Reef Fish Bandit Gear Fishing Sum (2007 - 2019)	Z-shaped membership function
Fishing	Reef Fish Longline Gear Sum (2007 - 2019)	Z-shaped membership function
Fishing	Shrimp Electronic Logbook Trawls Sum (2004 - 2019)	Z-shaped membership function
Vessel Traffic	Cargo Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Fishing Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Military Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Other Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Passenger Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Pleasure and Sailing Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Tanker Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Vessel Traffic	Tug and Tow Mean Vessel Transits (2015 - 2019)	Z-shaped membership function
Metocean	Current Speed Mean (2018 - 2020)	Z-shaped membership function
Metocean	Significant Wave Height Mean (2016 - 2018)	Z-shaped membership function
Metocean	Storm Frequency Sum (1900 - 2016)	Z-shaped membership function
Metocean	Wave Period Mean (2016 - 2018)	S-shaped membership function

Characterization of AOA Options

Many data layers were not appropriate for suitability modeling or the precision siting model, but are still important in the environmental review and decision-making process. For example, some data were at a resolution too coarse to include in the models, while other data did not provide complete coverage. Given those limitations, there is still value in these additional considerations for understanding the study areas and resulting AOA options. We evaluated all data layers that were considered for AOA option characterization to determine the resulting nine AOA options in the West (N = 3), Central (N = 3), and East (N = 3) Gulf of Mexico (Table 2.11). Number of final options were identified based on the next planning phase, and time allotted for that project phase. Three options were identified per study area, allowing for distribution of options throughout the region. Characterization included examining all relevant variables for each option and provided a detailed description of those variables for further consideration. These parameters reach beyond the suitability and precision siting analysis to provide specific characteristics for each option on a number of important aquaculture considerations. For instance, distance to certain discrete objects or inlet, vessel traffic, overlap with military use areas, oceanographic climatologies, or distance to or overlap with certain protected resources are described in detail for all final options. OceanReports was utilized to further enhance the characterization of each AOA option, and custom reports are provided for each AOA option (see Appendices E and F).

Table 2.11. Data included for characterization of Aquaculture Opportunity Area options. For more information on data sources and an exhaustive data inventory, please refer to Appendix A. An asterisk depicts layers used within the initial suitability model as well as in option characterization.

National Security Datasets				
Military Installations	Military Ship Shock Boxes	Military Grid Area	125-mi Military Mission Line	Military Operating Areas*
Special Use Airspace*	NASA Splashdown Zones and setback	Unexploded Ordnance*	Military Danger Zones and Restricted Areas*	
Natural and Cultural Resources Datasets				
Hardbottom/Live Bottom* (Natural Reefs)	Federal Consistency Location Descriptions	Spiny Lobster EFH	Flower Garden Banks National Marine Sanctuary*	BOEM Biological Stipulation Areas
Red Drum EFH	NOAA NERRS sites	Coral EFH	Archaeologically Sensitive Areas*	Coral 9 Amendment Area (2020 regulated)
Critical Wildlife Areas (CWA)	Smalltooth Sawfish Critical Habitat	Smalltooth Sawfish High Use Area (HUA)*	MPA Inventory*	Florida Keys National Marine Sanctuary*
Marine Economic Gross Domestic Product	Reef Fish EFH	Highly Migratory Species EFH	Rice's Whale Core Distribution Area*	Green Sea Turtle Critical Habitat
Deep-sea Coral (Stony/Soft) suitability models	Shrimp EFH	Snapper-Grouper EFH	Marine Dependent Jobs in Gulf States	Fish Havens and Artificial Reefs*
Rice's Whale Suitable Habitat Area*	Gulf Sturgeon Critical Habitat	National Wildlife Refuge System (NWFS)	Shipwrecks*	Deep-sea Coral Observational Data*
Loggerhead Sea Turtle Critical Habitat	Coastal States/Counties/Senate and House Legislative Districts	Loggerhead, Leatherback, Kemp's ridley, Green Sea Turtle HUA*	HABs *K. brevis* (NOAA - FWRI, TWFD, Louisiana Hospitals, HABSOS)	Flower Garden Banks National Marine Sanctuary Expansion (2016 Alternative)*
Manta Ray SDM area above the median probability of occurrence*	HABs (*K. brevis*) observations	Kemp's Ridley Sea Turtle Proposed Critical Habitat	Commercial Fish Landings by Annual Weight and Revenue	Loggerhead, Hawksbill, Green Sea Turtle Migratory Routes*

Industry, Navigation, and Transportation Datasets				
Natural Hydrocarbon Seeps	Offshore Wind Resource Potential	Renewable Energy Lease Blocks/Lease Areas	NMFS IFQ Fish Houses	EPA-designated Ocean Disposal Sites*
Oil and Gas Plays	Oil Spills (Raw Incidents)	Louisiana Wastewater Treatment Outfall Structures	Electrical Substations, Natural Gas and Power Plants	Federal Lightering Rendezvous Areas* and Prohibited Lightering Areas
BOEM 2019 - 2024 Draft Proposed Program Exclusion Option Areas	Principal Ports and Port Trade Statistics	Navigable Waterway Network Inlets*	NMFS IFQ Fish Dealers	Offshore Oil and Gas Planning Areas
Current Presidential Withdrawal and Congressional Moratoria Areas (oil and gas)	BOEM Offshore Federal Sand and Gravel Areas	Federal Aviation Administration Advisories for Airports	BOEM OCS Block Areas with Sand Resources	Fish Processing Plants
Oil and Gas Planning Areas: Federal Waters	Wind Planning Areas	Shipping Routes*	U.S. Ferry Routes	BOEM Platform Applications/Approvals
Active Oil and Gas Lease Blocks*	USACE Coastally Maintained Channels	Oil and Gas Well Directional Survey Points	BOEM Oil and Gas Resources in Gulf of Mexico	Borehole Locations*
Fishing and Aquaculture Datasets				
Live Rock with 500-m setback*	Fish Aggregating Devices	HMS Longline Observer Data (1993 – 2019)*	Headboat Survey Data Sum (2014 - 2020)*	Bandit Reef Fish Sum (2007 - 2019)*
Menhaden Fishery Data Sum (2000 – 2016) *	Longline Reef Fish Gear Sum (2007- 2019)*	Shrimp ELB Trawling Sum (2004 - 2019)*		
Physical, Chemical, and Biological Datasets				
Percent Transmissivity of Light (1-m Depth)	Slope Over Distance Across Options	Bathymetry*	Kd(490)	Nutrients (Nitrate, Phosphate, Silicate) and DO
Chlorophyll-*a*	Sediment Fractional Components/Texture	Temperature Profile at Depth	Salinity	Significant Wave Height (m)
Current Speed (m/s) Direction at Depth	Surface Wind Speed and Direction	Historical Tropical Cyclone Wind Exposure	Real Time Ocean Forecast System Model, Mixing Layer Depth	
Boundaries Datasets				
U.S. EEZ*	State and State Waters Boundaries*	Shoreline*	EPA Regional Boundaries	NMFS Regional Boundaries*
USCG Districts	COLREGs Demarcation Line	USACE Districts	USFWS Regions	Level III Ecoregions*

Final Considerations

Each study area is independent within the planning process and scores and statistics can only be compared within each distinct study area (e.g., West, Central, East, Southeast). The scores and statistics of the resulting AOA options cannot be compared among different study areas. Discrete variables given a score of 0.5 in the site suitability analysis should be considered conservative and further discussions with agencies charged with management of those resources could result in score adjustment, likely in the direction of higher compatibility.

RESULTS

Study Area Submodels

National Security

National security assets are relatively extensive throughout many portions of U.S. federal waters, and uses vary over time and space. For example, the eastern Gulf of Mexico is considered essential to the DOD to develop and maintain military readiness (DOD 2018). The eastern Gulf of Mexico alone offers approximately 261,589 km² (101,000 mi²) of surface and airspace, making it the largest over-water DOD test and training area in the contiguous U.S. (DOD 2018). National security operational areas and other areas of national security interest were reviewed in and around the four AOA study areas (Figure 3.1; Appendix D).

Military Operating Areas (MOAs) are defined as airspaces where military flight activities include air combat maneuvers, air intercepts, low-altitude tactics, and other flight training (FAA 2011). MOA Corpus Christi overlaps 34.3% of the West study area, while MOA New Orleans (2.4%), MOA Pensacola (10.8%), and the Eglin Gulf Test and Training Range (EGTTR) (10.8%) overlap the Central study area (Table 3.1). The EGTTR overlaps the majority of the eastern Gulf of Mexico, and overlaps the entire (100%) East and Southeast study areas. Nested within the EGTTR are MOAs Pensacola and Panama City, which overlap the northern portion of the East study area by 2.1% and 8.2%, respectively (Table 3.1). There are also two over-water training areas overlapping the East study area by 35.9%. The Key West MOA, located in the Straits of Florida, overlaps the southern portion of the Southeast study area

by 0.4%. Danger zones are waters used for target practice, bombing, rocket firing or other hazardous operations, while restricted areas prohibit or limit public access to water areas.[20] Danger zones and areas overlap the East (26.5%) and Southeast (6.5%) study areas, and overlap with the EGTTR and MOA Key West.

Special Use Airspace (SUA) warning areas are airspaces where activities must be confined due to their nature, or where they may limit other aircraft operations not involved in the training exercise.[21] SUAs overlap with portions of all four study areas, with scheduled daily training activities varying over space and time, particularly as use of areas perpetually changes with need and strategic national objectives. Military Training Routes (MTRs) have a floor of 457 m (1,500 ft) or below and are considered low-level altitude military airspaces (MAIASC 2021). Overlap with MTRs occurs in 6.1% of the Central study area. Unexploded ordnance sites (i.e., areas defined under 10 USC 101(e)(5)) where military munitions may

[20] https://www.govinfo.gov/content/pkg/CFR-2019-title33-vol3/xml/CFR-2019-title33-vol3-part334.xml
[21] https://www.faa.gov/air_traffic/publications/atpubs/aim_html/chap3_section_4.html

pose unique explosive safety risk),[22] occur in the West study area (1.5%), with a smaller area in the southern portion of the East study area (0.4% overlap) (Figure 3.1).

Guidance on compatibility of aquaculture operations in the AOA study areas with DOD activities was provided through consultations with DOD staff at regional and headquarters locations, USCG, NASA, and the Military Aviation and Installation Assurance Siting Clearinghouse (MAIASC).[23] Numerous national security data layers were scored as a 0 value (i.e., no suitability) and moved to the constraints submodel due to concerns about activities incompatible with aquaculture operations (Table 3.1; Figure 3.2). In the West study area, one interaction occurred with an unexploded ordnance area, which was scored as 0 and removed 1.5% of the study area. No 0 value constraints occurred in the Central study area. In the East study area, 14 layers were moved to the constraints submodel, including all W-470 SUAs, W-174A, W-168, all W-151 areas, danger zones and restricted areas, and an unexploded ordnance point (with a 500-m setback). MOA Panama City in the East study area was also given a score of 0 due to the hazardous nature and frequency of activities that occur in the area. This multitude of constraints removed 62.4% of the East study area. In the Southeast study area, W-174 SUAs were given a score of 0 as well, due to the nature of activities that occur in those defined areas. Lastly, a combination of constraints analysis and consultation with the DOD removed 100% of the Southeast study area from further consideration (Figure 3.2).

Some Gulf of Mexico national security considerations were assigned a score of 0.5 within the analysis to account for unknown types of training activities occurring or possibly occurring within a space (e.g., SUAs) (Table 3.1; Figure 3.2). These layers were included in the national security submodel for suitability analysis, as opposed to all 0 constraints, which were moved to the constraints submodel. In the West study area, layers with 0.5 scores included the Corpus Christi MOA and nine SUAs. In the Central study area, there is overlap with MOA New Orleans, the EGTTR, MOA Pensacola, 13 SUAs, and MTR flight corridors. In the East study area, the EGTTR, MOA Pensacola, and three SUAs were included in the submodel. In the Southeast study area, these layers included the EGTTR, MOA Key West, and MOA US 02174.

[22] https://www.law.cornell.edu/uscode/text/10/101
[23] https://www.acq.osd.mil/dodsc/

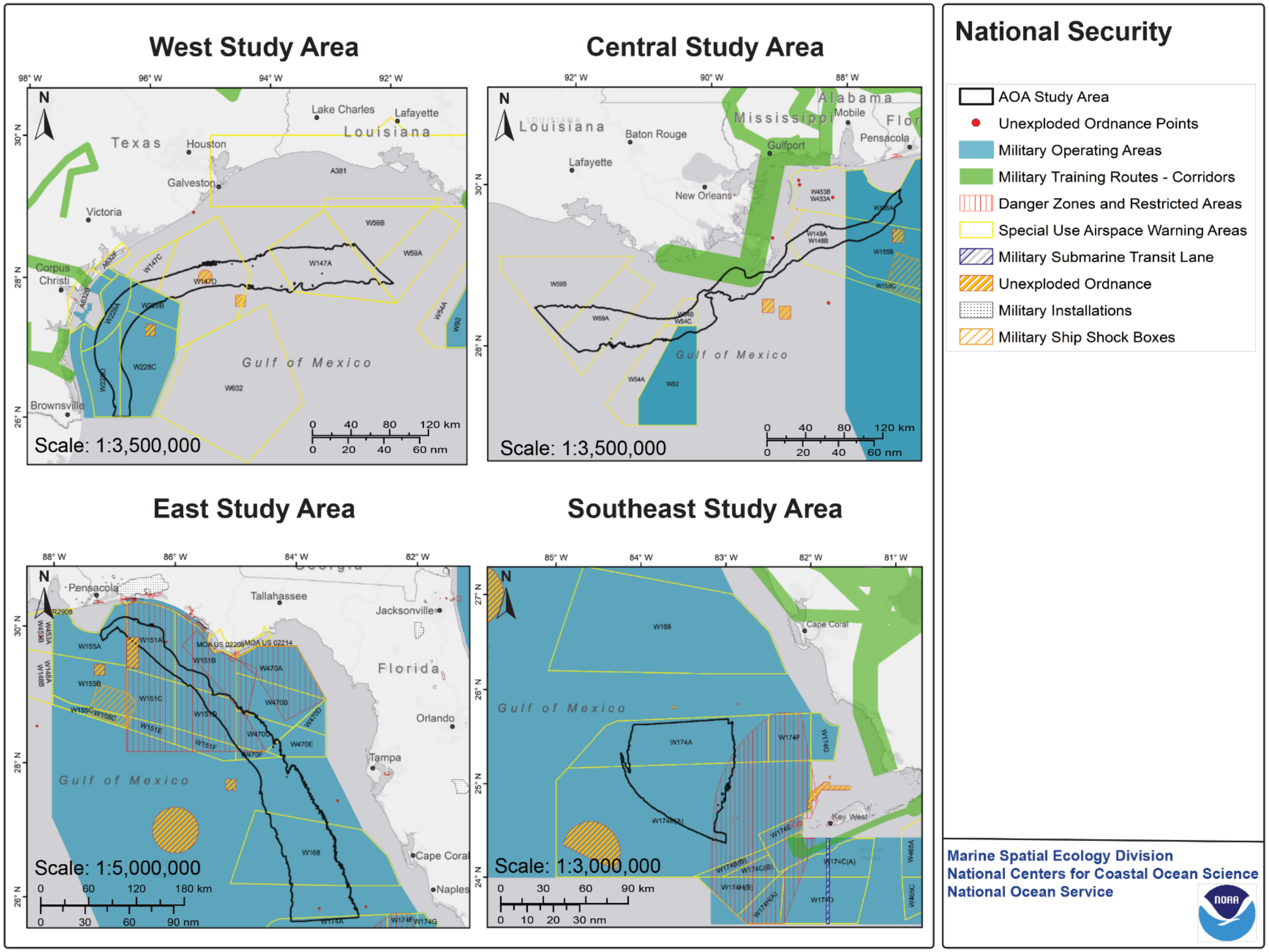


Figure 3.1. National Security considerations for the West, Central, East, and Southeast study areas. Considerations include unexploded ordnance points, special use airspace, danger zones and restricted areas, military operating areas, and military installations.

Table 3.1. National Security data layers included in the suitability analysis and the score assigned to each dataset. Each dataset is listed with the percent present in each of the four study areas – West (W), Central (C), East (E), or Southeast (SE). All zero values were included in the constraints submodel. A dash indicates areas where the corresponding data layer did not overlap with a given study area.

Dataset	Score	Percent Overlap			
		W	C	E	SE
Military Operating Area – Corpus Christi	0.5	34.3%	-	-	-
Military Operating Area – Eglin Gulf Test and Training Range	0.5	-	10.8%	100%	100%
Military Operating Area – Key West	0.5	-	-	-	0.4%
Military Operating Area – New Orleans	0.5	-	2.4%	-	-
Military Operating Area – Pensacola	0.5	-	10.8%	2.1%	-
Military Training Routes (MTR) – Flight Corridors	0.5	-	6.1%	-	-
Special Use Airspace – A381	0.5	-	0.1%	-	-
Special Use Airspace – EWTA-2A	0.5	-	-	0.2%	-
Special Use Airspace – EWTA-2B	0.5	-	-	20.5%	-
Special Use Airspace – EWTA-5	0.5	-	-	15.4%	-
Special Use Airspace – MOA US 02174	0.5	-	-	-	5.8%
Special Use Airspace – MOA US 02416 and 02417	0.5	-	0.5%	-	-
Special Use Airspace – W147A and W147B	0.5	30.8%	-	-	-
Special Use Airspace – W147C	0.5	1.6%	-	-	-
Special Use Airspace – W147D	0.5	19.5%	-	-	-
Special Use Airspace – W148A and W148B	0.5	-	12.4%	-	-
Special Use Airspace – W155A	0.5	-	4.8%	2.1%	-
Special Use Airspace – W155B	0.5	-	6.0%	-	-
Special Use Airspace – W228A	0.5	7.6%	-	-	-
Special Use Airspace – W228B	0.5	7.1%	-	-	-
Special Use Airspace – W228C	0.5	7.2%	-	-	-

Dataset	Score	Percent Overlap			
		W	C	E	SE
Special Use Airspace – W228D	0.5	12.5%	-	-	-
Special Use Airspace – W54A	0.5	-	2.6%	-	-
Special Use Airspace – W54B and W54C	0.5	-	4.3%	-	-
Special Use Airspace – W59A	0.5	1.4%	23.2%	-	-
Special Use Airspace – W59B	0.5	1.5%	8.1%	-	-
Special Use Airspace – W92	0.5	-	2.4%	-	-
Danger Zones and Restricted Areas (33 CFR § 334.2)	0	-	-	26.5%	6.5%
Military Operating Area – Panama City	0	-	-	8.2%	-
Special Use Airspace – W470B	0	-	-	0.4%	-
Special Use Airspace – W470C	0	-	-	8.5%	-
Special Use Airspace – W470E	0	-	-	1.0%	-
Special Use Airspace – W470F	0	-	-	2.0%	-
Special Use Airspace – W174A	0	-	-	1.5%	44.9%
Special Use Airspace – W174B(A)	0	-	-	-	55.3%
Special Use Airspace – W168	0	-	-	28.3%	-
Special Use Airspace – W151A	0	-	-	9.4%	-
Special Use Airspace – W151B	0	-	-	4.3%	-
Special Use Airspace – W151D	0	-	-	6.9%	-
Unexploded Ordnance (UXO) Points with 500-m setback	0	-	-	<0.1%	-
Unexploded Ordnance (UXO) Polygon	0	1.5%	-	0.4%	-

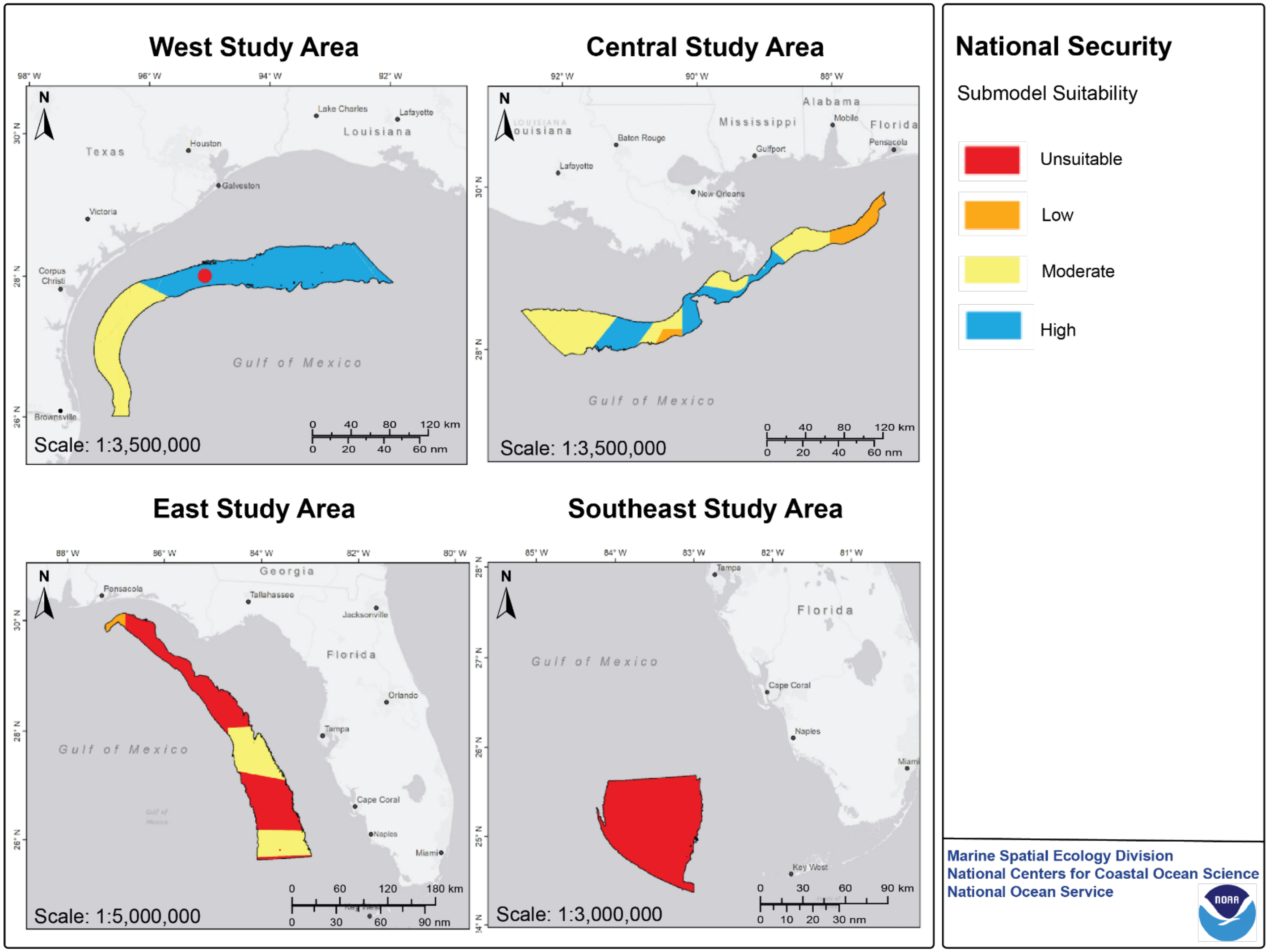


Figure 3.2. National Security submodel results for each study area (West, Central, East, Southeast) for the Gulf of Mexico. The color red indicates values of 0 that were considered unsuitable for AOA planning.

Natural and Cultural Resources

Natural resource assets were assessed to determine biologically important and sensitive habitats, culturally and archaeologically sensitive areas, and designated protected areas that are potentially incompatible with aquaculture. Most layers in this submodel were moved to the constraints model because of their ecological importance and the need for avoidance (Table 3.2). Archaeologically sensitive areas overlapped the East and Southeast study areas. Deep-sea coral observations occurred throughout the study areas, while potentially sensitive biological features and low relief structures and the BOEM No Activity Area were specifically located in and around the Flower Garden Banks National Marine Sanctuary in the West and Central study areas. Hardbottom and natural reefs were found throughout the Gulf AOI (Figures 3.3, 3.4).

Table 3.2. Natural and cultural resource data layers included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with the percent present in each of the four study areas – West (W), Central (C), East (E), or Southeast (SE). All zero values were included in the constraints submodel rather than the natural and cultural resources submodel. A dash represents areas where the corresponding layer did not overlap the given study area.

Dataset	Score	Percent Overlap			
		W	C	E	SE
Florida Keys National Marine Sanctuary	0.5	-	-	-	0.9%
Flower Garden Banks National Marine Sanctuary	0.5	0.6%	-	-	-
Protected Resource Consideration Combined Species Layer	0 - 1	84.2%	95.6%	99.4%	97.3%
Archaeologically Sensitive Areas	0	-	-	0.1%	-
Artificial Reefs with 500-ft setback	0	0.3%	0.7%	<0.1%	-
AWOIS Wrecks Polluting, RULET Wrecks, ENC Wrecks and Obstructions, ENC Danger Wrecks with 500-ft setback	0	0.1%	0.3%	0.1%	<0.1%
BOEM No Activity Zones with 1000-m setback	0	2.5%	0.8%	-	-
Coral 9 HAPC	0	2.6%	0.6%	-	-
Coral 9 HAPC (Regulated Areas)	0	0.2%	0.6%	-	2.4%
Coral, Coral Reefs, Live or Hardbottom EFH HAPC	0	-	-	-	0.9%
Deep-sea Coral and Sponge Observations (1985 to present) with 1000-m setback	0	1.8%	1.1%	0.6%	1.2%
Federally Managed Area Flower Garden Banks EFH HAPC	0	0.8%	-	-	-
Federally Managed Areas Madison-Swanson, The Edges, and Steamboat Lumps	0	-	-	5.9%	-
Federally Managed Area Pulley Ridge EFH HAPC	0	-	-	7.0%	38.2%
Federally Managed Area Tortugas Marine Reserve EFH HAPC	0	-	-	-	0.9%
Low Relief Structures with 1000-m setback	0	4.1%	0.7%	-	-
Natural Reefs (e.g., Escarpments, Pinnacles) with 1000-m setback	0	6.9%	13.0%	10.2%	4.7%
NOAA Fish Havens with 500-ft setback	0	0.4%	3.6%	1.0%	-
Potentially Sensitive Biological Features	0	2.6%	0.7%	-	-

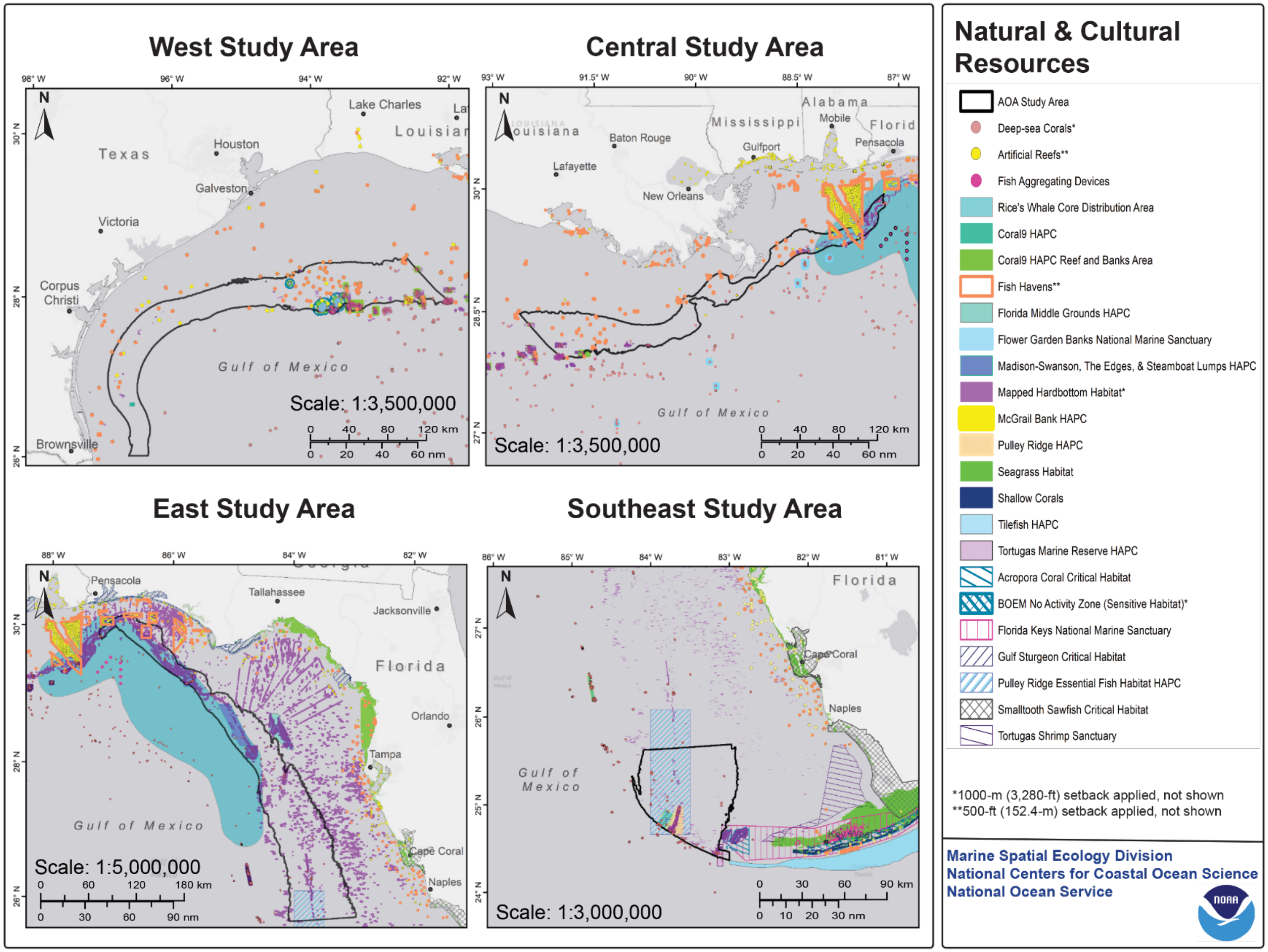


Figure 3.3. Natural and Cultural Resource considerations for the West, Central, East, and Southeast study areas. Considerations include National Marine Fisheries Service protected resources considerations, protected areas, fish aggregating devices, sensitive habitats (e.g., hardbottom, deep-sea corals), and artificial reefs and associated fish havens.

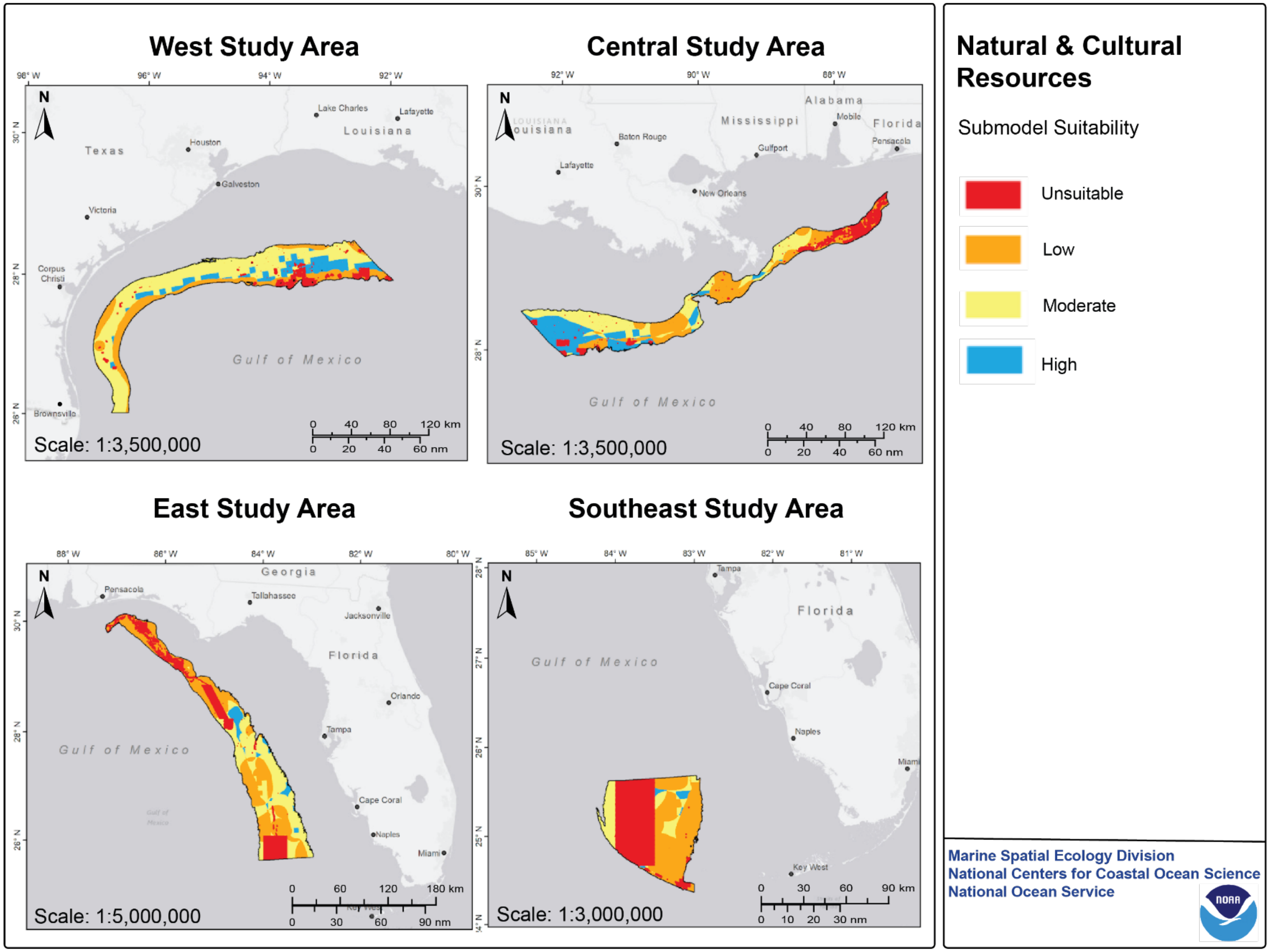


Figure 3.4. Final Natural and Cultural Resources submodel utilized in the suitability model for (from top to bottom, left to right) the West, Central, East, and Southeast study areas. Red color indicates those areas where layers with a score of 0 occurred due to conflict with an activity and were considered unsuitable for Aquaculture Opportunity Area planning.

NMFS Protected Resource Considerations

The final composite layer, representing a total of eight protected resource consideration layers, had high overlap with the East (99.4%), Southeast (97.3%), Central (95.6%), and West (84.2%) study areas (Figure 3.5). High use areas for Kemp's ridley sea turtle overlap all four study areas, but are most prominent in the Central study area. Leatherback and loggerhead sea turtle HUAs predominantly overlap the Central, East, and Southeast study areas. Hawksbill sea turtle HUAs overlap the Southeast study area. Green sea turtle HUAs are dispersed throughout the study areas. Smalltooth sawfish HUAs overlap the Southeast and East study areas. The probability of giant manta ray distribution indicates higher probability of occurrence in the shallower portions of all study areas. The Rice's whale Core Distribution Area overlaps the Central and East study areas. Additionally, the Rice's whale suitable habitat area was established for all study areas where depths exceed 100 m (328 ft) (Appendix B). For further details related to each ESA-listed species included in the NMFS protected resources considerations layer, see Appendix B.

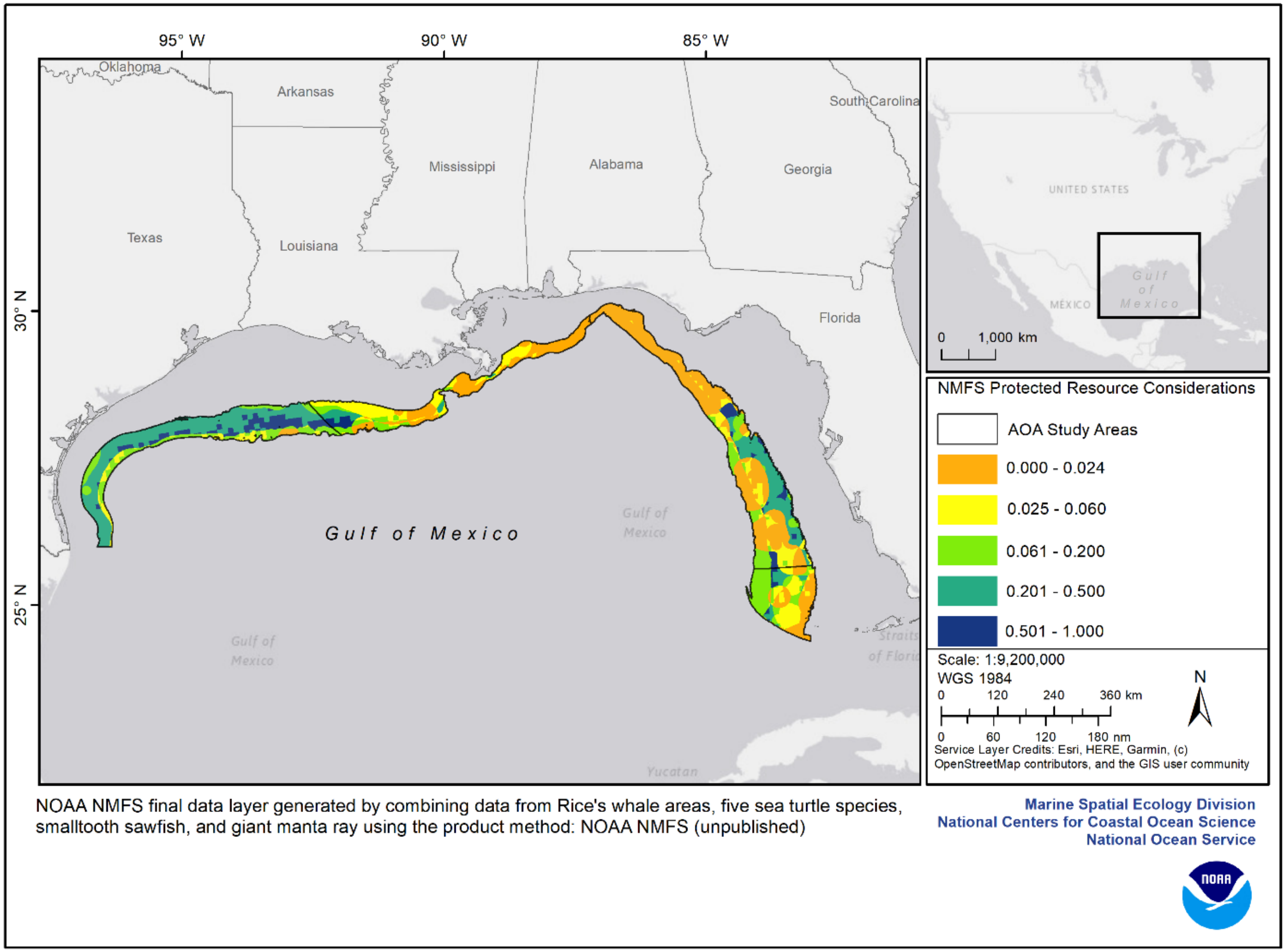


Figure 3.5. The combined data layer for National Marine Fisheries Service Protected Resources utilized in the Natural and Cultural Resources submodel for the West, Central, East, and Southeast study areas.

Industry, Navigation, and Transportation

Industry and Seafloor Infrastructure

The Gulf of Mexico supplies trillions of dollars annually to the national economy via major marine industries (e.g., oil and gas production, commercial seafood, shipping) (NOAA 2021a). Given the substantial presence of ocean industries in the region, industrial activity in and around the four study areas was examined (Table 3.3).

Over 90% of U.S. oil and gas production occurs in the Gulf of Mexico, making this energy sector one of the largest industrial users of regional marine resources (NOAA 2021a). BOEM active (or suspended) oil and gas lease blocks, platforms (including active drilling structures), oil and gas pipelines, and oil and gas boreholes were all included in the suitability analysis, given a score of 0, and moved to the constraints submodel for analysis (Table 3.3; Figure 3.6). In addition, a 500-m (1,640-ft) setback was applied and also scored as 0 within the suitability model for boreholes, pipelines, and platforms to provide conservative estimates of distance needed for operations among existing ocean infrastructure and AOA options. Oil and gas infrastructures were predominantly within the West and Central study areas, as the eastern Gulf of Mexico is under moratoria[24] to preserve and protect U.S. military readiness (DOD 2018). The most overlap with oil and gas infrastructure occurred in the Central study area, with 38.2% of the area intersecting pipelines, 22.6% with boreholes, 22.0% with active lease blocks, and 3.5% with drilling platforms. Presently, no wind energy infrastructure exists in the region, although the potential for future wind energy development does exist (BOEM 2020). In addition to energy sector projects, BOEM is charged with management of marine minerals in federal waters (BOEM 2021). In the Gulf of Mexico, this includes federal sand and gravel lease borrow areas and lease blocks with significant sediment resources. Only the Central study area overlapped a significant sediment resource block, removing 0.1% of the study area (Figure 3.7).

Submarine cables transmit 95% of international communications and approximately $10 trillion in financial transactions each day (Tri-Service Strategy 2020); therefore, they were considered critical infrastructure incompatible with marine aquaculture, assigned 0, given a 500-m (1,640-ft) setback with a score of 0, and moved to the constraints submodel. Figure 3.7 illustrates the NOAA charted submarine cables, a set of submarine cable data available for public display. Submarine cables intersect the West and Central study areas.

The U.S. Environmental Protection Agency (USEPA) is responsible for designation and management of ocean disposal sites under the Marine Protection, Research and Sanctuaries Act (40 CFR 220-229) (USEPA 2021a) (Figure 3.7). The vast majority of ocean disposal sites currently in use nationally are designated as ocean dredged material disposal sites (USEPA 2021a). Another discontinued, but notable, designation for ocean dumping is historic ocean disposal sites (USEPA 2021b). Some of these discontinued sites can include harmful pollutants at high concentrations such as heavy metals, inorganic nutrients, and chlorinated petrochemicals (USEPA 2021b). The Central study area overlaps two discontinued ocean disposal sites that were utilized by the USACE for disposal of dredged materials associated with navigation maintenance activities in the Mississippi River. These ocean disposal sites removed approximately 0.4% of the study area. No other study areas overlap USEPA ocean disposal sites. A 0 value was given to any area overlapping an ocean disposal site due to the nature of activities within designated areas.

[24] https://www.boem.gov/oil-gas-energy/leasing/areas-under-restriction

Table 3.3. Industry, Navigation, and Transportation parameters included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with the percent present in each of the four study areas – West (W), Central (C), East (E), or Southeast (SE). All zero values were included in the constraints submodel rather than the Industry, Navigation, and Transportation submodel. "Cont." denotes continuous data (0 - 1). A dash represents areas where the corresponding layer did not overlap with the given study area.

Parameter	Score	Percent Overlap or Intersection			
		W	C	E	SE
Federal Lightering (Rendezvous Areas)	0.5	15.2%	12.5%	-	-
AIS Vessel Traffic 2019 – Cargo	Cont.	11.8%	24.0%	27.7%	1.7%
AIS Vessel Traffic 2019 – Fishing	Cont.	31.0%	36.3%	9.3%	1.7%
AIS Vessel Traffic 2019 – Military	Cont.	-	<0.1%	<0.1%	-
AIS Vessel Traffic 2019 – Other	Cont.	48.5%	83.5%	16.5%	13.2%
AIS Vessel Traffic 2019 – Pleasure and Sailing	Cont.	2.8%	12.1%	8.9%	0.4%
AIS Vessel Traffic 2019 – Passenger	Cont.	17.2%	65.0%	8.0%	8.3%
AIS Vessel Traffic 2019 – Tanker	Cont.	20.5%	20.9%	6.8%	14.9%
AIS Vessel Traffic 2019 – Tug and Tow	Cont.	12.3%	31.7%	17.3%	12.0%
Aids to Navigation (Beacons and Buoys) with 500-m setback	0	0.1%	0.2%	<0.1%	-
Anchorage Areas (Used/Disused)	0	-	0.3%	-	-
Environmental Sensors and Buoys with 500-m setback	0	< 0.1%	< 0.1%	< 0.1%	< 0.1%
Lease Blocks with Significant Sediment Resources	0	-	0.1%	-	-
Ocean Disposal Sites	0	-	0.4%	-	-
Oil and Gas Active Leases	0	5.3%	22.0%	0.1%	-
Oil and Gas Boreholes, Test Wells, and Wells with 500-m setback	0	12.0%	22.6%	0.1%	-
Oil and Gas Drilling Platforms with 500-m setback	0	1.9%	3.5%	-	-
Oil and Gas Pipelines with 500-m setback	0	17.4%	38.2%	0.6%	-
Shipping Fairways and Regulations with 500-m setback	0	6.5%	6.5%	2.4%	-
Submarine Cables with 500-m setback	0	0.4%	1.4%	-	-

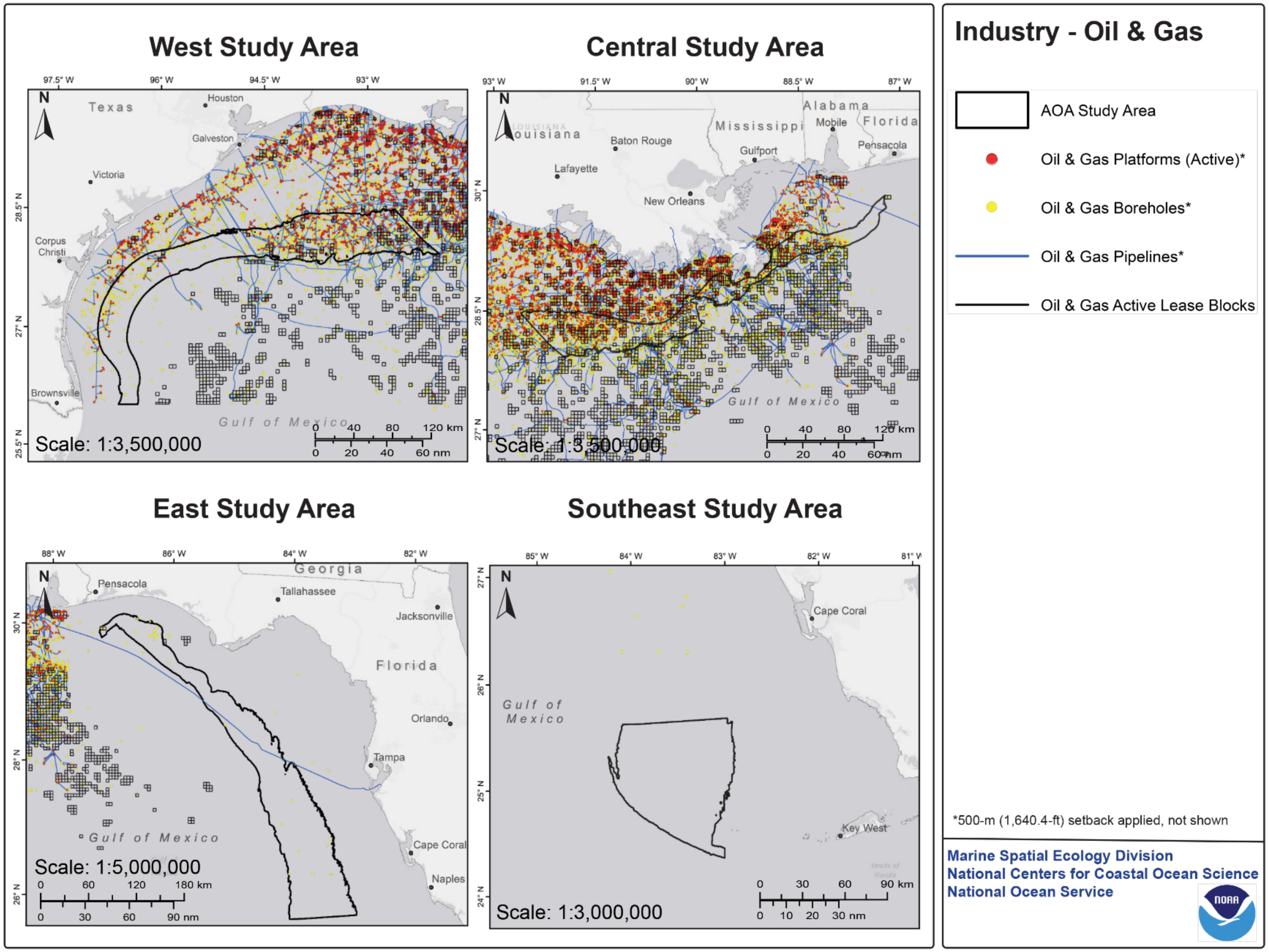


Figure 3.6. Energy infrastructure considerations for the West, Central, East, and Southeast study areas. Considerations include active oil and gas platforms, boreholes and test wells, oil and gas pipelines, and the Bureau of Ocean Energy Management active oil and gas lease blocks.

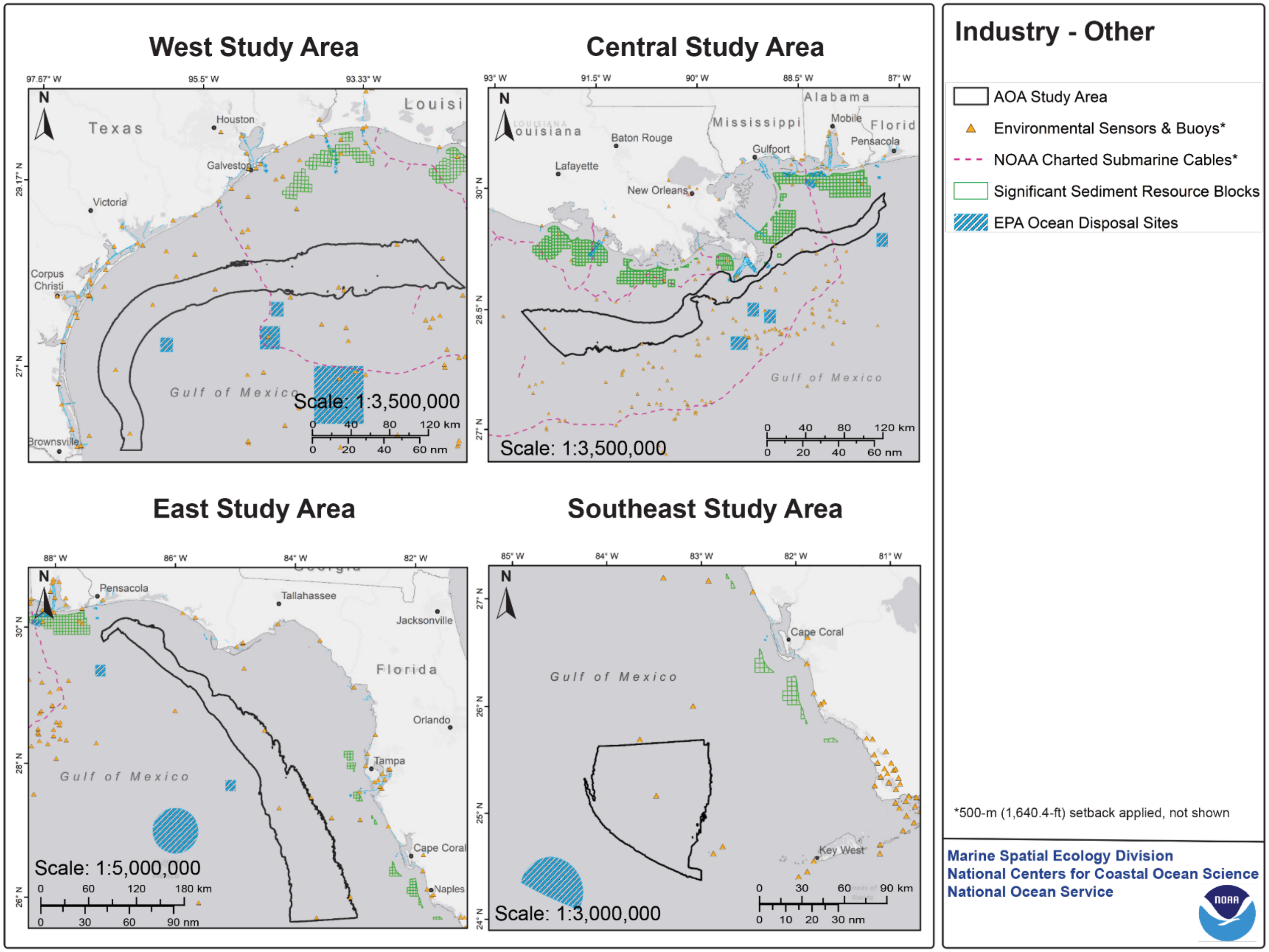


Figure 3.7. Ocean infrastructure considerations for the West, Central, East, and Southeast study areas. Considerations include USEPA ocean disposal sites, submarine cables, environmental sensors and buoys, and the Bureau of Ocean Energy Management significant sediment resource blocks.

Navigation

Shipping is a multi-billion-dollar industry in the Gulf of Mexico, with two of the largest ports in the world, Houston and New Orleans, in the region (NOAA 2021a). Navigational constraints were evaluated for the suitability model and included shipping fairways, areas to be avoided, deepwater ports, pilot boarding areas, active anchorage areas, aids to navigation, environmental sensors and buoys, and lightering rendezvous areas[25] (Figure 3.8). A 500-m (1,640.4-ft) setback was applied to aids to navigation, environmental sensors and buoys, and shipping fairways due to either movement of the object itself or due to vessel movements in and around the designated areas. Shipping fairways overlap 6.5% of both the West and Central study areas and 2.4% of the East. Lightering rendezvous areas overlap 15.2% of the West and 12.5% of the Central study areas (Table 3.3).

[25] https://www.fisheries.noaa.gov/inport/item/54387

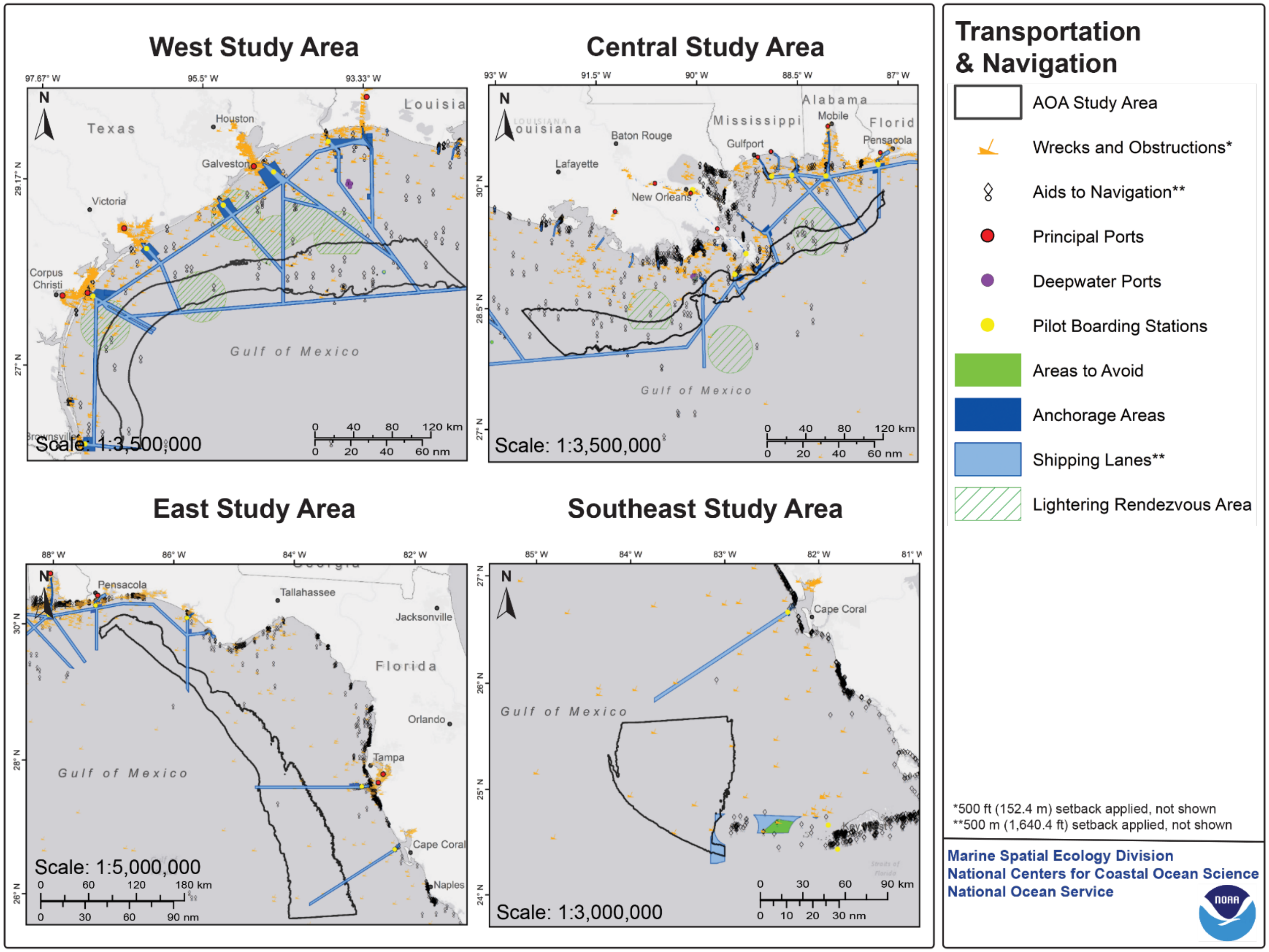


Figure 3.8. Transportation and Navigation considerations for the West, Central, East, and Southeast study areas. Considerations include principal ports, shipping infrastructure and routes (e.g., shipping lanes, anchorage areas, pilot boarding stations, deep-water ports, areas to avoid, lightering rendezvous areas, and aids to navigation).

Transportation: Automated Vessel Identification System Transit Count Data

Vessel traffic data, or Automatic Identification System (AIS) data, are collected in real time by the USCG using very high frequency (VHF) maritime-band transponders, which are capable of handling over 4,500 reports per minute and update as often as every two seconds (USCG 2020). AIS uses Self-Organizing Time Division Multiple Access technology, allowing for these high broadcast rates and ensuring reliable ship-to-ship operations (USCG 2020). AIS collects data on location and vessel characteristics (e.g., speed over ground, draft, beam, length, vessel type, maneuvering information) and was initially developed for ship collision avoidance (USCG 2020; MC 2021). In this study, AIS data were used as an approximation for potential transit conflicts with AOA options. Specifically, AIS data from 2019 were analyzed to determine the relative vessel transit counts (i.e., vessel traffic) of each vessel type: tanker, cargo, passenger, (e.g., cruise ships) ferries, tug and tow, pleasure and sailing, military, and other vessels (e.g., first responders)[26] within the study areas (Figures 3.9 through 3.16).

The West, Central, and East study areas have the highest percent coverage of AIS cargo vessel transits (Table 3.4). Cargo and tanker vessel transits in the West and Central areas disperse from land-based ports in the Houston/Galveston, TX area with additional dense traffic dispersing from Cameron, LA, and Freeport, Port Arthur, Matagorda, Corpus Christi, and Brownsville, TX. Vessels in the Central study area disperse from Mobile Bay, AL, Gulfport, MS, around East Bay, LA, and Bell Pass, LA, and onward east from two principal ports (Panama City and St. Petersburg/Tampa Bay, FL), but fan out (i.e., disperse) as they pass through the study area (Figures 3.9, 3.15). Tanker transits intersect with over 20% of the West and Central study areas, 27.7% of the Central area, and 14.9% of the Southeast study area. Dense traffic for cargo and tanker vessels (larger vessels) is largely confined to shipping fairways within the study areas, with some deviations of vessels (Figures 3.9, 3.15). The Southeast study area has relatively higher tanker traffic than the East, with transits predominantly to or from major ports across the Gulf region, or curving around the tip of Florida toward the Atlantic Ocean (Tables 3.3, 3.6; Figure 3.15).

The Central study area has the highest overlap with tug and tow vessel transits (31.7%), as this study area is closest to land-based infrastructure associated with ports in Louisiana (Table 3.3). Tug and tow vessels tend to occur inshore of the study areas around major ports or working around the shipping fairway as tenders (Figure 3.16). Passenger vessel transits from 2019 intersect with 65% of the Central study area (Figure 3.13). Pleasure and sailing vessel transits are relatively low, but had the highest percent of overlap in the Central study area (Figure 3.14). In the East study area, pleasure and sailing are heaviest in the northern portion, which is relatively closer to shore than the remainder of the study area. The Southeast study area has low overlap with pleasure and sailing (0.4%), but has relatively denser traffic to the east of the study area in waters off Key West, FL.

Transit counts from fishing vessels with AIS transponders in 2019 indicate 36.6% intersection with the Central study area and 31.0% with the West study area, with relatively less intersection in the East (9.3%) and Southeast (1.7%) study areas (Table 3.3; Figure 3.10). The majority of fishing activity is outside of the Southeast study area, and occurs to the east of the area. No military vessels

[26] https://www.google.com/url?q=https://www.navcen.uscg.gov/pdf/AIS/AISGuide.pdf&sa=D&source=editors&ust=1624640106728000&usg=AOvVaw0t9-X9iMuk-lF3VbUCDHf1

transmitting position information intersected with the West and Southeast study areas, and low levels of military vessel transits were recorded in the Central and East study areas (Table 3.3; Figure 3.11). Transits by the other category of AIS vessels, which includes several different craft types[27], are dispersed throughout the study areas. Other vessel transits were densest in the shipping fairways, and intersected at relatively high densities in the Central (83.5%) and West (48.5%) study areas. Relatively fewer other vessel transits were observed in the East study area (16.5%), as well as in the Southeast study area (13.2%) (Table 3.3; Figure 3.12). Suitability results for the industry, navigation, and transportation submodel for each study area are presented in Figure 3.17.

[27] https://www.navcen.uscg.gov/pdf/AIS/AISGuide.pdf

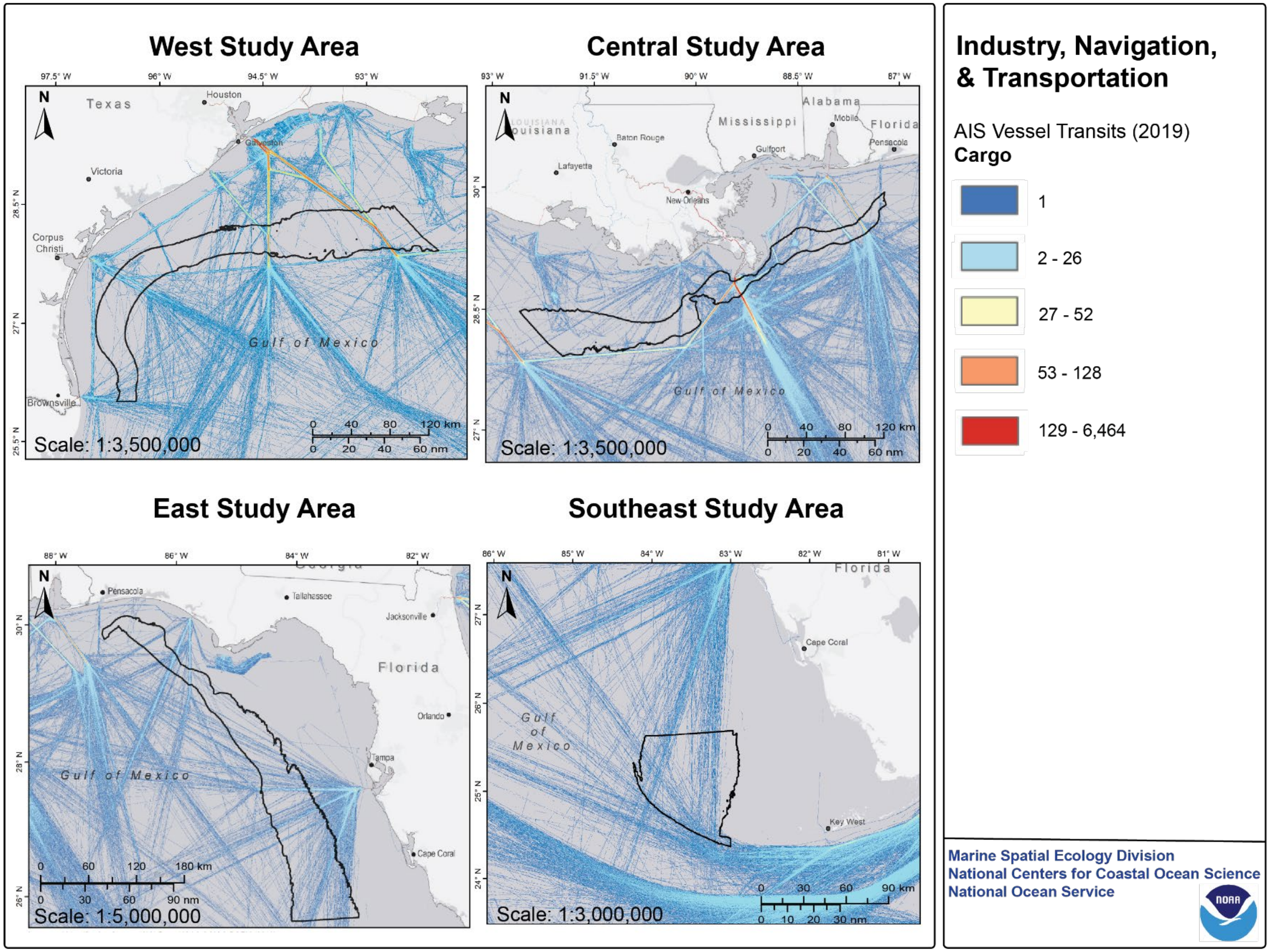


Figure 3.9. Automatic Identification System Vessel transit data from 2019 for cargo vessels in the West, Central, East, and Southeast study areas.

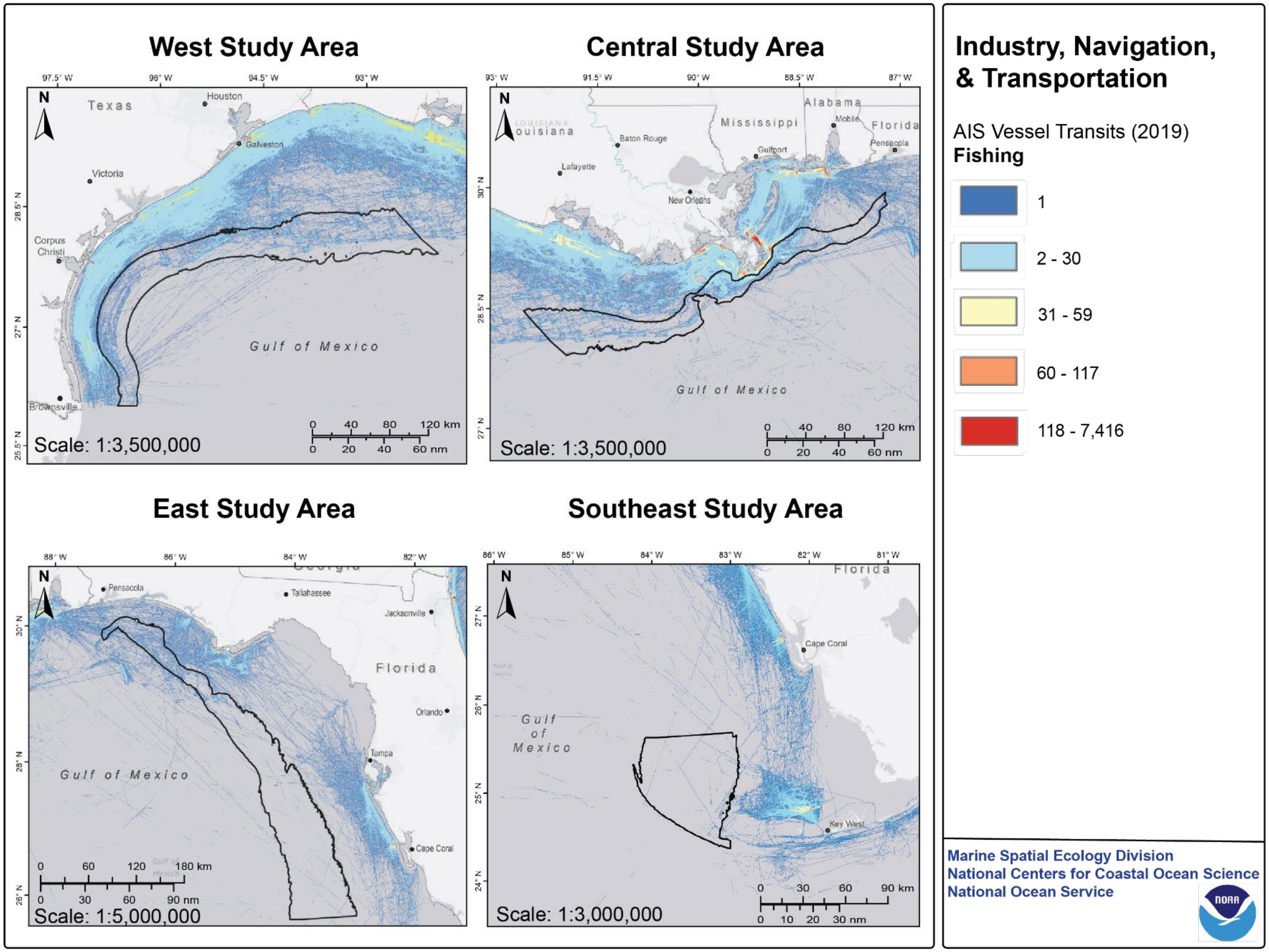


Figure 3.10. Automatic Identification System Vessel transit data from 2019 for fishing vessels with Very High Frequency transponders in the West, Central, East, and Southeast study areas.

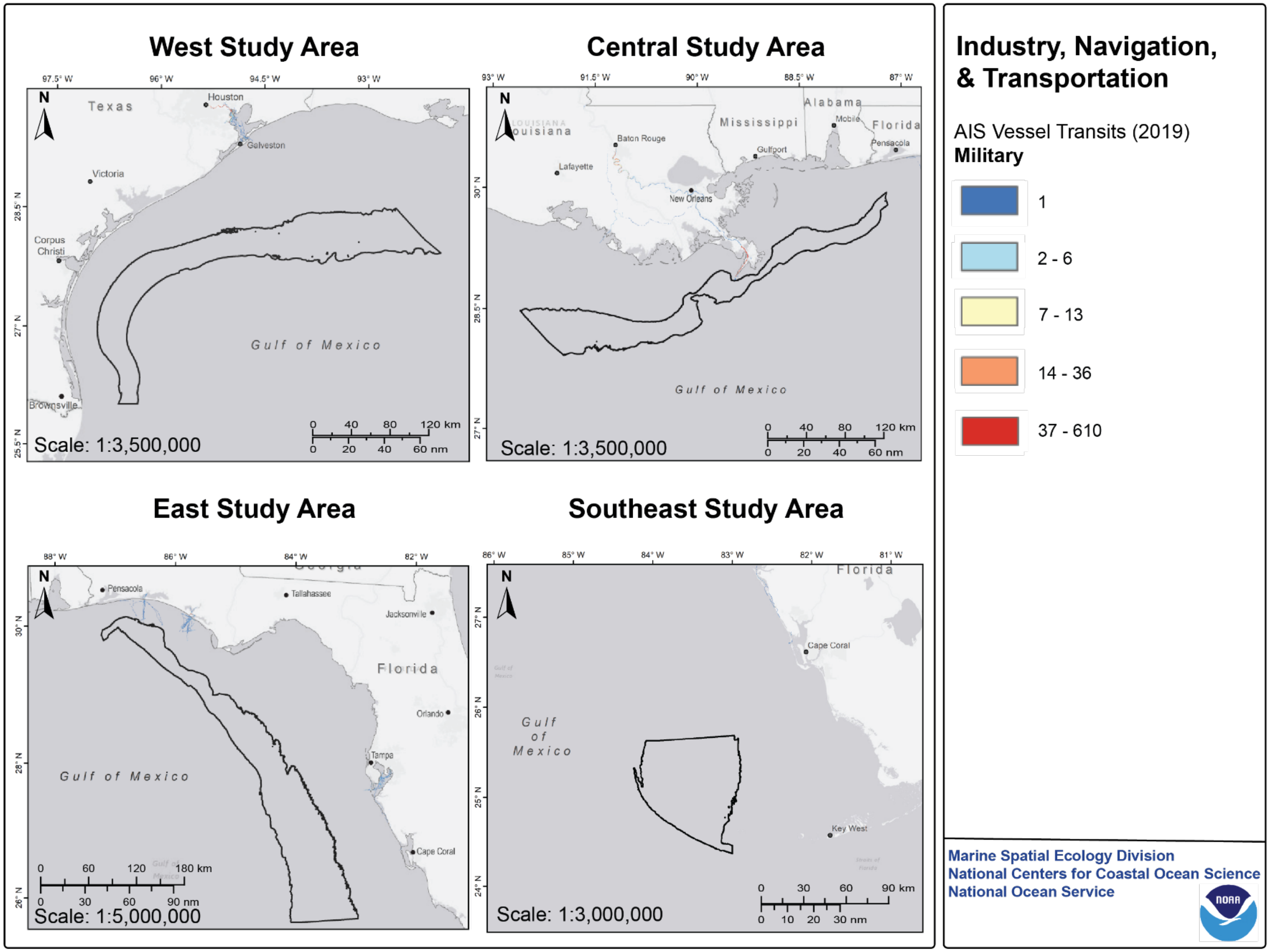


Figure 3.11. Automatic Identification System Vessel transit data from 2019 for military vessels in the West, Central, East, and Southeast study areas.

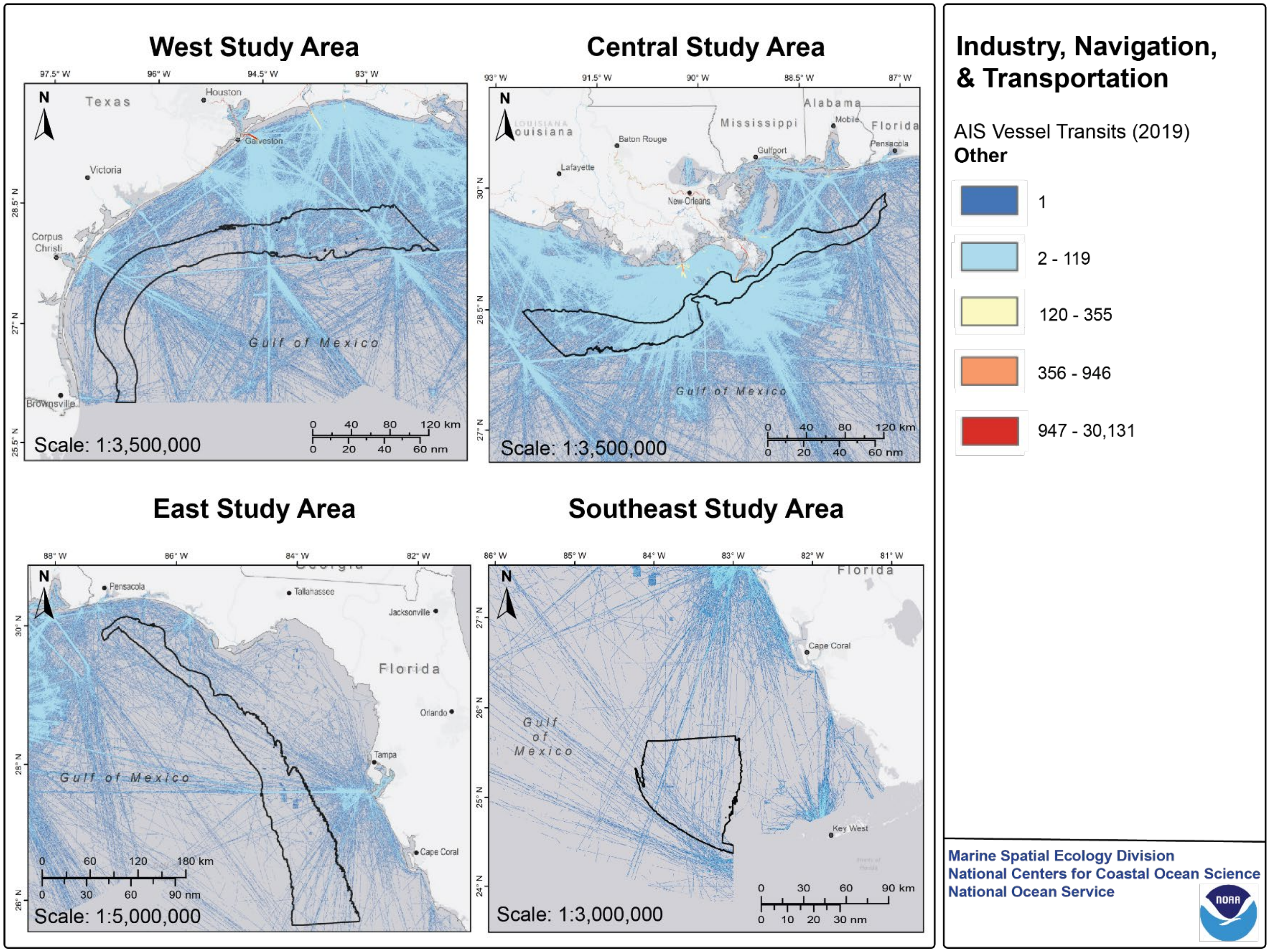


Figure 3.12. Automatic Identification System Vessel transit data from 2019 for vessels classified as other in the West, Central, East, and Southeast study areas.

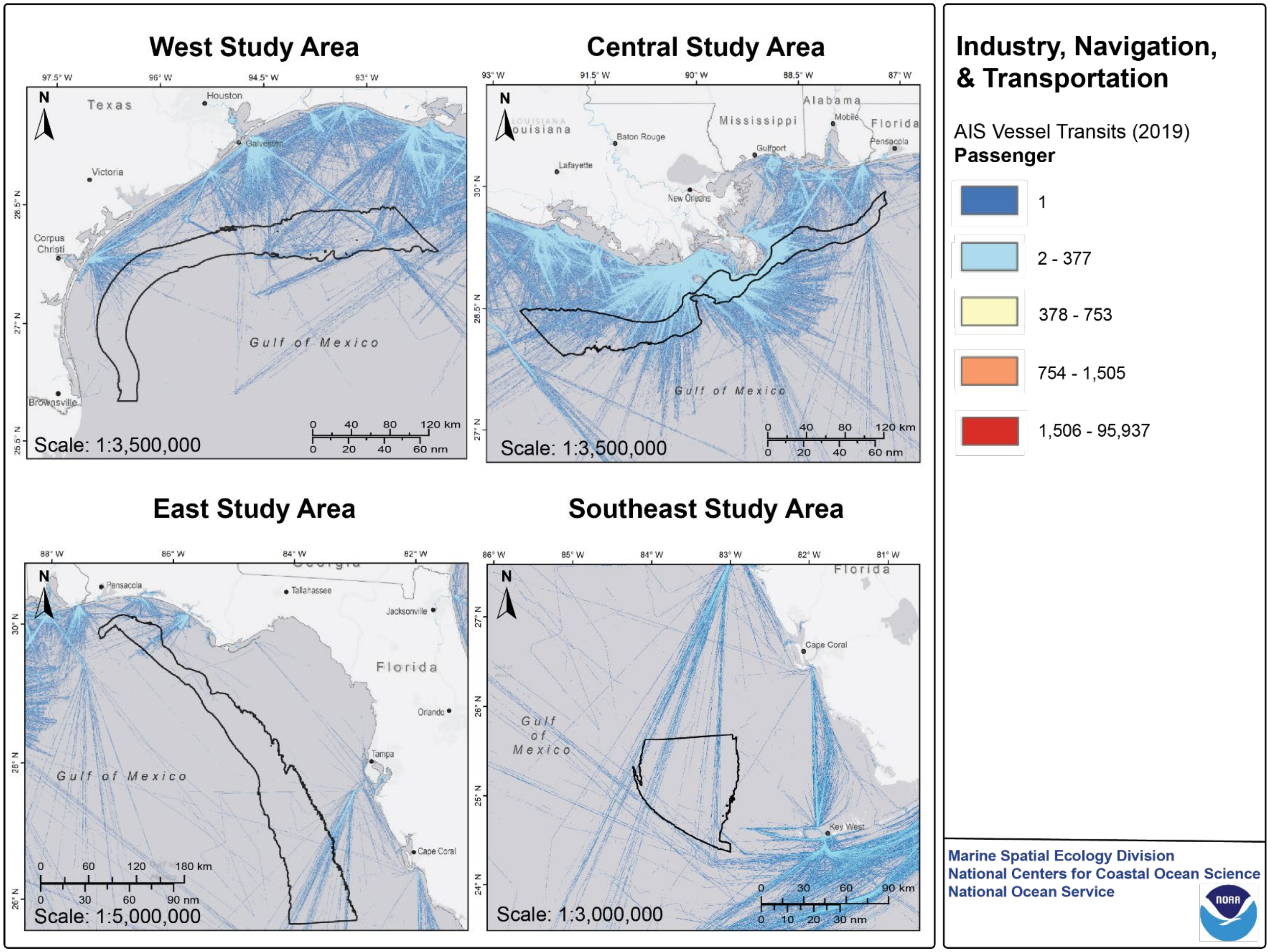


Figure 3.13. Automatic Identification System Vessel transit data from 2019 for passenger vessels in the West, Central, East, and Southeast study areas.

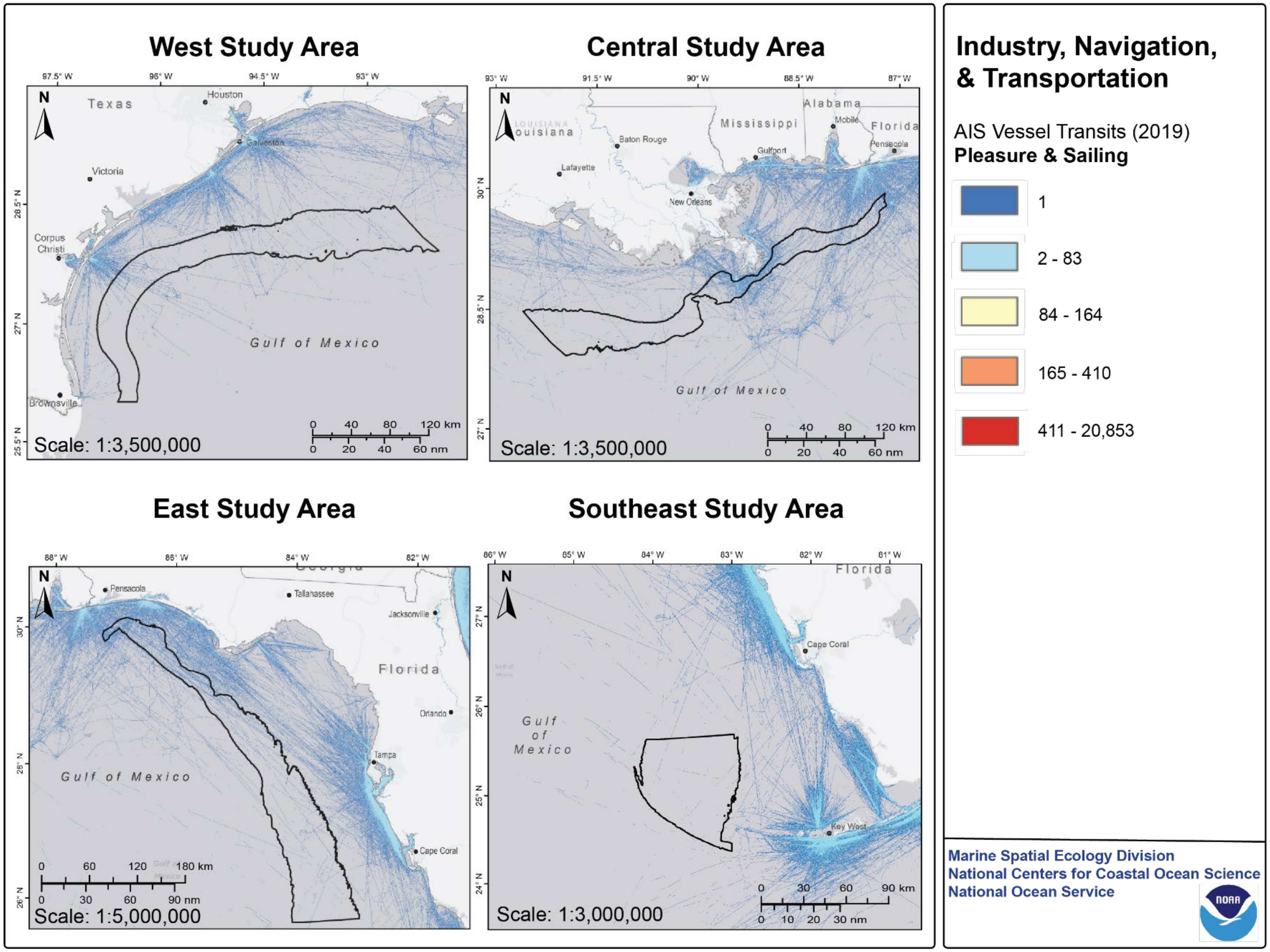


Figure 3.14. Automatic Identification System Vessel transit data from 2019 for pleasure and sailing vessels in the West, Central, East, and Southeast study areas.

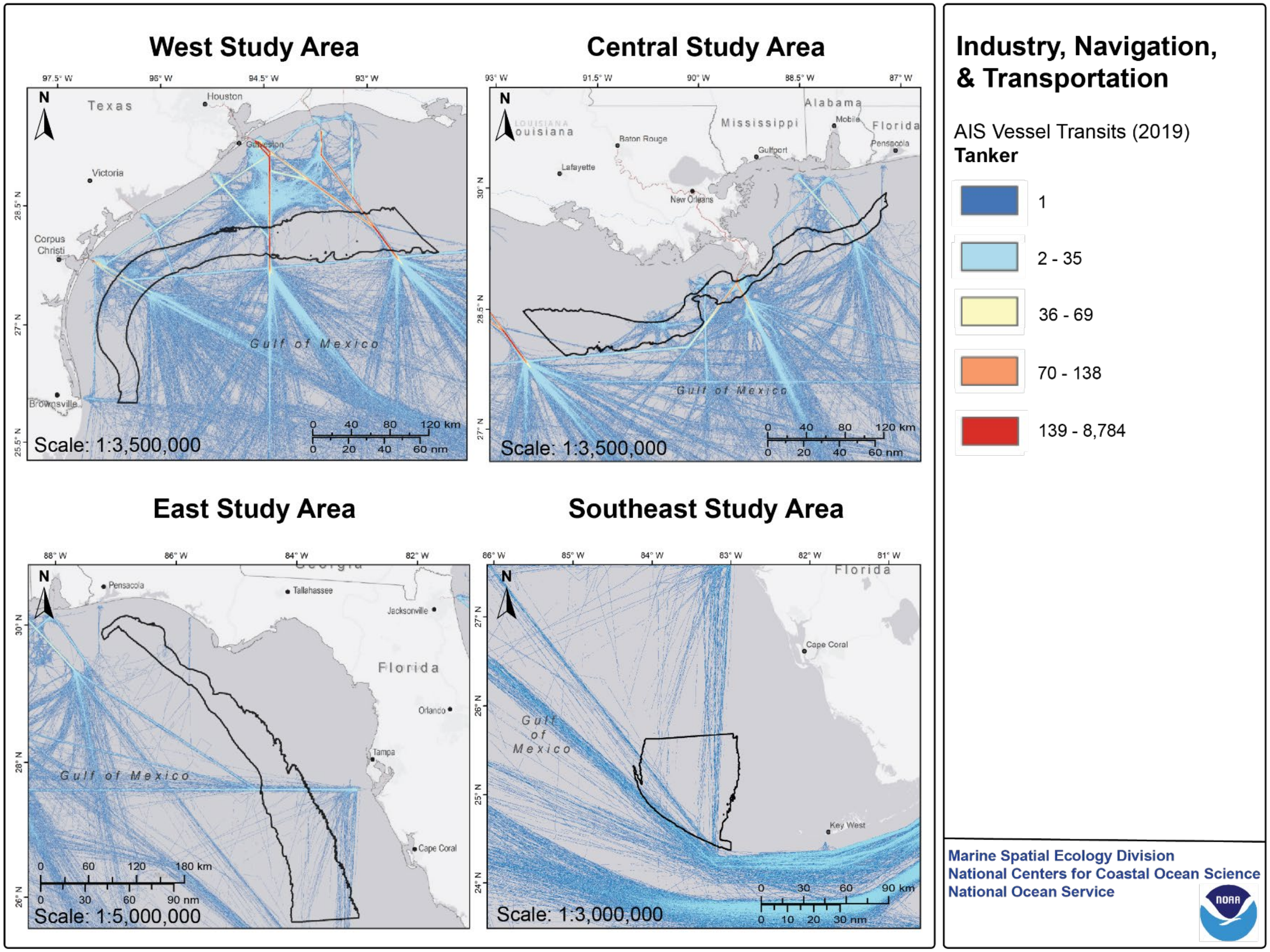


Figure 3.15. Automatic Identification System Vessel transit data from 2019 for tanker vessels in the West, Central, East, and Southeast study areas.

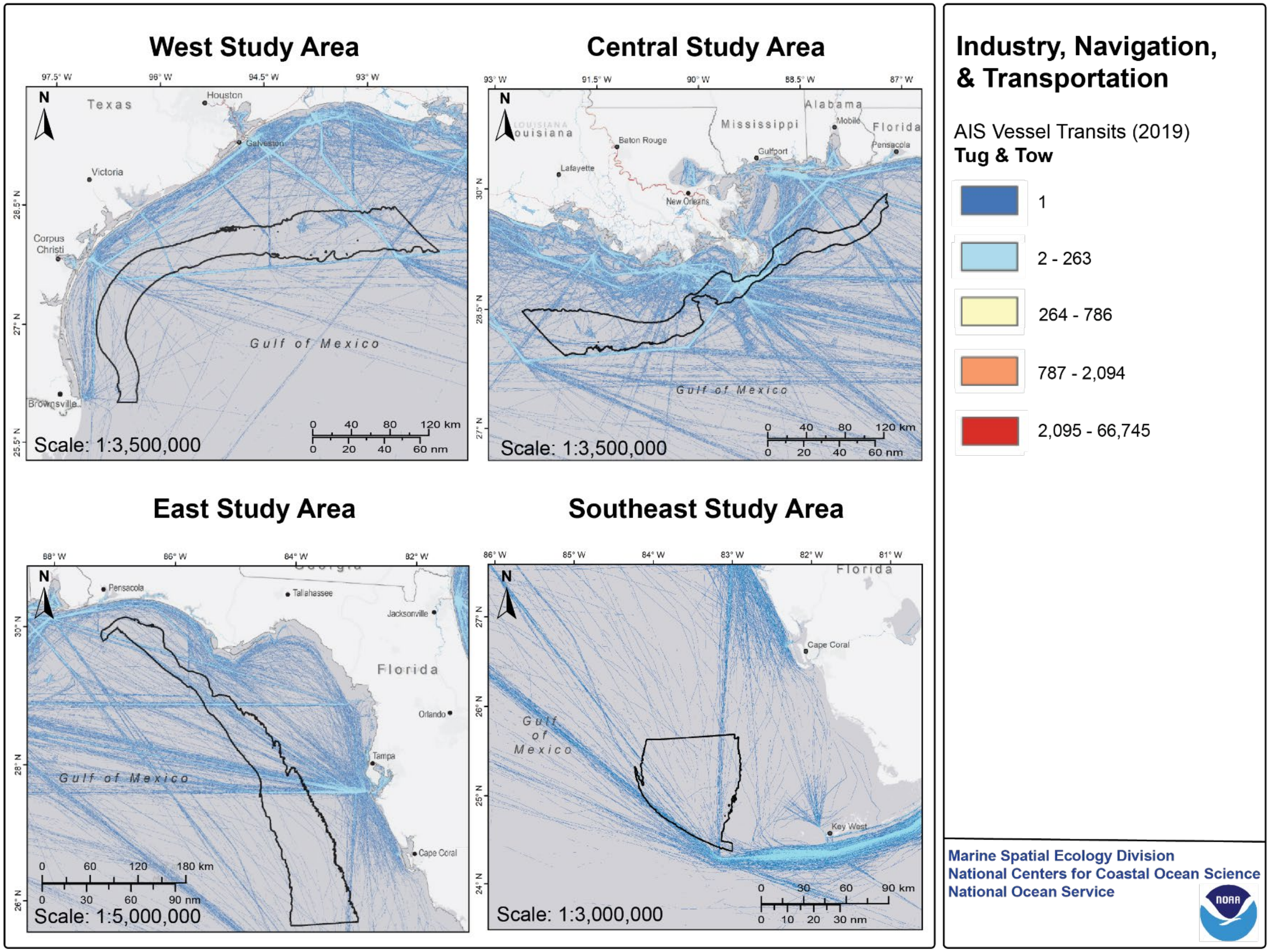


Figure 3.16. Automatic Identification System Vessel transit data from 2019 for tug and tow vessels in the West, Central, East, and Southeast study areas.

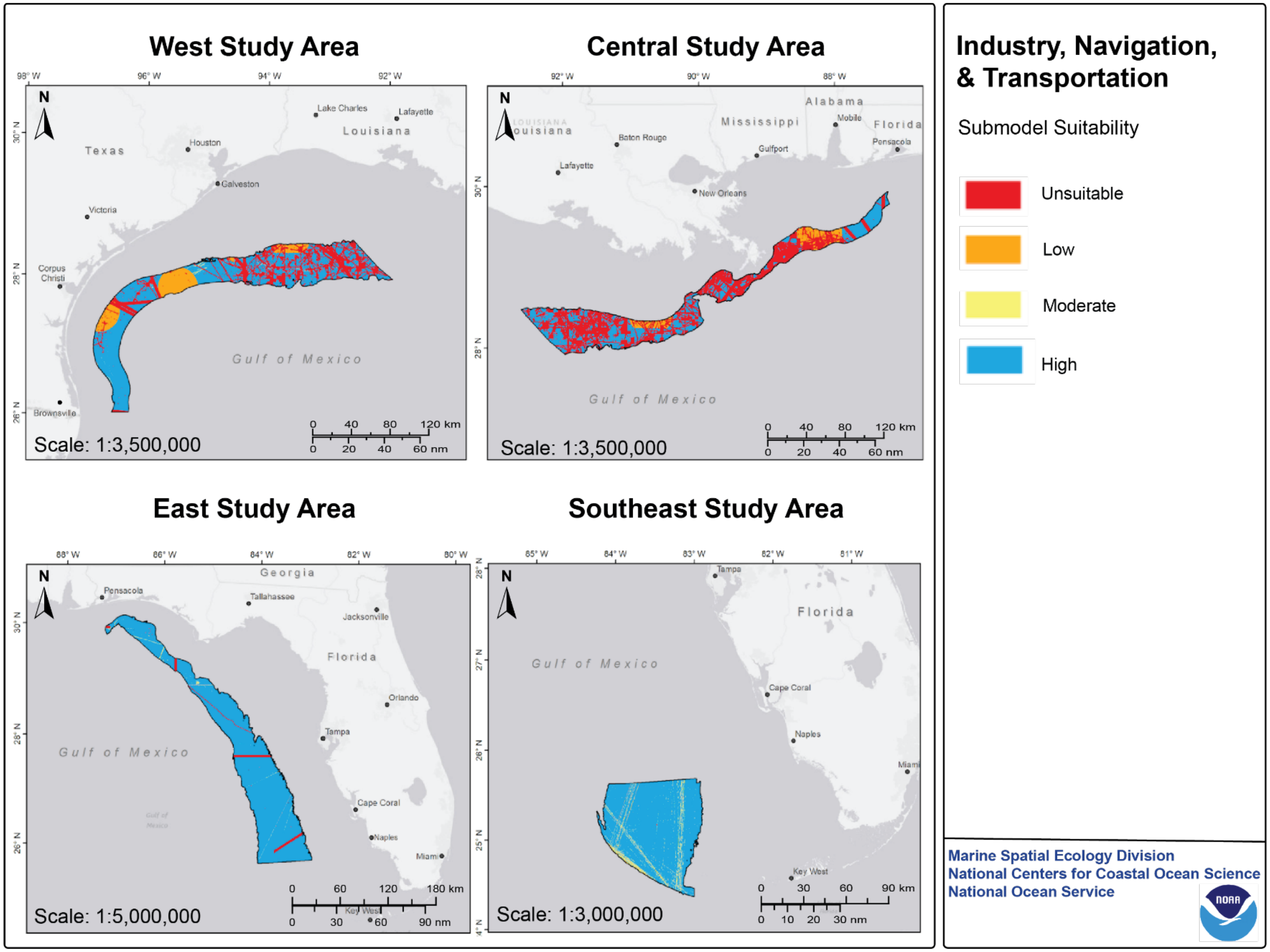


Figure 3.17. Industry, Navigation, and Transportation submodel utilized in the AOA suitability model (from top to bottom, left to right) for the West, Central, East, and Southeast study areas.

Fishing and Aquaculture

One permitted aquaculture activity (commercial live rock farm) was observed in the East study area and was included in the constraints submodel (Table 3.4). All remaining commercial and recreational fishing layers were included in the fishing and aquaculture submodel as numerical data.

For recreational fishing activity, the sum of trips from the SRHS (2014 - 2020) indicated the highest intersections of headboats within the West study area (12.5%), and occurred off of Corpus Christi, TX, with fewer trips off the Galveston area and in the central portion of the study area (Figure 3.18). Fewer SRHS vessel transits occurred within the East (5.7%), Central (5.5%), and Southeast (2.4%) study areas (Figure 3.18).

Commercial fishing data were included to avoid conflict with important and highly used fishing areas present within the study areas (Table 3.4). The penaeid shrimp fishery data (2004 - 2019) indicated trawls throughout all four study areas, with the highest occurrence in the West (62.2%) and Central (61.6%) study areas (Table 3.4; Figure 3.19). Effort in the West study area occurs throughout the area, but appears to taper off as depth approaches the 100-m (328.1-ft) contour. The Southeast (6.2%) and East (0.9%) study areas have less shrimp trawl effort intersecting these areas (Table 3.4).

The data (2007 - 2019) show that bandit fishing and longline reef fishing occur throughout all four study areas (Table 3.4; Figures 3.20, 3.21). Longline reef fishing data consistently indicate activity in deeper waters than the bandit fishing data in all study areas. The Central (64.6%) and East (60.6%) study areas had the highest intersections with bandit reef fishing gear, with a notable presence in the West (41.5%). Longline reef fishing activity intersected with the East (62.3%) and Southeast (58.4%) study areas, with 20 to 30% presence in the West and Central study areas (Figure 3.21). Examination of the menhaden fishing data identified slight overlap (0.6%) with the Central study area, with moderately low effort where overlaps occur (Table 3.4). In addition, HMS pelagic longline gear observer data (1993 - 2019) predominantly came from waters deeper than the four study areas, with very few occurrences in the West (0.04%), Central (0.3%), and Southeast (0.2 %) study areas (Table 3.4).

The final results of the fishing and aquaculture submodel are shown in Figure 3.22. Three fisheries had the greatest presence within the study areas, namely shrimp trawling, reef fish bandit gear, and reef fish longline gear. Shrimp trawls had the highest presence in the West and Central areas, reef fish bandit gear fishing had the highest presence in the Central and East study areas, and reef fish longline gear had the highest presence in the East and Southeast study areas.

Table 3.4. Fishing and Aquaculture data layers included in the relative suitability analysis and the score assigned to each dataset. All zero values were included in the constraints submodel rather than the fishing and aquaculture submodel. "Cont." denotes continuous data (0 - 1). A dash represents areas where the corresponding layer did not overlap with the given study area.

Dataset	Score	Percent Overlap or Intersection			
		W	C	E	SE
Commercial Shrimp Electronic Logbook Data (2004 - 2019)	Cont.	62.2%	61.6%	0.9%	6.2%
Highly Migratory Species Pelagic Longline Gear Observer Data (1993 - 2019)	Cont.	0.04%	0.3%	-	0.2%
Menhaden Fishery Data (2000 - 2016)	Cont.	-	0.6%	-	-
Reef Fish Bandit Gear Fishing Data (2007 - 2019)	Cont.	41.5%	64.6%	60.6%	36.4%
Reef Fish Longline Gear Fishing Data (2007 - 2019)	Cont.	22.6%	28.4%	62.3%	58.4%
Southeast Region Headboat Survey Data (2014 - 2020)	Cont.	12.5%	5.5%	5.7%	2.4%
Live Rock Aquaculture with 500-m setback	0	-	-	0.003%	-

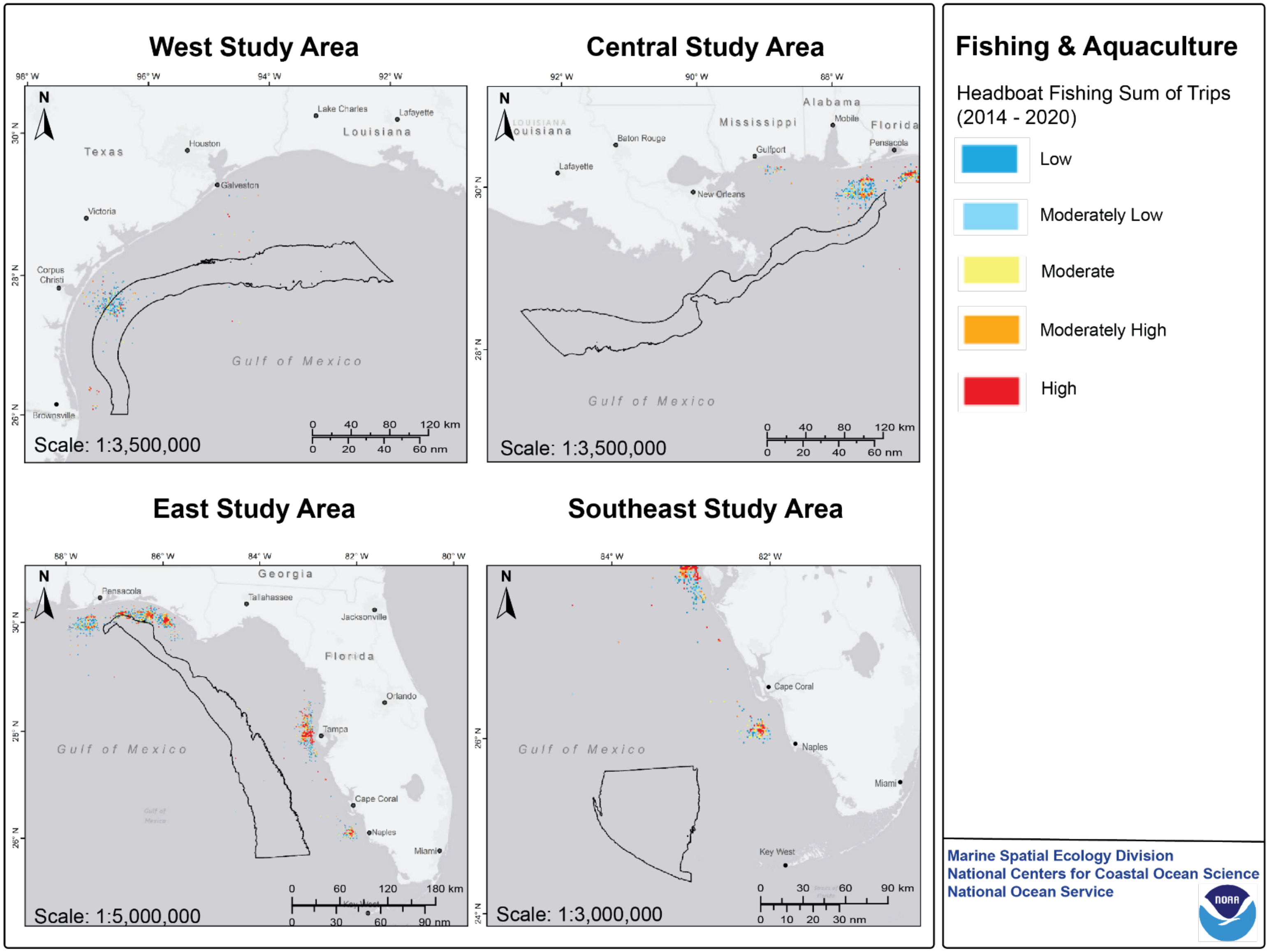


Figure 3.18. Southeast Region Headboat Survey data (2014 - 2020) for the West, Central, East, and Southeast study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher headboat fishing effort. Data and maps reflect the resolution at which data can be displayed to the public to ensure protection of confidential data components.

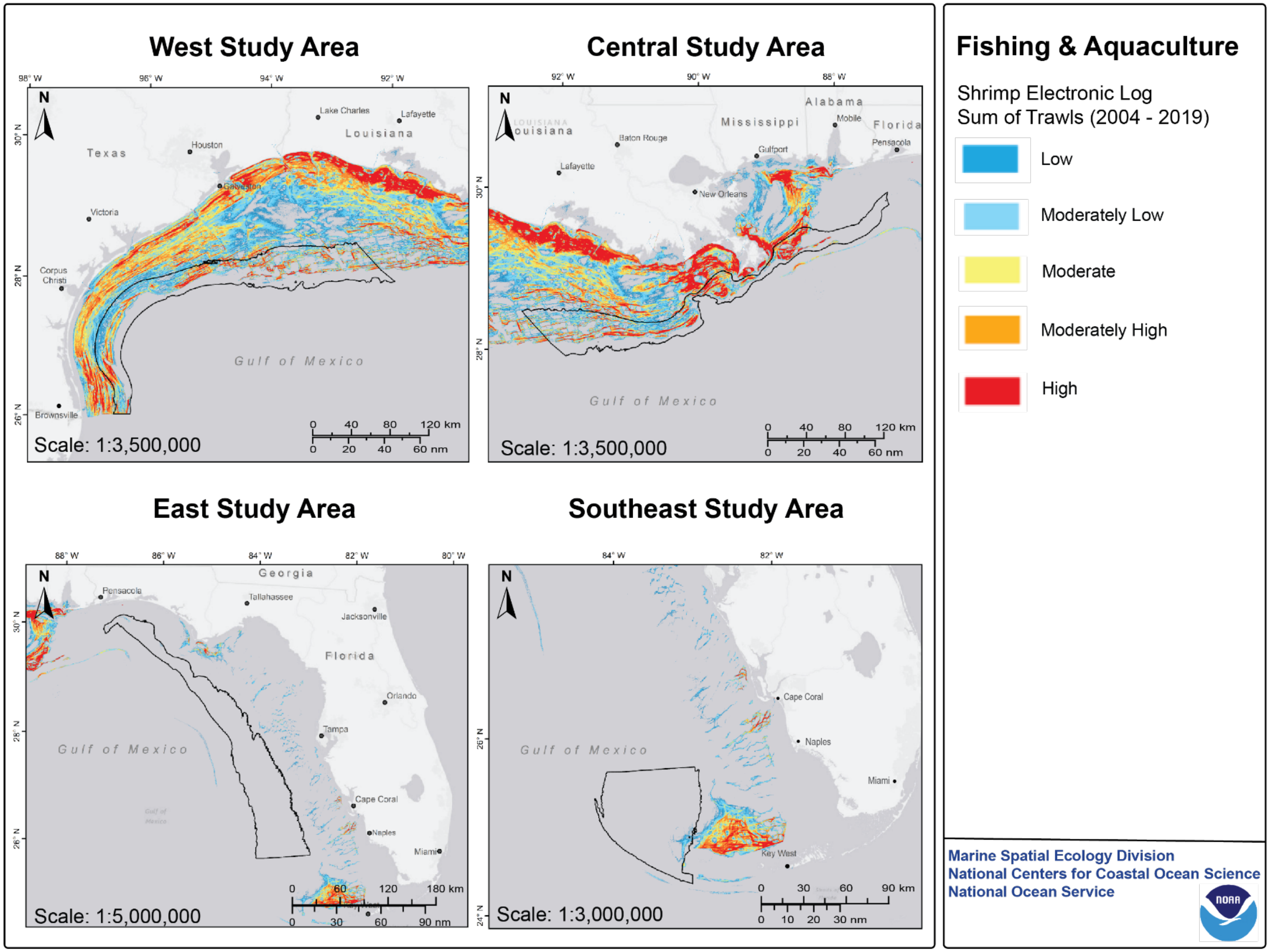


Figure 3.19. Commercial Shrimp Electronic Logbook data (2004 - 2019) for the West, Central, East, and Southeast study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher trawling effort. Data and maps reflect the resolution at which data can be displayed to the public to ensure protection of confidential data components.

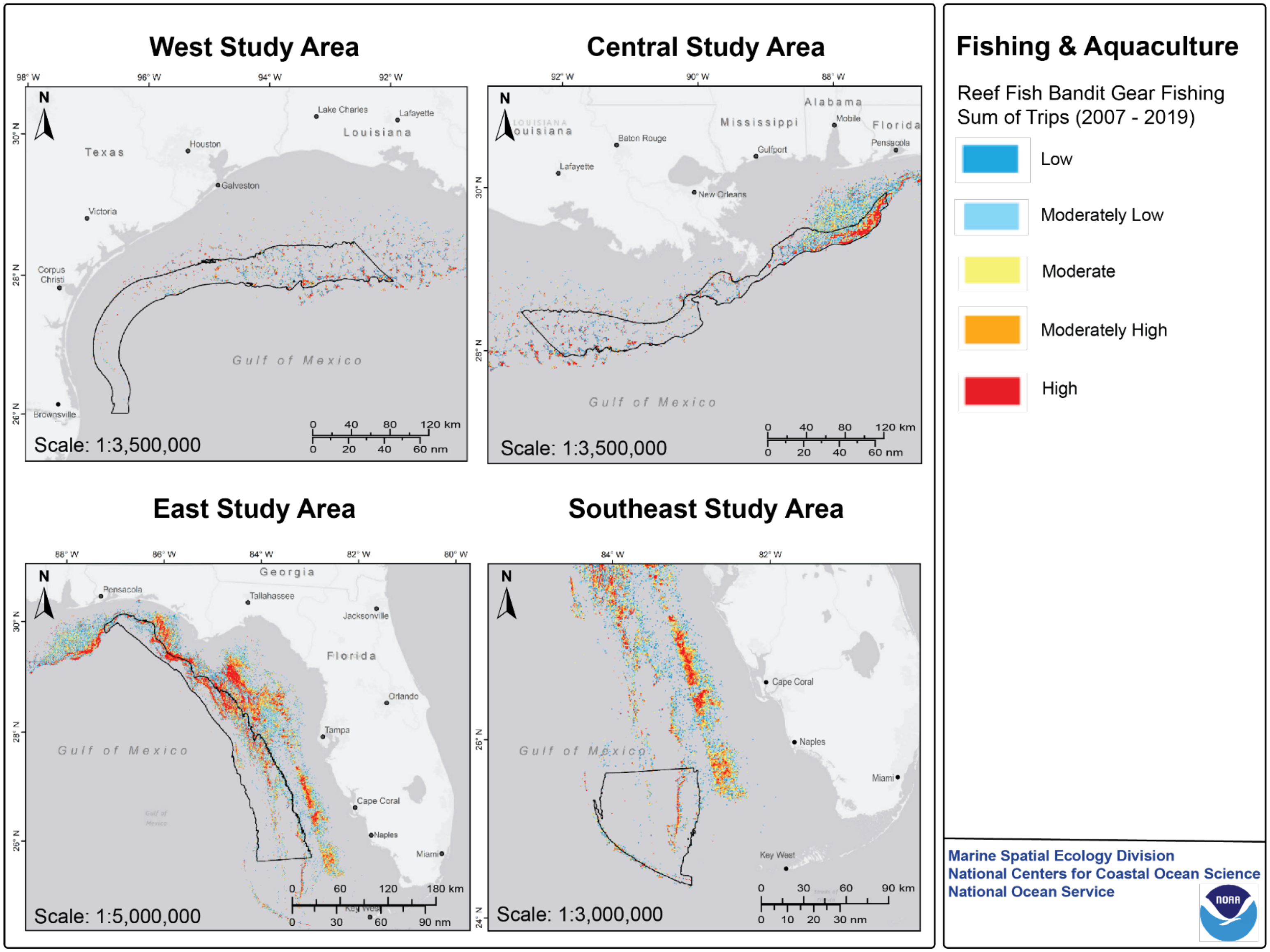


Figure 3.20. Reef Fish Bandit Gear Fishing Sum of Trips (2007 - 2019) for the West, Central, East, and Southeast study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher predicted fishing effort. Data and maps reflect the resolution at which data can be displayed to the public to ensure protection of confidential data components.

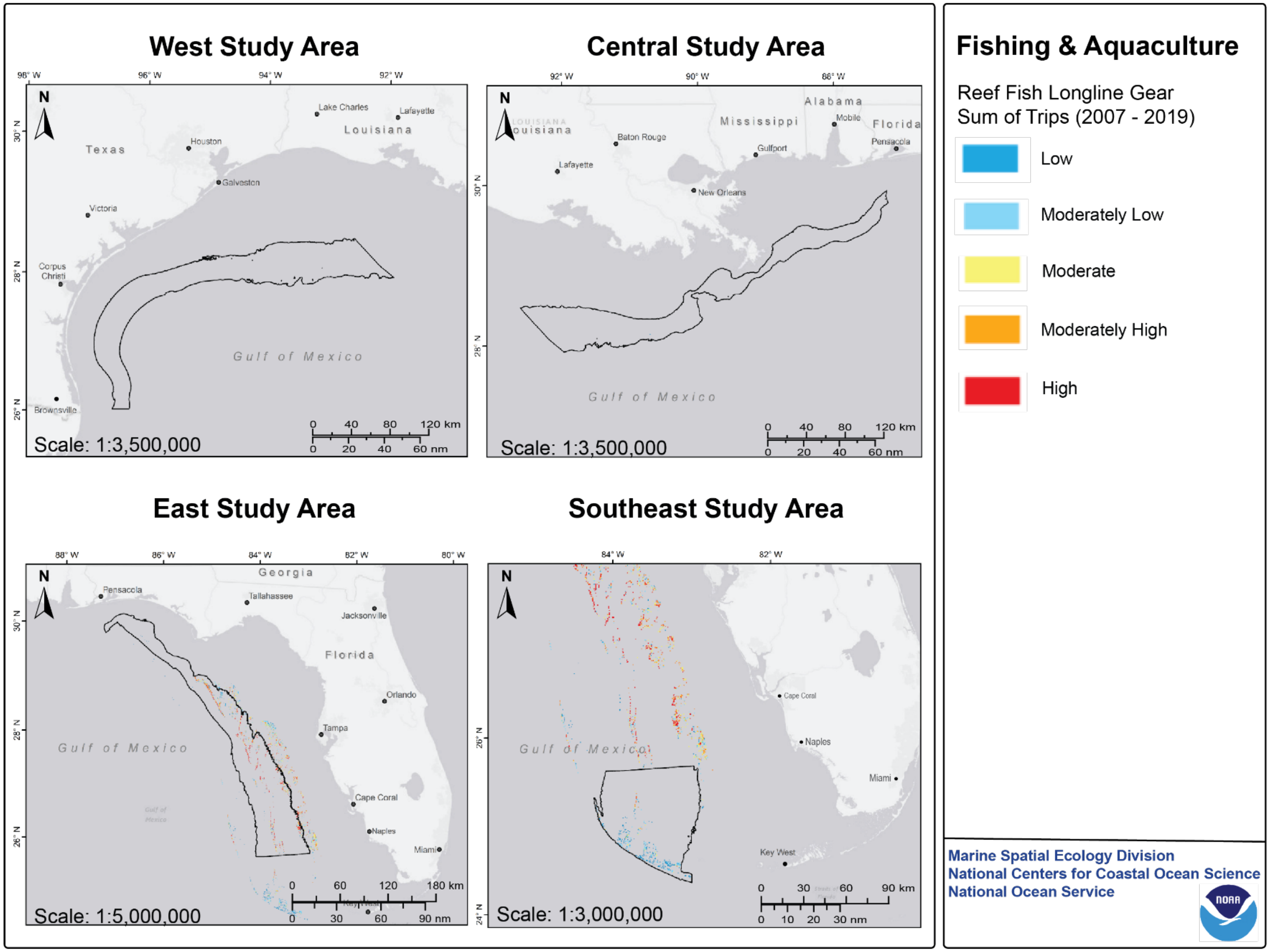


Figure 3.21. Reef Fish Longline Gear Fishing Sum of Trips (2007 - 2019) for the West, Central, East, and Southeast study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher predicted fishing effort. Data and maps reflect the resolution at which data can be displayed to the public to ensure protection of confidential data components.

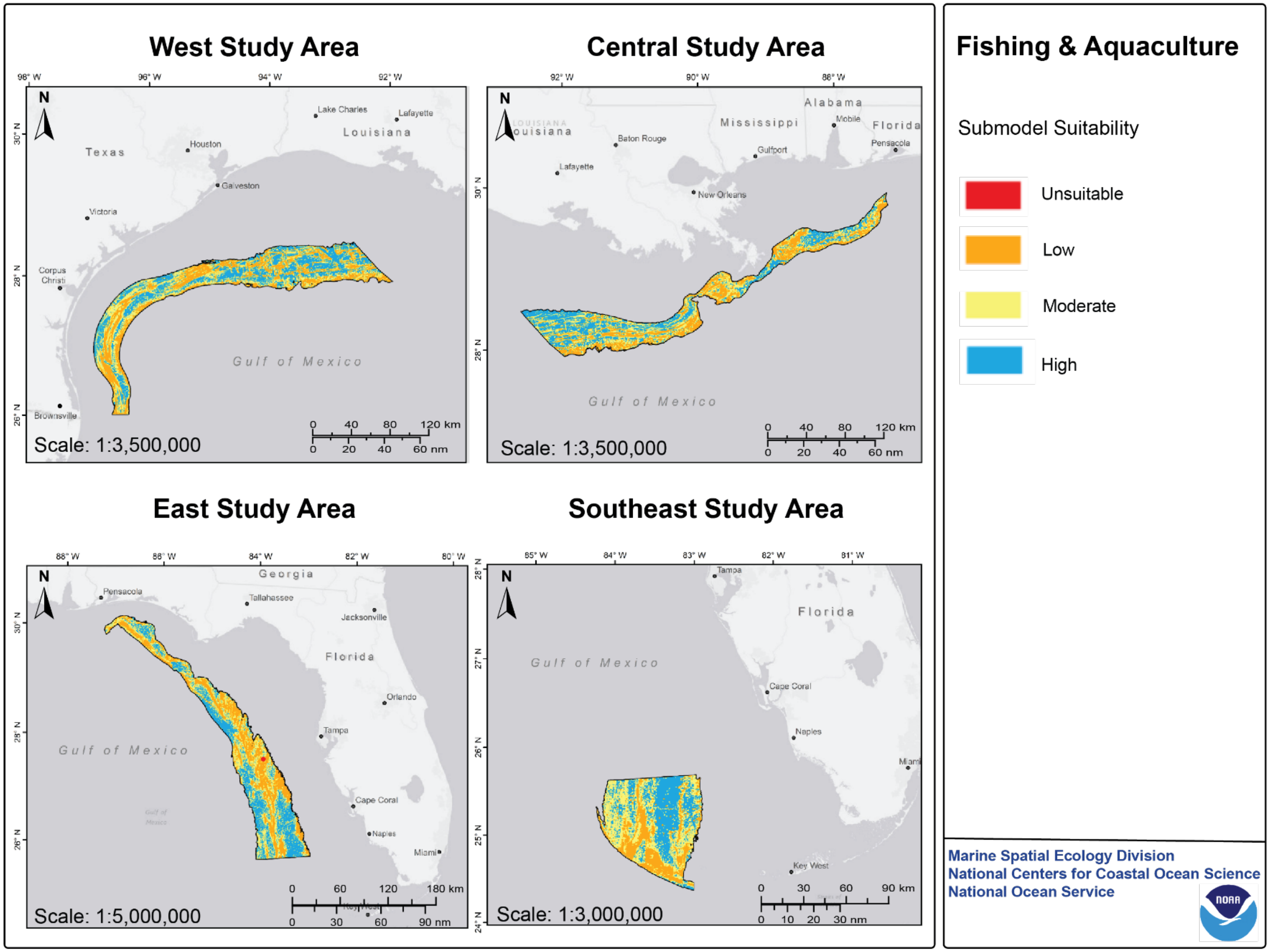


Figure 3.22. Final Fishing and Aquaculture submodel utilized in the suitability model for (from top to bottom, left to right) the West, Central, East, and Southeast study areas. Red color indicates those areas where layers with a score of 0 occurred due to conflict with an activity.

Constraints Submodel

All constraints submodel layers have a score of 0, but may impact study areas differently due to the varying degree of overlap those layers have with each study area (i.e., study areas with higher levels of overlap with constraint layers have less space for AOA suitability modeling). (Table 3.5). This section presents a summary of the constraints. It is important to note that the total area removed may not sum to 100% because of overlapping constraints in a study area. The fishing and aquaculture data consisted of continuous data, with the exception of a permitted aquaculture site in the East study area (Table 3.4). Continuous data were not scored as 0, and therefore were not included in the constraints submodel (e.g., fishing datasets).

In the West study area, constraints removed 35.2% of the total area. Industry, Navigation, and Transportation constraints removed 30.1% and Natural and Cultural Resource constraints removed 8.4%.

In the Central study area, constraints removed 67.2% of the total area. The Industry, Navigation, and Transportation constraints alone accounted for 57.8% of the area removed. This was predominantly due to the presence of oil and gas infrastructure. The Natural and Cultural Resources constraints removed 15.2%.

In the East study area, constraints removed 71.8% of the total area, which was largely a result of National Security constraints. Constraints associated with Natural and Cultural Resources reduced the area available by 21.3%.

National Security constraints severely impacted the Southeast study area, removing 100% of the area for consideration of potential AOA options. To a lesser extent, constraints associated with Natural and Cultural Resources removed 40.5% in this Southeast study area.

Table 3.5. Percent of area removed from each of the constraints, broken down by the data categories of the different submodels. The total area removed is the percent of cells removed from all constraints. The total area removed may not sum to 100% because of overlapping constraints.

Submodel Constraints	West	Central	East	Southeast
National Security	1.5%	0%	62.4%	100%
Natural and Cultural Resources	8.4%	15.2%	21.3%	40.5%
Industry, Navigation, and Transportation	30.1%	57.8%	3.3%	<0. 1%
Fishing and Aquaculture	0%	0%	<0. 1%	0%
Total Area Removed	35.2%	67.2%	71.8%	100%

Final Suitability

The final suitability results for all submodels are presented in Figure 3.23. Several suitable areas were distributed evenly across the West study area off Texas and the Central study area off Louisiana. Areas of the Central study area off Mississippi and Alabama had a significant number of constraints. Several large areas of suitability were observed within the East study area, principally off the coast of Florida below 28° latitude to the southern extent of the East study area boundary. A combination of constraints analysis and consultation with the DOD removed 100% of the Southeast study area. As such, the Southeast study area was not included in subsequent analyses given the incompatibility of this study area for consideration of an AOA. It is important to note that these suitability results are reflective of the planning objective to identify AOA options. In the Gulf of Mexico region, aquaculture opportunities may exist under different planning objectives or at smaller scales than suitable for AOAs (< 500 ac or 202.3 ha).

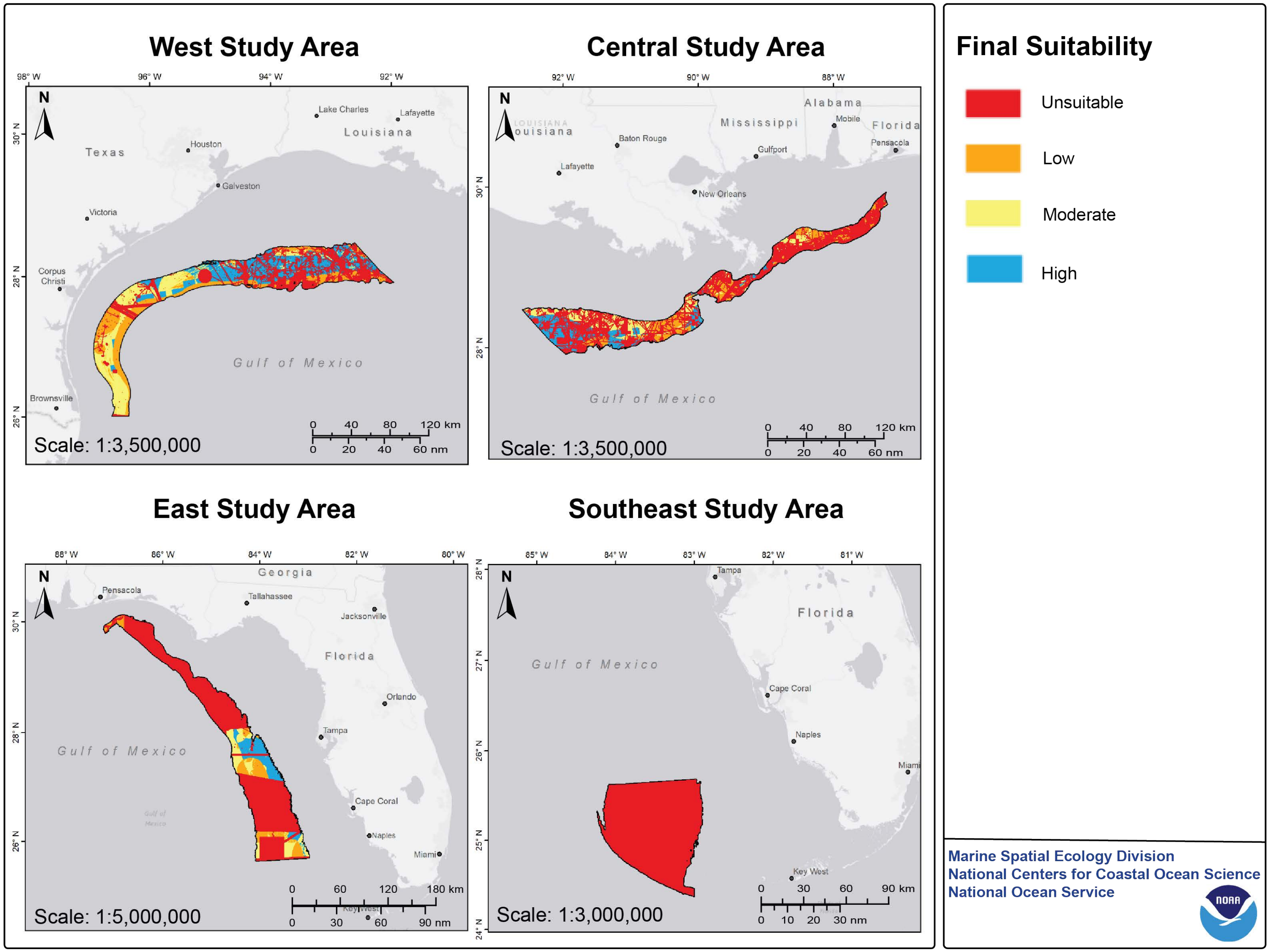


Figure 3.23. Suitability modeling results for each study area. Red color indicates those areas where layers with a score of 0 occurred due to conflict with an ocean activity.

Cluster Analysis and AOA Options

A total of 60 high-high clusters where AOA options between 500 and 2,000 ac could be sited were identified across all study areas (Table 3.6; Figures 3.24 - 3.26; Appendices E and F). Forty-three clusters were identified in the West study area with a total of 5,033 AOA options comprising 339,755 ac (Table 3.7). Within the Central study area, 13 clusters were identified with a total of 1,056 AOA options comprising 93,220 ac (Table 3.8). Lastly, four clusters were identified in the East study area with a total of 23,750 AOA options comprising 722,900 ac (Table 3.9). In total, 29,839 AOA options were evaluated across the Gulf of Mexico. The top three ranking AOA options per study area were identified using the among-cluster precision siting model with each study area producing two 2,000-ac AOA options and one 500-ac AOA option for a total of 4,500 ac per study area (Figures 3.27 - 3.29). It was unintentional that two 2,000-ac AOA and one 500-ac AOA option were identified as top-ranking options for each study area.

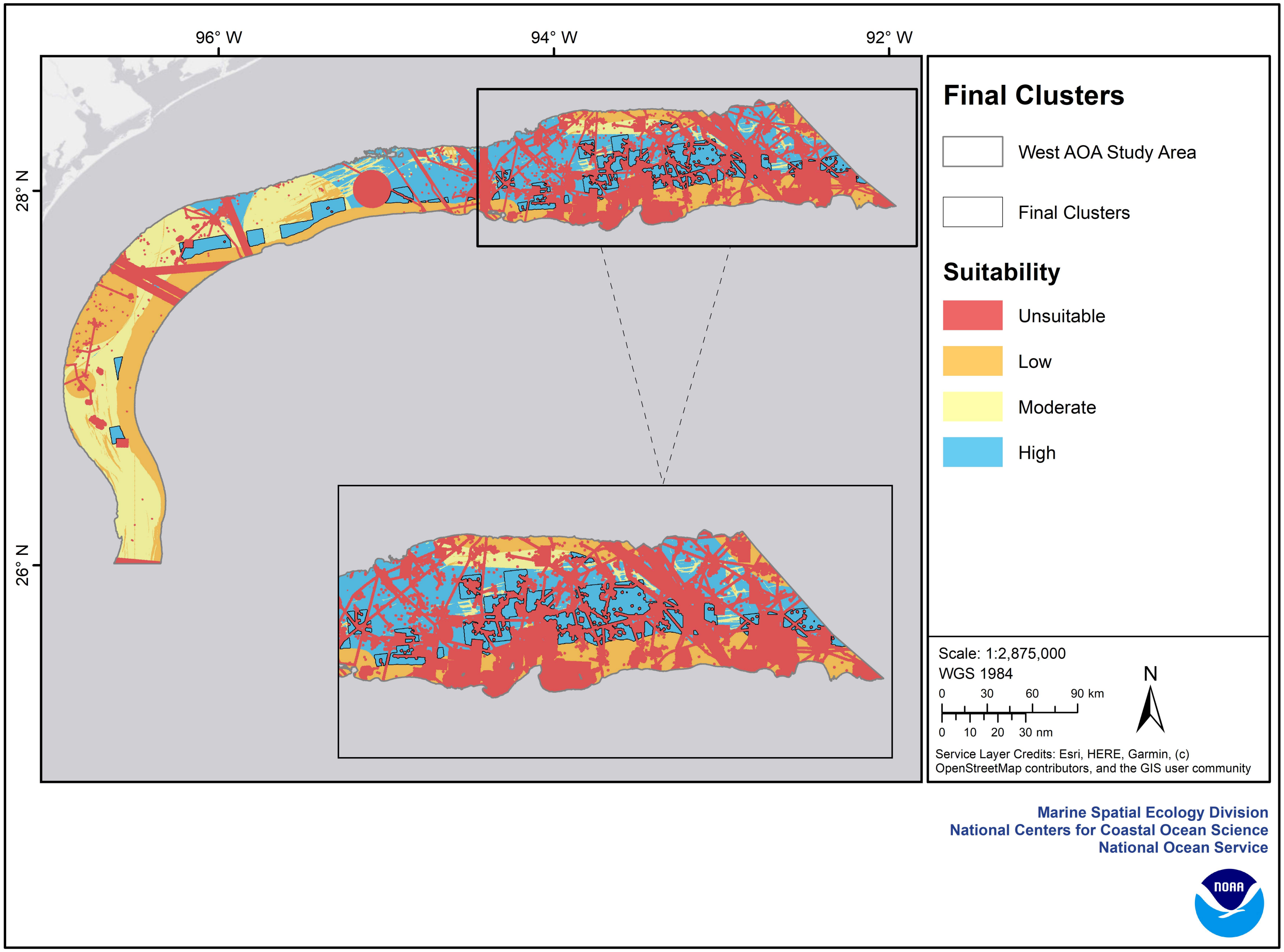


Figure 3.24. Cluster analysis of the West study area. Blue areas outlined with a black line indicate areas determined to have the highest suitability (i.e., high-high clusters). The inset map shows this area in more detail, given the size of the West study area, and the number of clusters identified as highly suitable within this portion of the study area.

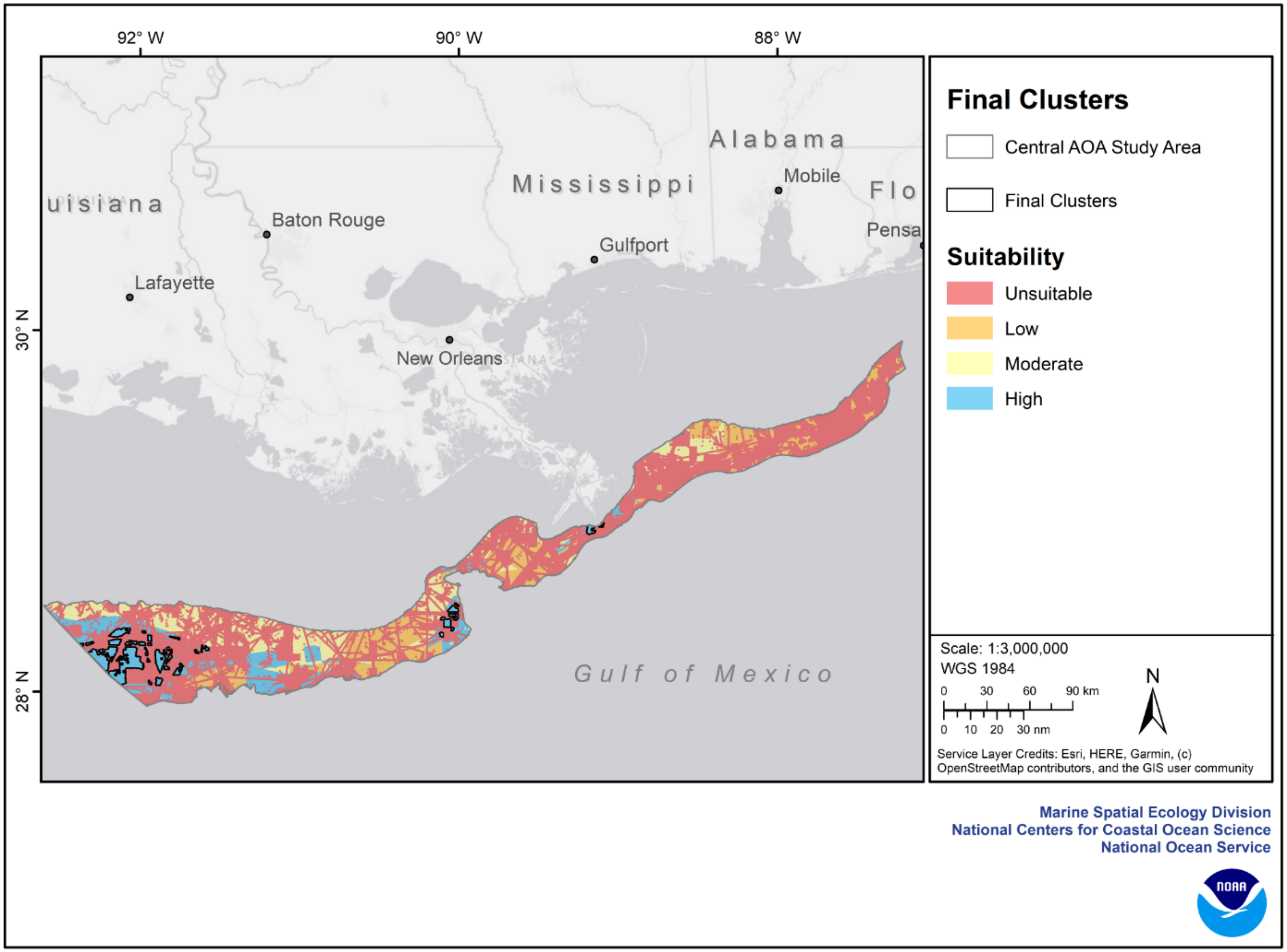


Figure 3.25. Cluster analysis of the Central study area. Blue areas outlined with a black line indicate areas determined to have the highest suitability (i.e., high-high clusters).

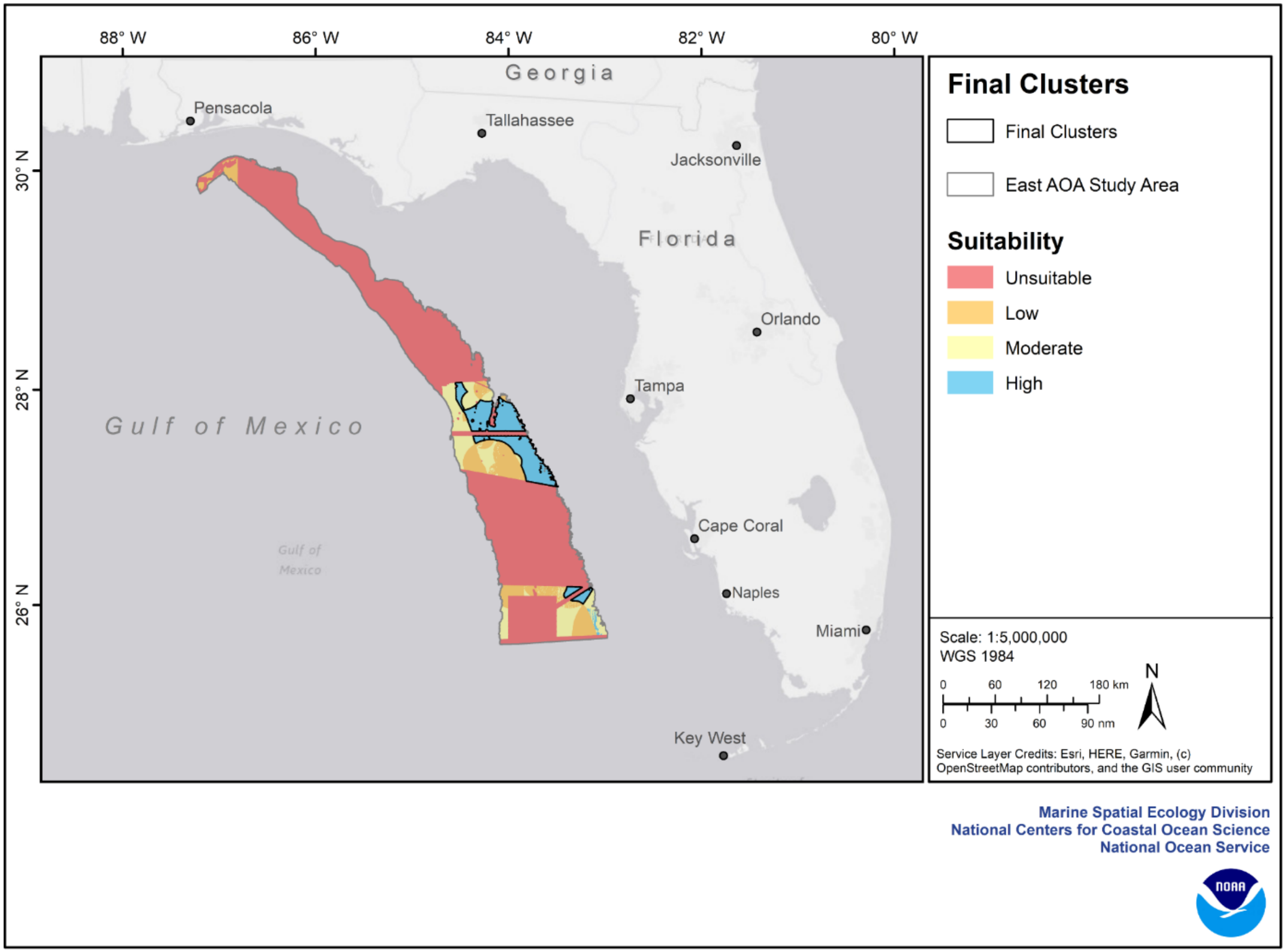


Figure 3.26. Cluster analysis of the East study area. Blue areas outlined with a black line indicate areas determined to have the highest suitability (i.e., high-high clusters).

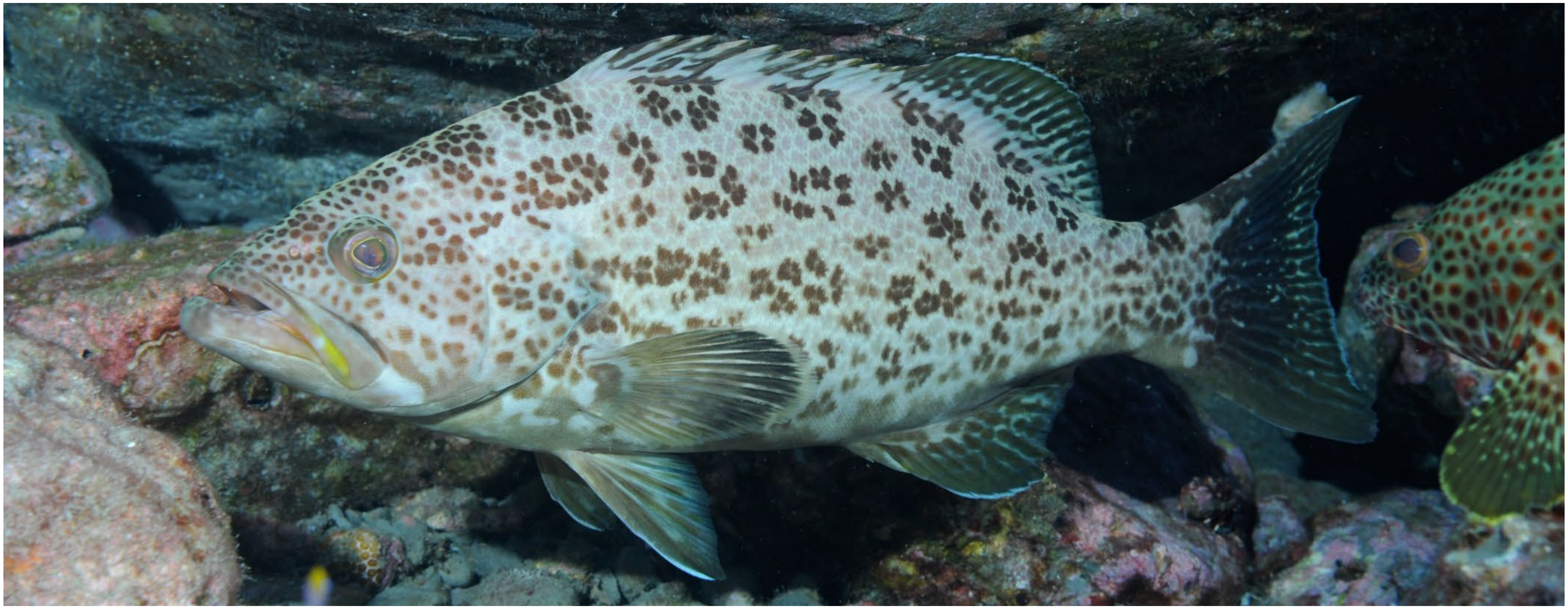
Table 3.6. Final high suitability clusters in the West study area (W-1 to W-43), the Central study area (C-1 to C-13), and East study area (E-1 to E-4). Corresponding with each Cluster ID are the number of Aquaculture Opportunity Area options identified within each cluster from the within-cluster analysis for the West, Central, and East study areas. For more information see Appendix F.

Cluster ID	# AOA options	Area (acres)
W-1	188	12,240
W-2	48	5,205
W-3	13	1,010
W-4	125	45,200
W-5	461	19,480
W-6	1428	66,595
W-7	943	9,685
W-8	56	7,510
W-9	4	650
W-10	9	1,530
W-11	28	1,220
W-12	16	1,025
W-13	12	915
W-14	77	3,040
W-15	64	9,345
W-16	71	2,290
W-17	9	1,530
W-18	66	7,950
W-19	13	4,425
W-20	24	1,065
W-21	67	6,485
W-22	41	7,300

Cluster ID	# AOA options	Area (acres)
W-31	11	820
W-32	36	1,940
W-33	191	15,730
W-34	423	31,480
W-35	68	4,945
W-36	3	2,400
W-37	13	1,840
W-38	8	2,535
W-39	29	4,780
W-40	19	1,490
W-41	1	1,000
W-42	51	10,805
W-43	3	1,540
C-1	227	21,300
C-2	5	3,400
C-3	54	6,195
C-4	537	37,920
C-5	5	700
C-6	35	1,300
C-7	47	9,550
C-8	15	1,860
C-9	45	1,440

Cluster ID	# AOA options	Area (acres)
W-23	53	7,120
W-24	175	11,680
W-25	91	7,910
W-26	39	1,770
W-27	29	7,110
W-28	9	3,920
W-29	4	1,210
W-30	14	2,035

Cluster ID	# AOA options	Area (acres)
C-10	8	805
C-11	24	3,900
C-12	13	2,325
C-13	41	2,525
E-1	626	30,520
E-2	440	23,155
E-3	10,803	313,920
E-4	11,881	355,305



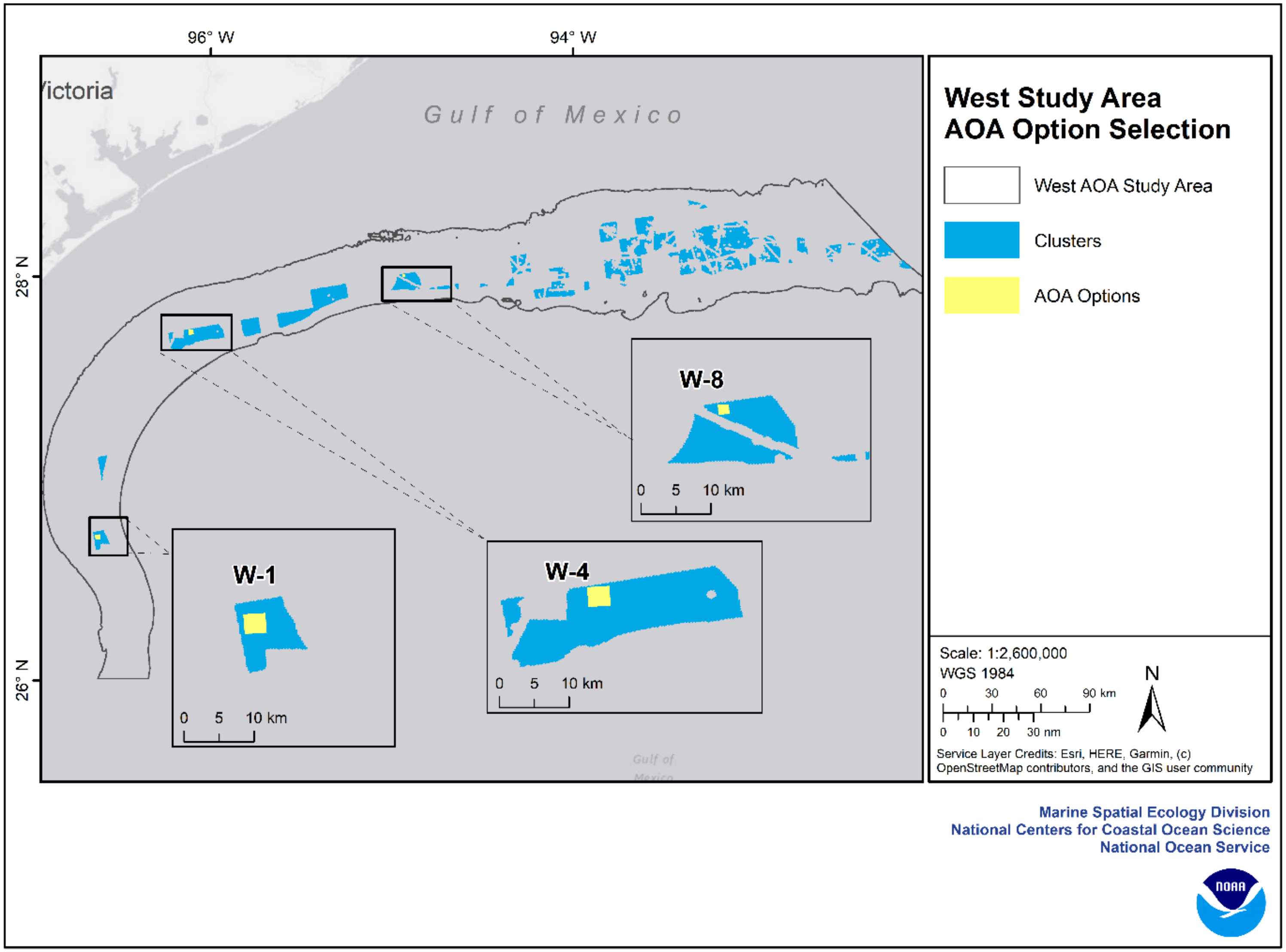


Figure 3.27. Precision modeling results for the West study area.

Table 3.7. West study area precision siting results with submodel scores for each Aquaculture Opportunity Area option. Top ranked options are highlighted in light blue and are W-1, W-4, and W-8. Aquaculture Opportunity Area options W-5, W-6, and W-3 were not included because of limitations with geographical dispersion and because the options were within 30 nm of a higher scoring option. For more information see Appendix F.

Option	Rank	Submodel				Final Score
		Logistic	Vessel Traffic	Fishing	Metocean	
W-1	1	1.00	0.99	0.91	1.00	0.97
W-4	2	0.89	0.97	1.00	1.00	0.96
W-5	3	0.82	0.97	0.87	0.97	0.90
W-6	4	0.75	0.95	0.85	0.95	0.87
W-3	5	0.88	0.45	0.97	1.00	0.79
W-8	6	0.65	0.77	0.92	0.84	0.79
W-13	7	0.42	0.93	1.00	0.74	0.73
W-12	8	0.45	0.83	0.99	0.77	0.73
W-2	9	0.84	0.96	0.33	0.99	0.72
W-10	10	0.39	0.82	0.93	0.71	0.68
W-16	11	0.29	0.98	1.00	0.74	0.68
W-20	12	0.3	0.72	0.97	0.88	0.66
W-19	13	0.3	0.71	1.00	0.86	0.65
W-24	14	0.25	0.87	0.99	0.83	0.65
W-15	15	0.26	0.99	1.00	0.71	0.65
W-14	16	0.29	0.92	1.00	0.67	0.65
W-21	17	0.19	0.95	0.97	0.83	0.62
W-33	18	0.18	0.92	1.00	0.77	0.60
W-34	19	0.19	0.93	1.00	0.70	0.60
W-11	20	0.42	0.63	0.68	0.67	0.59
W-18	21	0.16	0.97	0.97	0.77	0.59

Option	Rank	Submodel				Final Score
		Logistic	Vessel Traffic	Fishing	Metocean	
W-7	22	0.64	0.95	0.23	0.84	0.58
W-9	23	0.53	0.74	0.32	0.86	0.57
W-23	24	0.15	0.93	0.99	0.74	0.57
W-38	25	0.20	0.77	0.96	0.63	0.55
W-26	26	0.15	0.76	1.00	0.80	0.55
W-22	27	0.13	0.96	0.98	0.74	0.55
W-41	28	0.26	0.72	0.95	0.50	0.55
W-25	29	0.17	0.55	1.00	0.80	0.52
W-39	30	0.25	0.70	0.98	0.39	0.50
W-36	31	0.11	0.97	0.94	0.63	0.50
W-32	32	0.07	0.91	1.00	0.83	0.49
W-42	33	0.31	0.83	0.95	0.22	0.48
W-37	34	0.15	0.69	0.74	0.63	0.47
W-30	35	0.07	0.92	0.99	0.74	0.47
W-35	36	0.08	0.93	0.91	0.71	0.46
W-27	37	0.06	0.88	0.96	0.71	0.44
W-17	38	0.14	0.37	0.76	0.74	0.41
W-31	39	0.02	0.67	0.56	0.74	0.28
W-43	40	0.2	0.95	0.14	0.22	0.28
W-40	41	0.26	0.31	0.04	0.32	0.18
W-28	42	0	0.93	0.94	0.74	0.14
W-29	43	0	0.95	0.95	0.74	0.05

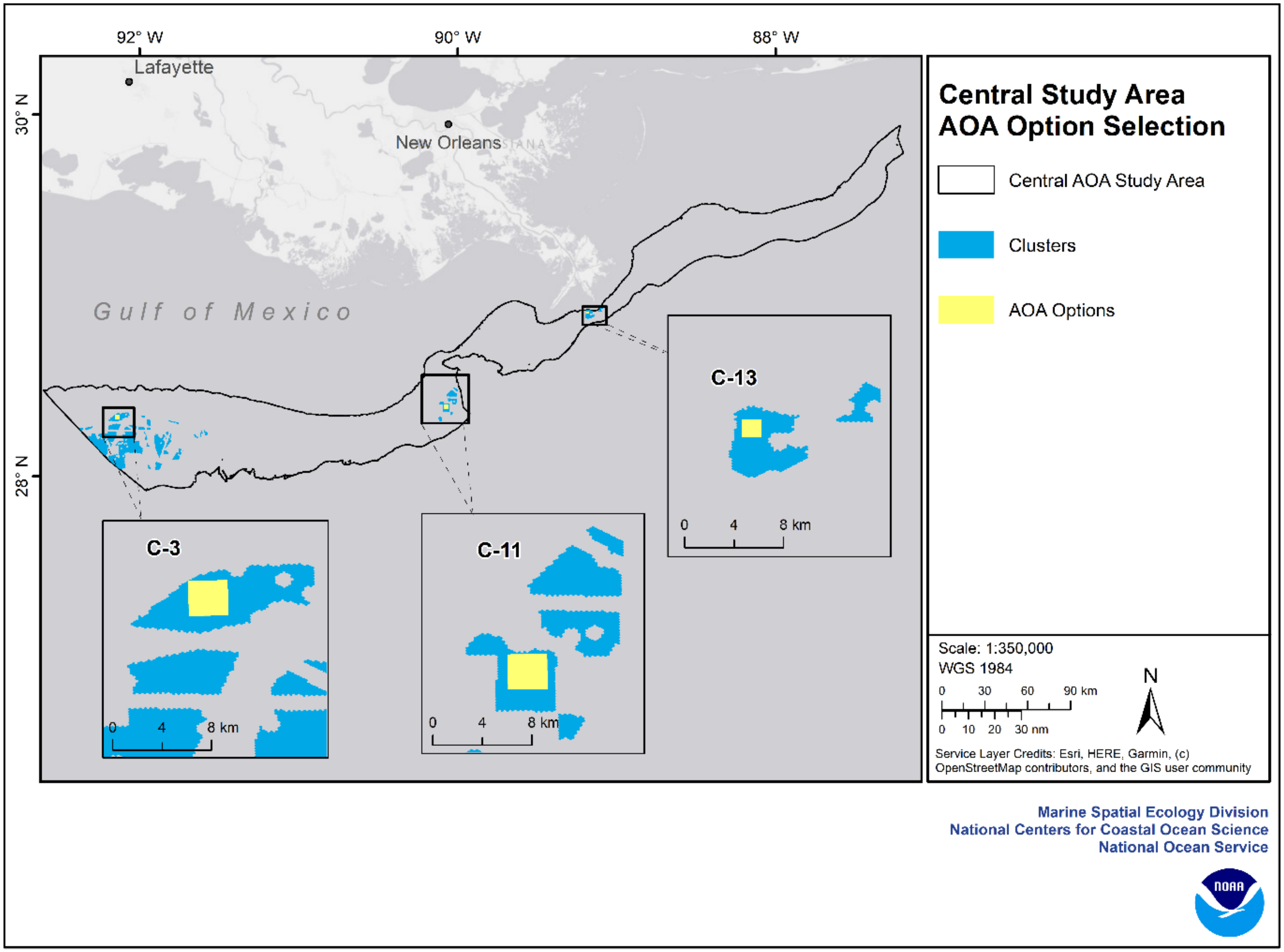


Figure 3.28. Precision modeling results for the Central study area.

Table 3.8. Central study area precision siting results with submodel scores for each Aquaculture Opportunity Area option. Top ranked options are highlighted in gray and were C-11, C-3, and C-13. Aquaculture Opportunity Area options that were ranked 3 through 11 were not included because of limitations with geographical dispersion and because the options were within 30 nm of a higher scoring option. For more information see Appendix F.

Option	Rank	Submodel				Final Score
		Logistic	Vessel Traffic	Fishing	Metocean	
C-11	1	0.53	0.98	0.96	0.74	0.78
C-3	2	0.13	1	0.99	1	0.6
C-6	3	0.12	1	0.98	0.98	0.58
C-12	4	0.56	0.98	0.27	0.74	0.58
C-2	5	0.09	1	1	0.98	0.54
C-7	6	0.09	1	0.98	0.94	0.54
C-5	7	0.08	1	0.95	0.9	0.51
C-9	8	0.07	1	0.98	0.83	0.5
C-1	9	0.05	1	1	0.98	0.48
C-4	10	0.04	1	1	0.9	0.43
C-10	11	0.47	0.89	0.01	0.37	0.18
C-13	12	1	0	0.97	0.97	0.16
C-8	13	0	0.56	0.03	0.9	0.02

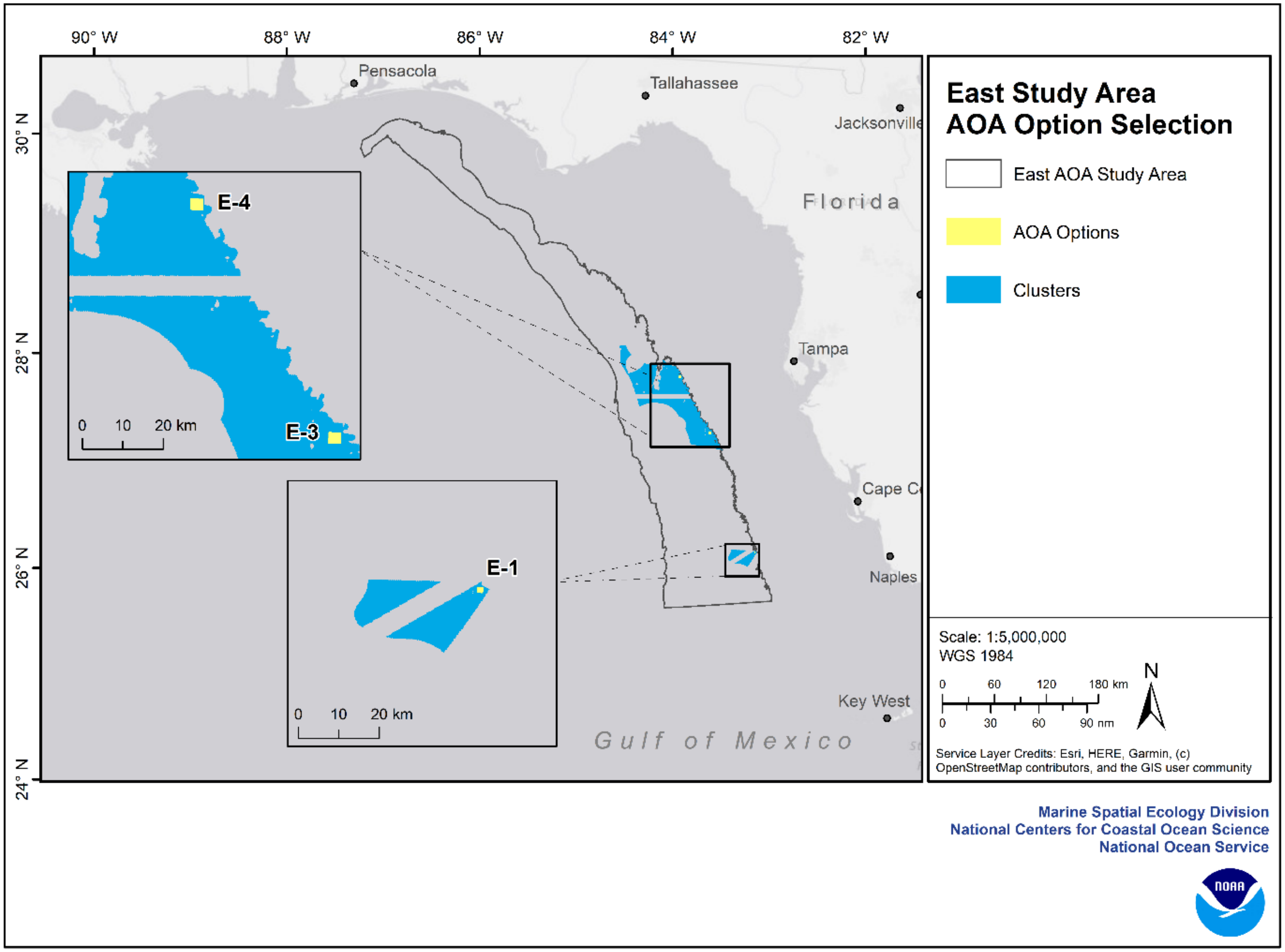


Figure 3.29. Precision modeling results for the East study area.

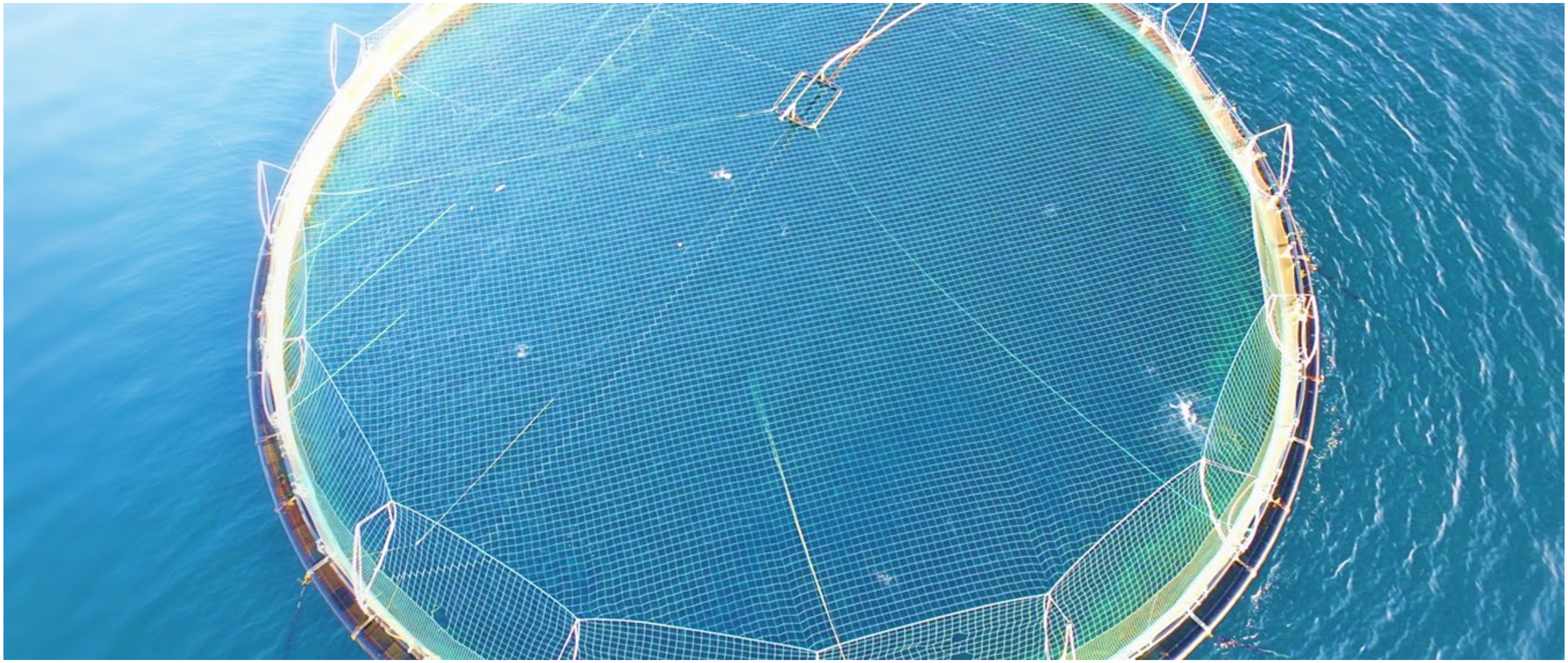
Table 3.9. East study area precision siting results with submodel scores for each Aquaculture Opportunity Area option. Top ranked options are highlighted in gray and were E-1, E-3, and E-4.

Option	Rank	Submodel				Final Score
		Logistic	Vessel Traffic	Fishing	Metocean	
E-1	1	0.49	0.65	0.96	0.51	0.63
E-3	2	1.00	0.36	0.01	0.87	0.21
E-4	3	0.34	0.09	0.01	1.00	0.13
E-2	4	0.00	1.00	1.00	0.36	0.06

Ranking and Characterization of AOA Options

Of the 29,839 AOA options from the three study areas, the top nine ranked options (three per study area) were selected for characterization (Figure 3.30). The characterizations provide site-specific detail regarding the geographic location, national security, natural and cultural resources, and environmental quality of the option. Additional characterization detail for the general locations can be explored with the OceanReports spatial analysis tool (see Appendix E). OceanReports provides characterization of ocean neighborhoods for each of the AOA options, pulling from more than 80 data sources.

Federal statutes cover a broad variety of legal restrictions and permitted activities within U.S. federal waters. The statutes listed in Table 3.10 are recommended to be reviewed for each of the nine Aquaculture Opportunity Area options. Please note that other federal statutes with complex or uncertain geographic boundaries may apply to the area.



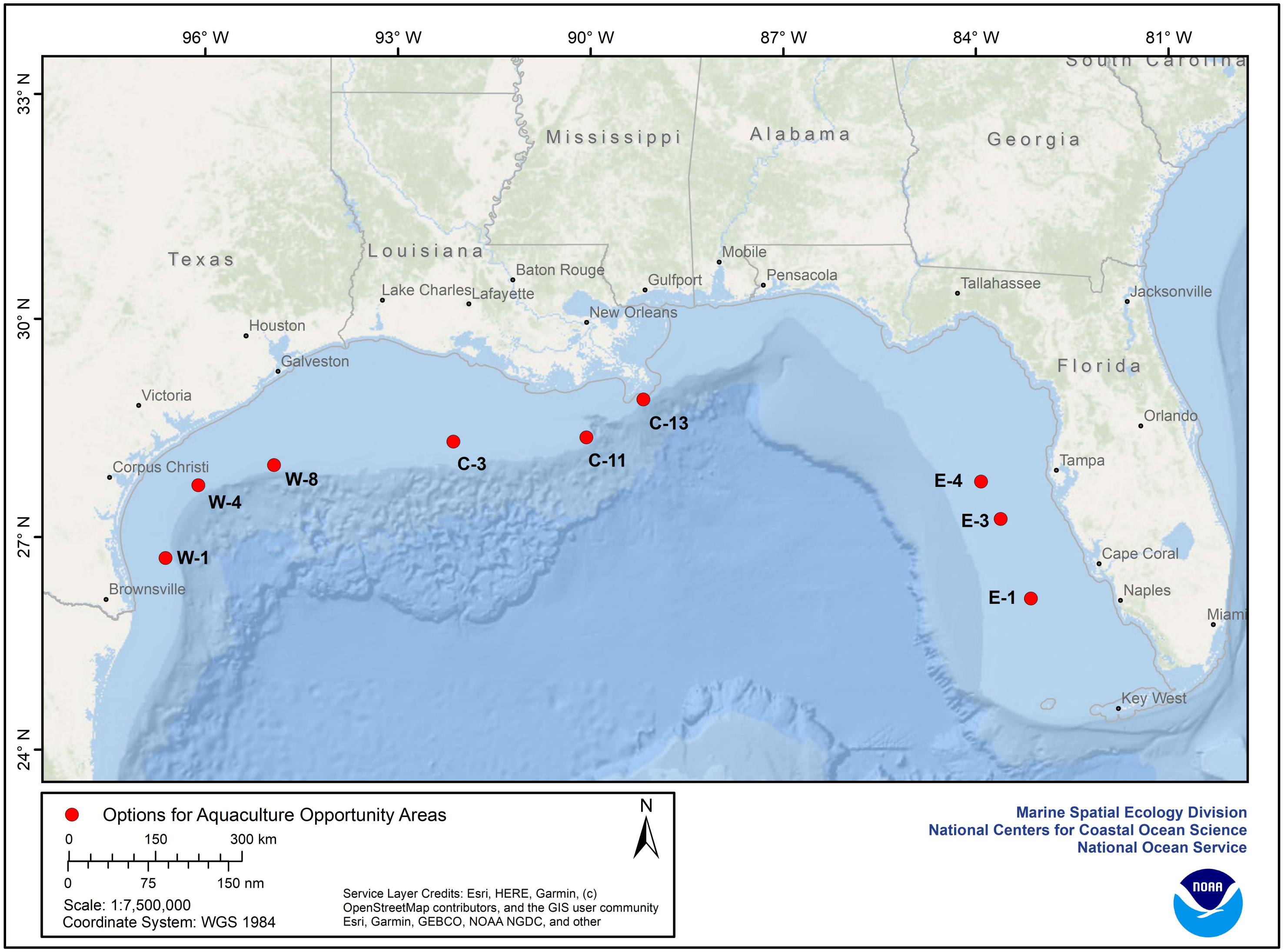


Figure 3.30. Distribution of options for Aquaculture Opportunity Areas in the U.S. federal waters of the Gulf of Mexico. The red circles represent the options, but do not reflect the size of the options.

Table 3.10. Federal statutes applicable to all Aquaculture Opportunity Area options.

Statute	Complete Description
Act to Prevent Pollution from Ships and MARPOL 73/78	https://coast.noaa.gov/data/Documents/OceanLawSearch/ActtoPreventPollutionfromShipsandMARPOL7378.pdf
Clean Water Act	https://www.epa.gov/laws-regulations/summary-clean-water-act
Coastal Zone Management Act	https://coast.noaa.gov/czm/act/
Comprehensive Environmental Response, Compensation, and Liability Act	https://www.epa.gov/laws-regulations/summary-comprehensive-environmental-response-compensation-and-liability-act
Endangered Species Act	https://www.fws.gov/endangered/esa-library/pdf/ESA_basics.pdf
Energy Policy Act	https://www.energy.gov/downloads/energy-policy-act-2005
Magnuson-Stevens Fishery Conservation and Management Act	https://www.fisheries.noaa.gov/topic/laws-policies#magnuson-stevens-act
Marine Debris Research, Prevention, and Reduction Act	https://marinedebris.noaa.gov/about-our-program/marine-debris-act
Marine Mammal Protection Act	https://www.fisheries.noaa.gov/topic/laws-policies#marine-mammal-protection-act
National Environmental Policy Act	https://www.epa.gov/laws-regulations/summary-national-environmental-policy-act
National Historic Preservation Act	https://www.nps.gov/subjects/historicpreservation/national-historic-preservation-act.htm
National Marine Sanctuaries Act	https://sanctuaries.noaa.gov/about/legislation/
Outer Continental Shelf Lands Act	https://www.boem.gov/Oil-and-Gas-Energy-Program/Leasing/Outer-Continental-Shelf/Lands-Act-History/OCSLA-History.aspx

West Options Precision Modeling Results

In the West study area, 43 unique high-high clusters were identified (W-1 to W-43) using the LISA analysis (Table 3.7). Using the within-cluster approach, each cluster (cluster W-1 through cluster W-43) was treated as an individual spatial unit in which options (500 ac, 1,000 ac, 1,500 ac, and 2,000 ac with 4 corner points in the cardinal directions) were iteratively created and modeled throughout each cluster using the logistics, vessel traffic, and aquaculture and fishing submodels (see Figure 2.21). Clusters larger in area generally had more options that could be developed within the area relative to smaller clusters, but depended upon the number of regularly shaped options that could be formed for suitability modeling. For instance, cluster W-6 had 1,428 options over 66,595 ac, whereas cluster W-9 had four options within a 650-ac area (Table 3.7). Due to its regularity in shape, cluster W-13 had 12 options created over 915 ac. Once the most suitable option was determined from each cluster, the among-cluster model (see Figure 2.22) using the logistics, vessel traffic, aquaculture and fishing, and metocean submodels identified (going from west to east) W-1, W-4, and W-8 as the highest scoring options based on the parameters considered (Table 3.7; Figure 3.27). Each option is discussed in detail below.

All West study area options (W-1, W-4, and W-8) have the closest proximity to the state of Texas. From an economic standpoint, the ocean economy supports 175,510 jobs in Texas, with wages totaling around $17.6 billion in 2018 (NOAA 2021b). The largest ocean sector contributions for the state are dedicated to offshore mineral extraction (46.4%), tourism (29.1%), and marine transportation (20.3%).

AOA Option W-1 Characterization

Option W-1 has the overall highest score in the West study area among-cluster analysis (Table 3.7). W-1 has the nearest distance to an inlet of all options identified in the West study area. This option also has relatively low AIS vessel traffic (2015 - 2019) and relatively low commercial fishing effort.

General Characteristics

Option W-1 is the southernmost option identified in the West study area. The 2,000-ac option is located approximately 79 km (43 nm) east of Port Mansfield, TX, and 90 km (48.6 nm) northeast of Port Isabel, TX. It is in Texas Congressional District 34, State District 27, and House District 31. There are 13 federal statutes applicable to all the options identified, including option W-1 (Table 3.10). The closest inlet, the Port Mansfield Channel, is approximately 64 km (35 nm) away from the W-1 closest corner point (Figure 3.31). Corner point coordinates (latitude, longitude in decimal degrees) for option W-1 are (-96.6387, 26.7004), (-96.6405, 26.726), (-96.612, 26.7276), (-96.6101, 26.702). W-1 is in the GMFMC, USACE Galveston District, the USCG Corpus Christi Sector (District 8), USEPA Region 6, U.S. Fish and Wildlife Service (USFWS) Southwest Region, and BOEM West Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across option W-1 is 90.8 m, with a minimum depth of 84.4 m and a maximum of 93.7 m (Figure 3.32). High resolution multibeam survey data are available for the entire W-1 option.[28] The shallowest depths are in the southwest corner of W-1, where there

[28] https://www.ngdc.noaa.gov/ships/falkor/FK005B_mb.html

appears to be a bathymetric feature with a localized increase in elevation. Overall depth is shallower on the western side of the option and gently slopes down eastward from 90 to 93 m to the east side of W-1 (Figure 3.32). Mean slope over W-1 is 0.15° and the percent slope is 0.25.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[29] the sediment of W-1 is composed of approximately 70% mud-like substrate. As proximity increases to the bathymetric rise in the southwest corner, sediment changes to predominantly fine sand which covers the remaining 30% of the option area. The predicted surficial sediment Phi values ranged from 4.2 to 4.3, which indicate sediment with a diameter of very fine sand to coarse silt (diameter = 0.0625 mm).

Water Temperature and Salinity

Seasonally, the mean daily surface water temperature at option W-1 is lowest from December through April, at which point it increases and remains above 25°C until October, when it begins to decrease again. The minimum mean daily surface water temperature between 2016 and 2020 was 16.0 °C, while the maximum was 30.8°C. The water temperature at 10-m depth followed a similar pattern as the surface water temperature, with a minimum daily mean value of 16.2°C, and a maximum value of 30.3°C. The water temperature near the bottom of option W-1 is more consistent year-round, with some slight increases from September to December, with a minimum temperature of 17.0°C and a maximum temperature at 27.3°C (Figure 3.33). Mean daily salinity concentration between 2016 and 2020 at option W-1 was consistent throughout the year, with no major variations or decreases.

Metocean Characteristics

Ocean current speeds at option W-1 rarely exceed 1.0 m/s at all depths examined (Figures 3.34 - 3.36). The currents at the surface predominantly move in a north and south direction, while currents at the bottom depth generally move in a southeast to northwest direction (Figures 3.34, 3.36). Wind direction at option W-1 is predominantly from the southeast, and only 7.11% of the time is the wind speed greater than 10.28 m/s (Figure 3.37). Ocean waves observed at option W-1 predominantly originate from the southeast (Figure 3.38).

Water Quality Considerations

To evaluate water quality at option W-1, nutrient concentration, dissolved oxygen, chlorophyll-*a*, and water clarity were examined. 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 (Figure 3.39). At 30-m depth, slight decreases were observed in concentrations of nitrate (0.08 µmol/L), phosphate (0.06 µmol/L), and silicate (0.6 µmol/L). At 70-m depth, nutrient levels were at the highest concentration, with nitrate at 1.26 µmol/L, phosphate at 0.12 µmol/L, and silicate at 1.6 µmol/L. Dissolved oxygen throughout the water column ranged from 4.7 ml/L at the surface to 4.9 ml/L around 50-m depth (Figure 3.39). Chl-*a* concentrations were highest in the spring, peaking in April at 1.2 mg/m^3, and lowest in August at 0.14 mg/m^3 (Figure 3.40). The diffuse light attenuation coefficient (Kd) at 490 nm was lowest from July through September with August having the lowest value at 0.03 m^{-1}. The highest values occurred in April, May, and June (around 0.09 and 0.10 m^{-1} (Figure 3.41). Percent light transmissivity at 1-m depth ranged between 88% (lowest in June) to 92% (highest in August) throughout the year (Figure 3.42).

[29] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

National Security Considerations

All national security layers with known direct constraints on aquaculture (e.g., unexploded ordnance areas, danger zones and restricted areas) were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, removing these areas from the remainder of the analysis. The nature of military activities varies over time and space, making full compatibility assessments complex, and increases the need for military clearance for training and scheduled activities in these areas to make a more fully formed decision regarding aquaculture compatibility. For instance, W-1 is located within the south-central portion of MOA Corpus Christi (15,000 mi² in size) and also overlaps SUA W228D, but does not overlap areas marked as danger zones or restricted areas (Table 3.11). The SUA is adjacent to other SUAs within the MOA, including W228A, 228B, and 228C. Because of the proximity of option W-1 to SUAs, some aquaculture operations may require coordination with the Federal Aviation Administration (FAA) regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

Option W-1 does not directly overlap with any species considered within the NMFS Protected Resources combined data layer. Although, option W-1 does not overlap with any sea turtle HUAs for residence or migratory areas, loggerhead, Kemp's ridley, leatherback, or green sea turtles may still be within range (see Appendix B for details). This option overlaps the loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat area (*Sargassum*).[30] It is also 2.8 km southeast of the Coral 9 Amendment area, Harte Bank. Harte Bank is 37.0 km² in size and ranges from 49 to 150 m in depth. Drowned barrier reefs provide hard substrate (Roberts et al. 2015) for corals (e.g., black coral, stony coral, sea fans) protected by Harte Bank through the Coral 9 Amendment.[31] W-1 does not overlap with the NMFS designated reef fish stressed area fishery management area. Overlap with EFH designated by the GMFMC and NMFS includes shrimp, reef fish, coastal migratory pelagic species, and 15 highly migratory species (see Table 3.39).

[30] https://www.fisheries.noaa.gov/action/critical-habitat-loggerhead-sea-turtle
[31] https://gulfcouncil.org/wp-content/uploads/Final-Coral-9-DEIS-20181005_508C.pdf

Industry, Navigation, and Transportation Considerations

There is no oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, boreholes) or seabed mining within 3 km (i.e., the reporting distance) of option W-1. There are no major interactions with any navigation and transportation infrastructure with this option. W-1 AIS vessel traffic is relatively low with no passenger vessel or pleasure and sailing and low cargo (n = 2), tanker vessel (n = 7), and tug and tow (n = 13) counts over the six years assessed (Table 3.12). The highest interaction occurring with AIS fishing vessels over all the years assessed was in 2020 with a total of 20 transits made by 10 individual vessels through the 2,000-ac option (Table 3.13).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate W-1 overlaps the designated Reef Fish Longline and Buoy Gear Restricted Area, and therefore no reef fish longline gear activity occurred in the option from 2007 - 2019. A relatively low amount of bandit gear fishing trips occurred over the 13-year period. Similarly, a relatively low amount of overlap occurred with shrimp trawling within option W-1.

Table 3.11. Characterization summary for Aquaculture Opportunity Area option W-1.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-96.12292, 27.71421
	-96.12469, 27.73983
	-96.09588, 27.74139
	-96.09412, 27.71577
Size (ac)	2,000
Closest inlet (km)	78.7
Depth (m) (minimum, mean, maximum)	(80.6, 84.1, 88.4)
National Security	
Military Operating Areas (MOA)	Overlaps MOA Corpus Christi
Special Use Airspace (SUA)	Overlaps SUA W228D
Transportation (AIS mean vessel transits per 500 ac)	
Cargo Vessels 2015 - 2019	0.45
Fishing Vessels 2015 - 2019	0.30
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	1.25
Passenger Vessels 2015 - 2019	1.00
Pleasure and Sailing Vessels 2015 - 2019	0.20
Tanker Vessels 2015 - 2019	1.05
Tug and Tow Vessels 2015 - 2019	0.80
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	7.11
Surface Current Speed % > 1.0 m/s (%)	0.06
Significant Wave Height % > 1.75 m (%)	20.0

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	Coral9 (Harte Bank)
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	No overlap with ESA species (Appendix B)
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	None within reporting range
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	None within reporting range
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.1
Salinity (PSU) at 5-m depth (mean)	34.2
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(0.13, 0.07, 1.05)
Mean Aragonite Saturation State (Ω)	3.8
Governance	
Agency boundary (USACE Districts)	Galveston District
Agency boundary (USCG Sectors)	Sector Corpus Christi; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southwest Region
Agency boundary (BOEM)	West Gulf of Mexico

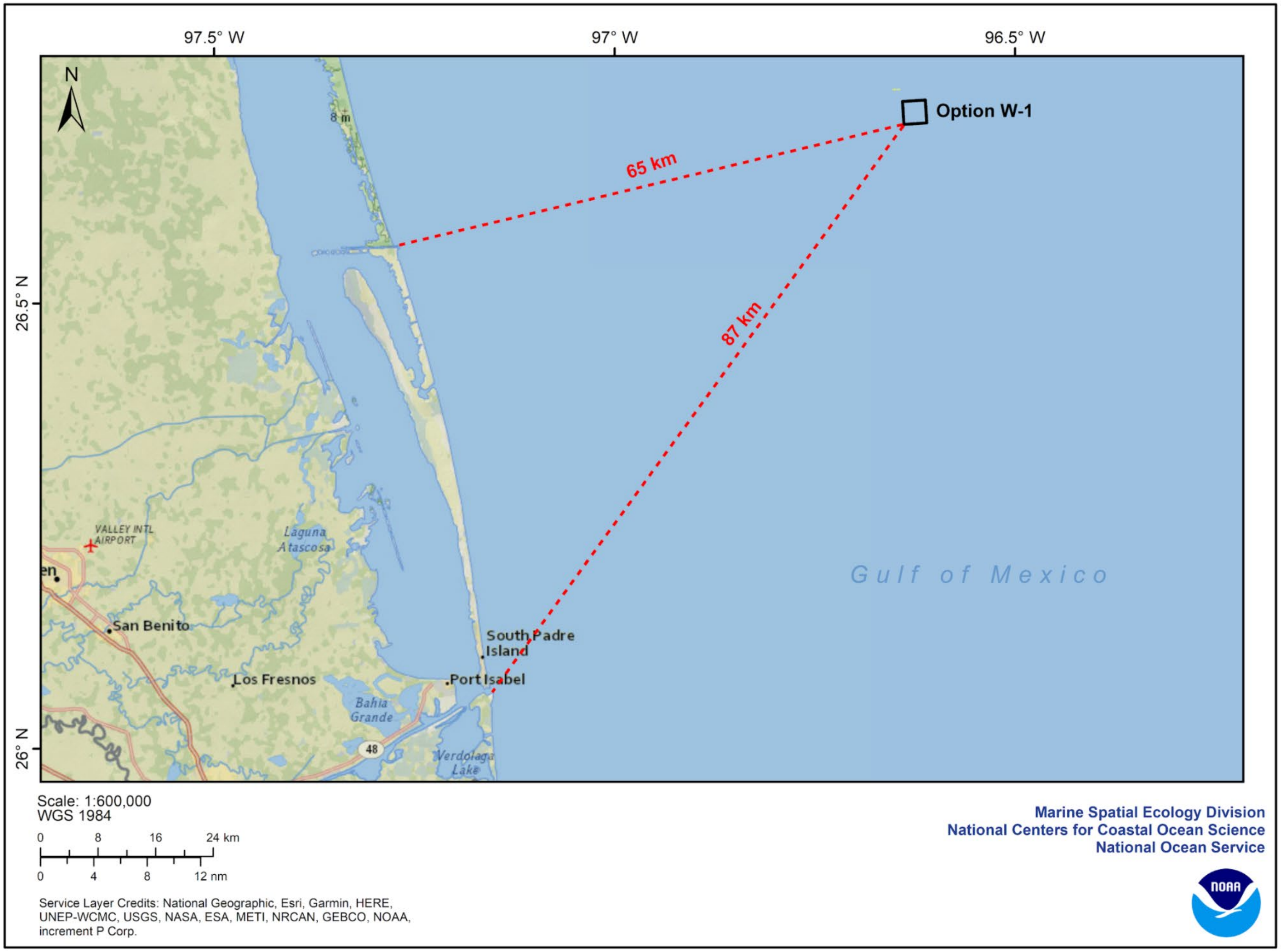


Figure 3.31. Option W-1 (black outlined box) and distance to the nearest inlet from the closest corner point of W-1; the area includes Port Mansfield, South Padre Island, and Port Isabel, Texas.

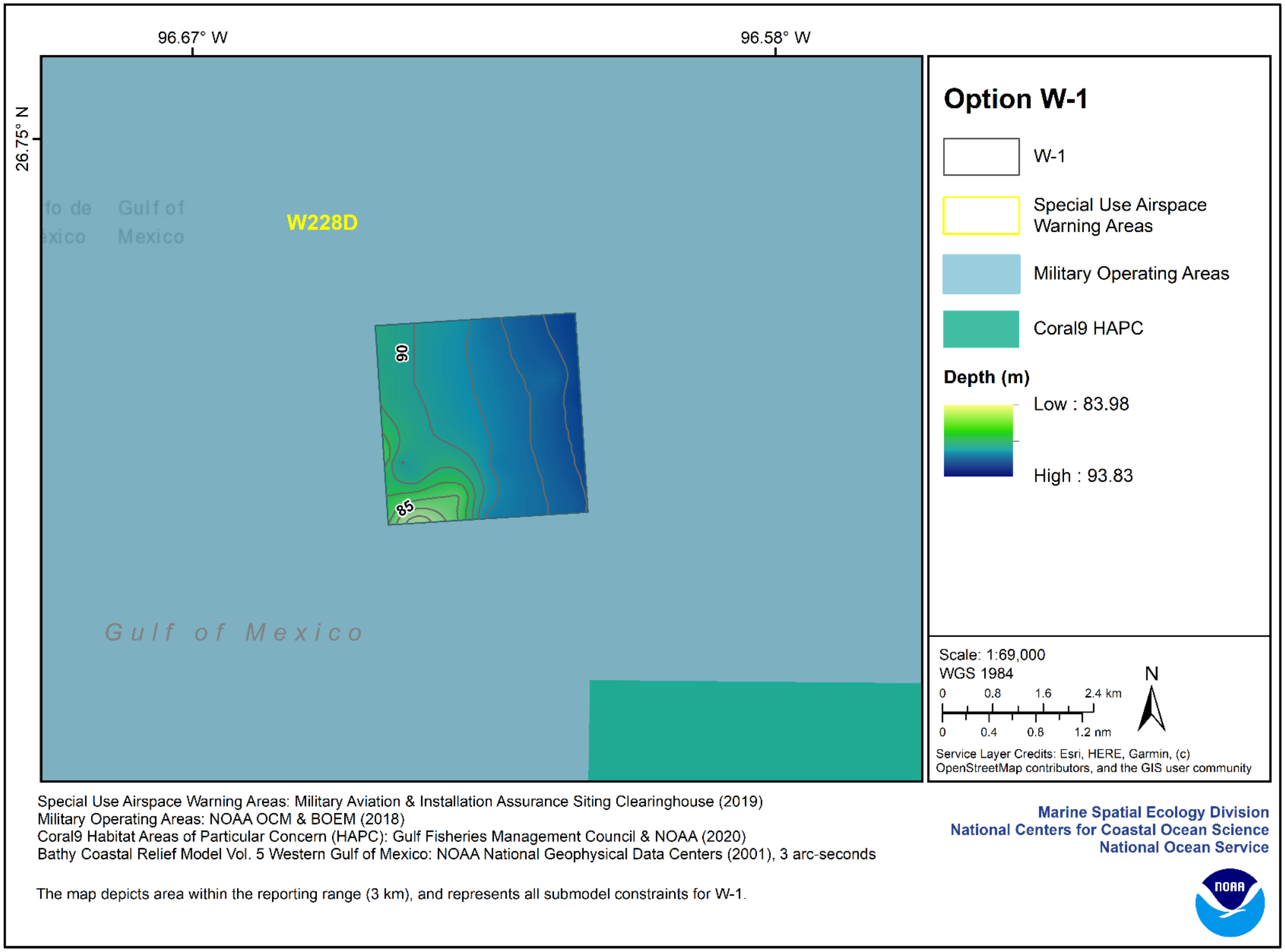


Figure 3.32. Map depicting noteworthy characterization features for Aquaculture Opportunity Area option W-1.

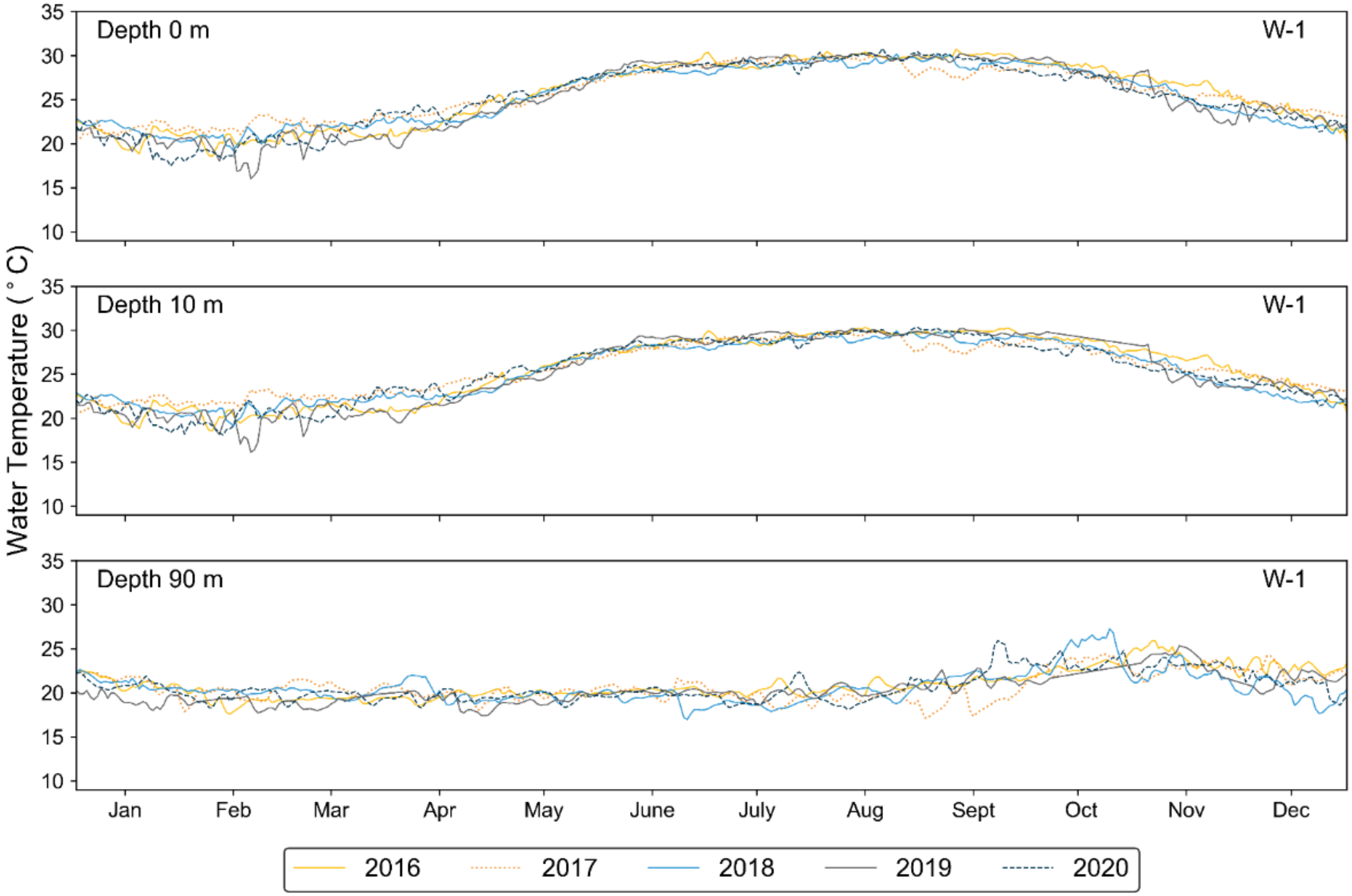


Figure 3.33. Option W-1 Navy Coastal Ocean Model regional model mean daily water temperature at the surface, 10-m depth, and near bottom depth (2016 - 2020).

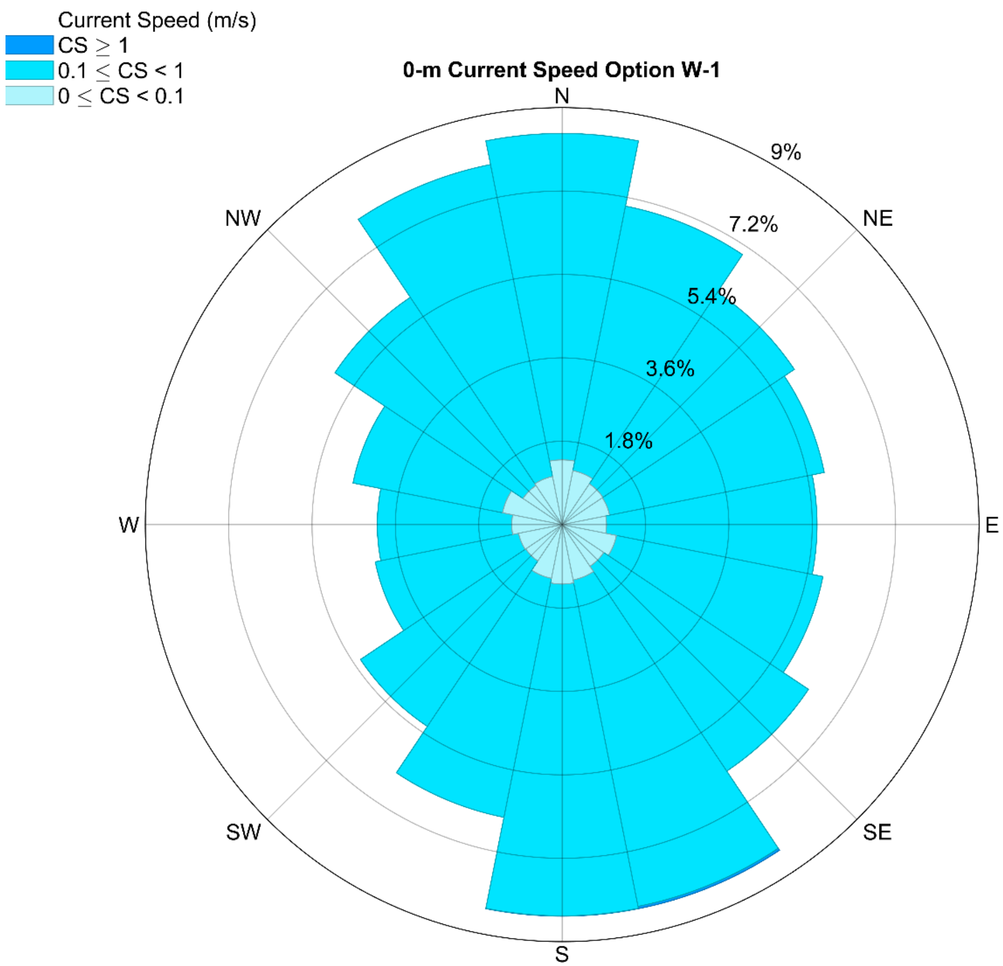


Figure 3.34. Ocean current magnitude and direction for option W-1 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

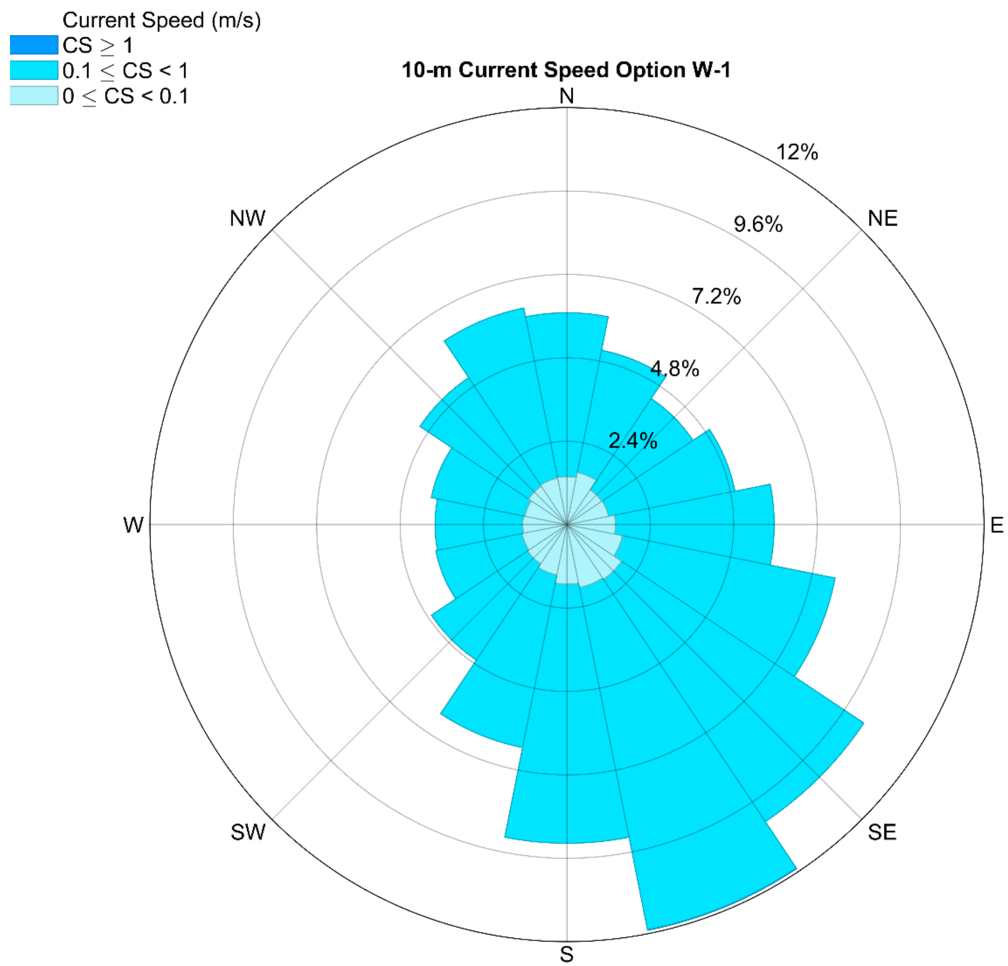


Figure 3.35. Ocean current magnitude and direction for option W-1 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

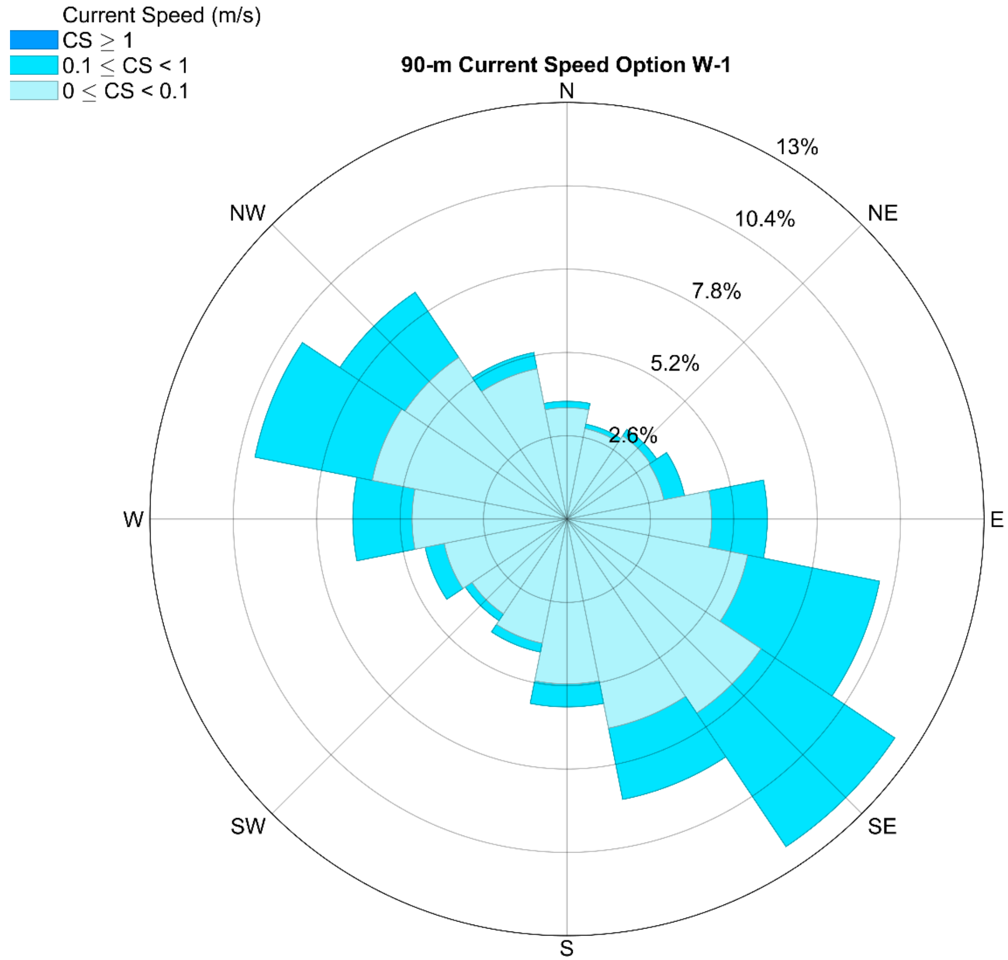


Figure 3.36. Ocean current magnitude and direction for option W-1 at 90-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

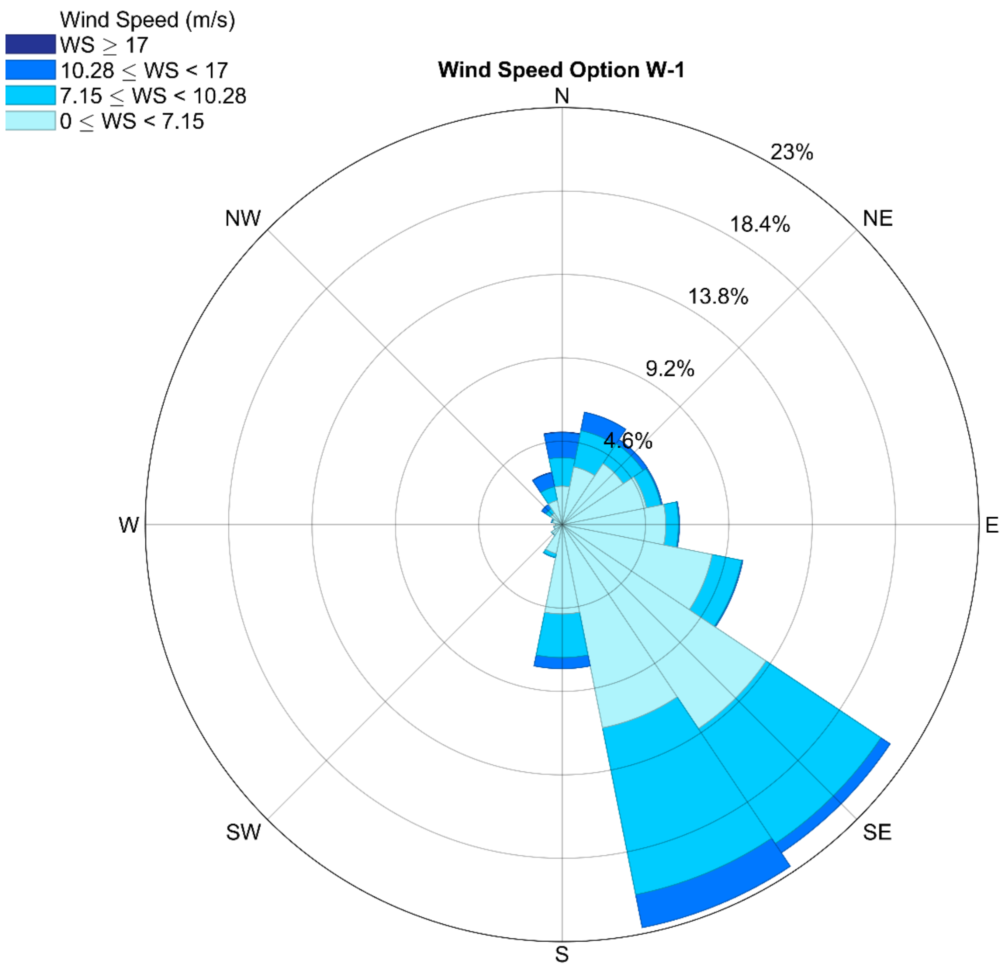


Figure 3.37. Wind velocity and direction at 10-m above sea level for option W-1. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

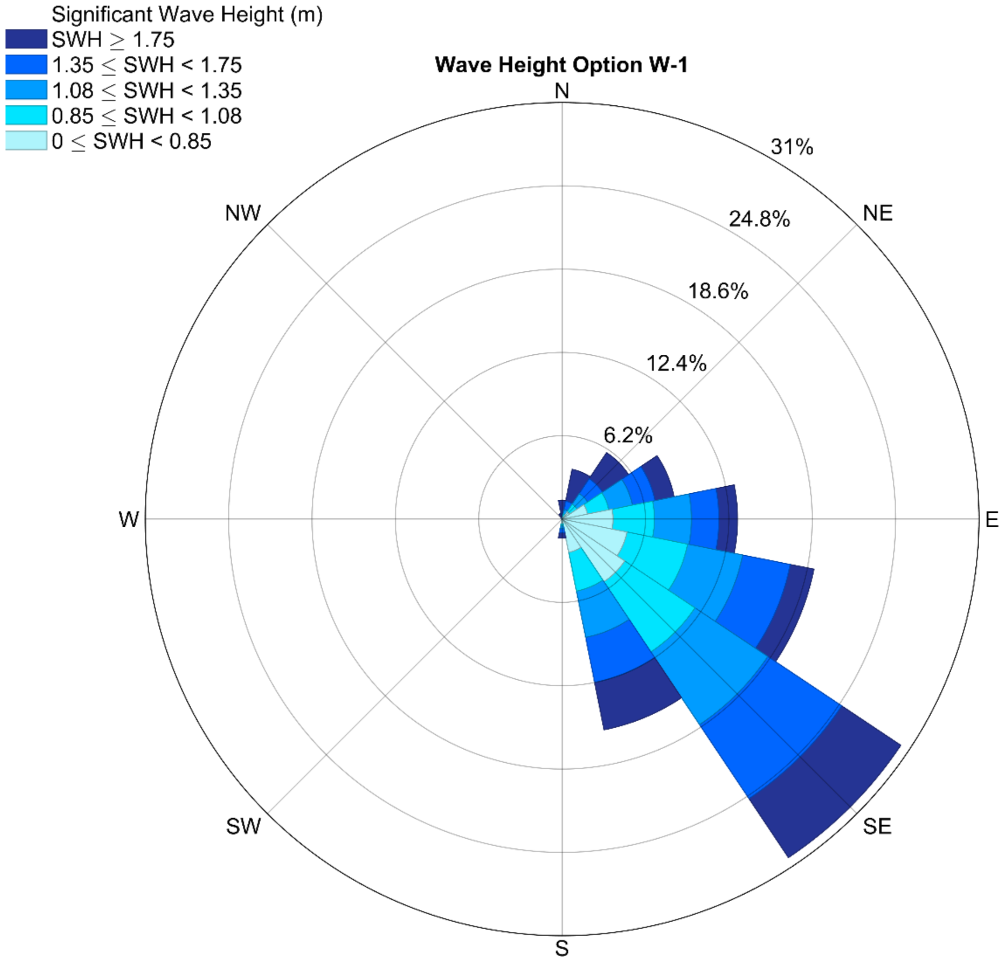


Figure 3.38. Significant wave height and direction at 10-m for option W-1. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

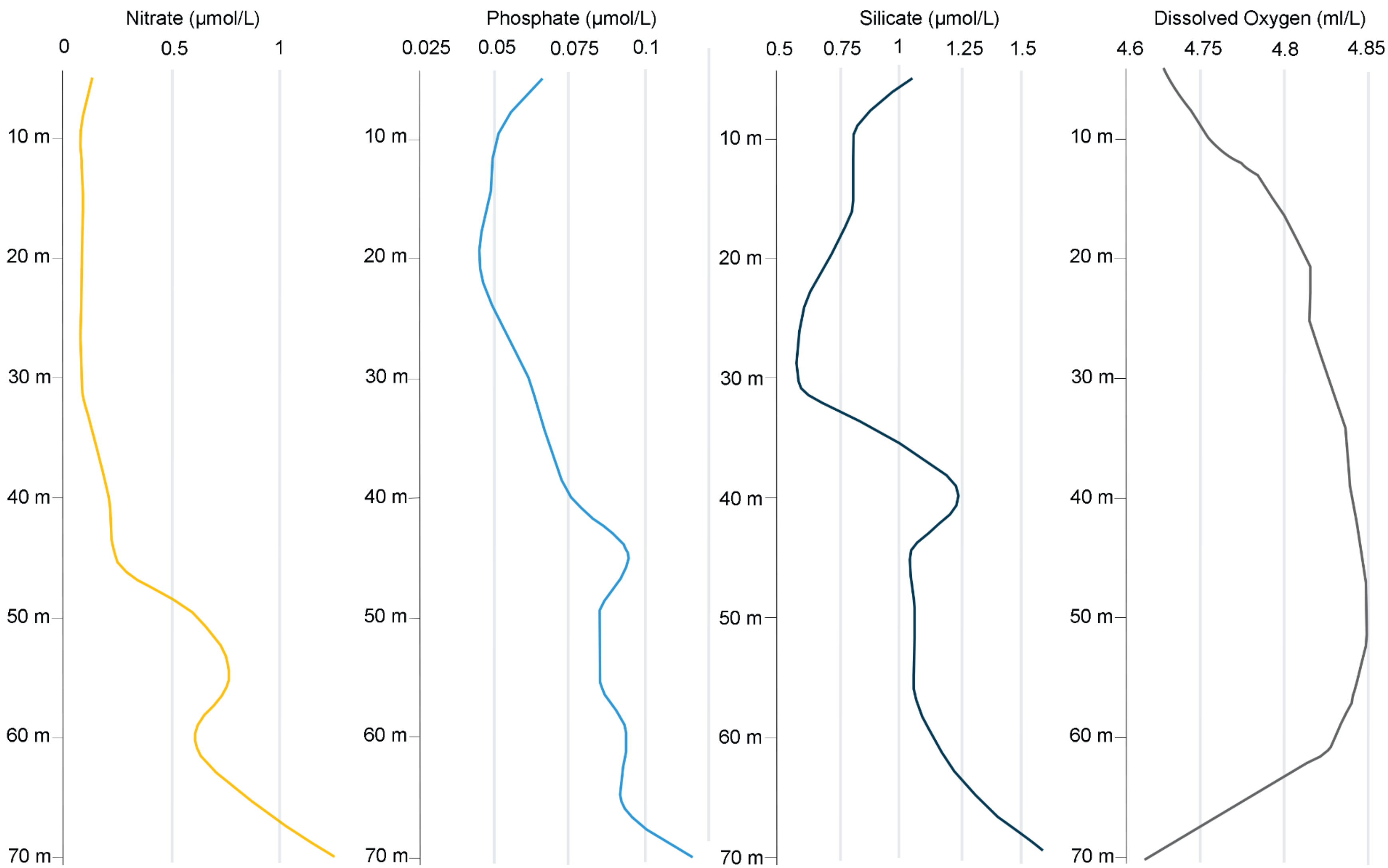


Figure 3.39. Option W-1 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels from the Ecological Marine Units (Sayre et al. 2017).

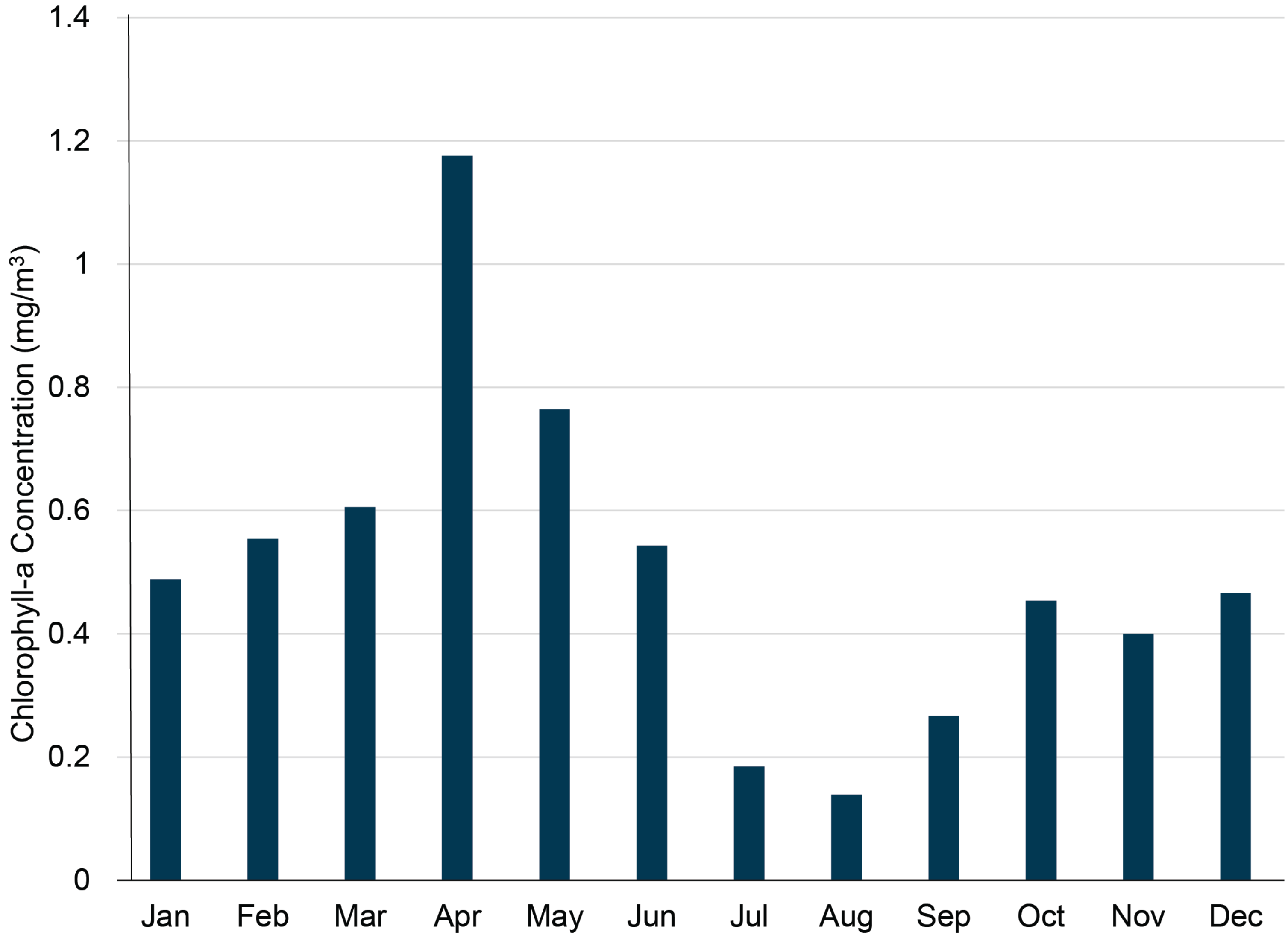


Figure 3.40. Option W-1 monthly climatological mean concentration of chlorophyll-*a* (mg/m³) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data (2016 - 2020).

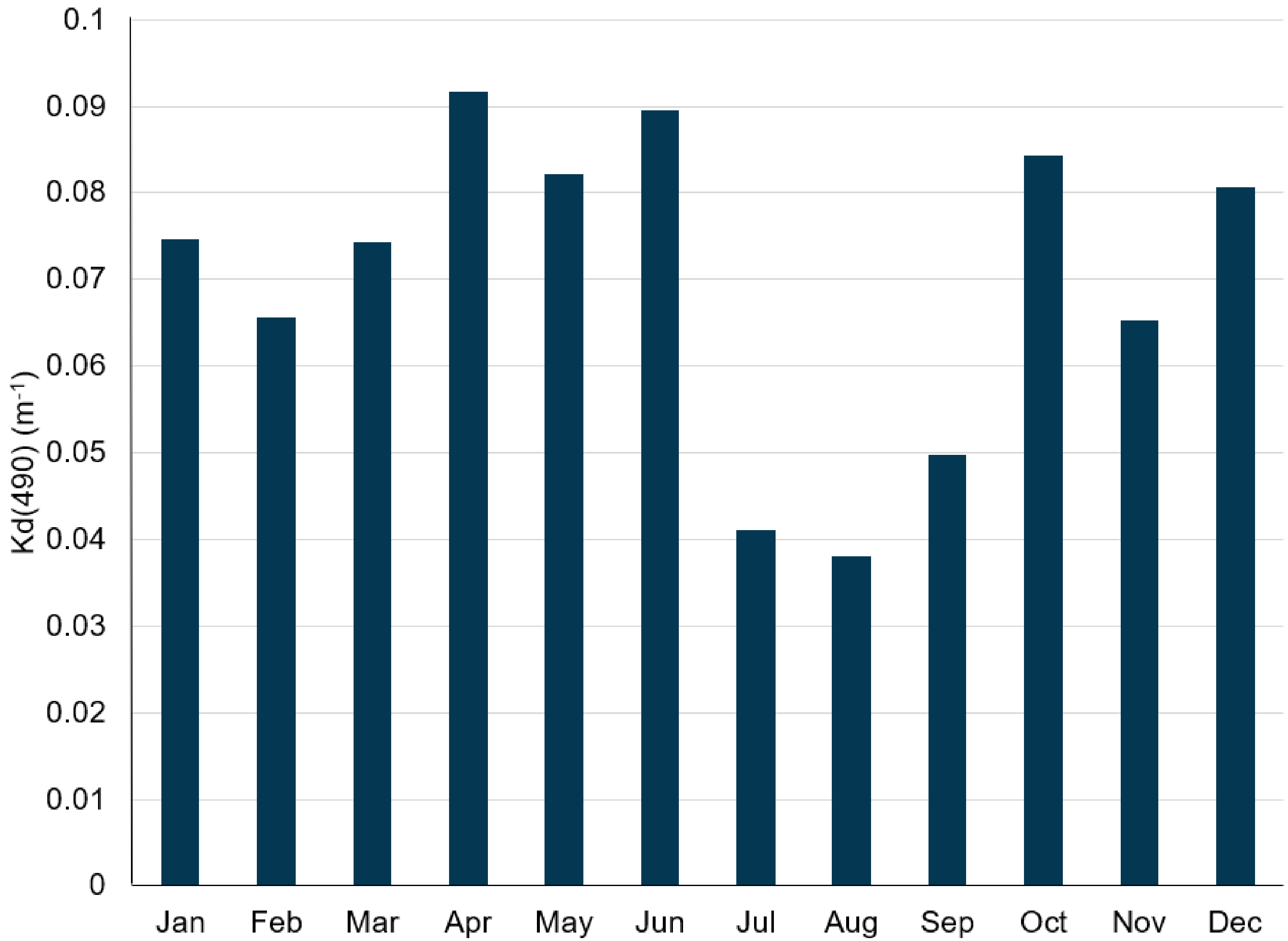


Figure 3.41. Option W-1 monthly climatological mean for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data (2010 - 2017).

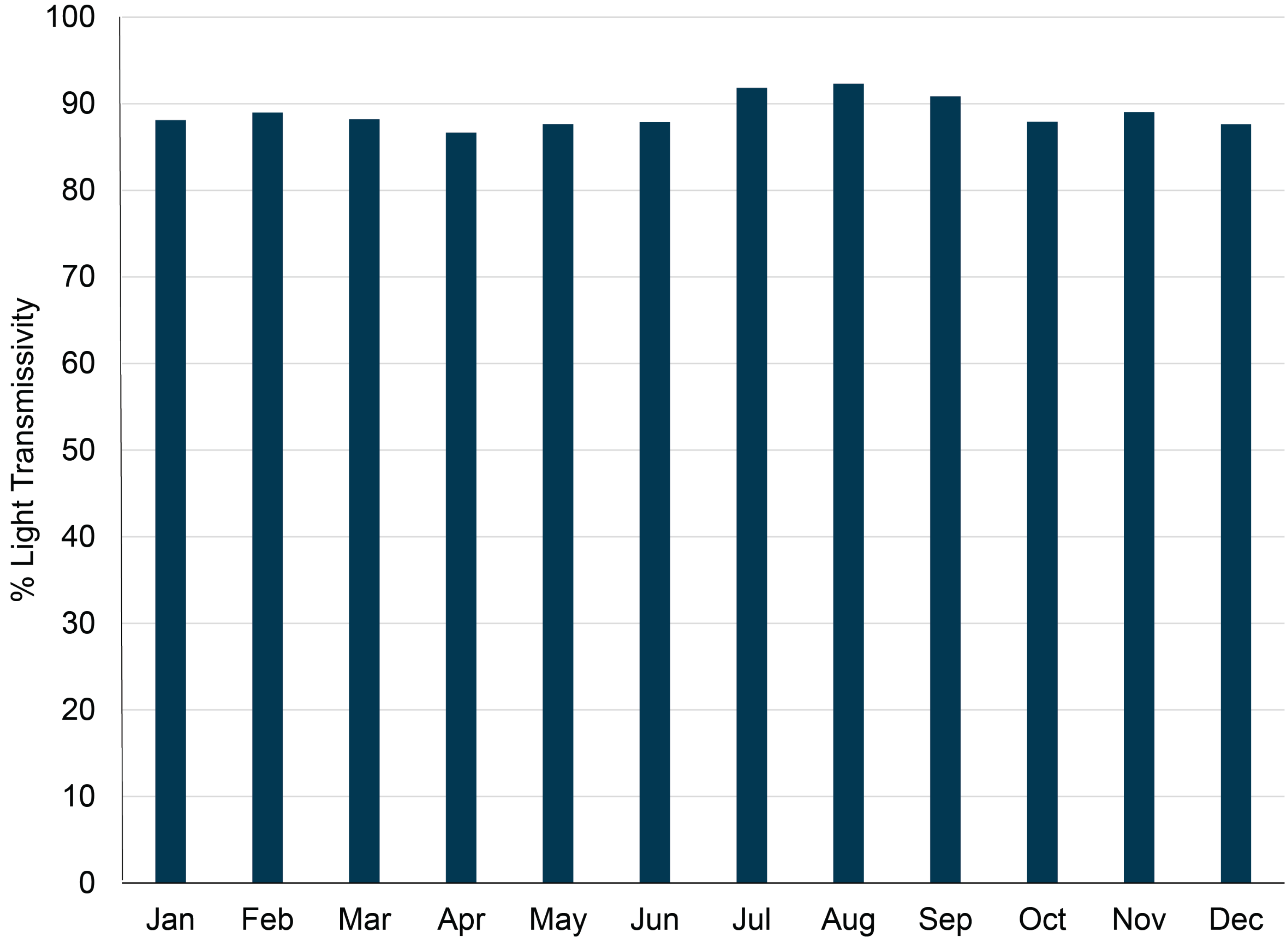


Figure 3.42. Option W-1 monthly climatological mean for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data (2010 - 2017).

Table 3.12. Option W-1 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits All Years (2,000 ac)
W-1	Cargo	0	0	0	0	0.25	0.25	2.00
W-1	Fishing	0	2.25	2.00	2.50	0.25	5.00	48.00
W-1	Other	1.25	1.00	1.75	0.75	0.25	1.50	26.00
W-1	Passenger	0	0	0	0	0	0	0
W-1	Pleasure and Sailing	0	0	0	0	0	0	0
W-1	Tanker	0	0.25	0	0	0	1.50	7.00
W-1	Tug and Tow	1.00	0.25	1.00	0.50	0.25	0.25	13.00

*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.

Table 3.13. Number of individual Automatic Identification System-equipped vessels that transited through option W-1.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
W-1	Cargo	0	0	0	0	1	1
W-1	Fishing	0	8	8	9	1	10
W-1	Other	4	3	4	3	1	5
W-1	Passenger	0	0	0	0	0	0
W-1	Pleasure and Sailing	0	0	0	0	0	0
W-1	Tanker	0	1	0	0	0	6
W-1	Tug and Tow	4	1	4	1	1	1

AOA Option W-4 Characterization

Option W-4 scored just below option W-1 in the among-cluster analysis for the West study area (Table 3.7). W-4 is farther offshore than W-1, down scoring the logistics submodel. W-4 has relatively low mean AIS vessel traffic (2015 - 2019) and no recorded fishing effort.

General Characteristics

Option W-4 is 134.4 km northeast of option W-1 and is 2,000 ac in size. W-4 is located approximately 89.8 km southeast of the Port Aransas Inlet entering Corpus Christi Bay and 103.4 km to the inlet into Matagorda, TX (Figure 3.43). It falls under Texas Congressional District 27, State Senate District 18, and House District 30. There are 13 federal statutes applicable to all the options identified, including option W-4 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option W-4 are (-96.12292, 27.71421), (-96.12469, 27.73983), (-96.09588, 27.74139, -96.09412, 27.71577). Option W-4 is in the GMFMC, USACE Galveston District, USCG Corpus Christi Sector (District 8), USEPA Region 6, USFWS Southwest Region, and BOEM West Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

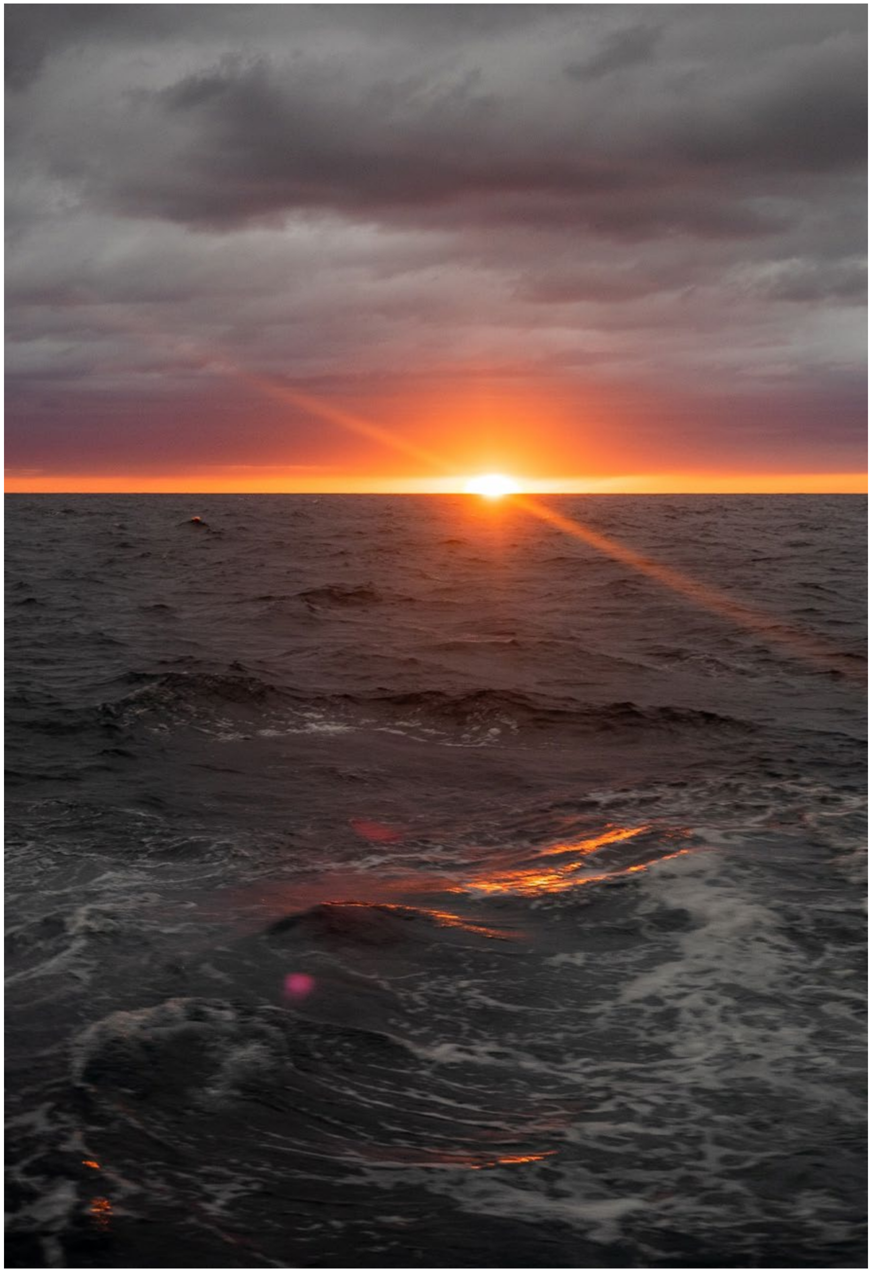
The mean depth across the entire area is 84.1 m, with a maximum depth of 88.4 m and a minimum of 80.6 m (Figure 3.44). No recent high-resolution bathymetric survey data are currently available for W-4. Based on available data, the appears to gently slope (0.15% slope) from the north side of W-4 to the south with a small depression-like feature occurring through the central portion of the option. Sand waves are visibly present within option W-4, as observed with high-resolution bathymetric data. Overall depth is shallower on the northern side of the option and decreases to the south side of W-4 (Figure 3.44).

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[32] W-4 is 97 to 99% mud-like (silt) substrate. The substrate in the northeastern corner of W-4 has a small percentage (3%) of sand. The predicted surficial sediment Phi values ranged from 4.9 to 5.1, which indicate sediment with a diameter of coarse silt to medium silt (diameter = 0.03125 mm).

Water Temperature and Salinity

Seasonally the mean daily surface water temperature at option W-4 is lowest from December through April, at which point it increases and remains above 25°C until October, when it begins to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 17.7°C and the maximum was 30.9°C. The water temperature at 10-m depth followed a similar pattern as the surface water temperature, with a minimum daily mean value of 18.0°C, and a maximum value of 30.4°C. The water temperature near the bottom of option W-4 is more consistent year-round, with some slight increases from September to December, with a minimum temperature of 17.2°C and a maximum temperature of 28.3°C (Figure 3.45). Mean daily salinity concentration from 2016 to 2020 at option W-4 were consistent throughout the year, with no major variations or decreases.

[32] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf



Metocean Characteristics

Ocean current speeds at option W-4 rarely exceed 1.0 m/s at all depths examined (Figures 3.46 - 3.48). The currents at the surface and at 10-m depth predominantly move in a northeast and southwest direction, while currents at the bottom depth generally move in a north-northeast and south-southwest direction. The predominant wind direction at option W-4 is from the south-southeast. At only 6.98% of the time is the wind speed greater than 10.28 m/s (Figure 3.49). Ocean waves observed at option W-4 predominantly originate from the southeast (Figure 3.50).

Water Quality Considerations

To evaluate water quality at option W-4, nutrient concentration, dissolved oxygen, chlorophyll-a, and water clarity were examined. 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. At 30-m depth, slight decreases in concentration occurred in nitrate (0.98 µmol/L), phosphate (0.03 µmol/L), and silicate (1.1 µmol/L). From 45- to 50-m depth, nitrate concentrations increased from 0.13 µmol/L to 0.70 µmol/L. At 50-m depth, phosphate concentrations were around 0.06 µmol/L and silicate concentrations were 1.66 µmol/L (Figure 3.51). Dissolved oxygen changed slightly with depth, ranging from 4.7 to 4.9 ml/L in surface water, with the highest DO found around 45- to 50-m depth. Chl-a concentration, a common approximation for phytoplankton in the ocean, was highest in the spring, peaking in June at 1.1 mg/m3, and lowest in the summer, with August having the lowest concentration at 0.14 mg/m3 (Figure 3.52). The diffuse light attenuation coefficient at 490 nm was lowest from June through September, with August having the lowest value at 0.03 m-1 and May the highest at 0.09m^{-1} (Figure 3.53). Percent light transmissivity was relatively constant throughout the year, with a range of 86% in May to 93% in August (Figure 3.54).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. Some national security areas require scheduling, vary over time and space, and may cover large portions of ocean space in the U.S. EEZ making full compatibility assessments complex and making the need for coordination with DOD imperative for these areas. W-4 occupies the same space as MOA Corpus Christi (15,000 mi² in size) and overlaps SUA W228B, but does not overlap areas marked as danger zones or restricted areas (Table 3.14). The SUA is adjacent to other SUAs within the MOA, including W228A, 228B, and 228C. Because of the proximity of option W-4 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

AOA Option W-4 does not directly overlap any species considered in the NMFS Protected Resources combined data layer. However, option W-4 overlaps with the ranges for loggerhead, Kemp's ridley, leatherback, and green sea turtles (see Appendix B for details). AOA option W-4 is located in the expansive loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat (*Sargassum*). Based on available data, no overlap occurs between deep-sea corals, fish havens, artificial reefs, or sensitive habitat (including Habitat Areas of Particular Concern (HAPC)) and option W-4. No artificial reefs, fish havens, or mapped hardbottom areas were found to overlap W-4 or the ocean area within 3 km of the option. Essential Fish Habitat designated by the GMFMC and NMFS includes shrimp, reef fish, coastal migratory pelagic species, and 15 highly migratory species (see Table 3.39).

Industry, Navigation, and Transportation Considerations

W-4 has no direct interaction with oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, boreholes). In the general vicinity of W-4, an active BOEM lease block (G03061) is currently in place, which is approximately 3 km from the west side of W-4 (Figure 3.44). Within the lease block, three pipelines and two platforms operate. Multiple boreholes are also within the lease block area. Multiple boreholes also exist north by northeast of W-4. All navigational infrastructure was avoided within the option. The nearest navigation and transportation infrastructure to W-4 is a shipping lane 12.7 km away from the closest corner point of the option. W-4 AIS vessel traffic data from 2015 - 2020 indicate a total of nine cargo vessels transiting W-4, all in 2016 and 2017 (Table 3.15). The vessel type with the lowest traffic was pleasure and sailing, with only 4 transits through the option over the years assessed. Tanker traffic remained relatively stable in W-4 with one to six transits through the option annually from 2015 - 2019. In 2020, fishing vessels, other vessel types, and tankers made more vessel transits than in the previous five years (Table 3.16).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate W-4 overlaps the designated Reef Fish Longline and Buoy Gear Restricted Area, and therefore no reef fish longline gear activity occurred in the option from 2007 - 2019. Relatively low amounts of bandit gear fishing and shrimp trawling occur within this option.

Table 3.14. Characterization summary for Aquaculture Opportunity Area option W-4.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-96.12292, 27.71421
	-96.12469, 27.73983
	-96.09588, 27.74139
	-96.09412, 27.71577
Size (ac)	2,000
Closest inlet (km)	78.7
Depth (m) (minimum, mean, maximum)	(80.6, 84.1, 88.4)
National Security	
Military Operating Areas (MOA)	Overlaps MOA Corpus Christi
Special Use Airspace (SUA)	Overlaps SUA W228B
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	0.45
Fishing Vessels 2015 - 2019	0.30
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	1.25
Passenger Vessels 2015 - 2019	1.00
Pleasure and Sailing Vessels 2015 - 2019	0.20
Tanker Vessels 2015 - 2019	1.05
Tug and Tow Vessels 2015 - 2019	0.80
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	6.98
Surface Current Speed % > 1.0 m/s (%)	0.06
Significant Wave Height % > 1.75 m (%)	18.6

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	None within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	No overlap with ESA species (Appendix B)
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	5
Oil and Gas Active Lease Blocks	1
Oil and Gas Pipelines	None within reporting range
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.1
Salinity at 5-m depth (mean)	34.2
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(0.11, 0.05, 1.34)
Mean Aragonite Saturation State (Ω)	3.8
Governance	
Agency boundary (USACE Districts)	Galveston District
Agency boundary (USCG Sectors)	Sector Corpus Christi; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southwest Region
Agency boundary (BOEM)	West Gulf of Mexico

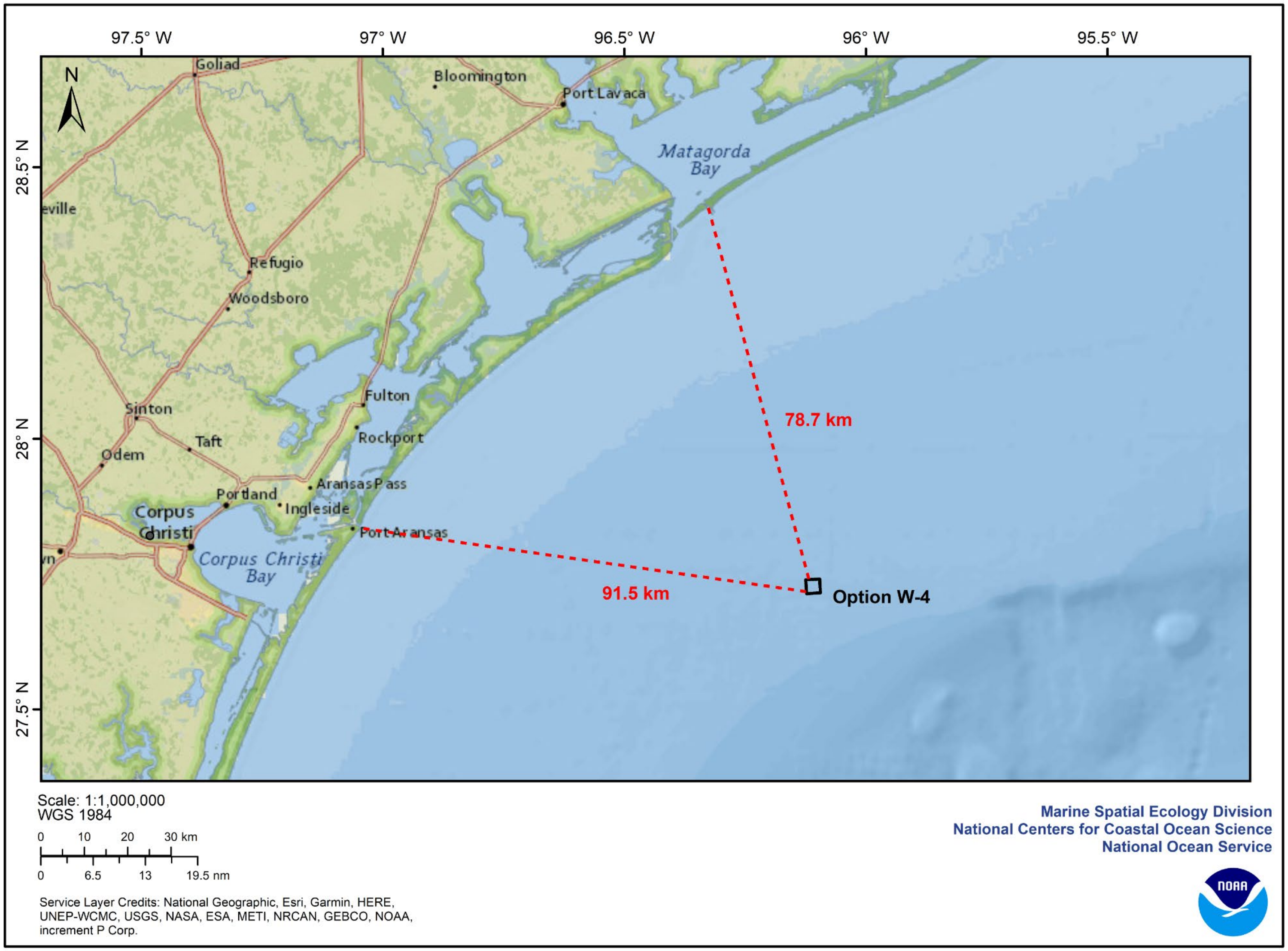


Figure 3.43. Option W-4 (black outlined box) and distance to the closest inlet from the closest corner point of W-4; the area includes Matagorda and Port Aransas, Texas.

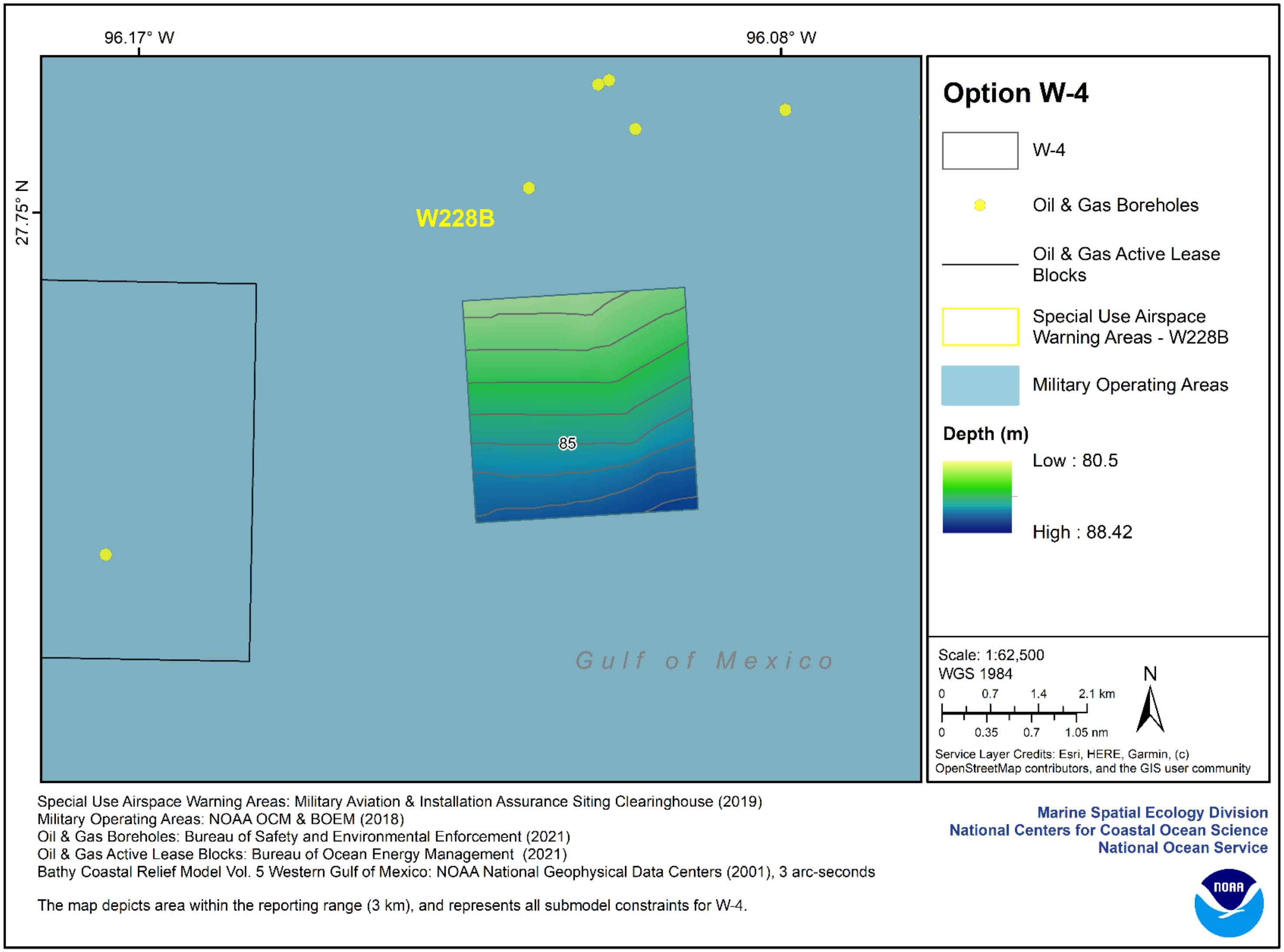


Figure 3.44. Map depicting noteworthy characterization features for Aquaculture Opportunity Area option W-4.

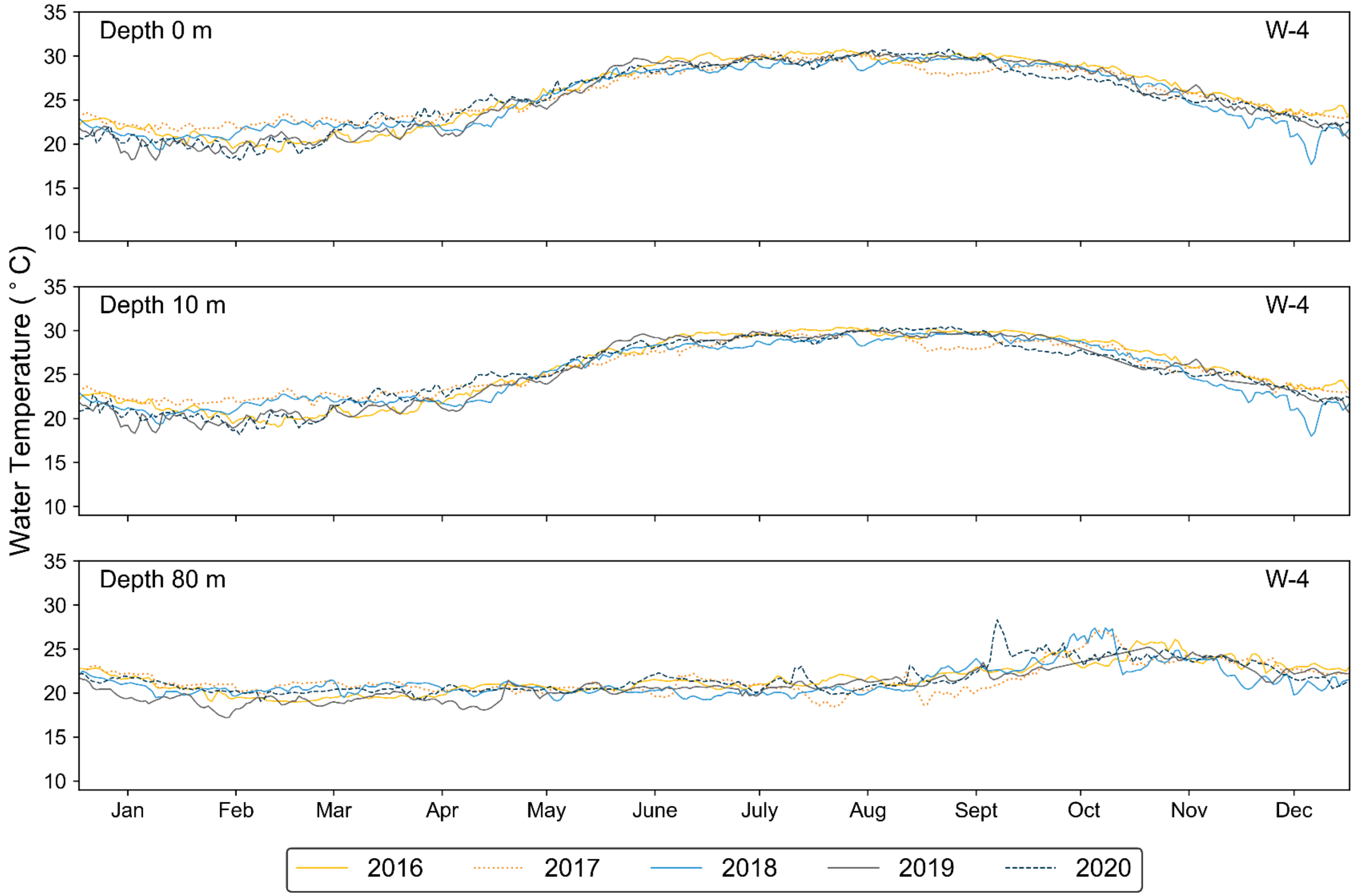


Figure 3.45. Option W-4 Navy Coastal Ocean Model regional model mean daily water temperature at the surface, 10-m depth, and 80-m depth (2016 - 2020).

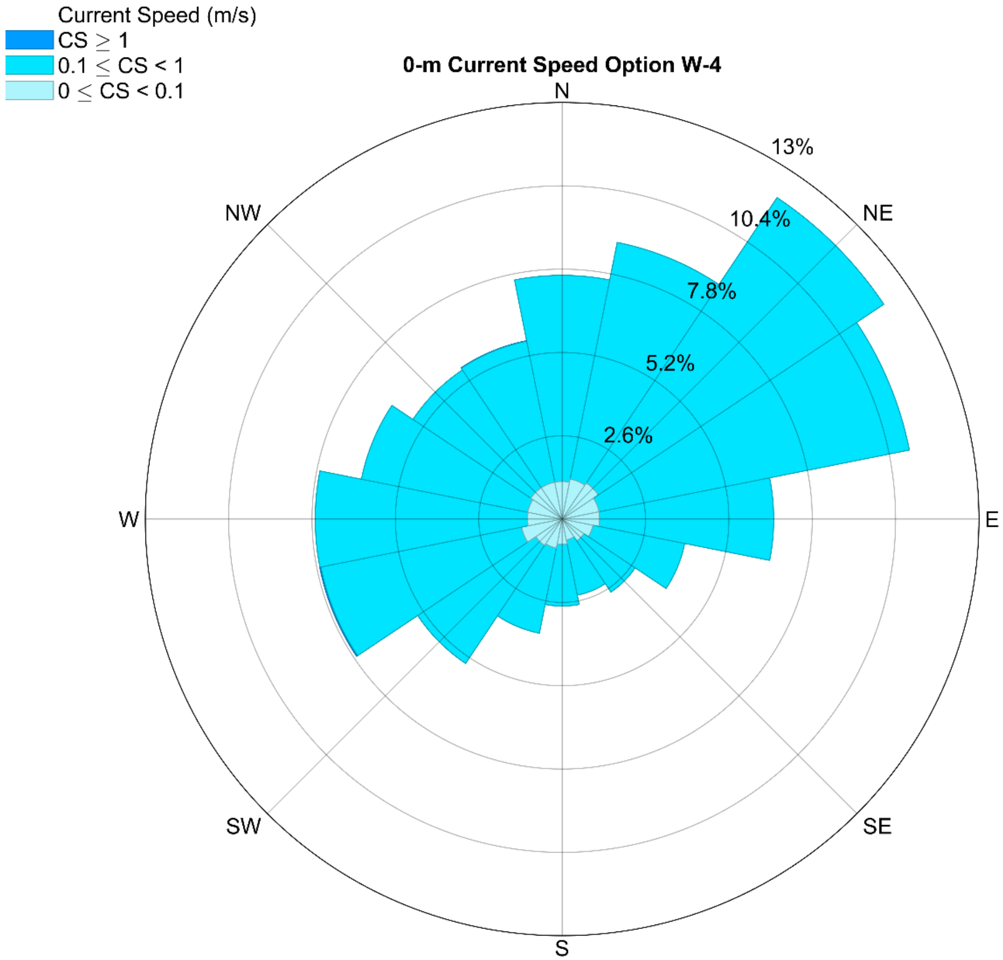


Figure 3.46. Ocean current magnitude and direction for option W-4 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

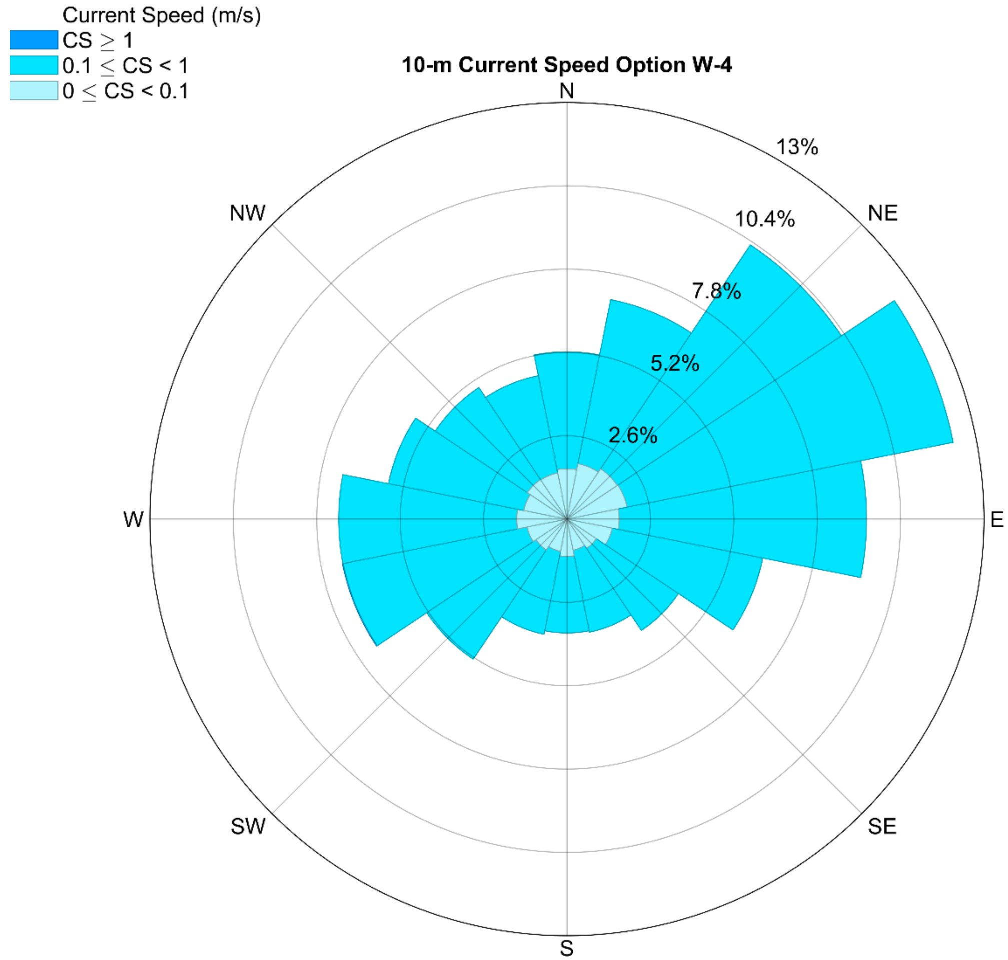


Figure 3.47. Ocean current magnitude and direction for option W-4 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

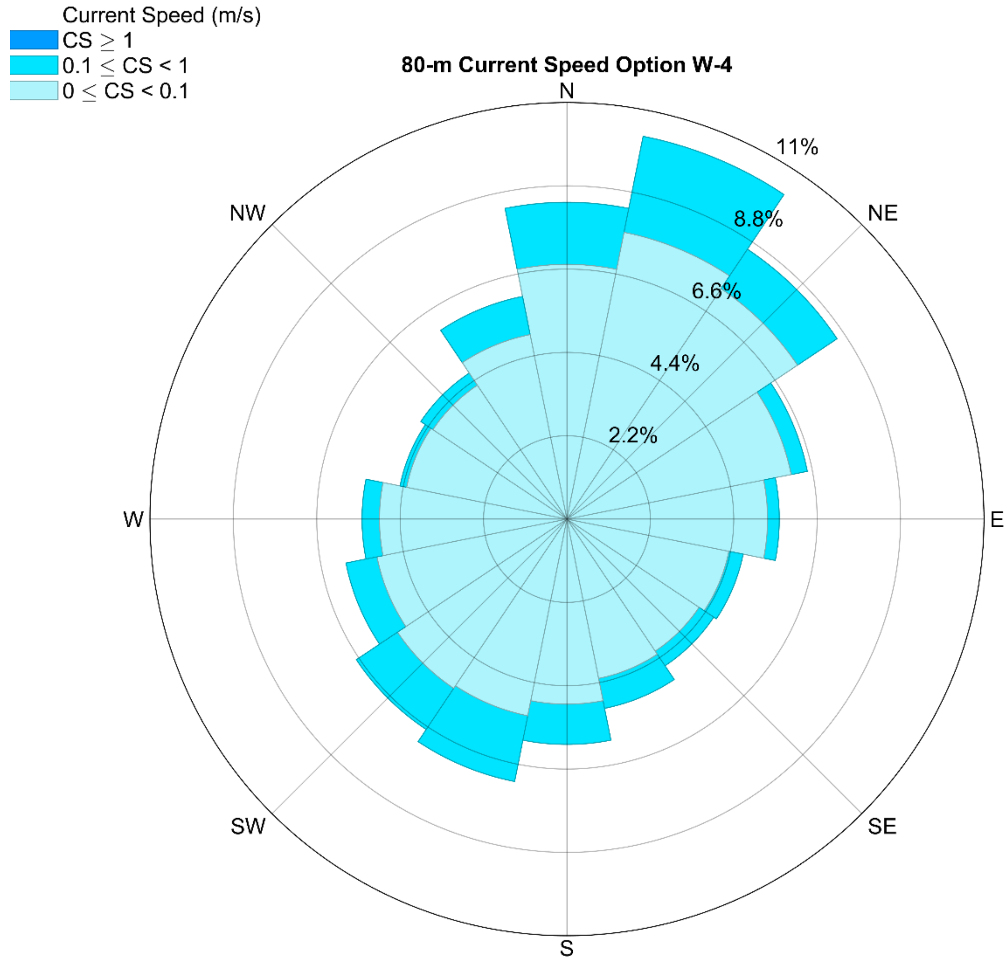


Figure 3.48. Ocean current magnitude and direction for option W-4 at 80-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

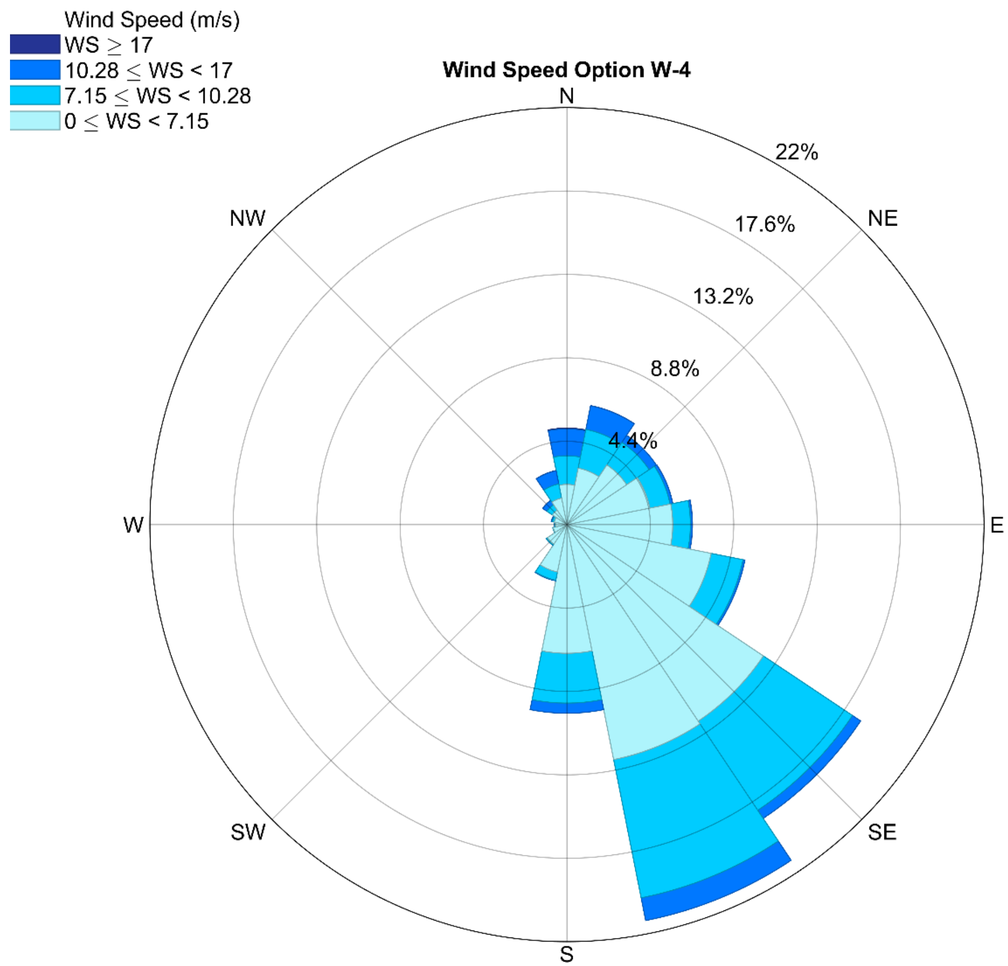


Figure 3.49. Wind velocity and direction at 10-m above sea level for option W-4. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

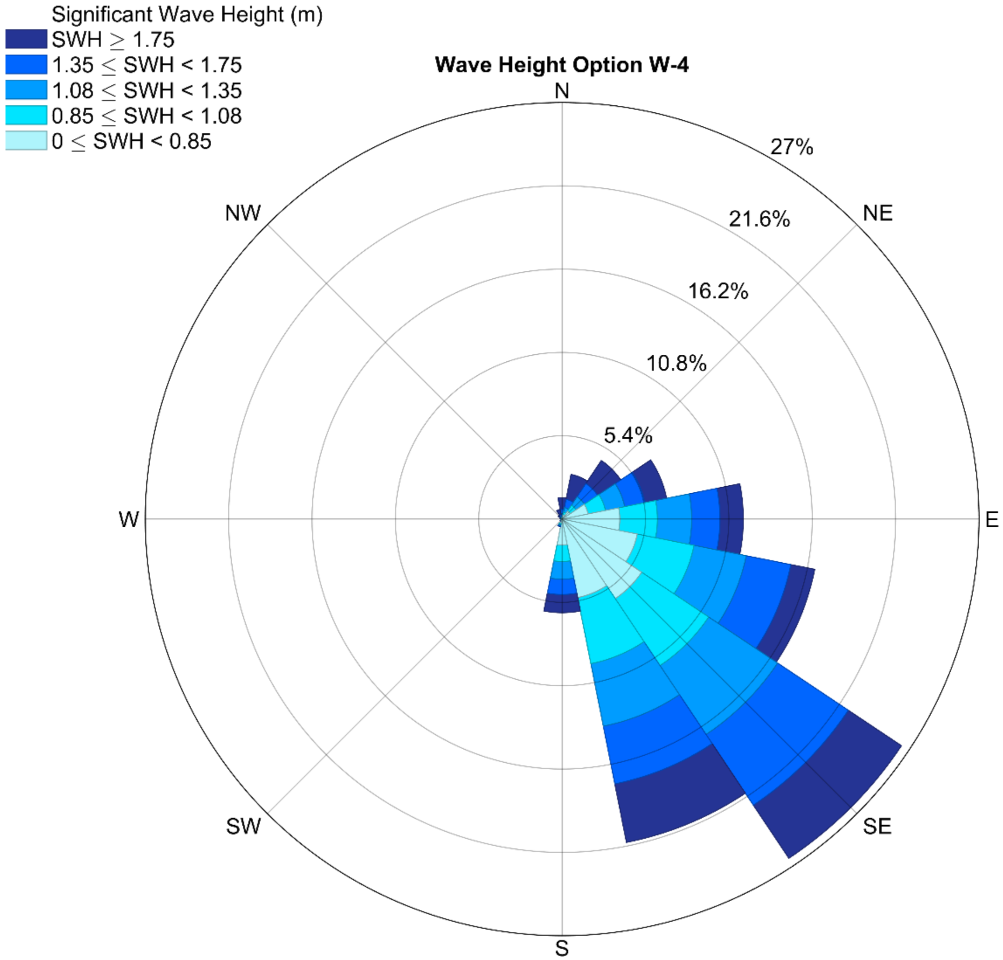


Figure 3.50. Significant wave height and direction at 10-m for option W-4. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

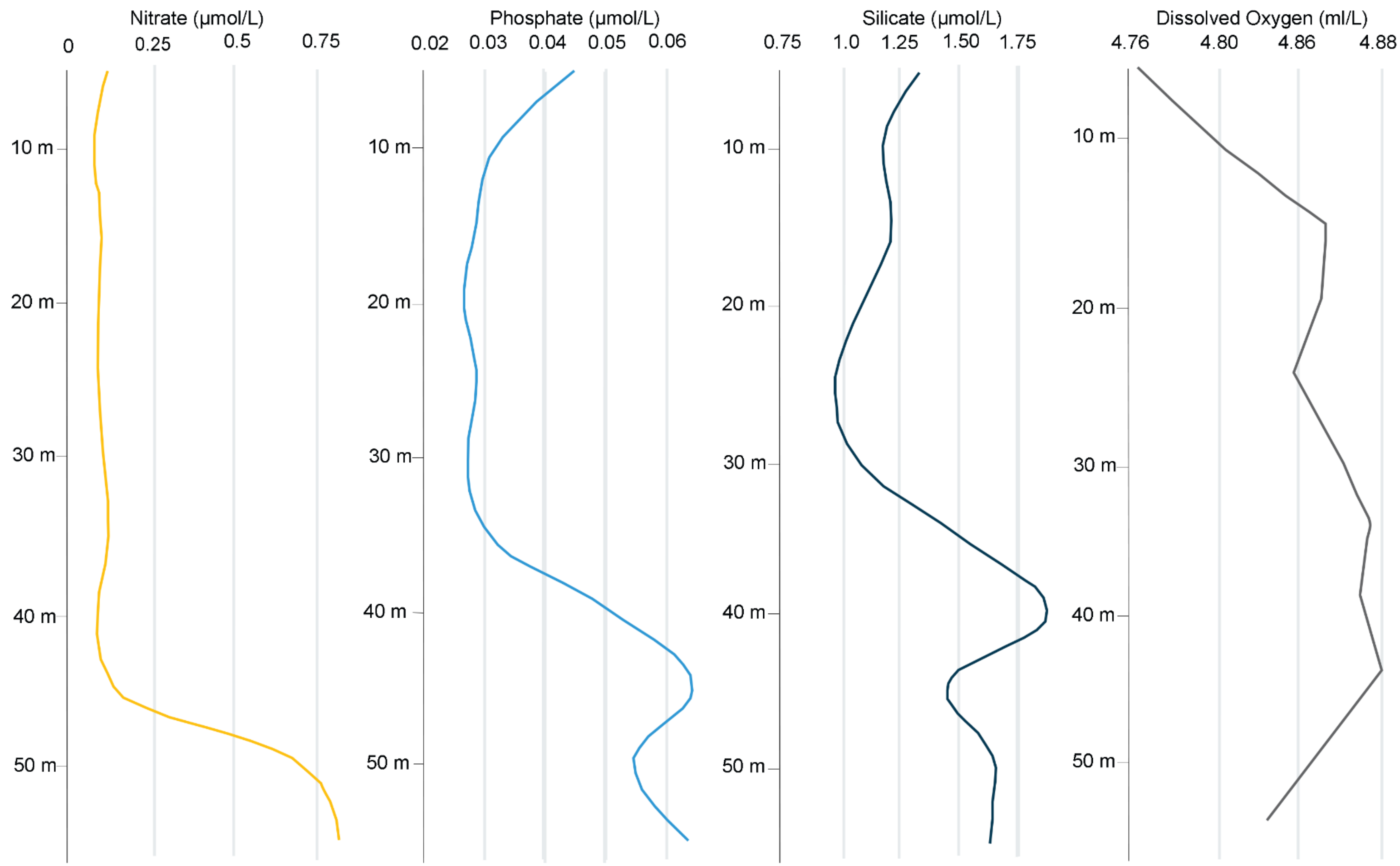


Figure 3.51. Option W-4 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels from the Ecological Marine Units (Sayre et al. 2017).

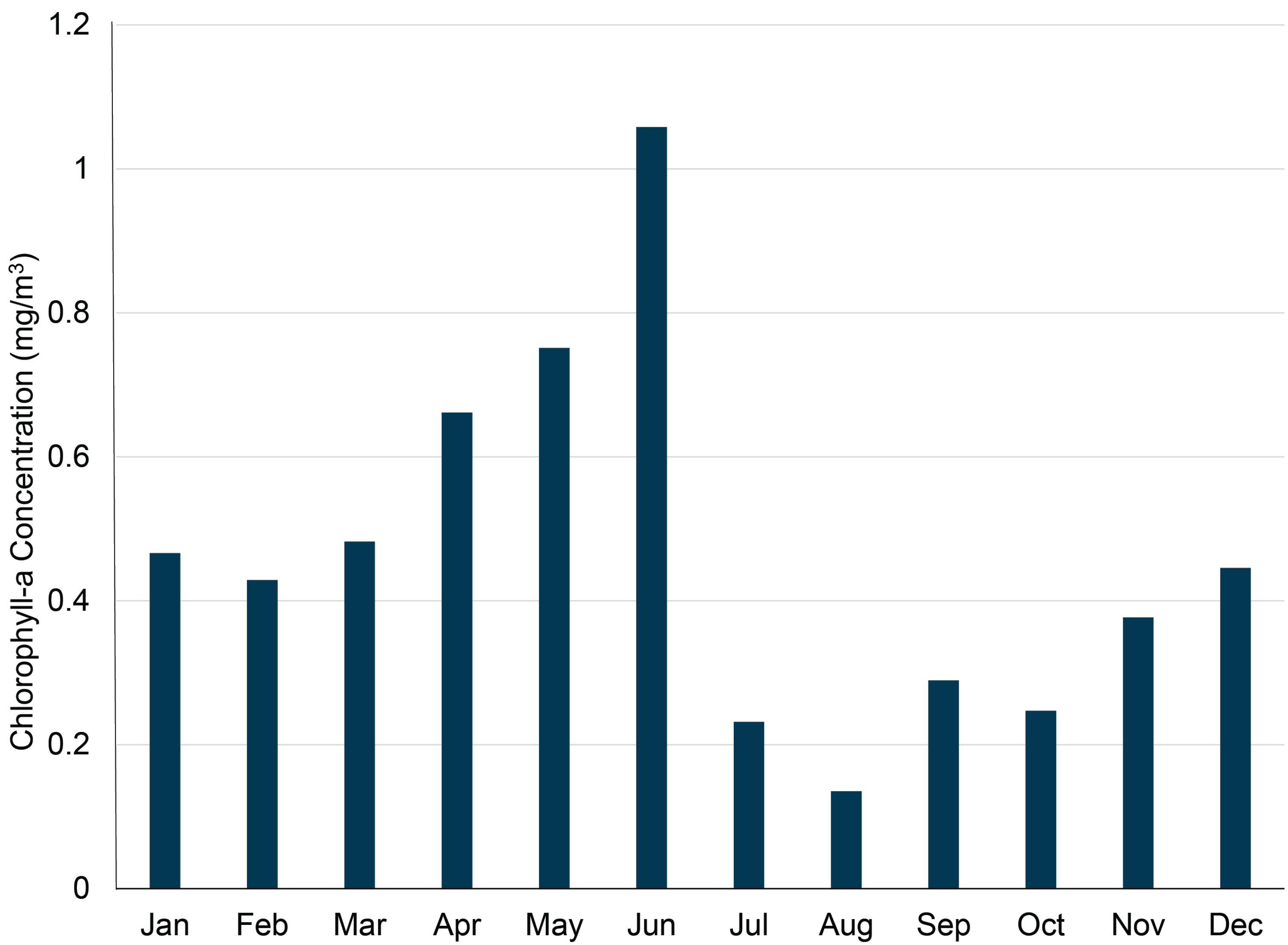


Figure 3.52. Option W-4 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

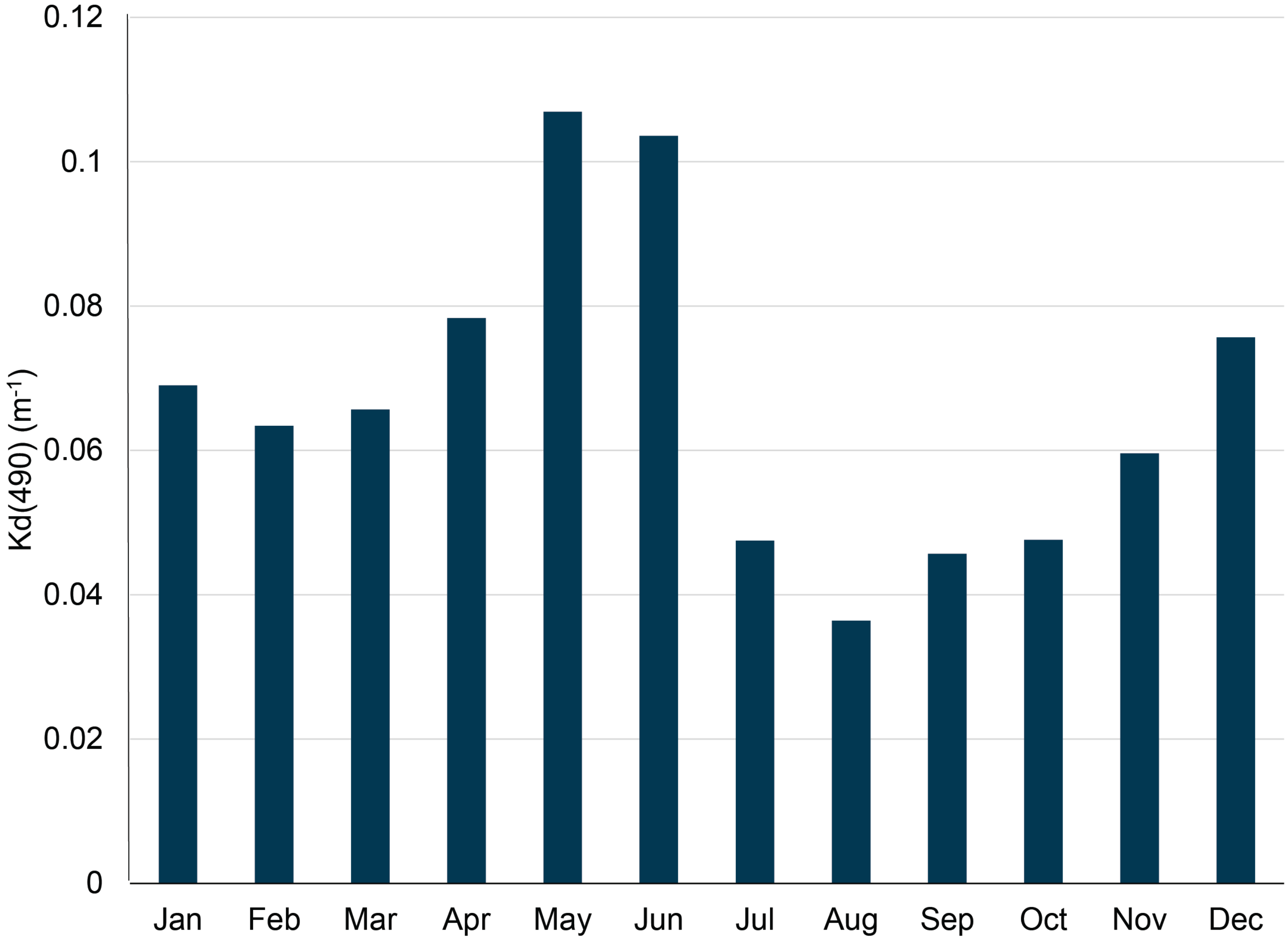


Figure 3.53. Option W-4 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

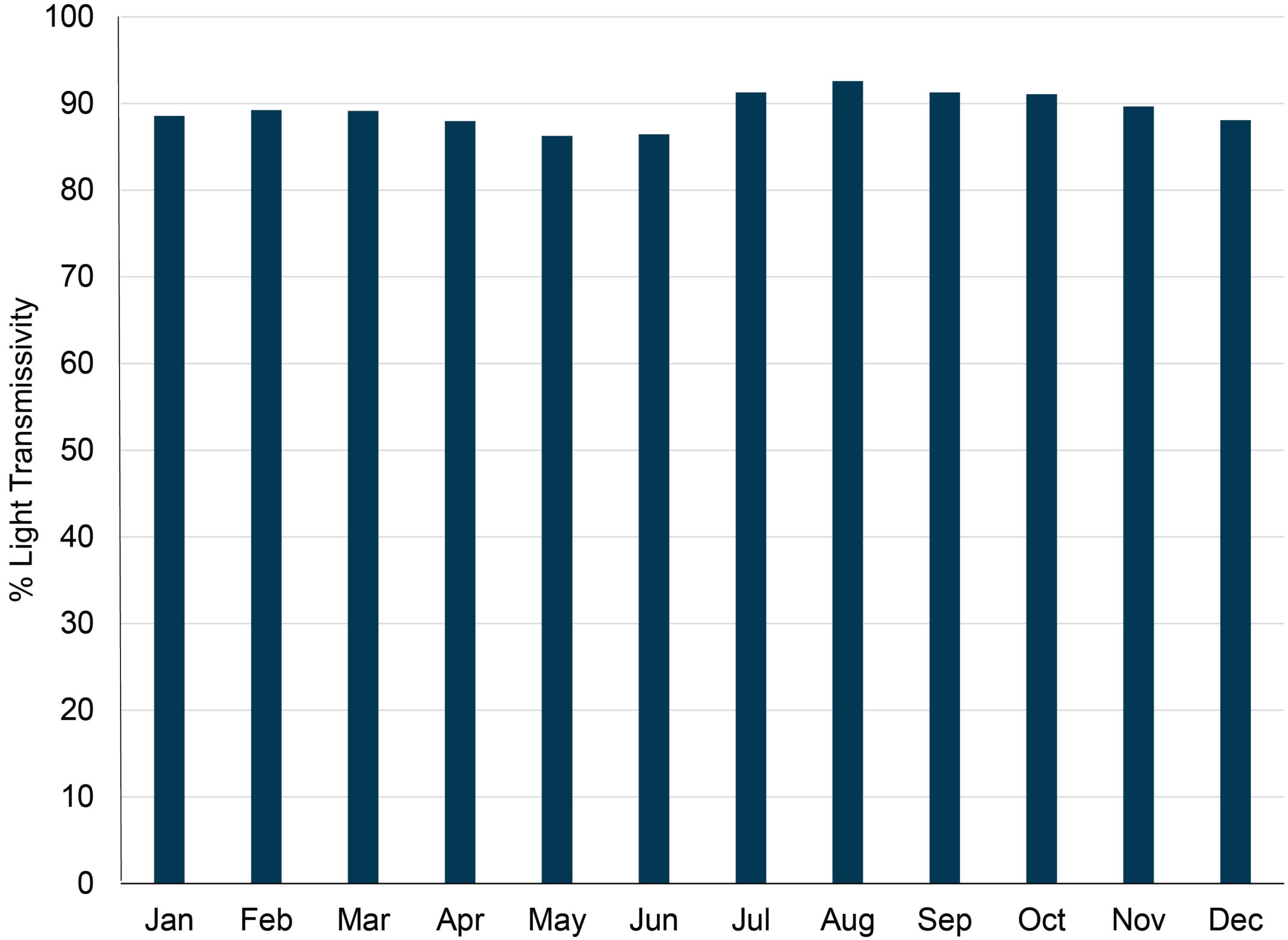


Figure 3.54. Option W-4 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.15. Option W-4 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits All Years (2,000 ac)
W-4	Cargo	0	0.25	2.00	0	0	0	9.00
W-4	Fishing	0	0.25	0.50	0.50	0.25	3.75	21.00
W-4	Other	2.00	1.50	0.50	2.00	0.25	3.75	40.00
W-4	Passenger	1.25	0.50	1.50	1.50	0.25	0.75	23.00
W-4	Pleasure and Sailing	0.25	0.25	0	0	0.50	0	4.00
W-4	Tanker	0.50	1.00	1.25	1.00	1.50	6.25	46.00
W-4	Tug and Tow	1.00	0.25	1.50	0.75	0.50	0	16.00
*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.								

Table 3.16. Number of individual Automatic Identification System-equipped vessels that transited through option W-4.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
W-4	Cargo	0	1	2	0	0	0
W-4	Fishing	0	1	2	2	1	7
W-4	Other	3	4	2	8	1	13
W-4	Passenger	2	2	3	5	1	2
W-4	Pleasure and Sailing	1	1	0	0	2	0
W-4	Tanker	1	4	5	4	5	18
W-4	Tug and Tow	3	1	5	3	2	0

AOA Option W-8 Characterization

Option W-8 was the lowest scoring of the three options identified for the west study area. This option was the farthest from shore, had higher vessel traffic, and suboptimal oceanographic conditions when compared to W-1 and W-4 (Table 3.7). Some commercial fishing effort was present in this option as well.

General Characteristics

Option W-8 is east of option W-4 and is 500 ac in size (Table 3.17). W-8 is located 107.4 km southeast of Freeport, TX (Figure 3.55). It falls under Texas Congressional District 14, State Senate District 17, and House District 25. There are 13 federal statutes applicable to all the options identified, including option W-8 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option W-8 are (-94.940947, 27.997986), (-94.9417, 28.010805), (-94.927257, 28.011473), (-94.926506, 27.998654). The option is in the GMFMC, USACE Galveston District; USCG Corpus Christi Sector (District 8), USEPA Region 6, USFWS Southwest Region, and the BOEM West Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the entire area of option W-8 is 80.6 m, with a maximum depth of 82.3 m and a minimum of 78.9 m (Figure 3.56). No recent high-resolution bathymetric survey data are currently available for W-8. Based on available data, the option appears to gently slope (0.14% slope/option) from north to south (i.e., shallowest to deepest) (Figure 3.56). The largest change in depth is 3.4 m. Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[33] the sediment of W-8 is composed of over 90% sand and mud-like substrate, with roughly 3% of the substrate classified as gravel. The predicted surficial sediment Phi values ranged from 3.9 to 4.4, which indicate sediment with a diameter of very fine sand to coarse silt (diameter = 0.0625 mm).

Water Temperature and Salinity

Seasonally, the mean daily surface water temperature at option W-8 is lowest from December through April, at which point it increases and remains above 25°C until October, when it begins to decrease again (Figure 3.57). The minimum mean daily surface temperature between 2016 and 2020 was 17.6°C, and the maximum was 31.0°C. The water temperature at 10-m depth followed a similar pattern to surface water temperature, with a minimum daily mean value of 17.6°C, and a maximum value of 30.7°C. The water temperature near the bottom of option W-8 is more consistent year-round, with some slight increases from September to December, with a minimum temperature of 16.8°C and a maximum temperature of 26.7°C (Figure 3.57). Mean daily salinity concentration between 2016 and 2020 at option W-8 was consistent throughout the year, with no major variations or decreases.

Metocean Characteristics

Ocean current speeds at option W-8 rarely exceed 1.0 m/s at all depths examined (Figures 3.58 - 3.60). The currents at all depths predominantly move in a northeast to east direction (Figures 3.58 - 3.60). Wind direction at option W-8 is predominantly from the south-southeast, and only 6.74% of the time is the wind speed greater

[33] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

than 10.28 m/s (Figure 3.61). Ocean waves observed at option W-8 predominantly originate from the southeast (Figure 3.62).

Water Quality Considerations

To evaluate water quality at option W-8, nutrient concentration, dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels at the surface of option W-8 for nitrate, phosphate, and silicate were 0.13 µmol/L, 0.12 µmol/L, and 1.96 µmol/L, respectively. At 50-m depth, nitrate concentration increases to 0.79 µmol/L, phosphate decreases (0.06 µmol/L), and silicate concentrations increase (2.36 µmol/L). Around 80-m depth (bottom water) nitrate concentrations increase even more (1.38 µmol/L), while decreases are seen in phosphate (0.12 µmol/L) and silicate concentrations (1.91 µmol/L). Notably, the highest concentration of silicate is found at 30-m depth, where it reaches a value of 3.62 µmol/L (Figure 3.63). Dissolved oxygen ranges from 4.6 to 4.9 ml/L throughout the water column (Figure 3.63). Chl-*a* concentration, a common approximation for phytoplankton in the ocean, at option W-8 peaked in May (0.43 mg/m^3) and was lowest in August (0.14 mg/m^3) (Figure 3.64). Dissolved oxygen ranged between 4.7 ml/L to 4.9 ml/L throughout the water column. The diffuse light attenuation coefficient at 490 nm was highest in June (0.07 m^{-1}) and lowest in August and September (0.30 m^{-1} and 0.04 m^{-1}, respectively). (Figure 3.65). Percent light transmissivity at 1-m depth was relatively constant throughout the year, with values ranging from 89% to 92% transmissivity (Figure 3.66).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. The closest military constraint is an expansive unexploded ordnance area that is 3 km to the west of option W-8. W-8 is outside of all Gulf of Mexico-based MOAs. It does overlap SUA W147D, but does not overlap areas marked as danger zones or restricted areas (Table 3.17). Because of the proximity of option W-8 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

AOA Option W-8 does not directly overlap any species considered in the NMFS Protected Resources combined data layer. However, option W-8 does exist within the range of loggerhead, Kemp's ridley, leatherback, and green sea turtles (see Appendix B for details). AOA option W-8 is located in the expansive loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat (*Sargassum*). Based on available data, no overlap occurs with deep-sea corals, fish havens, artificial reefs, or sensitive habitats (including HAPCs) and none are within a 3-km vicinity. Essential Fish Habitat designated by the GMFMC and NMFS includes shrimp, reef fish, coastal migratory pelagic species, and 15 highly migratory species (see Table 3.39).

Industry, Navigation, and Transportation Considerations

W-8 has no direct interactions with oil and gas infrastructure (i.e., active lease blocks, pipelines, platforms, boreholes). A single oil and gas pipeline is 750 m away from W-8's closest corner point (Figure 3.56). All navigational infrastructure was avoided within this option. W-8 AIS vessel traffic from 2015 to 2020 indicate the lowest vessel traffic by type were tug and tow, pleasure and sailing, and passenger vessels. Tanker traffic was the highest vessel type intersecting W-8 (n = 22). Additionally, there were a total of 10 cargo vessel transits over the six years assessed intersecting the 500-ac option (Tables 3.18, 3.19).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate W-8 overlaps the designated Reef Fish Longline and Buoy Gear Restricted Area, and a relatively low amount of reef fish longline gear activity occurred in the option from the 13-year period for which data were assessed. There was no observed reef fish bandit gear fishing that occurred within W-8 over the 13-year period that data were assessed. Additionally, a relatively low amount of shrimp trawls occurred within W-8 over the 16-year period that data were assessed.

Table 3.17. Characterization summary for Aquaculture Opportunity Area option W-8.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-94.940947, 27.997986
	-94.9417, 28.010805
	-94.927257, 28.011473
	-94.926506, 27.998654
Size (ac)	500
Closest inlet (km)	107
Depth (m) (minimum, mean, maximum)	(78.9, 80.6, 82.3)
National Security	
Military Operating Areas (MOA)	None
Special Use Airspace (SUA)	Overlaps W147D
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	2.00
Fishing Vessels 2015 - 2019	1.00
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	1.20
Passenger Vessels 2015 - 2019	0.80
Pleasure and Sailing Vessels 2015 - 2019	0.20
Tanker Vessels 2015 - 2019	3.20
Tug and Tow Vessels 2015 - 2019	0
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	6.74
Surface Current Speed % > 1.0 m/s (%)	0.08
Significant Wave Height % > 1.75 m (%)	18.0

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	None within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	No overlap with ESA species (Appendix B)
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	None within reporting range
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	1
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.42
Salinity (PSU) at 5-m depth (mean)	34.53
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(0.13, 0.12, 1.96)
Mean Aragonite Saturation State (Ω)	3.78
Governance	
Agency boundary (USACE Districts)	Galveston District
Agency boundary (USCG Sectors)	Sector Corpus Christi; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southwest Region
Agency boundary (BOEM)	West Gulf of Mexico

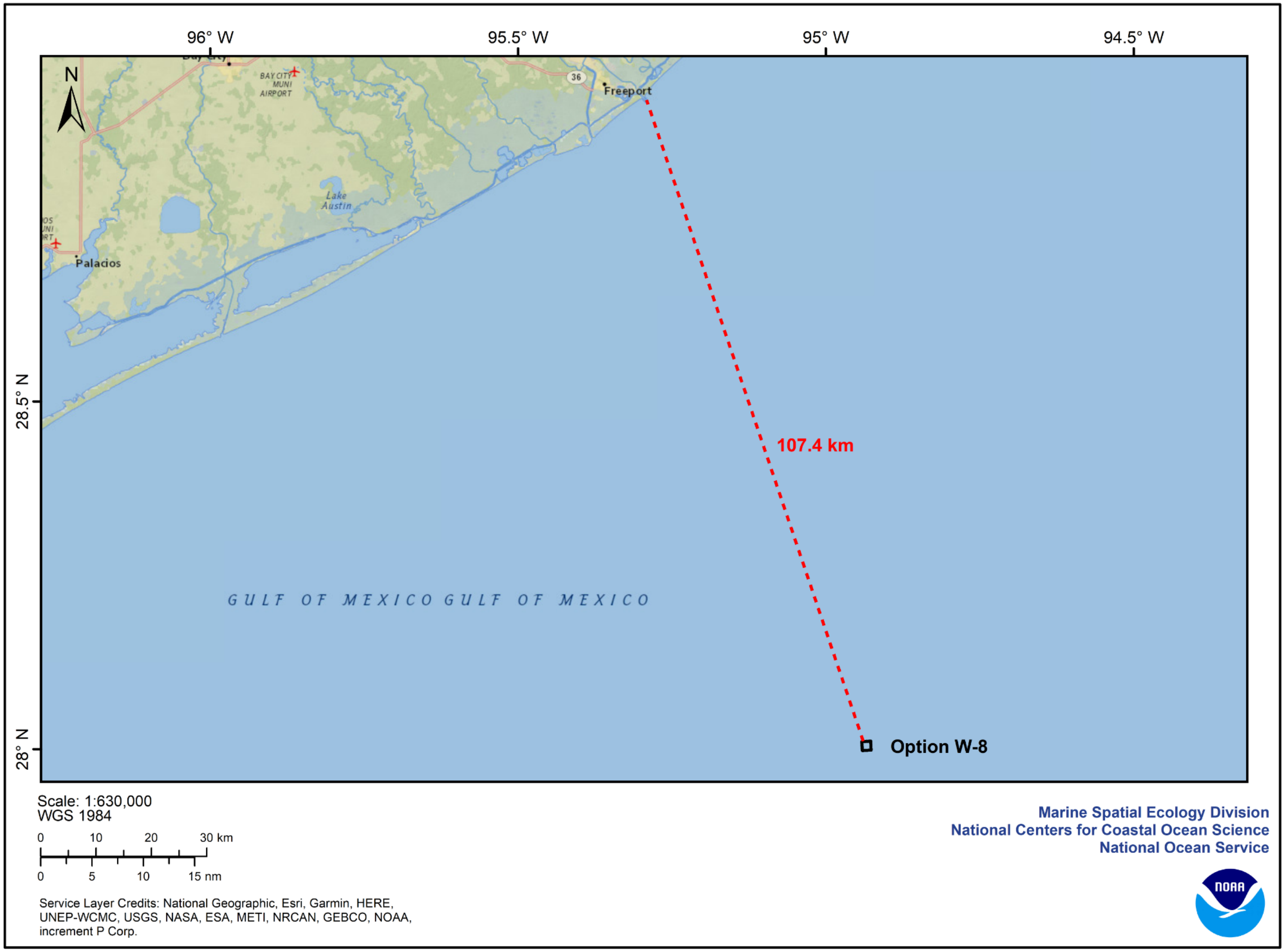


Figure 3.55. Option W-8 (black outlined box) and distance to the closest inlet from the closest corner point of W-8; the area includes Freeport, Texas.

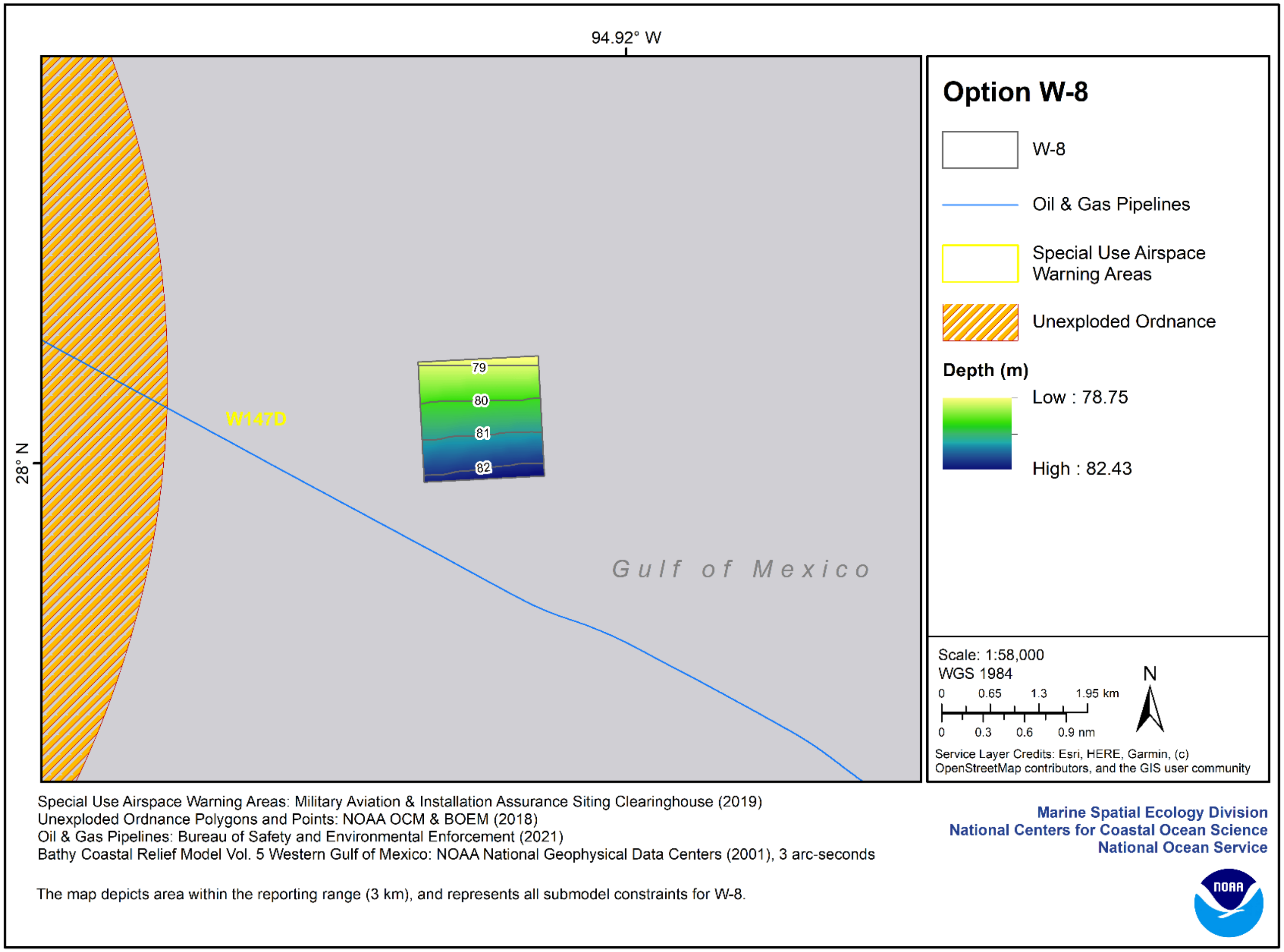


Figure 3.56. Map depicting noteworthy characterization features for Aquaculture Opportunity Area option W-8.

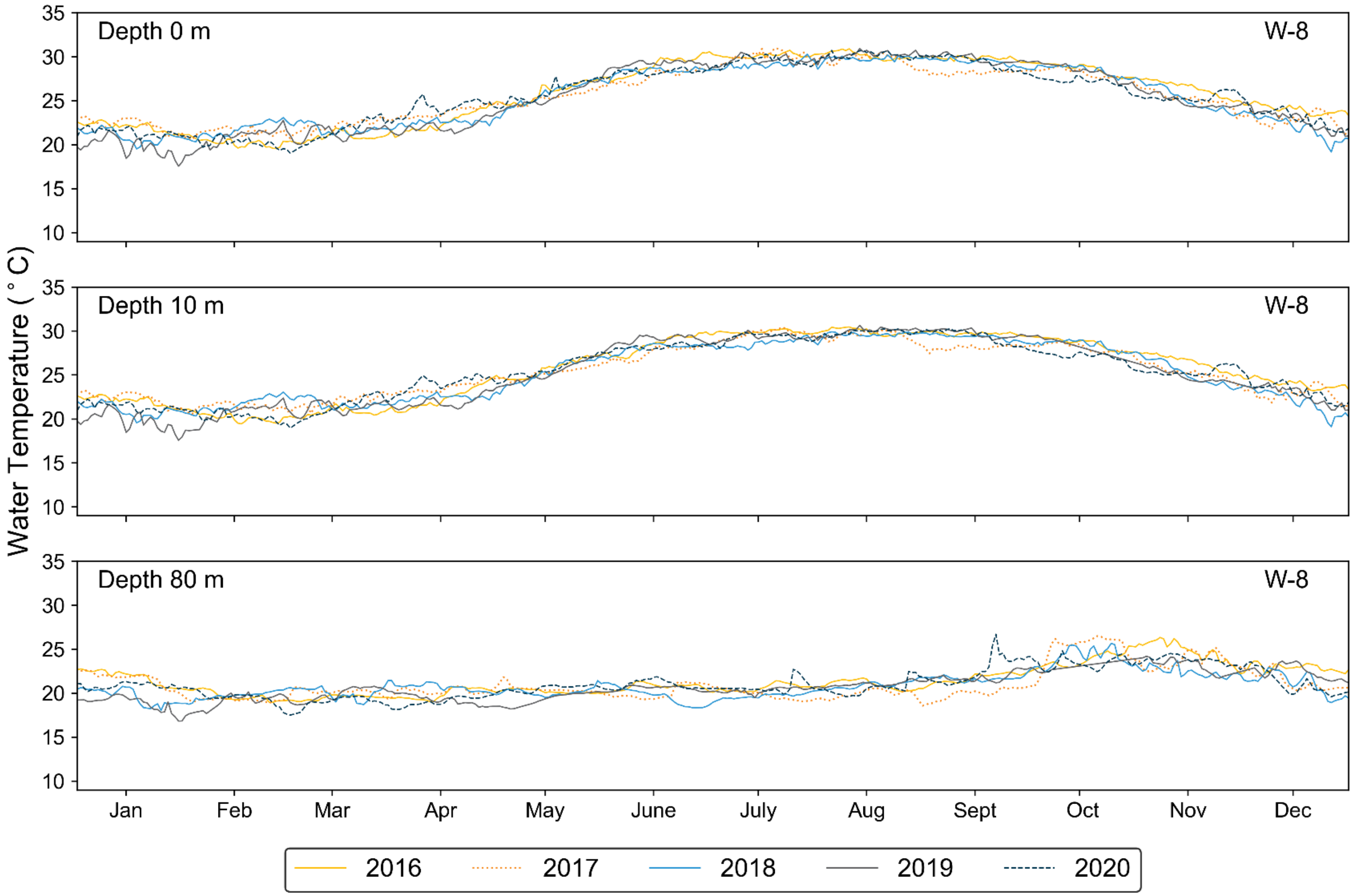


Figure 3.57. Option W-8 Navy Coastal Ocean Model regional model mean daily water temperature at the surface, 10-m depth, and 80-m depth (2016 – 2020).

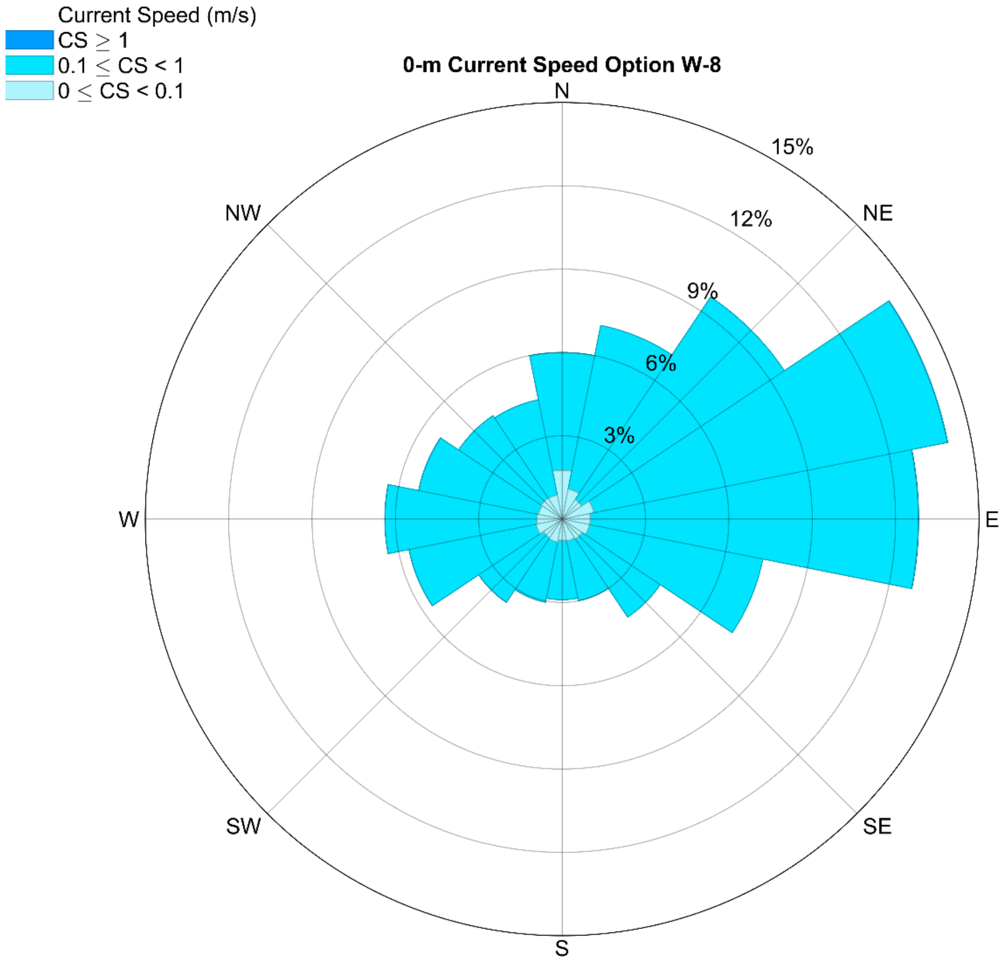


Figure 3.58. Ocean current magnitude and direction for option W-8 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

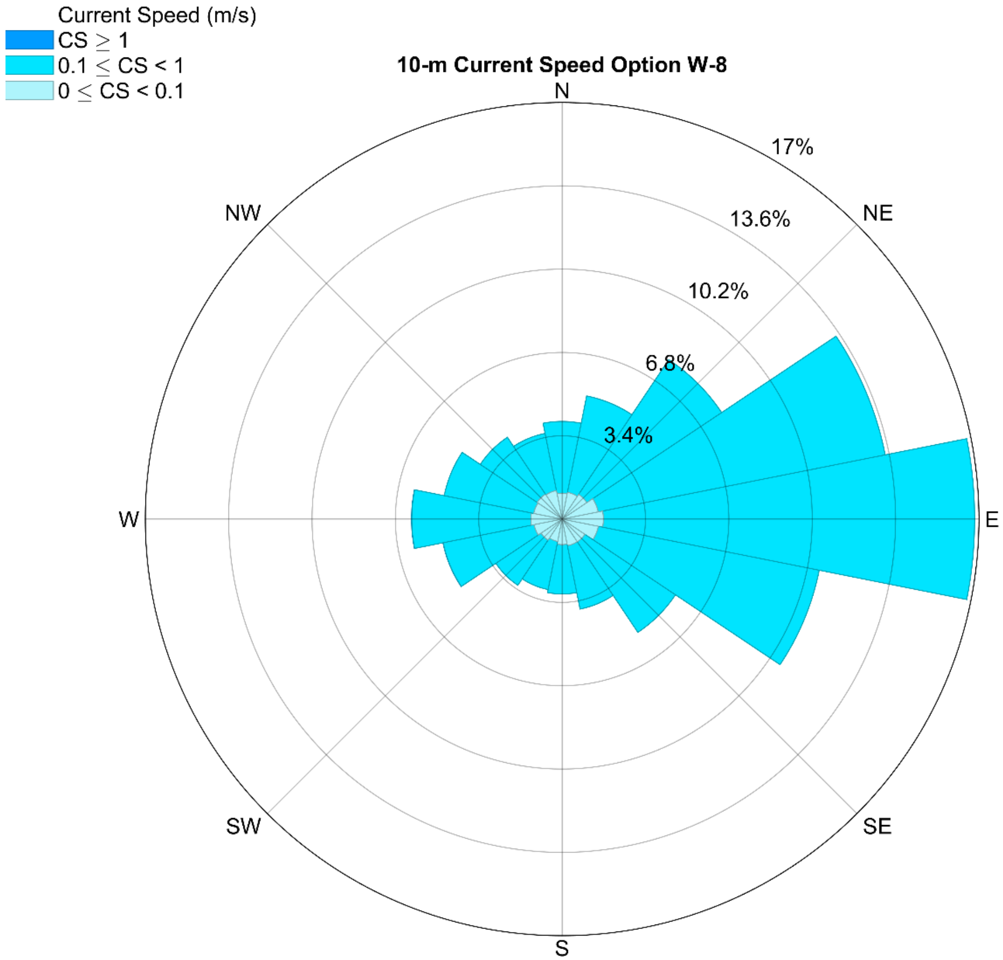


Figure 3.59. Ocean current magnitude and direction for option W-8 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

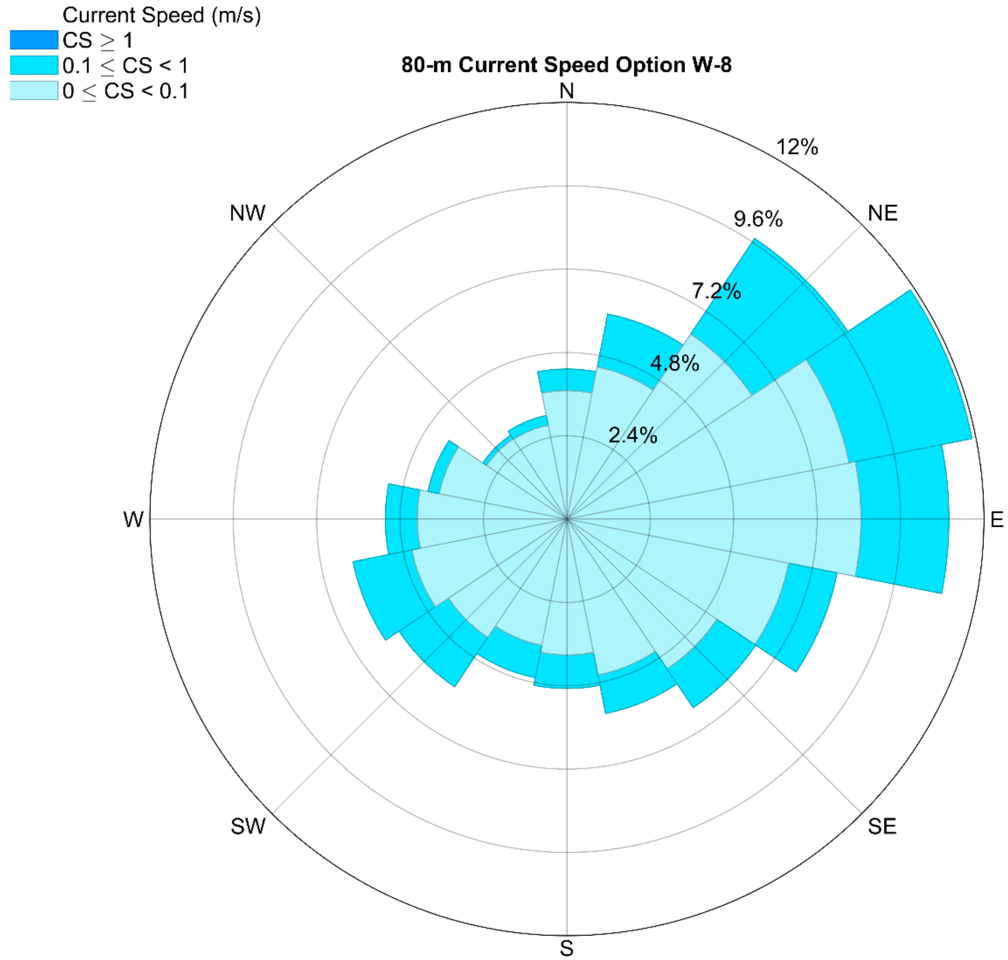


Figure 3.60. Ocean current magnitude and direction for option W-8 at 80-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

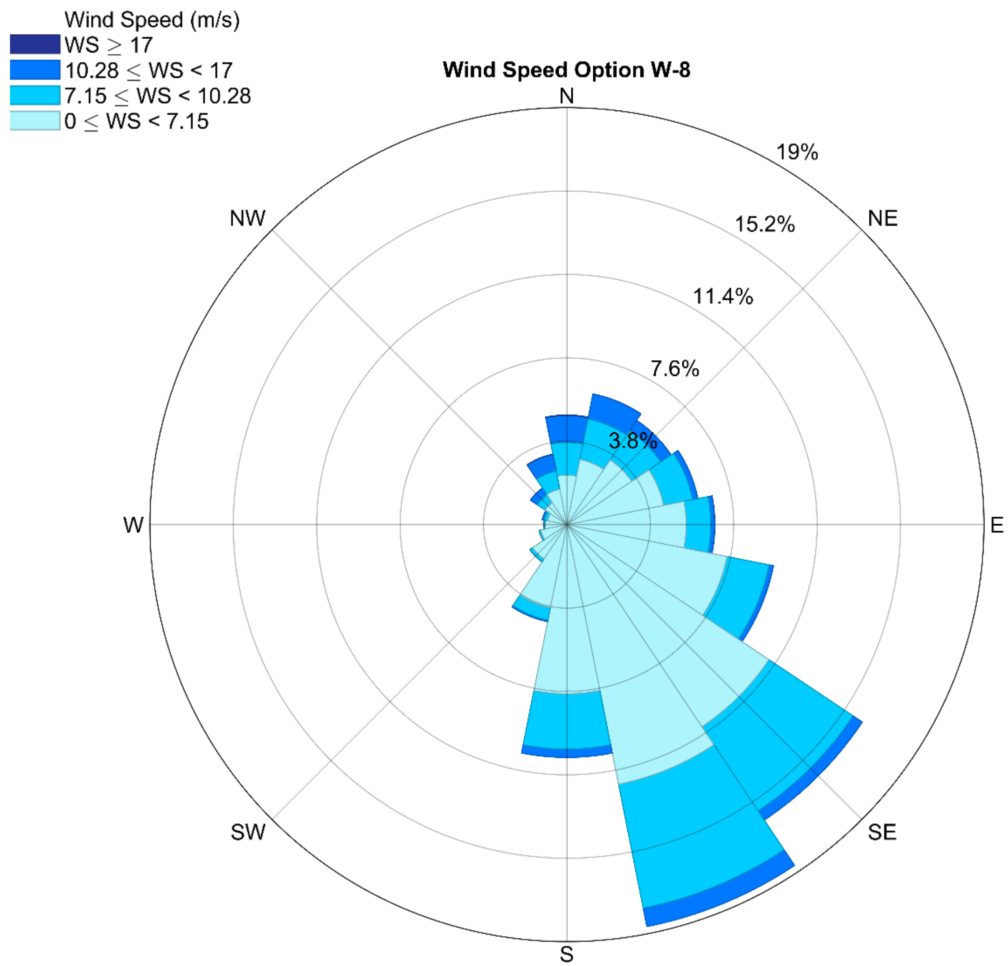


Figure 3.61. Wind velocity and direction at 10-m above sea level for option W-8. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

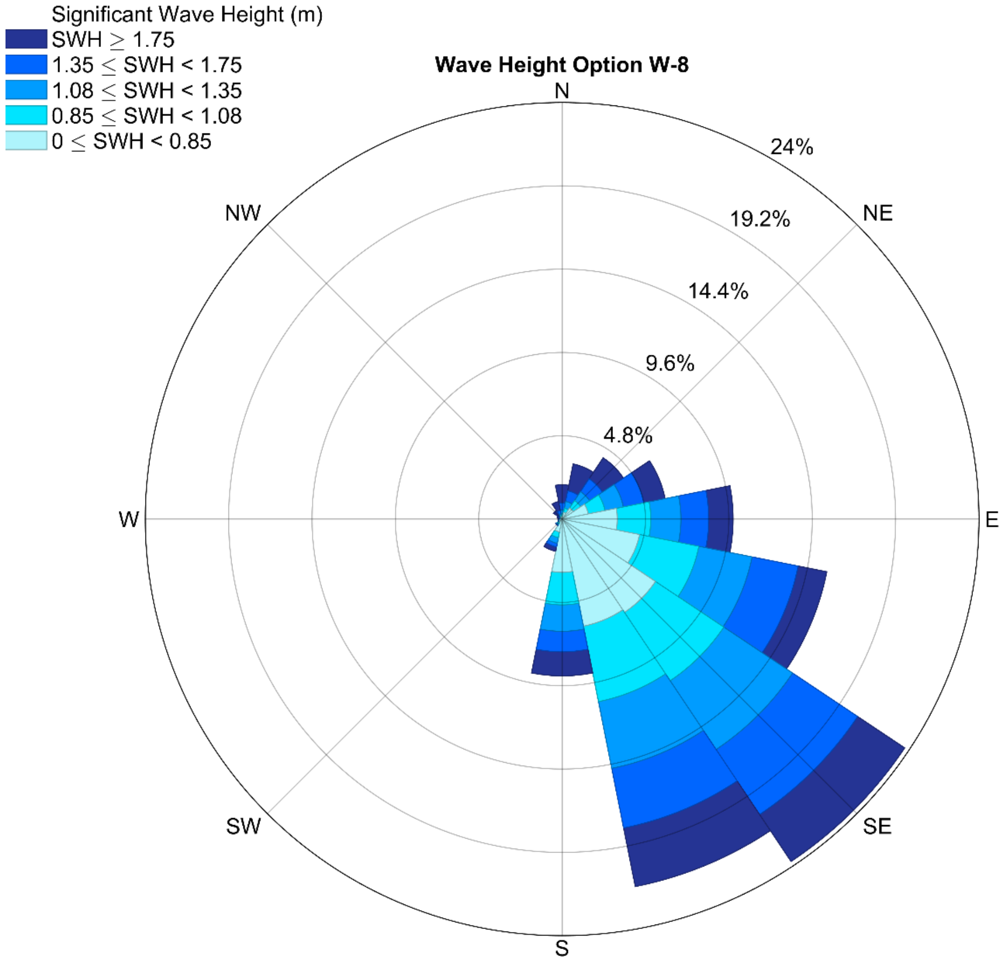


Figure 3.62. Significant wave height and direction at 10-m for option W-8. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

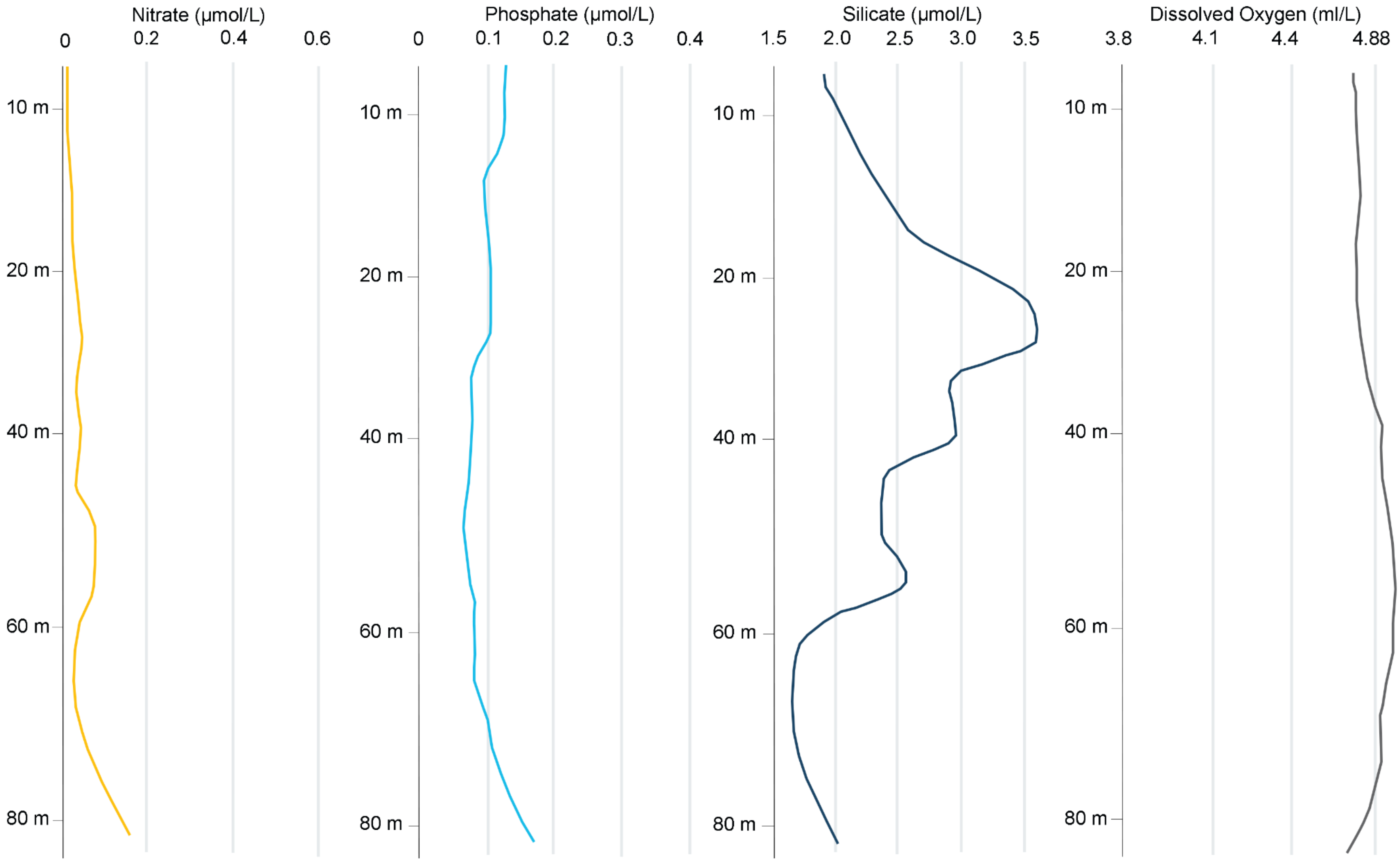


Figure 3.63. Option W-8 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels derived from the Ecological Marine Units (Sayre et al. 2017).

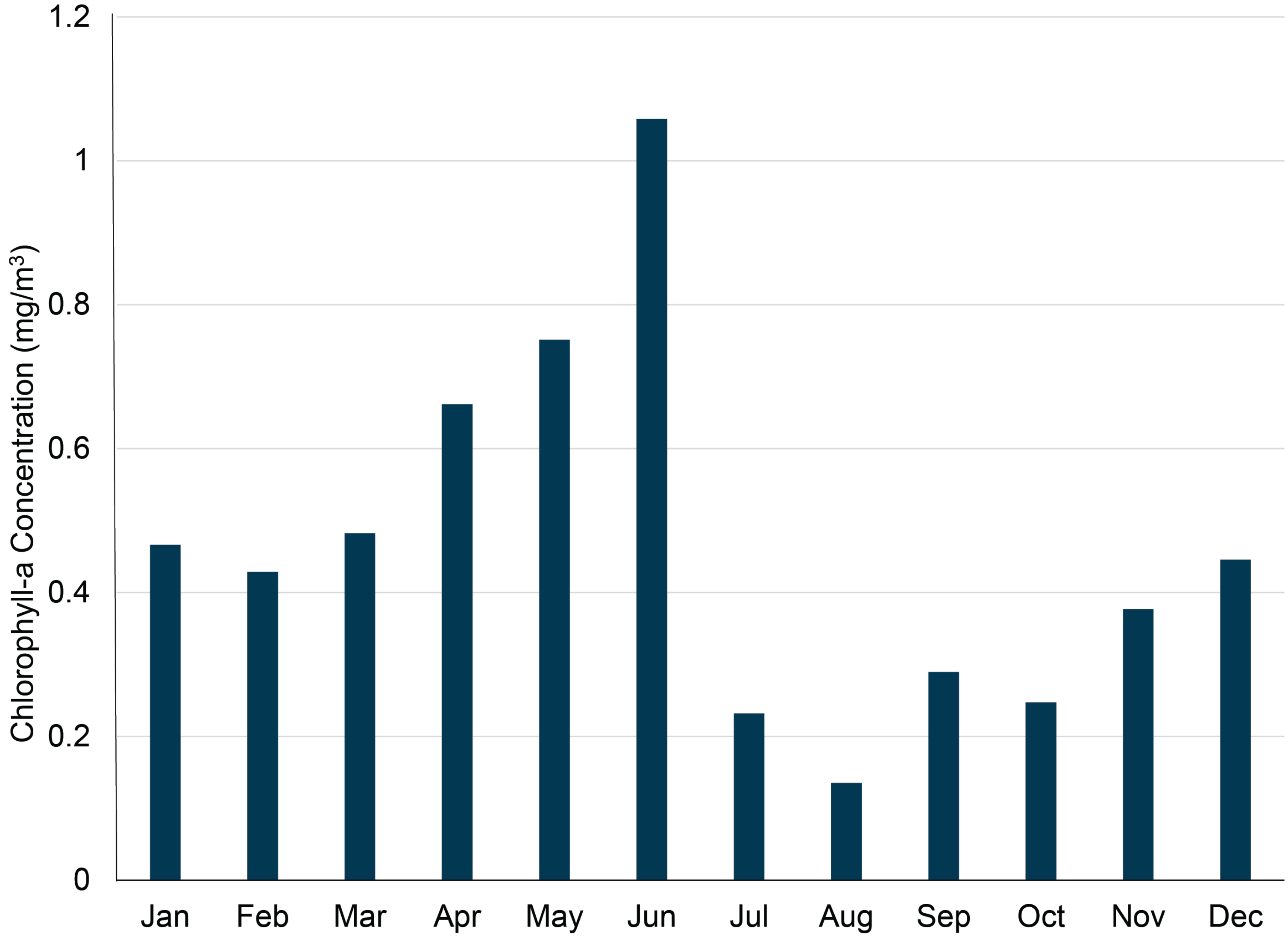


Figure 3.64. Option W-8 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

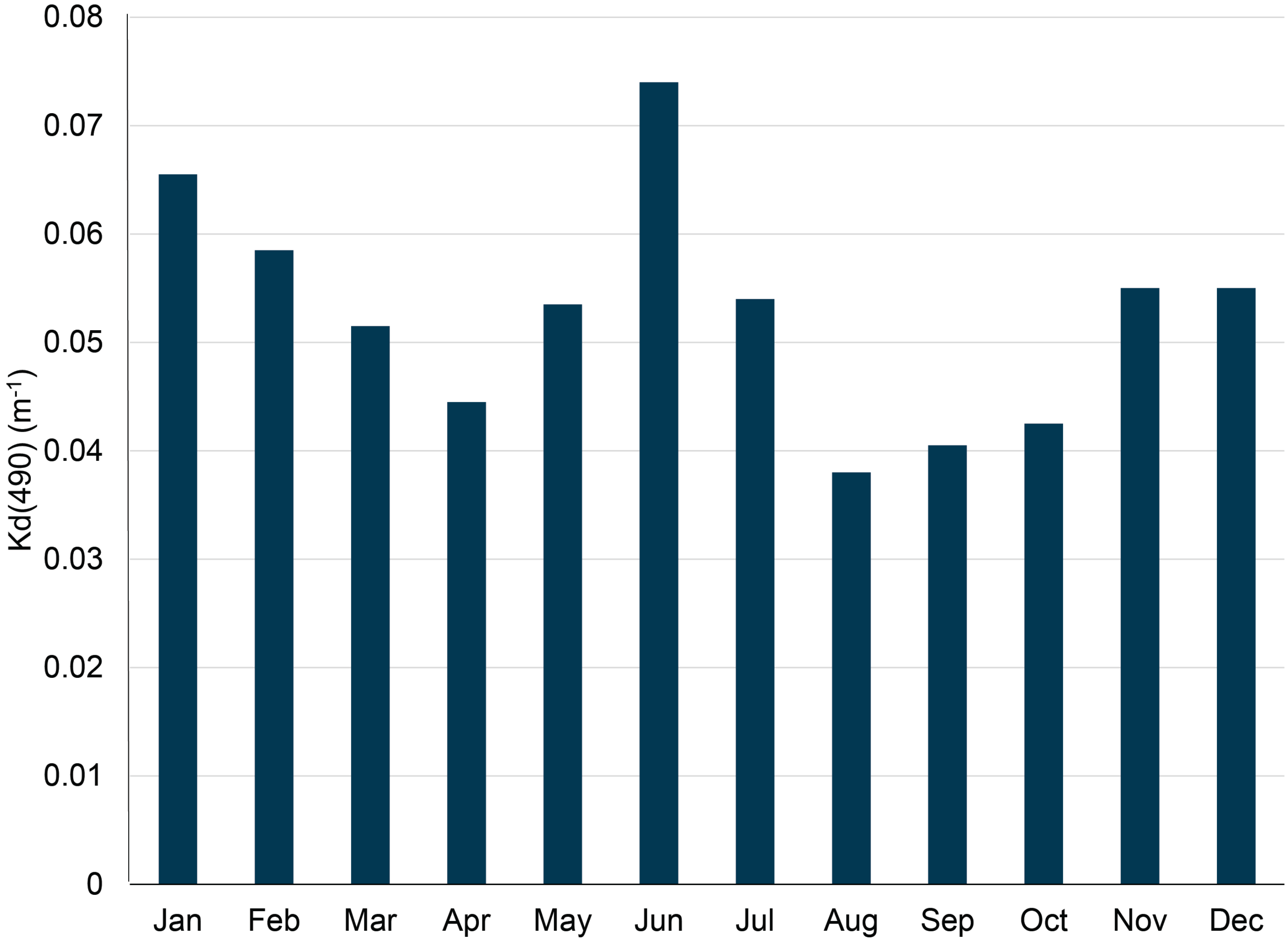


Figure 3.65. Option W-8 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

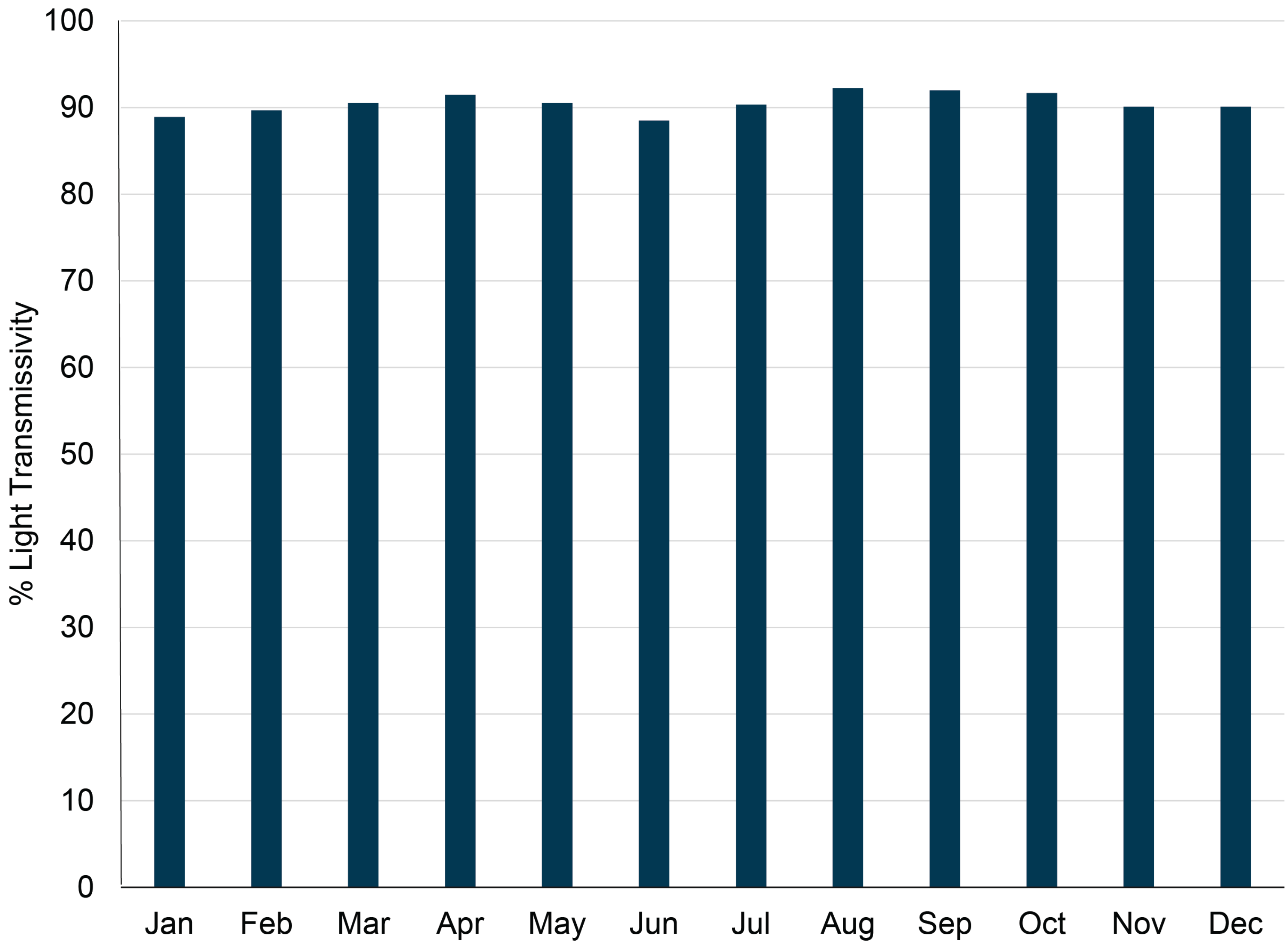


Figure 3.66. Option W-8 monthly climatological mean (2010 - 2017) for Kd(PAR) at the sea surface produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.18. Option W-8 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 500-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits All Years (500 ac)
W-8	Cargo	2.00	0	4.00	2.00	2.00	0	10.00
W-8	Fishing	1.00	0	1.00	2.00	1.00	0	5.00
W-8	Other	0	3.00	2.00	0	1.00	8.00	14.00
W-8	Passenger	2.00	1.00	0	0	1.00	2.00	6.00
W-8	Pleasure and Sailing	0	0	1.00	0	0	1.00	2.00
W-8	Tanker	2.00	3.00	2.00	7.00	2.00	6.00	22.00
W-8	Tug and Tow	0	0	0	0	0	1.00	1.00

*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.

Table 3.19. Number of individual Automatic Identification System-equipped vessels that transited through option W-8.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
W-8	Cargo	2	0	4	2	1	0
W-8	Fishing	1	0	1	2	1	0
W-8	Other	0	2	2	0	1	6
W-8	Passenger	1	1	0	0	1	1
W-8	Pleasure and Sailing	0	0	1	0	0	1
W-8	Tanker	2	2	2	5	2	6
W-8	Tug and Tow	0	0	0	0	0	1

Central Options Precision Modeling Results

In the Central study area, 13 unique high-high clusters were identified (C-1 to C-13) using the LISA analysis (Table 3.8). Using the within-cluster approach, each cluster (cluster C-1 through cluster C-13) was treated as an individual spatial unit in which options (500 ac, 1,000 ac, 1,500 ac, and 2,000 ac with 4 corner points in cardinal directions) were iteratively created and modeled throughout each cluster using the logistics, vessel traffic, and aquaculture and fishing submodels (see Figure 2.21). Executing the within-cluster model, C-4 had the highest number of potential options (537 potential options over 37,920 ac) iterated by the model to identify the highest suitability option within the cluster. C-2 had the lowest number of potential options identified (5 potential options over 3,400 ac) (Table 3.8). Once the most suitable option was determined from each cluster, the among-cluster model (see Figure 2.22) using the logistics, vessel traffic, aquaculture and fishing, and metocean submodels identified (from west to east) C-3, C-11, and C-13 as the highest scoring options based on parameters considered (Table 3.8; Figure 3.28). Each is discussed in detail below.

All Central study area options (C-3, C-11, and C-13) are in closest proximity to the state of Louisiana. From an economic standpoint, the state ocean economy supports 103,906 jobs in the state, with wages totaling around $5.3 billion in 2018 (NOAA 2021b). The largest ocean sector job categories were tourism and recreation (59%), offshore mineral extraction (13.0%), followed by marine transportation (12.5%).

AOA Option C-3 Characterization

Option C-3 was the second highest scoring of the three options in the Central study area based on the among-cluster analysis results (Table 3.8). C-3 is relatively low scoring for logistics due to its distance to inlet relative to other central options (i.e., three other options were closer to an inlet than C-3). Option C-3 has relatively low mean AIS vessel traffic (2015 - 2019) and low fishing effort spatially and temporally within the time periods assessed.

General Characteristics

Option C-3 is 2,000 ac in size and is in federal waters far offshore of Louisiana's coastline (Table 3.20; Figure 3.67). AOA option C-3 has an estimated travel distance of 133 km (72 nm) to the closest inlet or coastal community (Figure 3.67). There are many small communities or fishing villages within the Atchafalaya Basin that could support the option. Morgan City is the closest town with significant infrastructure. While option C-3 is considerably remote, there are a significant number of offshore supply and service companies that support oil and gas exploration. It falls under Louisiana Congressional District 03, State Senate District 22, and House District 49. There are 13 federal statutes applicable to all the options identified, including option C-3 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option C-3 are (-90.08456, 28.375922), (-90.08501, 28.401598), (-90.05599, 28.401997), (-90.05555. 28.376321). The option is in the GMFMC, USACE New Orleans District, USCG New Orleans Sector (District 8), USEPA Region 6, USFWS Southeast Region, and BOEM Central Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 2,000-ac area is 60.5 m, with a maximum depth of 61.4 m and a minimum depth of 59.8 m (Figure 3.68). No recent high-resolution bathymetric survey data are currently available for C-3. Based on available data, the bottom appears to be relatively flat (mean slope = 0.02°) across the option, with the largest change in depth being 1.6 m. Option C-3 is shallower on the northeast side and deeper on the southwest side (Figure 3.68).

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[34] the sediment of C-3 is composed of over 99% sandy or mud-like substrate. The northeast corner of C-3 has a slightly higher percent of sandy substrate relative to the southwest, where it more mud-like. The predicted surficial sediment Phi values ranged from 3.9 to 4.0, which indicate sediment with a diameter of very fine sand to coarse silt (diameter = 0.0625 mm).

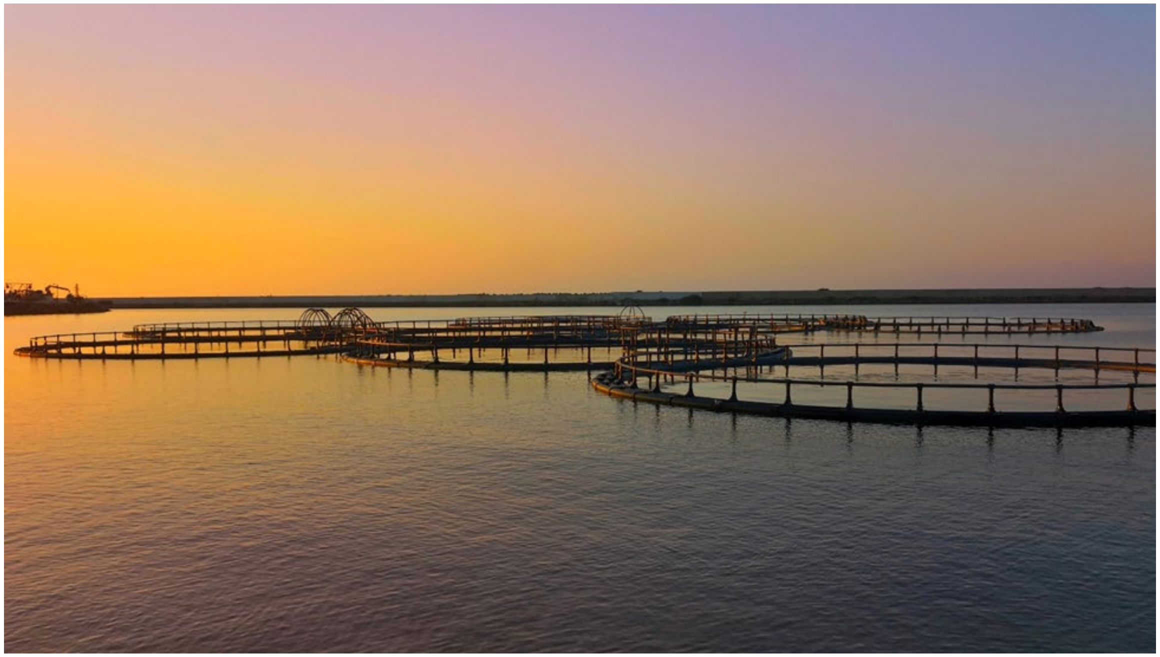
[34] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

Water Temperature and Salinity

Seasonally the mean daily surface water temperature at option C-3 is lowest from December through April, at which point it increases and remains above 25°C until October, when it begins to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 18.85°C, while the maximum was 32.1°C. The water temperature at 10-m depth followed a similar pattern as the surface water temperature, with a minimum daily mean value of 18.89°C, and a maximum value of 31.2°C. The water temperature near the bottom of option C-3 is more consistent year-round, with some slight increases from September to December, with a minimum temperature of 17.76°C and a maximum temperature of 28.5°C (Figure 3.69). Mean daily salinity concentration between 2016 and 2020 at option C-3 was consistent throughout the year, with no major variations or decreases.

Metocean Characteristics

Ocean current speeds at option C-3 rarely exceed 1.0 m/s at all depths examined (Figures 3.70 - 3.72). The currents at the surface and at 10 m predominantly move in an east and west direction, while currents at the bottom depth generally move in an east-northeast direction (Figures 3.70 - 3.72). Wind direction at option C-3 predominantly comes from the south-southeast, and only 6.65% of the time is the wind speed greater than 10.28 m/s (Figure 3.73). Ocean waves observed at option C-3 predominantly originate from the south-southeast (Figure 3.74).



Water Quality Considerations

To evaluate water quality at option C-3, nutrient concentration, Chl-*a*, dissolved oxygen, and water clarity were examined. Mean dissolved nutrient levels from the surface to 5-m depth of option C-3 for nitrate, phosphate, and silicate were 1.11 µmol/L, 0.33 µmol/L, and 4.27 µmol/L, respectively. At 25-m depth, nitrate concentration increased to 1.76 µmol/L, phosphate increased slightly to 0.36 µmol/L, and silicate concentration increased to 7.28 µmol/L (Figure 3.75). Around 45 m (i.e., bottom water) nitrate concentrations decreased (0.91 µmol/L), phosphate decreased (0.12 µmol/L) and silicate concentration was 3.28 µmol/L. Notably, the highest concentration of nitrate was found around the 40-m depth level, where it reached a maximum value of 1.91 µmol/L. Dissolved oxygen ranges between 4.5 and 4.8 ml/L throughout the water column (Figure 3.75). Chl-*a* concentration, a common approximation for phytoplankton in the ocean, was highest at option C-3 in July (0.79 mg/m^3) and December (0.75 mg/m^3). In February, chlorophyll-*a* began to decrease until May, when the lowest concentration (0.17 mg/m^3) was observed. In April, concentrations began to increase and continued to increase until July. Concentrations dropped again until October, when they increased into the winter months (Figure 3.76). The diffuse light attenuation coefficient (Kd) at 490 nm was lowest for the months of April and May (0.04 m^{-1}) and highest in December (0.10 m^{-1}) (Figure 3.77). Percent light transmissivity at 1-m depth was relatively constant at option C-3 throughout the year, ranging from 87% in January to 92% transmissivity in May (Figure 3.78).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. Option C-3 is outside all Gulf of Mexico-based MOAs. It overlaps SUA W59B, but does not overlap areas marked as danger zones or restricted areas (Table 3.20). Because of the proximity of option C-3 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

One fish haven is in the vicinity of option C-3 and is located about 1.5 km from the southeast corner point. Eleven artificial reefs are positioned inside the fish haven largely constructed from BOEM's rigs-to-reef program. Based on available data, no overlap occurs with deep-sea corals, fish havens, artificial reefs, or sensitive habitats (including HAPCs) and none are within a 3-km vicinity. AOA Option C-3 overlaps with the NMFS Protected Resources giant manta ray species distribution model, particularly with the areas above the median maximum predicted value to provide conservation measures for the species (Table 3.20, Appendix B). Although option C-3 does not overlap with any sea turtle HUAs for residence or migratory areas, loggerhead, Kemp's ridley, leatherback, or green sea turtles may still be within range of the option (see Appendix B for details). Option C-3 also overlaps the loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat area (*Sargassum*), but no other critical habitat. Essential Fish Habitat designated by the GMFMC and NMFS includes shrimp, reef fish, coastal migratory pelagic species, and 20 highly migratory species (Table 3.40).

Industry, Navigation, and Transportation Considerations

Option C-3 is in the Central Gulf of Mexico BOEM Offshore Oil and Gas Planning Area, where significant oil and gas energy sector infrastructure exists. There are three oil and gas pipelines within 3 km of the option. One of the three pipelines is located about 700 m from the northwest corner point of C-3. The other two in the vicinity are 1.5 to 2.0 km south of the south side of C-3. There are 13 boreholes within 3 km of option C-3, and one oil and gas platform about 2.5 km off the southeast corner point. All navigational infrastructure was avoided within and within a 3-km distance from option C-3. AIS vessel traffic from 2015 to 2020 within C-3 indicate the lowest vessel traffic by type was tanker (n = 0) and pleasure and sailing (n = 1). Fishing (n = 203), other (n = 187), and passenger (n = 110) vessels were the highest vessel type traffic intersecting option C-3 (Table 3.21; Table 3.22).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate option C-3 overlaps the designated Reef Fish Longline and Buoy Gear Restricted Area; no reef fish longline gear activity occurred in the option from the period assessed 2007 - 2019. A relatively low amount of bandit gear fishing trips occurred over the 13-year period. Similarly, a relatively low amount of overlap occurred with shrimp trawl fishing within the option over a 16-year period.

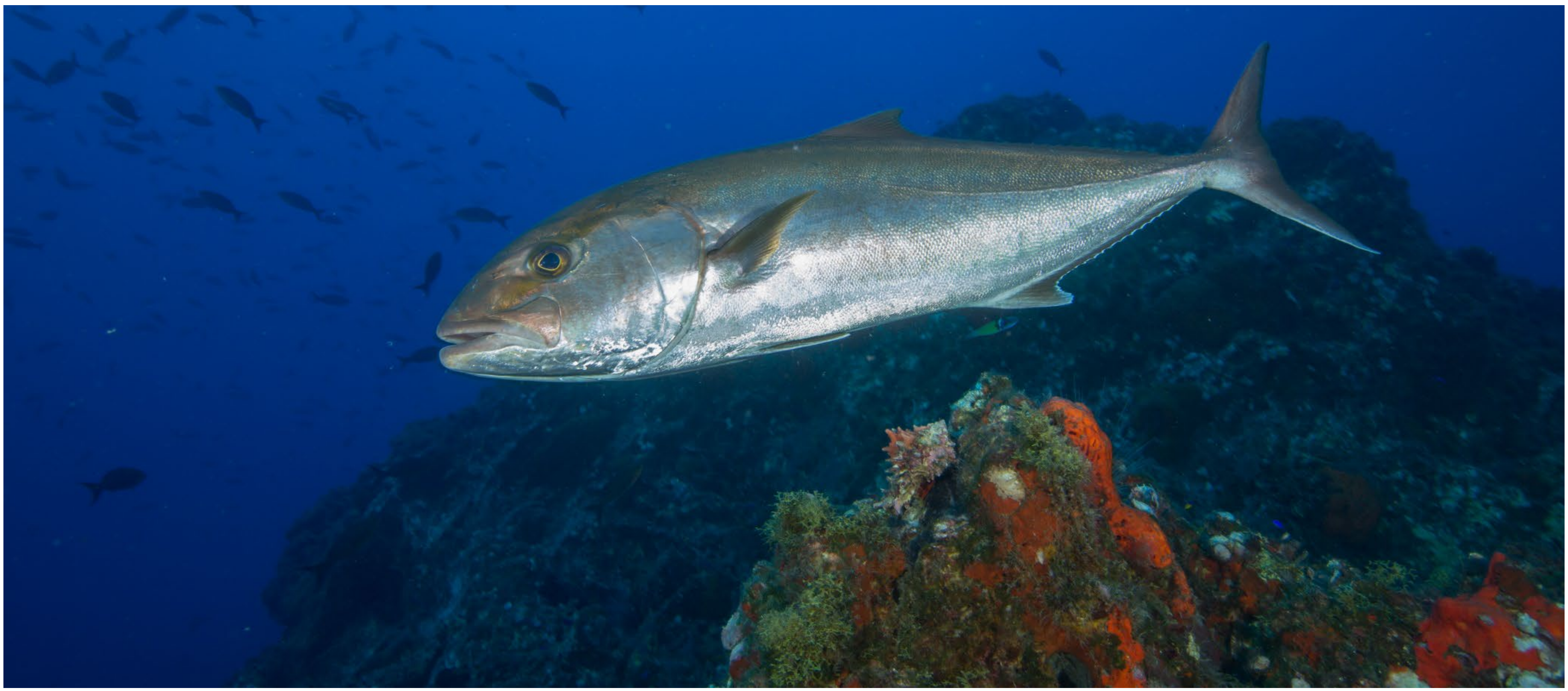


Table 3.20. Characterization summary for Aquaculture Opportunity Area option C-3.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-90.08456, 28.375922
	-90.08501, 28.401598
	-90.05599, 28.401997
	-90.05555. 28.376321
Size (ac)	2,000
Closest inlet (km)	76.7
Depth (m) (minimum, mean, maximum)	(59.8, 60.5, 61.4)
National Security	
Military Operating Areas (MOA)	None within reporting range
Special Use Airspace (SUA)	Overlaps SUA W59B
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	0.40
Fishing Vessels 2015 - 2019	4.60
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	7.90
Passenger Vessels 2015 - 2019	4.00
Pleasure and Sailing Vessels 2015 - 2019	0.05
Tanker Vessels 2015 - 2019	0.00
Tug and Tow Vessels 2015 - 2019	0.60
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	6.65
Surface Current Speed % > 1.0 m/s (%)	0.09
Significant Wave Height % > 1.75 m (%)	15.8

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	None within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	11
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlaps species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	2
Oil and Gas Boreholes	13
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	3
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.65
Salinity (PSU) at 5-m depth (mean)	32.72
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(1.11, 0.33, 4.27)
Mean Aragonite Saturation State (Ω)	3.59
Governance	
Agency boundary (USACE Districts)	New Orleans District
Agency boundary (USCG Sectors)	Sector New Orleans; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Central Gulf of Mexico

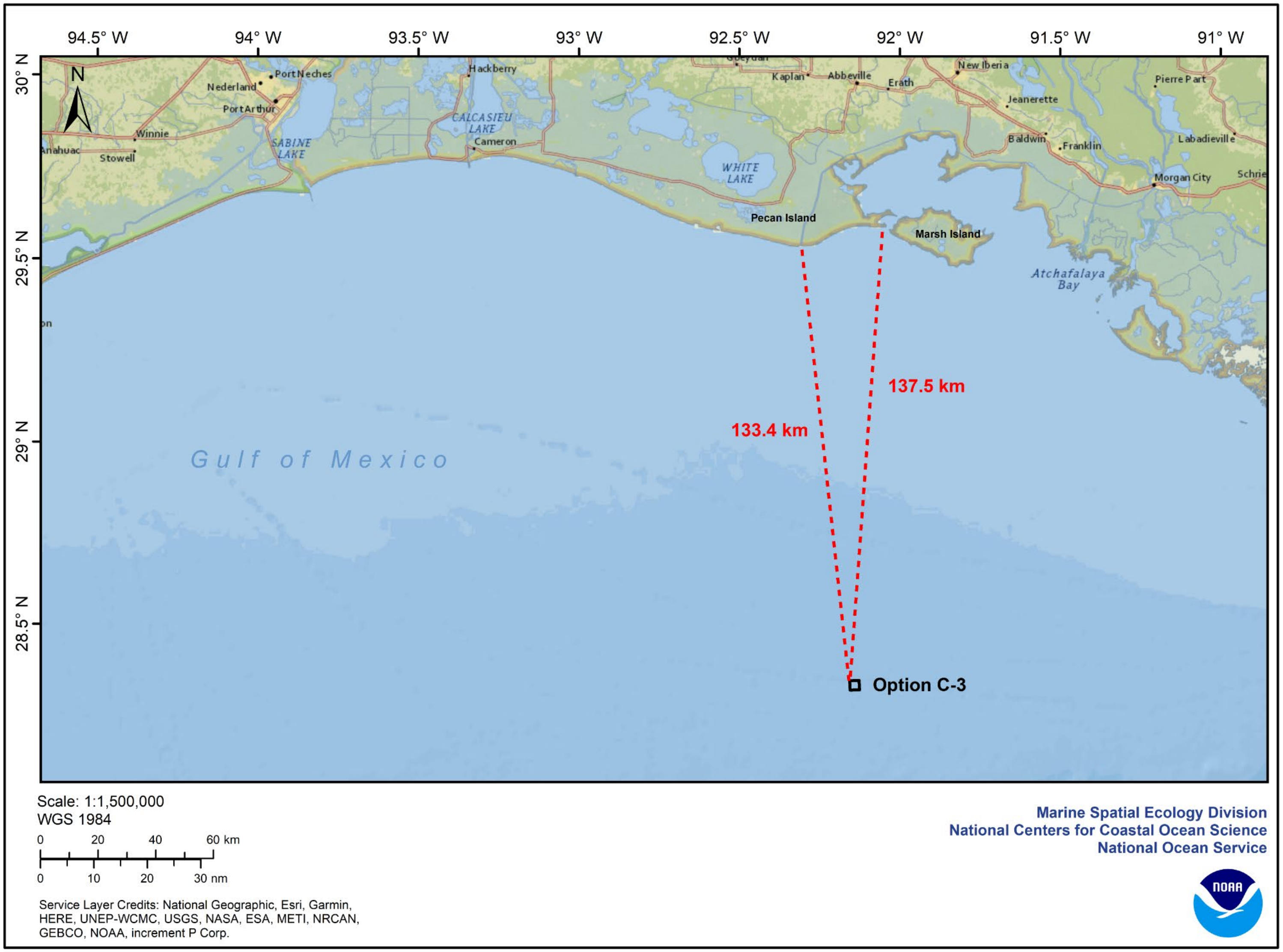
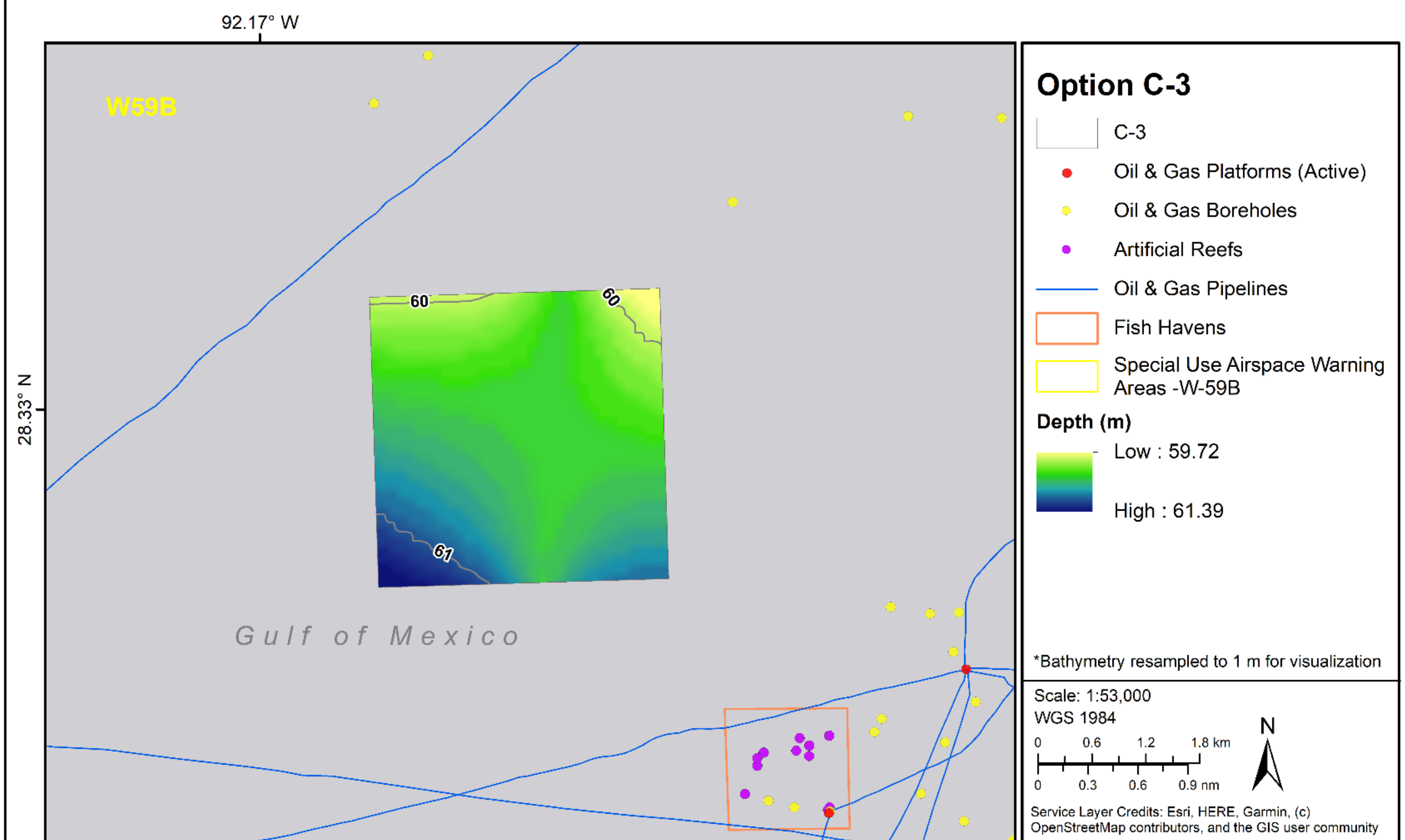


Figure 3.67. Option C-3 (black outlined box) and distance to the closest inlet from the closest corner point of C-3; the area includes Pecan Island and Marsh Island, Lousiana. Morgan City is to the east of Marsh Island.



Special use Airspace Warning Areas: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Artificial Reefs: NOAA OCM and BOEM (2018)
Fish Havens: NOAA Eletronic Navigation Chart (2019)
Oil & Gas Platforms: Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement (2021)
Oil & Gas Boreholes: Bureau of Safety and Environmental Enforcement (2021)
Oil & Gas Pipelines: Bureau of Safety and Environmental Enforcement (2021)
Bathy Coastal Relief Model Vol. 4 Central Gulf of Mexico: NOAA National Geophysical Data Center (2001), 3 arc-seconds

The map depicts area within the reporting range (3 km), and represents all submodel constraints for C-3.

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

Figure 3.68. Map depicting noteworthy characterization features for Aquaculture Opportunity Area option C-3.

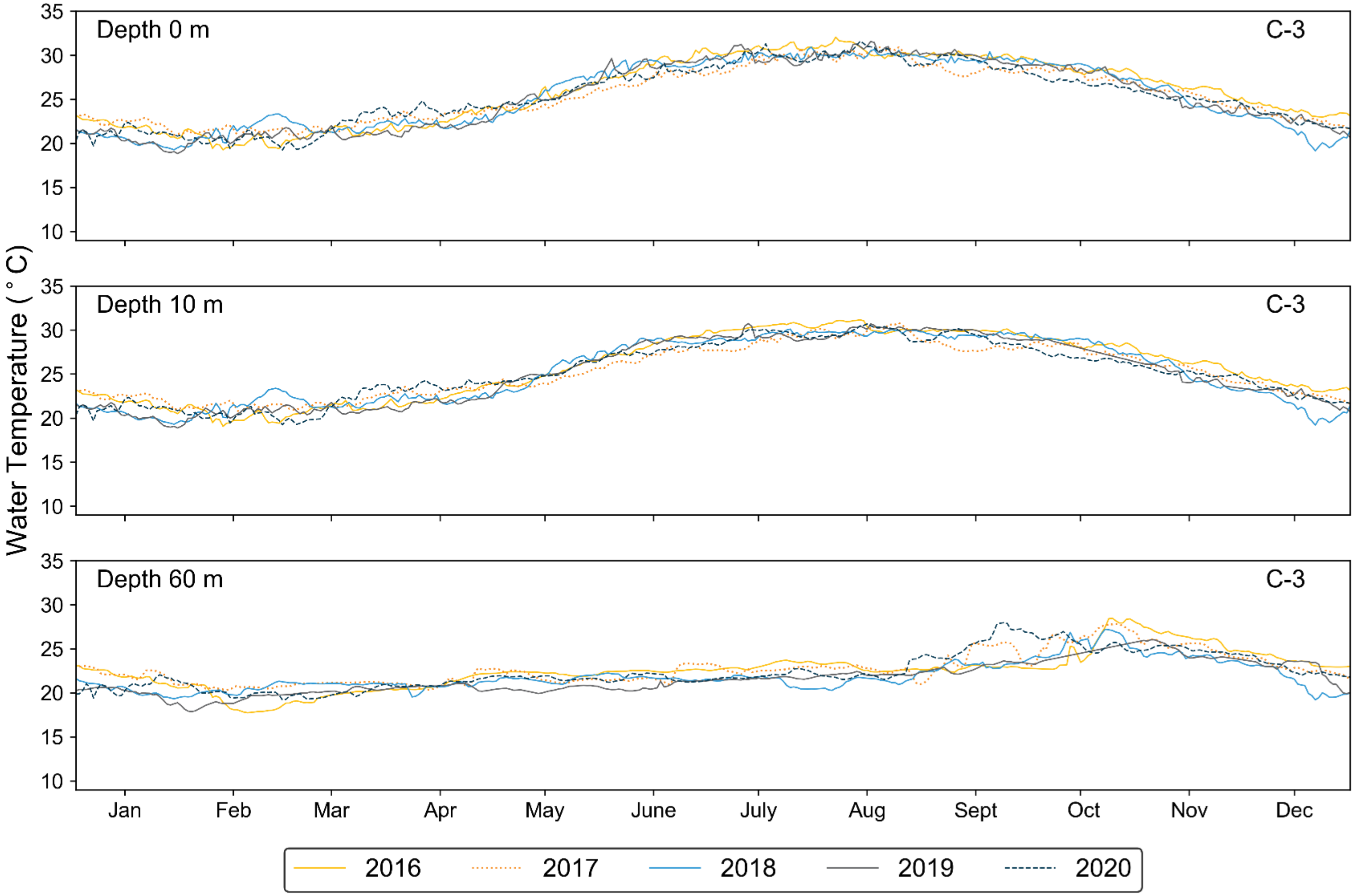


Figure 3.69. Option C-3 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 60-m depth (2016 - 2020).

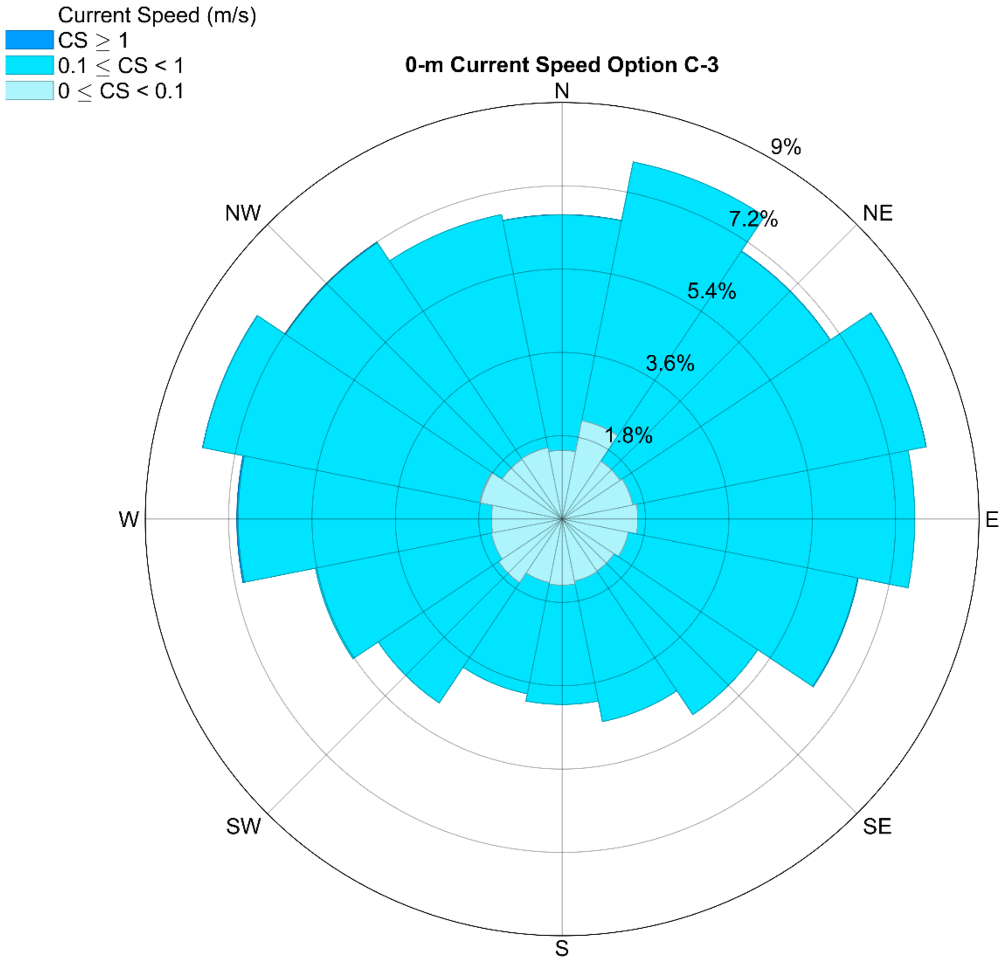


Figure 3.70. Ocean current magnitude and direction for option C-3 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

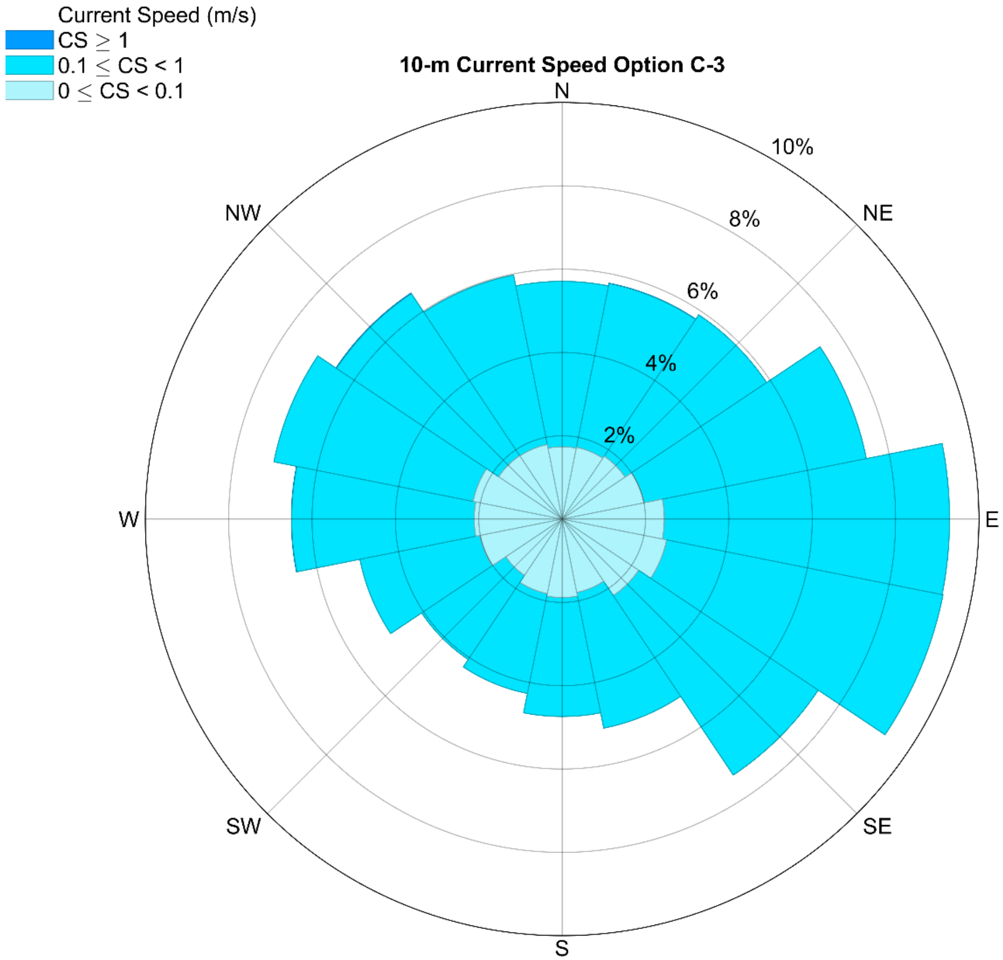


Figure 3.71. Ocean current magnitude and direction for option C-3 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

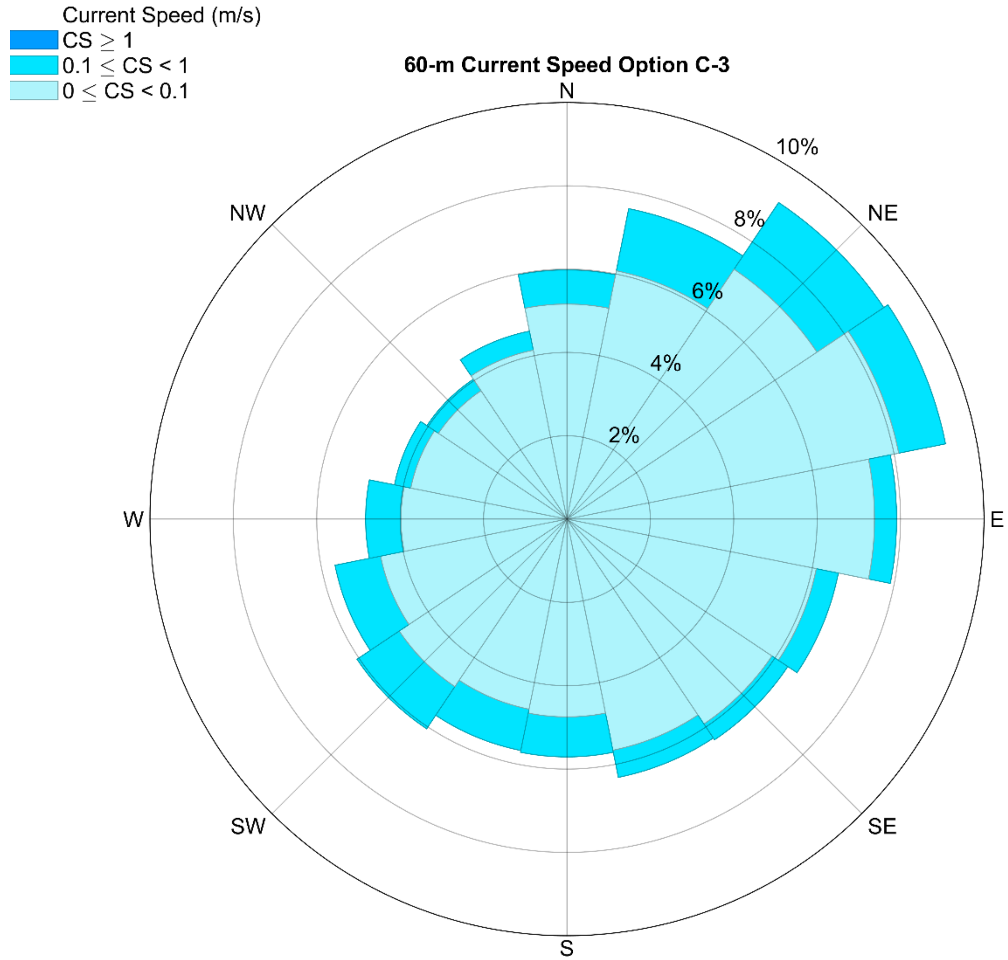


Figure 3.72. Ocean current magnitude and direction for option C-3 at 60-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

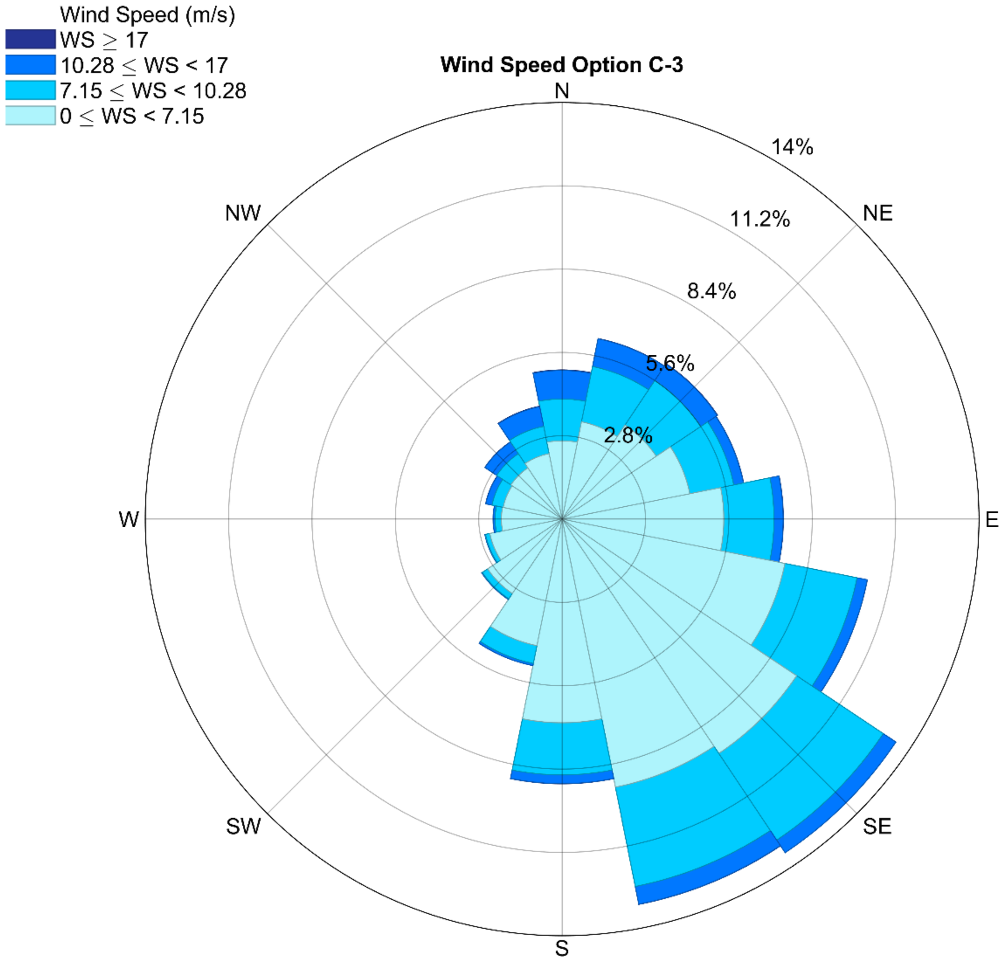


Figure 3.73. Wind velocity and direction at 10-m above sea level for option C-3. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

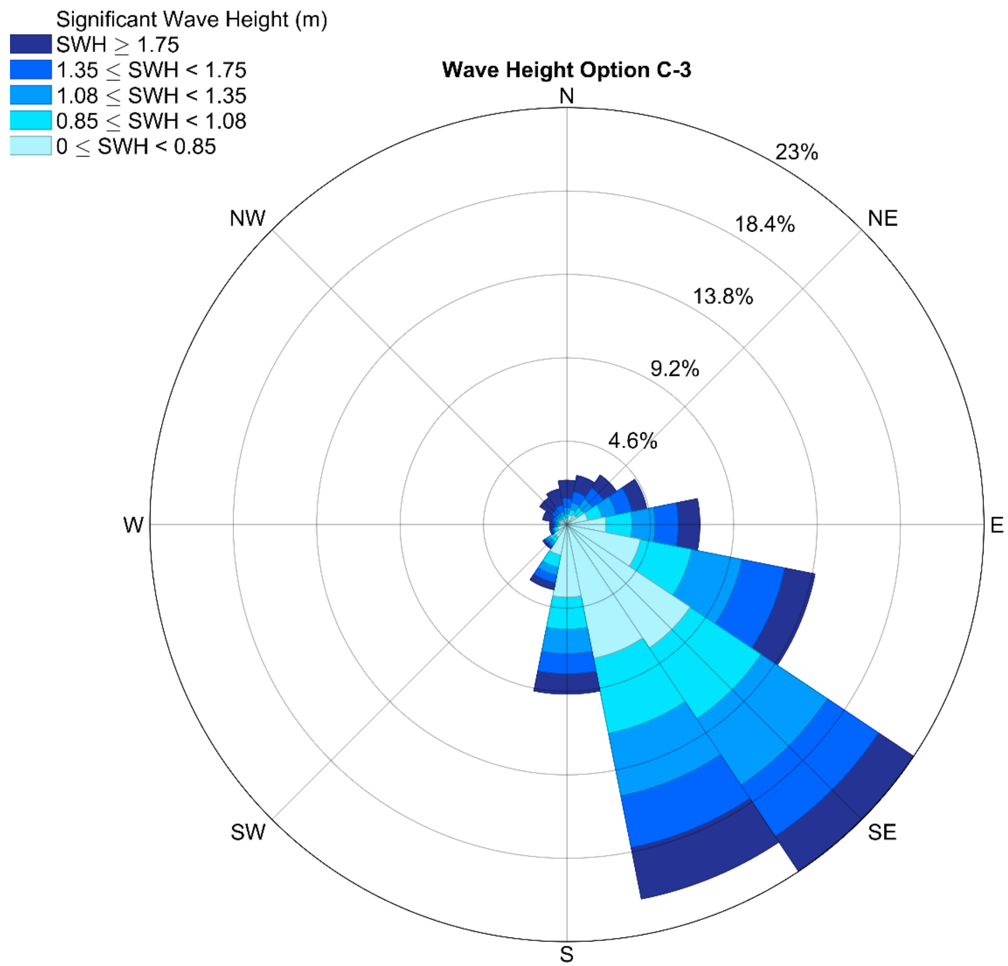


Figure 3.74. Significant wave height and direction at 10-m for option C-3. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

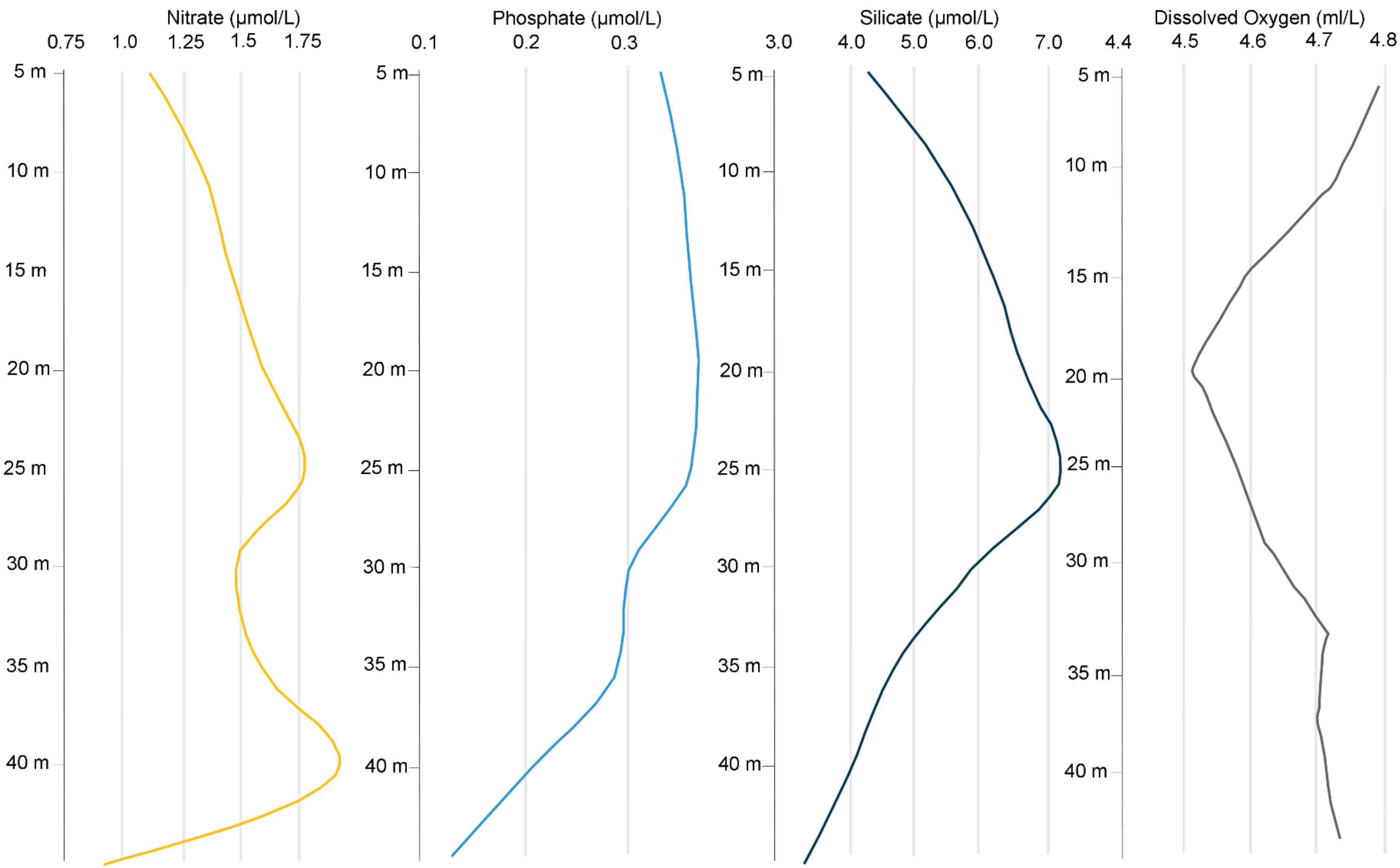


Figure 3.75. Option C-3 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels from the Ecological Marine Units (Sayre et al. 2017).

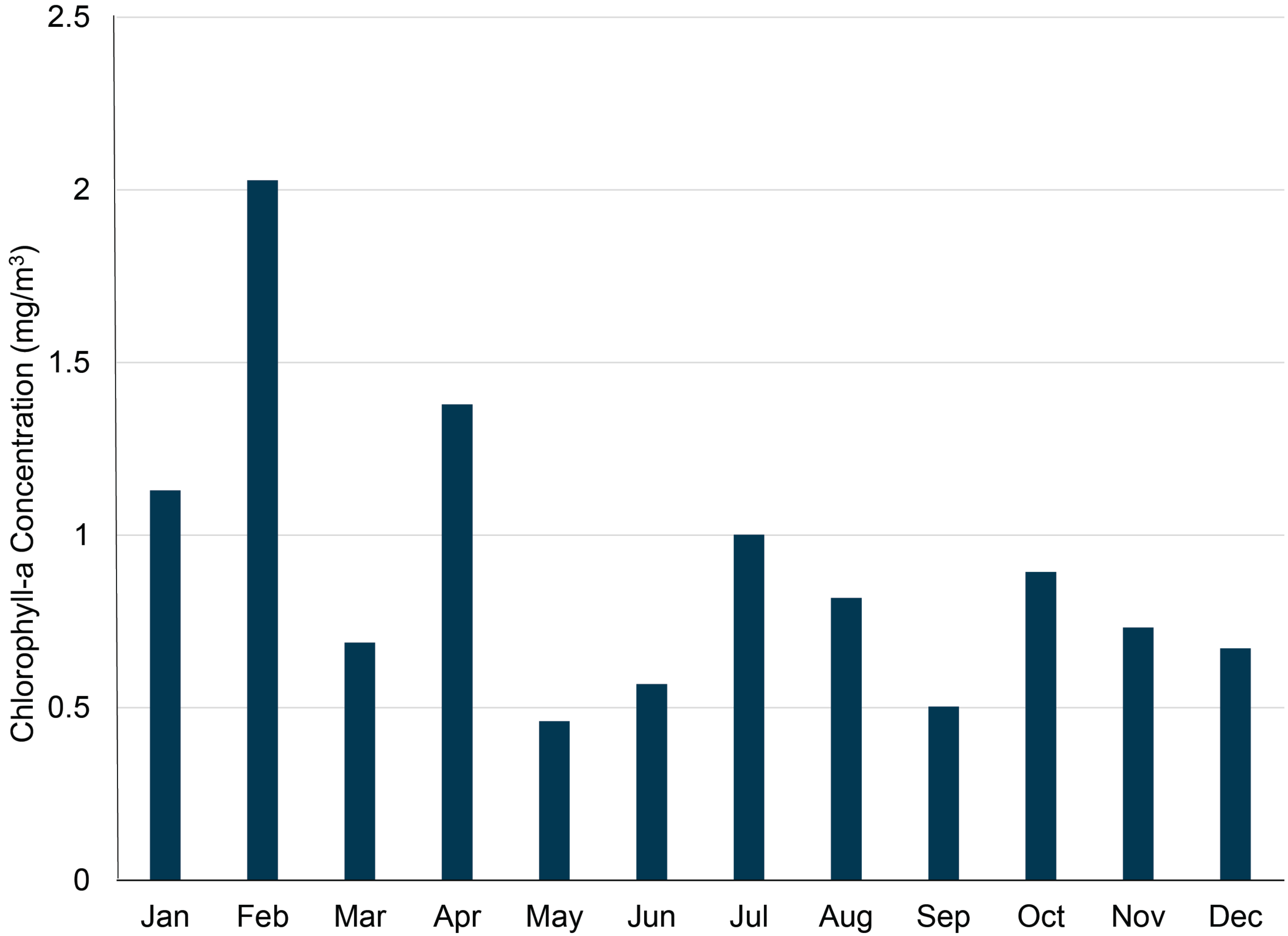


Figure 3.76. Option C-3 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m³) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

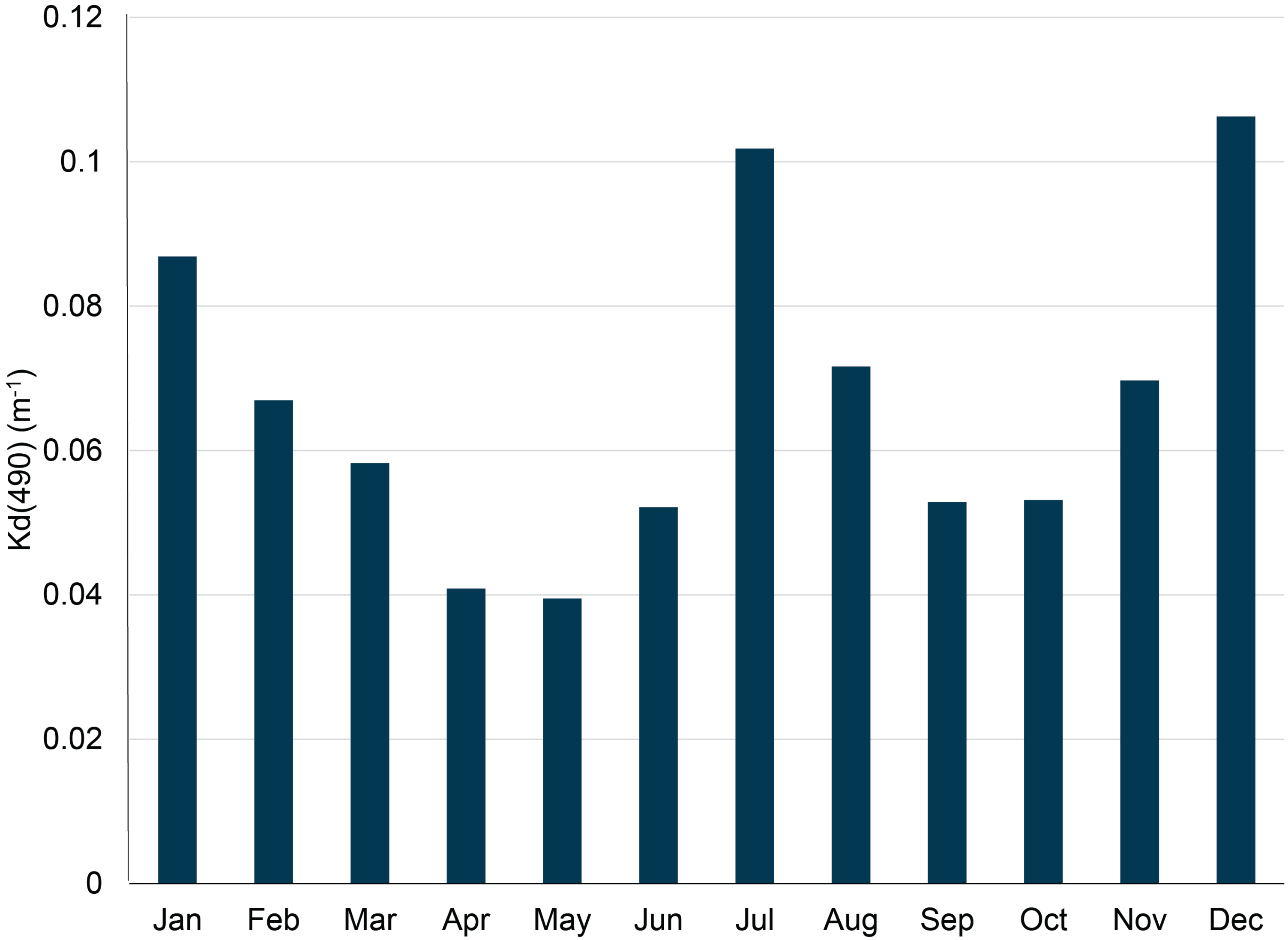


Figure 3.77. Option C-3 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

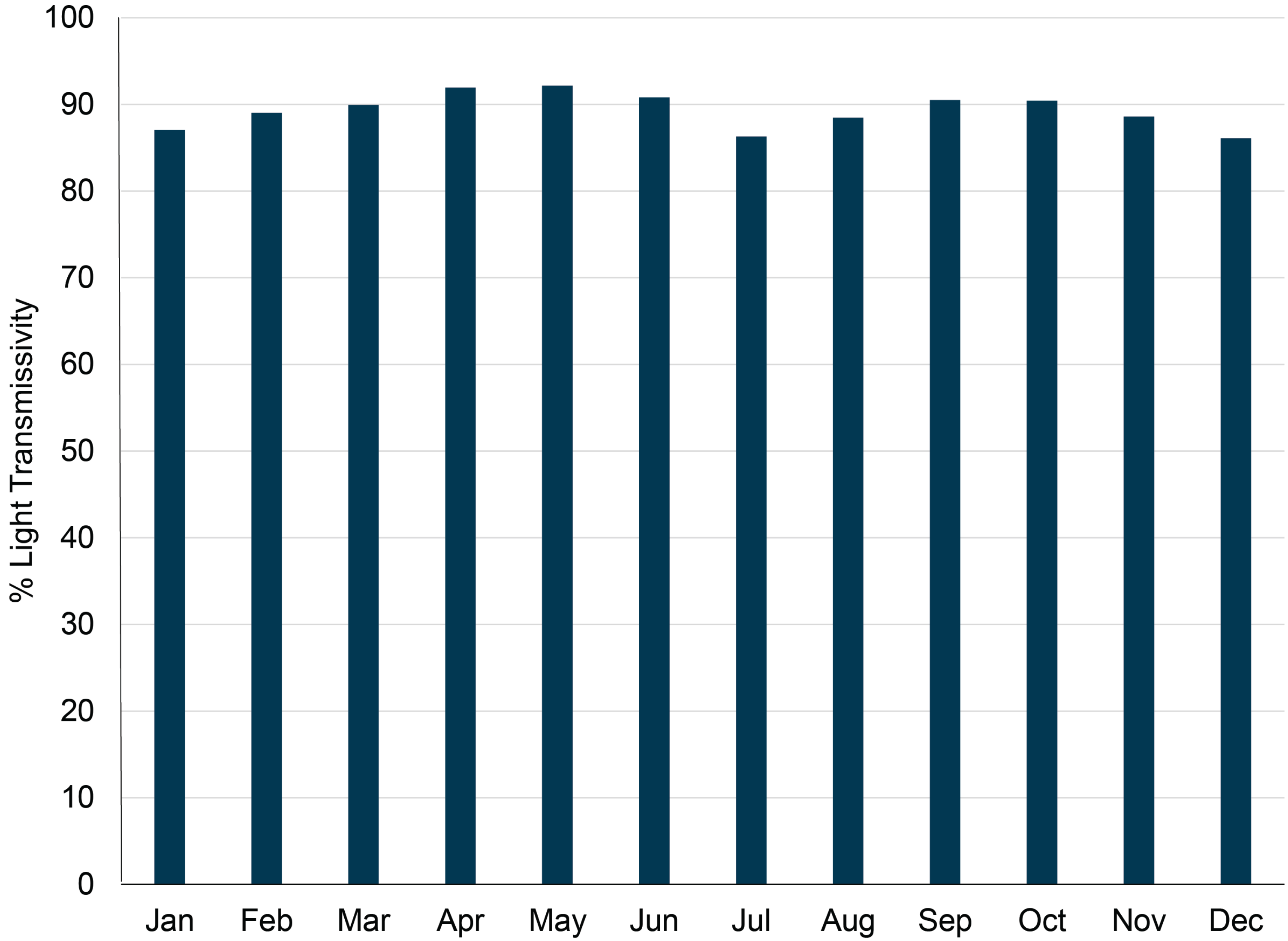


Figure 3.78. Option C-3 monthly climatological mean (2010 - 2017) for Kd(PAR) at the sea surface produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.21. Option C-3 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits all years (2,000 ac)
C-3	Cargo	0.50	0	0	0	1.50	1.00	12.00
C-3	Fishing	0	0.25	2.75	3.25	16.75	27.75	203.00
C-3	Other	4.00	5.00	13.25	11.00	6.25	7.25	187.00
C-3	Passenger	6.50	2.25	2.25	2.00	7.00	7.50	110.00
C-3	Pleasure and Sailing	0	0	0	0	0.25	0	1.00
C-3	Tanker	0	0	0	0	0	0	0
C-3	Tug and Tow	0.75	0.50	0.25	0.50	1.00	1.25	17.00
*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.								

Table 3.22. Number of individual Automatic Identification System-equipped vessels that transited through option C-3.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
C-3	Cargo	2	0	0	0	1	1
C-3	Fishing	0	1	4	2	15	27
C-3	Other	11	12	15	13	13	12
C-3	Passenger	8	8	6	5	9	13
C-3	Pleasure and Sailing	0	0	0	0	1	0
C-3	Tanker	0	0	0	0	0	0
C-3	Tug and Tow	2	2	1	2	3	5

AOA Option C-11 Characterization

Option C-11 was the highest scoring of the three options in the Central study area based on the among-cluster analysis results (Table 3.8). Option C-11's final logistics score was moderate relative to other Central study area options. C-11 has relatively low mean AIS vessel traffic (2015 - 2019) and low fishing effort spatially and temporally within the time periods assessed.

General Characteristics

AOA option C-11 is a 2,000-ac option located in the federal waters south of the Louisiana coastline (Table 3.23). Port Fourchon (76.7 km) and the Boothville-Venice area via the South Pass inlet (86 km) are two of the closest coastal communities to option C-11 (Figure 3.79). It falls under Louisiana Congressional District 01, State Senate District 20, and House District 54. There are 13 federal statutes applicable to all the options identified, including option C-11 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option C-11 are (-92.1548, 28.31758), (-92.1557, 28.34325), (-92.12671, 28.34405), (-92.12581, 28.31838). Option C-11 is in the GMFMC, USACE New Orleans District, USCG New Orleans Sector (District 8), USEPA Region 6, USFWS Southeast Region, and BOEM Central Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 2,000-ac area is 82.3 m, with a maximum depth of 87.8 m and a minimum depth of 76.4 m (Figure 3.80). No recent high-resolution bathymetric survey data are currently available for C-11. Based on available data, the largest differential in depth is 11.3 m. Shallower areas are found in the northwest corner of C-11, while deeper waters are observed in the southeast (Figure 3.80). Percent slope over the area is 0.28%. The mean slope across the area is 0.18 degrees with a maximum of 0.31 degrees.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[35] the sediment of C-11 is composed of over 99% sandy or mud-like substrate. The western side of C-11 has a sandier bottom type relative to the center and eastern portion of the option, where the sediment composition becomes more mud-like. The predicted surficial sediment Phi values ranged from 4.0 to 4.7, which indicate sediment with a diameter of coarse silt (diameter = 0.0625 to 0.03125).

[35] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

Water Temperature and Salinity

Seasonally the mean daily surface water temperature at option C-11 was lowest from December through April, at which point it increased and remained above 25°C until the end of October, when it began to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 16.95°C, while the maximum was 32.1°C. The water temperature at 10-m depth was slightly warmer than the surface water temperature, with a minimum daily mean value of 18.26°C and a maximum value of 31.0°C. The water temperature near the bottom of option C-11 was more consistent year-round, with some slight increases from September to December, with a minimum temperature of 18.0°C and a maximum temperature of 27.4°C (Figure 3.81). Mean daily salinity concentration between 2016 and 2020 at option C-11 was consistent throughout the year, with the exception being between April and May of 2016, when salinity dropped below 25 PSU for a short time, likely a result of freshwater outflow from the Mississippi River.

Metocean Characteristics

Ocean current speeds at option C-11 rarely exceed 1.0 m/s at all depths examined (Figures 3.82 - 3.84). The currents at the surface and at 10-m depth predominantly move toward the northeast, while currents at the bottom depth generally move in a northeast to southwest direction (Figures 3.82 and 3.84). Wind direction at option C-11 predominantly is from the southeast, and only 5.73% of the time is the wind speed greater than 10.28 m/s (Figure 3.85). Ocean waves observed at option C-11 predominantly originate from the south-southeast (Figure 3.86).

Water Quality Considerations

To evaluate water quality at option C-11, nutrient concentrations (nitrate, phosphate, silicate), dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels from the surface to 5-m depth for nitrate, phosphate, and silicate were 4.22 µmol/L, 0.45 µmol/L, and 8.59 µmol/L, respectively (Figure 3.87). At 45-m depth, nitrate concentration decreased to 1.74 µmol/L, phosphate increased to 0.20 µmol/L, and silicate concentration decreased (3.42 µmol/L) (Figure 3.87). Around 85 m (i.e., bottom water), nitrate concentration increased even more (4.96 µmol/L), phosphate increased (0.30 µmol/L) and silicate concentration decreased to 2.98 µmol/L. Dissolved oxygen concentrations were lowest in the deepest waters of option C-11 (4.1 ml/L) and highest at the surface (5.0 ml/L) (Figure 3.87). Chlorophyll-*a* concentration, a common approximation for phytoplankton in the ocean, was highest in late winter at option C-11 in February (2.0 mg/m^3). The remainder of the year, concentrations remained above 0.6 mg/m^3 and 1 mg/m^3 (Figure 3.88). The diffuse light attenuation coefficient at 490 nm for option C-11 was lowest in September and November (0.06 to 0.07 m^{-1}) and highest in April (0.19 m^{-1}) (Figure 3.89). Percent light transmissivity at 1-m depth was relatively constant throughout the year, ranging from 82% to 89% transmissivity (Figure 3.90).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. Option C-11 is outside of all Gulf of Mexico-based MOAs and known SUAs and does not overlap areas marked as danger zones or restricted areas (Table 3.23).

Natural and Cultural Resource Considerations

Option C-11 does not overlap or intersect deep-sea coral observations (1985 - present), fish havens, artificial reefs, or sensitive habitats (including HAPCs) and none are within a 3-km vicinity. AOA option C-11 overlaps the giant manta ray distribution model, particularly the areas above the median maximum predicted value to provide conservation measures for the species (Table 3.23). Although option C-11 does not overlap with any sea turtle HUAs for residence or migratory areas, loggerhead, Kemp's ridley, leatherback, or green sea turtles may still be within range of option C-11 (see Appendix B for details). C-11 does overlap the loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat area (*Sargassum*), but no other critical habitat. Essential Fish Habitat designated by the GMFMC and NMFS for option C-11 includes shrimp, reef fish, coastal migratory pelagic species, and 20 highly migratory species (Table 3.40).

Industry, Navigation, and Transportation Considerations

Option C-11 is in the Central Gulf of Mexico BOEM Offshore Oil and Gas Planning Area where significant oil and gas energy sector infrastructure exists. While there is no overlap of oil and gas infrastructure with C-11, there is some within the vicinity. There are three active BOEM oil and gas lease blocks that are between one and two kilometers away from option C-11 on the east, south, and west sides. Four oil and gas pipelines are within three km to the north of option C-11. There are 42 boreholes within three km of the north and east sides of option C-11 (Figure 3.80). Three oil and gas platforms are located between 1.5 km to the north of C-11, and another is about 3 km away from the option. All navigational infrastructure was avoided within option C-11. One aid to navigation marker is located 2.8 km northwest of the option. AIS vessel traffic from 2015 to 2020 within option C-11 indicates the lowest vessel traffic by type were pleasure and sailing (n = 2) and cargo vessels (n = 11). Other (n = 490), fishing vessels (n = 268), and passenger vessels (n = 204) were the highest vessel type traffic intersecting option C-11 over the six years examined (Tables 3.24, 3.25).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate option C-11 overlaps a moderate amount of shrimp trawling over the 15 years of data assessed. Additionally, a low amount of bandit reef fishing occurred in C-11 between 2007 and 2019. There was no longline reef fishing observed in option C-11 between 2007 and 2019.

Table 3.23. Characterization summary for Aquaculture Opportunity Area option C-11.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-92.1548, 28.31758
	-92.1557, 28.34325
	-92.12671, 28.34405
	-92.12581, 28.31838
Size (ac)	2,000
Closest inlet (km)	133.4
Depth (m) (minimum, mean, maximum)	(76.4, 82.3, 87.8)
National Security	
Military Operating Areas (MOA)	None within range
Special Use Airspace (SUA)	None within range
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	0.30
Fishing Vessels 2015 - 2019	9.30
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	17.90
Passenger Vessels 2015 - 2019	5.55
Pleasure and Sailing Vessels 2015 - 2019	0.05
Tanker Vessels 2015 - 2019	2.65
Tug and Tow Vessels 2015 - 2019	0.75
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	5.73
Surface Current Speed % > 1.0 m/s (%)	0.18
Significant Wave Height % > 1.75 m (%)	13.3

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	None within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	1
Artificial Reefs	11
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlaps species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	3
Oil and Gas Boreholes	41
Oil and Gas Active Lease Blocks	3
Oil and Gas Pipelines	4
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.4
Salinity (PSU) at 5-m depth (mean)	33.3
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(4.22, 0.45, 8.59)
Mean Aragonite Saturation State (Ω)	3.58
Governance	
Agency boundary (USACE Districts)	New Orleans District
Agency boundary (USCG Sectors)	Sector New Orleans; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Central Gulf of Mexico

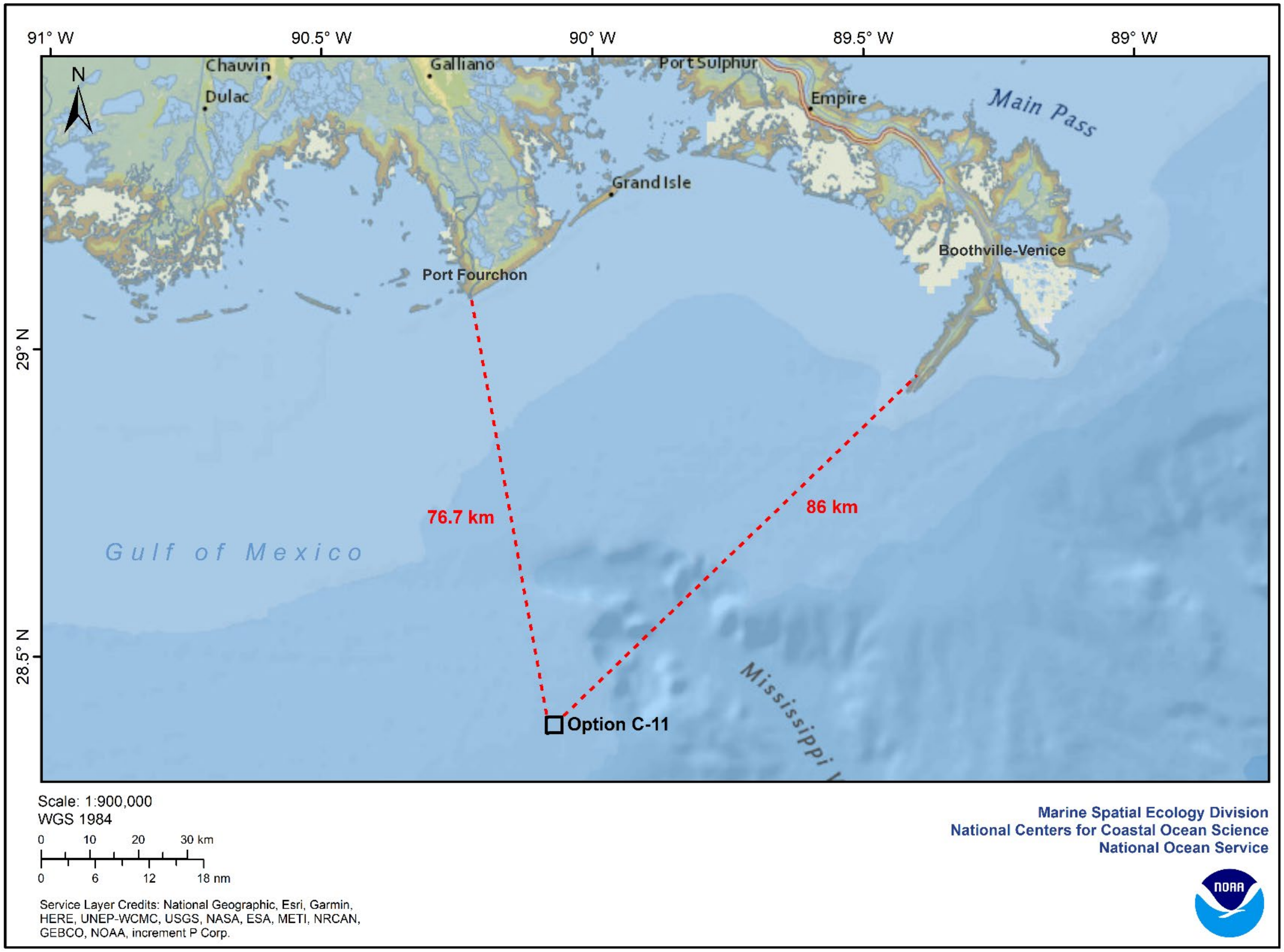


Figure 3.79. Option C-11 (black outlined box) and distance to the closest inlet from the closest corner point of C-11; the area includes Port Fourchon and Boothville-Venice, Lousiana.

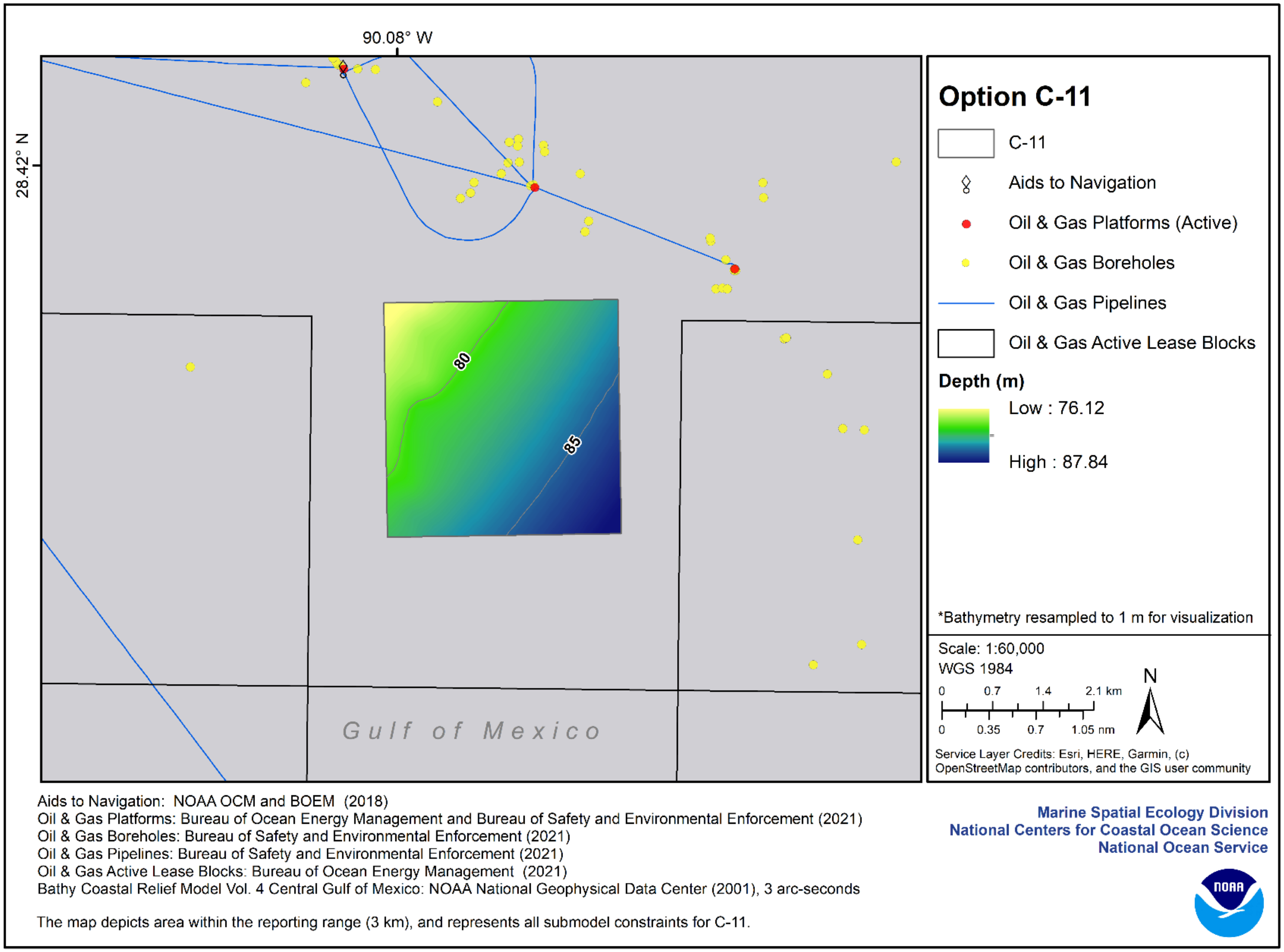


Figure 3.80. Option C-11 bathymetric constraints within the vicinity of the option.

Figure 3.81. Option C-11 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 60-m depth (2016 - 2020).

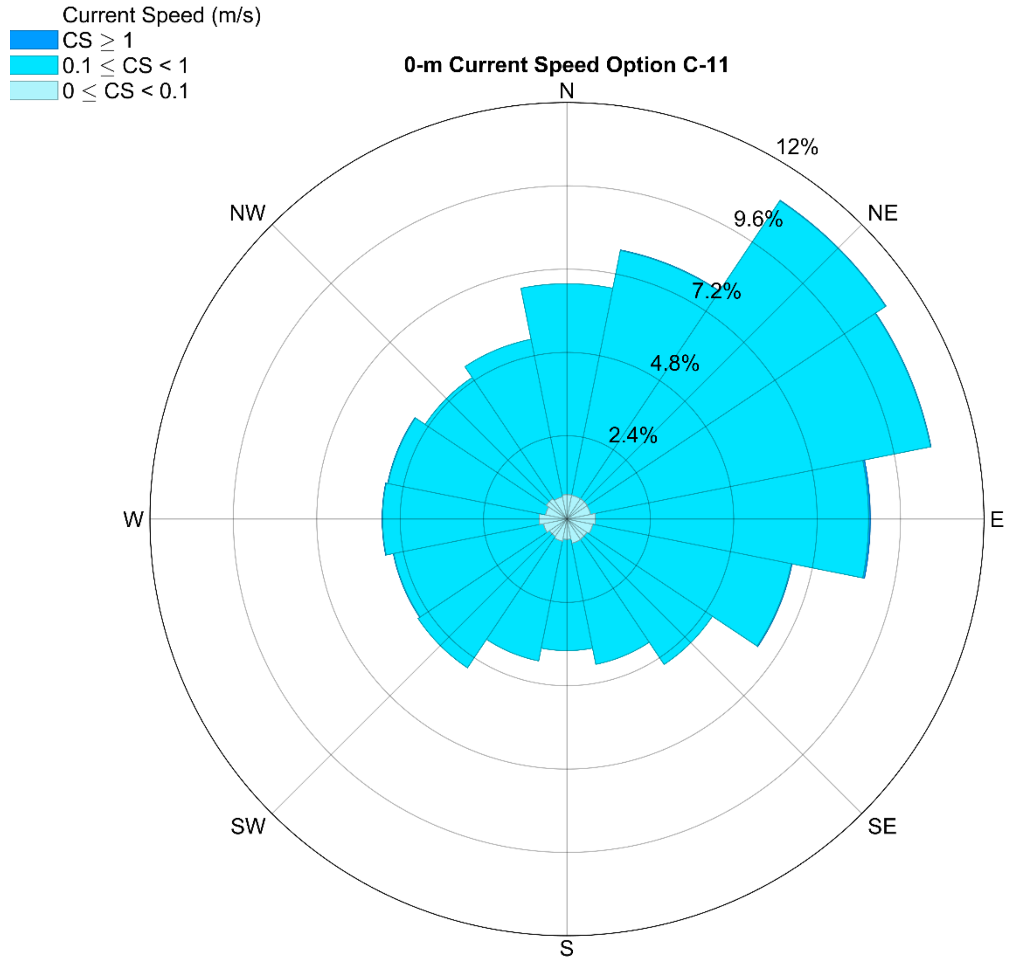


Figure 3.82. Ocean current magnitude and direction for option C-11 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

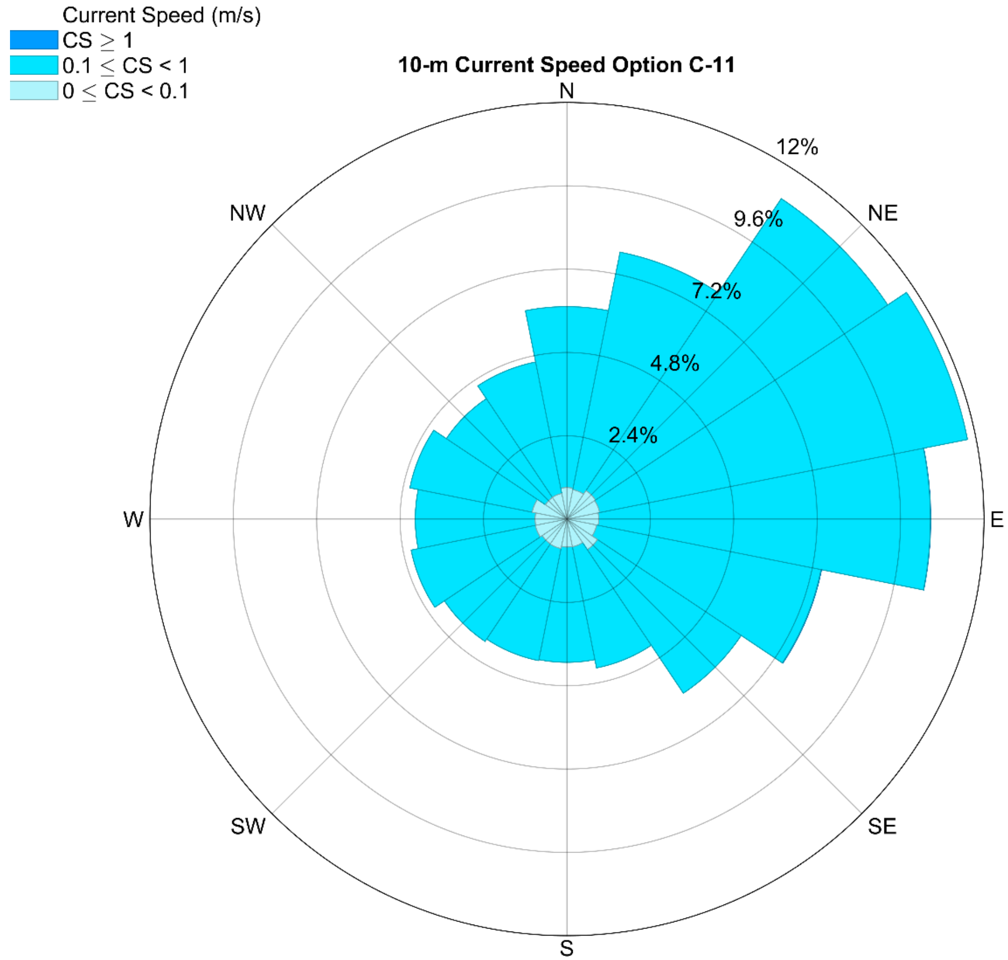


Figure 3.83. Ocean current magnitude and direction for option C-11 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

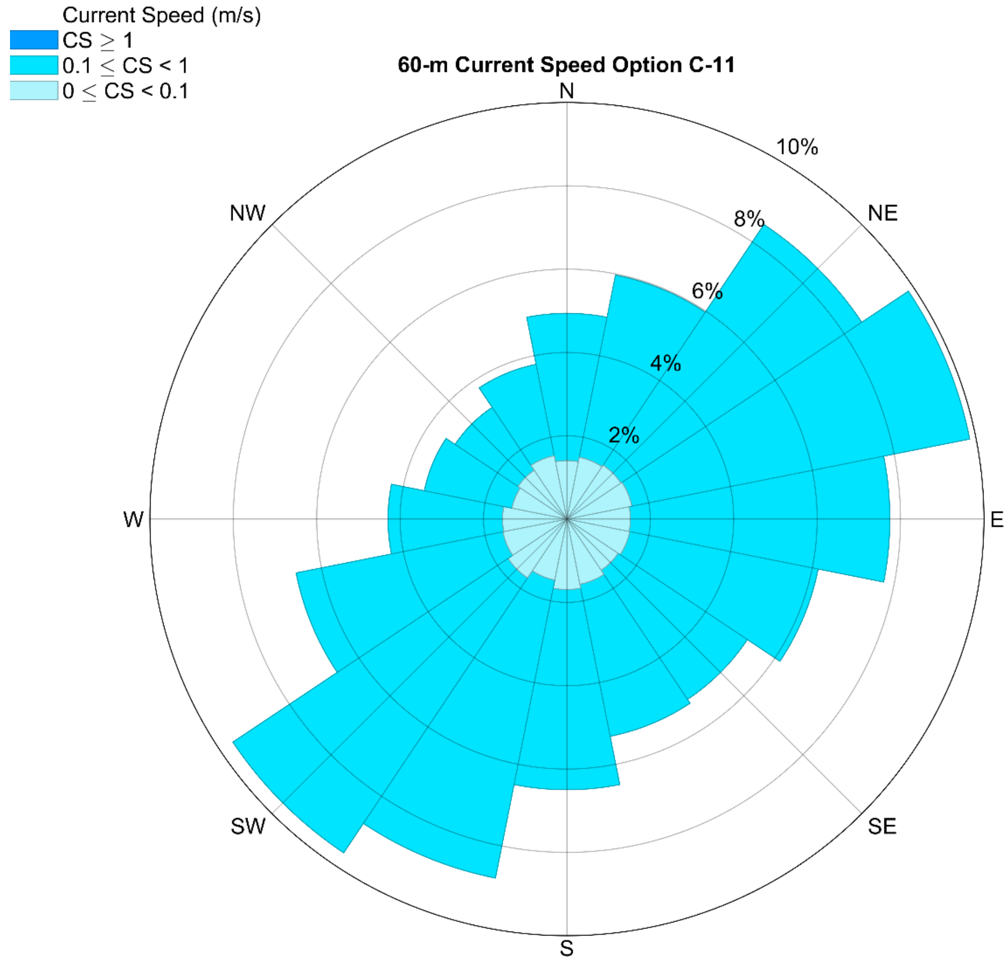


Figure 3.84. Ocean current magnitude and direction for option C-11 at 60-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

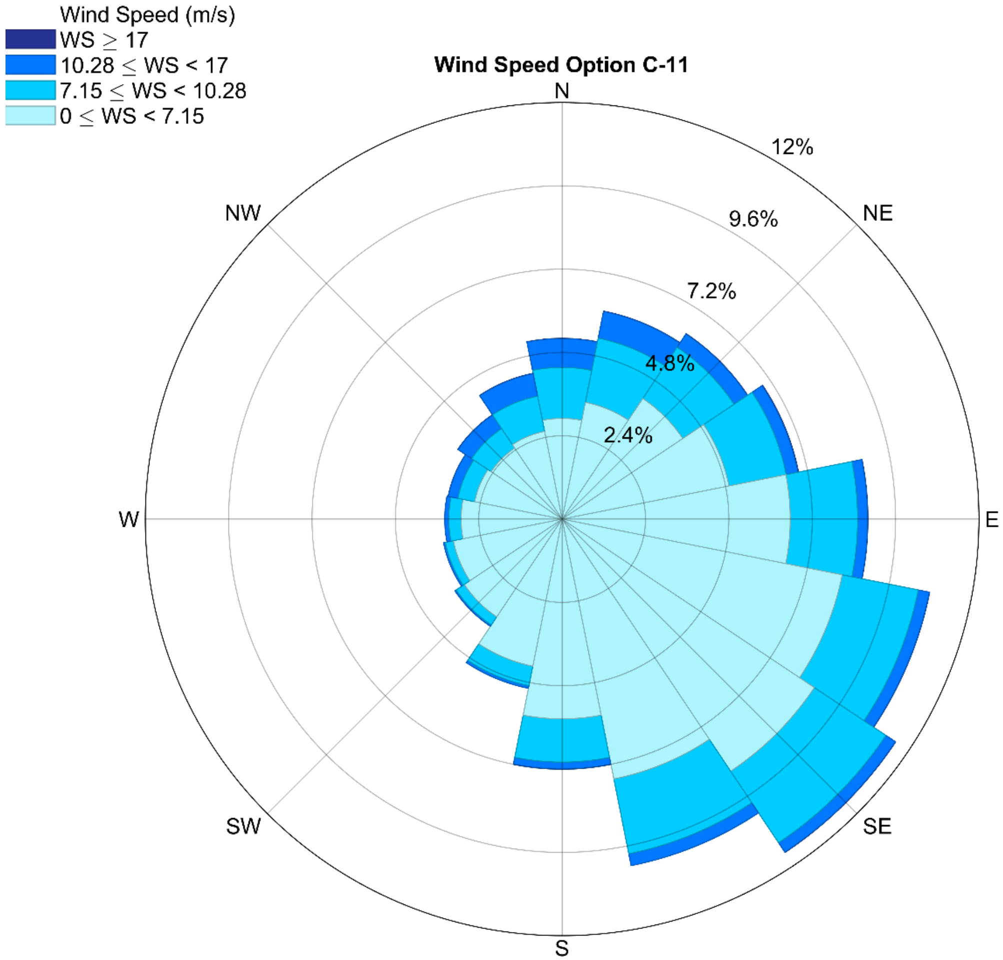


Figure 3.85. Wind velocity and direction at 10-m above sea level for option C-11. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

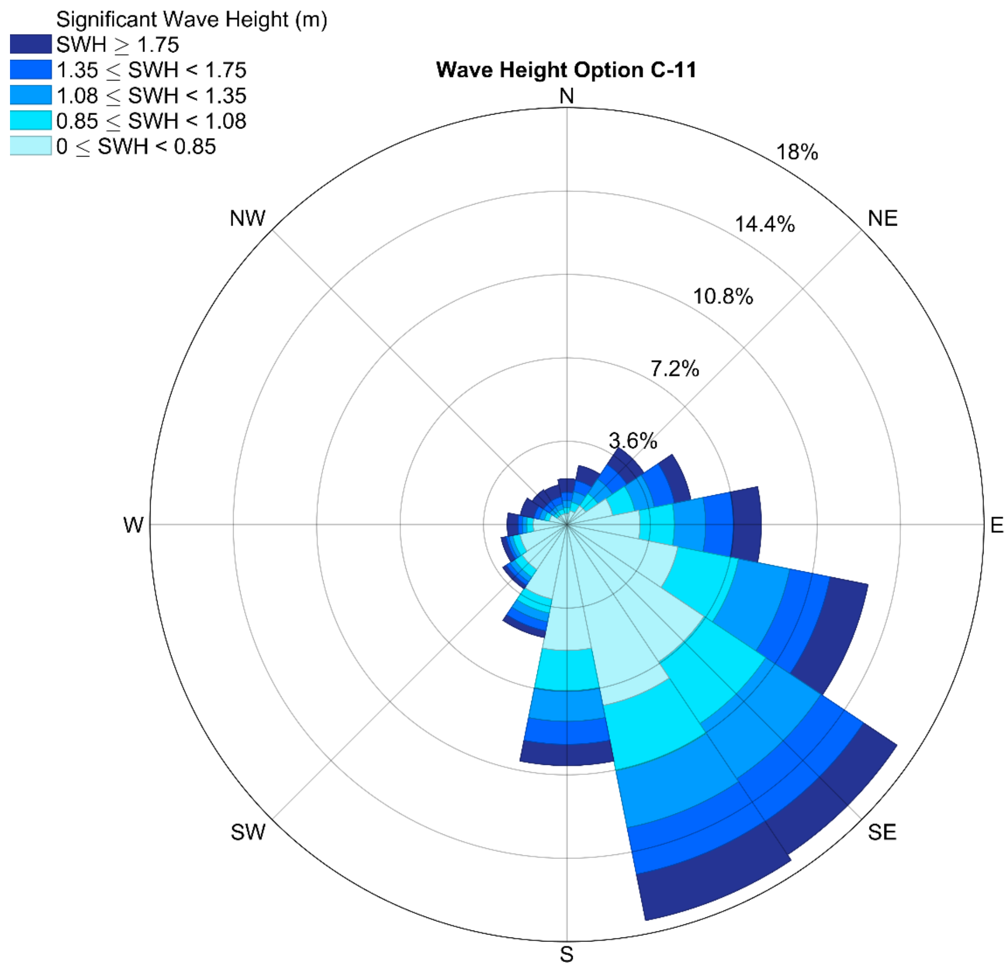


Figure 3.86. Significant wave height and direction at 10-m for option C-11. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

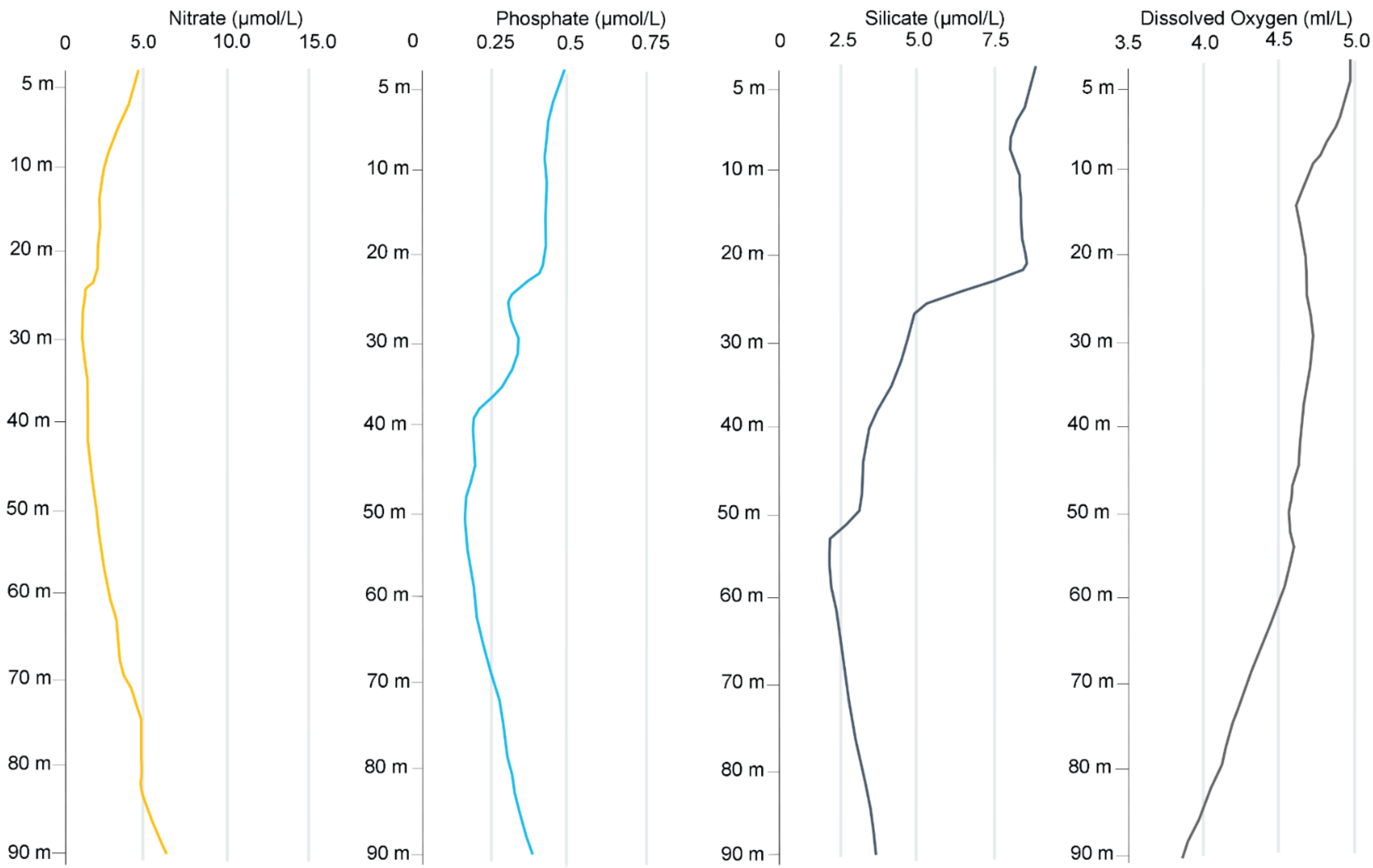


Figure 3.87. Option C-11 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels derived from the Ecological Marine Units (Sayre et al. 2017).

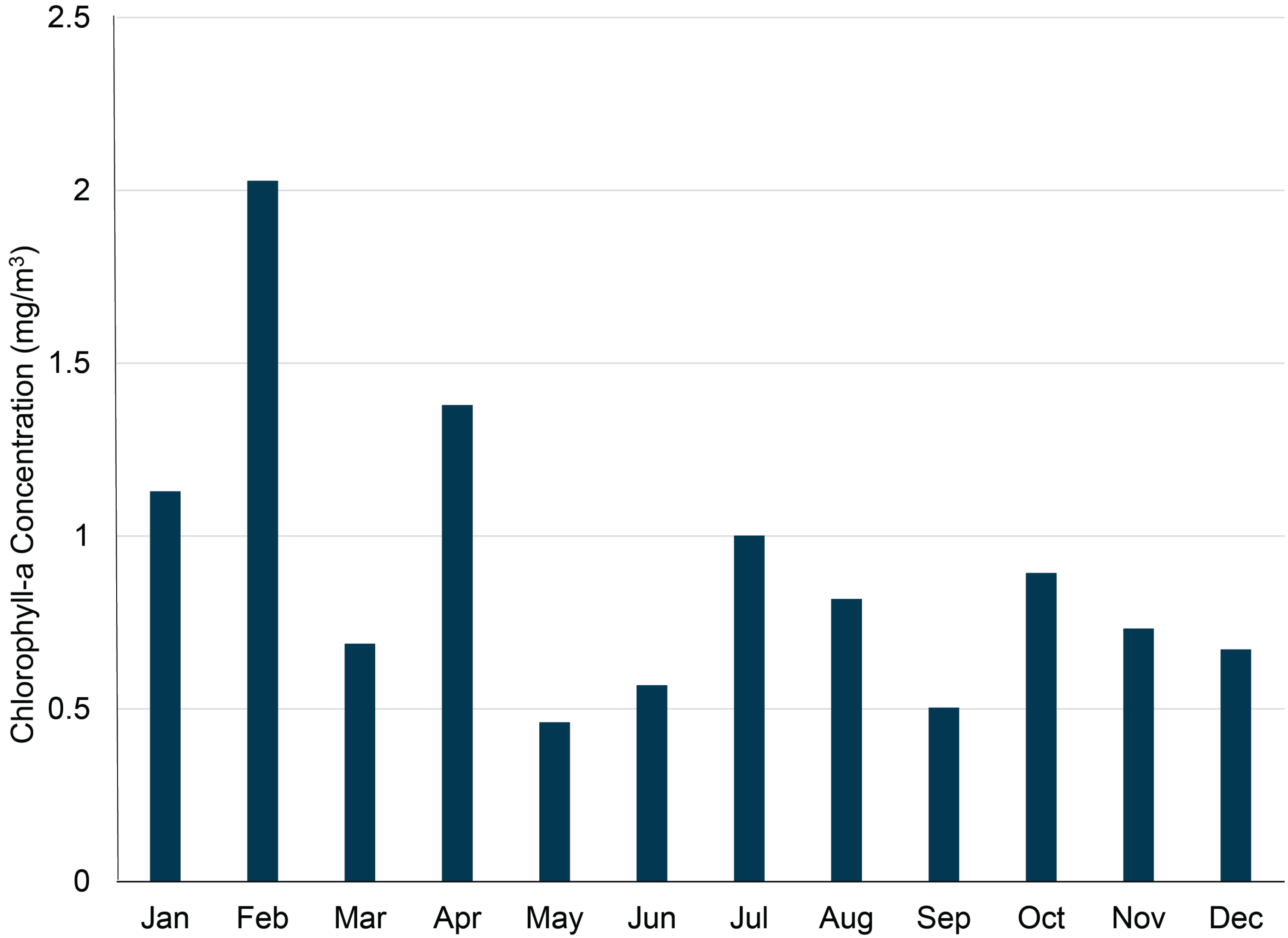


Figure 3.88. Option C-11 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

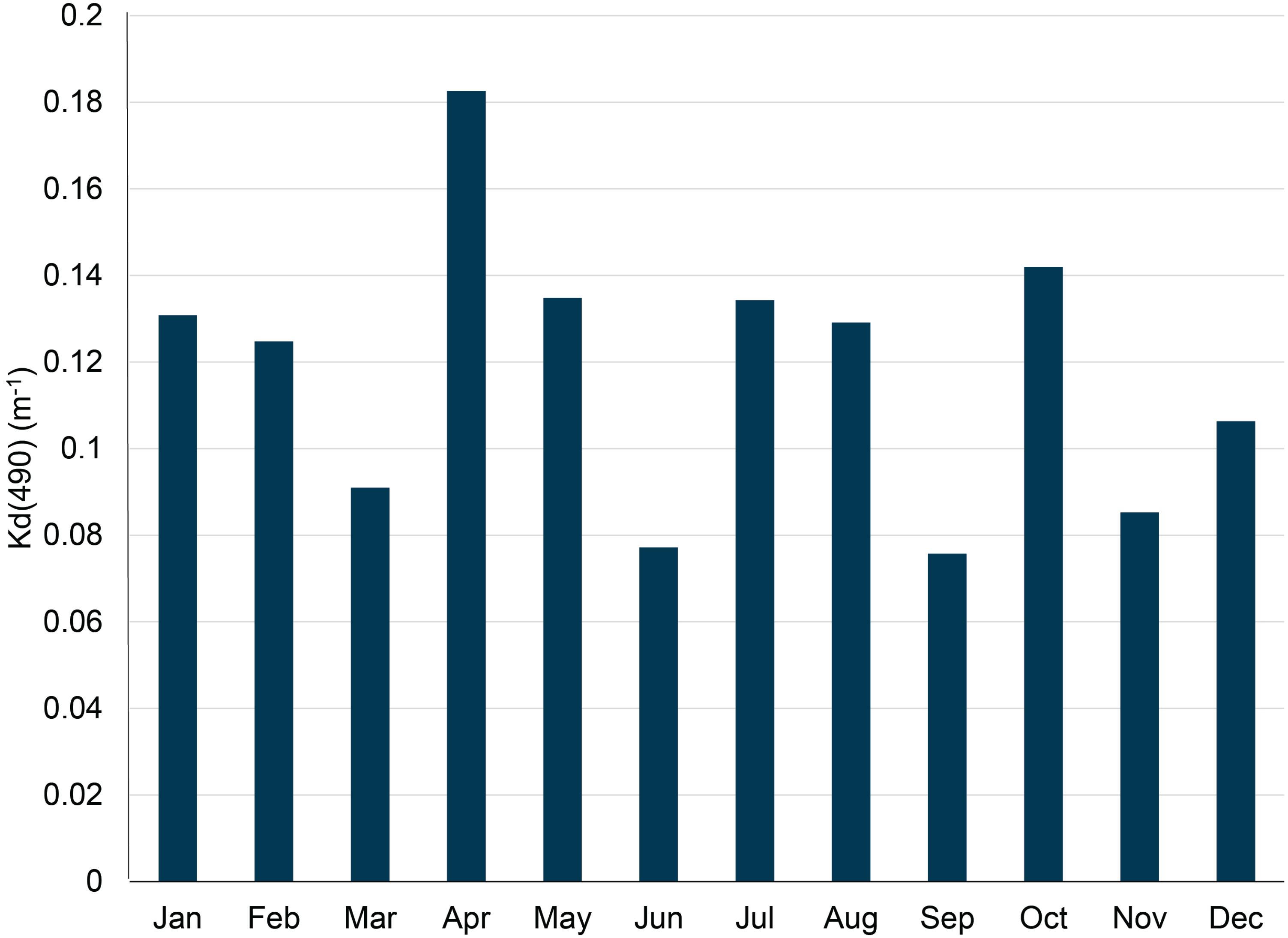


Figure 3.89. Option C-11 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

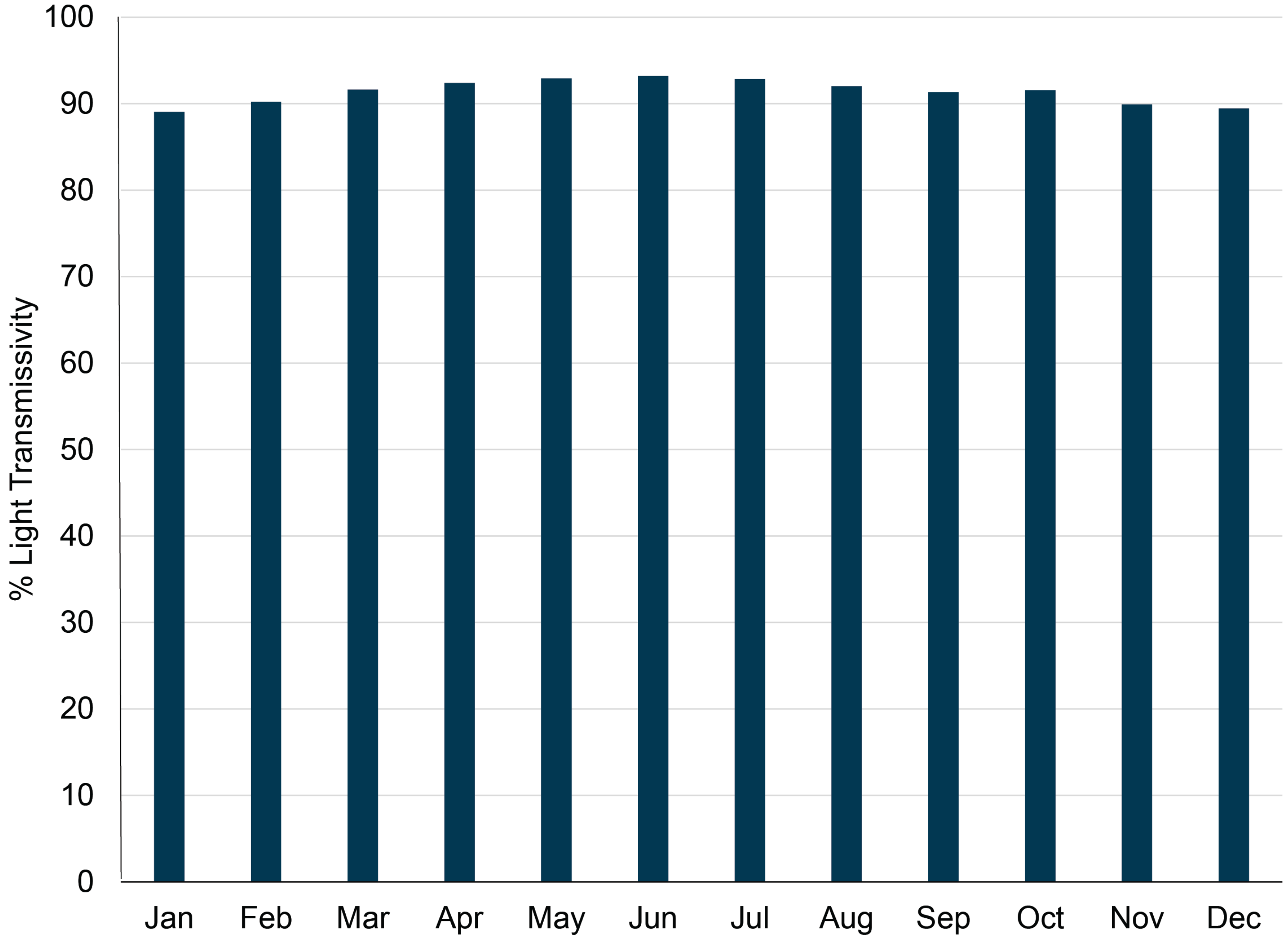


Figure 3.90. Option C-11 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.24. Option C-11 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits All Years (2,000 ac)
C-11	Cargo	0.50	0.50	0	0.25	0.25	1.25	11.00
C-11	Fishing	5.50	8.50	8.75	6.00	17.75	20.50	268.00
C-11	Other	12.50	13.00	23.50	11.75	28.75	33.00	490.00
C-11	Passenger	2.50	4.50	2.00	1.50	17.25	23.25	204.00
C-11	Pleasure and Sailing	0	0	0	0	0.25	0.25	2.00
C-11	Tanker	2.25	0.50	6.75	3.00	0.75	0.75	56.00
C-11	Tug and Tow	1.00	1.25	0	1.00	0.50	1.25	20.00

*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.

Table 3.25. Number of individual Automatic Identification System-equipped vessels that transited through option C-11.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
C-11	Cargo	2	2	0	1	1	5
C-11	Fishing	4	13	13	12	23	25
C-11	Other	31	29	40	32	41	42
C-11	Passenger	8	7	6	4	13	19
C-11	Pleasure and Sailing	0	0	0	0	1	1
C-11	Tanker	9	2	7	11	3	3
C-11	Tug and Tow	3	4	0	4	2	3

AOA Option C-13 Characterization

Option C-13 had the lowest overall score for the three options in the Central study area based on the among-cluster analysis results (Table 3.8). C-13 is, however, the closest option to an inlet, and therefore has a high logistics score. Due to the spatial dispersion rule and that the distance to inlet is the closest of any option, C-13 was the third option chosen for characterization. C-13 has high mean AIS vessel traffic (2015 - 2019) and low fishing effort spatially and temporally within the time periods assessed (Table 3.8).

General Characteristics

AOA option C-13 is a 500-ac option located in federal waters just south of the Louisiana coastline and state water boundary (Table 3.26). C-13 is closer to shore than all other options. The inlet to South Pass is 9.6 km from option C-13, and it is 21.8 km to the southwest pass entrance (Figure 3.91). Once in the sheltered navigation channels of the Mississippi River, Venice is located approximately 36 km (20 nm) upstream. Venice is a top U.S. commercial fishing port and is vital to supporting other offshore industries. Option C-13 could support land-based operations in any coastal community in Plaquemines or Jefferson Parishes. It falls under Louisiana Congressional District 1, State Senate District 1, and House District 105. There are 13 federal statutes applicable to all the options identified, including option C-13 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option C-13 are (-89.18816, 28.90386), (-89.18829, 28.91671), (-89.17371, 28.91682), (-89.17358, 28.90398). Option C-13 is in the GMFMC, USACE New Orleans District, USCG New Orleans Sector (District 8), USEPA Region 6, USFWS Southeast Region, and BOEM Central Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 500-ac area is 62.2 m, with a maximum depth of 69.2 m and a minimum depth of 56.4 m (Figure 3.92). No recent high-resolution bathymetric survey data are currently available for C-13. Based on available data, the largest differential in depth is 12.8 m. Shallower areas are found in the northwest corner of option C-13, while deeper waters are observed in the southeast (Figure 3.92). Percent slope over the area is 0.32%. The mean slope across the area is 0.43 degrees with a maximum of 0.67 degrees.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[36] the sediment of C-13 is composed of 99% mud-like substrate. The sediment composition is likely influenced by deposition of sediments from the Mississippi River. The predicted surficial sediment Phi value was 5.8, which indicate sediment with a diameter of medium silt (diameter = 0.03125 to 0.015625 mm).

Water Temperature and Salinity

Water temperature and salinity in the Gulf of Mexico can fluctuate seasonally, with episodic storm events, shifting current patterns, and effluent from the Mississippi River. Seasonally the mean daily surface water temperature at option C-13 is lowest from December through April, at which point it increases and remains above 25°C until the end of October, when it begins to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 14.4°C, while the maximum was 32.1°C. The water temperature at 10-m depth was slightly warmer than the surface

[36] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

water temperature, with a minimum daily mean value of 15.5°C, and a maximum value of 31.1°C. The water temperature near the bottom of option C-13 is more consistent year-round, with very slight increases from September to December, with a minimum temperature of 16.97°C and a maximum temperature of 27.4 °C (Figure 3.93). Mean daily surface salinity concentration values between 2016 and 2020 were extremely variable, with observations indicating salinity regularly fluctuated between 35 and 20 PSU any given month, with some instances of salinity going below 15 PSU. The maximum surface salinity value was 35.4 PSU, and the minimum value was 13.3 PSU. However, salinity at 10-m and at 60-m depths was much more stable and consistent year-round, remaining above 30 PSU and 34 PSU, respectively (Figure 3.94).

Metocean Characteristics

Surface ocean current speeds at option C-13 exceed 1.0 m/s 2.38% of the time examined (Figures 3.95 - 3.97). The currents at the surface predominantly move in a southwest direction, while currents at 10-m depth and at the bottom depth generally move in a south-southwest to east-northeast direction (Figures 3.95 and 3.97). Wind direction at option C-13 predominantly comes from the southeast, and only 5.01% of the time is the wind speed greater than 10.28 m/s (Figure 3.98). Ocean waves observed at option C-13 predominantly originate from the south-southeast (Figure 3.99).

Water Quality Considerations

To evaluate water quality at option C-13, nutrient concentration, dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels from the surface to 5-m depth of option C-13 for nitrate, phosphate, and silicate were 4.54 µmol/L, 0.44 µmol/L, and 8.96 µmol/L, respectively. At 30-m depth, nitrate decreased to 1.44 µmol/L, phosphate decreased to 0.31 µmol/L, and silicate decreased to 5.19 µmol/L (Figure 3.100). Around the 55-m to 65-m depth (i.e., bottom water), nitrate concentration increased to 2.25 - 2.89 µmol/L, phosphate decreased (0.17 - 0.20 µmol/L) and silicate concentration decreased to 2.20 - 3.10 µmol/L. Dissolved oxygen was highest in surface waters (5.0 ml/L) and decreased with depth to a lowest value of 4.1 ml/L (Figure 3.100). Option C-13 had the highest overall mean Chl-*a* concentration compared to any other option. Chlorophyll-*a* concentration was highest in the summer, namely July (18.2 mg/m^3). The lowest value (5.1 mg/m^3) occurred in January (Figure 3.101). The diffuse light attenuation coefficient (Kd) value at 490 nm was relatively high throughout the year, and ranged from 0.90 m^{-1} to 1.80 m^{-1} (Figure 3.102). The monthly mean for percent light transmissivity at 1-m depth for option C-13 is also consistently the lowest throughout the year compared to any other option. 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% (Figure 3.103).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. Option C-13 is outside of all Gulf of Mexico-based MOAs and known SUAs and does not overlap areas marked as danger zones or restricted areas (Table 3.26).

Natural and Cultural Resource Considerations

Option C-13 does not overlap or intersect deep-sea coral observations (1985 - present), fish havens, or artificial reefs within a 3-km vicinity. AOA option C-13 overlaps the giant manta ray species distribution model, particularly the areas above the median maximum predicted value to provide conservation measures for the species (Table 3.26). Option C-13 also overlaps NMFS-defined green sea turtle (North Atlantic DPS) high use areas for resident populations, as well as the loggerhead sea turtle (Northwest Atlantic Ocean DPS) NMFS critical habitat area (*Sargassum*). AOA option C-13 does not overlap any additional sea turtle HUAs for residence or migratory areas, but loggerhead, Kemp's ridley, and leatherback sea turtles may still be within range of option C-13 (see Appendix B for details). Essential Fish Habitat designated by the GMFMC and NMFS for option C-13 includes shrimp, reef fish, coastal migratory pelagic species, and 20 highly migratory species (Table 3.40).

Industry, Navigation, and Transportation Considerations

Option C-13 is in the Central Gulf of Mexico BOEM Offshore Oil and Gas Planning Area where significant oil and gas energy sector infrastructure exists. While there is no overlap of oil and gas infrastructure with C-13, there is some infrastructure within the vicinity. Two oil and gas pipelines are within 3 km to the west of option C-13. Four boreholes are within 3 km of this option (Figure 3.92). One oil and gas platform is located 3 km east of option C-13. All navigational infrastructure was avoided within C-13. One shipwreck is approximately 2.5 km from the closest corner point of option C-13. Assessment of the cumulative AIS vessel traffic from 2015 to 2020 within C-13 indicated lower vessel traffic occurred with tanker vessels (n = 11), pleasure and sailing (n = 54), and cargo vessels (n = 160). Other (n = 2,178), fishing vessels (n = 2,450), passenger (n = 1,278), and tug and tow (n = 571) vessels were the highest vessel type traffic intersecting option C-13 (Tables 3.27, 3.28).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate option C-13 overlaps a moderate amount of shrimp trawling vessels over the 16 years of data assessed. A low amount of bandit reef fishing also occurred in C-13 between 2007 and 2019. There were no observed instances of longline reef fishing within option C-13.

Table 3.26. Characterization summary for Aquaculture Opportunity Area option C-13.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-89.18816, 28.90386
	-89.18829, 28.91671
	-89.17371, 28.91682
	-89.17358, 28.90398
Size (ac)	500
Closest inlet (km)	9.6 km
Depth (m) (minimum, mean, maximum)	(56.4, 62.2, 69.2)
National Security	
Military Operating Areas (MOA)	None within reporting range
Special Use Airspace (SUA)	None within reporting range
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	30.20
Fishing Vessels 2015 - 2019	419.80
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	385.60
Passenger Vessels 2015 - 2019	203.00
Pleasure and Sailing Vessels 2015 - 2019	8.60
Tanker Vessels 2015 - 2019	2.20
Tug and Tow Vessels 2015 - 2019	99.60
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	5.01
Surface Current Speed % > 1.0 m/s (%)	2.38
Significant Wave Height % > 1.75 m (%)	8.7

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	None within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlaps green sea turtle HUA and species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	1
Oil and Gas Boreholes	4
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	2
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.3
Salinity (PSU) at 5-m depth (mean)	31.4
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(4.54, 0.44, 8.96)
Mean Aragonite Saturation State (Ω)	3.60
Governance	
Agency boundary (USACE Districts)	New Orleans District
Agency boundary (USCG Sectors)	Sector New Orleans; District 8
Agency boundary (USEPA Regions)	Region 6
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Central Gulf of Mexico

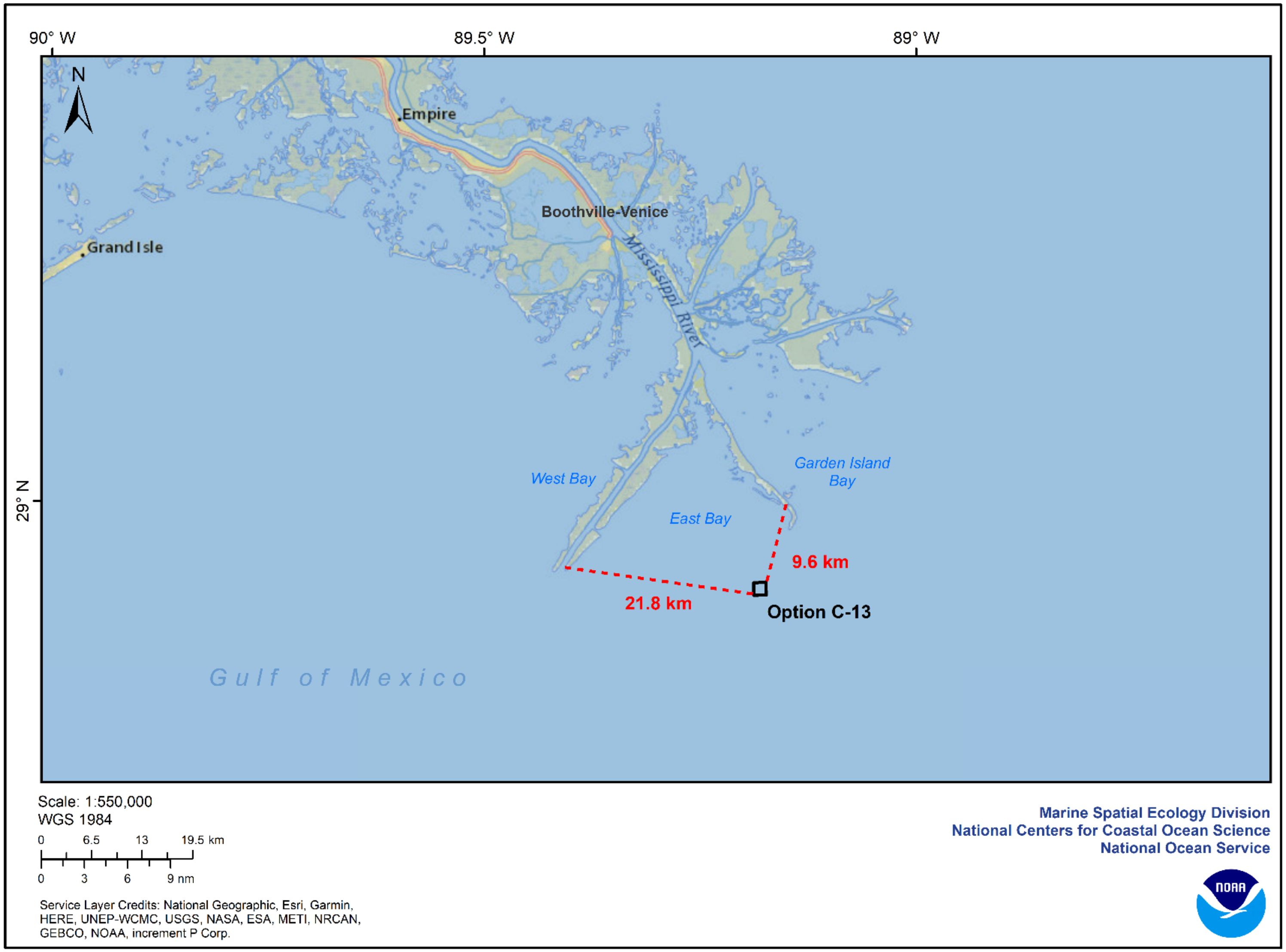


Figure 3.91. Option C-13 (black outlined box) and distance to the closest inlet from the closest corner points of option C-13; the area is located south of the Mississippi River and outside of the East Bay area in southern Louisiana.

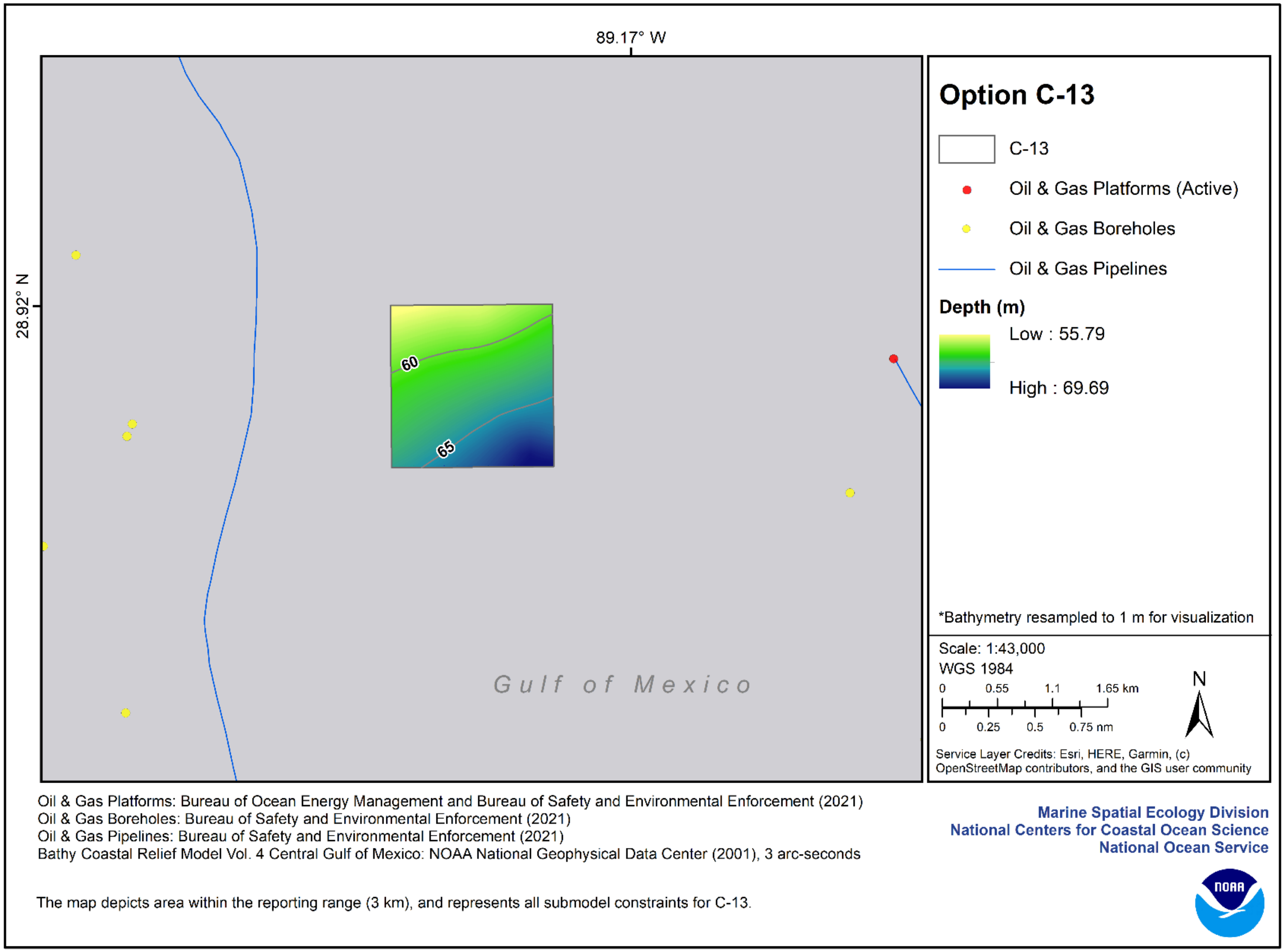


Figure 3.92. Bathymetric constraints within the vicinity of option C-13.

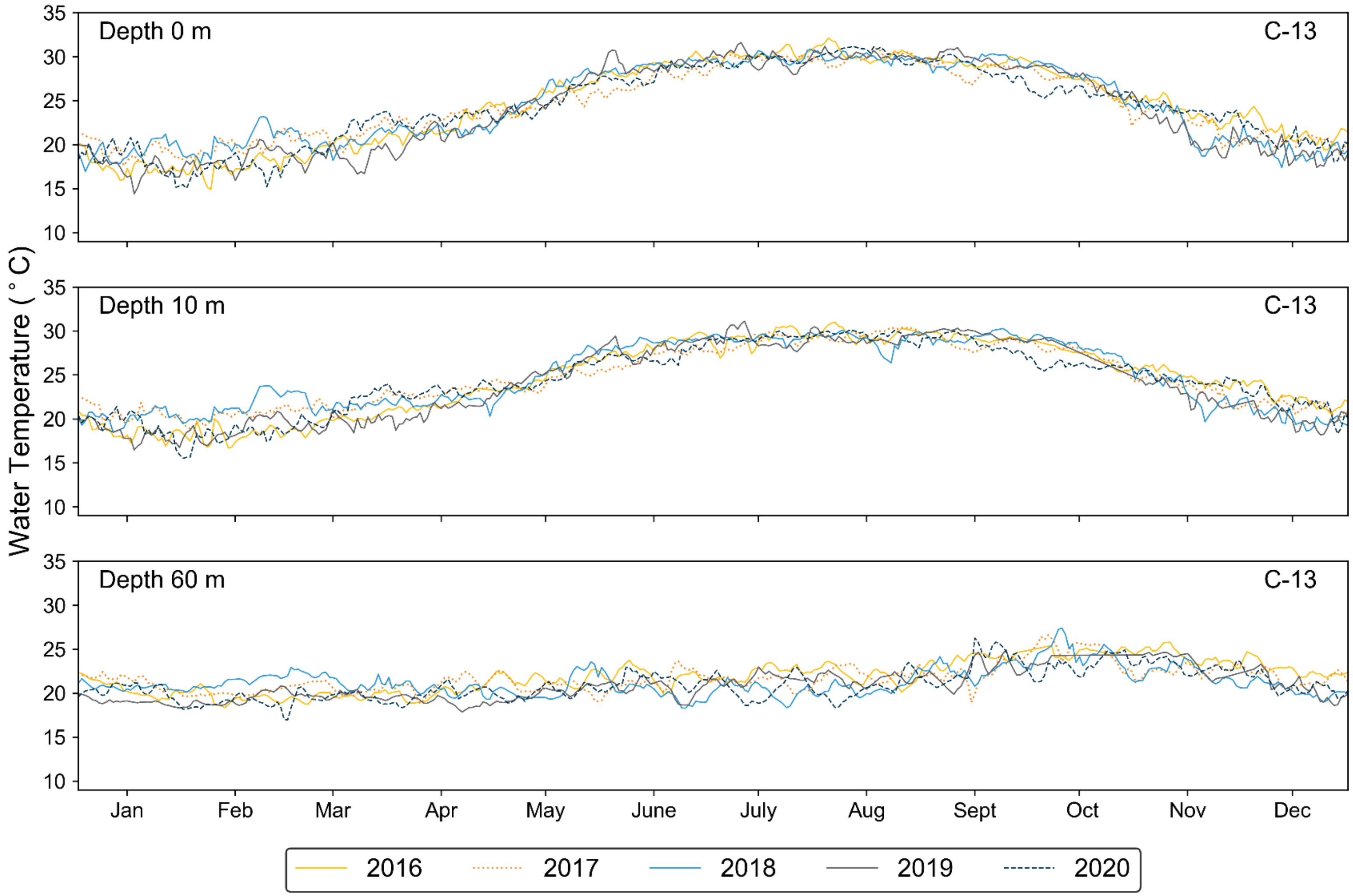


Figure 3.93. Option C-13 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 60-m depth (2016 - 2020).

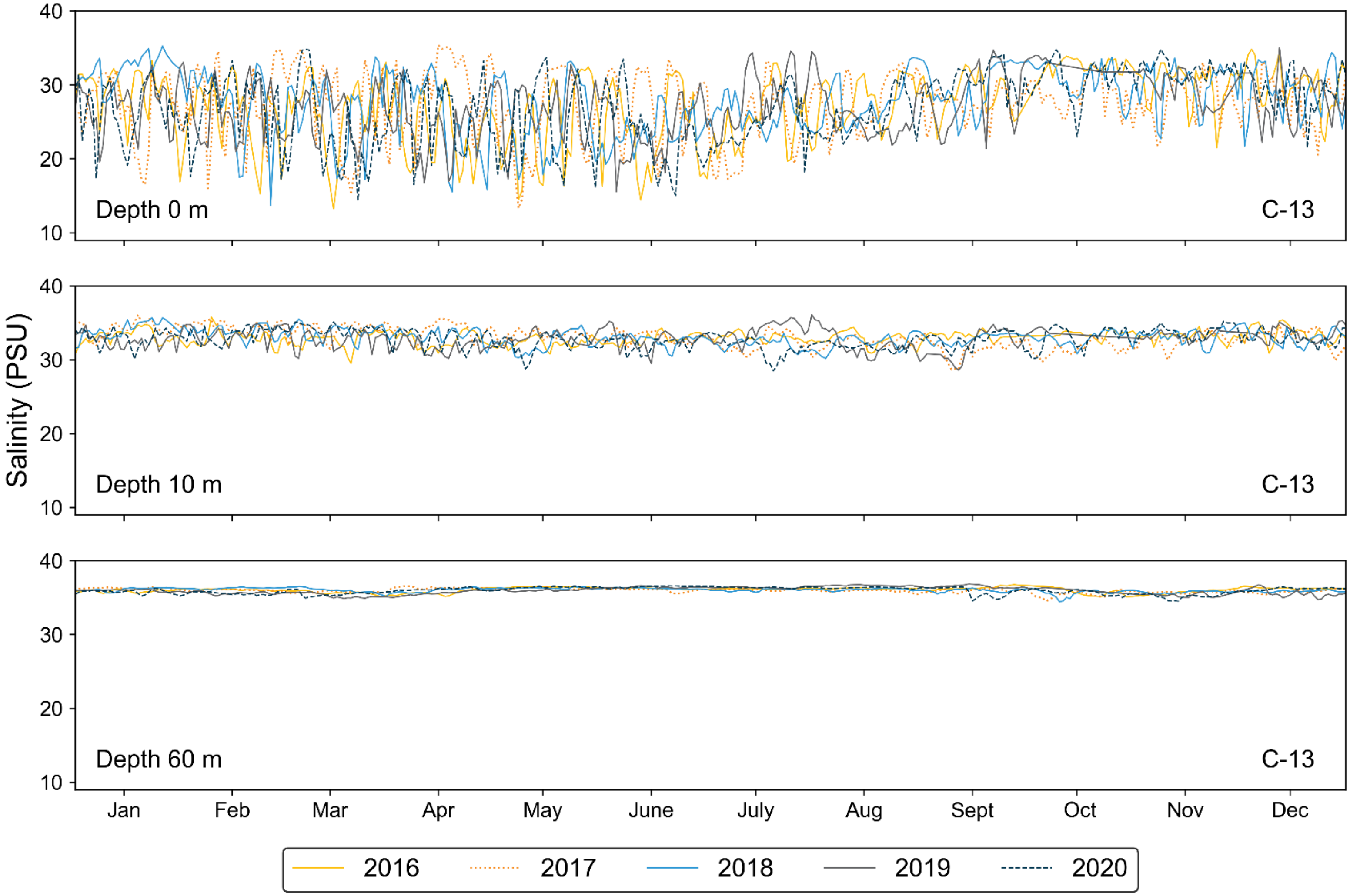


Figure 3.94. Option C-13 Navy Coastal Ocean Model regional American seas model mean daily salinity at the surface, 10-m depth, and 60-m depth (2016 – 2020).

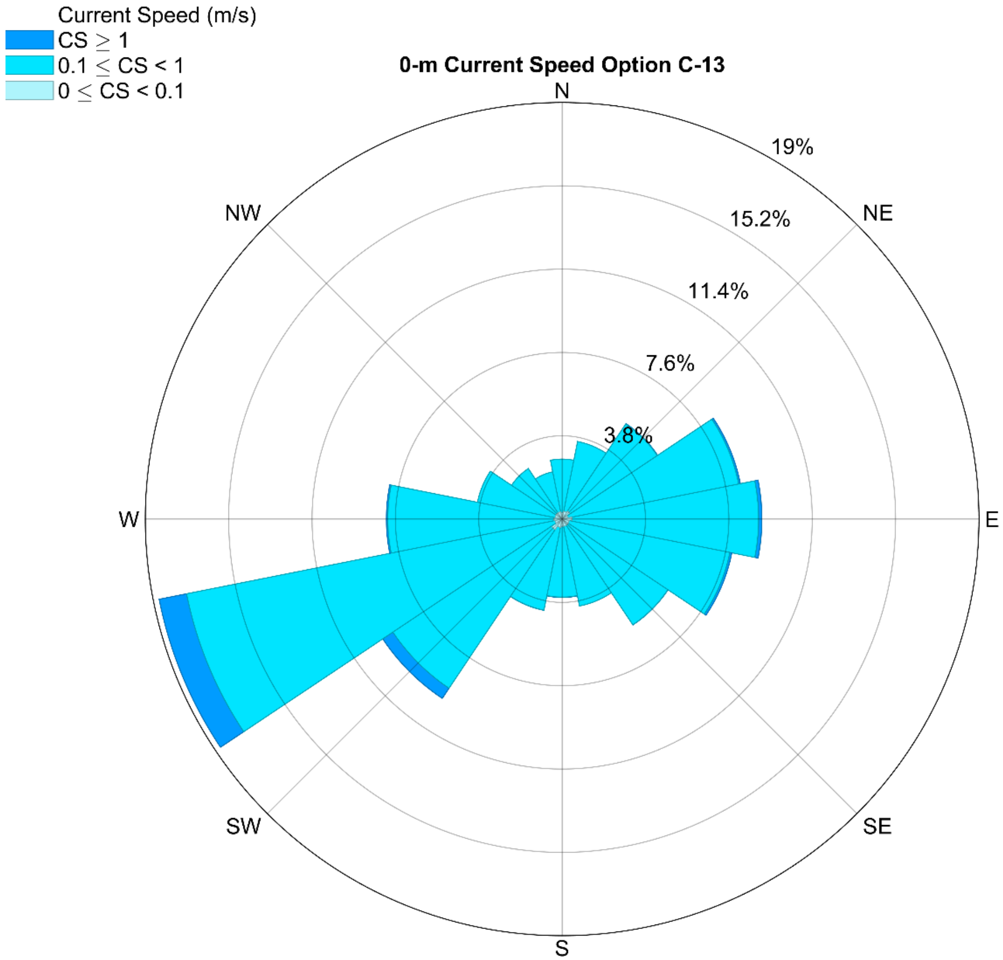


Figure 3.95. Ocean current magnitude and direction for option C-13 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

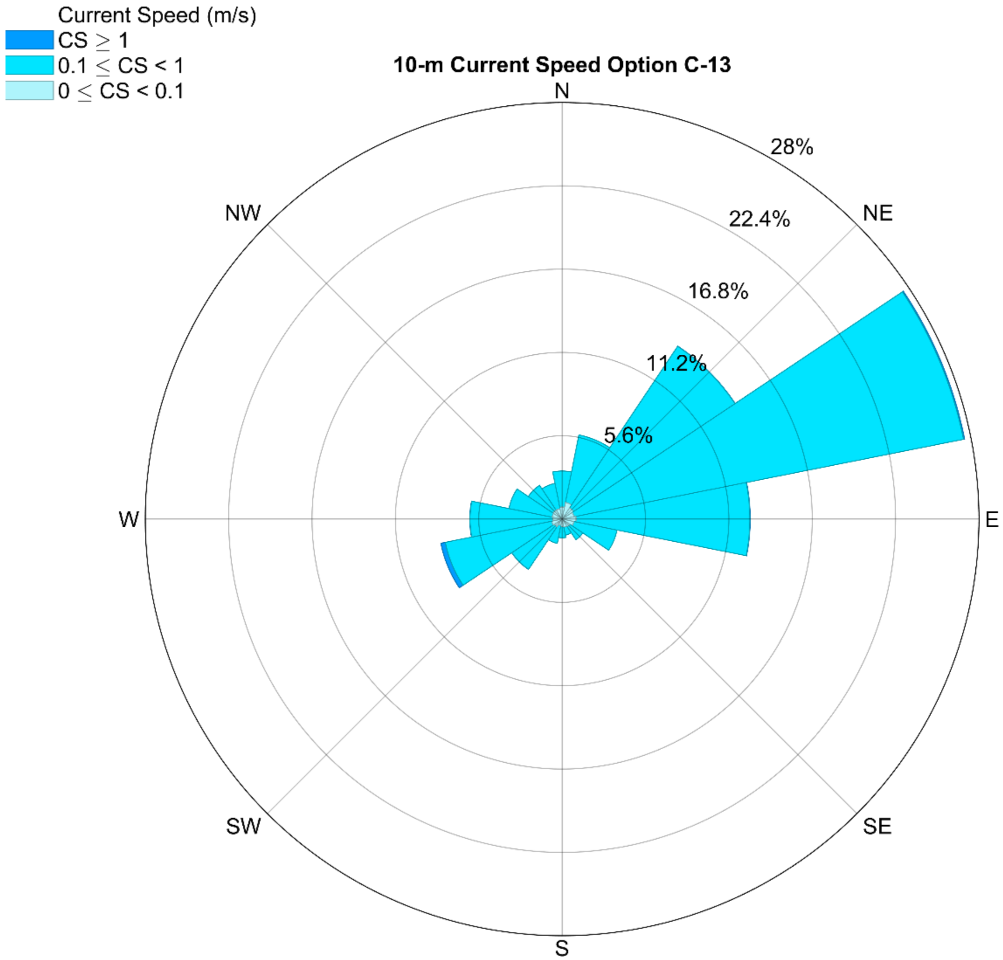


Figure 3.96. Ocean current magnitude and direction for option C-13 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

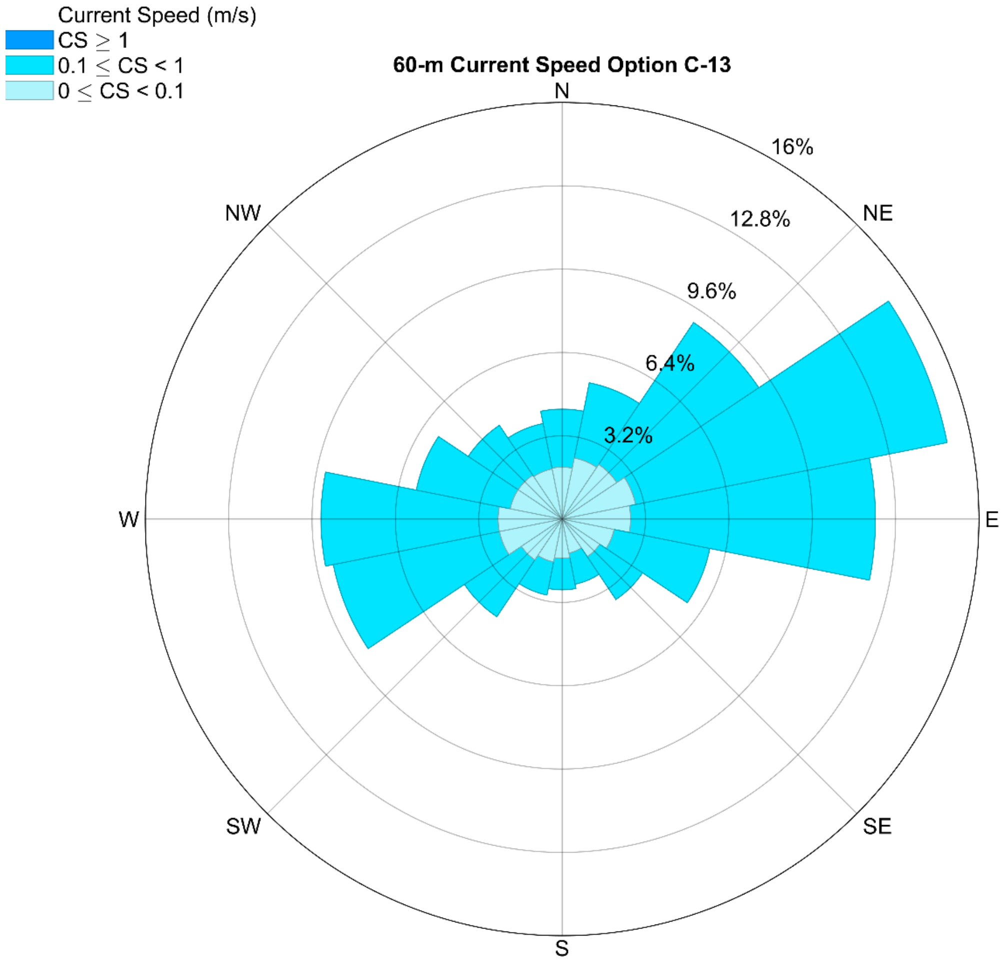


Figure 3.97. Ocean current magnitude and direction for option C-13 at 60-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

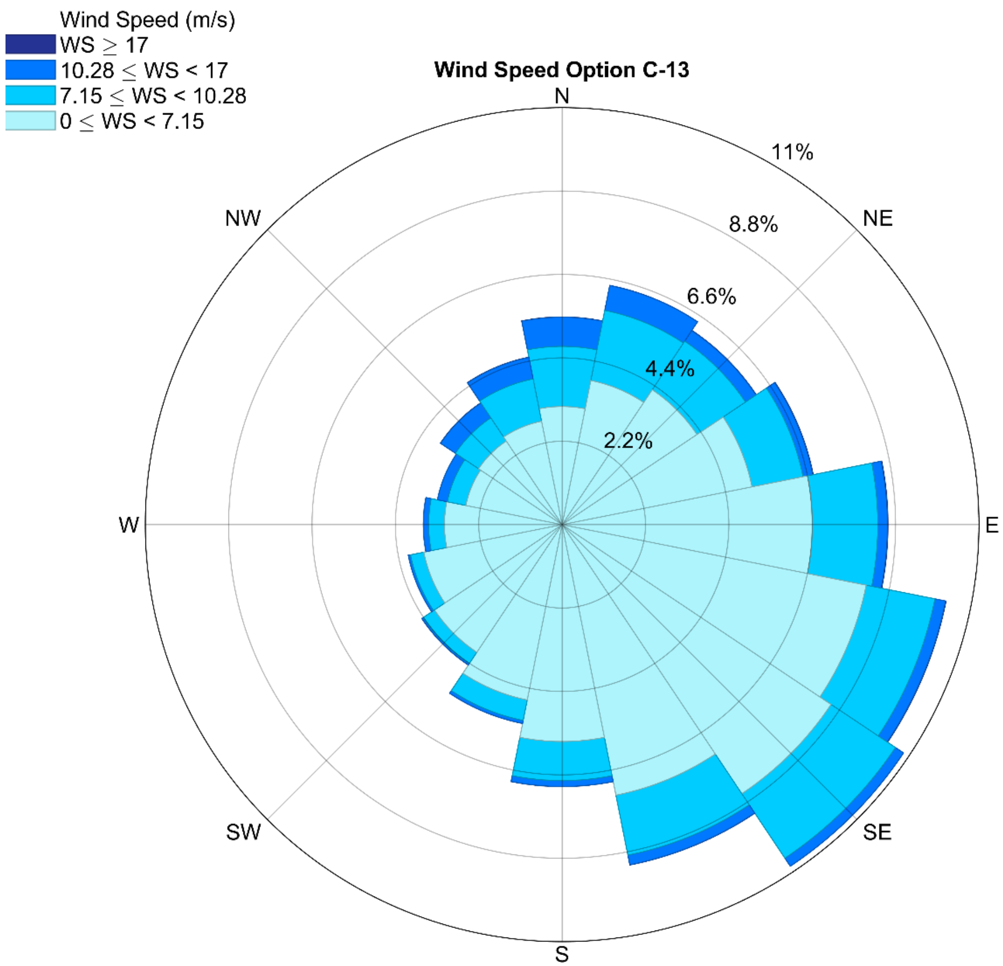


Figure 3.98. Wind velocity and direction at 10-m above sea level for option C-13. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

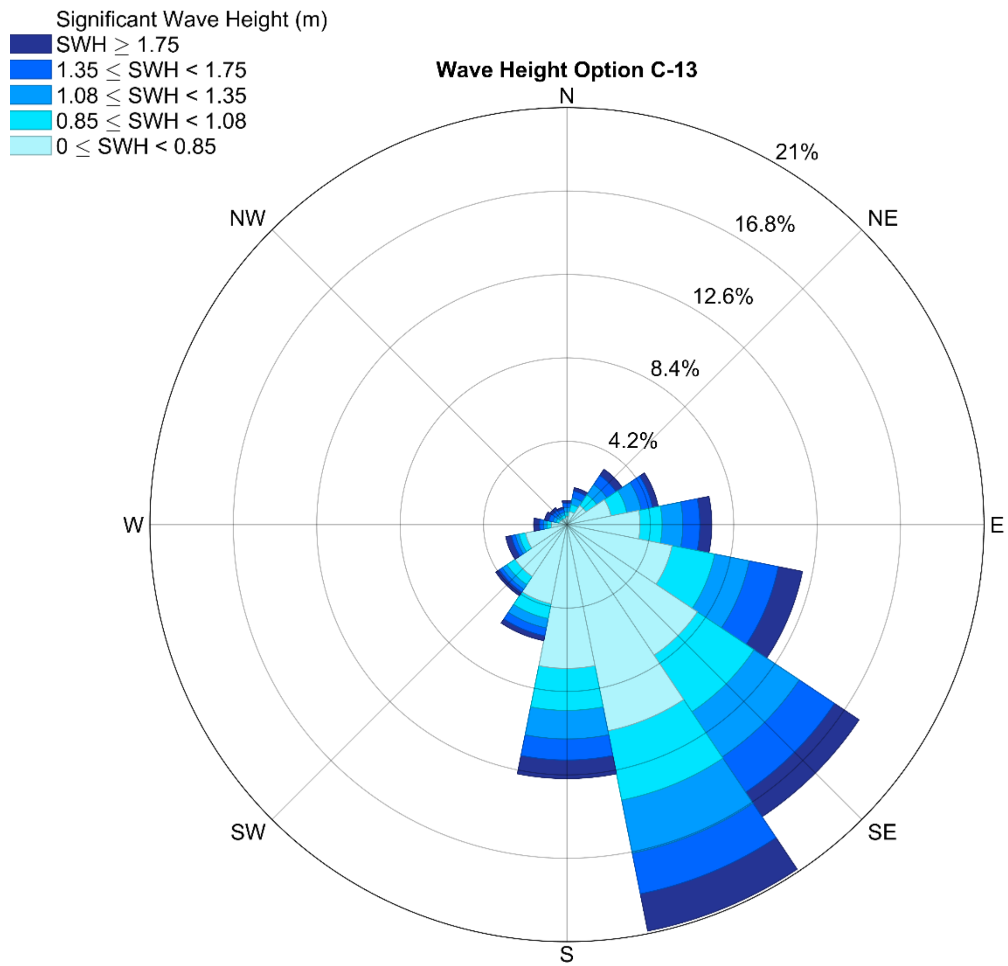


Figure 3.99. Significant wave height and direction at 10-m for option C-13. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

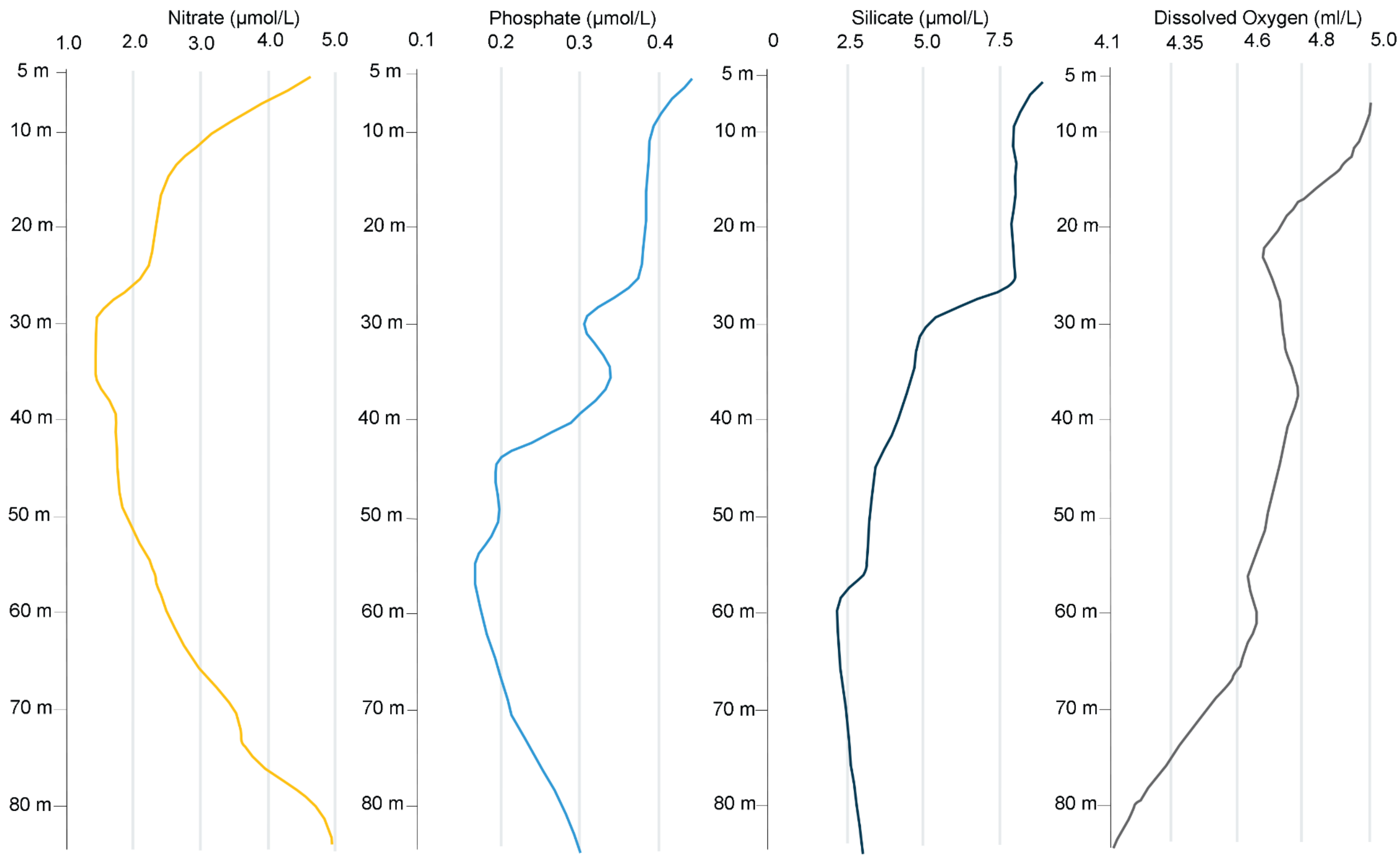


Figure 3.100. Option C-13 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels derived from the Ecological Marine Units (Sayre et al. 2017).

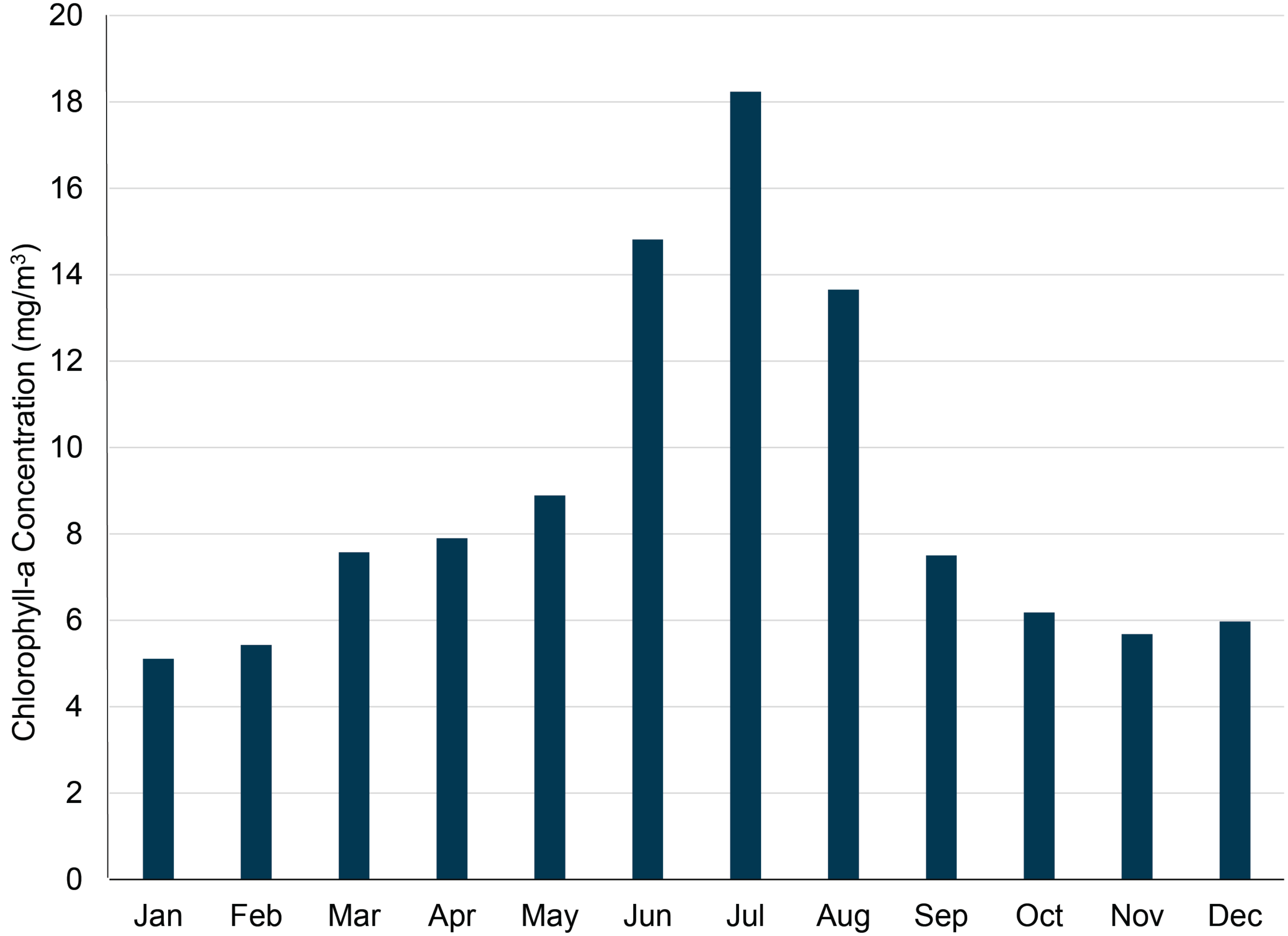


Figure 3.101. Option C-13 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m³) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

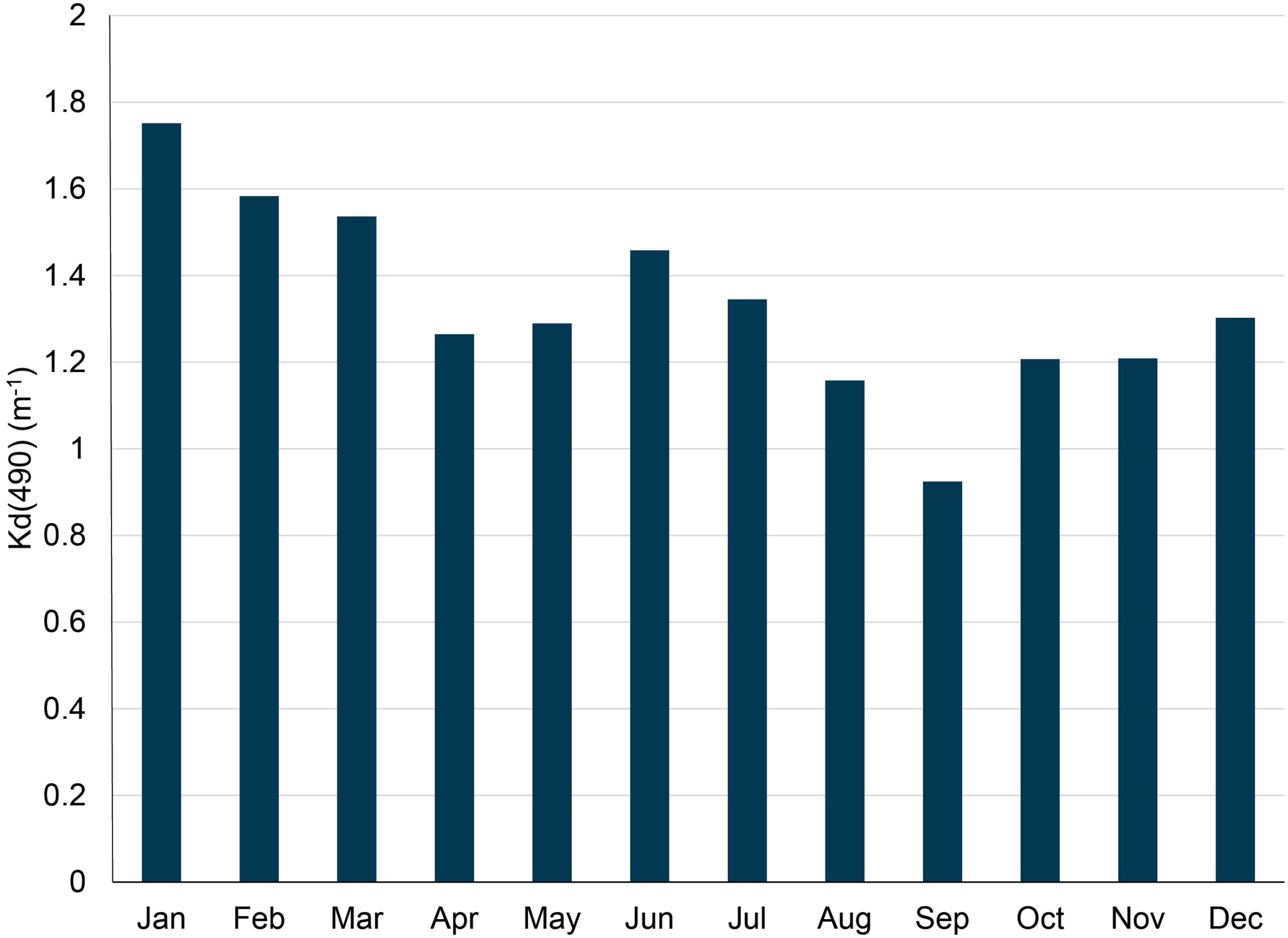


Figure 3.102. Option C-13 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

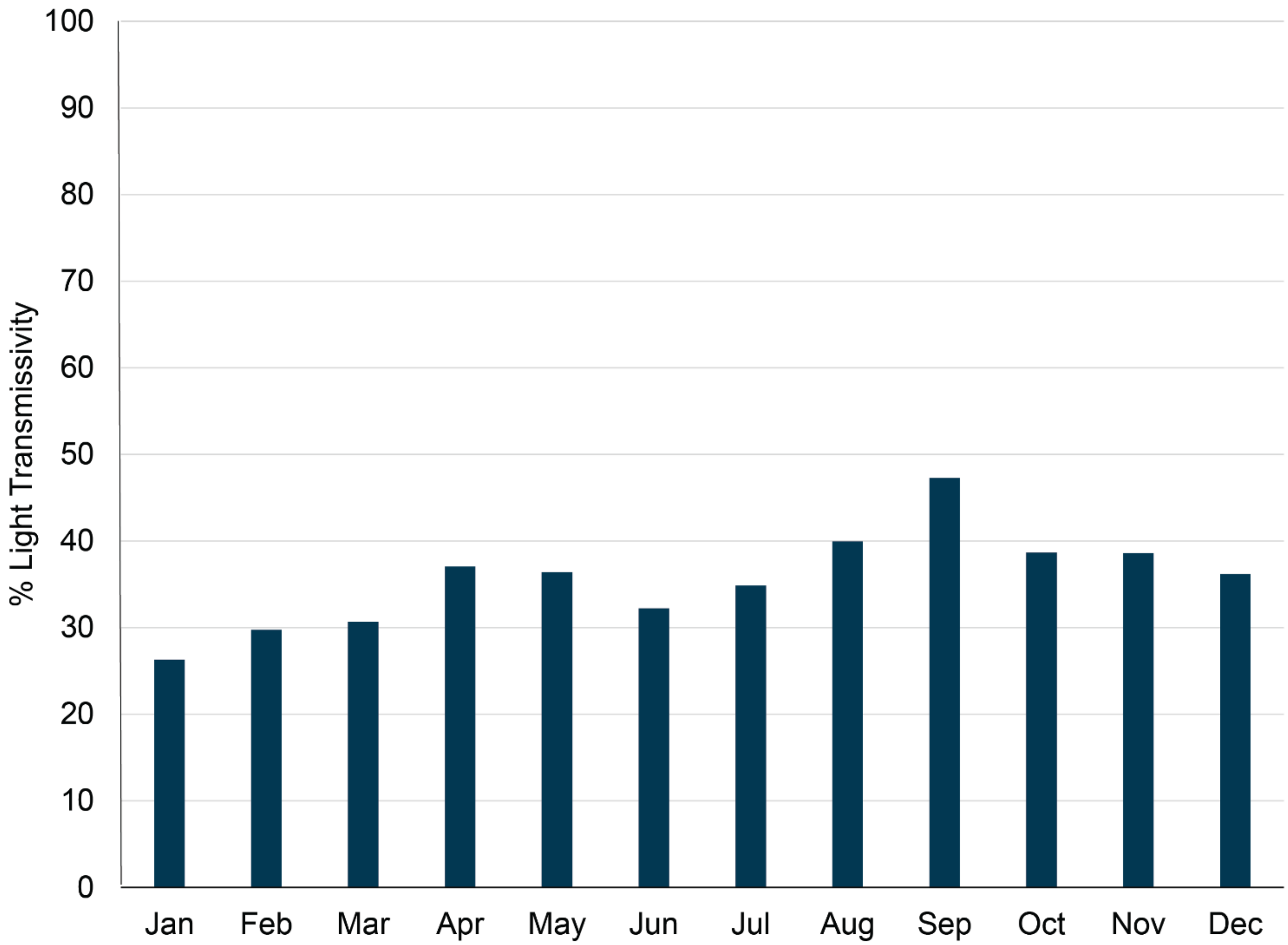


Figure 3.103. Option C-13 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.27. Option C-13 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 500-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total Transits All Years (500 ac)
C-13	Cargo	25.00	15.00	20.00	48.00	43.00	9.00	160.00
C-13	Fishing	450.00	147.00	260.00	350.00	892.00	351.00	2450.00
C-13	Other	322.00	278.00	403.00	535.00	390.00	250.00	2178.00
C-13	Passenger	159.00	203.00	103.00	278.00	272.00	263.00	1278.00
C-13	Pleasure and Sailing	4.00	5.00	11.00	11.00	12.00	11.00	54.00
C-13	Tanker	3.00	0	7.00	1.00	0	0	11.00
C-13	Tug and Tow	82.00	89.00	91.00	162.00	74.00	73.00	571.00
*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.								

Table 3.28. Number of unique individual Automatic Identification System-equipped vessels that transited through option C-13.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
C-13	Cargo	8	8	5	4	10	3
C-13	Fishing	15	52	63	87	73	71
C-13	Other	103	86	85	103	96	71
C-13	Passenger	45	41	38	54	58	47
C-13	Pleasure and Sailing	4	5	9	10	12	7
C-13	Tanker	1	0	3	1	0	0
C-13	Tug and Tow	47	52	49	50	42	33

East Options Precision Modeling Results

In the East study area, four unique high-high clusters were identified (E-1, E-2, E-3, and E-4) once the LISA analysis was completed (Table 3.9). Using the within-cluster approach, each cluster was treated as an individual spatial unit in which options (500 ac, 1,000 ac, 1,500 ac, and 2,000 ac with 4 corner points in cardinal directions) were iteratively created and modeled throughout each cluster using the logistics, vessel traffic, and aquaculture and fishing submodels (see Figure 2.21). Notably, each of the four clusters was relatively large in size (> 20,000 ac), compared to other study area clusters. After executing the within-cluster model, E-4 had the highest number of potential options (11,881 potential options over 355,305 ac) iterated through by the model to identify the highest suitability option within the cluster. E-2 had the lowest number of potential options identified (440 potential options over 23,155 ac), and was also the smallest of the four East Study Area clusters (Table 3.9). Once the most suitable option was determined from each cluster, the among-cluster model (see Figure 2.22) using the logistics, vessel traffic, aquaculture and fishing, and metocean submodels identified (going from west to east) E-4, E-3, and E-1 as the highest scoring options based on parameters considered (Table 3.9, Figure 3.29).

All East study area options (E-4, E-3, and E-1) have the closest proximity to the state of Florida. From an economic standpoint, the state's ocean economy supports 521,440 jobs, with wages totaling around $16.6 billion. The largest ocean sector job categories were tourism and recreation (82.3%) and marine transportation (6.6%) in 2018 (NOAA 2021b).

AOA Option E-4 Characterization

Option E-4 had the lowest overall score for the three options in the East study area based on the among-cluster analysis results (Table 3.9). E-4 has a moderately low logistics score based on distance to the closest inlet. E-4 also had high mean AIS vessel traffic (2015 - 2019) and high overlap with fishing effort spatially and temporally within the time periods assessed (Table 3.9).

General Characteristics

AOA option E-4 is a 2,000-ac option located in federal waters to the west of Florida's Gulf of Mexico coastline and state water boundary (Table 3.29). E-4 is 107.8 km from the inlet in Clearwater, FL, and 110.1 km from the St. Petersburg, FL, inlet (Figure 3.104). Notably, there are many inlets that may be equally desirable based on infrastructure and aquaculture farm needs. Option E-4 falls under Florida Congressional District 13, State Senate District 24, and House District 66. There are 13 federal statutes applicable to all the options identified, including option E-4 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option E-4 are (-83.153637, 26.141176), (-83.153119, 26.153996), (-83.138889, 26.153528), (-83.139408, 26.140709). Option E-4 is located in the GMFMC, USACE Jacksonville District, USCG St. Petersburg Sector (District 7), USEPA Region 4, USFWS Southeast Region, and BOEM Eastern Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 2,000-ac option E-4 is 51.1 m, with a maximum depth of 52.9 m and a minimum depth of 49.5 m (Figure 3.105). No recent high-resolution bathymetric survey data are currently available for E-4. Based on available data, the largest differential in depth is 3.4 m. Shallower areas are found in the eastern portion of E-4, while deeper waters are observed in the southwest corner of the option (Figure 3.105). Percent slope over the area is 0.13%. The mean slope across the area is 0.05 degrees with a maximum of 0.25 degrees. In the central eastern portion of option E-4, a small raised area occurs, where depths are the shallowest (49.5 m). The raised areas could indicate potentially sensitive habitat (e.g., corals) and require further in situ validation.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[37] the sediment of E-4 is composed of 74 to 94% sandy substrate. With some areas of coarser sediments (i.e., predominantly gravel) located in the

[37] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

northwest, southwest, and southeast corners of the option making up to 24% of the sediment composition. The predicted surficial sediment Phi values ranged from 0.5 to 1.8, which indicate sediment with a diameter of coarse to medium sand (diameter = 0.5 mm).

Water Temperature and Salinity

Water temperature and salinity in the Gulf of Mexico can fluctuate seasonally, with episodic storm events and with shifting current patterns. For the years 2016 - 2020, temperature at the surface and at 10-m depth followed the same seasonal trends (Figure 3.106). Seasonally, the mean daily surface water temperature at option E-4 was lowest from December through April, at which point it increased and remained above 25°C until October, when it began to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 18.4°C, while the maximum was 31.7°C. The water temperature at 10-m depth followed a similar pattern to the surface water temperature, with a minimum daily mean value of 18.4°C, and a maximum value of 31.1°C. The water temperature near the bottom of option E-4 was more consistent year-round; however, it was the most variable across the five years examined, ranging between 17.1°C and 26.3°C (Figure 3.106). Mean daily salinity concentration between 2016 and 2020 at option E-4 was consistent throughout the year, with no major variations or decreases.

Metocean Characteristics

Ocean current speeds at option E-4 rarely exceed 1.0 m/s at all depths examined (Figures 3.107 - 3.109). The currents at the surface and at 10 m predominantly move in a south-southeast direction, while currents at the bottom depth predominantly move in an east-northeast direction (Figures 3.107 and 3.109). Wind direction at option E-4 is predominantly from the east, and only 3.36% of the time is the wind speed greater than 10.28 m/s (Figure 3.110). Ocean waves observed at option E-4 predominantly originate from the south-southeast (Figure 3.111).

Water Quality Considerations

To evaluate water quality at option E-4, nutrient concentration, dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels from the surface to 5-m depth of option E-4 for nitrate, phosphate, and silicate were 0.21 µmol/L, 0.07 µmol/L, and 0.72 µmol/L, respectively. At 25-m depth, nitrate concentration increased to 0.47 µmol/L, phosphate decreased to 0.06 µmol/L, and silicate concentration increased (2.56 µmol/L) (Figure 3.112). Around 50-m depth (i.e., bottom water), nitrate concentration increased to 1.57 µmol/L, phosphate increased to 0.13 µmol/L, and silicate concentration decreased to 1.89 µmol/L. Dissolved oxygen was consistent and relatively high throughout the year, and ranged from 4.8 ml/L to 5.1 ml/L (Figure 3.112). Chlorophyll-*a* concentration, a common approximation for phytoplankton in the ocean, was highest in January (0.39 mg/m^3) and December (0.34 mg/m^3) at option E-4 (Figure 3.113). The remainder of the year, concentrations ranged from 0.17 mg/m^3 to 0.26 mg/m^3, with the lowest concentration in May. The diffuse light attenuation coefficient at 490 nm for E-4 was highest in December, January, and February (0.06 - 0.07 m^{-1} for all three months). For the remainder of the year, Kd(490) ranged from 0.04 m^{-1} to 0.05 m^{-1} (Figure 3.114). Percent light transmissivity at 1-m depth ranged from 89% to 92% throughout the year (Figure 3.115). Although sampling for *K. brevis* has been conducted around option E-4, no samples ever exceeded the 100,000 cells/L threshold in and around the area.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. E-4 overlaps with SUA testing and training area EWTA-2b, and also overlaps the EGTTR (Table 3.29). E-4 does not overlap areas marked as danger zones or restricted areas. Because of the proximity of option E-4 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

AOA option E-4 does not overlap or intersect deep-sea coral observations (1985 - present), fish havens, artificial reefs, or HAPCs. Within 1 to 2 km of E-4, off the northwest corner or the option, there are four areas marked as flat or pothole hardbottom areas (i.e., sensitive habitat), ranging in size from 33 to 443 m². Option E-4 overlaps the giant manta ray species distribution model, specifically above the median maximum predicted value to provide conservation measures for the species (Table 3.29). Although Option E-4 does not overlap any sea turtle HUAs for residence or migratory areas, loggerhead, Kemp's riley, leatherback, hawksbill or green sea turtles may still be within range (see Appendix B for details). E-4 does not overlap with any current NMFS critical habitat. Essential Fish Habitat designated by the GMFMC and NMFS for option E-4 includes shrimp, reef fish, coastal migratory pelagic species, and six highly migratory species (Table 3.41). Harmful algal blooms (*Karenia brevis*) were not detected within option E-4 from 2000 to 2018, with the nearest detected bloom occurring 45 km east of the option.

Industry, Navigation, and Transportation Considerations

E-4 is located in the Eastern Gulf of Mexico BOEM Offshore Oil and Gas Planning Area. Under the Gulf of Mexico Energy Security Act (2006),[38] restrictions were established with a complete moratorium on oil and gas leasing through June 30, 2022.[39] Therefore, no oil and gas infrastructure or marine mineral extraction occurs within E-4 or within a 3-km distance. All navigational infrastructure was avoided within and within 3 km of E-4. Assessment of the cumulative AIS vessel traffic by type from 2015 to 2020 within E-4 indicated that lower vessel traffic occurred with fishing (n = 1), passenger (n = 2), and pleasure and sailing (n = 8). Other (n = 27), cargo vessels (n = 56), and tug and tow (n = 679) had higher vessel traffic intersecting option E-4 (Tables 3.30, 3.31).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate option E-4 had no overlap with shrimp trawling over the 16 years of data assessed. Moderately low bandit reef fishing and low longline reef fishing occurs in option E-4. No headboat surveys occurred in this option.

[38] https://www.boem.gov/oil-gas-energy/energy-economics/gulf-mexico-energy-security-act-gomesa
[39] https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/GOMESA-Map.pdf

Table 3.29. Characterization summary for Aquaculture Opportunity Area option E-4.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-83.153637, 26.141176
	-83.153119, 26.153996
	-83.138889, 26.153528
	-83.139408, 26.140709
Size (ac)	2,000
Closest inlet (km)	104 km
Depth (m) (minimum, mean, maximum)	(49.5, 51.0, 51.9)
National Security	
Military Operating Areas (MOA)	Overlaps EGTTR
Special Use Airspace (SUA)	Overlaps EWTA-2b
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	11.75
Fishing Vessels 2015 - 2019	0.75
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	3.25
Passenger Vessels 2015 - 2019	0.25
Pleasure and Sailing Vessels 2015 - 2019	0.50
Tanker Vessels 2015 - 2019	4.00
Tug and Tow Vessels 2015 - 2019	0.75
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	3.36
Surface Current Speed % > 1.0 m/s (%)	0.01
Significant Wave Height % > 1.75 m (%)	6.9

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	Hardbottom present around option
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlaps species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	None within reporting range
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	None within reporting range
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	25.24
Salinity (PSU) at 5-m depth (mean)	35.83
Nutrients (nitrate, phosphate, silicate) (μmol/L) – 5 m depth (mean)	(0.21, 0.07, 0.72)
Mean Aragonite Saturation State (Ω)	3.92
Governance	
Agency boundary (USACE Districts)	Jacksonville District
Agency boundary (USCG Sectors)	Sector St. Petersburg; District 7
Agency boundary (USEPA Regions)	Region 4
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Eastern Gulf of Mexico

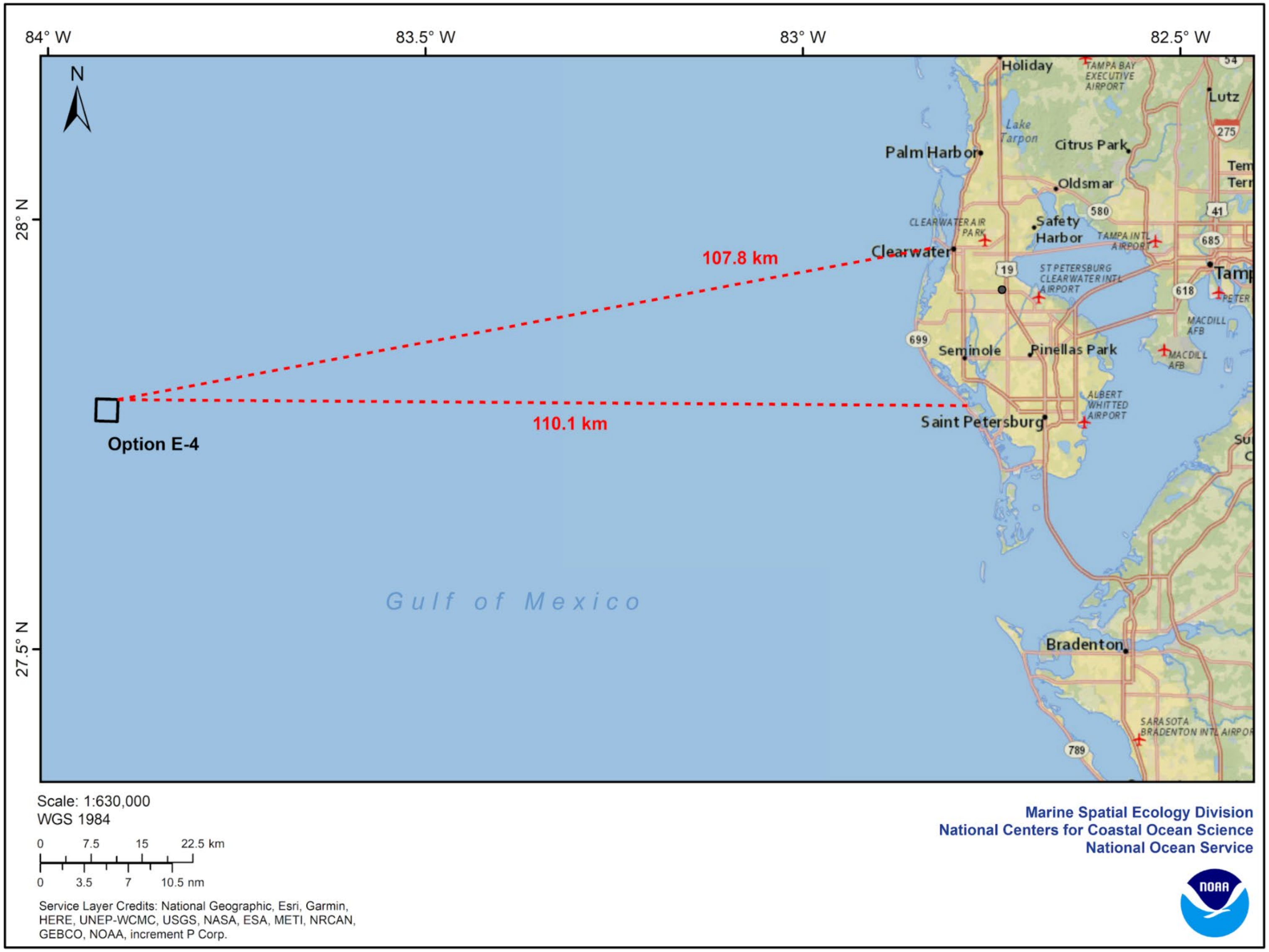
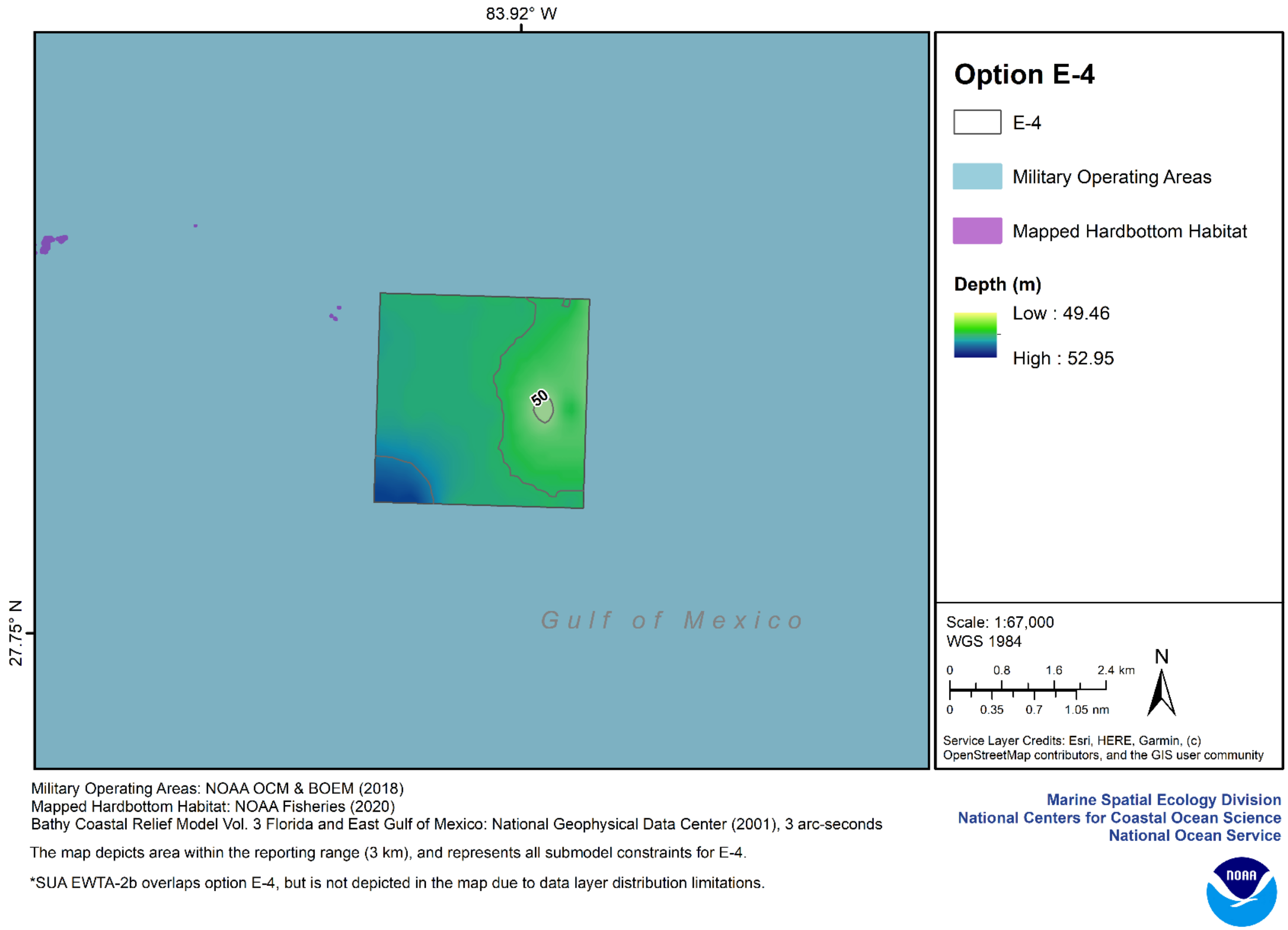


Figure 3.104. Option E-4 (black outlined box) and distance to the closest inlet from the closest corner point of E-4; the area is located in federal waters off the Gulf coast of Florida.



Military Operating Areas: NOAA OCM & BOEM (2018)
Mapped Hardbottom Habitat: NOAA Fisheries (2020)
Bathy Coastal Relief Model Vol. 3 Florida and East Gulf of Mexico: National Geophysical Data Center (2001), 3 arc-seconds

The map depicts area within the reporting range (3 km), and represents all submodel constraints for E-4.

*SUA EWTA-2b overlaps option E-4, but is not depicted in the map due to data layer distribution limitations.

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

Figure 3.105. Option E-4 bathymetric constraints within the vicinity of the option.

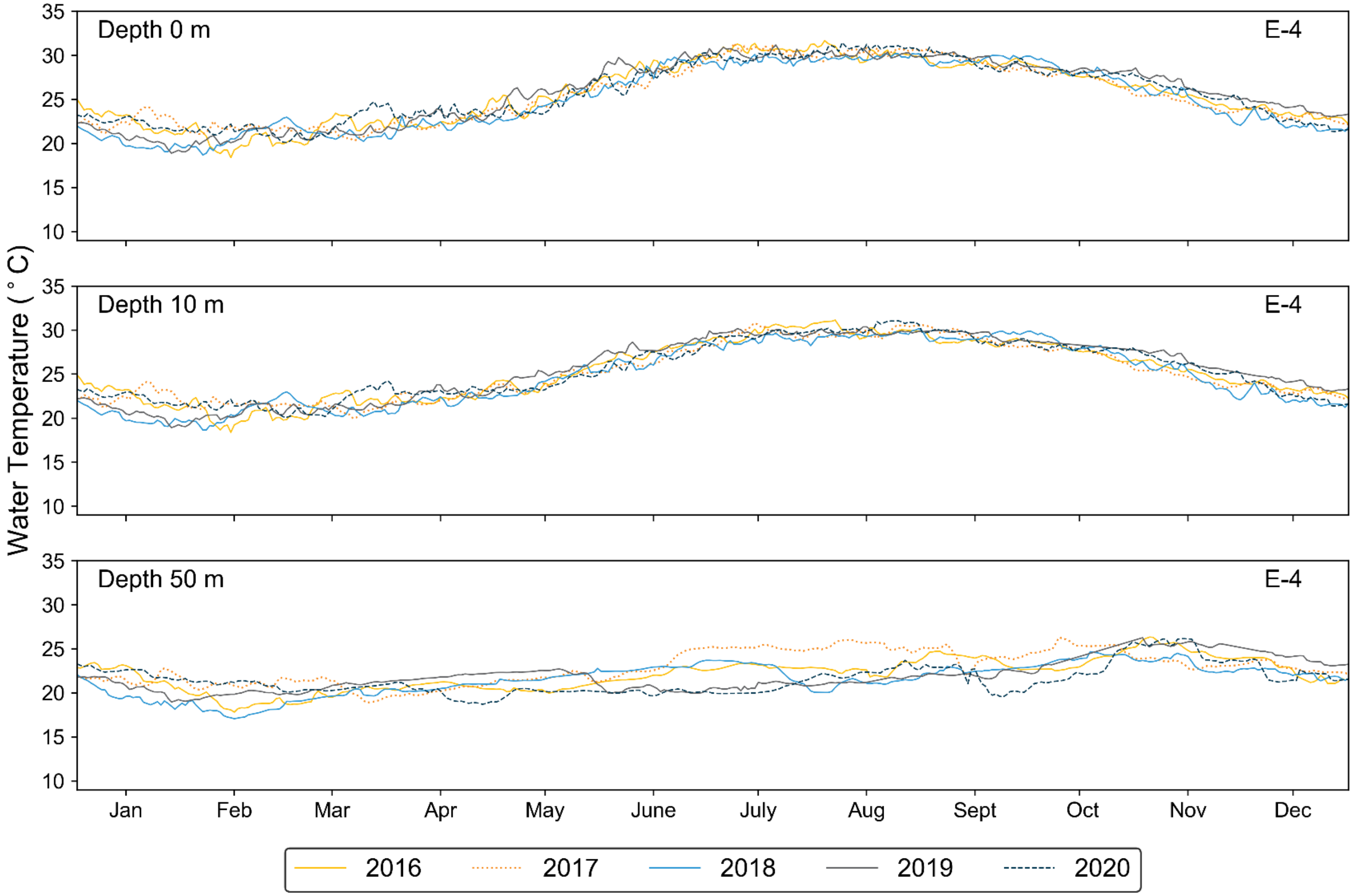


Figure 3.106. Option E-4 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 50-m depth (2016 - 2020).

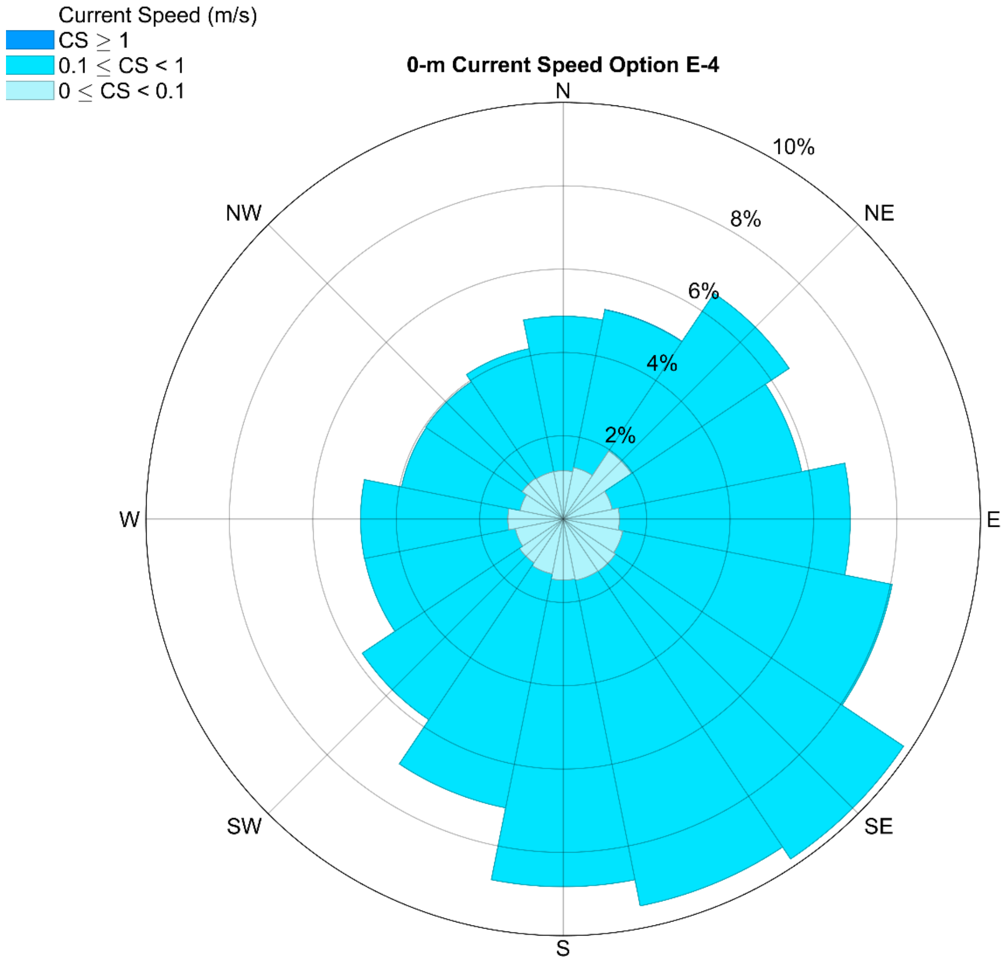


Figure 3.107. Ocean current magnitude and direction for option E-4 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

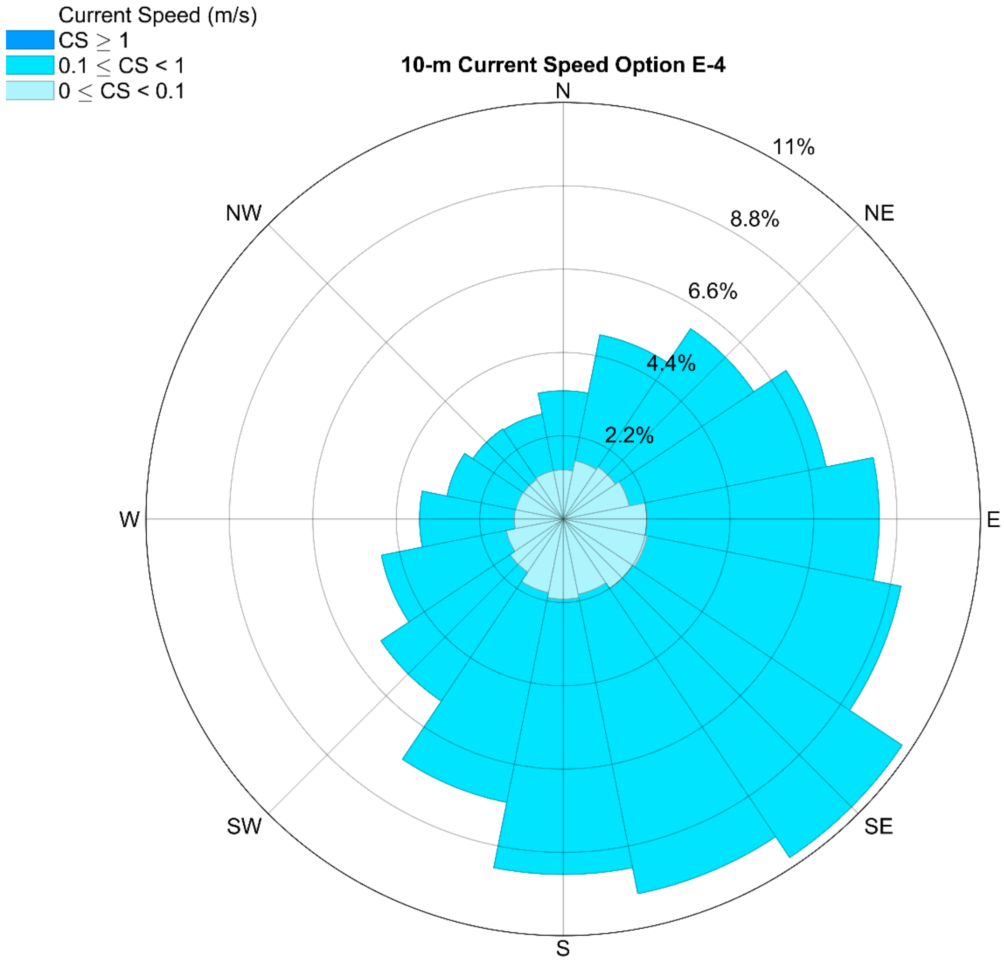


Figure 3.108. Ocean current magnitude and direction for option E-4 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

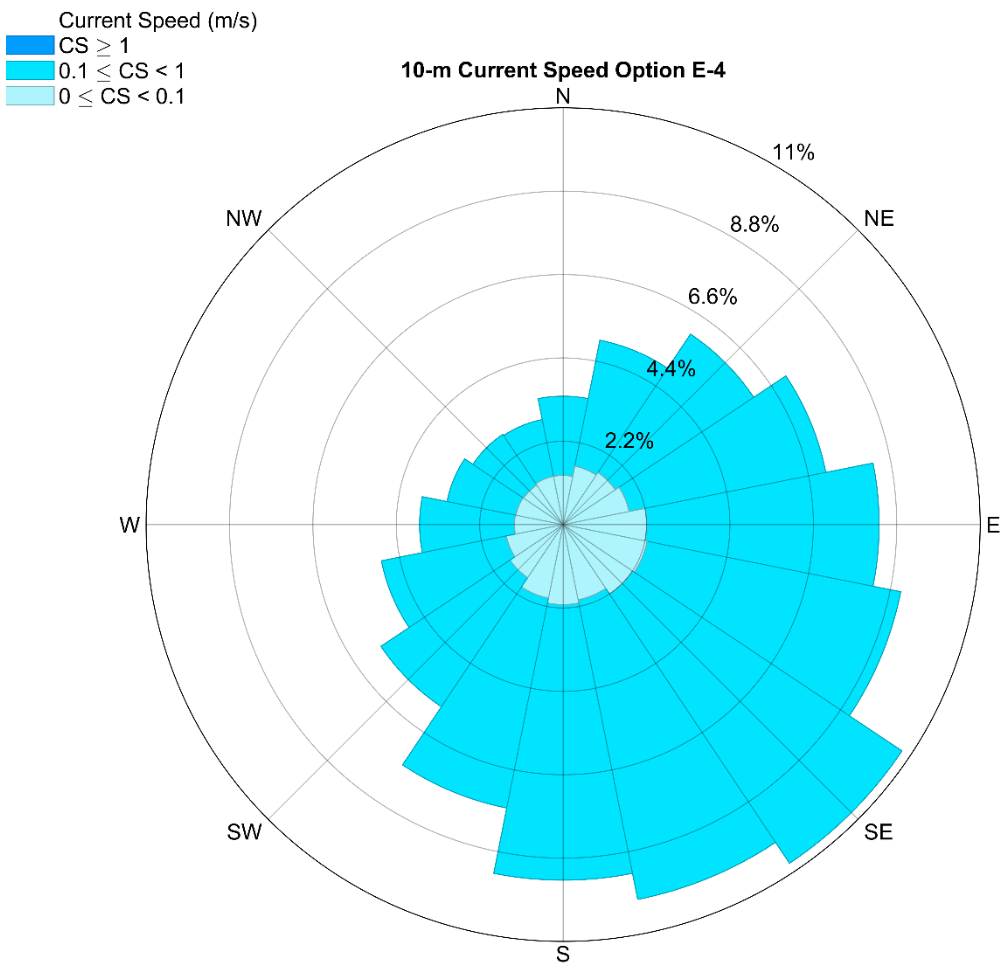


Figure 3.109. Ocean current magnitude and direction for option E-4 at 50-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

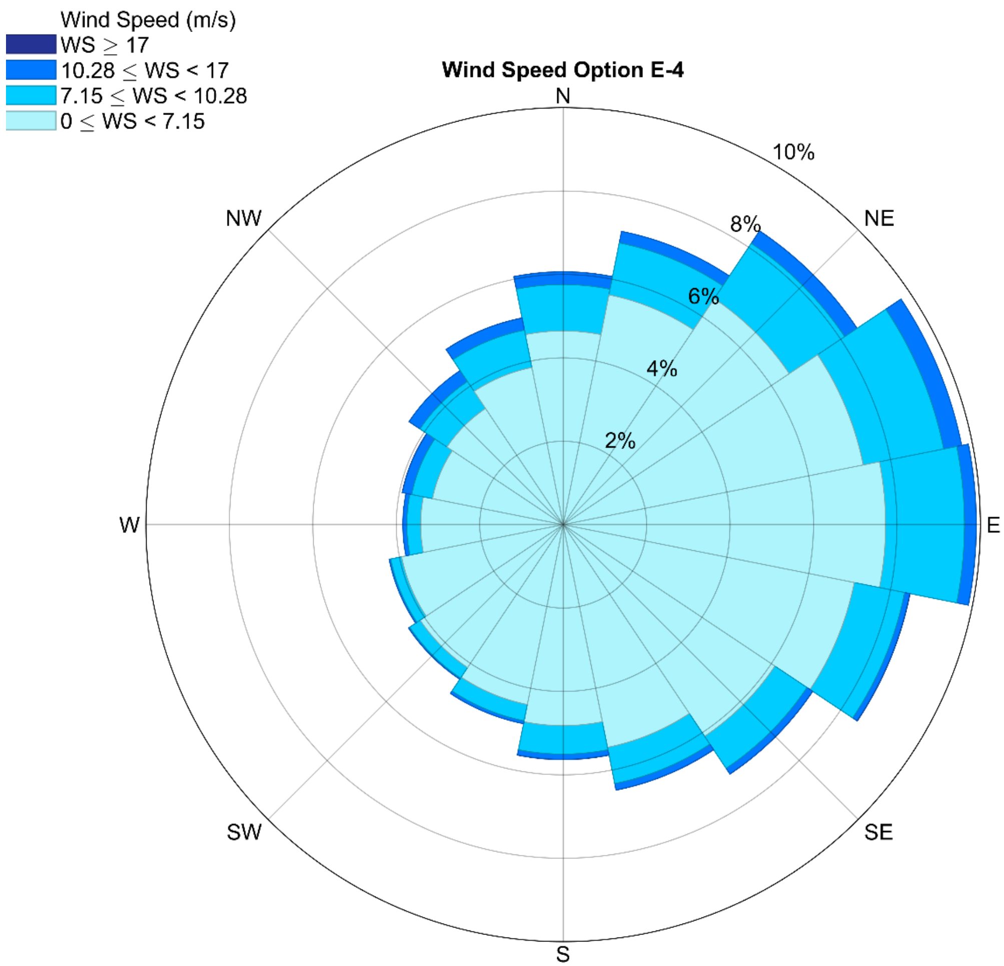


Figure 3.110. Wind velocity and direction at 10-m above sea level for option E-4. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

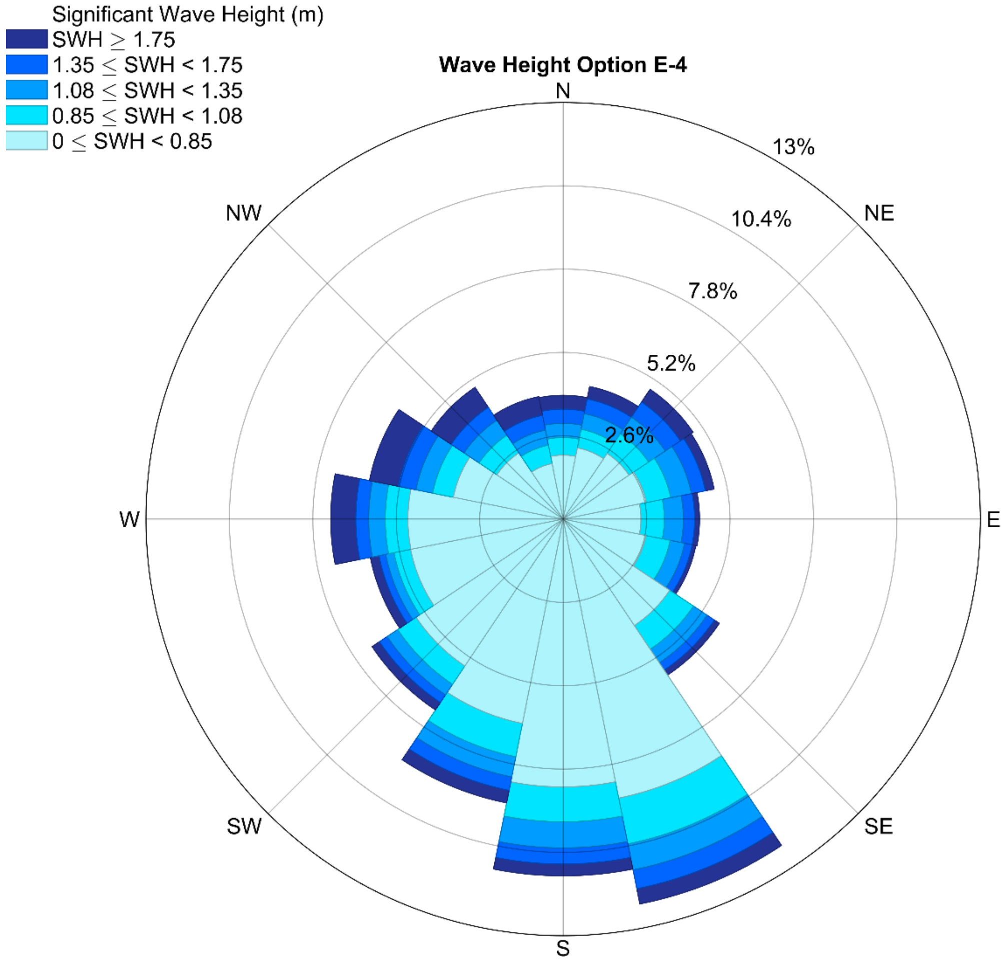


Figure 3.111. Significant wave height and direction at 10-m for option E-4. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

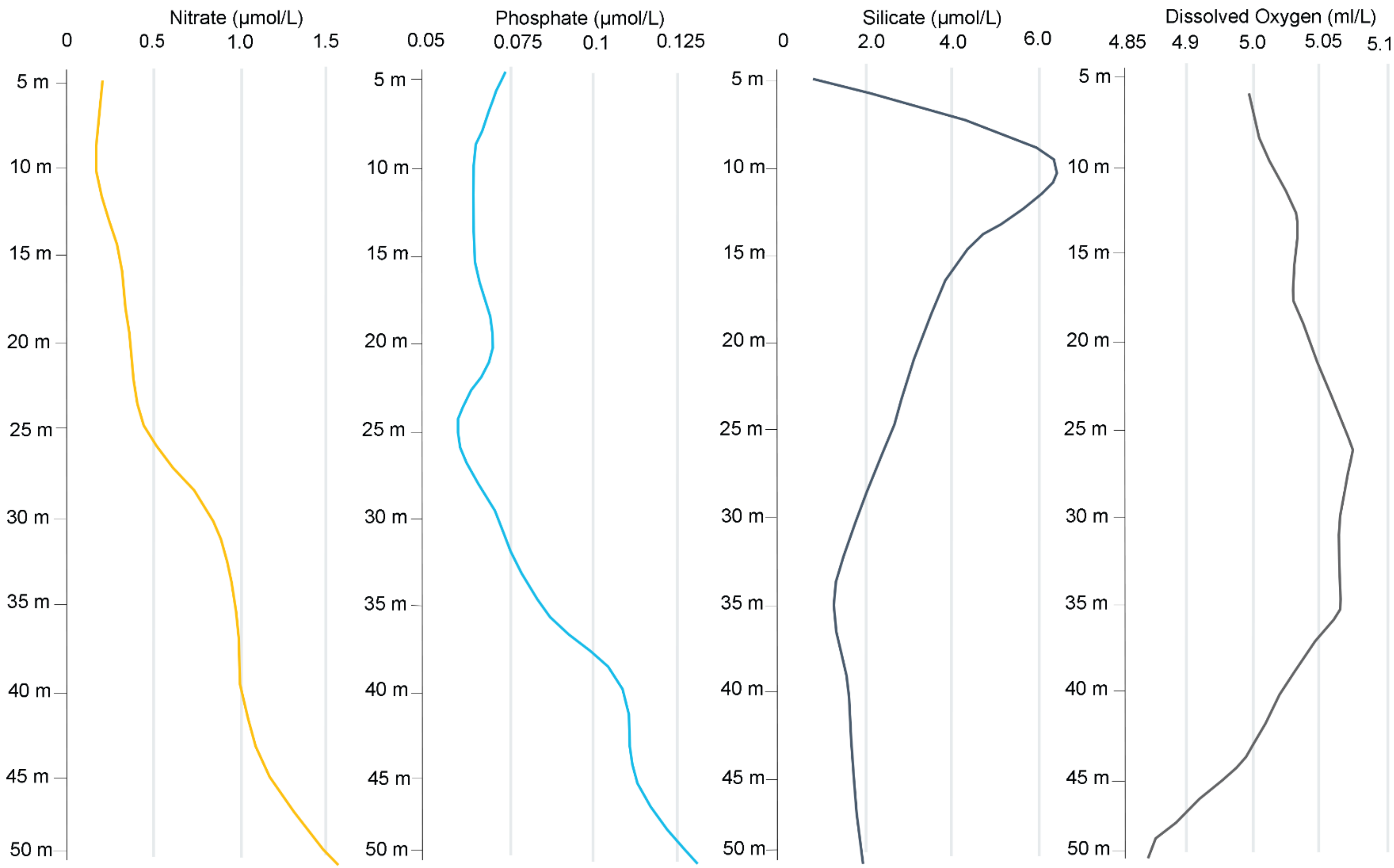


Figure 3.112. Option E-4 concentration of dissolved nitrate, phosphate, silicate, and oxygen at different depth levels derived from the Ecological Marine Units (Sayre et al. 2017).

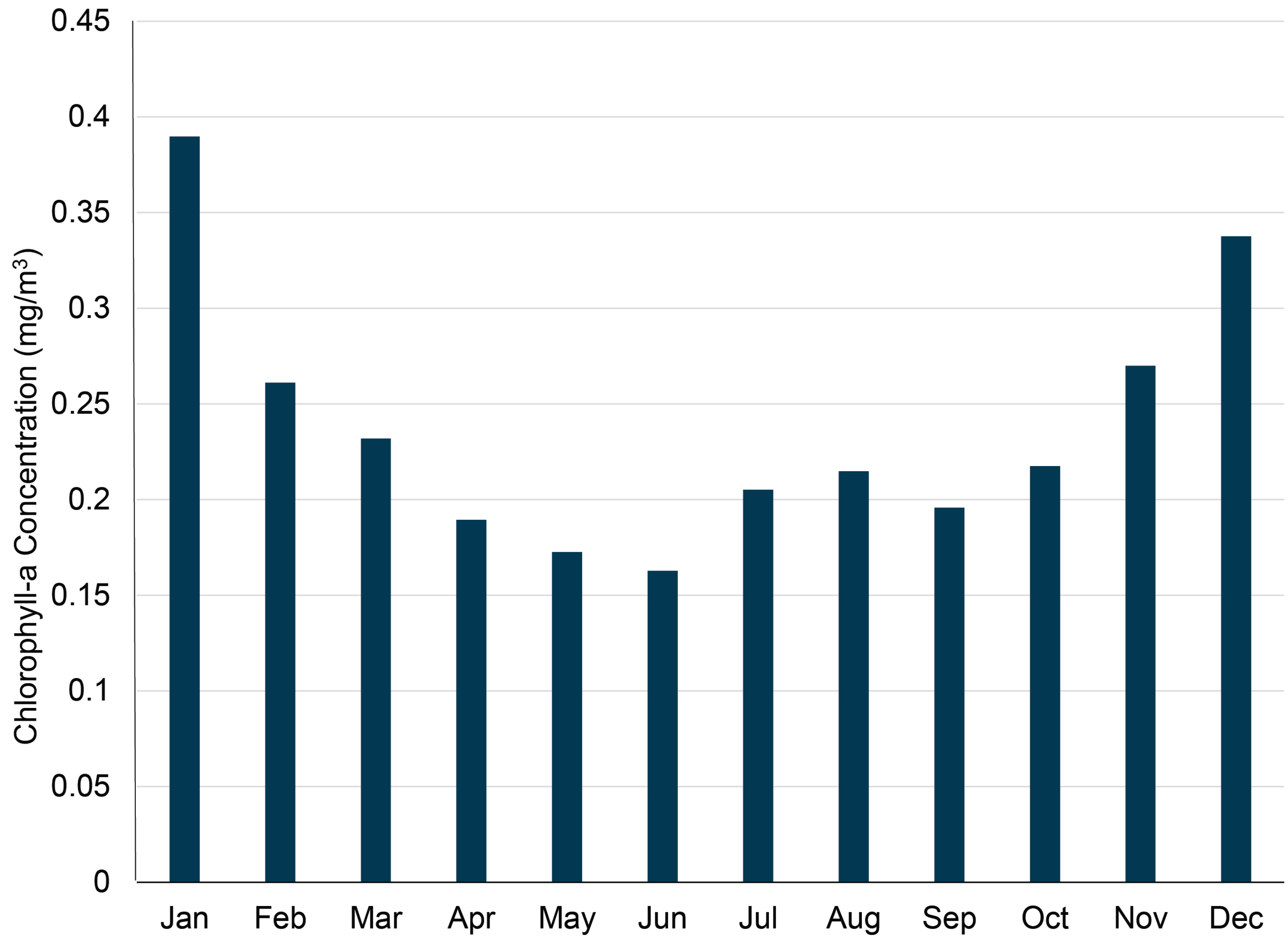


Figure 3.113. Option E-4 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

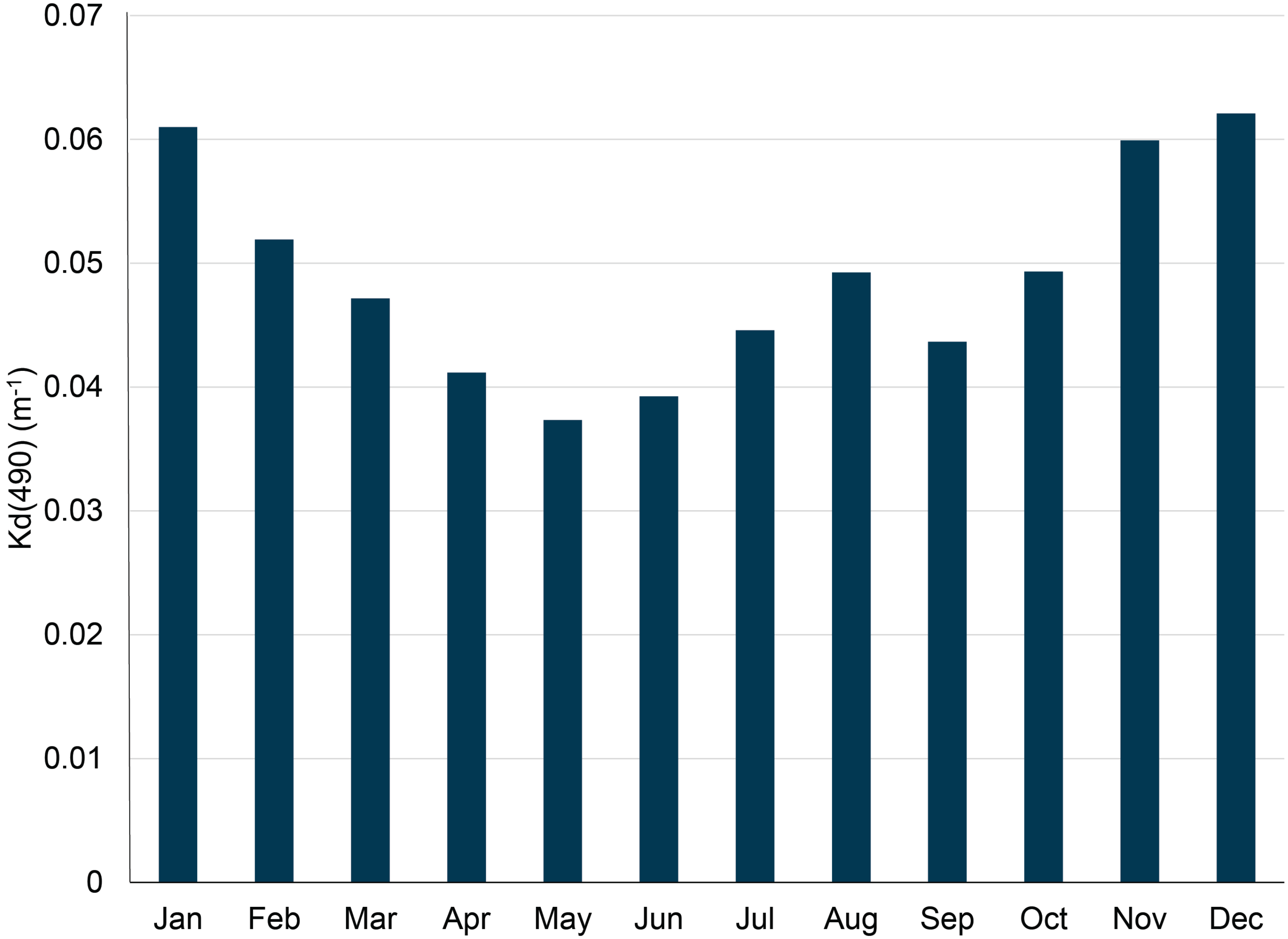


Figure 3.114. Option E-4 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

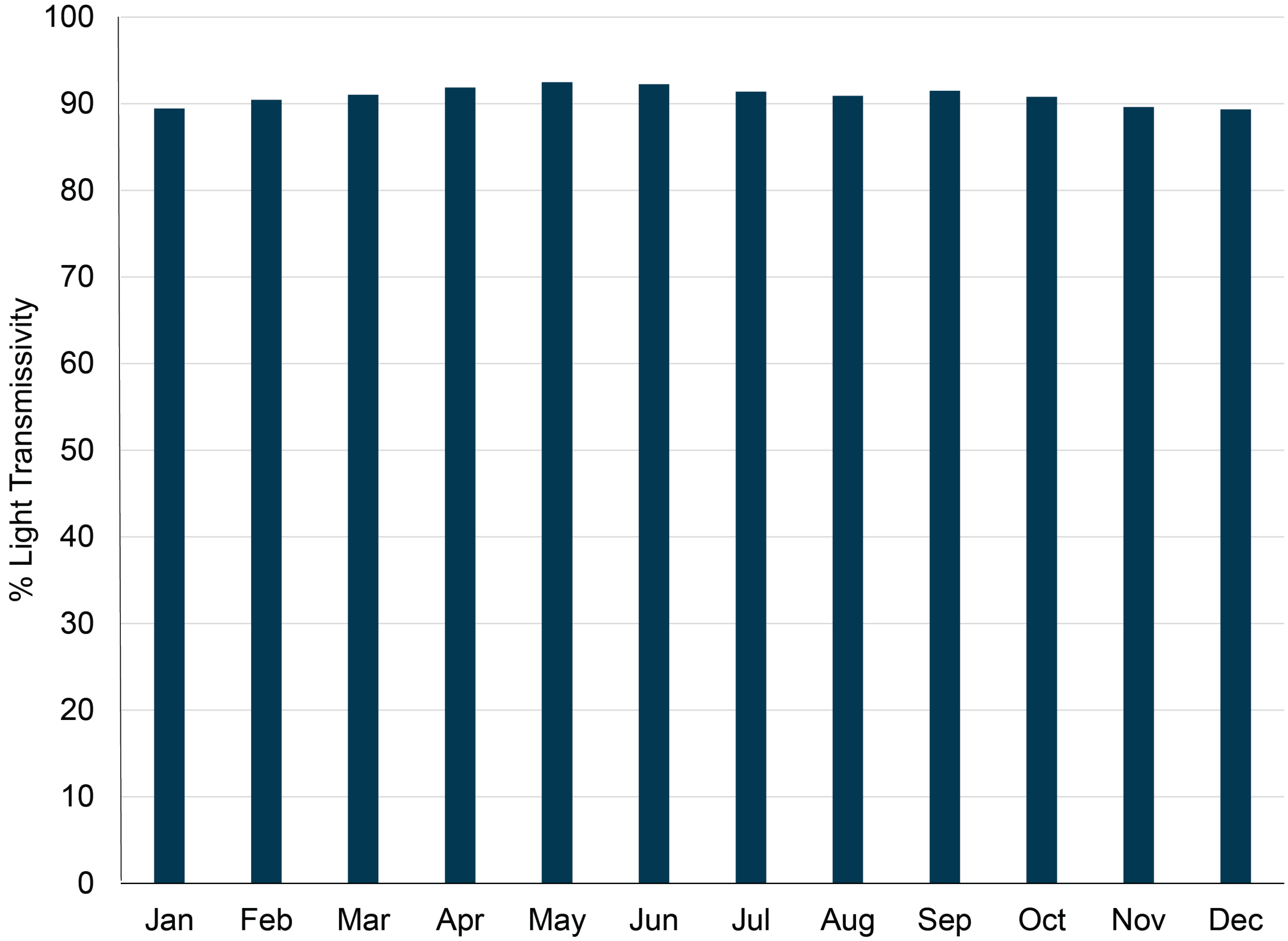


Figure 3.115. Option E-4 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.30. Option E-4 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total (2,000 ac)
E-4	Cargo	2.75	3.00	1.75	1.50	3.00	2.00	56.00
E-4	Fishing	0	0	0	0	0.25	0	1.00
E-4	Other	0.75	1.00	1.50	0.50	0.50	2.50	27.00
E-4	Passenger	0	0.25	0	0	0	0.25	2.00
E-4	Pleasure and Sailing	0	0.25	0	0.50	0.25	1.00	8.00
E-4	Tanker	0.25	0.25	1.50	0.25	0	0.50	11.00
E-4	Tug and Tow	46.25	32.25	31.50	26.00	16.25	17.50	679.00
*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.								

Table 3.31. Number of individual Automatic Identification System-equipped vessels that transited through option E-4.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
E-4	Cargo	9	7	6	6	10	4
E-4	Fishing	0	0	0	0	1	0
E-4	Other	3	4	6	2	2	7
E-4	Passenger	0	1	0	0	0	1
E-4	Pleasure and Sailing	0	1	0	2	1	4
E-4	Tanker	1	1	2	1	0	2
E-4	Tug and Tow	37	28	33	25	14	16

AOA Option E-3 Characterization

Option E-3 was the middle option when considering the overall score based on the among-cluster analysis results (Table 3.9). E-3 has the highest logistics score based on distance to the closest inlet. E-3 also had moderately low AIS vessel traffic (2015 - 2019) and high overlap with fishing effort spatially and temporally within the time periods assessed (Table 3.9).

General Characteristics

AOA option E-3 is a 2,000-ac option located in the federal waters to the west of Florida's Gulf of Mexico coastline and state water boundary (Table 3.32). E-3 is between 90 and 91.6 km to the inlets off Port Manatee and Tampa, FL (Figure 3.116). Notably, there are many inlets that may be equally desirable based on infrastructure and aquaculture farm needs. Option E-3 falls under Florida Congressional District 16, State Senate District 21, and House District 70. There are 13 federal statutes applicable to all the options identified, including option E-3 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option E-3 are (-83.62981, 27.24644), (-83.62886, 27.27209), (-83.60013, 27.27124), (-83.60108, 27.2456). Option E-3 is located in the GMFMC, USACE Jacksonville District, USCG St. Petersburg Sector (District 7), USEPA Region 4, USFWS Southeast Region, and BOEM Eastern Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 2,000-ac area is 51.0 m, with a maximum depth of 51.9 m and a minimum depth of 49.6 m (Figure 3.117). No recent high-resolution bathymetric survey data are currently available for E-3. Based on available data, the largest differential in depth is 2.4 m. There are multiple high points within E-3 as well as a depression in the western portion, which could potentially indicate areas of hardbottom or coral habitat (Figure 3.117). Percent slope over the area is 0.20%. The mean slope across the area is 0.05° and a maximum of 0.21°.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[40] the sediment of E-3 is composed of approximately 50% sand and 50% gravel. The coarsest sediments (i.e., predominantly gravel) are in the northwest and southeast corners of the option, while less coarse sediments (i.e., predominantly sand) are in the northeast and southwest corners of E-3. The predicted surficial sediment Phi values ranged from -0.2 to -0.4, which indicate sediment with the diameter of very coarse sand (diameter = 1 to 2 mm).

Water Temperature and Salinity

Seasonally the mean daily surface water temperature at option E-3 is lowest from December through April, at which point it increases and remains above 25 °C until October, when it begins to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 18.5 °C, while the maximum was 31.8 °C. The water temperature at 10-m depth followed a similar pattern to the surface water temperature, with a minimum daily mean value of 18.5 °C,

[40] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

and a maximum value of 31.0 °C. The water temperature near the bottom of option E-3 is more consistent year-round, however the most variable among years. The bottom temperature ranged between 18.0 to 27.3 °C (Figure 3.118). Mean daily salinity concentration between 2016 and 2020 at option E-3 was consistent throughout the year, with no major variations or decreases.

Metocean Characteristics

Ocean current speeds at option E-3 rarely exceed 1.0 m/s at all depths examined (Figures 3.119 - 3.121). The currents at the surface and at 10-m depth predominantly move in a south to southeast direction, while currents at the bottom depth generally move in an east to east-southeast direction (Figures 3.119 and 3.121). Wind direction at option E-3 predominantly comes from the east, and only 3.06% of the time is the wind speed greater than 10.28 m/s (Figure 3.122). Ocean waves observed at option E-3 predominantly originate from the south-southeast (Figure 3.123).

Water Quality Considerations

To evaluate water quality at option E-3, nutrient concentration, dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels from the surface to 5-m depth of option E-3 for nitrate, phosphate, and silicate were 0.21 μmol/L, 0.07 μmol/L, and 0.72 μmol/L, respectively. At 25-m depth, nitrate concentration increased to 0.47 μmol/L, phosphate decreased to 0.06 μmol/L, and silicate concentration increased (2.56 μmol/L). Around 50-m depth (i.e., bottom water) nitrate concentration increased to 1.57 μmol/L, phosphate increased (0.13 μmol/L) and silicate concentration decreased to 1.89 μmol/L (Figure 3.124). Dissolved oxygen throughout the water column ranged from 5.0 ml/L at the surface, and 4.9 ml/L at 50-m depth (Figure 3.124). Chlorophyll-*a* concentrations at option E-3 were highest in January (0.35 mg/m^3). The remainder of the year, concentrations ranged from 0.14 mg/m^3 to 0.24 mg/m^3, with the lowest concentration in June (Figure 3.125). The diffuse light attenuation coefficient (Kd) at 490 nm for E-3 was highest in November, December, and January (0.06 to 0.07 m^{-1} for all three months). For the remainder of the year, Kd at 490 nm ranged from 0.03 to 0.05 m^{-1} (Figure 3.126). Percent light transmissivity at 1-m depth ranged between 89.3% (lowest in January) to 92.7% (highest in May) throughout the year (Figure 3.127). Harmful algal blooms (*Karenia brevis*) were not detected within E-3 from 2000 to 2018, however a bloom was detected 4 km to the southeast of the option.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. E-3 does overlap with SUA testing and training area EWTA-2b and overlaps the EGTTR. E-3 does not overlap areas marked as danger zones or restricted areas (Table 3.32). Because of the proximity of option E-3 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

AOA option E-3 does not overlap or intersect deep-sea coral observations (1985 - present), fish havens, artificial reefs, or HAPCs. Within 1 to 3 km of E-3, there are 224 unique hardbottom areas (i.e., natural reefs). E-3 is within the giant manta ray distribution model, overlapping the area deemed to be above the median maximum predicted value to provide conservation measures for the species (Table 3.32). This option also overlaps the loggerhead sea turtle Northwest Atlantic Ocean DPS high use areas. Although no overlap occurs with other sea turtle HUAs for residence or migratory areas, Kemp's ridley, leatherback, hawksbill, or green sea turtles may still be within range of option E-3 (see Appendix B for details). E-3 does not overlap with any current NMFS critical habitat. Essential Fish Habitat designated by the GMFMC and NMFS for E-3 includes shrimp, reef fish, coastal migratory pelagic species, and six highly migratory species (Table 3.41).

Industry, Navigation, and Transportation Considerations

E-3 is located in the Eastern Gulf of Mexico BOEM Offshore Oil and Gas Planning Area. Under the Gulf of Mexico Energy Security Act (2006),[41] restrictions were established with a complete moratorium on oil and gas leasing through June 30, 2022.[42] Therefore, no oil and gas infrastructure, or any marine mineral extraction occurs within E-3 or within a 3 km distance. All navigational infrastructure was avoided within and within 3 km of E-3. Assessment of the cumulative AIS vessel traffic from 2015 to 2020 within E-3 indicated lower vessel traffic by type occurred with pleasure and sailing (n = 2), tug and tow vessels (n = 3), passenger and fishing (n = 6). Cargo vessels (n = 72), tanker vessels (n = 18), and other vessels (n = 16) had relatively higher vessel traffic intersecting option E-3 (Tables 3.33, 3.34).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate E-3 does not intersect with shrimp trawling over the 16 years of data assessed; however, there is a relatively low amount of bandit reef fishing and long line reef fishing that interacted with option E-3 sometime between 2007 – 2019.

[41] https://www.boem.gov/oil-gas-energy/energy-economics/gulf-mexico-energy-security-act-gomesa
[42] https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/GOMESA-Map.pdf

Table 3.32. Characterization summary for Aquaculture Opportunity Area option E-3.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-83.62981, 27.24644
	-83.62886, 27.27209
	-83.60013, 27.27124
	-83.60108, 27.2456
Size (ac)	2,000
Closest inlet (km)	89
Depth (m) (minimum, mean, maximum)	(49.6, 51.0, 51.9)
National Security	
Military Operating Areas (MOA)	Overlaps EGTTR
Special Use Airspace (SUA)	Overlaps SUA ETWA-2b
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	11.75
Fishing Vessels 2015 - 2019	0.75
Military Vessels 2015 - 2019	0
Other Vessels 2015 – 2019	3.25
Passenger Vessels 2015 - 2019	0.25
Pleasure and Sailing Vessels 2015 - 2019	0.50
Tanker Vessels 2015 - 2019	4.00
Tug and Tow Vessels 2015 - 2019	0.75
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	3.06
Surface Current Speed % > 1.0 m/s (%)	0.03
Significant Wave Height % > 1.75 m (%)	6.6

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	Hardbottom within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlap with NW Atlantic DPS loggerhead sea turtle HUA and species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	None within reporting range
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	None within reporting range
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.8
Salinity (PSU) at 5-m depth (mean)	35.6
Nutrients (nitrate, phosphate, silicate) (μmol/L) – 5 m depth (mean)	(0.21, 0.07, 0.72)
Mean Aragonite Saturation State (Ω)	4
Governance	
Agency boundary (USACE Districts)	Jacksonville District
Agency boundary (USCG Sectors)	Sector St. Petersburg; District 7
Agency boundary (USEPA Regions)	Region 4
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Eastern Gulf of Mexico

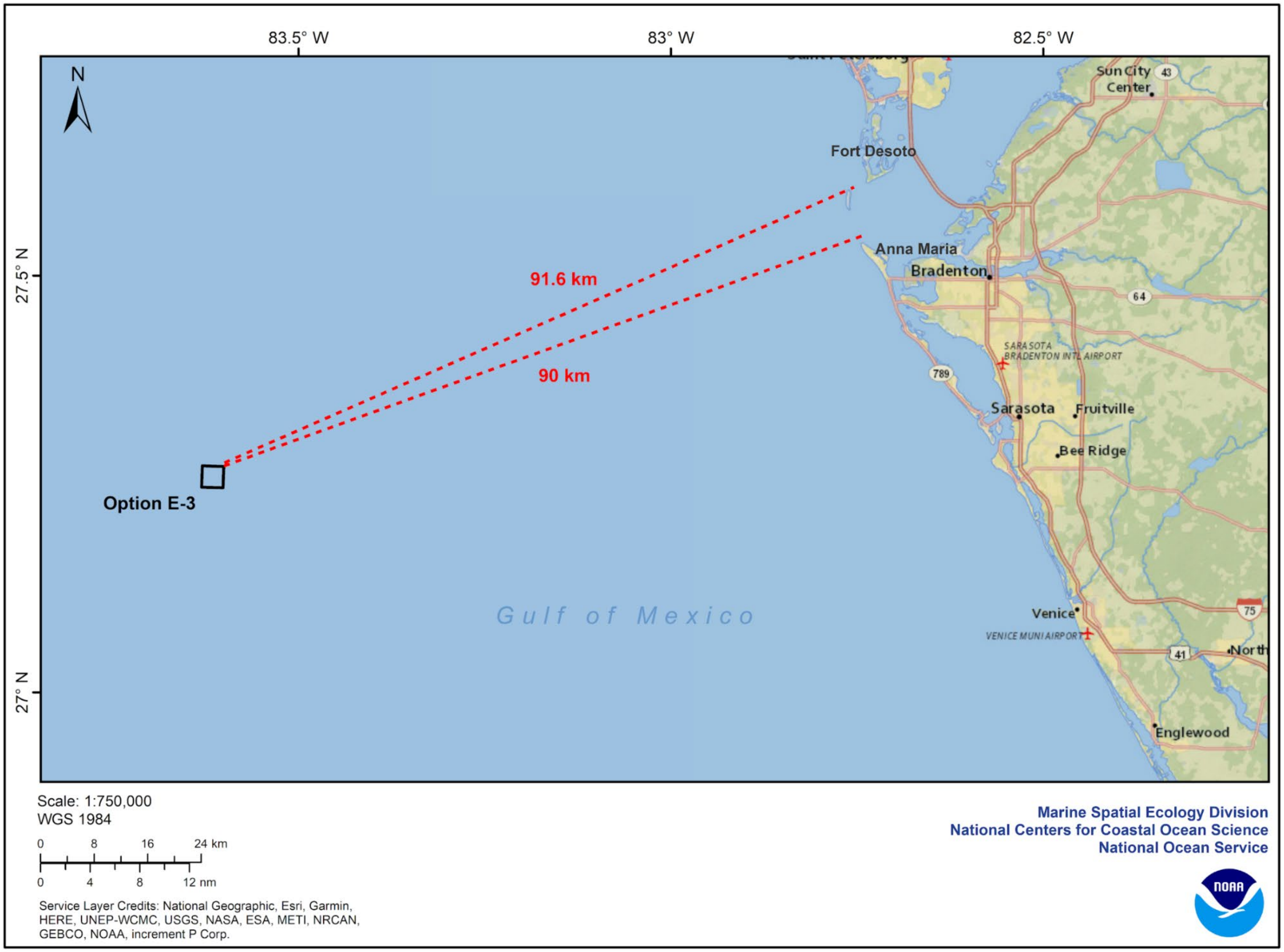


Figure 3.116. Option E-3 (black outlined box) and distance to the closest inlet from the closest corner points of E-3; the area is located in federal waters off the Gulf coast of Florida.

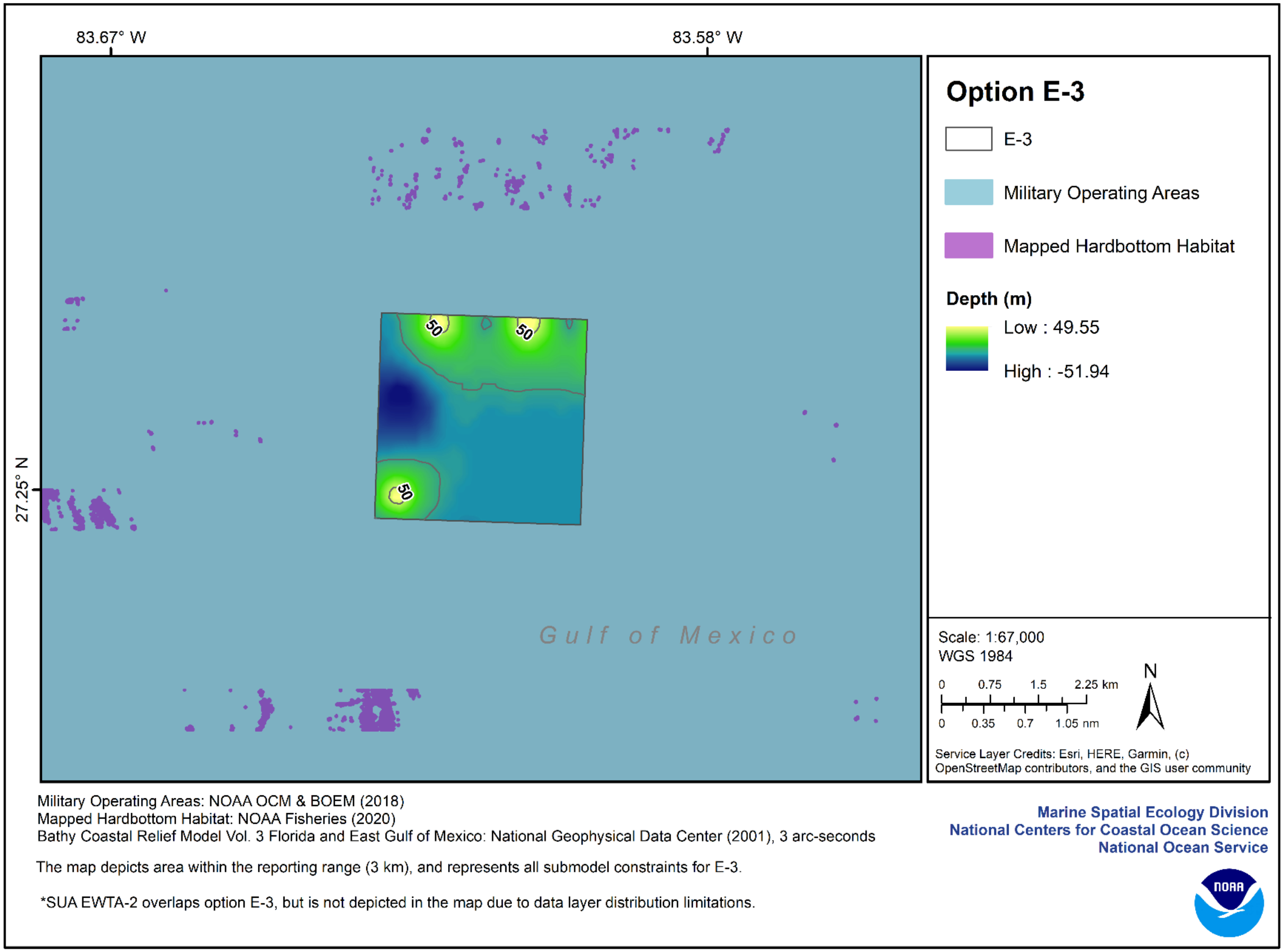


Figure 3.117. Option E-3 bathymetric data and constraints within the vicinity of the option.

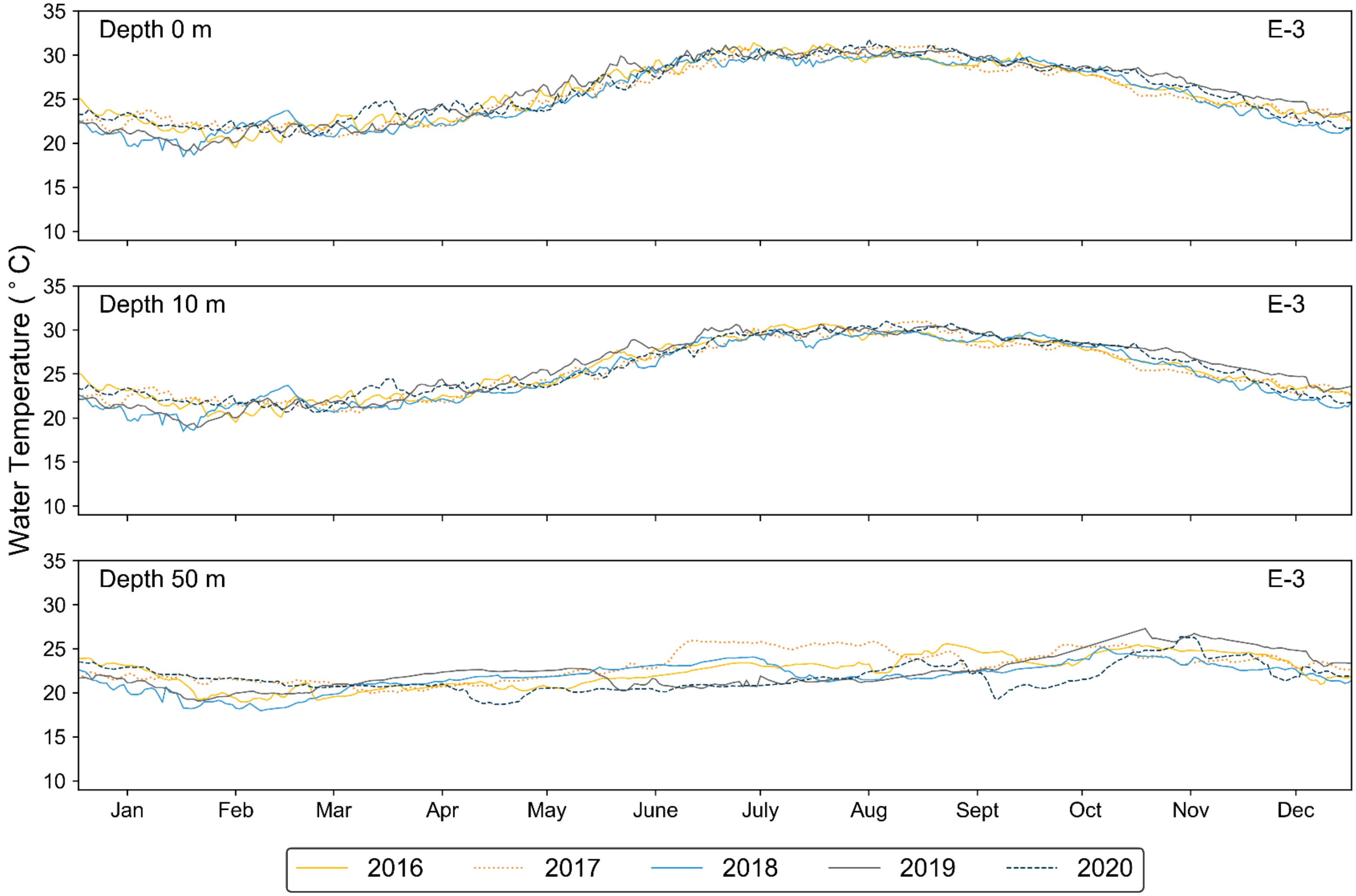


Figure 3.118. Option E-3 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 50-m depth (2016 - 2020).

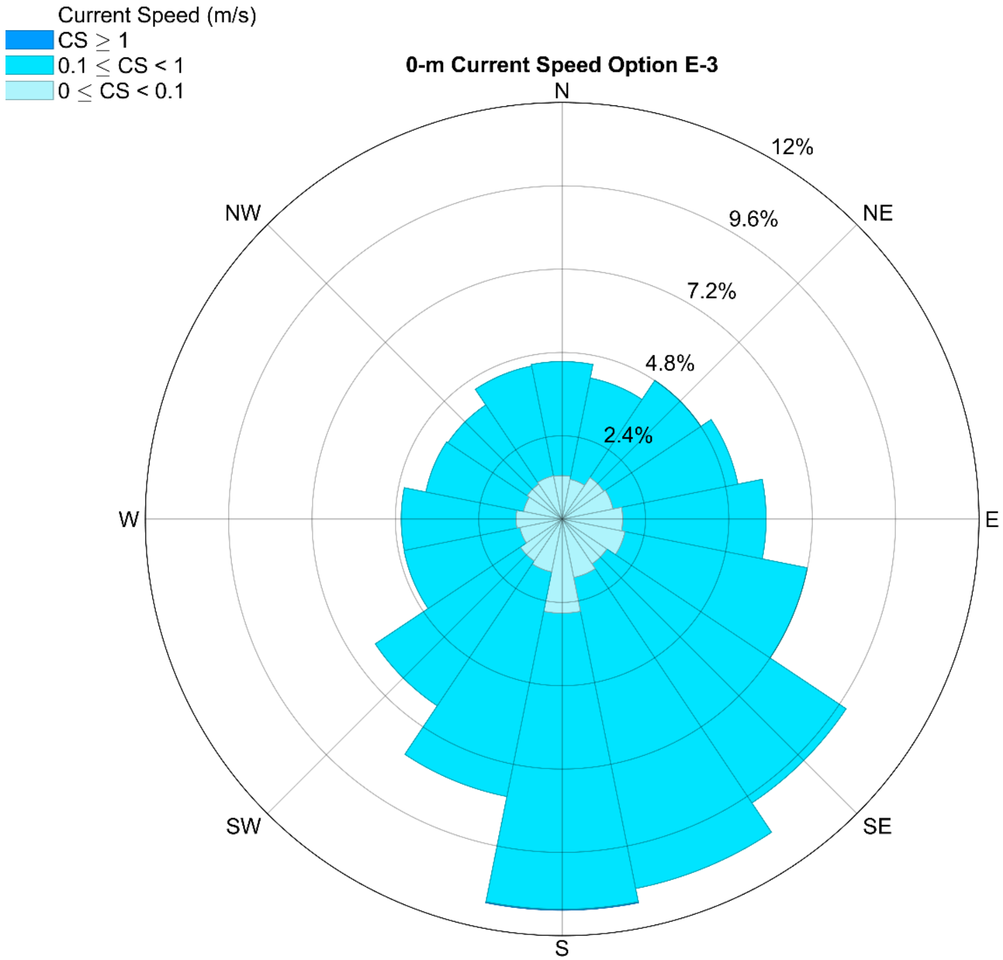


Figure 3.119. Ocean current magnitude and direction for option E-3 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

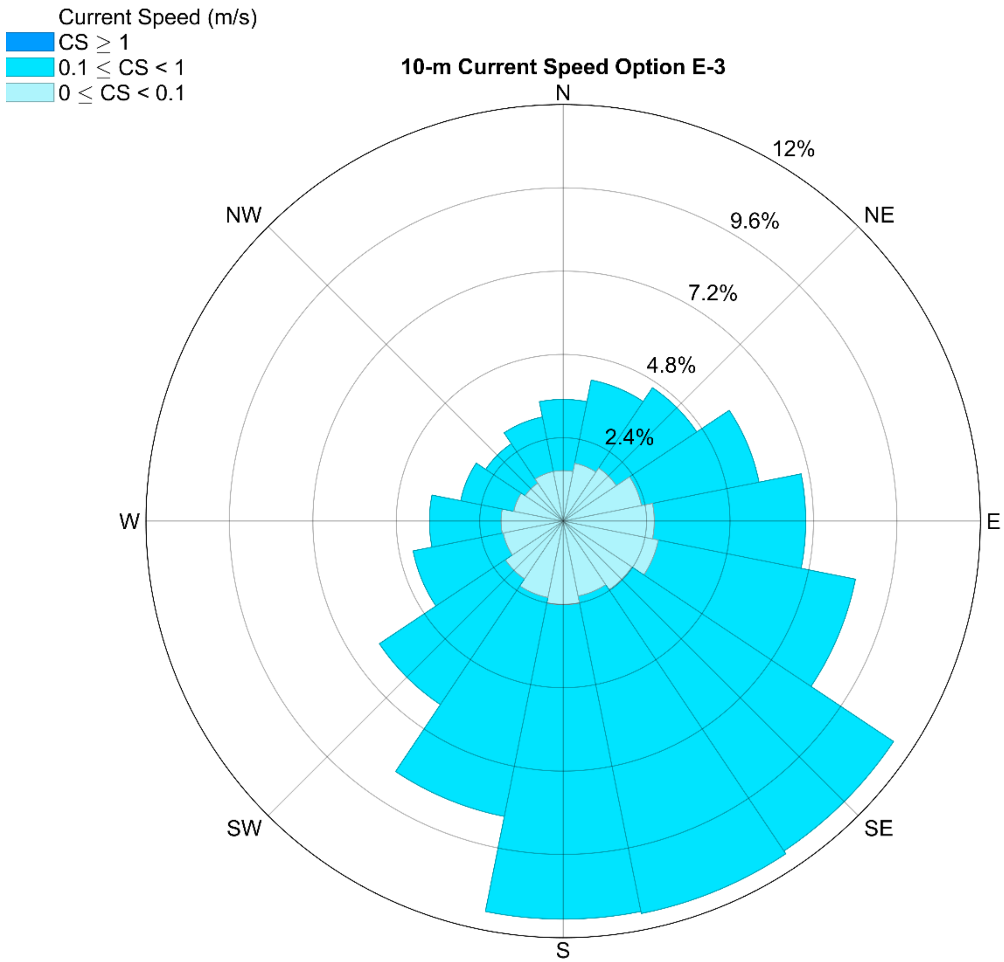


Figure 3.120. Ocean current magnitude and direction for option E-3 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

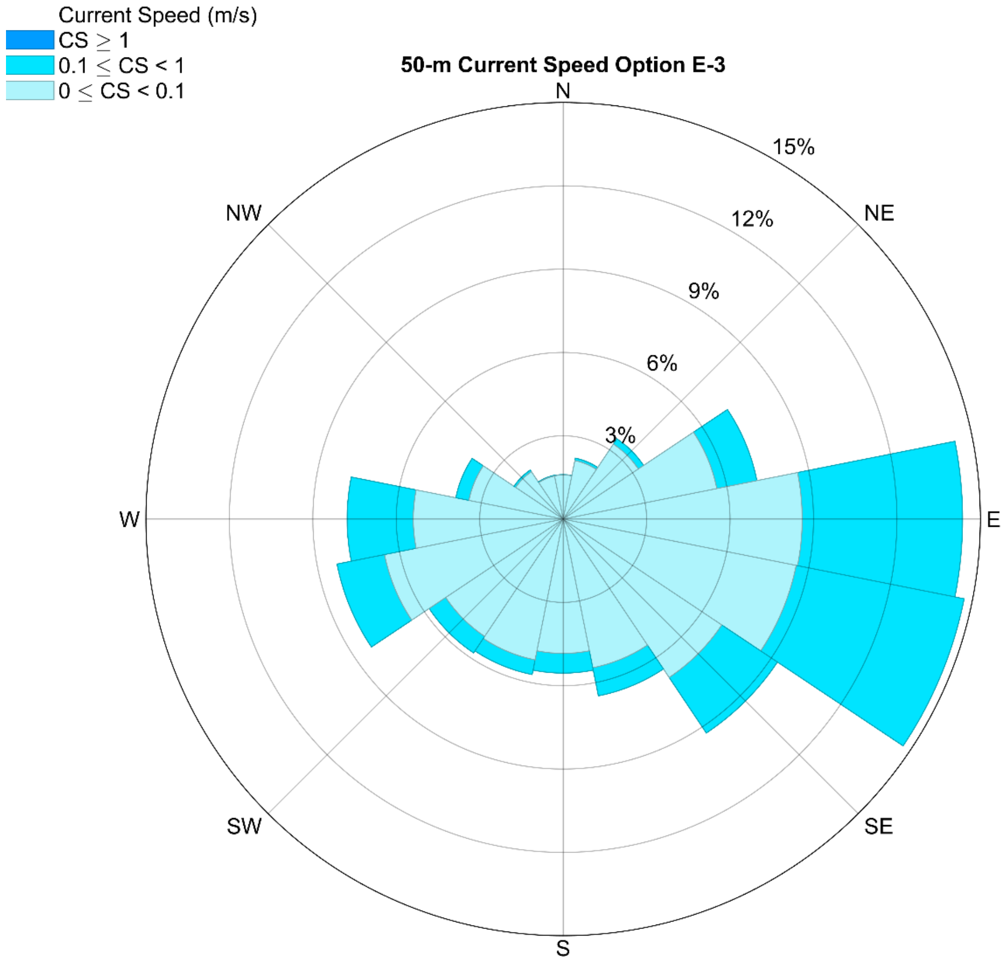


Figure 3.121. Ocean current magnitude and direction for option E-3 at 50-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

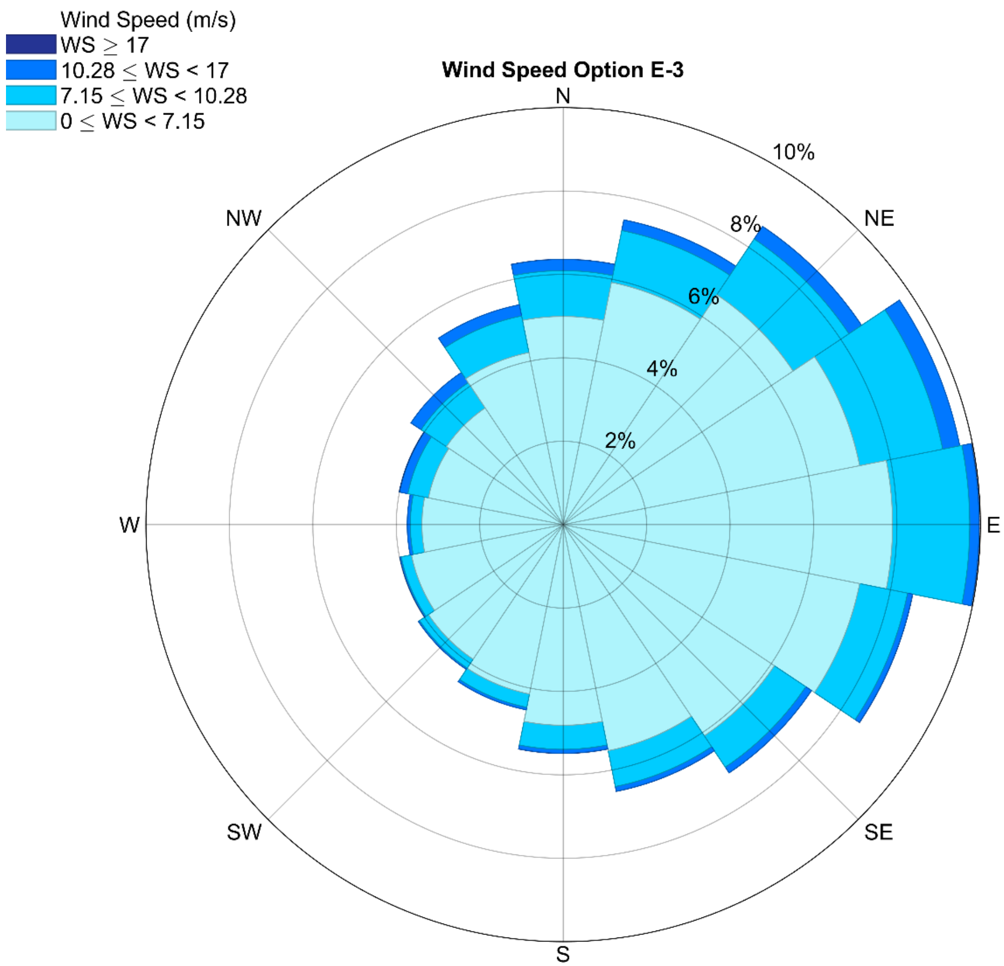


Figure 3.122. Wind velocity and direction at 10-m above sea level for option E-3. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

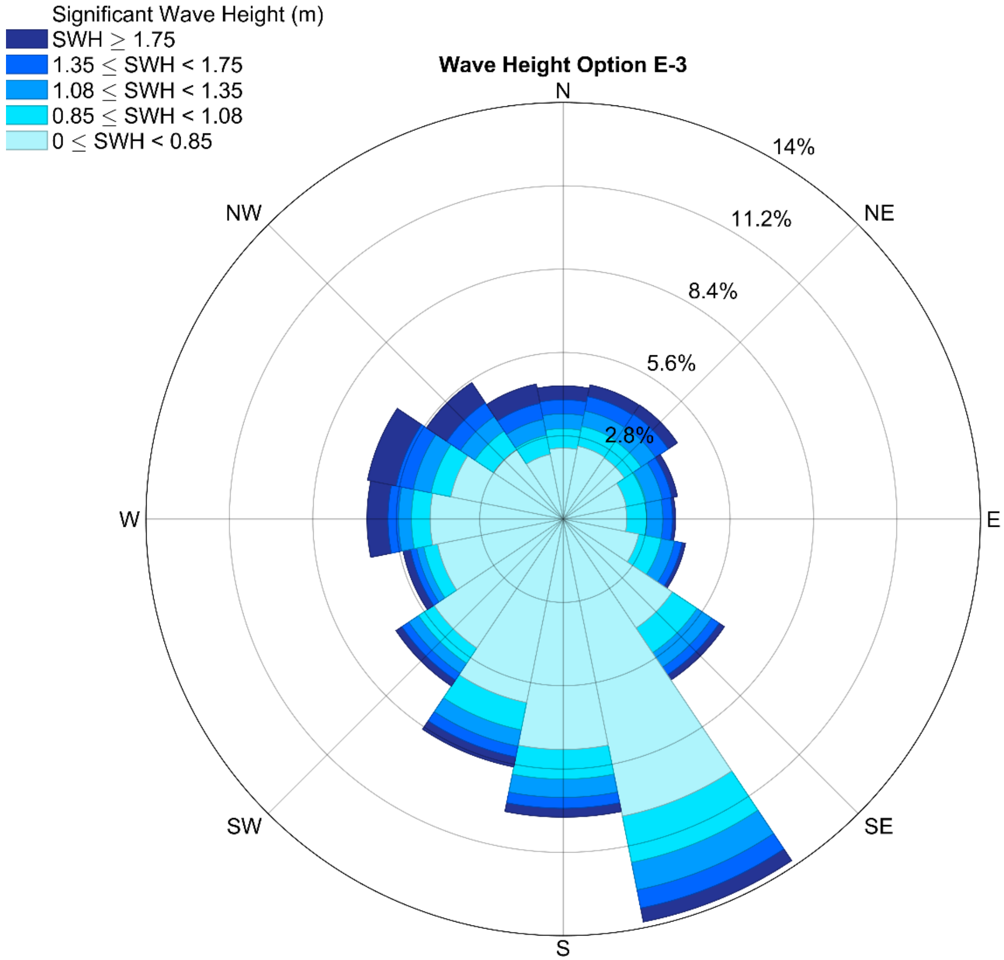


Figure 3.123. Significant wave height and direction at 10-m for option E-3. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

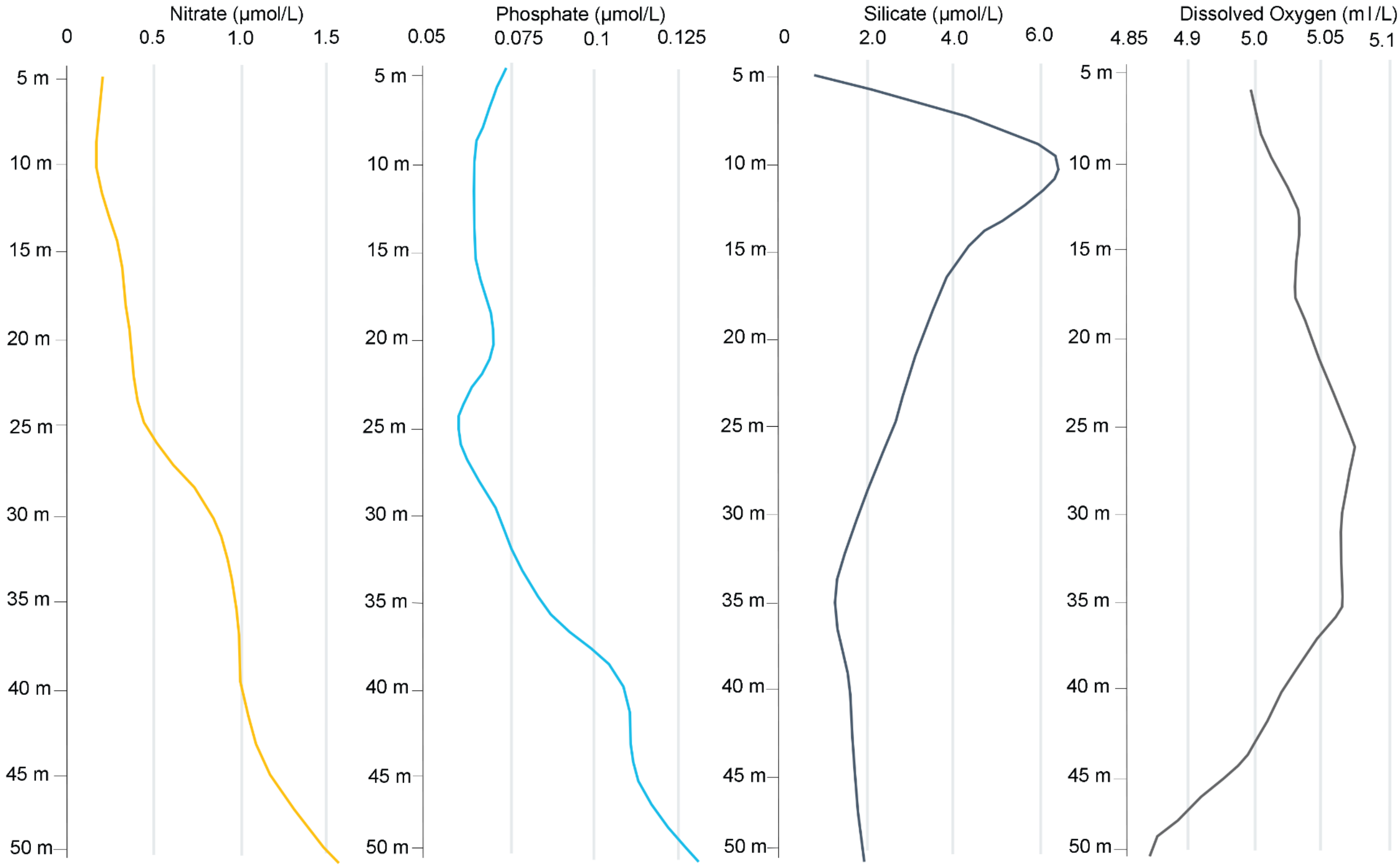


Figure 3.124. Option E-3 concentration of dissolved nitrate, phosphate, silicate and oxygen at different depth levels derived from the Ecological Marine Units (Sayre et al. 2017).

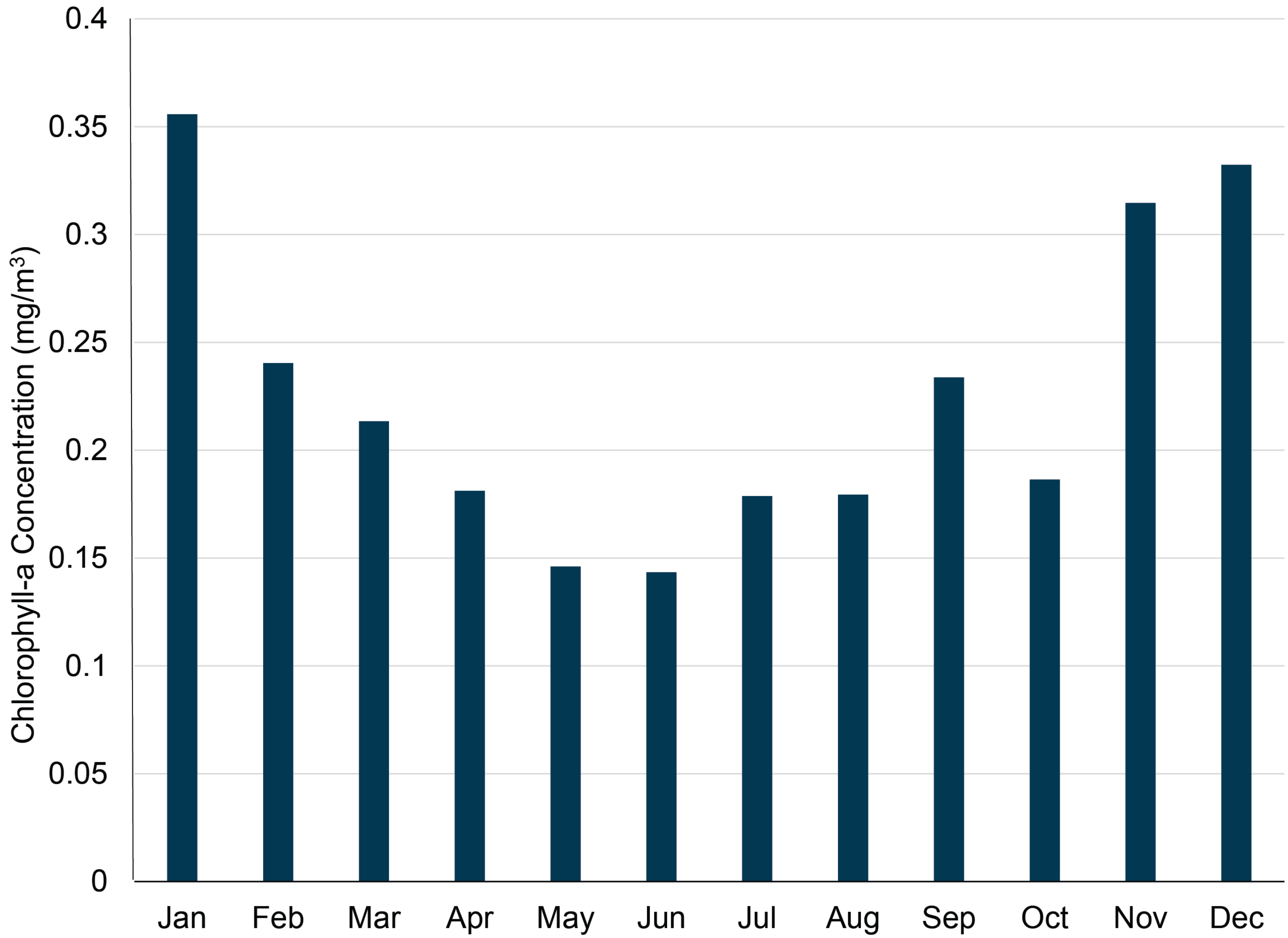


Figure 3.125. Option E-3 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

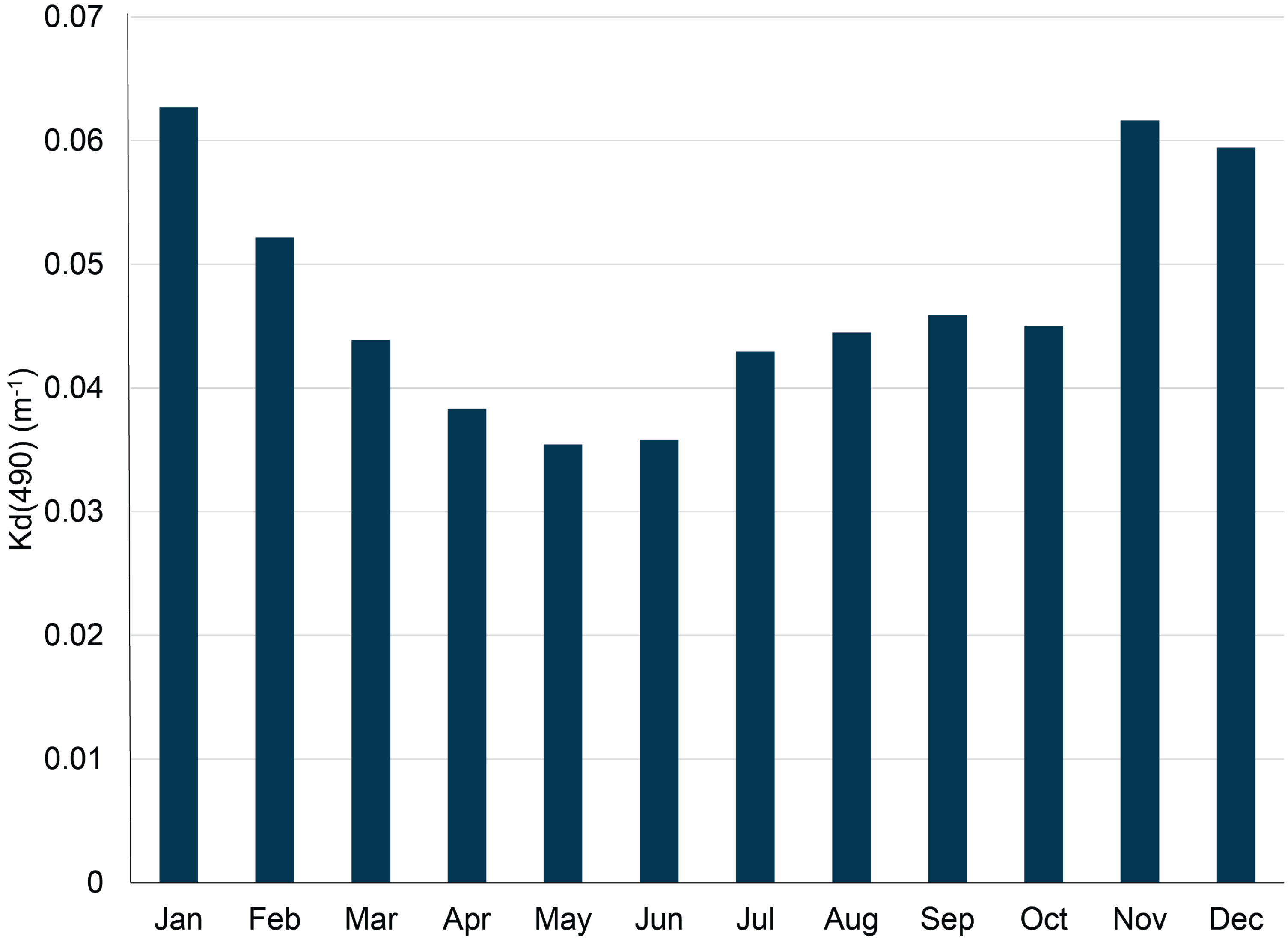


Figure 3.126. Option E-3 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

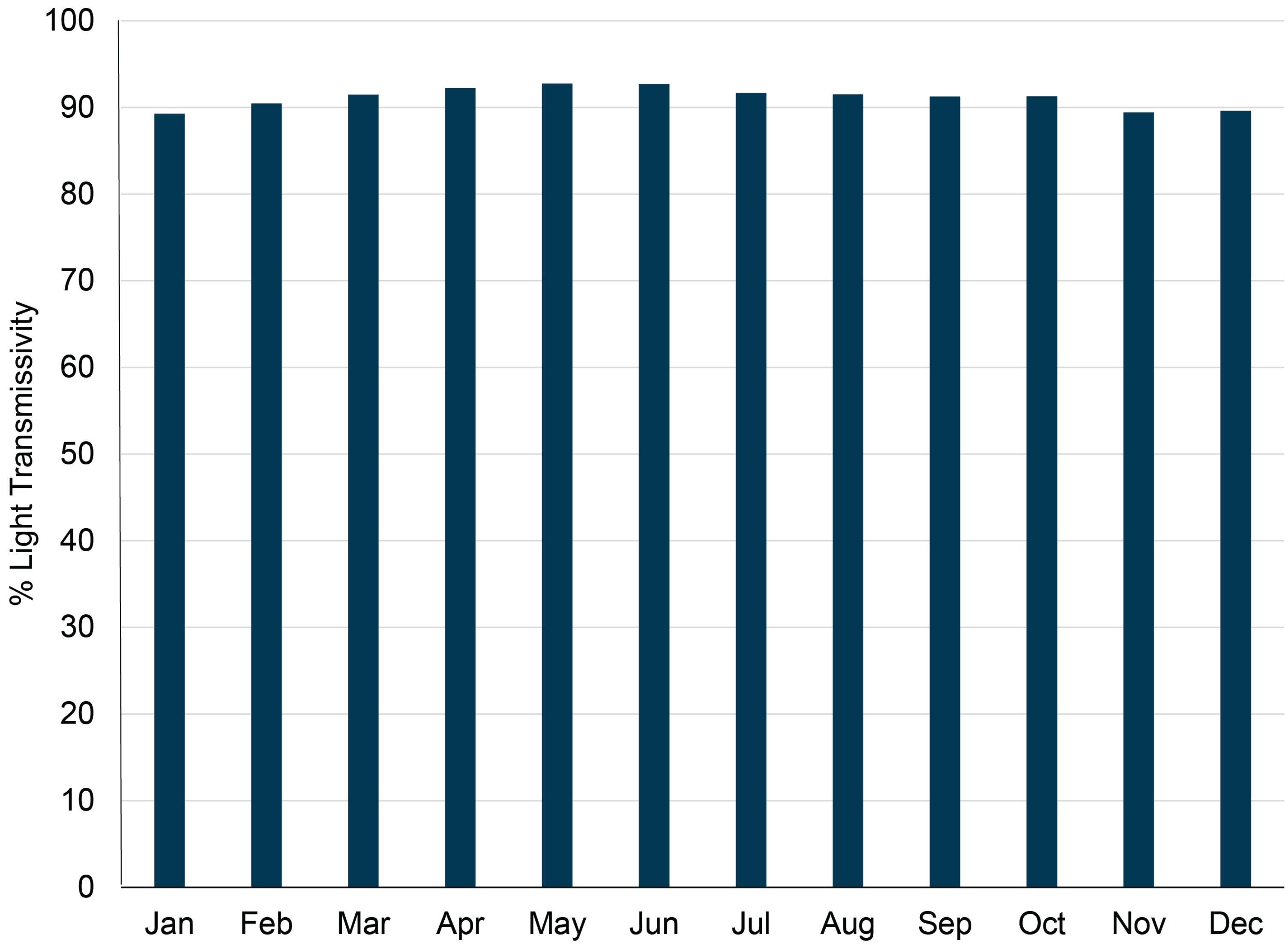


Figure 3.127. Option E-3 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.33. Option E-3 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 2,000-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total (2,000 ac)
E-3	Cargo	2.25	1.75	2.25	3.00	2.50	6.25	72.00
E-3	Fishing	0	0.25	0.25	0.25	0	0.75	6.00
E-3	Other	0.25	0.75	1.25	0.25	0.75	0.75	16.00
E-3	Passenger	0	0	0	0.25	0	1.25	6.00
E-3	Pleasure and Sailing	0	0.25	0	0.25	0	0	2.00
E-3	Tanker	2.00	0.50	1	0.25	0.25	0.50	18.00
E-3	Tug and Tow	0.25	0	0.25	0	0.25	0	3.00

*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.

Table 3.34. Number of individual Automatic Identification System-equipped vessels that transited through option E-3.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
E-3	Cargo	8	7	8	11	9	10
E-3	Fishing	0	1	1	1	0	3
E-3	Other	1	3	3	1	3	1
E-3	Passenger	0	0	0	1	0	2
E-3	Pleasure and Sailing	0	1	0	1	0	0
E-3	Tanker	6	2	4	1	1	2
E-3	Tug and Tow	1	0	1	0	1	0

AOA Option E-1 Characterization

Option E-1 was the highest scoring option when looking at the overall score based on the among-cluster analysis results (Table 3.9). E-1 has a moderate logistics score based on distance to the closest inlet. E-1 AIS vessel traffic (2015 - 2019) has a moderate score relative to other East study area options, reflecting the moderate amount of vessel traffic intersecting the option. There is relatively low overlap with fishing effort spatially and temporally within the time periods assessed (Table 3.9).

General Characteristics

AOA option E-1 is between 104 km and 107.7 km to the inlets off of Fort Myers, FL (Figure 3.128). Notably, there are many inlets that may be equally desirable based on infrastructure and farm needs. Option E-1 falls under Florida Congressional District 19, State Senate District 27, and House District 76. There are 13 federal statutes applicable to all of the options identified, including option E-1 (Table 3.10). Corner point coordinates (latitude, longitude in decimal degrees) for option E-1 are (83.93697, 27.7661), (-83.9361, 27.79175), (-83.90723, 27.79097), (-83.90813, 27.76531). Option E-1 is located in the GMFMC, USACE Jacksonville District, the USCG St. Petersburg Sector (District 7), USEPA Region 4, USFWS Southeast Region, and BOEM Eastern Gulf of Mexico Planning Area for the energy sector.

Oceanographic and Biophysical Considerations

Depth and Substrate Type

The mean depth across the 500-ac area of option E-1 is 50.6 m, with a maximum depth of 51.0 m and a minimum depth of 50.1 m calculated from a ~90-m raster surface (Figure 3.129). No recent high-resolution bathymetric survey data are currently available for E-1. Based on available data, the largest differential in depth was 0.9 m. E-1 has a relatively flat bottom (e.g., % slope = 0.06) with the shallower waters in the northeast portion of the option, and deeper waters in the southern portion of the option (Figure 3.129).

Based on predicted surficial sediment data (as percent sand/mud/gravel) for the Gulf of Mexico,[43] the sediment of E-1 is composed of 86 to 92% sandy substrate. The northwest corner of E-1 has a sandier bottom type relative to the southeast corner, where it becomes slightly more mud-like. The predicted surficial sediment Phi values ranged from 2.0 to 2.2, which indicate sediment with the diameter of fine sand (diameter = 0.25 mm).

Water Temperature and Salinity

Seasonally the mean daily surface water temperature at option E-1 is lowest from late December through April, at which point it increases and remains above 25°C until December, when it begins to decrease again. The minimum mean daily surface temperature between 2016 and 2020 was 19.7°C, while the maximum was 31.6°C. The water temperature at 10-m depth followed a similar pattern to the surface water temperature, with a minimum daily mean value of 19.5°C, and a maximum value of 30.7°C. The water temperature near the bottom of option E-1 is more consistent year-round, and stayed between 18.1°C and 27.7°C (Figure 3.130). Mean daily salinity concentration between 2016 and 2020 at option E-1 was consistent throughout the year, with no major variations or decreases.

[43] https://deepseacoraldata.noaa.gov/library/2015-state-of-dsc-report-folder/Ch8_Spotlight_Guinotte.pdf

Metocean Characteristics

Ocean current speeds at option E-1 rarely exceed 1.0 m/s at all depths examined (Figures 3.131 - 3.133). The currents at all depths follow a similar pattern that predominantly was in a south to southeast direction (Figures 3.131 - 3.133). Wind direction at option E-1 predominantly is from the east, and only 3.36% of the time is the wind speed greater than 10.28 m/s (Figure 3.134). Ocean waves observed at option E-1 predominantly originate from the south-southeast (Figure 3.135).

Water Quality Considerations

To evaluate water quality at option E-1, nutrient concentration, dissolved oxygen, Chl-*a*, and water clarity were examined. Mean dissolved nutrient levels at the surface for nitrate, phosphate, and silicate were 0.36 μmol/L, 0.08 μmol/L, and 1.13 μmol/L, respectively. Notably, at 10-m depth silicate rapidly increased to 5.13 μmol/L. At 30-m depth, nitrate concentration increased to 0.83 μmol/L, phosphate remained steady at 0.08 μmol/L, and silicate concentration increased (1.73 μmol/L). Around 50-m depth (i.e., bottom water) nitrate concentration increased to 1.47 μmol/L, phosphate increased (0.10 μmol/L) and silicate concentration decreased to 1.55 μmol/L (Figure 3.136). Dissolved oxygen throughout the water column ranged from 4.9 ml/L at the surface to 5.0 ml/L at 40-m depth (Figure 3.136). Chlorophyll-*a* concentrations at option E-1 were highest in winter, i.e., December (0.39 mg/m^3) and January (0.39 mg/m^3). The remainder of the year, concentrations ranged from 0.12 mg/m^3 to 0.27 mg/m^3, with the lowest concentration in June (0.12 mg/m^3) (Figure 3.137). The diffuse light attenuation coefficient (Kd) at 490 nm for E-1 was highest in December and January (0.06 m^{-1} for both months). For the remainder of the year, Kd at 490 nm ranged from 0.03 to 0.05 m^{-1} (Figure 3.138). Percent light transmissivity at 1-m depth ranged between 89% (lowest in January) to 93% (highest in May) (Figure 3.139). option E-1 had no harmful algal blooms (*Karenia brevis*) detected within it from 2000 to 2018, with the closest detected *K. brevis* bloom occurring 21 km to the northeast.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) (e.g., unexploded ordnance areas, danger zones and restricted areas) and moved to the constraints submodel, removing these areas from the remainder of the analysis. Option E-1 overlaps SUA testing and training area EWTA-5 and overlaps the EGTTR. E-1 is within 3 km of SUA W-168. E-1 does not overlap areas marked as danger zones or restricted areas (Table 3.35). Because of the proximity of option E-1 to SUAs, some aquaculture operations may require coordination with the FAA regarding changing conditions or status of the National Airspace System.

Natural and Cultural Resource Considerations

AOA option E-1 does not overlap or intersect deep-sea coral observations (1985 - present), fish havens, artificial reefs, or HAPCs. Within 1 to 3 km of E-1, there are 36 unique hardbottom areas (i.e., natural reefs). Option E-1 is within the giant manta ray species distribution model, overlapping the area deemed to be above the median maximum predicted value to provide conservation measures for the species (Table 3.35). This option also overlaps the loggerhead sea turtle Northwest Atlantic Ocean DPS high use areas. Although no overlap occurs with other sea turtle HUAs for residence or migratory areas, Kemp's ridley, leatherback, hawksbill, or green sea turtles may still be within range (see Appendix B for details). E-1 does not overlap with any current NMFS critical habitat. Essential Fish Habitat designated by the GMFMC and NMFS for option E-1 includes shrimp, reef fish, coastal migratory pelagic species, and six highly migratory species (Table 3.41).

Industry, Navigation and Transportation Considerations

Option E-1 is in the Eastern Gulf of Mexico BOEM Offshore Oil and Gas Planning Area. Under the Gulf of Mexico Energy Security Act (2006),[44] restrictions were established with a complete moratorium on oil and gas leasing through June 30, 2022.[45] Therefore, no oil and gas infrastructure and no marine mineral extraction occurs within option E-1 or within a 3-km distance. All navigational infrastructure is avoided in and within 3-km of option E-1, except for a shipping lane located 750 m to the northwest of this option. Assessment of the cumulative AIS vessel traffic by type from 2015 to 2020 within E-1 indicated lower vessel traffic by pleasure and sailing (n = 1), fishing (n = 2), and tug and tow vessels (n = 9). Cargo vessels (n = 38), passenger vessels (n = 18), and tanker vessels (n = 13) had relatively higher vessel traffic intersecting option E-1 (Tables 3.36, 3.37).

Commercial Fishing Considerations

NOAA NMFS fishing data indicate option E-1 had low interaction with commercial fishing, with no overlap with shrimp trawling or headboat fishing. However, a low amount of bandit gear fishing and reef longline fishing occurred over the 13-year period examined.

[44] https://www.boem.gov/oil-gas-energy/energy-economics/gulf-mexico-energy-security-act-gomesa
[45] https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/GOMESA-Map.pdf

Table 3.35. Characterization summary for Aquaculture Opportunity Area option E-1.

Description	Value
General Characteristics	
Corner Coordinates (latitude, longitude) (decimal degrees)	-83.93697, 27.7661
	-83.9361, 27.79175
	-83.90723, 27.79097
	-83.90813, 27.76531
Size (ac)	500
Closest inlet (km)	104.0
Depth (m) (minimum, mean, maximum)	49.6, 51.1, 52.9
National Security	
Military Operating Areas (MOA)	Overlaps EGTTR
Special Use Airspace (SUA)	Overlaps EWTA-5; W168 within reporting range
Transportation (AIS vessel mean transits per 500 ac)	
Cargo Vessels 2015 - 2019	7.20
Fishing Vessels 2015 - 2019	0.40
Military Vessels 2015 - 2019	0
Other Vessels 2015 - 2019	1.40
Passenger Vessels 2015 - 2019	3.40
Pleasure and Sailing Vessels 2015 - 2019	0
Tanker Vessels 2015 - 2019	2.40
Tug and Tow Vessels 2015 - 2019	1.60
Metocean Characteristics	
Wind Speed % > 10.28 m/s (%)	3.36
Surface Current Speed % > 1.0 m/s (%)	0.01
Significant Wave Height % > 1.75 m (%)	7.0

Description	Value
Natural and Cultural Resources (within 3 km of option)	
Habitat - Distance to hardbottom and other sensitive habitats	Hardbottom within reporting range
Habitat - Distance to deep-sea coral observations	None within reporting range
Important Bird Areas	None within reporting range
Protected Areas	None within reporting range
Artificial Reefs	None within reporting range
Cultural Resources	None within reporting range
NMFS Protected Resources Combined Data Layer	Overlap with NW Atlantic loggerhead sea turtle HUA and species distribution model above the median for giant manta ray (Appendix B).
Industry and Navigation (within 3 km of option, but outside option)	
Oil and Gas Platforms	None within reporting range
Oil and Gas Boreholes	None within reporting range
Oil and Gas Active Lease Blocks	None within reporting range
Oil and Gas Pipelines	None within reporting range
Seabed Mining	None within reporting range
Aquaculture	None within reporting range
Water Quality	
Water Temperature (°C) at 5-m depth (mean)	24.6
Salinity (PSU) at 5-m depth (mean)	35.4
Nutrients (nitrate, phosphate, silicate) (µmol/L) – 5 m depth (mean)	(0.36, 0.08, 1.13)
Mean Aragonite Saturation State (Ω)	3.9
Governance	
Agency boundary (USACE Districts)	Jacksonville District
Agency boundary (USCG Sectors)	Sector St. Petersburg; District 7
Agency boundary (USEPA Regions)	Region 4
Agency boundary (USFWS)	Southeast Region
Agency boundary (BOEM)	Eastern Gulf of Mexico

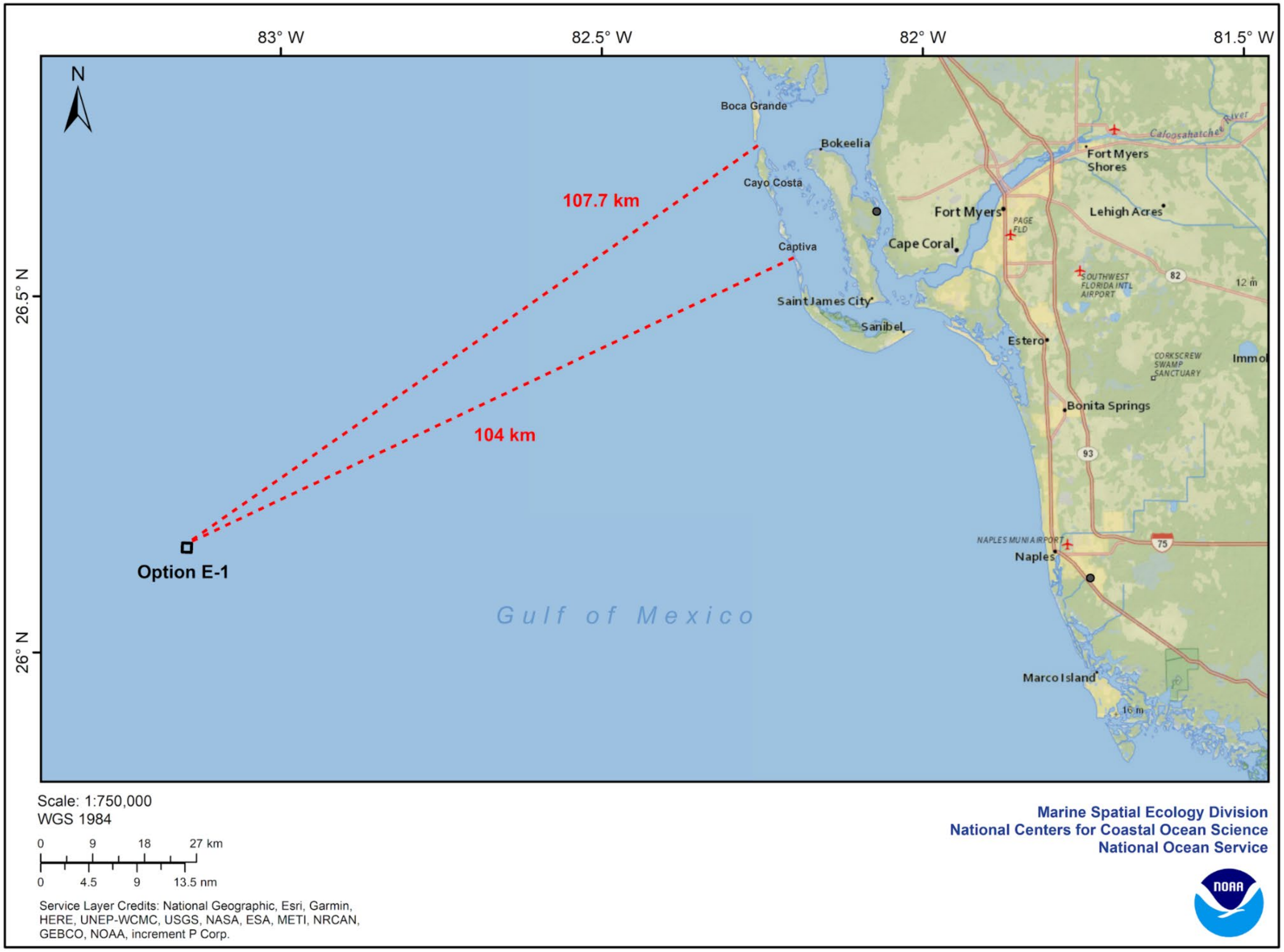


Figure 3.128. Option E-1 (black outlined box) and distance to the closest inlet from the closest corner points of E-1; the area is located in federal waters off the Gulf coast of Florida.

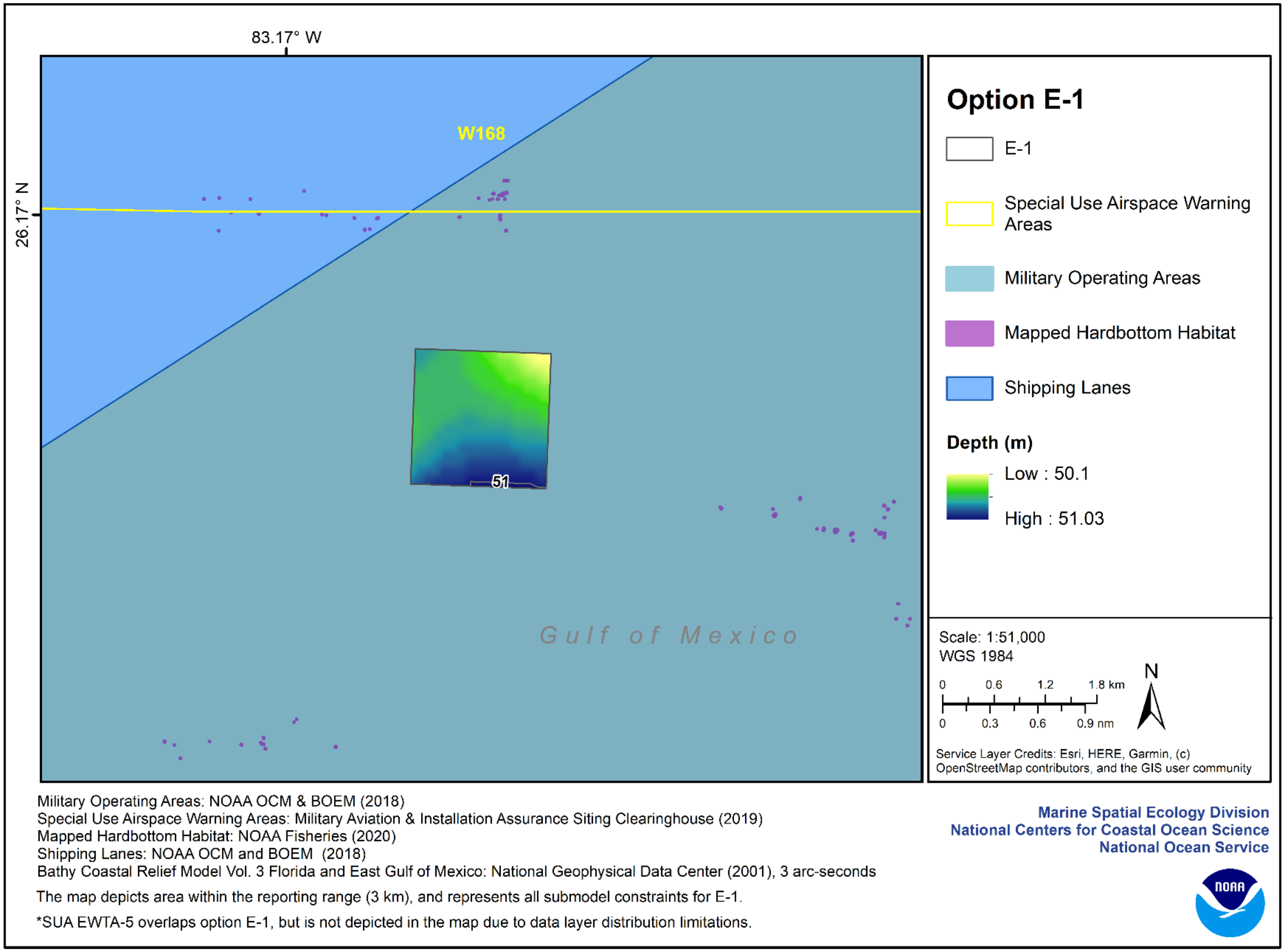


Figure 3.129. Option E-1 bathymetric constraints within the vicinity of the option.

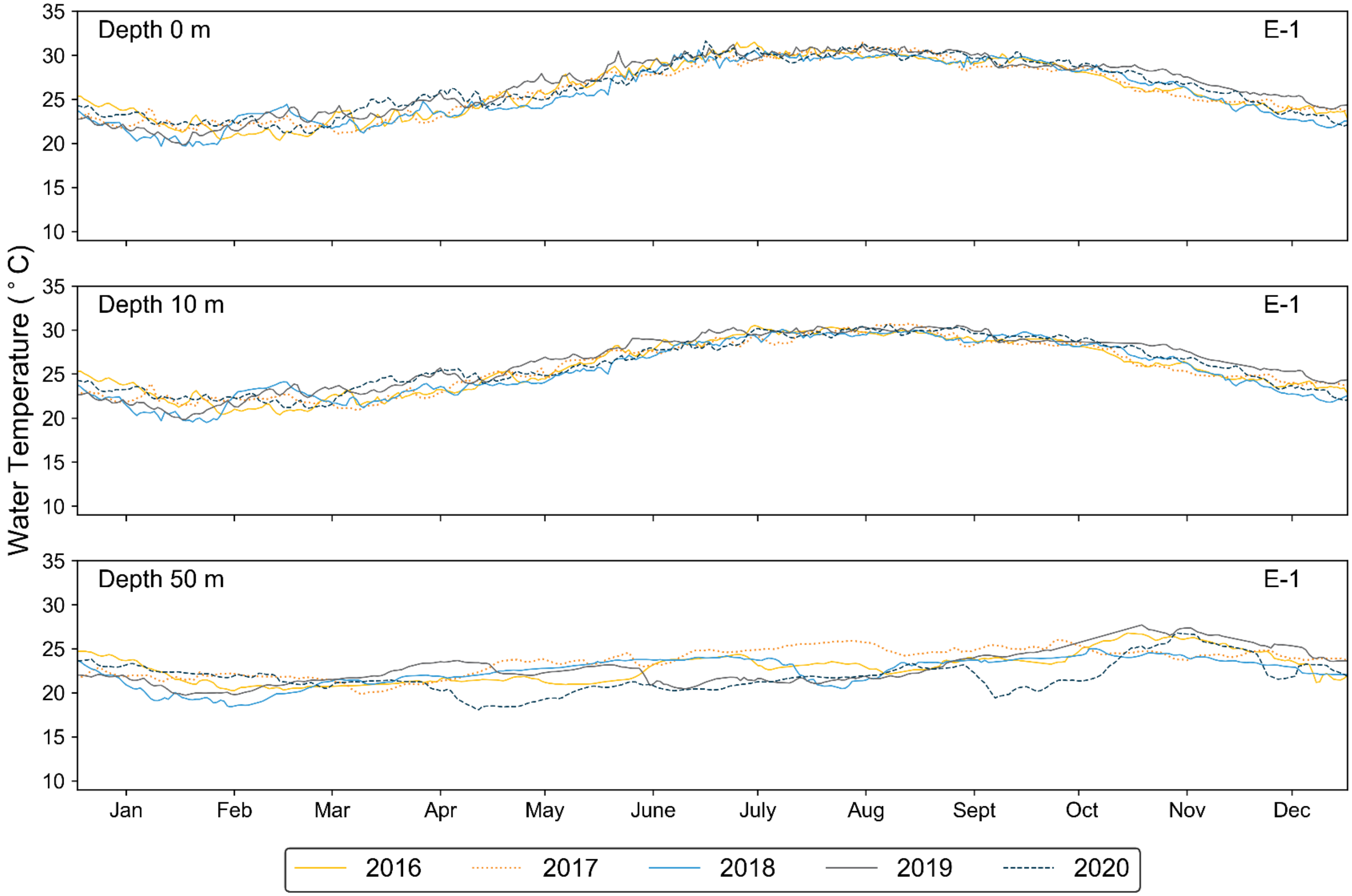


Figure 3.130. Option E-1 Navy Coastal Ocean Model regional American seas model mean daily water temperature at the surface, 10-m depth, and 50-m depth (2016 - 2020).

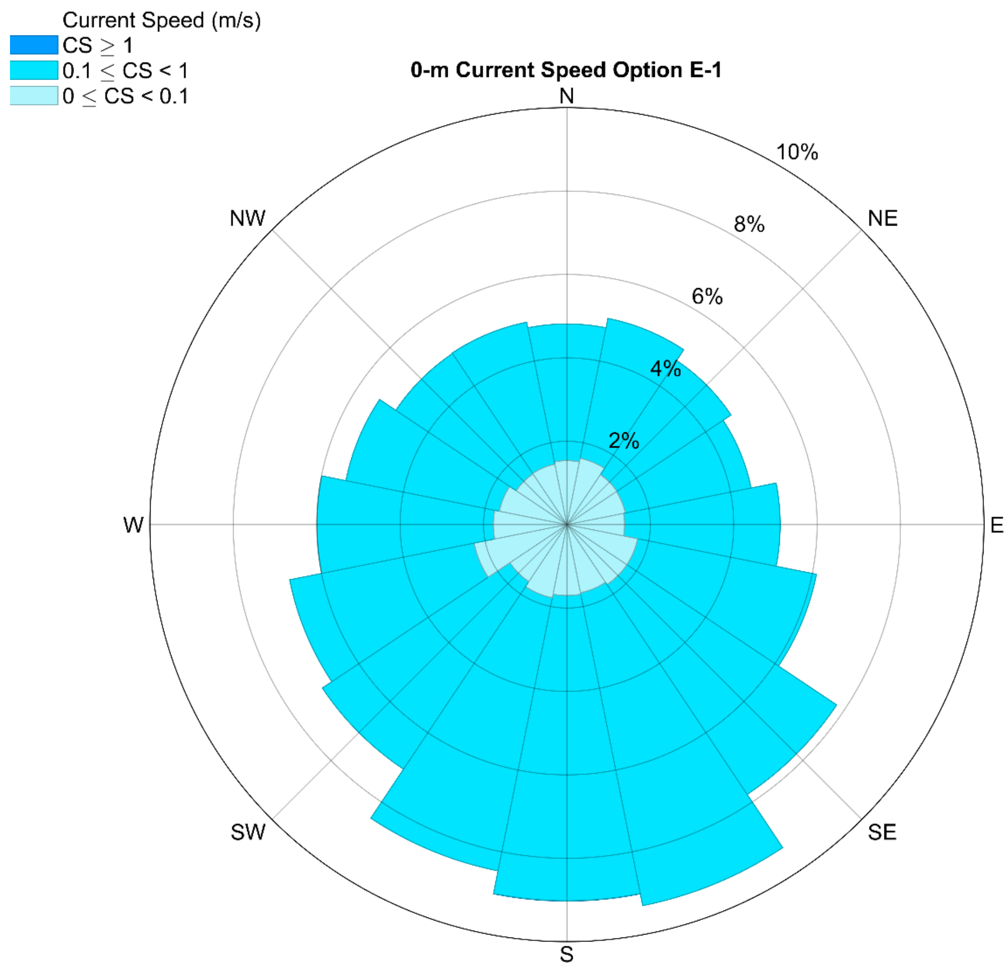


Figure 3.131. Ocean current magnitude and direction for option E-1 at the ocean surface. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

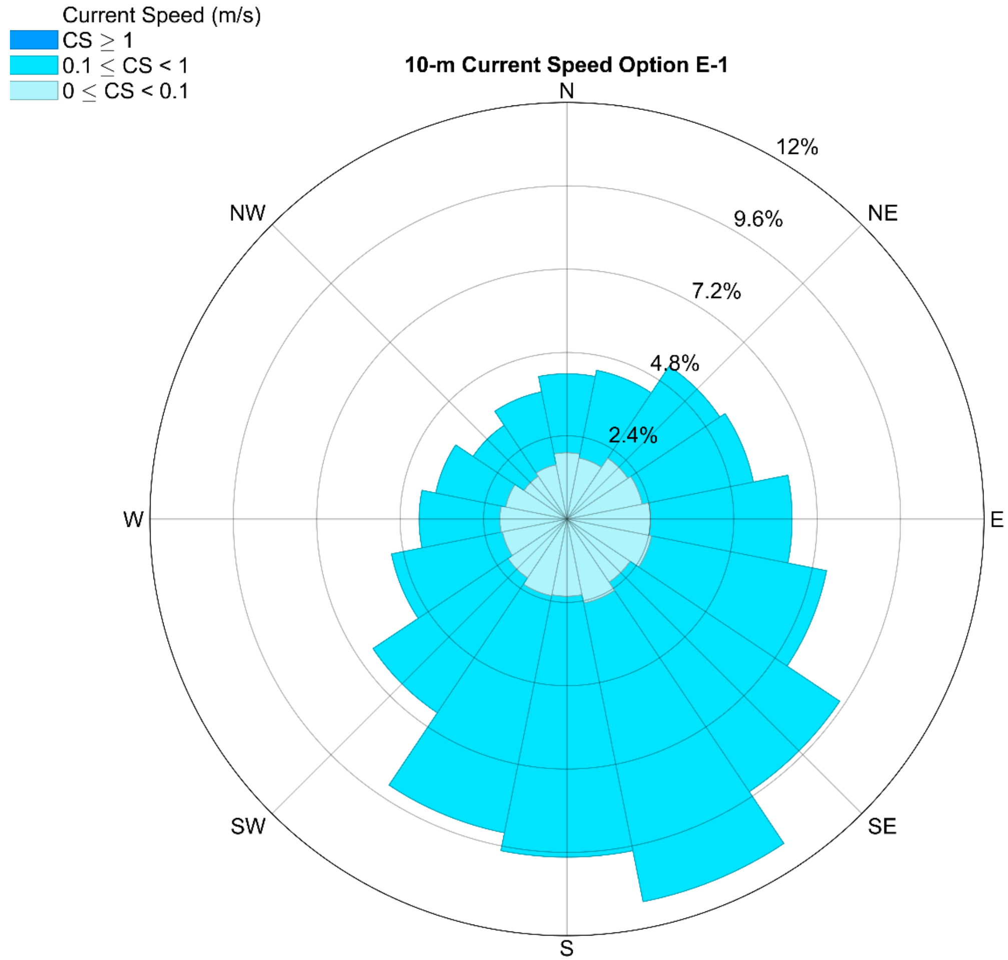


Figure 3.132. Ocean current magnitude and direction for option E-1 at 10-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

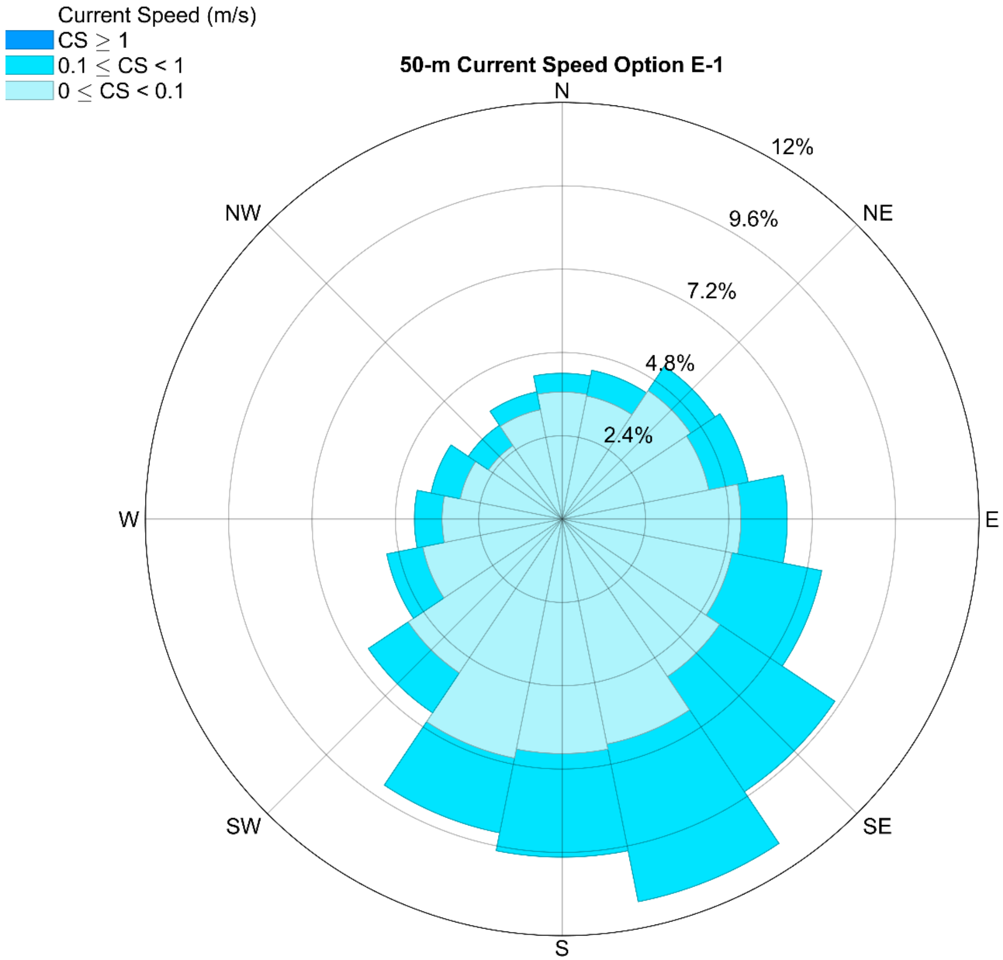


Figure 3.133. Ocean current magnitude and direction for option E-1 at 50-m depth. The rose diagram provides percent occurrence for each current speed category. Current flow is in the direction of the compass heading. Data are from the Navy Coastal Ocean Model, Regional American Seas Model (2016 - 2020).

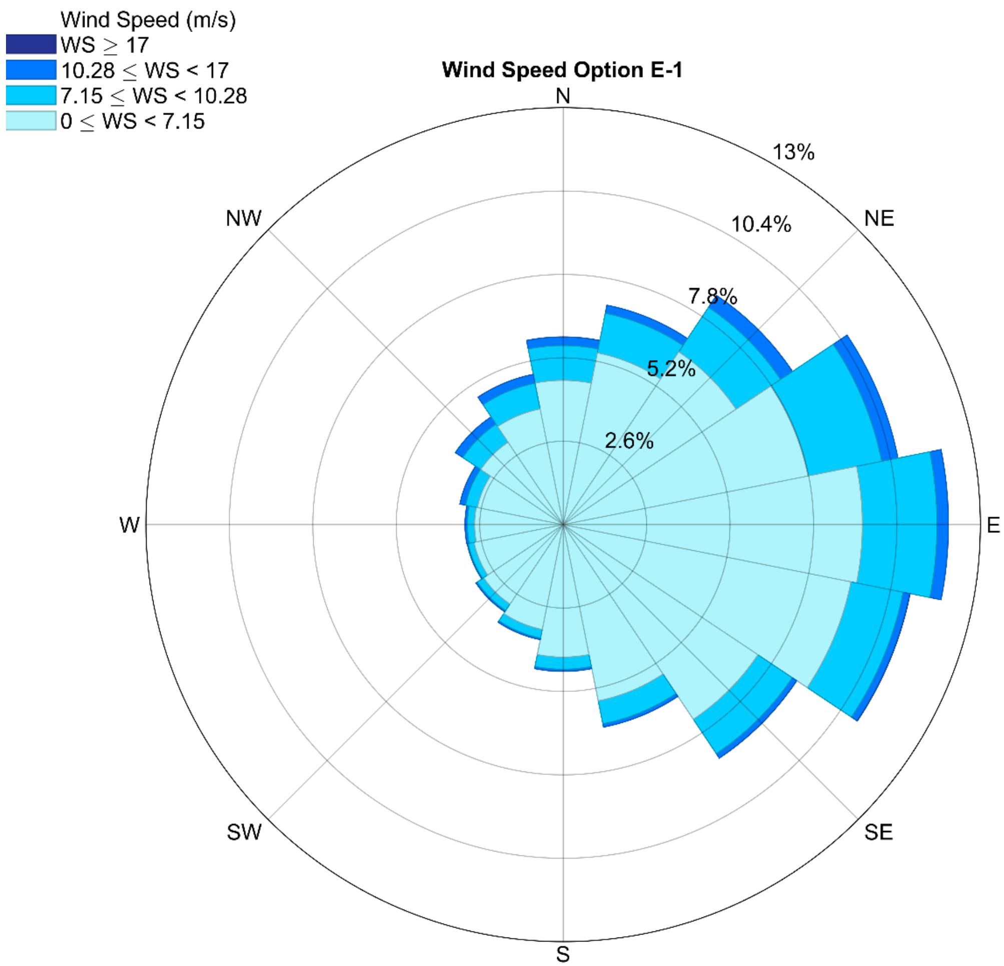


Figure 3.134. Wind velocity and direction at 10-m above sea level for option E-1. The rose diagram provides percent occurrence for each wind speed category. Wind direction is displayed as the origin. Wind data are from the North American Regional Reanalysis model (1979 - 2008).

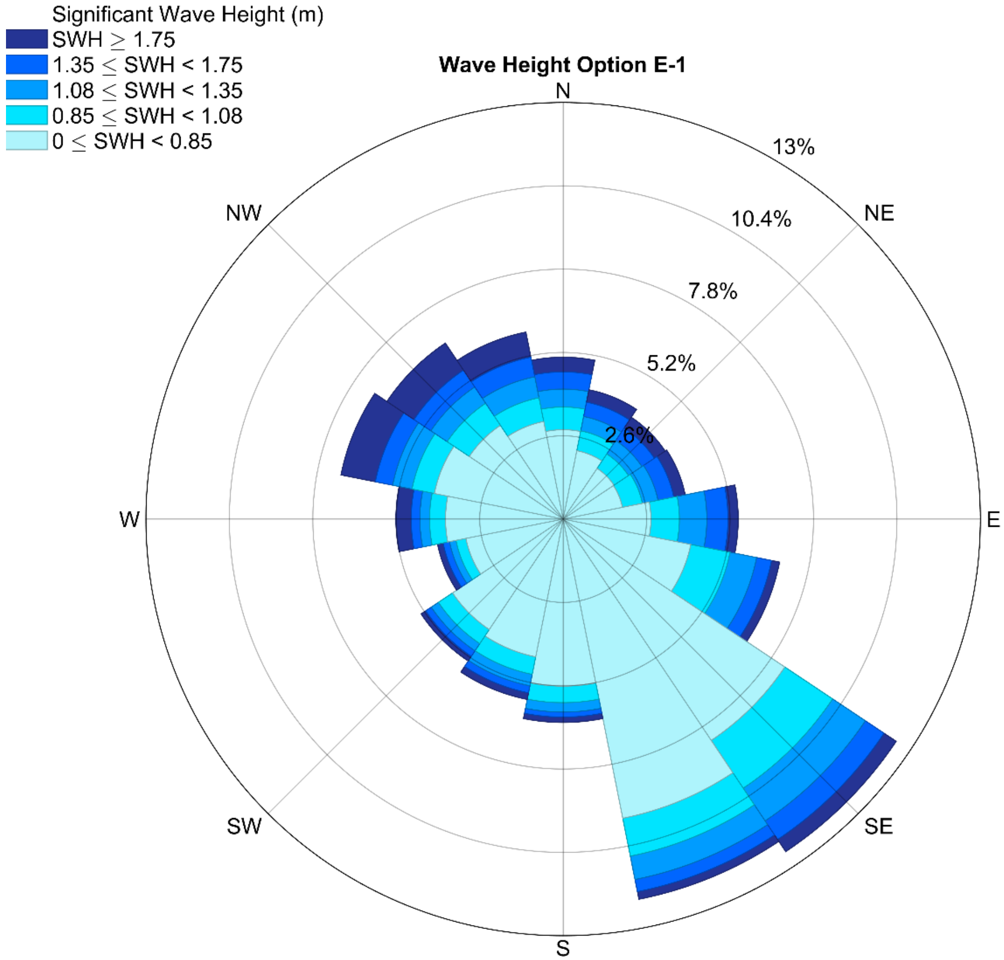


Figure 3.135. Significant wave height and direction at 10-m for option E-1. The rose diagram provides percent occurrence for each significant wave height category. Wave direction is displayed as the origin. Wave data are from the MIKE 21 model for the Gulf of Mexico (1979 - 2008).

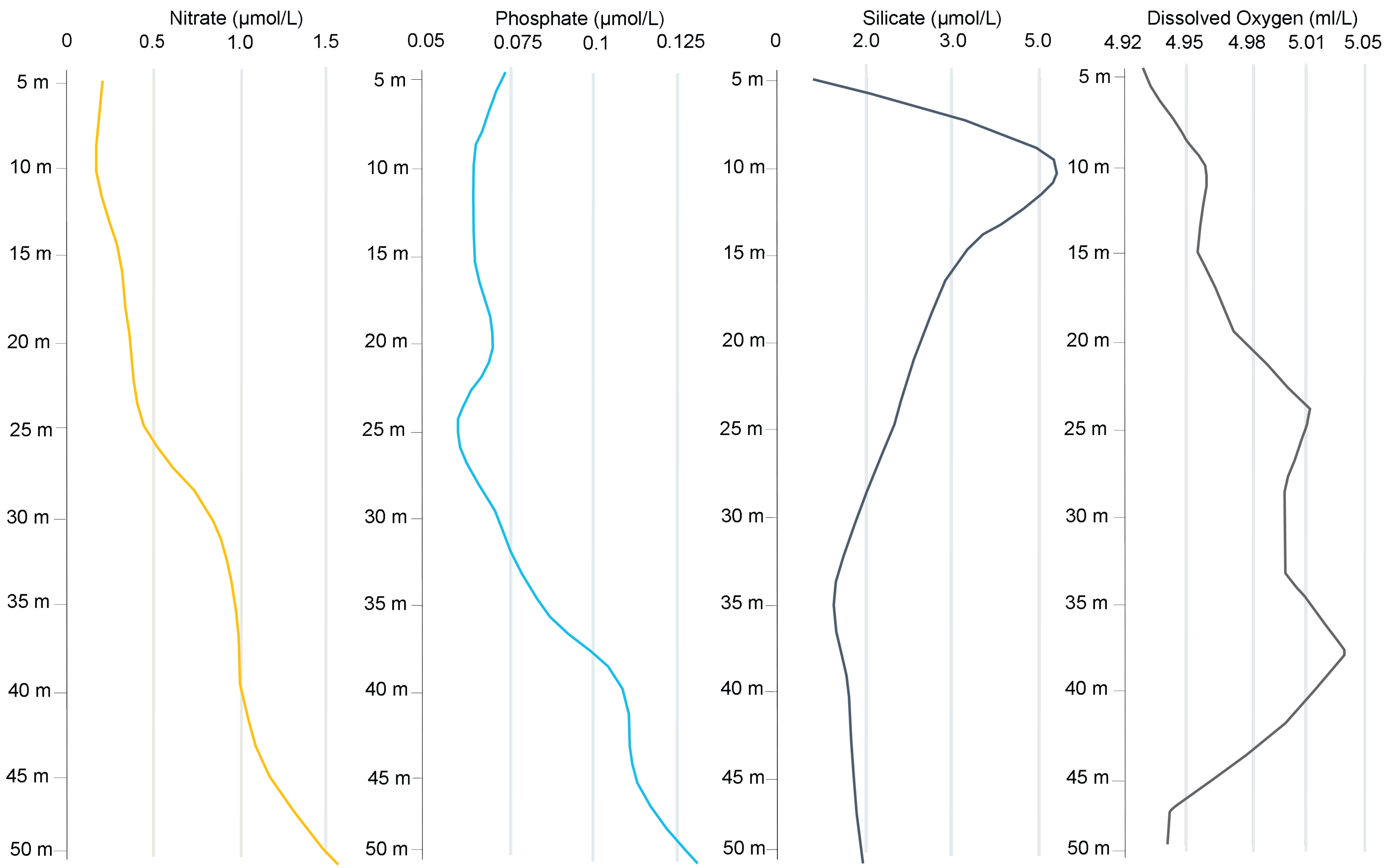


Figure 3.136. Option E-1 concentration of dissolved nitrates, phosphates, and silicates at different depth levels from the Ecological Marine Units (Sayre et al 2017).

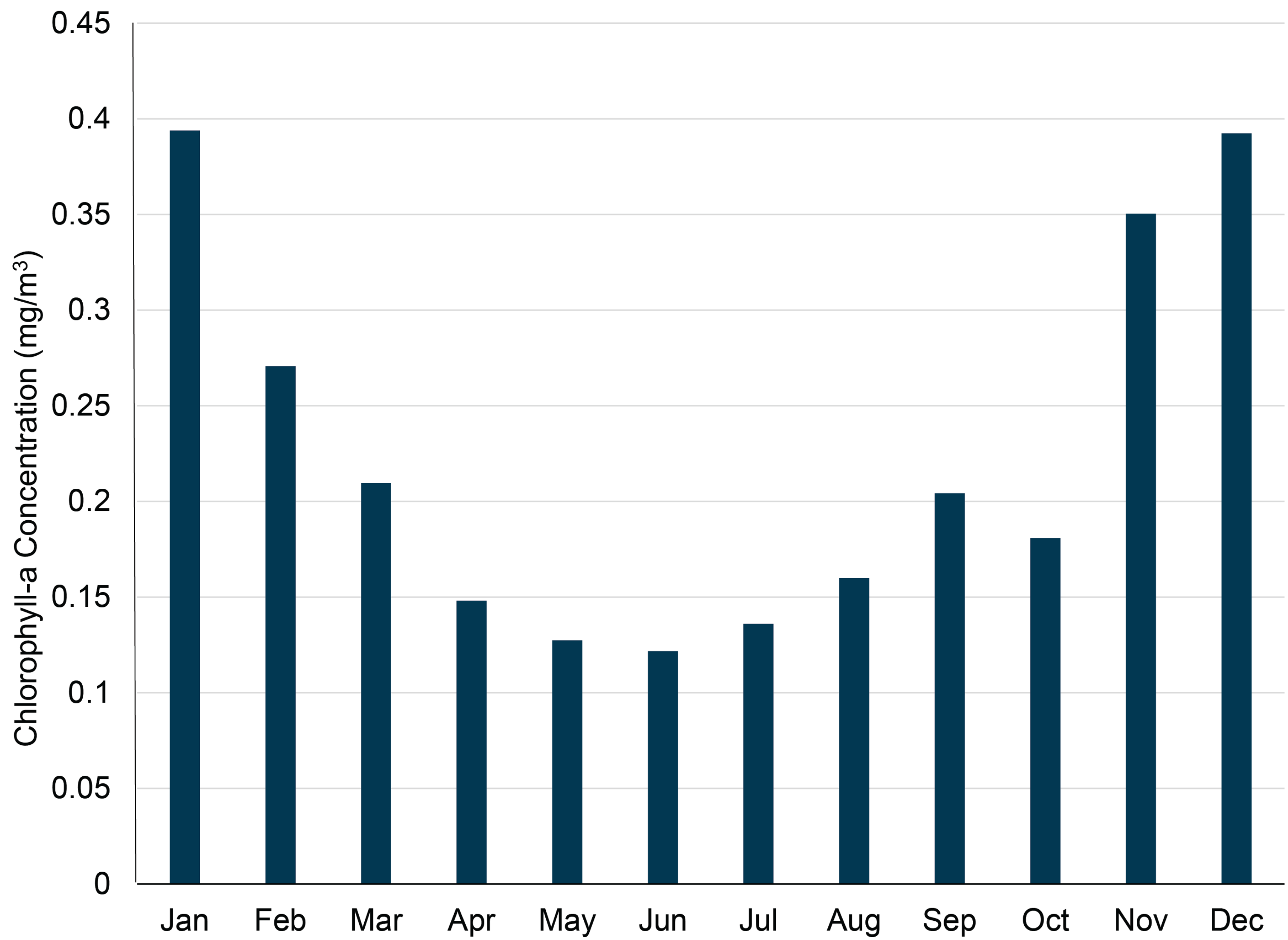


Figure 3.137. Option E-1 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m³) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

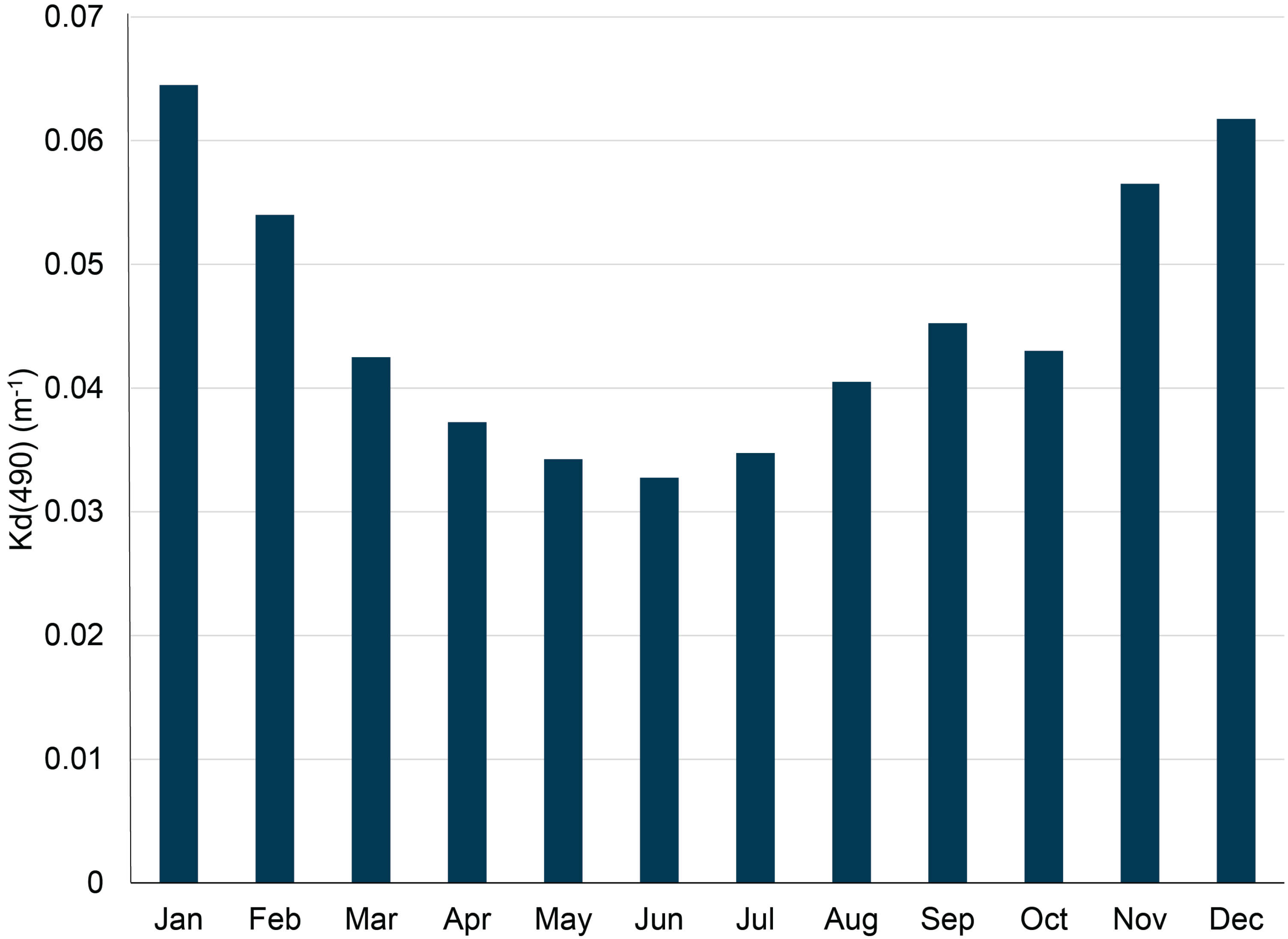


Figure 3.138. Option E-1 monthly climatological mean (2010 - 2017) for Kd(490) within the top meter of water produced by Visible Infrared Imaging Radiometer Suite 750-m data.

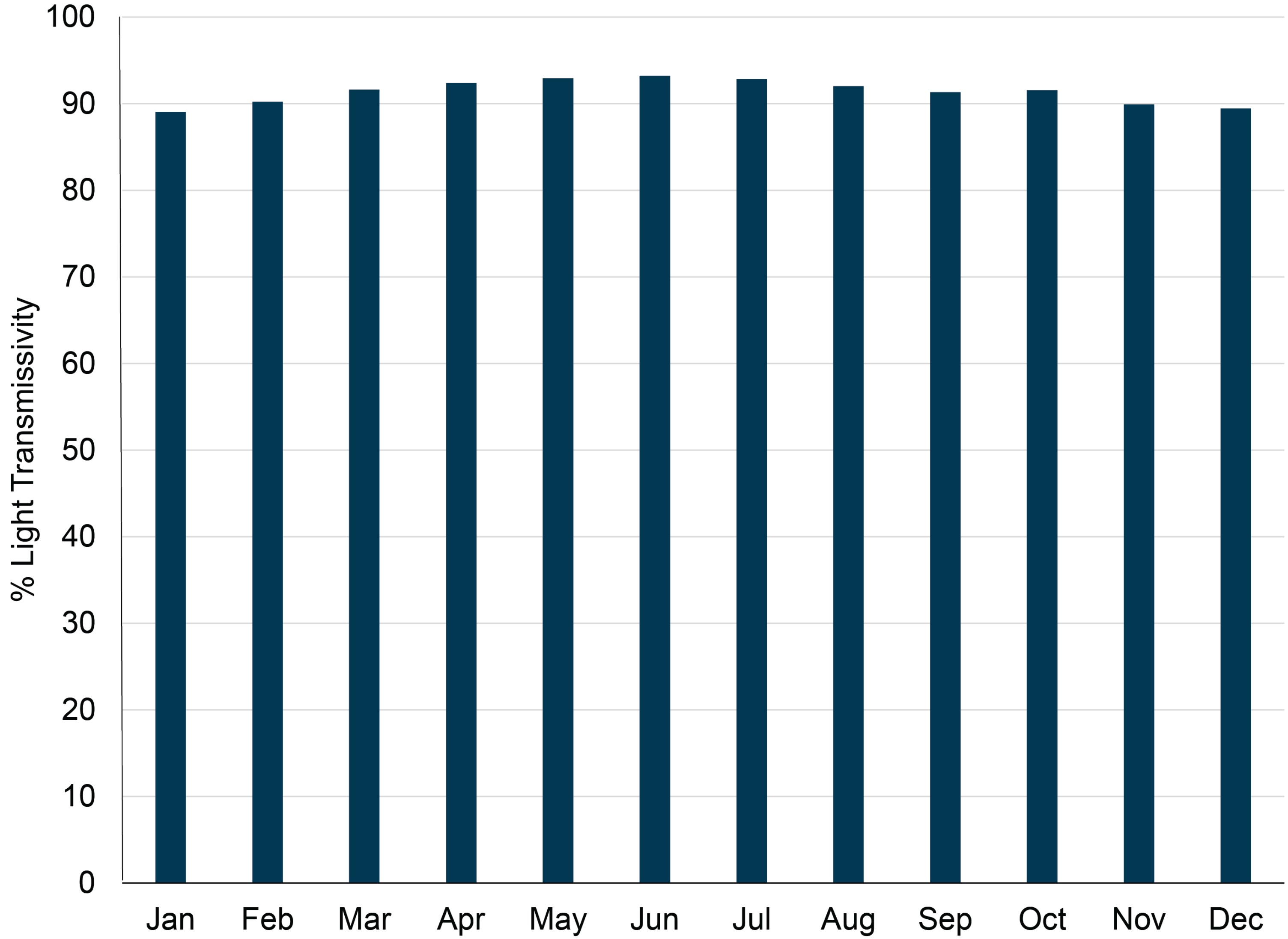


Figure 3.139. Option E-1 monthly climatological mean (2010 - 2017) for percent light transmissivity at 1-m depth produced by Visible Infrared Imaging Radiometer Suite 750-m data.

Table 3.36. Option E-1 Automatic Identification System vessel transits per 500 ac by vessel type and year and total number of transits for the entire 500-ac option. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020*	Total (500 ac)
E-1	Cargo	9.00	7.00	6.00	5.00	9.00	2.00	38.00
E-1	Fishing	0	0	2.00	0	0	0	2.00
E-1	Other	1.00	2.00	1.00	1.00	2.00	5.00	12.00
E-1	Passenger	0	2.00	8.00	4.00	3.00	0	17.00
E-1	Pleasure and Sailing	0	0	0	0	0	1.00	1.00
E-1	Tanker	6.00	1.00	2.00	1.00	2.00	1.00	13.00
E-1	Tug and Tow	0	3.00	3.00	1.00	1.00	1.00	9.00

*AIS vessel transit data from 2020 were not included in any modeled analyses due to the unknown impact on and variability of vessel traffic during the COVID-19 pandemic.

Table 3.37. Number of individual Automatic Identification System-equipped vessels that transited through option E-1.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
E-1	Cargo	8	6	6	4	6	2
E-1	Fishing	0	0	2	0	0	0
E-1	Other	1	2	1	1	2	5
E-1	Passenger	0	1	4	4	2	0
E-1	Pleasure and Sailing	0	0	0	0	0	0
E-1	Tanker	5	1	2	1	1	1
E-1	Tug and Tow	0	3	2	1	1	1

Similar Characteristics Across All AOA Options

NMFS Protected Resources Combined Data

To holistically consider protected species in the region, a novel combined data layer providing the overall score for select protected species was developed through collaboration with NMFS West Coast Region and NMFS Office of Protected Resources. A scoring table (see Methods) was developed providing detailed information on protected species vulnerability based on species status, population size, and trajectory for the species under the ESA and MMPA. Table 3.38 summarizes potential overlap with the NMFS Protected Resources Data Layer and the options for AOAs.

Table 3.38. Spatial analysis of Aquaculture Opportunity Area options and overlap with down-scored data within the National Marine Fisheries Service Protected Resources combined data layer.

Species Descriptions	West Study Area			Central Study Area			East Study Area		
	W-1	W- 4	W-8	C-3	C-11	C-13	E-4	E-3	E-1
Rice's Whale Core Distribution Area	No	No	No	No	No	No	No	No	No
Rice's Whale Suitable Habitat	No	No	No	No	No	No	No	No	No
Leatherback Sea Turtle High Use Areas	No	No	No	No	No	No	No	No	No
Loggerhead Sea Turtle High Use Areas	No	No	No	No	No	No	No	Yes	Yes
Hawksbill Sea Turtle High Use Areas	No	No	No	No	No	No	No	No	No
Kemp's Ridley Sea Turtle High Use Areas	No	No	No	No	No	No	No	No	No
Green Sea Turtle High Use Areas	No	No	No	No	No	Yes	No	No	No
Hawksbill Sea Turtle Migratory Corridor	No	No	No	No	No	No	No	No	No
Loggerhead Sea Turtle Migratory Corridor	No	No	No	No	No	No	No	No	No
Green Sea Turtle Migratory Corridor	No	No	No	No	No	No	No	No	No
Giant Manta Ray Upper Modeled Distribution*	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
U.S. Distinct Population Segment Smalltooth Sawfish High Use Areas	No	No	No	No	No	No	No	No	No
*See Appendix B for the giant manta ray species distribution model description.									

Essential Fish Habitat

Essential Fish Habitat (EFH) covers waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (16 U.S.C. 1802(10)).[46] EFH species data were compiled from NOAA's Guide to Essential Fish Habitat Designations in the US Gulf of Mexico (NMFS 2021d). The guide summarizes EFH designated by species for each study area's options. Tables 3.39 - 3.41 provide lists of federally managed species and their EFH that occur for each study area.

Table 3.39. Essential Fish Habitat species within the three options in the West study area. Each species' common name is listed in the table. For highly migratory species Essential Fish Habitat, an asterisk accompanies the species name in the table.

West Study Area Federally Managed Species Essential Fish Habitat		
Shrimp	Reef fish	Coastal migratory pelagic spp.
Atlantic Angel Shark*	Sailfish*	Scalloped Hammerhead Shark*
Silky Shark*	Blue Marlin*	Smoothhound Shark complex*
Bluefin Tuna*	Yellowfin Tuna*	Atlantic Sharpnose Shark*
Blacktip Shark*	Whale Shark*	Spinner Shark*
Blacknose Shark*	Bull Shark*	Sandbar Shark*

[46] https://www.federalregister.gov/documents/2002/01/17/02-885/magnuson-stevens-act-provisions-essential-fish-habitat-efh

Table 3.40. Essential Fish Habitat species within the three options in the Central study area. Each species' common name is listed in the table. For highly migratory species Essential Fish Habitat, an asterisk accompanies the species name in the table.

Central Study Area Federally Managed Species Essential Fish Habitat		
Shrimp	Reef fish	Coastal migratory pelagic spp.
Atlantic Angel Shark*	Skipjack Tuna*	Atlantic Sharpnose Shark*
Silky Shark*	Blacktip Shark*	Spinner Shark*
Bluefin Tuna*	Sandbar Shark*	Dusky Shark*
Scalloped Hammerhead Shark*	Blacknose Shark*	Yellowfin Tuna*
Shortfin Mako Shark*	Bull Shark*	Longfin Mako Shark*
Whale Shark*	Tiger Shark*	Finetooth Shark*
Sailfish*	Smoothhound Shark complex*	

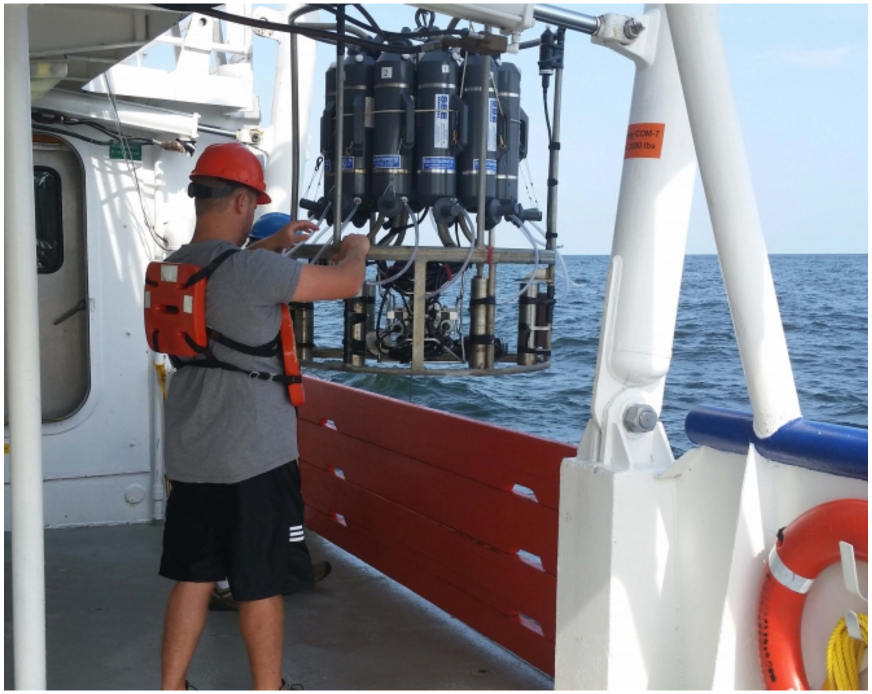
Table 3.41. Essential Fish Habitat species within the three options in the East study area. Each species' common name is listed in the table. For highly migratory species Essential Fish Habitat, an asterisk accompanies the species name in the table.

East Study Area Federally Managed Species Essential Fish Habitat		
Shrimp	Reef fish	Coastal migratory pelagic spp.
Sandbar Shark*	Silky Shark*	Bull Shark*
Blacknose Shark*	Blacktip Shark*	Atlantic Sharpnose Shark*

Other Environmental Considerations

Hypoxia

The largest hypoxic zone in U.S. coastal waters and the second largest in the world is located in the northern Gulf of Mexico and is seasonally situated along the Louisiana coast extending west toward Texas. Hypoxia, a phenomenon defined by dissolved oxygen concentrations below 2 mg/L, naturally occurs in many coastal oceans, but the northern Gulf area is exacerbated by freshwater discharge and nutrient loading from the Mississippi River (Rabalais and Turner 2001). It typically occurs from March through October in waters below the pycnocline, and extends between 5 and 60-m depth (Rabalais et al. 2007). Hypoxia in the Gulf has been observed since the 1970s, monitored since 1985, and forecast since 2002 (Justić et al. 2007). Over the past five years (2016 - 2020), the hypoxic zone has averaged 13,986 km^2 (5,400 mi^2). The 2021 NCCOS forecast ensemble predicted the hypoxic zone to be 12,639 km^2 (4,880 mi^2) and substantially less than the record of 22,730 km^2 (8,776 mi^2) observed in 2017 (NCCOS 2021). The historical extent of the hypoxic zone was considered in development of study areas and identification of AOA options as hypoxia rarely reaches depths beyond 50 m (164 ft) (N. Rabalais, LSU College of the Coast and Environment, personal communication). Because of depth constraints for the historical extent of hypoxia observations, models, and forecasts, aquaculture development within the study areas and AOA options should not be constrained by hypoxia (Figure 3.140). Environmental surveys and surveillance may be required for selecting a farming location or safeguarding production. Notably, some forms of aquaculture (macroalgae or multitrophic systems) may afford opportunities to mitigate nutrient pollution and eutrophication, the leading causes for hypoxia (Racine et al. 2021).



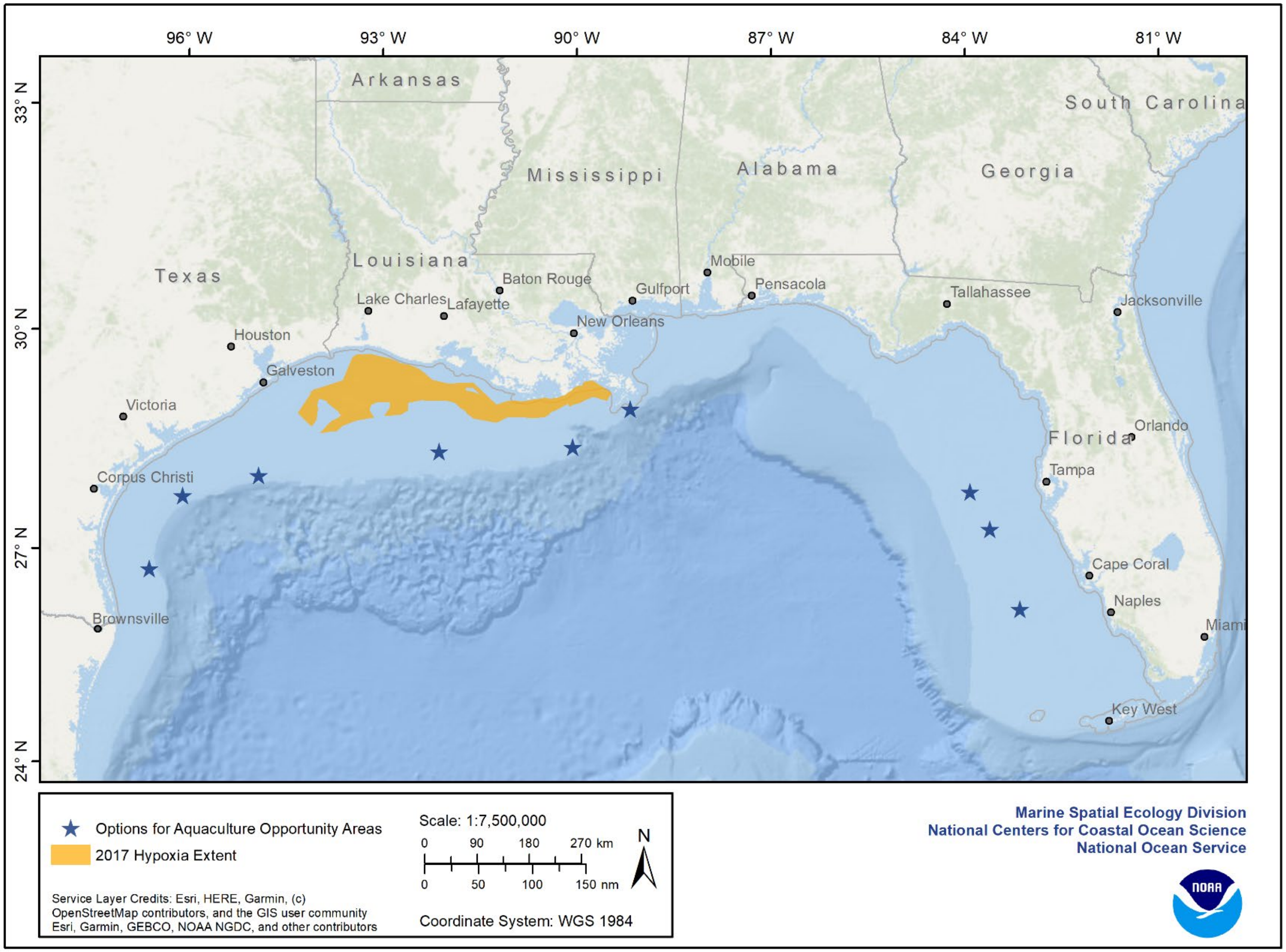


Figure 3.140. The historical extent of the hypoxic zone was considered in spatial planning for Aquaculture Opportunity Areas (AOA). Aquaculture development within the study areas and AOA options should not be constrained by hypoxia. The 2017 hypoxic zone was the largest on record. Data source: Rabalais (2020).

Contaminants

The Gulf of Mexico plays an important role in oil and gas production in the U.S. In 2017, the Gulf of Mexico produced 604 million barrels of oil (one barrel is equivalent to 159 L) and 33.1 million cubic meters (1.17 trillion cubic feet) of natural gas, about 10% of domestic oil and gas production, generating around $34 billion in revenues for oil and gas companies (Kaiser and Narra 2019; Humphries 2018). Significant interest remains in offshore oil and gas exploration in the Gulf of Mexico. Production for both oil and gas is forecast to increase over the next few years with a major focus in deep water (>122 m [400 ft]) (Kaiser 2019). On April 20, 2010, British Petroleum's Deepwater Horizon (DWH) Macondo oil drilling platform exploded approximately 67 km (42 miles) off the coast of Louisiana. The ruptured wellhead released an estimated 3.19 million barrels (>507 billion liters or 130 million gallons) of oil into Gulf waters over an 87-day period, making it the largest oil spill in U.S. history (NOAA Gulf Spill Restoration 2015; Smithsonian Inst. 2015).

Oil pollution and other legacy contaminants can disrupt aquaculture with economic loss arising from suspension of operations, loss or contamination of product, or loss of seafood markets. In addition to accidental oil spills, natural seeps occur throughout the region. Seeps are estimated to account for 95% of oil annually discharged into the Gulf of Mexico (Kennicutt 2017). Based on satellite remote sensing, the total Gulf of Mexico seep rate is estimated at 42 million gallons (1 million barrels) per year (Kennicutt 2017). Using remote sensing data acquired from the Gulf of Mexico Research Initiative (Garcia-Pineda and MacDonald 2017), we reviewed locations of persistent sea-surface slicks from 2001 to 2009 and the proximity to AOA options. The resulting analysis and map demonstrate a relatively low seepage density and prevalence of oil slicks in the vicinity of AOA options (Figure 3.141).

Major environmental events like the DWH oil spill trigger a legal process called Natural Resource Damage Assessment that can bring together federal, state and local agencies, universities, private industry, and non-governmental organizations (NGOs) to conduct extensive monitoring activities. Systematic monitoring of the environment and restoration activities has provided tremendous insight into the ecosystem health of the Gulf of Mexico. NCCOS worked with partners at U.S. Geological Survey (USGS) to establish the Council Monitoring and Assessment Program (CMAP) to identify and compile monitoring program metadata in the Gulf of Mexico and identify comparable parameters, methods, and programs (NOAA and USGS 2020). The CMAP inventory currently houses 544 water quality monitoring, habitat monitoring, and mapping programs in the Gulf of Mexico (NOAA and USGS 2019) and is accessible online via a searchable database[47]. These resources represent some of the best available data ever compiled and readily available to inform coastal managers, stakeholders, and industry.

[47] https://restorethegulf.gov/cmap

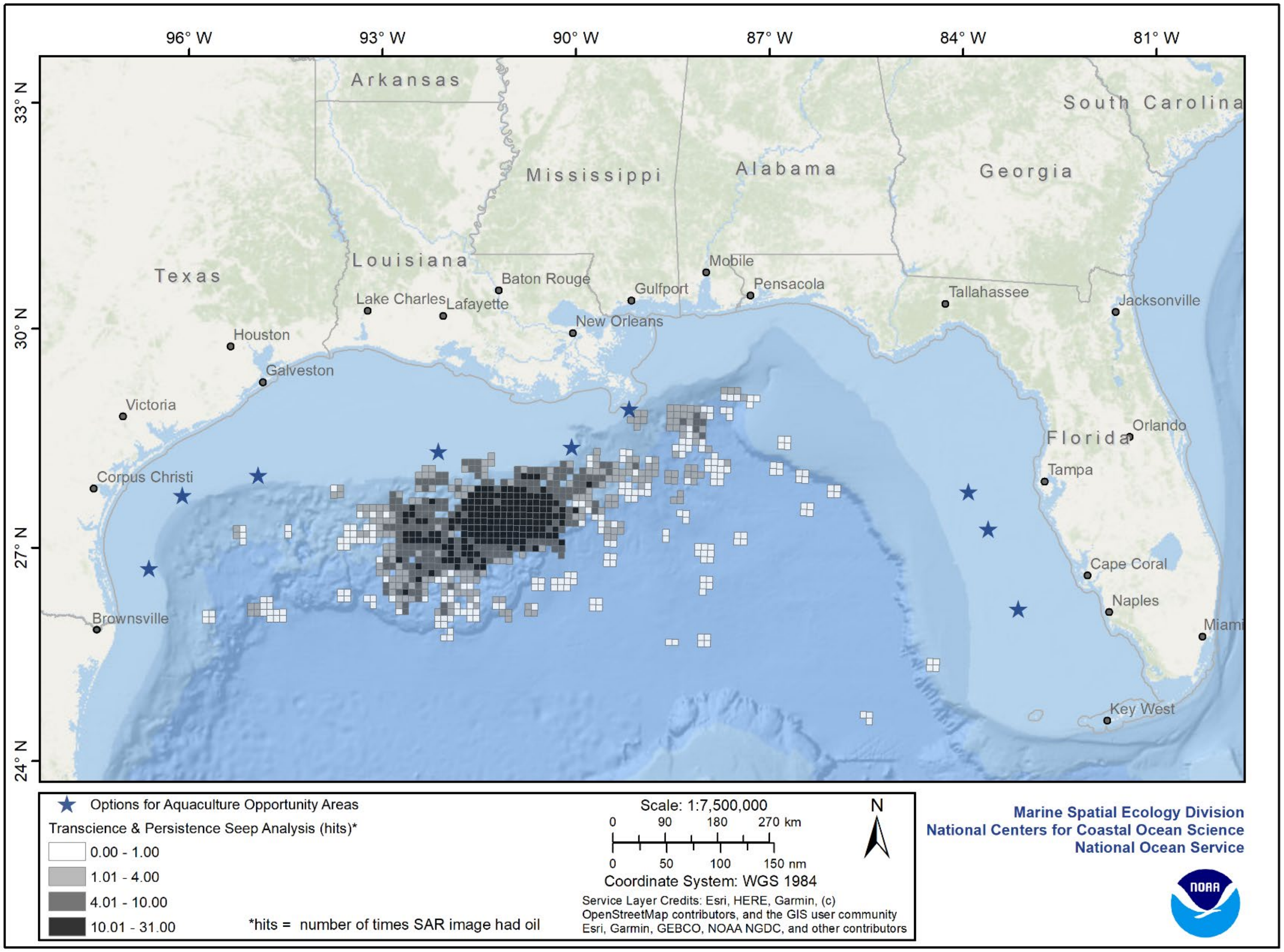


Figure 3.141. Remote-sensing data denotes persistence of sea-surface petroleum slicks from 2001 to 2009 and the proximity to options for Aquaculture Opportunity Areas. Data source: Garcia-Pineda and MacDonald (2017).

DISCUSSION

Over the past fifty years, the U.S. Gulf of Mexico has garnered significant interest from the aquaculture industry, forward-thinking fishermen, and investors who are inspired to bring sustainable seafood, wild and farmed, to market. The Gulf of Mexico region could support a vibrant aquaculture industry with its warm waters, suitable depths and currents, and access to working waterfronts, processing plants, and wholesale businesses in over 400 coastal communities. Planning for offshore aquaculture operations in the Gulf of Mexico requires careful consideration given the diversity of coastal communities, shared natural resources, and multiple ecosystem services provided in the region. A critical element needed by coastal resource managers and stakeholders is awareness and confidence in geospatial analytical tools and science to inform regulation, protect the environment, and equitably resolve points of resistance to aquaculture industry development. The spatial analyses presented herein provide supporting intelligence that will assist NOAA in the AOA identification process. This Atlas was developed for the specific purpose of identifying locations that are possibly the most suitable for locating AOAs and includes limitations specific to the planning goal. However, much of the spatial information provided will also be useful to the aquaculture industry and coastal managers in early consideration for siting specific projects and types of projects (e.g., shellfish, finfish, macroalgae). Caution should be exercised when using the Atlas for purposes other than planning for AOAs as many data layers were developed specifically for this project (e.g., protected resource data layer).

The spatial analysis provides the most comprehensive marine spatial modeling for the Gulf of Mexico to date. The methods and models aim to significantly improve the next generation of MSP providing support far beyond aquaculture development by unleashing the power of large datasets and spatial analytics for shipping and navigation, national security and military strategy, offshore energy exploration, identification of marine protected areas, and burgeoning sectors of the ocean economy (e.g., wind or space commerce). With over 200 data layers included in this analysis, the maps, models, and descriptions provide unprecedented insights into the characteristics of the study areas and marine ecoregions. While the overall suitability modeling reported is consistent with previous approaches used globally (Ehler and Douvere 2009), novel modeling approaches were developed for national security and NOAA trust resources (fishing, habitat, and protected species). Further, new data products were developed and refined to provide increased resolution and geographic coverage. These modeling approaches and data products will be useful for other marine planning efforts within the Gulf of Mexico but also elsewhere in the U.S.

Stakeholder input on relevant data and spatial modeling methodology was gathered through an RFI published in the Federal Register (85 FR 67519; October 23, 2020), public listening sessions, and one-on-one sessions with stakeholders. More than 175 one-on-one sessions with stakeholders and experts were held to inform this analysis. Much effort was given to vetting data and methods with data-limited stakeholders including the fishing community, military, and protected resources. This stakeholder process was not a consensus building or task force driven process that included prescribed representation. The goal of this study was to produce descriptive analyses that provided in-depth understanding of constraints and opportunities for identification of AOAs. Future AOA spatial planning efforts could benefit from adjustments to the stakeholder input process to include formal advisory panels where consensus could be obtained or unavoidable trade-offs could be addressed, thereby potentially improving the results (Gentry et al. 2017). These processes, however, would require additional time and resources above those expended for this analysis. The next opportunity for public input into the AOA identification process in the Gulf of Mexico will be when the Notice of Intent to prepare a Programmatic Environmental Impact Statement (PEIS) is published.

This spatial modeling approach was specific to the planning goal of identifying discrete areas between 500 and 2,000 ac that are potentially more suitable for all types of aquaculture development including the cultivation of finfish, macroalgae, shellfish, or a combination of species within a discrete square polygon area. The AOA options identified herein will be one source of information used by NMFS to inform the development of a PEIS for each AOA. At the end of the PEIS process, one or more areas may be identified as an AOA. Further, siting considerations within an AOA option or other areas may require additional environmental surveillance to assess oceanographic or local conditions. It is important to note that while this analysis provides in-depth modeling and descriptive information on aquaculture opportunities, the parameters that were selected to conduct spatial modeling for AOAs (depth, distance to shore, spatial dispersion in federal waters) were high level and meant to encompass all types of aquaculture. Additional spatial analyses that are specific to types of aquaculture and/or cultivation approaches (e.g., macroalgae aquaculture) could identify alternative discrete areas that are more suitable than those proposed by this more general analysis. Nevertheless, the options identified here have the lowest conflict with other ocean users in ocean spaces meeting basic industry requirements for generalized aquaculture operations.

The results of this analysis include detailed ocean neighborhood-level descriptions of the Gulf of Mexico AOA study areas, which are areas that met the industry and engineering requirements of depth and distance from shore. Spatial modeling was performed at 10-ac (4.05 ha) grid cell resolution providing high contrast of suitability throughout the study areas. Modeling results identified three AOA options from each study area, with the exception of the Southeast Study Area. Major constraints in the Southeast Study Area included interactions with military activities, a National Marine Sanctuary, and sensitive biological resources (e.g., corals, submerged aquatic vegetation). A combination of constraints analysis and consultation with the DOD removed 100% of the Southeast Study Area. Any aquaculture development within the boundaries of the Southeast Study Area will have to contend with these constraints, which may affect siting and permitting efficiency.

Similar conclusions can be drawn for siting aquaculture along Mississippi, Alabama, and the Florida Panhandle. The suitability analysis would suggest that aquaculture opportunities may exist in these areas at smaller scales than suitable for AOAs (< 500 ac or

202.3 ha). Historically, the aquaculture industry has expressed interest in developing aquaculture within the northeast region of the Gulf of Mexico because of the water quality (i.e., no Mississippi River influence), suitable depths, and shorter distances between the shore and deep water. Major constraints in the northeast region of the Gulf of Mexico included interactions with military activities, intensive recreational and commercial fishing, large artificial reefs, and proximity to the distribution of several species of ESA-listed sea turtles and the critically endangered Rice's whale. The aquaculture industry may continue to pursue development in this region, but the results of this study suggest that the industry will have to contend with these constraints, which may affect siting and permitting efficiency. Any proposed projects with the potential to adversely affect EFH, ESA-listed species, or marine mammals will require review and consultation within NMFS. Review of marine mammal and sea turtle interactions will likely require consideration of entanglement risk, habitat displacement, and many other considerations (Price and Morris 2013; Price et al. 2017).

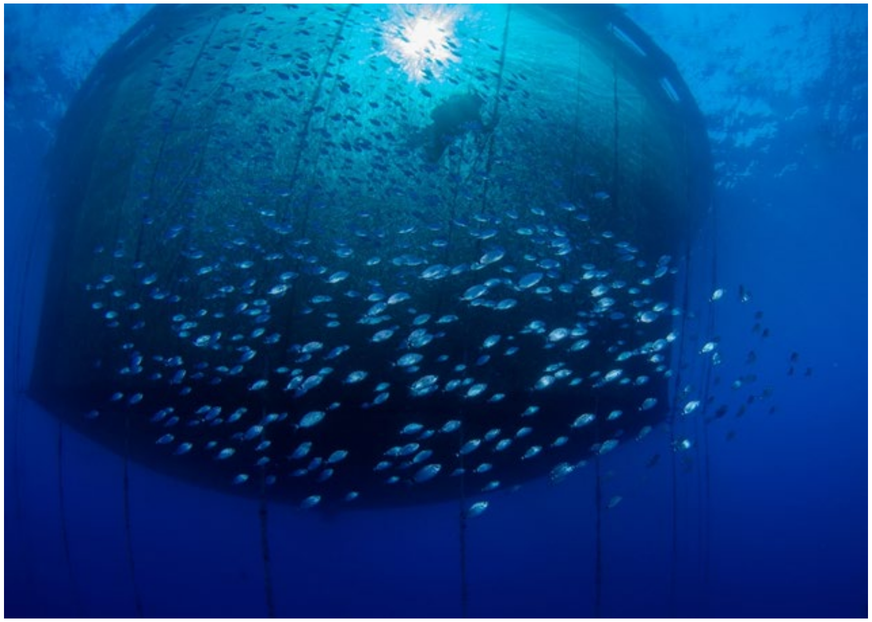
The AOA options identified were selected from 29,839 possibilities of the highest scoring ocean spaces from the West, Central, and East Study Areas. While the purpose of this planning effort was to identify the most suitable AOA options for each study area, the remaining ranked options provide a high level of spatial intelligence which could prove useful for future planning. The remaining options represent areas that are similar in suitability in that they also have low levels of conflict with other ocean users while meeting basic industry requirements for generalized aquaculture operations, albeit with some constraints resulting in slightly lower scores. Industry, coastal managers, and coastal planners could utilize these other options outside of the AOA process to inform industry planning and early siting discussions with permitting agencies.

West Study Area

The identification of three AOA options in the West study area located in the federal waters off Texas would complement wild-capture fisheries, working waterfronts, and regional seafood processing and distribution infrastructure. Commercial fishing supports many communities along the Texas coastline, providing employment, income, and revenue from seafood sales. Landings in Texas are highly seasonal, driven by periods of abundance, fisheries management, and regulations. Commercial harvests include tuna, snapper, grouper, black drum, flounder, oysters, blue crabs, and shrimp, with the latter harvested both for food and for bait. Top commercial fishing ports in Texas in proximity to the AOA options are Galveston, Palacios, and Brownsville-Port Isabel (Table 4.1; NMFS 2021a). AOA West option W-1 is located near Port Mansfield and could easily tie into existing seafood infrastructure in this area or neighboring communities to the south with Brownsville-Port Isabel. The position of AOA West option W-4 could be supported by communities surrounding Port O'Connor and the other fishing communities on Matagorda Bay (e.g., Palacios, Port Lavaca). Alternatively, AOA West option W-4 could be supported by communities surrounding Port Aransas and its neighboring communities. AOA West option W-8 is a bit more distant offshore and could be supported by communities between Port O'Connor, Matagorda, and Freeport. One-third of all seafood caught in the Gulf of Mexico moves through Galveston, located slightly north of Freeport (NMFS 2021a).

Table 4.1. Commercial Fishery Landings and Value at Major U.S. Gulf of Mexico Ports, 2018 - 2019. Quantities are reported in millions of pounds; values are reported as millions of U.S. dollars (NMFS 2021a).

Port	Quantity		Port	Value	
	2018	2019		2018	2019
Pascagoula-Moss Point, MS	310	331	Empire-Venice, LA	148	79
Intracoastal City, LA	328	234	Galveston, TX	60	65
Dulac-Chauvin, LA	34	35	Key West, FL	73	55
Bayou La Batre, AL	32	23	Bayou La Batre, AL	63	53
Galveston, TX	20	19	Dulac-Chauvin, LA	47	50
Palacios, TX	19	17	Brownsville-Port Isabel, TX	51	46
Brownsville-Port Isabel, TX	20	17	Pascagoula-Moss Point, MS	27	43
Grand Isle, LA	18	16	Palacios, TX	43	42
Golden Meadow-Leeville, LA	20	15	Tampa Bay-St. Petersburg, FL	31	36
Key West, FL	16	14	Port Arthur, TX	36	30
Port Arthur, TX	17	14	Delacroix-Yscloskey, LA	36	26
Tampa Bay-St. Petersburg, FL	15	13	Golden Meadow-Leeville, LA	27	23



Central Study Area

The identification of three AOA options in the Central study area located in the federal waters off Louisiana would also complement wild-capture fisheries, working waterfronts, and regional seafood processing and distribution infrastructure. Louisiana is the largest seafood producer in the lower 48 states, and for decades, Louisiana has ranked with major U.S. ports supporting commercial fishery landings by tonnage and value (Table 4.1; NMFS 2021a). Empire-Venice, Intracoastal City, Dulac-Chauvin, and Grand Isle are some of the most notable ports, but commercial fishing supports the entire network of communities along the bayous leading to the Gulf of Mexico oceanic basin. Seafood is part of Louisiana culture and heritage as well as a characteristic and defining quality of community resilience. Louisiana coastal communities are adept at changing in response to natural and economic cycles, most often driven by natural forces beyond human control. Change and adaptation, benchmarks of resilience, are reflected as fishing communities contend with fishery access issues and barriers into entry, changing sea levels and coastal flooding, land loss and subsidence, water quality and hypoxia, and disasters such as hurricanes and the nation's largest oil spill, British Petroleum's Deepwater Horizon.

AOA Central option C-3 is located the farthest offshore of all AOA options with an estimated travel distance of 133 km (72 nm) to the closest inlet or coastal community. Small isolated working waterfronts and fishing villages within the Atchafalaya Basin could support AOA Central option C-3. Alternatively, the aquaculture industry may find value leveraging resources and partnering with the petroleum industry and affiliated supply sectors. Similarly, AOA Central option C-11 may find value leveraging resources and partnering with the petroleum industry. The site is located almost 77 km (42 nm) from Port Fourchon and Grand Isle and is located a little to the east of C-3. Both communities serve as base operations for a variety of offshore industries including energy exploration, oil and gas supply, commercial fishing, recreational fishing, and tourism. Port Fourchon is unique in serving as the land base for the Louisiana Offshore Oil Port, the nation's first and only strategic deepwater port located offshore approximately 29 km (16 nm) and serving some of the world's largest supertankers (i.e., ultra large crude carriers). AOA Central option C-13 is located closest to shore relative to all other AOA options with an estimated travel distance of 9 km (5 nm) to the South Pass of the Mississippi River and Port Eads, a small riverside marina and lighthouse community that once supported commercial traffic in the river. Port Eads is accessible only by boat and is situated 35.4 km (19.1 nm) south of Venice, where the state highway terminates. In recent years shallow water and shoaling has constrained some navigation for South Pass; as such AOA Central option C-13 could also be served by the Southwest Pass of the Mississippi River located approximately 18 km (10 nm) to the east-northeast. The Southwest Pass is a critical component of the U.S. marine transportation system as it provides access to 23,000 km (14,500 mi) of navigable inland waterways on the Mississippi River and its tributaries (USACE 2018).

East Study Area

The Gulf coast of Florida has more than 8,200 km (4,427 nm) of coastline, and the ocean is part of the state's history, heritage, and economy. Southwest Florida has a long tradition and a persistent presence of commercial fishing nested in communities like Cedar Key, Tarpon Springs, Clearwater, St. Petersburg, and Key West. Further, recognizing that the commercial fleet and infrastructure are in decline, the state designated some locations as working waterfronts, such as Cortez, Bradenton Beach, Fort Myers, and San Carlos Island, to preserve cultural heritage, provide economic opportunity, and ensure equitable access to water-dependent businesses.

Each of the AOA East options could easily tie into existing onshore seafood infrastructure. The AOA East option E-4 is located approximately 107 km (58 nm) due west of Egmont Key. This site could tie into working waterfronts and infrastructure to the north in Clearwater and St. Petersburg and south toward Cortez, Bradenton, and Sarasota. AOA East option E-3 is located 89 km (48 nm) southwest of Longboat Key and about 100 km (54 nm) west of Siesta Key. AOA East option E-3 could support waterfront and land-based operations between Cortez and Sarasota. Lastly, further to the south is AOA East option E-1. It is located approximately 100 km (54 nm) southwest of Captiva and Sanibel. AOA East option E-1 could utilize working waterfronts and infrastructure from Pine Island south to Fort Myers.

While it is expected that findings of this analysis will be relevant for some time, it is likely that specific and measurable changes may occur in the suitability of the study areas. Ocean space is inherently temporally dynamic in nature, including both environmental and ocean use patterns. For example, growth of ports, such as the Louisiana Offshore Oil Port, can drastically change the magnitude of shipping traffic, creating new ocean shipping fairways, anchorages, and associated safety zones. The ecology of a study area can also vary in time and space as the distribution and habitats of marine life respond to human impacts and natural and sometimes even stochastic influences. For these reasons, spatial analyses such as the one discussed here should be viewed as “living analyses” and decision support infrastructure to be consulted for understanding opportunity in the context of time and space.

The consideration of climate change interactions was beyond the scope of this spatial analysis, but much work has been done to understand climate change impacts on fishing and aquaculture industries (Phillips and Pérez-Ramírez 2018). Aquaculture industries are resilient to some impacts of climate change in that the industry can adapt (to some degree) by adjusting species, cultivation practices, breeding approaches, and adaptive engineering in response to changing weather. Nevertheless, climate change impacts on aquaculture can be severe and present additional risks due to effects on water quality, disease, and harmful algal blooms. For example, the increasing frequency of extreme events such as heat waves is causing significant impacts on salmon farms (Wade et al. 2019). Future work to incorporate climate change scenarios along with species-specific gear combinations and techno-economic analyses (Bridger 2004; Rubino 2008) could provide significant insight to assist the industry and coastal managers with planning for a resilient and sustainable aquaculture industry.

Visual impact is considered one of the main issues for coastal development activities, such as wind farms, port expansion projects, and aquaculture. Visual impact on the coastal landscape is a leading cause for public opposition, especially in areas with high-value properties and/or historically important scenic views, or when a project is in the vicinity of a cultural resource. Within the Gulf of Mexico, stakeholders will not be able to discern visual impacts to the coastal landscape resulting from aquaculture development within the AOA options because of the distance from shore.

The results of this analysis provide compelling evidence of the opportunities and challenges of siting aquaculture in the coastal and open ocean. Further, this analysis demonstrates the inherent value of advanced regional-scale planning before permitting actions begin. The history of commercial aquaculture ventures in the Gulf of Mexico demonstrates some of the challenges in permitting and finding suitable space for aquaculture development. Advanced marine planning for aquaculture, prior to embarking on permitting, can support effective permitting processes, avoid space-use conflicts, increase conservation, reduce unnecessary public controversy, and support business planning practices. Provision of this intelligence in advance to industry, the public, and coastal managers will unquestionably save resources and potentially shorten permitting timelines.

The permitting and authorization requirements for aquaculture development within Gulf of Mexico AOAs are the same as any other project in federal waters. The federal government and coastal states each have roles in the permitting process. Aquaculture operations proposed within an AOA would be required to comply with all applicable federal and state laws and regulations. e.g., Clean Water Act, Rivers and Harbors Act, Endangered Species Act, Essential Fish Habitat under the Magnuson-Stevens Act, Marine Mammal Protection Act, and National Marine Sanctuaries Act. Compliance may include ESA and EFH consultations, MMPA authorizations, and consultations regarding impacts on cultural resources. Site-specific environmental surveys may be required. Lastly, depending on location and type of aquaculture operation, applicants may be required to coordinate with the DOD to assess potential impacts to military operations or national security.

This spatial analysis identified a number of improvements in data resources that could dramatically improve regional marine planning within the Gulf of Mexico and nationally. While this analysis did incorporate the best readily available fishing data, there is a lack of spatial data for commercial fisheries in federal waters at the spatial scale needed for comprehensive regional marine planning. Similar challenges exist with recreational fisheries in the Gulf of Mexico. The only data collected on recreational fisheries and included in this study were represented by the NMFS Southeast Region Headboat Survey. Compared to the 2.5 million anglers that took 19.7 million

fishing trips in the Gulf of Mexico, spending $10.4 billion in 2015, the NMFS Southeast Region Headboat Survey is a very small fraction of recreational anglers. Spatial fishing data are inherently difficult to obtain given confidentiality requirements and reluctance of fishermen to provide data. Future marine planning efforts would benefit from efforts to obtain higher resolution data, perhaps through participatory mapping processes with fishermen (NOAA OCM 2014), as well as other recreational stakeholders (e.g., scuba). Future AOA spatial planning efforts could benefit from participatory mapping efforts focused on addressing spatial data that are currently limited for specific fisheries, geographies, or activities.

Improvement of marine traffic data could also benefit marine spatial planning efforts. Marine traffic data used in this study were largely sourced from terrestrial AIS data sources, which have well-documented limitations including but not limited to noise due to erroneous transmissions, equipment compatibility issues that affect reliability of signal transmission and reception, incomplete or unrealistic tracks due to signal loss, transmission failures in high density areas due to message collisions, and weather/atmospheric refraction that affects signal reliability (Emmens et al. 2021). Another challenge is that many vessels, especially smaller vessels, are not required to or do not transmit AIS data, making all AIS analysis a likely under-representation of actual marine traffic. In spite of these challenges, AIS remains the best readily available data for marine traffic analyses. Future marine planning work for aquaculture (and other industries) at the local or regional scale could benefit from investment in additional marine traffic data sources to validate AIS and provide additional data, especially for under-represented vessels (e.g., small pleasure craft). Some possibilities could include data from radar, visual surveys, and satellite tracking (Patraiko and Holthus 2013; Kanjir et al. 2018). Engagement with the USCG and local bodies such as port authorities and pilots could address specific safety issues and navigation concerns.

Given the broad planning objective of this analysis (e.g., all types of aquaculture), a quantitative assessment of uncertainty was not performed. Because the majority of the best available data layers are from authoritative sources, and the small acreage target (2,000 ac) of the AOA options relative to the region, it is anticipated that overall uncertainty is low. Further, the data layers that were assigned a score of 0 likely have small uncertainty given the absolute unsuitability of these layers (e.g., shipping lanes, military areas, oil and gas platforms, etc.). Future efforts are warranted to quantify uncertainty related to the 0.5 scored layers; however, this would likely require further refinement of the planning objective specific to the type of aquaculture being considered. For example, a conflict related to navigation may not be an issue for a type of aquaculture that is completely submerged. Future research quantifying uncertainty using an uncertainty matrix that considers the level (statistical, scenario, recognized ignorance) and nature (epistemic or variability) of the uncertainty, as well as the location (context, model, inputs, parameters, or model outcomes) (Walker et al. 2003) could prove insightful and inform data preparations and modeling methods for next generation marine spatial analyses.

In conclusion, NOAA continues to develop science-based tools to help coastal communities navigate through and balance coastal development challenges. This robust marine planning process to support the identification of AOAs uses the best available data to account for key environmental, economic, social, and cultural considerations to identify appropriate space for sustainable aquaculture and support efficient permitting. Aquaculture development can support U.S. jobs, sustain working waterfronts, and increase domestic food security. This analysis supports AOA identification directly through provision of regional spatial modeling results to inform possible locations for AOAs in the Gulf of Mexico. While Executive Order 13921 focused on aquaculture for the purpose of seafood production, the results of this analysis are relevant to all aquaculture types including aquaculture for the purpose of restoration or increasing ecosystem services

(Theuerkauf et al. 2019b, 2021) and energy production through cultivation of macroalgae (Rajkumar et al. 2014).

While the data layers used in this analysis provide a wealth of information that may be useful to the aquaculture community and coastal managers in early consideration for siting specific projects, the results of the spatial modeling are for the specific purpose of identifying locations that might be suitable for locating AOAs and include limitations specific to that purpose. Caution should be exercised when using the Atlas for purposes other than planning for AOAs. Using the results of this analysis, NOAA and others could consider utilizing scenario planning approaches (Couture et al. 2021) to further explore the opportunity for aquaculture for aquaculture as part of the AOA identification process. Scenario models provide industry and coastal managers with the powerful ability to examine the effect of multiple scenarios that capture economic opportunities and assess impacts on resources of concern. Lastly, it is our aim that this analysis will empower industry and coastal managers to continue ocean innovation toward increased conservation, more efficient space use, and increased sustainability of our ocean ecosystems as we collectively work to support the Nation's growing Blue Economy.

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APPENDICES

Appendix A

Appendix A: Full data inventory for the Gulf of Mexico with data processing notes for those data sets where processing was required.

Table A-1: National security data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

National Security Datasets	Source	Source/link	Metadata link
Danger Zones and Restricted Areas in Coastal Marine Waters	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/DangerZonesAndRestrictedAreas.zip	https://www.fisheries.noaa.gov/inport/item/48876
Military Operating Area - Key West	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Military Operating Area - Eglin Gulf Test and Training Range (EGTTR)	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Military Operating Area - Panama City	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Military Operating Area - Pensacola	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Military Operating Area - New Orleans	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Military Operating Area - Corpus Christi	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/55364
Special Use Airspace (Over Water - Not Warning Areas) - Testing and Training Area EWTA-2A	Range Operations and Sustainment via DOD Safe	Available with DOD request/approval	Available with DOD request/approval
Special Use Airspace (Over Water - Not Warning Areas) - Testing and Training Area EWTA-2B	Range Operations and Sustainment via DOD Safe	Available with DOD request/approval	Available with DOD request/approval
Special Use Airspace (Over Water - Not Warning Areas) - Testing and Training Area EWTA-5	Range Operations and Sustainment via DOD Safe	Available with DOD request/approval	Available with DOD request/approval

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Not Warning Areas) - Testing and Training Area EWTA-2C	Range Operations and Sustainment via DOD Safe	Available with DOD request/approval	Available with DOD request/approval
Special Use Airspace (Over Water - Warning Areas) - W174E	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174B(A)	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W168	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W470E	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W151B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W151D	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W151A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W151E	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W151F	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W151C	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W155A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W155B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W155C	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W148A/B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - MOA US 02116	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - MOA US 02416	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W92	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W54A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W54B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W59A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W59B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - A381	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W147D	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W147C	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W228B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W228A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W228C	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W228D	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174C(A)	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174H(B)	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W174C(B)	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W174F & G	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W470B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - W470A	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html

National Security Datasets	Source	Source/link	Metadata link
Special Use Airspace (Over Water - Warning Areas) - W453B	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - MOA U.S. 02214	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Special Use Airspace (Over Water - Warning Areas) - MOA U.S. 02208	MAIASC	https://www.acq.osd.mil/dodsc/about/maps.html; https://hub.arcgis.com/Datasets/dd0d1b726e504137ab3c41b21835d05b_0?geometry=162.853%2C20.649%2C26.359%2C45.970	https://sua.faa.gov/sua/siteFrame.app; https://www.arcgis.com/sharing/rest/content/items/dd0d1b726e504137ab3c41b21835d05b/info/metaData/metaData.xml?format=default&output=html
Unexploded Ordnance Point Data	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance.zip	https://www.fisheries.noaa.gov/inport/item/54408
Unexploded Ordnance Polygon Data	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance.zip	https://www.fisheries.noaa.gov/inport/item/54407
Unexploded Ordnance Formerly Used Defense Sites	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance_FUDS.zip	https://www.fisheries.noaa.gov/inport/item/54409
Military Submarine Transit Lanes	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/51523
Military Surface Grid Area	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/48899

National Security Datasets	Source	Source/link	Metadata link
125 Mile (86º 41' west longitude) Military Mission Line[48]	BOEM	https://www.Data.boem.gov/Mapping/Files/GOMR_WithdrawAreas.zip; https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/GOMESA-Map.pdf	https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/GOMESA-Map.pdf
SpaceX Splashdown Zones	NASA, SpaceX, Space Force	Controlled Unclassified Information (CUI)[49]	Controlled Unclassified Information (CUI)
SpaceX Requested Setback from Splashdown Zones	NASA, SpaceX, Space Force	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Military Installations	DOD	https://catalog.data.gov/dataset/military-installations-ranges-and-training-areas	https://catalog.data.gov/dataset/military-installations-ranges-and-training-areas
U.S. Military Ship Shock Boxes	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/54962
Military Regulated Airspace	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/MilitaryAreas.zip	https://www.fisheries.noaa.gov/inport/item/48897

48 https://www.boem.gov/oil-gas-energy/leasing/areas-under-restriction
49 https://www.archives.gov/cui/about

Table A-2: Natural and cultural resources data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Rice's Whale Core Distribution Area	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/gulf-mexico-brydes-Whale-core-distribution-area-map-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_gomx_brydes_whale_core_distribution_area_jun2019_sero.zip?null
Cetacean Biologically Important Areas (BIAs) Including Reproductive, Migratory Corridors, Feeding Areas, and Those with Small and Resident Populations	NOAA NMFS	http://cetsound.noaa.gov/Assets/cetsound/Data/CetMap_BIA_WGS84.zip	https://inport.nmfs.noaa.gov/inport/item/23643
Rice's Whale Suitable Habitat	NOAA NMFS	Appendix B	Unpublished
Manatee Protection Zones	FWC	https://myfwc.com/wildlifehabitats/wildlife/manatee/Data-and-maps/	https://myfwc.com/wildlifehabitats/wildlife/manatee/Data-and-maps/
Loggerhead Sea Turtle (Northwest Atlantic DPS) High Use Areas (GOM)[50]	NOAA NMFS	Appendix B	Unpublished
Leatherback Sea Turtle High Use Areas (GOM)	NOAA NMFS	Appendix B	Unpublished
Kemp's Ridley Sea Turtle High Use Areas (GOM)	NOAA NMFS	Appendix B	Unpublished
Green Sea Turtle (North Atlantic DPS) High Use Areas (GOM)	NOAA NMFS	Appendix B	Unpublished
Hawksbill Sea Turtle Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/hawksbill-turtle-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_hawksbill_turtle_critical_habitat_caribbean_sero.htm?null
Green Sea Turtle (Northwest Atlantic DPS) Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/green-turtle-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata-green-turtle-critical-habitat-caribbean-sero.htm?null

[50] Note: NOAA NMFS also provided migratory corridors for sea turtles. Military interactions and activities within those designated areas make the planning areas overlapping with the migratory routes completely incompatible with aquaculture.

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Leatherback Sea Turtle Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/leatherback-turtle-caribbean-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_leatherback_turtle_critical_habitat_caribbean_sero.htm?null
Loggerhead Sea Turtle (Northwest Atlantic DPS) Critical Habitat - Sargassum	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map; https://www.fisheries.noaa.gov/inport/item/54209
Loggerhead Sea Turtle (Northwest Atlantic DPS) Critical Habitat - Breeding	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map	https://www.fisheries.noaa.gov/inport/item/54209
Loggerhead Sea Turtle (Northwest Atlantic DPS) Critical Habitat – Constricted Migratory	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map	https://www.fisheries.noaa.gov/inport/item/54209
Loggerhead Sea Turtle (Northwest Atlantic DPS) Critical Habitat – Nearshore Reproductive	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map	https://www.fisheries.noaa.gov/inport/item/54209
Loggerhead Sea Turtle (Northwest Atlantic DPS) Critical Habitat - Winter	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/loggerhead-turtle-northwest-atlantic-ocean-dps-critical-habitat-map	https://www.fisheries.noaa.gov/inport/item/54209
Deep-sea Coral Habitat Suitability (Soft Corals/Hard Corals) Models	NOAA NOS NCCOS	ftp://ftp.coast.noaa.gov/pub/MSP/DeepSeaCoralHabitatSuitability.zip	https://inport.nmfs.noaa.gov/inport/item/48877
Deep-sea Coral Individual Species Models	NOAA NOS NCCOS	https://gis.ngdc.noaa.gov/arcgis/rest/services/EnvironmentalMonitoring/DSC_Models/MapServer	https://gis.ngdc.noaa.gov/arcgis/rest/services/EnvironmentalMonitoring/DSC_Models/MapServer

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Coral (Black Corals, Fire Corals, Hydrocorals, Stony Corals) Essential Fish Habitat (EFH)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/coral-essential-fish-habitat-efh-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/coral-essential-fish-habitat-efh-map-gis-Data
Natural Reefs (e.g., hardbottom, pinnacles, escarpments, ledges)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Potentially Sensitive Biological Features with 1000 m Setback	NOAA NOS ONMS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Low Relief Structures with 1000 m Setback	NOAA NOS ONMS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Acropora: Elkhorn and Staghorn Coral Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/acropora-elkhorn-and-staghorn-coral-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_acropora_critical_habitat_florida_caribbean_sero.zip?null
Shallow Corals	NOAA NMFS	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ShallowCorals.zip	https://inport.nmfs.noaa.gov/inport/item/54400
Deep-Sea Coral and Sponge Observations (1985 – present)	NOAA NOS	https://deepseacoralData.noaa.gov/DatasetID_Table/DatasetID_Table.html	https://deepseacoralData.noaa.gov/library/dscrtp-Database-metaData
Coral 9 Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/reef-banks-essential-fish-habitat-efh-habitat-area-particular-concern-hapc-map-gis	https://www.fisheries.noaa.gov/resource/map/reef-banks-essential-fish-habitat-efh-habitat-area-particular-concern-hapc-map-gis
Coral 9 Habitat Area of Particular Concern (HAPC) (2020 Update) With and Without Regulations Proposed	GMFMC	http://portal.gulfcouncil.org/Regulations/HAPCshapefiles.zip	https://portal.gulfcouncil.org/coralhapc.html
Smalltooth Sawfish Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/smalltooth-sawfish-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_smalltooth_sawfish_critical_habitat_florida_sero.htm?null
Smalltooth Sawfish High Use Area	NOAA NMFS	Appendix B	Unpublished

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Gulf Sturgeon Critical Habitat	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/gulf-sturgeon-critical-habitat-map-and-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata-gulf-sturgeon-critical-habitat-all-units-usfws-nmfs-sero.zip?null
Red Drum Essential Fish Habitat (EFH)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/red-drum-essential-fish-habitat-efh-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/red-drum-essential-fish-habitat-efh-map-gis-Data
Reef Fish (Snapper, Groupers, Tilefishes, Jacks, Triggerfish, Hogfish)[51] Essential Fish Habitat (EFH)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/reef-fish-essential-fish-habitat-efh-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/reef-fish-essential-fish-habitat-efh-map-gis-Data
Highly Migratory Species (Albacore Tuna, Bigeye Tuna, Bluefin Tuna, Skipjack Tuna, Yellowfin Tuna, Swordfish, Blue Marlin, Longbill Spearfish, Sailfish, White Marlin, and numerous species of sharks)[52] Essential Fish Habitat (EFH)	NOAA NMFS	https://www.habitat.noaa.gov/application/efhinventory/data/gulf_of_mexico/gulf_efh.zip	https://ezmt.anl.gov/layer/1018/metaData_file; https://www.fisheries.noaa.gov/inport/item/23734
Coastal Migratory Pelagic (Cobia, King Mackerel, Spanish Mackerel) Essential Fish Habitat (EFH)	NOAA NMFS	https://www.habitat.noaa.gov/application/efhinventory/index.html	http://ocean.floridamarine.org/efh_coral/metaData/Coastal%20Migratory%20Pelagics%20EFH.htm; https://www.fisheries.noaa.gov/inport/item/23734
Spiny Lobster (Spiny Lobster, Slipper Lobster) Essential Fish Habitat (EFH)	NOAA NMFS	https://www.habitat.noaa.gov/application/efhinventory/Data/gulf_of_mexico/gulf_efh.zip	http://ocean.floridamarine.org/efh_coral/metaData/Spiny%20Lobster%20EFH.htm ; https://www.fisheries.noaa.gov/inport/item/23734

[51] Although goliath grouper and yellow tail snapper are within the Reef Fish EFH complex, they are currently not mapped. (https://www.habitat.noaa.gov/application/efhinventory/index.html)

[52] Atlantic angel, Atlantic sharpnose (Gulf of Mexico stock), bigeye thresher, blacknose (Gulf of Mexico stock), blacktip (Gulf of Mexico stock), bonnethead (Gulf of Mexico stock), bull, Caribbean reef, dusky, finetooth, great hammerhead, lemon, longfin mako, night, nurse, oceanic whitetip, sandbar, scalloped hammerhead, shortfin mako, silky, smoothhound shark complex (Gulf of Mexico stock), spinner, tiger, and whale sharks.

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Shrimp (Brown Shrimp, Pink Shrimp, Rock Shrimp, Royal Red Shrimp, Seabob Shrimp, White Shrimp) Essential Fish Habitat (EFH)	NOAA NMFS	https://www.habitat.noaa.gov/application/efhinventory/Data/gulf_of_mexico/gulf_efh.zip	https://www.fisheries.noaa.gov/resource/map/shrimp-essential-fish-habitat-efh-map-gis-Data
Bluefin Tuna Amendment 7 Closure Area	NOAA NMFS	Digitization via figure 2 in https://hmspermits.noaa.gov/other/listserv%20a7%20final%20rule_final.pdf	https://www.fisheries.noaa.gov/action/amendment-7-2006-consolidated-hms-fishery-management-plan-bluefin-tuna-management
Federally Managed Areas Madison-Swanson, The Edges, and Steamboat Lumps	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/tortugas-marine-reserves-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5
Federally Managed Area Pulley Ridge Essential Fish Habitat (EFH), Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/pulley-ridge-essential-fish-habitat-efh-habitat-area-particular-concern-hapc-map-gis	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Federally Managed Area Middle Grounds Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/florida-middle-grounds-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Federally Managed Area Stetson Bank	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/stetson-bank-habitat-area-particular-concern-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Federally Managed Area Reef Fish Stressed Area	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/reef-fish-stressed-area-fishery-management-area-map-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_reef_fish_stressed_area.zip?null
Federally Managed Area Seasonal Prohibitions for Bottom Longline Reef Fish	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/seasonal-prohibitions-bottom-longline-reef-fish-fishery-management-area-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/seasonal-prohibitions-bottom-longline-reef-fish-fishery-management-area-map-gis-Data

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Federally Managed Area Reef Fish Longline and Buoy Gear Restricted	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/reef-fish-longline-and-buoy-gear-restricted-fishery-management-area-map-gis-Data	https://media.fisheries.noaa.gov/2020-04/metadata_reef_fish_longline_buoy_gear.zip?null
Florida Aquatic Preserves	FDEP	https://geoData.dep.state.fl.us/Datasets/81841412d3984e9aac2c00c21e41d32e_0?geometry=-111.510%2C24.229%2C-55.633%2C31.036	https://www.arcgis.com/sharing/rest/content/items/81841412d3984e9aac2c00c21e41d32e/info/metaData/metaData.xml?format=default&output=html
Federally Managed Area Southwest Florida Seasonal Trawl Closure	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/southwest-florida-seasonal-trawl-closure-fishery-management-area-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/southwest-florida-seasonal-trawl-closure-fishery-management-area-map-gis-Data
Federally Managed Area Texas Closure Shrimp	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/texas-closure-shrimp-fishery-management-area-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/texas-closure-shrimp-fishery-management-area-map-gis-Data
Federally Managed Area Tortugas Shrimp Sanctuary	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/tortugas-shrimp-sanctuary-fishery-management-areas-map-gis-Data	https://www.fisheries.noaa.gov/resource/map/tortugas-shrimp-sanctuary-fishery-management-areas-map-gis-Data
Federally Managed Area King Mackerel Migratory Group Zones	NOAA NMFS	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_1369	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_1369
Federally Managed Area Shrimp and Stone Crab Separation Zone	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/shrimp-stone-crab-separation-zones-fishery-management-areas-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5#sp50.12.622.c

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Federally Managed Area Spanish Mackerel Migratory Group Zones	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/spanish-mackerel-migratory-group-zones-fishery-management-areas-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_1369
Federally Managed Area Cobia Migratory Group Zones	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/cobia-migratory-group-zones-fishery-management-areas-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_1369
Federally Managed Area Spiny Lobster Trap Gear	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/spiny-lobster-trap-gear-fishery-management-areas-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_1406
Federally Managed Area McGrail Bank Essential Fish Habitat (EFH) Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/mcgrail-bank-habitat-area-particular-concern-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Federally Managed Area Tortugas Marine Reserve North/South Essential Fish Habitat (EFH) Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/tortugas-marine-reserves-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Federally Managed Area Flower Garden Banks Essential Fish Habitat (EFH) Habitat Area of Particular Concern (HAPC)	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/west-and-east-flower-garden-banks-hapc-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b6b6b1c12d2e95217ebea33eb3fbb333&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
Gulf Exclusive Economic Zone (EEZ) - Bottom Trawl Weak Link Requirement	NOAA NMFS	https://www.habitat.noaa.gov/application/efhinventory/docs/gfmc_Datasheet.pdf	https://www.habitat.noaa.gov/application/efhinventory/docs/gfmc_Datasheet.pdf
Alabama Special Management Zone	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/alabama-special-management-zone-smz-fishery-management-area-map-gis-Data	https://www.ecfr.gov/cgi-bin/text-idx?SID=b409dbab40388c5008b41245328b70e9&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_135

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Bouma Bank Habitat Area of Particular Concern (HAPC)	GMFMC	https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=2a6a5493bfc04705998b727fd9ce475f#	https://flowergarden.noaa.gov/management/expansionnpr.html
Sonnier Bank Habitat Area of Particular Concern (HAPC)	GMFMC	https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=2a6a5493bfc04705998b727fd9ce475f#	https://flowergarden.noaa.gov/management/expansionnpr.html
Deepwater Coral Habitat Area of Particular Concern (HAPCs) (e.g., Pourtalès Terrace)	SAFMC	https://safmc.net/safmc-managed-areas/deepwater-coral-hapcs/	https://safmc.net/safmc-managed-areas/deepwater-coral-hapcs/
Geyer Bank Habitat Area of Particular Concern (HAPC)	GMFMC	https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=2a6a5493bfc04705998b727fd9ce475f#	https://flowergarden.noaa.gov/management/expansionnpr.html
Rezak Sidner Bank Habitat Area of Particular Concern (HAPC)	GMFMC	https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=2a6a5493bfc04705998b727fd9ce475f#	https://flowergarden.noaa.gov/management/expansionnpr.html
Jakkula Bank Habitat Area of Particular Concern (HAPC)	GMFMC	https://noaa.maps.arcgis.com/apps/MapSeries/index.html?appid=2a6a5493bfc04705998b727fd9ce475f#	https://flowergarden.noaa.gov/management/expansionnpr.html
Flower Garden Banks National Marine Sanctuary	NOAA NOS ONMS	https://sanctuaries.noaa.gov/library/imast_gis.html	https://sanctuaries.noaa.gov/library/imast/fgbnms_py.html
Bureau of Ocean Energy Management (BOEM) No Activity Zone (Applied to Flower Garden Banks NMS)	NOAA and BOEM	Available upon request and approval from BOEM and NOAA	https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Regional-Leasing/Gulf-of-Mexico-Region/Topographic-Features-Stipulation-Map-Package.pdf
Gulf of Mexico Giant Manta Ray [53] Species Distribution Model for AOAs	NOAA NMFS	Appendix B	Unpublished
Archaeological Sensitive Areas	Florida National Historic Society	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)

53 https://www.fisheries.noaa.gov/species/giant-manta-ray

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Coastal Tribal Lands	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/CoastalTribalLands.zip	https://inport.nmfs.noaa.gov/inport/item/48860
Economics: National Ocean Watch	NOAA NOS OCM	https://coast.noaa.gov/digitalcoast/data/enow.html	https://www.fisheries.noaa.gov/inport/item/48033
Automated Wreck and Obstruction Information System (AWOIS) and Electronic Navigational Charts (ENC Wrecks) and Obstructions	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/WrecksAndObstructions.zip	ftp://ftp.coast.noaa.gov/pub/MSP/WrecksAndObstructions.zip
Remediation of Underwater Legacy Environmental Threats (RULET) Wrecks	USACE	https://sanctuaries.noaa.gov/protect/ppw/wrecks.html	https://nmssanctuaries.blob.core.windows.net/sanctuaries-prod/media/archive/protect/ppw/pdfs/2013_potentiallypollutingwrecks.pdf
U.S. Fish and Wildlife Service (USFWS) Threatened and Endangered Species Act Critical Habitat	USFWS	https://www.fws.gov/gis/Data/national/	https://ecos.fws.gov/ecp/report/table/critical-habitat.html
Seagrasses of the United States	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/Seagrasses.zip	https://inport.nmfs.noaa.gov/inport/item/56960/
Seagrasses – Florida	FWC	https://geoData.myfwc.com/Datasets/seagrass-habitat-in-florida	https://www.arcgis.com/sharing/rest/content/items/3c899a92589a4f8dba2cdbba734697c5/info/metaData/metaData.xml?format=default&output=html
Seagrasses – Florida Seagrass Integrated Mapping and Monitoring Program	FWRI	https://atoll.floridamarine.org/Data/Zips/SDE/seagrass_fl_poly.zip	https://atoll.floridamarine.org/Data/Zips/SDE/seagrass_fl_poly.zip
NOAA Electronic Navigational Charts (ENC Wrecks) Artificial Reefs	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ArtificialReefs.zip	https://inport.nmfs.noaa.gov/inport/item/54191
Florida Artificial Reefs	FWC	https://openData.arcgis.com/Datasets/eb2bfd225149405bba23604f20159f56_1.zip	https://myfwc.com/fishing/saltwater/artificial-reefs/locate/

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Alabama Artificial Reefs	Alabama DCNR	https://www.arcgis.com/home/item.html?id=6a9f8a0e8f6e4aad94f3b09aed6f8562	https://www.arcgis.com/home/item.html?id=6a9f8a0e8f6e4aad94f3b09aed6f8562
Mississippi Artificial Reefs	MDMR	https://dmr.ms.gov/wp-content/uploads/2019/07/offshore-reef-coordinates-052918-1.xls; https://dmr.ms.gov/wp-content/uploads/2019/07/Rigs-to-Reef.xlsx; https://dmr.ms.gov/wp-content/uploads/2019/07/2016-Inshore-Reef-Coordinates.xls	https://dmr.ms.gov/artificial-reef/
Louisiana Artificial Reefs	LDWF	Data available upon request	https://www.wlf.louisiana.gov/assets/Fishing/Enhancing_Fish_Populations_Habitat/Files/offshore_coordinates_12-17-19.pdf
Texas Artificial Reefs	TPWD	Data available upon request	https://tpwd.texas.gov/landwater/water/habitats/artificial_reef/; https://tpwd.texas.gov/gis/ris/artificialreefs/
NOAA Electronic Navigational Charts (ENC Wrecks) Fish Havens	NOAA NOS	https://encdirect.noaa.gov/	https://www.fisheries.noaa.gov/inport/item/39976
Fish Aggregating Devices	USACE	https://www.saj.usace.army.mil/Missions/Regulatory/Public-Notices/Article/1112463/saj-2016-02457-sp-swa/	https://www.saj.usace.army.mil/Missions/Regulatory/Public-Notices/Article/1112463/saj-2016-02457-sp-swa/
U.S. Fish and Wildlife Service (USFWS) Coastal Barrier Resource System	USFWS	https://www.fws.gov/cbra/maps/boundaries.html	https://www.fws.gov/cbra/MetaData.html
Critical Wildlife Areas (CWA) - Florida	FWC	https://myfwc.com/conservation/terrestrial/cwa/	https://myfwc.com/conservation/terrestrial/cwa/

Natural and Cultural Resources Datasets	Source	Source/link	Metadata link
Biological Stipulation Areas	BOEM	https://www.boem.gov/oil-gas-energy/mapping-and-Data/gomr-geographic-information-system-gis-Data-and-maps	https://www.boem.gov/sites/default/files/oil-and-gas-energy-program/Leasing/Regional-Leasing/Gulf-of-Mexico-Region/Topographic-Features-Stipulation-Map-Package.pdf
Marine Protected Area Inventory	NOAA	https://www.arcgis.com/apps/webappviewer/index.html?id=7eb7f3112be14713a8540cab37a36af0 ; https://protectedseas.net/mpa-download-Data/	https://services9.arcgis.com/lm7wE8a9YA9rKfzy/arcgis/rest/services/usa_10sqkmgrid2/FeatureServer/0
Coastal Wetlands	USFWS	https://www.fws.gov/wetlands/Data/Data-Download.html	https://www.fws.gov/wetlands/Data/Historic-Wetlands-Data.html

Table A-3: Industry, navigation, and transportation data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Industry, Navigation, and Transportation Datasets	Source	Source/link	Metadata link
Ocean Disposal Sites	USEPA	ftp://ftp.coast.noaa.gov/pub/MSP/OceanDisposalSites.zip	https://inport.nmfs.noaa.gov/inport/item/54193
Submarine Cables	NOAA and BOEM (i.e., marinecadastre.gov)	Confidential; version for public distribution available at ftp://ftp.coast.noaa.gov/pub/MSP/SubmarineCables.zip	Confidential; version for public distribution available at https://inport.nmfs.noaa.gov/inport/item/54403
Submarine Cable Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SubmarineCableAreas.zip	https://inport.nmfs.noaa.gov/inport/item/54402
Oil and Gas Pipeline Locations	BOEM and BSEE	https://www.Data.boem.gov/Mapping/Files/ppl_arcs.zip; https://www.Data.boem.gov/Main/Pipeline.aspx#ascii; https://www.Data.bsee.gov/Main/RawData.aspx	https://www.Data.boem.gov/Mapping/Files/ppl_arcs_meta.html
Natural Gas Interstate/Intrastate Pipelines	DOE	https://hub.arcgis.com/Datasets/fedmaps::natural-gas-interstate-and-intrastate-pipelines	https://hub.arcgis.com/Datasets/fedmaps::natural-gas-interstate-and-intrastate-pipelines
Pilot Boarding Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PilotBoarding.zip	https://inport.nmfs.noaa.gov/inport/item/54393
Pilot Boarding Stations	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PilotBoarding.zip	https://inport.nmfs.noaa.gov/inport/item/54394
Coastal Maintained Channels	USACE	http://encdirect.noaa.gov/theme_layers/Data/coastal_maintained_channels/maintainedchannels.zip	https://inport.nmfs.noaa.gov/inport/item/39972
Aids to Navigation	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://csc.noaa.gov/pub/MSP/AidsToNavigation.zip	https://inport.nmfs.noaa.gov/inport/item/56120
Anchorage Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/AnchorageAreas.zip	https://www.fisheries.noaa.gov/inport/item/48849
U.S. Shipping Fairways	NOAA NOS	http://encdirect.noaa.gov/theme_layers/Data/shipping_lanes/Shippinglanes.zip	https://inport.nmfs.noaa.gov/inport/item/39986

Industry, Navigation, and Transportation Datasets	Source	Source/link	Metadata link
Navigable Waterway Network (NWN) and Commercial Waterway Network (CWN)	NWGISDC[54]	https://usace.contentdm.oclc.org/digital/collection/p16021coll2/id/1472/	https://usace.contentdm.oclc.org/digital/collection/p16021coll2/id/1472/
U.S. Ferry Routes	National Atlas of the U.S.	https://geo.nyu.edu/catalog/stanford-gd729dg1947	https://geo.nyu.edu/catalog/stanford-gd729dg1947
Automatic Identification System (AIS) Vessel Traffic (2015, 2016, 2017, 2018, 2019, 2020) for Each Vessel Type (Cargo, Tanker, Passenger, Fishing, Tug and Tow, Pleasure and Sailing, Military, and Other)	NOAA and BOEM (i.e., marinecadastre.gov) and USCG	https://marinecadastre.gov/ais/	https://inport.nmfs.noaa.gov/inport/item/53161
Deepwater Ports	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/DeepwaterPorts.zip	https://inport.nmfs.noaa.gov/inport/item/54192
Federal Lightering - Non-Lightering Prohibited Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/LighteringZones.zip	https://inport.nmfs.noaa.gov/inport/item/54387
Federal Lightering - Rendezvous Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/LighteringZones.zip	https://inport.nmfs.noaa.gov/inport/item/54387
Principal Ports	USACE	ftp://ftp.coast.noaa.gov/pub/MSP/PrincipalPorts.zip	https://inport.nmfs.noaa.gov/inport/item/56124
NOAA NMFS Individual Fishing Quota Seafood Dealers	NOAA NMFS	https://secatchshares.fisheries.noaa.gov/viewDealers	https://secatchshares.fisheries.noaa.gov/viewDealers
NOAA NMFS Individual Fishing Quota Landing Locations	NOAA NMFS	https://secatchshares.fisheries.noaa.gov/viewLandingLocations	https://noaa.maps.arcgis.com/home/webmap/viewer.html?webmap=b8ecbae770ec495c92f2b7bdfe3dd22a
Seafood Processors	NOAA NMFS Fisheries Statistics Division	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Environmental Sensors and Buoys	NOAA NWS	https://www.ndbc.noaa.gov/	https://www.ndbc.noaa.gov/

[54] The National Waterway GIS Design Committee (NWGISDC) consists of USACE, USDOT, Volpe National Transportation Systems Center, Maritime Administration, Military Traffic Management Command, Tennessee Valley Authority, U.S. EPA, U.S. Bureau of Census, USCG, and the Federal Railroad Administration. Data were derived from USGS digital line graph files, starting with the USACE Waterway Link Network, along with the NOAA ENC.

Industry, Navigation, and Transportation Datasets	Source	Source/link	Metadata link
Platform Masters, Location (i.e., Drilling Platforms)	BOEM and BSEE	https://www.Data.bsee.gov/Platform/Files/platmastfixed.zip; https://www.Data.bsee.gov/Main/RawData.aspx (platform structures); https://www.Data.boem.gov/Mapping/Files/Platforms.gdb.zip	http://metaData.boem.gov/geospatial/OCSplatforms-GOMR-NA https://www.Data.boem.gov/Mapping/Files/platform_meta.html D27.xml
Platform Applications and Approvals	BSEE	https://www.Data.bsee.gov/Platform/Files/platformapprovalsfixed.zip	https://www.Data.bsee.gov/Main/HtmlPage.aspx?page=platformAppAppr
Platform List of Structures Removed and Method of Removal	BSEE	https://www.Data.bsee.gov/Platform/Files/platstruremdelimit.zip	https://www.Data.bsee.gov/Main/HtmlPage.aspx?page=platformStrucRem
Gulf of Mexico Lease Blocks with Significant Sediment Resources	BOEM	https://mmis.doi.gov/boemmmis/downloads/layers/GOMSigSedBlocks_fgdb.zip	https://mmis.doi.gov/boemmmis/metaData/PlanningAndAdministration/GOMSigSedBlocks.xml
Federal Sand and Gravel Lease Borrow Areas	BOEM	https://mmis.doi.gov/boemmmis/downloads/layers/LeaseAreas_fgdb.zip	https://mmis.doi.gov/boemmmis/metaData/PlanningAndAdministration/LeaseAreas.xml
Beach Nourishment	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/BeachNourishmentProjects.zip	https://inport.nmfs.noaa.gov/inport/item/59711
Boreholes, Test Wells, and Wells	BSEE	https://www.Data.bsee.gov/Main/RawData.aspx; https://www.Data.bsee.gov/Mapping/Files/Well.zip	http://metaData.boem.gov/geospatial/OCSwells-GOMR-NAD27.xml
Bureau of Ocean Energy Management (BOEM) Active Lease Polygons	BOEM	https://www.Data.boem.gov/Mapping/Files/ActiveLeasePolygons.gdb.zip; https://www.Data.boem.gov/Main/Mapping.aspx	https://www.Data.boem.gov/Mapping/Files/actlease_meta.html
Oil and Gas Lease Blocks (Active vs. Inactive) (5yr, 8yr, 10yr) Clipped to Federal Waters	BOEM	https://www.Data.boem.gov/Mapping/Files/510LeaseLines.gdb.zip; https://www.Data.boem.gov/Main/Mapping.aspx	https://www.Data.boem.gov/Mapping/Files/leas510_meta.html
Right-Of-Way Easements	BOEM	https://www.Data.bsee.gov/Pipeline/Files/RowDescRawData.zip	https://www.Data.bsee.gov/Pipeline/ROWDescriptions/Default.aspx
Planned Wells and Structure Sites	BSEE	https://www.Data.boem.gov/Plans/Files/plandelimit.zip	https://www.Data.boem.gov/Main/HtmlPage.aspx?page=planSites

Industry, Navigation, and Transportation Datasets	Source	Source/link	Metadata link
Lease Blocks	BOEM	https://www.Data.boem.gov/Mapping/Files/Blocks.gdb.zip	https://www.Data.boem.gov/Mapping/Files/blocks_meta.html
Block Polygons in Federal Waters	BOEM	https://www.Data.boem.gov/Mapping/Files/BlockPolygonsClipped.gdb.zip	https://www.Data.boem.gov/Mapping/Files/blk_clip_meta.html
Bureau of Ocean Energy Management BOEM 2017-2022 OCS Oil and Gas Leasing Gulf of Mexico Proposed Final Program Area	BOEM	https://www.Data.boem.gov/Mapping/Files/Boem2017-2022FinalProgramAreas.zip	https://metaData.boem.gov/geospatial/GOMR_Proposed_Final_Program_Area.xml
Bureau of Ocean Energy Management BOEM 2019-2024 Draft Proposed Program Area - Gulf of Mexico Region	BOEM	https://www.Data.boem.gov/Mapping/Files/Gom_5yr_2019_2024.zip	https://metaData.boem.gov/geospatial/2019-2024_Draft_Proposed_Program_Area.xml
Bureau of Ocean Energy Management BOEM 2019-2024 Draft Proposed Program Exclusion Option Areas - Gulf of Mexico Region	BOEM	https://www.Data.boem.gov/Mapping/Files/GOM_5yr_2019_2024_excl_opt.zip +	https://www.data.boem.gov/Main/Default.aspx
Gulf of Mexico Current Presidential Withdrawal and Congressional Moratoria Areas	BOEM	https://www.Data.boem.gov/Mapping/Files/GOMR_WithdrawAreas.zip	https://www.data.boem.gov/Main/Default.aspx
Protraction Polygons – Clipped to Federal Waters	BOEM	https://www.Data.boem.gov/Mapping/Files/ProtractionPolygonsClipped.gdb.zip	https://www.Data.boem.gov/Mapping/Files/protclip_meta.html
Unit Polygons	BOEM	https://www.Data.boem.gov/Mapping/Files/UnitPolygons.gdb.zip	https://www.Data.boem.gov/Mapping/Files/fld_unit_meta.html
Bureau of Ocean Energy Management (BOEM) Funded Studies (e.g., hourly wind studies)	BOEM	https://www.boem.gov/NREL-HourlyWind-Gulf-polysandpoints/	https://www.boem.gov/renewable-energy/mapping-and-Data/renewable-energy-gis-Data
Renewable Energy Leases and Planning Areas	BOEM	https://www.boem.gov/oil-gas-energy/boem-renewable-energy-geoDatabase	https://www.boem.gov/renewable-energy/mapping-and-Data/renewable-energy-gis-Data
Coastal Energy Facilities	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://csc.noaa.gov/pub/MSP/CoastalEnergyFacilities.zip	https://inport.nmfs.noaa.gov/inport/item/56119
Deepwater Natural Gas and Oil Fields (Quantified)	BSEE	https://www.Data.bsee.gov/Other/Files/DeepQualRawData.zip	https://www.Data.bsee.gov/Other/DataTables/DeepQualFields.aspx

Industry, Navigation, and Transportation Datasets	Source	Source/link	Metadata link
Electrical Substations	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/Substations.zip	https://inport.nmfs.noaa.gov/inport/item/54404
Airports	FAA	https://www.faa.gov/documentLibrary/media/Advisory_Circular/150-5200-33C.pdf	https://www.faa.gov/documentLibrary/media/Advisory_Circular/150-5200-33C.pdf
Strategic Petroleum Reserves	DOE Office of Fossil Energy and Carbon Management, U.S. Petroleum Reserves	https://www.eia.gov/maps/map_Data/SPR_US_EIA.zip	http://www.fossil.energy.gov/programs/reserves/spr/spr-sites.html
Power Plants	Energy Information Administration (EIA)	https://www.eia.gov/maps/map_Data/PowerPlants_US_EIA.zip	https://www.eia.gov/maps/layer_info-m.php
Offshore Wind Resource Potential	BOEM	https://www.boem.gov/NREL-HourlyWind-Gulf-polysandpoints/	https://metaData.boem.gov/geospatial/NREL_HourlyWind_Gulf_polysandpoints.xml
Bureau of Safety and Environmental Enforcement (BSEE) Plans	BSEE	https://www.Data.bsee.gov/Plans/Files/PlansRawData.zip	https://www.Data.bsee.gov/Plans/Plans/Default.aspx
Directional Survey Points from Oil Wells (Master American Petroleum Institute List)	BOEM	https://www.Data.boem.gov/Well/Files/dspapidelimit.zip	https://www.Data.boem.gov/Main/HtmlPage.aspx?page=dirSurvMaster

Table A-4: Fishing and aquaculture data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Fishing and Aquaculture Datasets	Source	Source/link	Metadata link
Live Rock Aquaculture	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Ocean Era, Inc. Velella Epsilon Aquaculture Site	USEPA	https://www.epa.gov/sites/production/files/2019-08/documents/velella_environmental_assessment_draft.pdf	https://www.epa.gov/sites/production/files/2019-08/documents/velella_environmental_assessment_draft.pdf
Highly Migratory Species Longline Gear Observer Data (1993 - 2019)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Menhaden Fishery Data Sum (2000 - 2016)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Commercial Shrimp Electronic Logbook Data (2004 - 2019)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Reef Fish Longline Gear Fishing Data (2007 - 2019)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Reef Fish Bandit Gear Fishing Data (2007 - 2019)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)
Southeast Region Headboat Survey Data (2014 - 2020)	NOAA NMFS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)

Table A-5: Boundary data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Boundary Datasets	Source	Source/link	Metadata link
U.S. Exclusive Economic Zone (EEZ)	NOAA	https://coast.noaa.gov/digitalcoast/tools/enow.html	https://coast.noaa.gov/digitalcoast/tools/enow.html
Continental Shelf Boundary	BOEM	https://www.Data.boem.gov/Mapping/Files/ContinentalShelfBoundary.gdb.zip	https://www.Data.boem.gov/Mapping/Files/csb_meta.html
Bureau of Ocean Energy Management (BOEM) Gulf of Mexico District Boundary	BOEM	https://www.Data.boem.gov/Mapping/Files/DistrictBoundaries.gdb.zip	https://www.Data.boem.gov/Mapping/Files/district_meta.html
Bureau of Ocean Energy Management (BOEM) Planning Area Boundaries	BOEM	https://www.Data.boem.gov/Mapping/Files/PlanningAreaBoundary.gdb.zip	https://www.Data.boem.gov/Mapping/Files/planarea_meta.html
National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Fisheries Regional Boundaries	NOAA NMFS	Data available upon Agency request/approval	Data available upon Agency request/approval
Federal/State Boundary	BOEM	https://www.Data.boem.gov/Mapping/Files/FedStateBoundary.gdb.zip	https://www.Data.boem.gov/Mapping/Files/fedstate_meta.html
Environmental Protection Agency (EPA) Regions	USEPA	https://www.epa.gov/frs/epa-regional-kml-download	https://www.epa.gov/ceam/metaData-epa-regional-boundaries
U.S. Fish and Wildlife Service (USFWS) Regions	USFWS	https://Data.geospatialhub.org/Datasets/85f8c9053d6d4970bd5807eff042a167_0	https://www.arcgis.com/home/item.html?id=85f8c9053d6d4970bd5807eff042a167
Convention on the International Regulations for Preventing Collisions at Sea 1972 (COLREGs) Demarcation line	NOAA and BOEM (i.e., marinecadastre.gov)	https://www.northeastoceanData.org/Data-download/?Data=Marine%20Transportation	https://inport.nmfs.noaa.gov/inport/item/56121
U.S. Coast Guard (USCG) Districts	USCG	https://www.northeastoceanData.org/Data-download/?Data=Administrative%20Boundaries	https://services.northeastoceanData.org/arcgis1/rest/services/Administrative/MapServer/5

Boundary Datasets	Source	Source/link	Metadata link
U.S. Army Corps of Engineers (USACE) Districts	USACE	https://www.northeastoceanData.org/Data-download/?Data=Administrative%20 Boundaries	https://www.arcgis.com/sharing/rest/content/items/70805e1a8fd74e42b0a9585088d6d151/info/metaData/metaData.xml?format=default&output=html
Coastal Counties	NOAA and BOEM (i.e., marinecadastre.gov) and U.S. Census Bureau	http://www2.census.gov/geo/tiger/TIGER2017/COUNTY/tl_2017_us_county.zip	https://inport.nmfs.noaa.gov/inport/item/54371
Federal Consistency Location Descriptions	NOAA NMFS	ftp://ftp.coast.noaa.gov/pub/MSP/GeographicLocationDescriptions.zip	https://inport.nmfs.noaa.gov/inport/item/51544
Coastal States	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalStates.zip	https://inport.nmfs.noaa.gov/inport/item/54375
Gulf of Mexico Shoreline	GCOOS	https://geo.gcoos.org/Data/topography/Shoreline_files/GSHHS_f_GOM.zip	https://geo.gcoos.org/Data/topography/Shoreline.html
National Oceanic and Atmospheric Administration (NOAA) National Estuarine Research Reserve System (NERRS)	NOAA	http://cdmo.baruch.sc.edu/Data/available-Data/	http://cdmo.baruch.sc.edu/data/metadata.cfm
National Wildlife Refuge System (NWRS)	USFWS	https://www.fws.gov/gis/Data/CadastralDB/links_cadastral.html	https://www.fws.gov/gis/Data/CadastralDB/links_cadastral.html
U.S. Congressional Districts	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/CongressionalDistricts.zip	https://inport.nmfs.noaa.gov/inport/item/56122
State Legislative Districts: House	U.S. Census Bureau	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalStateLegislativeDistricts.zip	https://inport.nmfs.noaa.gov/inport/item/54373
State Legislative Districts: Senate	U.S. Census Bureau	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalStateLegislativeDistricts.zip	https://inport.nmfs.noaa.gov/inport/item/54374

Table A-6: Socio-economic data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Socio-economic Datasets	Source	Source/link	Metadata link
National Oceanic and Atmospheric Administration (NOAA) Economics: National Ocean Watch Marine Economic Gross Domestic Product by State	NOAA NOS OCM	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ENOW2015.zip	https://inport.nmfs.noaa.gov/inport/item/54382
National Oceanic and Atmospheric Administration (NOAA) Economics: National Ocean Watch Marine Ocean Economy Percent by State	NOAA NOS OCM	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ENOW2015.zip	https://inport.nmfs.noaa.gov/inport/item/54381
National Oceanic and Atmospheric Administration (NOAA) Economics: National Ocean Watch Ocean Economy State Statistics	NOAA NOS OCM	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ENOW2015.zip	https://inport.nmfs.noaa.gov/inport/item/54382
Port Trade Statistics	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/PrincipalPorts.zip	ftp://ftp.coast.noaa.gov/pub/MSP/PrincipalPorts.zip
Federal Statutes	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/Legis-Atlas/FederalGeoregulations/	https://inport.nmfs.noaa.gov/inport/item/52784

Table A-7: Public health Indicators data layers used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters.

Public Health Indicators[55] Datasets	Source	Source/link	Metadata link
Harmful Algal Bloom (*Karenia brevis*) in the Gulf of Mexico	NOAA NOS	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/HarmfulAlgalBlooms.zip	https://inport.nmfs.noaa.gov/inport/item/58081
National Pollutant Discharge Elimination System (NPDES) Permitted Facilities (wastewater input)	USEPA	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/WastewaterOutfalls.zip	https://inport.nmfs.noaa.gov/inport/item/54410
Northern Gulf of Mexico Hypoxia Zone (2010 - 2020)	NOAA NOS NCCOS	N.N. Rabalais, Louisiana Universities Marine Consortium, and R.E. Turner, Louisiana State University	Available Upon Request/approval
Oil Spills (Raw Incident)	NOAA	https://incidentnews.noaa.gov/raw/incidents.csv	https://incidentnews.noaa.gov/raw/index
Phytoplankton Time Series (Flow Cytobots) for HABs Monitoring	GCOOS	https://geo.gcoos.org/hab/	https://geo.gcoos.org/hab/
Unexploded Ordnance Point Data	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance.zip	https://www.fisheries.noaa.gov/inport/item/54408
Unexploded Ordnance Polygon Data	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/UnexplodedOrdnance.zip	https://www.fisheries.noaa.gov/inport/item/54407
Natural Hydrocarbon Seeps	BOEM	https://www.boem.gov/BOEM-Seafloor-Anomalies-Layer-Package/	https://www.boem.gov/oil-gas-energy/mapping-and-Data/map-gallery/seismic-water-bottom-anomalies-map-gallery
Ocean Disposal Sites	USEPA	ftp://ftp.coast.noaa.gov/pub/MSP/OceanDisposalSites.zip	https://inport.nmfs.noaa.gov/inport/item/54193

55 These Datasets and any information contained with provided sources in this table have not been evaluated by the FDA, and therefore are only available indicators of public and human health for AOA characterization. This information is intended for planning purposes only and is not meant to substitute for FDA seafood assessments, particularly pertaining to risk of consumption.

Table A-8: Physical, chemical, and biological data used for Aquaculture Opportunity Area planning in U.S. Gulf of Mexico waters. Additional information is provided for each dataset, as these data are largely in raster format where temporal and spatial resolution are important for the reader. N/A indicates data types where spatial resolution and temporal range were not needed.

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
Bathymetry (Gulf-wide) (2013, 2015)	Coastal Relief Model (2013), GEBCO (2015)	https://www.ngdc.noaa.gov/mgg/coastal/crm.html; https://www.gebco.net/Data_and_products/historical_Data_sets/	https://inport.nmfs.noaa.gov/inport/item/54365	3 Arc Seconds (~90 m)	N/A
Surficial Sediment Classification	USGS usSEABED and Sediment Texture Databases	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SurficialSedimentClassification.zip	https://inport.nmfs.noaa.gov/inport/item/54406	N/A	N/A
USGS usSEABED Data Series 146 (Gulf of Mexico and Caribbean)[56]	USGS[57]	https://pubs.usgs.gov/ds/2006/146/htmldocs/usseabed.htm; https://pubs.usgs.gov/ds/2006/146/Data/gmx_ext.zip	https://pubs.usgs.gov/ds/2006/146/Data/gmx_extmeta.htm	N/A	1960 - 2019
Predicted Surficial Sediment Mean Grain Size (Also Percent Gravel, Sand, Mud)	NOAA NOS NCCOS	Controlled Unclassified Information (CUI)	Controlled Unclassified Information (CUI)	3 Arc Seconds (~90-m)	1960 - 2019

[56] https://pubs.usgs.gov/ds/2006/146/htmldocs/Data_cata.htm

[57] https://pubs.usgs.gov/ds/2006/146/htmldocs/gmx_sources.htm

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
Chlorophyll - *a* Concentration (µg/l)	NOAA Coastwatch and NOAA MSL 12 Ocean Color – Science Quality – VIIRS SNPP	https://coastwatch.noaa.gov/cw/satellite-data-products/ocean-color/science-quality/viirs-snpp.html monthly	https://www.star.nesdis.noaa.gov/thredds/socd/coastwatch/catalog_MECB_viirs_npp_lom_sector_chlora_monthly.html?dataset=CoastWatch/VIIRS/npp/chlora/SCIMonthlySectorAgg/VY00	750 m	2012 to 2019/monthly/1
Aragonite Saturation State	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SurfaceAragonite.zip	https://inport.nmfs.noaa.gov/inport/item/54405	1 Arc Degree	1989 to 2010/annually/1
Kd(PAR)	NOAA NOS NCCOS using VIIRS imagery[58]	https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/viirs-a-nrt	https://inport.nmfs.noaa.gov/inport/item/54386	750 m	2012 to 2019/monthly/5
Kd(490)	NOAA NOS NCCOS using VIIRS imagery	https://earthdata.nasa.gov/earth-observation-data/near-real-time/download-nrt-data/viirs-a-nrt	https://inport.nmfs.noaa.gov/inport/item/54385	750 m	2012 to 2019/monthly/1
Nutrients at Depth (Silicate, Phosphate, Nitrate)	Bio-ORACLE	https://bio-oracle.org/downloads-to-email.php	https://bio-oracle.org/release-notes-2-1.php	4 km	2000 to 2014/annual/4

[58] Son and Wang (2015)

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
Nutrients at Depth (Nitrate, Phosphate, Silicate) (EMU data)	Esri Ecological Marine Units (Sayre et al., 2017)[59]	https://www.arcgis.com/home/item.html?id=5075d771f6894080ac190c3ccd954f0e; https://www.arcgis.com/home/group.html?id=6c78a5125d3244f38d1bc732ef0ee743#overview	https://www.arcgis.com/home/item.html?id=24885cd6bd9544f5a8e15d0bf40f67d6	1/4° (~27 km)	1878 to 2017/annual/102
Dissolved Oxygen	Bio-ORACLE	https://bio-oracle.org/downloads-to-email.php	https://bio-oracle.org/release-notes-2-1.php	4 km	2000 to 2014/annual/4
Iron Concentration	Bio-ORACLE	https://bio-oracle.org/downloads-to-email.php	https://bio-oracle.org/release-notes-2-1.php	4 km	2000 to 2014/annual/4
Sediment Thickness	NCEI	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GC008115; http://earthdynamics.org/Data/	http://www.earthdynamics.org/page5.html	5 arc min	Refer to https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GC008115
Mixed Layer Thickness	NCEI	https://polar.ncep.noaa.gov/ofs/download.shtml	https://polar.ncep.noaa.gov/global/nc/?-global-mixed_layer_thickness-000-small-rundate=latest	0.333 °lat x 1.0°long	1980 to 2019/hourly/39
High Frequency Radar Locations	GCOOS	https://Data.gcoos.org/fullView.php	http://gcoos5.geos.tamu.edu:6060/erddap/metaData/iso19115/xml/WS0603_ws0603_01_iso19115.xml	6 km	variable

59 https://www.tos.org/oceanography/article/a-three-dimensional-mapping-of-the-ocean-based-on-environmental-data

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
NOAA ERDDAP Walton-Smith CTD Data	GCOOS	https://gcoos5.geos.tamu.edu/erddap/tabledap/WS19322_WS19322_Stn7.html	https://gcoos5.geos.tamu.edu/erddap/info/WS19322_WS19322_Stn7/index.html	variable	2006 to 2012
GCOOS Glider Data (Wave gliders - USM/MSU)	GCOOS	https://gisData.gcoos.org/Datasets/7fda7eb452674a0e9a797be37bf508a8	https://products.gcoos.org/gliders/	N/A	N/A
Current Speed (m/s) and direction (U, V)	NCOM (American Seas)	https://www.ncei.noaa.gov/thredds-coastal/catalog/amseas/catalog.html	https://www.ncdc.noaa.gov/Data-access/model-Data/model-Datasets/navoceano-ncom-reg	1/30° (3 km)	2010 – present/3 hours/40 depth levels
Seawater Temperature (°C)	NCOM (American Seas)	https://www.ncei.noaa.gov/thredds-coastal/catalog/amseas/catalog.html	https://www.ncdc.noaa.gov/Data-access/model-Data/model-Datasets/navoceano-ncom-reg	1/30° (3 km)	2010 – present/3 hours/40 depth levels
Salinity	NCOM (American Seas)	https://www.ncei.noaa.gov/thredds-coastal/catalog/amseas/catalog.html	https://www.ncdc.noaa.gov/Data-access/model-Data/model-Datasets/navoceano-ncom-reg	1/30° (3 km)	2010 – present/3 hours/40 depth levels
Natural Hydrocarbon Seeps	BOEM	https://www.boem.gov/BOEM-Seafloor-Anomalies-Layer-Package/	https://www.boem.gov/oil-gas-energy/mapping-and-Data/map-gallery/seismic-water-bottom-anomalies-map-gallery	N/A	N/A

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
Salinity and Temperature Scenarios by Season for the Mississippi River Delta	USACE	Request Data via USACE Environmental Review Appeals Commission	https://apps.dtic.mil/dtic/tr/fulltext/u2/1081387.pdf	N/A	N/A
Storm Information	NOAA NWS	https://www.weather.gov/gis/NWS_Shapefile	https://www.weather.gov/gis/	N/A	N/A
National Weather Service Prediction Center Wind and Wave Forecast	NOAA NWS	https://ocean.weather.gov/gis/index.php	https://ocean.weather.gov/digital_forecasts.php	N/A	N/A
Wave Height and Direction (MIKE21) (3-hr time steps)	MIKE21 Model[60]	http://www.iingen.unam.mx/es-mx/Investigacion/Paginas/default.aspx - Christian Mario Appendini Albrechtsen	Limited Distribution Data	Unstructured Grid (variable resolution)	32 yrs/3 hours/
Sea Surface Height	NASA	https://podaac.jpl.nasa.gov/Dataset/SEA_SURFACE_HEIGHT_ALT_GRIDS_L4_2SATS_5DAY_6THDEG_V_JPL1812	https://podaac.jpl.nasa.gov/Dataset/SEA_SURFACE_HEIGHT_ALT_GRIDS_L4_2SATS_5DAY_6THDEG_V_JPL1812	0.17° x 0.17°	1993 to 2015/monthly/
Regional Offshore Sand Source Inventory (ROSSI) Borrow Areas	Florida ROSSI	https://catalog.Data.gov/harvest/florida-regional-offshore-sand-source-inventory-rossi	https://catalog.Data.gov/harvest/florida-regional-offshore-sand-source-inventory-rossi; http://rossi.urs-tally.com/Map	N/A	N/A
Regional Offshore Sand Source Inventory (ROSSI) Paleo Ebb Deltas	Florida ROSSI	http://rossi.urs-tally.com/Home/Downloads	http://rossi.urs-tally.com/Home/Downloads	N/A	N/A

[60] https://www.mikepoweredbydhi.com/products/mike-21/waves

Physical, Chemical, and Biological Datasets	Source	Source Link	Metadata Link	Spatial Resolution	Temporal Range/Time-step (interval of Data collection)/Z levels
Regional Offshore Sand Source Inventory (ROSSI) Shoreline Complex	Florida ROSSI	http://rossi.urs-tally.com/Home/Downloads	http://rossi.urs-tally.com/Home/Downloads	N/A	N/A
Regional Offshore Sand Source Inventory (ROSSI) Barrier Islands	Florida ROSSI	http://rossi.urs-tally.com/Home/Downloads	http://rossi.urs-tally.com/Home/Downloads	N/A	N/A
Regional Offshore Sand Source Inventory (ROSSI) Holocene sand	Florida ROSSI	http://rossi.urs-tally.com/Home/Downloads	http://rossi.urs-tally.com/Home/Downloads	N/A	N/A
Regional Offshore Sand Source Inventory (ROSSI) sediment samples	Florida ROSSI	http://rossi.urs-tally.com/Home/Downloads	http://rossi.urs-tally.com/Home/Downloads	N/A	N/A

Appendix B

Appendix B: Memorandum from the National Marine Fisheries Service Southeast Region, West Coast Region, and Office of Protected Resources with recommendations for data layers and scoring for protected species.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701-5505
https://www.fisheries.noaa.gov/region/southeast

May 19, 2021 F/SER31:NF

MEMORANDUM FOR: James A. Morris, Jr., Ph.D.
Coastal Aquaculture Siting and Sustainability
National Centers for Coastal Ocean Science (NCCOS)

Kristine Cherry
Chief, Regulatory and Policy Branch
NOAA Fisheries, Office of Aquaculture (OAQ)

FROM: Nicholas A. Farmer, Ph.D.
Chief, Species Conservation Branch
NOAA Fisheries, Southeast Regional Office (SERO)

Penny Ruvelas
Chief, Long Beach Office Branch
NOAA Fisheries, West Coast Region (WCR)

Shannon Bettridge, Ph.D.
Chief, Marine Mammal and Sea Turtle Conservation Division
NOAA Fisheries, Office of Protected Resources (OPR)

Cathy Tortorici
Chief, ESA Interagency Cooperation Division
NOAA Fisheries, OPR

SUBJECT: SERO and WCR Protected Resources Division (PRD) Data Layers and Scoring for NCCOS Aquaculture Opportunity Atlas (Atlas)

PURPOSE:

OAQ and OPR have shared goals for NOAA Fisheries to identify ten aquaculture opportunity areas (AOAs) over seven or more years using the best-available science to identify areas suitable for domestic aquaculture production, while minimizing impacts to NOAA-trust resources. To accomplish this, OAQ, OPR, and Regional Office PRDs are coordinating data provision and scoring to inform the development of Atlases that are being developed by NCCOS.

OAQ, OPR, SERO-PRD, and WCR-PRD have coordinated to develop an approach that describes how to include and score data layers for species listed as endangered or threatened under the Endangered Species Act (ESA) in the NCCOS spatial models and resulting in a peer-reviewed Atlas of potential AOAs. The Atlas will be used by NOAA Fisheries to inform the development of preliminary alternatives that will be described in the Notice of Intent (NOI) to prepare a programmatic environmental impact statement (PEIS). The approach outlined below was developed collaboratively between OAQ, OPR, WCR-PRD, SERO-PRD, Southeast Fisheries Science Center (SEFSC), and NCCOS, and describes how the final SERO-PRD data layer was developed for the Gulf of Mexico Atlas in Appendix I. WCR-PRD followed the same approach, with their data layers described in Appendix II. This approach may serve as a template for other regional Atlases.

APPROACH:

OAQ, OPR, WCR-PRD, SERO-PRD, and NCCOS collaboratively developed a scoring table to provide more detailed information on protected species vulnerability based on species status, population size, and trajectory for species protected under the Endangered Species Act (ESA) and/or Marine Mammal Protection Act (MMPA) in the spatial model (**Table 1**). Because specific aquaculture activities will not be identified until later in the process, a generalized approach was desired that could transfer easily across regions and inform PEIS development with regards to areas containing protected species of the highest concern. Table 1 scores MMPA and ESA-listed species data layers ranging from 0.1 (most vulnerable species, based on their biological status) to 0.8 (least vulnerable species) for the best available data on protected species. Species and stocks are ranked according to factors that are more or less likely to affect their ability to withstand mortality, serious injury, or other impacts to the species' ability to survive and recover. A generalized score of 0.5 was also reserved for layers or areas within layers to reflect types of data needing further consideration during the site characterization process. The generalized score is the standard score used in the spatial model for data where suitability of a location for potential aquaculture activities is uncertain (i.e., not incompatible, but certainty of high compatibility is low).

Table 1. AOA model scoring system for endangered and threatened species data layers.

Status	*Trend*	*Converted scores for model*
Endangered	declining, small population* or both	0.10
Endangered	stable or unknown	0.20
Endangered	increasing	0.30
Threatened	declining or unknown	0.40
Threatened	stable or increasing	0.50
MMPA Strategic	declining or unknown	0.60
MMPA listed	small population	0.70
MMPA listed	large population	0.80

**Small population equates to populations of 500 individuals or less (Franklin 1980[1]).*

The first Phase of the AOA process is NCCOS' development of a public-facing Atlas that visually represents the relative suitability of different locations for potential aquaculture activities.

[1] Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135-140 in: M. E. Soule and B. A. Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Sunderland, Mass.: Sinauer Associates.

APPENDIX I - SERO-PRD DATA LAYERS

The study areas for the Gulf of Mexico potential AOA are in federal waters between 50-150 m depth and delineated using an ecosystem-based approach that results in four separate study areas (Western, Central, Eastern, and Southeastern Gulf of Mexico study areas). SERO-PRD staff evaluated the best scientific information available for the distributions of vulnerable ESA-listed species within the proposed Gulf of Mexico Atlas study areas. ESA-listed Sperm Whales were not included because they typically occur in waters deeper than the Atlas study areas. Gulf Sturgeon were not evaluated as they occur primarily inshore of the 50 m depth contour. Similarly, Oceanic Whitetip Shark were not considered, as they occur primarily offshore of the 150 m depth contour, although there are some anecdotal reports from the Pacific Islands suggesting this species may be attracted to certain aquaculture activities. Marine mammals protected under the MMPA were not included in the data layer because insufficient time and resources were available to obtain and evaluate their distributions relative to the proposed Atlas study areas. These species will be further discussed during the Site Characterization phase of the AOA process and to inform site selection in the PEIS. Table 2 presents the scores for ESA-listed species evaluated by SERO-PRD that are known to occur within the Gulf of Mexico Atlas study areas, as determined by species status and trend. These scores are reflective of relative differences in statutory protection, status, and trend, and are consistent with SERO-PRD Congressional reporting through the Government Performance and Results Act (GPRA) process.

Table 2. ESA-listed species known to occur within the Gulf of Mexico Atlas study areas and their suitability scores, as determined by species status and trend. Note ESA-listed corals are not listed because areas containing corals are scored as Zero (not suitable) for the Atlas.

Species	*Status and Trend*	*Score*
Gulf of Mexico Bryde's Whale (Rice's Whale)	Endangered, small and declining	0.1
Leatherback Sea Turtle	Endangered, declining	0.1
Kemp's Ridley Sea Turtle	Endangered, unknown	0.2
Hawksbill Sea Turtle	Endangered, unknown	0.2
Smalltooth Sawfish, U.S. DPS	Endangered, increasing	0.3
Giant Manta Ray	Threatened, declining	0.4
Loggerhead Sea Turtle, North Atlantic DPS	Threatened, unknown	0.4
Green Sea Turtle	Threatened, increasing	0.5

The SERO-PRD data layers presented below represent the best available data which SERO-PRD and SEFSC were able to access and evaluate within the time available to complete this work. While we were able to include the largest datasets available in the Gulf of Mexico, due to the timeline, several datasets on protected species distribution and habitat use could not be included. Significant progress has been made in advancing our understanding of protected species distributions since NCCOS's initial request in summer 2020. For example, manuscripts describing the expanded distribution of Gulf of Mexico Bryde's Whale (Rice's Whale)[2], Giant Manta Ray[3], Smalltooth Sawfish[4], and ESA-listed Sea Turtles[5] are in prep, in press, or recently published. We have attempted to capture those latest results in the analyses we document via this memo; however, many projects are currently planned or in progress that will continue to inform our knowledge of protected species distributions.

The time and resource constraints also reduced the opportunity for expert review of results. Satellite telemetry data are biased in focal species, life stages, and regions. Fishery observer records are biased to areas and time periods where fishing occurs and the life stage impacted by each fishery. The inclusion of observations made during standardized aerial surveys mitigates some, but not all, of the bias introduced by the other datasets. If future iterations of the suitability model are planned, we would encourage the modelers to request an updated version of the protected species distribution layers described below.

[2] Soldevilla MS, Debich AJ, Garrison LP, Hildebrand JA, Wiggins SM (In Prep) Gulf of Mexico Bryde's Whales in the Northwestern Gulf: Call variation and occurrence beyond the core habitat. Endangered Species Research.

[3] Farmer NA, Garrison LP, Horn C, Miller M, Gowan T, et al. (In Prep) The distribution of giant manta rays in the northwestern Atlantic Ocean and Gulf of Mexico.

[4] Graham J, Kroetz AM, Poulakis GR, Scharer RM, Carlson JK, Lowerre-Barbieri S, Morley D, Reyier EA, Grubbs RD (In Prep) Commercial fishery bycatch risk for large juvenile and adult smalltooth sawfish (*Pristis pectinata*) in Florida waters.

[5] Hart KM, Guzy JC, Smith BJ (2021) Drivers of realized satellite tracking duration in marine turtles. Movement Ecology 9(1).

GULF OF MEXICO BRYDE'S WHALE

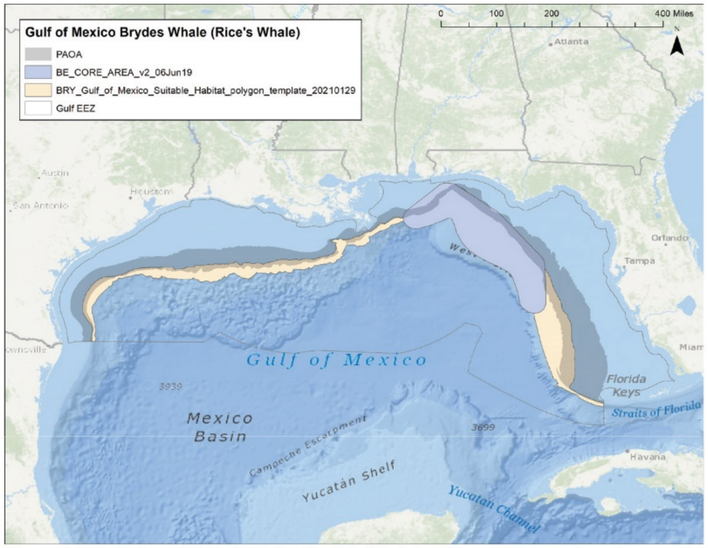


Figure 1. Distribution of Gulf of Mexico Bryde's Whale based on sightings and passive acoustic monitoring. PAOA: proposed aquaculture opportunity atlas study areas.

Layer: BE_CORE_AREA_v2_06Jun19

The blue polygon in **Figure 1** represents the primary distribution of the Gulf of Mexico Bryde's Whale, also known as Rice's Whale[6], based on the best available data available on June 6, 2019. This map is based on visual sightings and tag data. It doesn't imply knowledge of habitat preferences, and it will be updated periodically with new sightings and telemetry tag locations. This updates the previously described Biologically Important Area[7] based on new sightings data since 2017 and with an additional buffer to better account for uncertainty in the distribution that arises from the rarity of the whales and a lack of long-term systematic data that would more comprehensively address their distribution.

[6] Rosel PE, Wilcox LA, Yamada TK, Mullin KD (2020) A new species of baleen whale (Balaenoptera) from the Gulf of Mexico, with a review of its geographic distribution. Marine Mammal Science 2021:1-34.
[7] LeBrecque E, Curtice C, Harrison J, Van Parijs S, Halpin PN (2015) Biological important areas for cetaceans within U.S. waters - Gulf of Mexico region. Aquatic Mammals 41(1):30-38.

The map was created by first drawing a convex hull polygon[8] around all recorded Gulf of Mexico whale sighting locations (Bryde's Whale, Bryde's/sei, Bryde's/sei/fin) from SEFSC surveys, telemetry tag locations (n = 52) from a single Bryde's Whale tagged in 2010 in the northeastern Gulf of Mexico, and acousonde tag locations (n = 41) for one whale tagged in 2015[9]; a total of 212 data points collected between 1989 and 2018. It should be noted that, other than the positions obtained from the two individually tagged whales, it is unknown how many individual whales these sightings represent as individual whales may have been sighted more than once during a cruise or across years. The convex hull polygon was trimmed on the western-side to the 410 m isobath, determined based on the current deepest known sighting of 408 m.

Given the limited systematic survey effort and lack of systematic seasonal surveys, there are sparse data from which to accurately define the distribution. Furthermore, without a buffer on the polygon, by its very nature many of the sightings fall on the boundary of the convex hull polygon and therefore the polygon under-estimates the range of the species. To incorporate the high degree of uncertainty in the whales' distribution into a definition of core distribution, SEFSC applied a buffer around the convex hull polygon. A 10 km buffer was applied to capture the uncertainty in position and the 10 km strip width of the visual surveys. This buffer ensures that no sightings are on a boundary of the area. Next, an additional 20 km buffer was added to this "position uncertainty" to account for the possible movement whales could make in any one direction from an observed sighting. This 20 km buffer was identified by examining the daily movement data from a whale tagged for 33 days in 2010 with a satellite-linked telemetry tag. Two alternative methods were used to identify the best indicator of possible daily distance traveled by a whale. First, a "daily range" of movement was estimated by calculating swim speeds (km/hr) based upon the distances (and times) between successive satellite-tag returns and multiplying that by 24 hr. These daily ranges were highly skewed, with most in the 10-30 km range when the whale remained in a relatively small area and a few large ranges when the whale was traveling northeast to southeast through the habitat. The mean of this daily range was 46 km and the median was 21 km. To reduce the influence of differences in the number of satellite positions returned on any given day, the total distance moved within each 24 hr period was summed using all daily satellite positions. The median of this daily range was 17 km and the mean was 30 km. The median is a better measure of central tendency than the mean of highly skewed distributions such as those seen here. Therefore, 20 km was chosen as the most likely distance any given observed whale could move within a day of the detection. In combination with the 10 km buffer to account for uncertainty in whale location during the sighting, this results in the placement of a total of a 30 km buffer around the convex hull polygon based on sighting locations.

[8] IUCN. (2012). IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp
[9] Soldevilla, M. S., J. A. Hildebrand, K. E. Frasier, et al. 2017. Spatial distribution and dive behavior of Gulf of Mexico Bryde's Whales: potential risk of vessel strikes and fisheries interactions. Endangered Species Research 32:533-550.

Layer: BRY_Gulf_of_Mexico_Suitable_Habitat_polygon_template_20210129

The beige layer in **Figure 1** represents the distribution of Bryde's Whales in the western and eastern Gulf of Mexico between the 100-400 m isobaths, inferred from sightings data, long-term passive acoustic monitoring (PAM), and habitat suitability modeling.[10,11] In 2016-2017, low-frequency acoustic recording packages (LARPs) were deployed in areas of historic Gulf of Mexico Bryde's whale habitat ranging along the shelf-break from a long-term monitoring site at De Soto Canyon in the east to new sites ranging from offshore of Grand Isle to sites offshore of the Flower Garden Banks National Marine Sanctuary (FGBNMS) in the west. The new PAM sites were selected to maximize the likelihood of finding Gulf of Mexico Bryde's Whales outside their known habitat; selection was based on the median water depth of 221 m for Gulf of Mexico Bryde's Whale sightings in the core northeastern habitat[7], location of historic sightings of unidentified baleen whales[7], and an approximately evenly spaced sampling along the north-central/northwestern Gulf of Mexico shelf break. Stereotypical Bryde's Whale calls in the recordings were identified using custom software.[8]

Six new stereotyped variants of Bryde's Whale long-moan calls were identified in the western Gulf of Mexico. These calls shared distinctive and similar features with typical eastern Gulf of Mexico long-moan calls and were detected at three of four northwestern Gulf sites. Additionally, the western variants were heard at the PAM site in the Gulf of Mexico Bryde's Whale core northeastern habitat. The strong similarity in the features of the start tone and tail between the calls recorded in the eastern and western Gulf of Mexico suggest these are variants of the typical long-moan call produced by Gulf of Mexico Bryde's Whales in the eastern Gulf of Mexico and are helpful to identify the presence of Gulf of Mexico Bryde's Whales in autonomous acoustic recordings. Bryde's Whale calls were detected on 16% of days at the westernmost site near the Flower Garden Banks as compared to 1% of days at the central Eugene Isle site. By comparison, typical long-moan calls are detected on 90-100% of days in the eastern Gulf of Mexico[12] and western variants are detected on 6.6% of days at the eastern Gulf site. Further, a National Reference Station Buoy deployed at 800 m depth offshore of Alabama for two years had no detections of Bryde's Whale calls. Sound propagation conditions and site-specific ambient sound levels strongly influence detection range. This makes it difficult to compare acoustic call density between sites; higher numbers of detections at a site may reflect higher call rates or better detectability conditions rather than higher numbers of animals present. Ambient sound levels are much lower in the eastern Gulf of Mexico[13]; at least one call was heard on 3 hydrophones with a maximum spacing of 150 km, suggesting a detection range of up to 75 km is possible. By contrast, western Gulf detection ranges may be limited to around 20 km.

[10] Soldevilla MS, Debich AJ, Garrison LP, Hildebrand JA, Wiggins SM (In Prep) Gulf of Mexico Bryde's Whales in the Northwestern Gulf: Call variation and occurrence beyond the core habitat. Endangered Species Research.
[11] Garrison LP (2021) Physical Oceanography and the habitat of Gulf of Mexico Bryde's Whales (Rice's Whales). Presentation to "Bryde's Whale Trophic Ecology Workshop."
[12] Rice AN, Tielens JT, Morano JL, Estabrook BJ, Shiu Y, Popescu CM, Palmer KJ, Muirhead C, Pitzrick MS, Clark CW (2014). Passive Acoustic Monitoring of Marine Mammals in the Northern Gulf of Mexico: June 2010 - March 2012 (submitted to BP Production and Exploration, Inc. and the National Oceanic and Atmospheric Administration. Cornell Lab of Ornithology, Cornell University, Ithaca, NY).
[13] Wiggins SM, Hall JM, Thayre BJ, Hildebrand JA (2016) Gulf of Mexico low-frequency ocean soundscape impacted by airguns. The Journal of the Acoustical Society of America 140(1):176-83.

There was no obvious seasonality in detections among the LARP sites. Based on known water depth preferences of 100-400 m, the current acoustic findings at the 3 sites with up to 16% of days present at a site near the Flower Garden Banks National Marine Sanctuary (FGBNMS), a genetically verified sighting further west along the shelf break offshore of Corpus Cristi, Texas in August 2017[14], the northwestern GOM shelf break region should be considered an important habitat for this species. Additional data are being collected to understand the importance of this area following these western acoustic detections and visual sighting PAM receivers were deployed at two western sites in 2019-2020. Preliminary analysis of call detections at a LARP placed in 200 m water depth off Corpus Christi, Texas indicates Bryde's Whale occupancy during at least 23% of days. Further, a baleen whale sighting with Bryde's Whale call detections on a concurrently deployed sonobouy in the eastern Gulf of Mexico along the shelf break offshore of Venice Beach, Florida, suggests a similar distributional extension between 100-400 m in that area. This ongoing research provides evidence for regular occupancy of a broader Gulf of Mexico distribution than previously understood.

This understanding of Gulf of Mexico Bryde's Whale distribution is further supported by habitat preference modeling results. Preliminary spatial density modeling efforts for Gulf of Mexico Bryde's Whale based on sightings data identified a relatively high density area ranging from shelf-edge Alabama to southwest Florida, with further suitable habitat in a more narrow shelf-edge strip extending to central Texas to the west and the Florida Keys to the east.[15] This model was based on general habitat features and may not have captured the biological and physical conditions required to support the Bryde's Whale population. Recently, the SEFSC, Florida International University, and Scripps Institution of Oceanography have been collaborating to evaluate the physical oceanography and habitat of Gulf of Mexico Bryde's Whales.[16] This project evaluates nutrient inputs from both surface and bottom waters on the outer shelf, using remote sensing data for chlorophyll-a (Chl-a), sea surface temperature (SST), and sea surface height (SSH), along with in situ hydrographic profiles from CTD data, underway surface data (salinity, temperature), hydrographic model data (GoMex HYCOM) for surface and bottom characteristics, and visual survey data from large vessel surveys.

On 14 surveys from 2003-2019, 154 Gulf of Mexico Bryde's Whale groups were sighted using a combination of directed surveys and multispecies line transect surveys. A generalized additive model (GAM) was used to evaluate the environmental drivers of Bryde's Whale distribution. Variables considered included depth, SST, surface and bottom salinity, SSH, Velocity, log Chl-a, and bottom temperature. The selected model included depth, bottom temperature, log Chl-a, and SSH. This model was used to predict Gulf of Mexico Bryde's Whale distribution both within the core habitat and elsewhere in the broader Gulf of Mexico. The model showed good fits to sightings data and low uncertainty within the sampled region. It showed higher uncertainty in

[14] Rosel PE, Wilcox LA, Yamada TK, Mullin KD (2020) A new species of baleen whale (Balaenoptera) from the Gulf of Mexico, with a review of its geographic distribution. Marine Mammal Science 2021:1-34.
[15] Roberts JJ, Best BD, Mannocci L, Fujioka EI, Halpin PN, Palka DL, Garrison LP, Mullin KD, Cole TV, Khan CB, McLellan WA (2016) Habitat-based cetacean density models for the US Atlantic and Gulf of Mexico. Scientific reports 6(1):1-2.
[16] Garrison LP (2021) Physical Oceanography and the habitat of Gulf of Mexico Bryde's Whales (Rice's Whales). Presentation to "Bryde's Whale Trophic Ecology Workshop."

deep and shallow waters, but had very low predicted occurrence in those habitats. Similar to PAM findings above, the modeling process, which did not consider the PAM data, identified a probable distribution along the Gulf of Mexico shelf break concentrated in the core area but extending in a narrow band contained within the 100 m and 400 m depth contours following preferred bottom temperatures along the shelf break throughout the Gulf of Mexico. Therefore, the 100m to 400m depth contour was considered an appropriate proxy for the model results. The increased concentration of Gulf of Mexico Bryde's Whale in the core habitat appeared to be explained by notably higher summer Chl-a concentrations in that area as compared to other regions with suitable bottom temperatures. This area is characterized by seasonal advection of low salinity, high productivity surface waters, leading to persistent upwelling driven by both local processes (winds) and intrusion of Loop Current features. Bryde's Whales are most commonly observed in the mixing area, characterized by intermediate (non-oceanic) Chl-a concentrations, intermediate bottom temperatures, and high salinity bottom water at the boundary between coastal and deep oceanic waters. Other regions in the Gulf have similar bottom temperatures at the shelf-break, but less surface productivity, which may partially explain the less frequent observations of the species in those areas. The areas west of the core distribution are also characterized by much higher levels of shipping activity and noise associated with oil and gas exploration, both of which have been identified as threats to the species and implicated in the possible contraction of their geographic range.[17]

The Gulf of Mexico Bryde's Whale (Rice's Whale) is the only species of large whale indigenous to the United States[18]. The population is estimated at fewer than 100 individuals, with mean estimates <50 individuals remaining[11]. As such, the loss of a single individual could help drive the species to extinction. Sightings data, habitat modeling, and PAM data all suggest a core northeastern area with less frequent but potentially year-round occurrences in habitats between 100-400 m depth contour. These results will also inform the development of critical habitat designation for this recently-listed species. SERO-PRD recommends the union of the two Bryde's Whale layers be scored as 0.1.

[17] Rosel PE, Corkeron PJ, Engleby L, Epperson DM, Mullin K, Soldevilla MS, Taylor BL. (2016) Status review of Bryde's whales (*Balaenoptera edeni*) in the Gulf of Mexico under the Endangered Species Act.
[18] Rosel PE, Wilcox LA, Yamada TK, Mullin KD (2021) A new species of baleen whale (Balaenoptera) from the Gulf of Mexico, with a review of its geographic distribution. Marine Mammal Science.

SEA TURTLES

Layers: Sea Turtle HUAs and Migratory Corridors

OPR, SEFSC, and SERO sea turtle experts identified critical data that could be used to characterize important areas for sea turtles within the study area. The Atlas study area was derived from the US Coastal Relief Model bathymetry raster. A polygon was created encompassing depths from 50–150 m, bounded in the west by the US EEZ, and in the east at -80.17° longitude (based on the apparent eastern boundary in Atlas presentation slides).

The following datasets were obtained:

- L. Garrison provided aerial survey data from the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS (three surveys from 2017–2018) and National Resources Damage Assessment (NRDA) (four surveys from 2011–2012) efforts which spanned the northern Gulf of Mexico and covered the aquaculture study area. These data included observations of 2,253 loggerheads, 1,209 Kemp's ridleys, 276 green turtles, and 252 leatherbacks.
- K. Hart provided residence area locations from multiple satellite telemetry studies[19]. The dataset included records from 188 loggerheads, 72 green turtles, 42 hawksbills, and 33 Kemp's ridleys.
- C. Sasso provided data on leatherback distribution in the northern Gulf of Mexico[20].
- B. Schroeder provided residence area locations from a satellite telemetry study which included 15 adult female green turtles.
- L. Stokes provided sea turtle observations made by fishery observers in the Gulf of Mexico during 2005–2020 in the pelagic longline, shrimp, reef fish, gillnet and shark bottom longline fisheries. These data included observations of 365 leatherbacks, 180 loggerheads, 136 Kemp's ridley, 35 green turtles, and 1 hawksbill.
- R. Hardy provided residence area locations from multiple loggerhead satellite telemetry studies[21]. The dataset included records from 81 adult female loggerhead turtles.

High Use Areas

These datasets were analyzed in a geographic information system (GIS) and used to produce a final representation of high-use areas (HUAs) within the Atlas study area. First, residence area locations derived from satellite telemetry data were converted to polygons (buffered 18.98 km radius) to produce representations of high-use residence areas consistent with those identified in

[19] Hart KM, Guzy JC, Smith BJ (2021) Drivers of realized satellite tracking duration in marine turtles. Movement Ecology 9(1). https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-020-00237-3
[20] Aleksa KT, Sasso CR, Nero RW, Evans DR (2018) Movements of leatherback turtles (*Dermochelys coriacea*) in the Gulf of Mexico. Marine Biology 165:1–13. Springer Berlin Heidelberg. <https://doi.org/10.1007/s00227-018-3417-9>.
[21] Hardy RF, Tucker AD, Foley AM, Schroeder BA, Giove RJ, Meylan AB (2014) Spatiotemporal occurrence of loggerhead turtles (Caretta caretta) on the West Florida Shelf and apparent overlap with a commercial fishery. Canadian Journal of Fisheries and Aquatic Sciences 71:1924–193.

the literature[22,23,24]. Next, separate kernel density surfaces were created from the aerial survey and fishery observations, incorporating differences in search radius. The resultant density surfaces were classified into quartiles and the upper two quartiles were extracted as high-use areas, producing two outputs, one based on aerial survey observation density and another based on fishery observer observation density. Those three polygon outputs were combined with the Atlas polygon to identify portions of the Atlas that were high-use areas. This process was repeated for loggerheads, green turtles, and Kemp's ridleys. For leatherbacks, only the aerial survey and fishery observer data were used to produce high-use areas (**Figure 2**). The resultant output encompassed the identified high-use areas[19]; thus, the inclusion of telemetry data was not necessary for this species. A recently published leartherback telemetry study confirmed the high-use areas identified using the previous telemetry and observer data.[25] Insufficient data were available on hawksbill turtles to identify high-use areas using these methods.

Migratory Corridors

The southern portion of the Atlas study area, near the Florida Keys, was identified as a high-use migratory corridor for loggerheads, green turtles, and hawksbills based on a review of previous satellite telemetry studies.[26,27,28,29]

[22] Foley AM, Schroeder BA, Hardy R, MacPherson SL, Nicholas M (2014) Long-term behavior at foraging sites of adult female loggerhead sea turtles (*Caretta caretta*) from three Florida rookeries. Marine Biology 161:1251–1262. <http://link.springer.com/10.1007/s00227-014-2415-9>.

[23] Hart KM, Lamont MM, Sartain AR, Fujisaki I (2014) Migration, foraging, and residency patterns for Northern Gulf Loggerheads: Implications of local threats and international movements. PLOS One. < https://doi.org/10.1371/journal.pone.0103453>

[24] Phillips KF, Addison DS, Sasso CR, Mansfield KL (2021) Postnesting migration routes and fidelity to foraging sites among loggerhead turtles in the western North Atlantic. Bulletin of Marine Science 97:1–18.

[25] Sasso CR, Richards PM, Benson SR, Judge M, Putman NF, Snodgrass D, Stacy BA (2021) Leatherback Turtles in the Eastern Gulf of Mexico: Foraging and Migration Behavior During the Autumn and Winter. Frontiers in Marine Science. https://doi.org/10.3389/fmars.2021.660798

[26] Hart KM, Guzy JC, Smith BJ (2021) Drivers of realized satellite tracking duration in marine turtles. Movement Ecology 9(1). https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-020-00237-3

[27] Foley AM, Schroeder BA, Hardy R, MacPherson SL, Nicholas M, Coyne MS (2013) Postnesting migratory behavior of loggerhead sea turtles *Caretta caretta* from three Florida rookeries. Endangered Species Research 21:129–142. <http://www.int-res.com/abstracts/esr/v21/n2/p129-142/>

[28] Iverson AR, Benscoter AM, Fujisaki I, Lamont MM, Hart KM (2020) Migration Corridors and Threats in the Gulf of Mexico and Florida Straits for Loggerhead Sea Turtles. Frontiers in Marine Science 7:1–12.

[29] Shaver DJ, Hart KM, Fujisaki I, Rubio C, Sartain-Iverson AR, Peña J, Gamez DG, de Jesus Gonzales Diaz Miron R, Burchfield PM, Martinez HJ, Ortiz J (2016) Migratory corridors of adult female Kemp's ridley turtles in the Gulf of Mexico. Biological Conservation 194:158–167.

LEATHERBACK SEA TURTLE

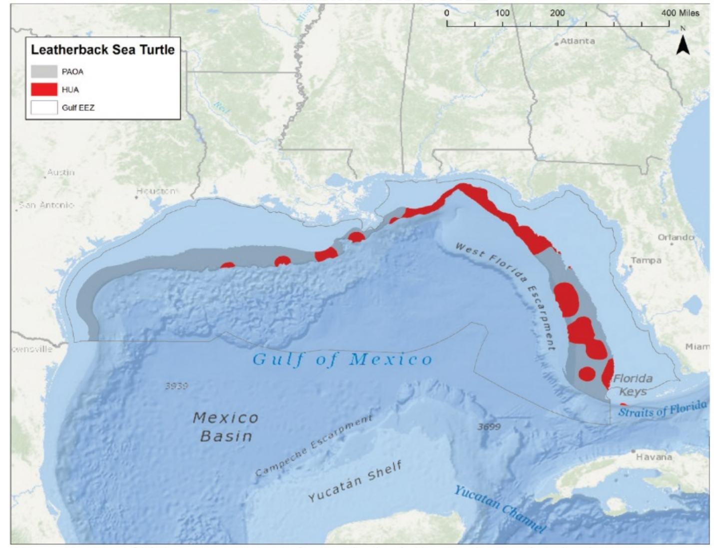


Figure 2. Map of high use area (HUA) for Leatherback Sea Turtle, North Atlantic DPS.

The high use area intersecting the Atlas for Leatherback Sea Turtle, North Atlantic DPS is shown in **Figure 2**. For a complete data layer description, refer to the previous section: *Sea Turtle HUAs and Migratory Corridors*. SERO-PRD recommends the union of HUAs for Leatherback Sea Turtle be scored as 0.1.

KEMP'S RIDLEY SEA TURTLE

Figure 3. Map of high use area (HUA) for Kemp's Ridley Sea Turtle.

The high use area intersecting the Atlas for Kemp's Ridley Sea Turtle is shown in **Figure 3**. For a complete data layer description, refer to the previous section: *Sea Turtle HUAs and Migratory Corridors*. SERO-PRD recommends the union of HUAs for Kemp's Ridley Sea Turtle be scored as 0.2.

HAWKSBILL SEA TURTLE

Figure 4. Map of migratory corridor for Hawksbill Sea Turtle.

The high use area intersecting the Atlas for Hawksbill Sea Turtle is shown in **Figure 4**. For a complete data layer description, refer to the previous section: *Sea Turtle HUAs and Migratory Corridors*. SERO-PRD recommends the migratory corridor for Hawksbill Sea Turtle be scored as 0.2.

LOGGERHEAD SEA TURTLE, NORTH ATLANTIC DPS

Figure 5. Map of high use areas (HUA) and migratory corridors for Loggerhead Sea Turtle.

The high use area intersecting the Atlas for Loggerhead Sea Turtle, North Atlantic DPS is shown in **Figure 5**. For a complete data layer description, refer to the previous section: *Sea Turtle HUAs and Migratory Corridors*. SERO-PRD recommends the union of HUAs and the migratory corridor for Loggerhead Sea Turtle, North Atlantic DPS be scored as 0.4.

GREEN SEA TURTLE

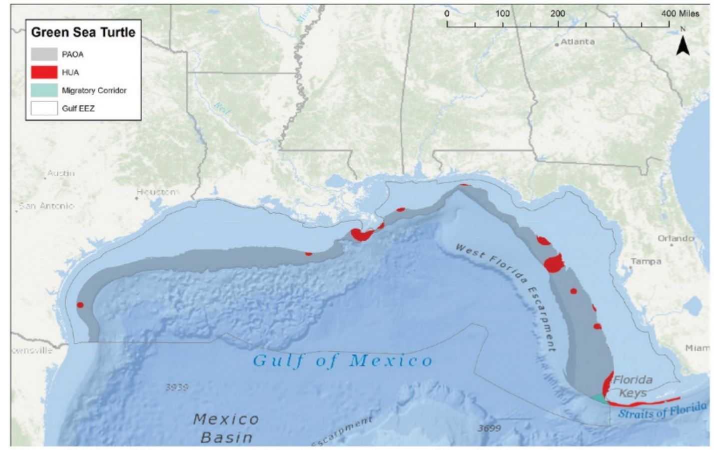


Figure 6. Map of high use areas (HUA) and migratory corridors for Green Sea Turtle.

The high use area intersecting the Atlas for Green Sea Turtle is shown in **Figure 6**. For a complete data layer description, refer to the previous section: *Sea Turtle HUAs and Migratory Corridors*. SERO-PRD recommends the union of HUAs and the migratory corridor for Green Sea Turtle be scored as 0.5.

SMALLTOOTH SAWFISH, U.S. DPS

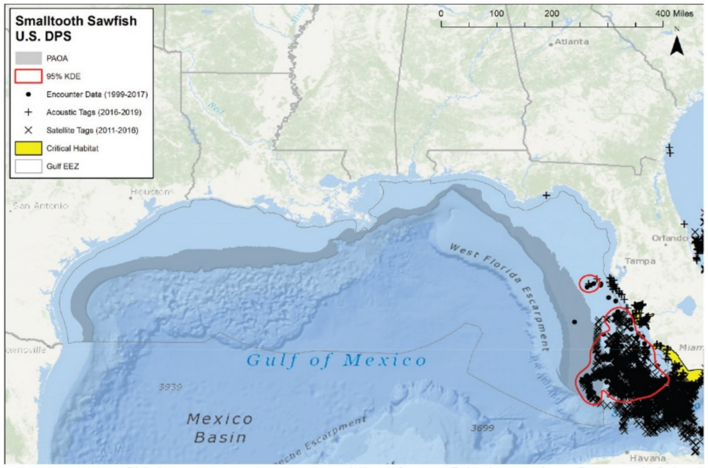


Figure 7. Map of high use areas (95% KDE; red line) for sawfish observations fit to pooled data from Sawfish Encounter Database (1999-2017), sawfish acoustic tag detections (2016-2019), and sawfish positioning estimates from satellite tags (2011-2016).

Layers: High Use Areas

Smalltooth Sawfish location data were obtained from three point sources: 1) US Sawfish Recovery Encounter Database[30,31], 2) Acoustic tag data[32,33], and 3) Satellite tag data[34] (**Figure 7**). The US Sawfish Recovery Encounter Database provides data on sawfish observations from 1999-2017; additional data are continually added. The U.S. Smalltooth Sawfish Recovery

[30] Simpfendorfer CA, Wiley TR (2006) National smalltooth sawfish encounter database: final report. Mote Marine Laboratory Technical Report 1134, 13 pp.

[31] International Sawfish Encounter Database, https://www.floridamuseum.ufl.edu/sawfish/ised/, updated through 2017

[32] Graham J, Kroetz AM, Poulakis GR, Scharer RM, Carlson JK, Lowerre-Barbieri S, Morley D, Reyier EA, Grubbs RD (2021) Large-scale space use of large juvenile and adult smalltooth sawfish *Pristis pectinata*: implications for management. Endangered Species Research 44:45-59.

[33] Graham J, Kroetz AM, Poulakis GR, Scharer RM, Carlson JK, Lowerre-Barbieri S, Morley D, Reyier EA, Grubbs RD (*In Prep*) Commercial fishery bycatch risk for large juvenile and adult smalltooth sawfish (*Pristis pectinata*) in Florida waters.

[34] Carlson JK, Gulak SJB, Simpfendorfer CA, Grubbs RD, Romine JG, Burgess GH (2014) Movement patterns and habitat use of smalltooth sawfish, *Pristis pectinata*, determined using pop-up satellite archival tags. Aquatic Conservation 24(1): 104-117.

Team[35] manages the most updated version of domestic sawfish encounter records and shares these with other databases including the International Sawfish Encounter Database (ISED), curated by the Florida Program for Shark Research (FPSR) at the Florida Museum of Natural History on the University of Florida campus.[36] Information from verified sawfish encounter reports is entered into the database and used for monitoring sawfish populations. This information assists in the evaluation of species abundance and range, helping to estimate the population sizes and also to identify habitat preferences. This type of information is vital for monitoring the recovery of worldwide sawfish populations, and greatly assists in conservation efforts.

Between May 2016 and April 2019, SERO-PRD and partners used passive acoustic telemetry and 3 large data sharing networks of receivers to track movements of 43 large juvenile and adult smalltooth sawfish. During this study, 24 females and 19 males were implanted with transmitters with estimated 4- or 10-year battery lives. These tagged individuals were detected off the southeastern U.S.A. on 461 receivers ranging from off the coast of Brunswick, Georgia, to the lower Florida Keys, and along the Gulf coast to Apalachee Bay, Florida. Seasonal migrations were undertaken by 58% (43% mature; 57% immature) of the tagged individuals, with the remainder being apparent residents of their tagging locations. Tagged sawfish from both size classes and of both sexes migrated, which indicates that neither sex nor length is a predictor of whether a sawfish will migrate or not. Although both coasts of Florida were used for migration, most individuals consistently used the same coast when they migrated. The areas surrounding Boca Grande, Cape Canaveral, and the lower Florida Keys were the most heavily visited sites.

Since 2011, members of the Smalltooth Sawfish Recovery Team have been satellite-tagging juvenile and adult sawfish to track broad-scale movements.[29-31] Maximum likelihood positioning estimates generated by Wildlife Computers GPE3 positioning software for 15 satellite-tagged sawfish were provided by Jasmin Graham (FSU).

Smalltooth Sawfish point data from the three sources described above were merged into a single GIS dataset and filtered to include only locations in the Gulf of Mexico EEZ. A 95% Kernel Density Estimate was generated to encompass a Smalltooth Sawfish high-use area using the *kernelUD* function in the 'adeHabitat' package in *R* (**Figure 7**, red polygon). SERO-PRD recommends cells in the Atlas intersecting this 95% KDE receive a score of 0.3 and all other cells receive a score of 1 for Smalltooth Sawfish.

[35] http://www.sawfishrecovery.org/who-we-are/

[36] International Sawfish Encounter Database, https://www.floridamuseum.ufl.edu/sawfish/ised/, updated through 2017

GIANT MANTA RAY

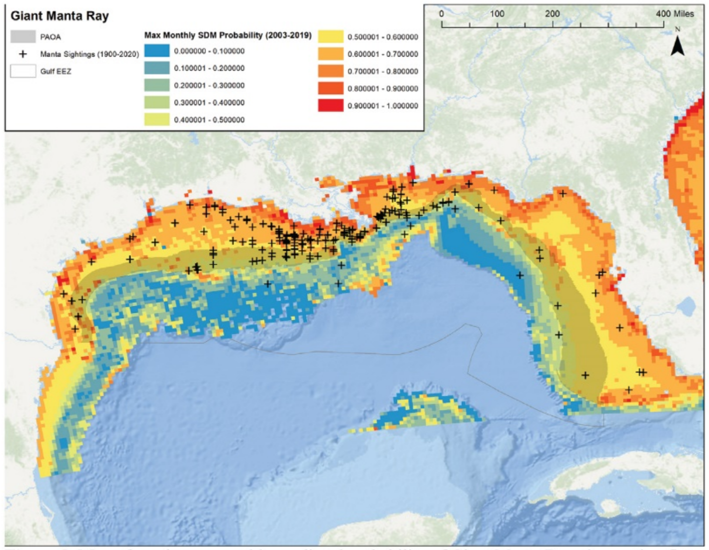


Figure 8. Map of maximum monthly predicted probability of Giant Manta Ray observation fit to environmental data from January 2003 to December 2019, overlaid with Giant Manta Ray sightings from 1900-2020.

Layer: *Giant Manta Ray Species Distribution Model*

Few dedicated surveys for Giant Manta Ray (*Manta/Mobula birostris, Manta/Mobula cf. birostris)* exist in the SEUS; however, due to their large size and distinct appearance, they are often observed and recorded during visual aerial surveys that target marine mammals and sea turtles. To better characterize the distribution of Giant Manta Ray in SEUS waters, SERO-PRD and SEFSC assembled an exhaustive GIS database of manta sightings from peer-reviewed literature, survey databases, gray literature reports, and anecdotal sources (e.g., social media, press reports, personal communications). Informal interviews with observers were used to assess the reliability of identification records from surveys and grey literature. Photographs and videos were used to verify the accuracy of species identification from anecdotal sources. Over 5000 purported Giant Manta Ray sightings were reported in the northwestern Atlantic Ocean and Gulf of Mexico (SEUS) from 1900-2019.

To evaluate environmental drivers of Giant Manta Ray distributions in the SEUS, distance-weighting methods were used to account for individual survey effort and then evaluated a combined dataset generated from 1) SEFSC, 2) North Atlantic Right Whale Consortium (NARWC), and 3) New York State Energy Research and Development (NYSERDA) aerial surveys.[37]

The SEFSC conducted aerial line transect surveys along the U.S. Gulf of Mexico and Atlantic coasts between Florida and Maine from 2010 to 2019. These aerial surveys were primarily designed to estimate the abundance of marine mammals and sea turtles over continental shelf waters. Seasonal surveys were also conducted in the Gulf of Mexico during 2011-2012 as part of the Natural Resources Damage Assessment associated with the Deepwater Horizon oil spill (SEFSC-GOMNRDA), and three surveys of the Gulf of Mexico were conducted during 2017-2018 as part of the Gulf of Mexico Marine Assessment Program for Protected Species (SEFSC-GoMMAPPS). Along the U.S. Atlantic coast, similar surveys were flown covering all four seasons between 2010-2019. These surveys were conducted as part of the Atlantic Marine Assessment Program for Protected Species (SEFSC-AMAPPS) and covered continental shelf and the inner continental slope from southern Florida to New Jersey.

Sightings and effort data were combined for all SEFSC aerial surveys. Effective search effort for mantas was determined in a mark-recapture distance sampling framework using package '*mrds'* in R[38] for "On Effort" sightings by the forward and aft survey teams. Sightings angles were determined for both observer teams based on side (i.e., left, right) and position (e.g., belly, bubble) of recorded sighting. Because the survey was not specifically defined for Giant Manta Ray, sighted individuals were not assigned unique identifiers. Using forward team sightings as a reference, aft team matching sightings were assigned when an equal number of animals were recorded by the aft team within 15 seconds, on the same side of the plane, with an angle difference of <15 degrees. Sighting distances were determined based on altitude (183 m) and angle to the animal. Any sightings where the aft team could not have seen the animal due to the sighting angle recorded by the forward team were eliminated. Based on histograms and quantiles of sightings distance, the right truncation distance was set at 300 m.

For the SEFSC surveys, the probability of detection and effective area searched were derived using the independent observer approach assuming point independence implemented in R package 'mrds'. A hazard rate MRDS model was selected by Akaike Information Criterion (AIC). The MCDS and MRDS fitting of the MRDS model considered all possible permutations of covariates that may influence both detection probability in the surveyed strip and detection probability on the trackline including Beaufort sea state, cloud cover, glare intensity (level of visual obstruction due to sea surface glare), glare coverage (proportion of viewing area obstructed), and turbidity, along with interactions between distance and observer in the MRDS function. All combinations of variables were considered for inclusion, and the best model was selected from the candidate models based on the lowest AIC. For a given trackline segment, search effort was expressed as the multiple of trackline length, estimated detection probability

[37] Farmer NA, Garrison LP, Horn C, Miller M, Gowan T, et al. (*In Prep*) The distribution of giant manta rays in the northwestern Atlantic Ocean and Gulf of Mexico.
[38] Laake J, Borchers D. Package 'mrds'.

within the strip, and the truncation distance. The log-transformed effective search area for each segment was included as an offset term in the SDMs.

Sightings distances by NARWC aerial surveys were reported in nautical mile intervals corresponding to window markings on the survey platform and were converted to meters. For distance function fitting, sightings were restricted to on-effort distance-sampling sightings during New England Aquarium aerial surveys (1990-1991) on the Skymaster platform at altitudes of ≤376 m with Beaufort sea states of ≤4. AIC was used to guide selection of the best-fitting detection function considering possible covariates of sea state, cloud cover, and glare using function '*ds'* in the R '*Distance'* package (Miller et al. 2019). This detection function was then applied to estimate effective search area for non-distance sampling Skymaster on-effort surveys by the State of Florida from 2002-2017. Because departures from the trackline for North Atlantic right whale sightings were not explicitly coded as such, and it was unclear mantas would be recorded during this activity, off trackline effort was eliminated by dropping waypoints that deviated from the previous bearing by greater than 20 degrees. Visual inspection of tracklines indicated this approach was effective at eliminating loops off the trackline. Sightings from all other surveys were retained for external validation of model fits, but not included in the distribution modeling input due to lack of clarity whether mantas would have been explicitly recorded during all on-effort surveys and lack of data suitable for fitting a detection function.

In NYSERDA surveys, mantas were preliminarily identified using digital photographs taken from 396 m altitude. Effort was expressed as the swept area within the camera view. Detection probability was assumed to be 100% within the swept area. Rays were photographed during the summers of 2016-2018, spring of 2019, and fall of 2016-2018. All photographs with observed rays were reviewed and classified to species. The high resolution of the photographs (1.5 cm) facilitated the estimation of disc width for observed Giant Manta Ray.

Conversations with observers suggested possible misidentification of Giant Manta Ray (*M. birostris)* with Chilean Devil Ray (*M. tarapacana)* and Giant Devil Ray (*M. mobular)* in SEFSC and NARWC surveys north of Cape Hatteras, North Carolina (T. Pusser, pers. comm. to C. Jones). To avoid overestimation of Giant Manta Ray in those areas, sightings and effort north of 35°N were excluded from the SEFSC and NARWC surveys; these sightings were retained for external validation of the models. Correct identification was confirmed north of 35°N for NYSERDA surveys as discussed above. Additionally, Florida Fish and Wildlife Research Institute (FWRI) confirmed correct identification for all but three *M. birostris* sightings in their photographic archive subset (J. Jakush, pers. comm. to N. Farmer).

Bathymetry depth was assigned to transect segments from the NOAA National Centers for Environmental Information Coastal Relief Model, which provides 3 arc-second resolution bathymetry for most areas in the study domain. Data gaps were filled with 1 arc-minute

resolution bathymetry from the NOAA ETOP01 database using the R '*marmap'* package[39]. Slope was derived from bathymetry for each layer using Spatial Analyst in ESRI ArcMap 10.7, with higher-resolution CRM-bathymetry and slope retained when available. Satellite observations of sea surface temperature (SST), primary productivity, chlorophyll-a, north-bound water velocity from HYCOM models, k490 irradiance, and predicted wave height from the Global Wave Model were assigned to transect segments from the ERRDAP server using the R '*rerddap'* package. Frontal gradients of SST were computed using the R '*grec'* package[40]. Daily Z-scaled frontal gradients ('Front-Z') were computed by dividing frontal gradient raster values by the daily maximum within the raster domain.

Sightings, effort, and environmental parameters were summarized by survey source to 10 km grid cells within a model domain encompassing all surveys from all sources. Trackline segments were assigned to grid cells and environmental characteristics were averaged within the grid for a given survey day with the exception of slope, where the maximum recorded value was retained. Generalized additive models (GAMs) were fit to all possible permutations of bathymetry and environmental parameters using the '*mgcv'* package in R[41]. GAMs were fit with a binomial distribution using a logit link function, with tensor splines limited to 3 knots, such that the resultant species distribution models (SDMs) describe the probability of species presence, also termed "habitat suitability"[42] or "habitat preference"[43]. The best-fitting model was selected by lowest AIC and compared to three competing GAM configurations tiered off the best-fitting GAM by excluding non-significant terms in the model summary. The final model was selected by comparing residual deviance explained and predictive power as evaluated through 10-fold internal cross validation and external validation using independent sources.

The best GAM fit to combined SEFSC, NARWC, and NYSERDA surveys explained 19% of residual deviance and predicted higher probabilities of observation with warm sea surface temperatures (SST), moderate Z-transformed SST frontal gradients (Front-Z), nearshore and shelf-edge depths, moderate bathymetric slopes, and increasing Chlorophyll-a concentrations (Chl-a). AUC for internal and external validation were comparable and indicated "excellent" model fits[44]. The combined survey model predicted highest probabilities of detection at offshore sloped habitats (e.g., seamounts) and in the nearshore environment off Louisiana at the Mississippi River delta between April to June and again in October. Probability of detection increased at moderate frontal gradients with SSTs between 20-30 °C in both nearshore and shelf-edge environments with moderate slopes and high concentrations of Chl-a. External validation

[39] Pante E, Simon-Bouhet B (2013) marmap: a package for importing, plotting and analyzing bathymetric and topographic data in R. PLoS One 8(9):e73051.
[40] Belkin IM, O'Reilly JE (2009) An algorithm for oceanic front detection in chlorophyll and SST satellite imagery. Journal of Marine Systems 78(3):319-26.
[41] Wood S, Wood MS. (2015) Package 'mgcv'. R package version
[42] Brodie S, Jacox MG, Bograd SJ, Welch H, Dewar H, Scales KL, Maxwell SM, Briscoe DM, Edwards CA, Crowder LB, Lewison RL (2018) Integrating dynamic subsurface habitat metrics into species distribution models. Frontiers in Marine Science 5:219.
[43] Hazen EL, Palacios DM, Forney KA, Howell EA, Becker E, Hoover AL, Irvine L, DeAngelis M, Bograd SJ, Mate BR, Bailey H (2017) WhaleWatch: a dynamic management tool for predicting blue whale density in the California Current. Journal of Applied Ecology 54(5):1415-28.
[44] Hosmer DW, Lemeshow S, Klar J (1988) Goodness-of-fit testing for the logistic regression model when the estimated probabilities are small. Biometrical Journal 30(8):911-24.

using median Z-score standardized probabilities of observation[45,46] confirmed that SDM model predictions were highly consistent with independent observations of Giant Manta Ray ($t(4025)=128.01$, $p<0.0001$).

To evaluate Giant Manta Ray distribution relative to the Atlas, the final combined survey SDM was fit to monthly data from January 2003 to December 2019. The maximum predicted species presence across these 204 months was retained in a final predictive grid for each cell (**Figure 8**). To provide meaningful contrast to inform the Atlas site selection process, SERO-PRD evaluated several potential cutoffs based on quantiles for maximum probability of presence that would receive the **Table 1** score of 0.4. Because predictions from the Giant Manta Ray SDM are not normally distributed, the median is a better measure of central tendency. Consistent with the HUA approach described for Sea Turtles, SERO-PRD recommends a score of 0.4 to areas above the median maximum predicted value (**Figure 9**).

[45] Farmer NA, Heyman WD, Karnauskas M, Kobara S, Smart T, Ballenger J, Reichert M, Wyanski D, Tishler MS, Lindeman KC, Lowerre-Barbieri S, Switzer T, Solomon J, McCain K, Marhefka M, Sedberry GR (2017) Timing and location of reef fish spawning activity in the Atlantic Ocean off the southeastern United States. PLoS ONE 12(3): e0172968.

[46] Heyman WD, Grüss A, Biggs C, Kobara S, Farmer N, Karnauskas M, Lowerre-Barbieri S, Erisman B (2019) Cooperative monitoring, assessment, and management of fish spawning aggregations and associated fisheries in the U.S. Gulf of Mexico. Marine Policy, 109: 103689.

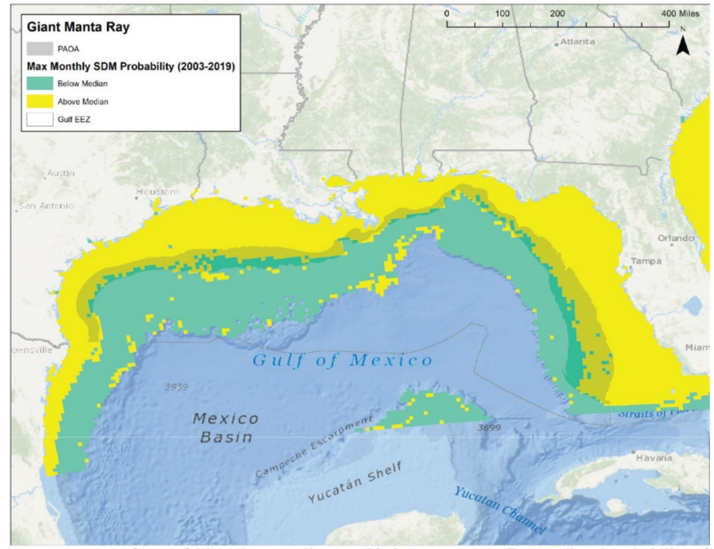


Figure 9. Map of areas falling above (yellow) and below (green) median predicted probability of occurrence values from maximum monthly predicted probabilities fit to environmental data from January 2004 to December 2019.

FINAL COMBINED SERO-PRD DATA LAYER

Layer: **PAOA_GRID_ALL_SERO_FINAL_sf.shp**
Column to Use: **Product**

There are four submodels in the NCCOS Atlas model, which assess suitability related to: 1) National Security, 2) Industry Navigation and Transportation, 3) Aquaculture and Commercial Fishing, and 4) Natural Resources. These submodels are combined to calculate a "Cumulative Suitability Model" that is then used to identify clusters of the most suitable areas within each of the four study areas. Within the most suitable clusters, a precision siting model will be used to identify multiple aquaculture opportunity area options within each of the four study areas, which will be characterized and used to inform development of preliminary alternatives that will be considered in the PEIS.

Based on conversations with NCCOS, SERO-PRD's understanding is that NCCOS does not impose any relative weighting on the submodels before combining their scores into the "Cumulative Suitability Model." Submodel comparisons in the Atlas "Cumulative Suitability Model" are unweighted because multiple types of aquaculture are proposed and NCCOS believes comparisons can be more effectively made during later phases in the process. The use of submodels is designed to avoid more numerous data layers having greater control over final model outcomes, such that each submodel contributes an equal amount to the final suitability score. Because the final suitability scores compare very different types of activities, the overall score does not have an empirical meaning; however, the relative rank of the scores is important to determining which sites are more suitable. Therefore, it is important that the ranked scores of the areas in the SERO-PRD Layer of the Natural Resources submodel are reflective of where SERO-PRD is more or less concerned with regards to the vulnerability of protected species.

In the Gulf of Mexico Atlas study areas, the Natural Resources submodel contains a National Ocean Service "Sanctuaries" data layer, consisting of only Flower Garden Banks National Marine Sanctuary (FGBNMS), and any layers submitted by SERO-PRD. The FGBNMS layer is scored as a 0.5 within FGBNMS boundaries and a 1 in all other areas (i.e., "suitable" for aquaculture). Other areas not suitable for aquaculture [e.g., hardbottom and coral habitat areas of particular concern (CHAPCs)] are eliminated from the Atlas after the mathematics are run to combine layers. For the Gulf of Mexico Atlas study areas, following discussion with SERO-PRD, NCCOS has agreed to evaluate three different mathematical approaches to combining the four submodels: 1) Geometric Mean (g), 2) Arithmetic Mean (μ), and 3) Product (ρ). These are computed as follows:

$$g = \sqrt[n]{x_1 \times x_2 \times \ldots \times x_n}$$

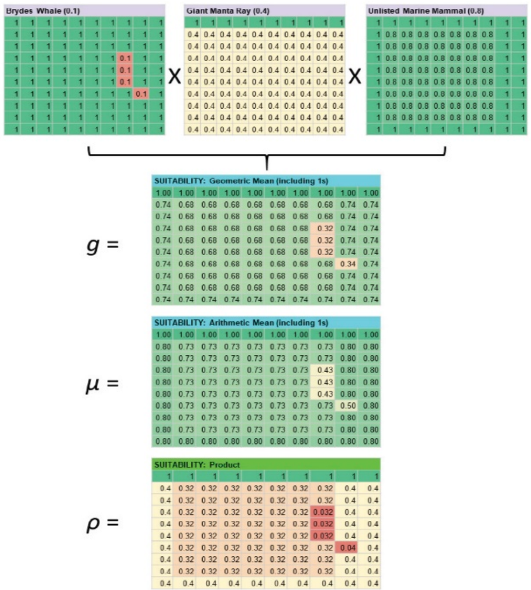
$$\mu = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

$$\rho = x_1 \times x_2 \times \ldots \times x_n$$

SERO-PRD's understanding is that NCCOS will evaluate where all three approaches provide similar outcomes with regards to recommended siting of aquaculture activities. NCCOS also suggested SERO-PRD evaluate an approach for the combined protected species data layer that assigns the lowest value to any cell with overlapping layers ("Lowest"). Unlike the majority of layers in the NCCOS Atlas, which are scored as 0/0.5/1, the PRD data layers have a relative value scale imposed (0.1-0.8) which, based on our evaluation, makes the Product approach more appropriate. For categorical scores (0/0.5/1) we anticipate the Geometric Mean functions correctly because a 0 in a cell results in an overall score of 0, and more overlapping cells at 0.5 results in a cumulative lower score without a relative value system imposed. For continuous scores (0.1-0.8) with distributions that don't cover the whole model domain, the Geometric Mean drives scores towards 1, as illustrated below.

SERO-PRD identified issues of concern with regards to the geometric and arithmetic mean approaches as they pertain to the PRD scoring table (**Table 1**). When multiple protected species layers overlap, both the geometric and arithmetic mean methods result in final scores within individual Atlas cells that can be higher than the score for the species of greatest concern within the cell. For example, using the hypothetical distributions in **Figure 10**, the score for cells containing Gulf of Mexico Bryde's Whale is higher than 0.1 in both the arithmetic and geometric mean approaches, because those cells also contain Giant Manta Ray and/or an Unlisted MMPA Stock. Also of concern, as more layers are incorporated with relatively limited spatial distributions for the species in question and the remaining areas are scored as 1s for that species, the geometric mean tends towards 1 (**Figure 10**: *Worked Geometric Mean Example*). Therefore, both averaging approaches reduce the spread in the data with regards to differences between cells, and the geometric mean further compresses the data towards a score of 1 (i.e., no protected species in cell). Only the product approach generates scores below 0.1 when multiple species overlap. Mathematically, the averaging approaches can also result in different rank orders for cells as compared to the product approach, depending on the scores for overlapping species layers.

To evaluate the appropriate layer to provide to NCCOS for the Atlas process, SERO-PRD compared four approaches to combining protected species data layers across species: 1) Product, 2) Geometric mean, 3) Arithmetic mean, and 4) Lowest scoring species in a given cell, using a custom R script (see Appendix I). NCCOS provided four separate Atlas grids for the Gulf of Mexico, dividing the Gulf into four subregions: West, Central, East, and Southeast. SERO-PRD combined PRD layers within each subregion and then merged the four subregions for comparison of scoring approaches, noting that although PRD data can be compared between areas, Atlas study areas will be modeled independently and may not be comparable for the "Cumulative Suitability Model" given potential differences in data types between areas. All approaches indicated nearshore environments in the Western, Eastern, and Southeastern Gulf of Mexico contain more overlapping species of high concern than the Central Gulf of Mexico. The resulting scores clearly show the greatest contrast between cells for the Product [median (M)=0.08, range (R)=0.000096-1) and Lowest (M=0.1, R=0.1-1) scoring layer approaches, as expressed by both visual spatial contrast between locations (**Figure 11**) and quantitative analysis of spread in the overall scoring (**Figure 12**). The arithmetic (M=0.81, R=0.39-1) and geometric mean (M=0.73, R=0.31-1) approaches generated the highest overall scores and least contrast between scores (**Figures 11-12**).



Worked example for Geometric Mean:

3 layers: (0.1×0.4×1)^(⅓) = **0.34**

4 layers: (0.1×0.4×1×1)^(¼) = **0.4**

5 layers: (0.1×0.4×1×1×1)^(⅕) = **0.5**

6 layers: (0.1×0.4×1×1×1×1)^(⅙)

7 layers: (0.1×0.4×1×1×1×1×1)^(⅐) = **0.63**

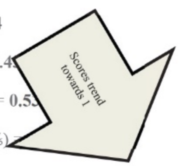


Figure 10. Comparison of geometric mean (g), arithmetic mean (μ), and product (ρ) approaches for hypothetical distributions of protected species with different scores based on status and trend.

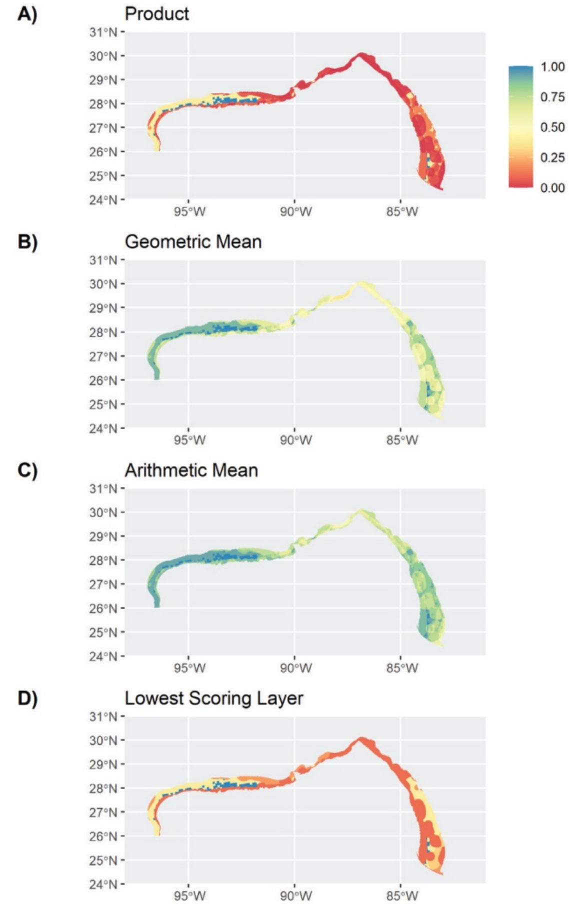


Figure 11. Comparison of SERO-PRD overall vulnerability scores using four different approaches. Warmer colors denote areas of greatest vulnerability.

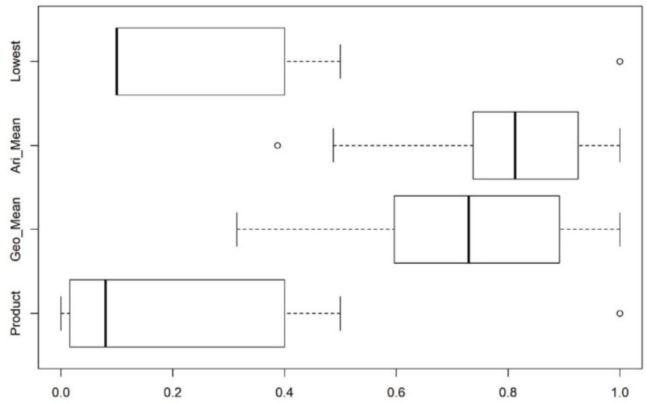
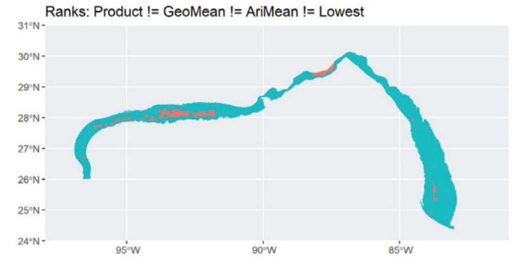


Figure 12. Comparison of vulnerability scores for protected species across the entire Gulf of Mexico study area under Product, Geometric mean, Arithmetic mean, and Lowest scoring layer methods. Lower scores denote greater vulnerability.

Because the results of each Atlas will be used to identify the most suitable (top-ranked) clusters of cells to inform the development of preliminary alternatives for the PEIS phase of the AOA process, the relative ordering of scoring across cells is more important to the final outcome of the model than the actual scores within cells. It is unclear whether the cluster analysis proposed by NCCOS to identify areas with adjacent more suitable cells is sensitive to the spread in the data or just the order; if they are sensitive to the spread in the data, this further supports the Product approach for protected species data layers, which results in a broad distribution of realized scores in space that will generate more appropriate results for informing the Atlas. SERO-PRD evaluated the outcomes of ranking protected species scores on a cell-by-cell basis, with ties ranked by minimum value similar to sports rankings (i.e., 1, 2, 3, 3, 4, 5, 6, 6, 7, etc.). Rankings were inconsistent in 93% of cells when comparing between all four methods; the Lowest approach was the least consistent with regards to rankings of cells, presumably because it did not account for overlap of species in any way (**Figure 13A**). Although the geographic distribution of ranks was relatively similar between the remaining three methods, the specific ranks for the averaging approaches were different from the Product approach in 62% of cells (**Figure 13B**). As previously mentioned, the spread of the actual scores was substantially narrower in the averaging approaches, which may influence ultimate clustering outcomes, especially when combined with other non-PRD data layers in the "Cumulative Suitability Model."

A)



B)

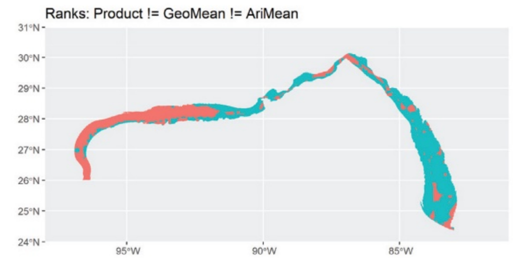


Figure 13. Comparison of protected species ranked scores by cell between methods, with blue denoting areas where approaches had inconsistencies in ranking.

In conclusion, SERO-PRD finds that the Product approach represents the most appropriate method for spatially combining overlapping vulnerability scores (**Table 2**) from SERO-PRD data layers (**Figure 14**). The Product approach provides the correct ordering of the layers, appropriately accounts for overlap between layers, and provides contrast between cells that should prove informative to the Atlas siting process (**Figure 14**, **Figure 15**). Consequently, SERO-PRD is providing a data layer based on that approach to NCCOS for the Atlas process. This layer is intended for use in the Gulf of Mexico Atlas mapping and siting process only; if NCCOS feels there may be utility for this layer to inform other NCCOS products, such as Industry Siting Analysis models, please contact Nick Farmer (nick.farmer@noaa.gov) to discuss. SERO-PRD notes that given consistency in methods and scoring, this final layer can be used to classify relative vulnerability both within and across the four sub-regions (i.e., West, Central, East, and Southeast) in the Gulf of Mexico Atlas.

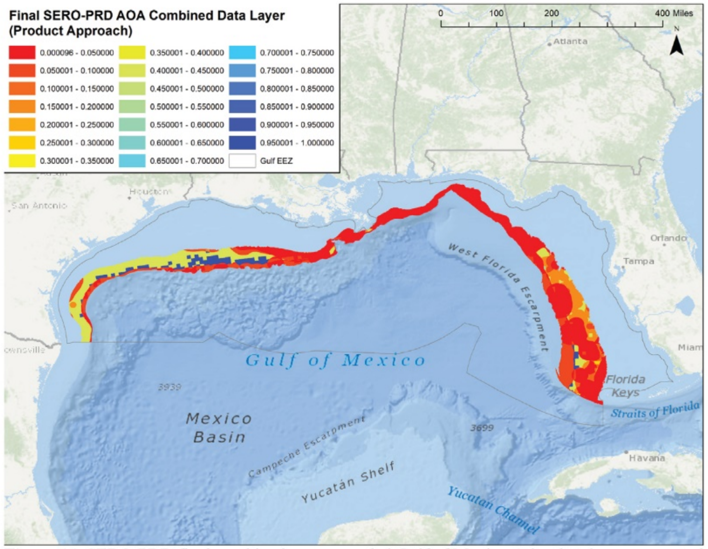


Figure 14. SERO-PRD final combined recommended Gulf of Mexico Atlas data layer, generated by combining layers for Gulf of Mexico Bryde's Whale, five Sea Turtles, Smalltooth Sawfish, and Giant Manta Ray using the Product method. Note that warmer colored areas are of relatively higher concern with regards to species status, population size, and trajectory.

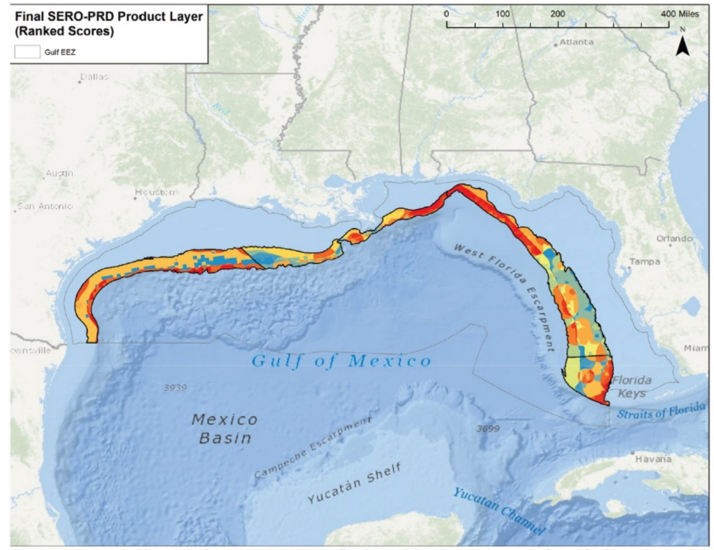


Figure 15. Ranked scores from SERO-PRD final combined recommended Gulf of Mexico Atlas data layer for each of the four Atlas sub-regions, generated using the Product method. Note that warmer colored areas are of relatively higher concern with regards to species status, population size, and trajectory.

APPENDIX II - WCR-PRD DATA LAYERS

WCR-PRD staff evaluated the best scientific information available for the distributions of vulnerable ESA-listed species within the four proposed southern California AOA Atlas study areas (North, Central North, Central South, and South) for the purpose of identifying available data for use in the suitability modeling and characterization phases of the development of the AOA Atlas and subsequent Programmatic Environmental Impact Statement. Some ESA-listed species did not have quantitative data layers available (at all or of sufficient resolution) at the time of this consideration and thus could not be included in the suitability modeling but will be included in the characterization descriptions within the development of the southern California AOA Atlas. These include ESA-listed sea turtles, giant manta ray, oceanic whitetip shark, scalloped hammerhead, Guadalupe fur seal, ESA-listed salmonids and sturgeon, and Gulf grouper.

Available species distribution model layers for ESA-listed sperm whales, sei whales, and North Pacific right whales were not included because of their rarity in the study areas or that they typically occur in waters deeper than the Atlas study areas. Similarly, the specific distribution model and "biologically important areas" for gray whales, which includes the unlisted Eastern North Pacific gray whales and the endangered Western North Pacific gray whale DPSs, was not included in the WCR-PRD data layer primarily because the layer "blankets" the entire Southern California Bight and thus provides no meaningful contrast between or within the four study areas in terms of relative suitability. Further, while the endangered Western North Pacific gray whale might receive a very low score on the basis of its status and trend (see Table 1. in the cover memo), WCR-PRD determined that applying this score to a data layer that both blankets the study areas and is also predominantly used by the Eastern North Pacific gray whale DPS was not likely to result in meaningful conservation benefits for the endangered DPS through the suitability modeling effort. The Western North Pacific DPS will be flagged during the characterization step to ensure users of the Atlas are informed of the potential presence of this rare and critically endangered species when considering siting suitability.

Other marine mammals protected under the MMPA, such as coastal delphinids, were not included in the data layers at this time but certain stocks are flagged below to ensure their inclusion in subsequent characterization steps for the proposed Atlas study areas. All of the species, including those with data layers in the spatial model, will be further discussed during the Site Characterization phase of the AOA process.

Following the approach laid out in the memo, Table 3 presents the recommended scores for ESA-listed species evaluated by WCR-PRD that are known to occur within the southern California Atlas study areas, as determined by species status and trend. These scores are reflective of relative differences in statutory protection, status, and trend, and are consistent with WCR-PRD Congressional reporting through the Government Performance and Results Act (GPRA) process, except where local study area information is known. Given data availability and time constraints, only the scores for the blue whales, the endangered humpback whale, and the humpback whale critical habitat are included in the data layers submitted. Information and scores for other species are provided in Tables 4 (ESA) and 5 (MMPA) as reference and for use as appropriate in Site Characterization.

Table 3. ESA-listed species known to occur within the southern California region and their recommended scores, as determined by species status and trend, for use in the suitability model.

Species	*Status and Trend*	*Score*	*Notes for Study Areas*
Blue whale	Endangered, stable	0.2	Global trend is unknown, local stock assessment is stable
Humpback whale Central America DPS	Endangered, unknown	0.2	Designated critical habitat areas are scored a 0.2 as well.

Table 4. ESA-listed species known to occur within the southern California region but not included in the suitability model. Scores, as determined by species status and trend, are provided for informational purposes for consideration in site characterization descriptions.

Species	*Status and Trend*	*Score*	*Notes for Study Areas*
Humpback whale Mexico DPS	Threatened, unknown	0.4	
Fin whale	Endangered, stable	0.2	Global trend is unknown, local stock assessment is stable
WNP Gray whale	Endangered, small	0.1	very rare
North Pac Right whale	Endangered, small	0.1	very rare
Sei whale	Endangered, small	0.1	rare
Sperm whale	Endangered, small	0.2	offshore
Guadalupe fur seal	Threatened, increasing	0.5	
Loggerhead sea turtle	Endangered, unknown	0.2	occurs in the area during warm water events such as El Nino
Green sea turtle	Threatened, increasing	0.5	coastal and bays/estuaries
Olive Ridley sea turtle	Endangered, increasing	0.3	Rare, strandings documented
Leatherback sea turtle	Endangered, declining	0.1	Rare in SoCal, strandings documented
Oceanic Whitetip shark	Threatened, declining	0.4	offshore
Giant Manta Ray	Threatened, declining	0.4	offshore
Scalloped Hammerhead	Endangered, declining	0.1	Southern California is northern extent of current distribution
White Abalone	Endangered, declining	0.1	rocky substrates
Black Abalone	Endangered, declining	0.1	rocky substrates
Gulf Grouper	Endangered, unknown	0.2	Very rare, San Diego area primarily

Table 5. MMPA stocks known to occur within the southern California region but not included in the suitability model. Scores, as determined by species status and trend, are provided for informational purposes for consideration in site characterization descriptions.

Species	*Status and Trend*	*Score*	*Notes for Study Areas*
ENP Gray whale	large	0.8	

Minke whale	small	0.7	
Baird's beaked whale	large	0.8	offshore
Cuvier's beaked whale	large	0.8	offshore
Dwarf Sperm whale	unknown	0.6	offshore - not strategic
Transient killer whale	small	0.7	offshore
Short finned pilot whale	small	0.7	somewhat offshore
Pygmy sperm whale	large	0.8	offshore
CA coastal bottlenose dolphin	small	0.7	nearshore
Long beaked common dolphin	large	0.8	localized distribution in AOA
Short beaked common dolphin	large	0.8	nearshore and offshore
Northern right whale dolphin	large	0.8	offshore
Risso's dolphin	large	0.8	nearshore
Striped dolphin	large	0.8	offshore
Pacific white sided dolphin	large	0.8	nearshore
Dall's porpoise	large	0.8	nearshore
CA harbor seal	large	0.8	
CA sea lion	large	0.8	
Northern fur seal	large	0.8	

The WCR-PRD data layers presented below represent the best available data which WCR-PRD was able to access and evaluate within the timeline available to complete this work. If future iterations of the suitability model are planned, we would encourage the modelers to request an updated version of the protected species distribution layers described below.

DATA AVAILABLE FOR CONSIDERATION

The study areas within the southern California region have been split into four zones: North (approximately between Lompoc and Point Mugu), Central North (off of Santa Monica and Redondo Beach), Central South (off of Long Beach), and South (approximately off the San Diego and Point Loma areas). WCR-PRD reviewed the available information for these four zones and identified multiple data layers for use in the North study area and a data layer for use in the Central North, Central South, and South study areas. NCCOS provided four separate Atlas

grids for the study areas described above, dividing the region into four subregions: North, Central North, Central South, and South. WCRO-PRD combined PRD layers within each subregion and then merged the four subregions for comparison of scoring approaches, noting that although PRD data can be compared between areas, Atlas study areas will be modeled independently and may not be comparable for the "Cumulative Suitability Model" given potential differences in data types between areas.

Three primary types of data layers were evaluated to provide protected species scores for the Atlas study areas. The first of these are the cetacean "biologically important areas" (BIA) layers developed by NMFS in collaboration with regional and species experts.[47] In particular, these include the humpback whale and blue whale BIAs that co-occur with the southern California Atlas study areas, as depicted below in Figure 16.

Several caveats related to the identification of BIAs are important to note here and should be kept in mind when using BIAs in environmental assessments or impact analyses:

1. Only known areas and periods of biological importance were identified; other areas that are biologically important to cetaceans could exist within the U.S. EEZ but not be included here due to insufficient information.

2. The quantity and type of data from within the U.S. EEZ used to define the Important Areas were spatially and temporally heterogeneous. The types of data used included sighting, acoustic, tagging, genetic, and photo identification data.

3. The Important Area designation is not equivalent to habitat or range. For distinctly migratory species or populations, Important Areas highlight specific locations and periods within which critical behaviors occur and likely represent only a fraction of the overall range.

The second type of data layer is the final designated critical habitat for humpback whales. As a result of the 2016 revisions to the ESA-listing of humpback whales, NMFS has designated critical habitat for the Central America and Mexico DPSs of humpback whales (86 FR 21082)[48,49]. A portion of this critical habitat falls within the Southern California Bight and overlaps most of the North study area. Critical habitat is defined as those areas "essential to the conservation of the species" and designations include identification of physical and biological features important to species recovery. For humpback whales, the primary feature is prey: Prey species, primarily euphausiids (*Thysanoessa, Euphausia, Nyctiphanes*, and *Nematoscelis*) and small pelagic schooling fishes, such as Pacific sardine (*Sardinops sagax*), northern anchovy (*Engraulis mordax*), and Pacific herring (*Clupea pallasii*), of sufficient quality, abundance, and accessibility within humpback whale feeding areas to support feeding and population growth.

Critical habitat differs from BIAs in several important ways. First, it receives protection under the ESA as a separate entity and consultations conducted on Federal actions within critical

47 This data is provided at https://cetsound.noaa.gov/important and the accompanying Aquatic Mammals special edition, accessible at https://www.aquaticmammalsjournal.org/images/files/AM_41.1_Complete_Issue.pdf .

48 https://www.federalregister.gov/documents/2021/04/21/2021-08175/endangered-and-threatened-wildlife-and-plants-designating-critical-habitat-for-the-central-america

49 Maps and GIS data for this designation are posted at https://www.fisheries.noaa.gov/resource/map/humpback-whale-critical-habitat-maps-and-gis-data.

habitat are required to have considered the level and severity of impacts to critical habitat even if the actions occur when the animals for which that habitat is designated are not present. BIAs have no such separate consideration under the ESA. Second, critical habitats encompass all areas essential to the conservation of a species that require special management considerations and in this instance include a wider area of expected whale forage and aggregations of whales than that covered by the BIAs.

The third type of data layer available are the species distribution models developed by Becker et al (2020).[50] This data layer was evaluated for use in the unified, single data layer provided to NCCOS but was not included specifically in the data layer. WCR-PRD considered the predicted densities for blue, fin, and humpback whales within the Southern California Bight and specifically within the Atlas study areas to determine if there were areas of higher predicted densities not covered by either the BIA data layers or the designated critical habitat for humpback whales. As part of this effort, WCR-PRD considered the minimum, maximum, mean and standard deviation of the predicted estimates within the study areas. After comparison with the areas covered by the designated humpback whale critical habitat and the BIA data layers, WCR-PRD decided to not add the species distribution model layers (or certain grid cells within those predictions) to the single layer provided to NCCOS for the following reasons:

1. The areas of highest predicted densities were almost entirely covered within either the BIAs or the humpback whale critical habitat, ensuring those highest predicted density areas would receive a protected species score in the suitability model.

2. Scores for the humpback whale critical habitat would also be multiplied with scores of humpback whale BIA, and also the blue whale BIA where there was overlap, to provide an overall lower protected species score in those areas. This provides some contrast within study areas for the purpose of considering suitability.

3. For blue whales, there are some areas of high predicted densities in the South study area outside of the blue whale BIA layer. WCR-PRD considered adding these areas to the single data layer but preliminary assessment of this area for other uses indicates that the entire area may not rank as suitable for an AOA at all. As a result, adding further low scores to address the protected species in this area is unlikely to change the overall suitability of this area.

4. For fin whales, the areas of highest density are encompassed within areas already receiving one or more low scores for humpback and/or blue whales and no further meaningful contrast between portions of study areas is likely to be gained by scoring those higher density fin whale areas at this time.

[50] https://repository.library.noaa.gov/view/noaa/27826

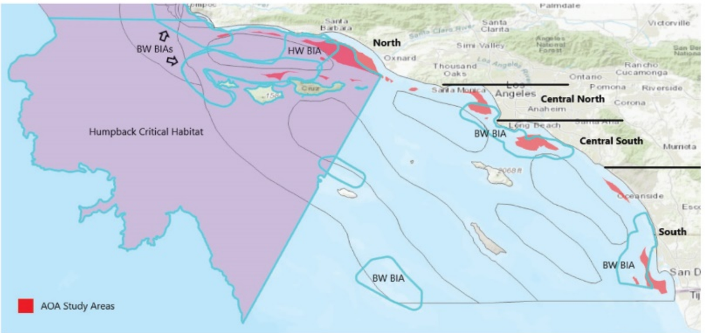


Figure 16. Cetacean Biologically Important Areas and Humpback critical habitat (blue outlines) and Aquaculture Opportunity Area study areas in red.

FINAL COMBINED WCR-PRD DATA LAYER

There are four submodels in the NCCOS Atlas model, which assess suitability related to: 1) National Security, 2) Industry Navigation and Transportation, 3) Aquaculture and Commercial Fishing, and 4) Natural Resources. These submodels are combined to calculate a "Cumulative Suitability Model" that is then used to identify clusters of the most suitable areas within each of the four study areas. Within the most suitable clusters, a precision siting model will be used to identify multiple aquaculture opportunity area options within each of the four study areas, which will be characterized and used to inform development of preliminary alternatives that will be considered in the PEIS.

WCR-PRD's understanding is that NCCOS does not impose any relative weighting on the submodels before combining their scores into the "Cumulative Suitability Model." Submodel comparisons in the AOA Atlas are unweighted because multiple types of aquaculture are proposed and NCCOS believes comparisons can be more effectively made during later phases in the process. The use of submodels is designed to avoid more numerous data layers having greater control over final model outcomes, such that each submodel contributes an equal amount to the final suitability score. Because the final suitability scores compare very different types of activities, the overall score does not have an empirical meaning; however, the relative rank of the scores is important to determining which sites are more suitable. Therefore, it is important that the ranked scores of the areas in the WCR-PRD Layer of the Natural Resources submodel are reflective of where WCR-PRD is more or less concerned with regards to the vulnerability of protected species.

Based on discussions between WCR-PRD and NCCOS, for the southern California Atlas study areas protected species scores within the unified data layer would be calculated using the product method (versus geometric mean or arithmetic mean) to ensure that the final score for grid cells with multiple protected species layers would reflect the lowest possible score versus areas with a single protected species or no quantitative species data at all.

In conclusion, WCR-PRD is providing a data layer based on combining the humpback whale BIA, humpback whale critical habitat, and blue whale BIAs data layers and calculating the product of the scores from overlaps between those layers to NCCOS for the Atlas process (Figure 17). This layer is intended for use in the southern California Atlas mapping and siting process only. Future project or site-specific siting processes should benefit from consideration of other available information specific to that area and proposed activity.

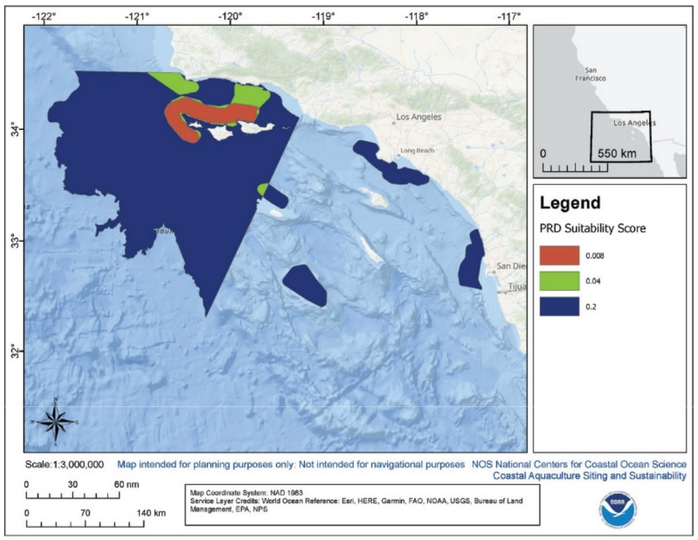


Figure 17. WCR-PRD-recommended southern California Atlas data layer, generated by combining layers for humpback whales, blue whales, and humpback critical habitat using the Product method. The legend provides the results of the protected species scoring and highlights areas that are of relatively higher concern with regards to species status, population size, and trajectory. Consideration should also be given to neighborhood characterization as other protected species may also occur within these areas but were not included in the scoring model.

SITE CHARACTERIZATION CONSIDERATIONS

The following is a brief discussion of certain ESA-listed species and MMPA stocks that should be included within the site characterization with reference to available information on range and status of the species. Tables 4 and 5 above provide a summary list of ESA-listed species and MMPA stocks. Here, WCR-PRD provides more specific information on some of these species and stocks below. This includes information collected or developed by scientists at the Southwest Fisheries Science Center as cited below. The following is not an exhaustive summary of species and information that should be considered but selected vulnerable species that should be highlighted. For example, not all marine mammal stocks listed in Table 4 are discussed further below.

LARGE WHALES

Blue Whales and Humpback Whales - Although the data layer submitted covers primarily these two species, it should be noted elsewhere in the AOA Atlas that both species may be found throughout the Atlas study areas depending on season and oceanographic conditions. For example, Figure 18 depicts the species distribution model results from Becker *et al.* (2020)[51] for the blue whale in the Southern California Bight. This species is predicted to occur (and sightings by survey vessels and citizen scientists corroborate) in areas outside of the BIAs.

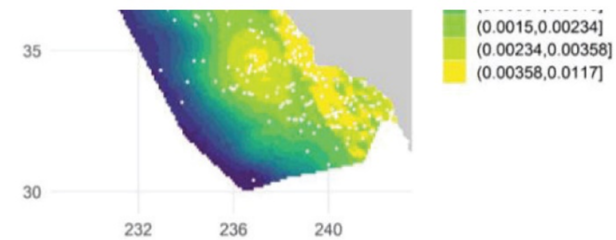


Figure 18. Screen capture excerpt of blue whale density predictions, taken from Becker et al (2020, Figure 2-k). Densities are reported as means in animals/km^2.

Gray Whales - Both Eastern and Western North Pacific gray whales occur in the Atlas study areas. While the ENP population has been removed from the list of threatened and endangered species by virtue of its recovery, the ENP population remains very small and is critically endangered. Animals from this population have been tracked along the coast of California, including into southern California waters and NMFS considers impacts to this species when consulting on Federal actions under the ESA. The recommended score for the WNP population

[51] Becker, E.A., K.A. Forney, D.L. Miller, P.C. Fiedler, J. Barlow, J.E. Moore. 2020. Habitat-based density estimates for cetaceans in the California Current Ecosystem based on 1991–2018 survey data. U.S. Dept. of Commerce, NOAA Technical Memorandum 78 p. https://doi.org/10.25923/3znq-yx13

would be a 0.1, whereas the recommended score for the ENP population would be a 0.8 on the basis of its status. As noted above, a BIA layer for "gray whales" exists for this species but was not included in the suitability model.

Fin Whales - Fin whales are an ESA-listed endangered species that occurs within the Atlas study area. Becker *et al* (2020) published updated species distribution models including one for fin whales. A screen capture of the model results is included here in Figure 3. Fin whales have a recommended score of 0.2 (the same as blue whales and Central America DPS humpback whales) on the basis of their status and trend information. As can be seen in Figure 19, based on NOAA survey data, they also occur within and adjacent to the Atlas study areas, although at higher densities per km2 in more offshore areas. Fin whales are similar in size, shape, and foraging behavior as blue whales and thus share similar risks from entanglement or forage quality and accessibility impacts.

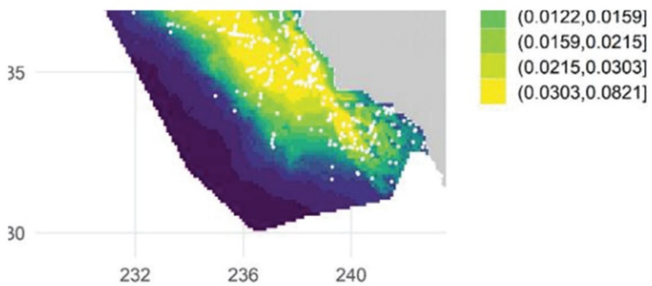


Figure 19. Screen capture excerpt of fin whale density predictions, taken from Becker et al (2020, Figure 2-l). Densities are reported as means in animals/km^2.

SEA TURTLES

There are four sea turtle species that could potentially be found in the AOA study areas. Three primary species can potentially occur in the area, including green turtles, loggerhead turtles, and leatherback turtles. Below is a summary for each, including comments about the relative probability that they could be found in the AOA study areas. In addition, the olive ridley turtle occurs sporadically in the region, although data are restricted to beach strandings of live and dead turtles. This summary is intended to provide a broad visual portrayal of the distributions and movements of sea turtles in the region. Scientists at NOAA SWFSC are happy to provide original source data upon request.

Green turtles

There are four areas of known year-round presence for green turtles (recommended score 0.5) in coastal waters of the SCB, including San Diego Bay, La Jolla Cove, Seal Beach National Wildlife Refuge, and San Gabriel River. In addition, NOAA-SWFSC has managed a sea turtle sightings database that records sea turtle reports provided by the public (Fig. 20).

In general, green turtles are a largely coastal-dwelling species and reports by the public (See figure below) as well as NOAA research have found turtles to mostly occur in nearshore habitats. There are, however, telemetry data that depict movements in slightly more offshore areas as turtles a) move out of Seal Beach NWR into deep waters of Anaheim Bay (n=2; Fig. 21), b) transition between San Diego Bay and Orange County (n=1; Fig. 22), and c) migrate between foraging areas in southern California and nesting beaches in Mexico (n=4, Fig. 23).

For the most part, green turtle presence is restricted to the coast, except for when individuals are conducting reproductive migrations. The AOA Central South study area is one where green turtles may occur, albeit in low numbers, near Anaheim Bay where green turtles tagged in Seal Beach have visited on occasion (Fig. 21).

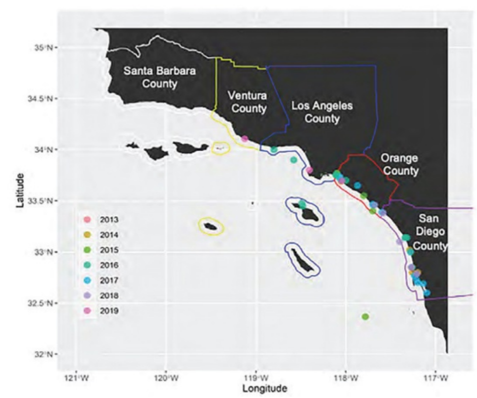


Figure 20. Location of public-reported green turtle sightings in the southern California Bight. From Hanna et al. (2021)[52].

[52] Hanna, M.E., E.M. Chandler, B.X. Semmens, T. Eguchi, G.E. Lemons, J.A. Seminoff. 2021. Citizen sourced sightings and underwater photography reveal novel insights about green sea turtle distribution and ecology in southern California. Frontiers in Marine Science 8:671061.

Figure 21. Map of kernel home range estimates for two green turtles included as part of the inshore Seal Beach NWR tracking project that departed the Refuge and moved into Anaheim Bay. Data from Hanna et al. (2020) interim report to Navy[53].

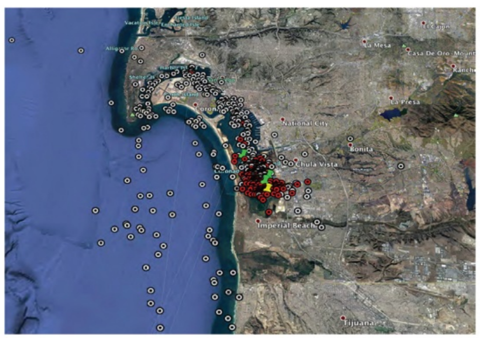


Figure 22 Satellite-tracked locations (circles) and putative track lines (gray lines) of 4

[53] Hanna, M.E., J. Bredvik, S.E. Graham, B. Saunders, J.A. Seminoff, T. Eguchi and C. Turner Tomaszewicz. 2020. Movements and habitat use of green sea turtles at the Seal Beach National Wildlife Refuge, CA. Prepared for Naval Weapons Station Seal Beach, California, September 2020.

green turtle during migration between the San Diego Bay foraging area and nesting sites in southern Mexico. Data from Dutton et al. (2019)[54] and NOAA Unpubl. data.

Figure 23. Satellite-tracked movements of a juvenile green turtle from San Diego Bay to Orange County. NOAA Unpubl. data.

Leatherback Turtles

The epicenter of leatherback turtle (recommended score of 0.1) presence in California waters is the Monterey Bay – Gulf of Farallon region of the central coast. Leatherbacks occur here largely during late summer through fall, arriving to take advantage of seasonal sea jelly blooms. Knowledge of their locations and movements is based on aerial surveys in central California and to the north as well as satellite telemetry (Figs. 24 and 25) undertaken during NOAA field research. A subset of these data as well as additional data points are included on the OBIS Seamap website (https://seamap.env.duke.edu/species/173843).

[54] Dutton, P.H., R.A. LeRoux, E. LaCasella E, J.A. Seminoff, T. Eguchi , and D.L. Dutton. 2019. Genetic analysis and satellite tracking reveal origin of the green turtles in San Diego Bay. Marine Biology 166:3

Figure 24. Satellite tracked movements of a leatherback turtle in the southern California bight region. This individual was tagged in 2019 and was the second smallest leatherback captured during many years of NOAA research. The track was unusual relative to previous tracks and the animal may have been 'exploring' the environment. NOAA Unpubl. data.

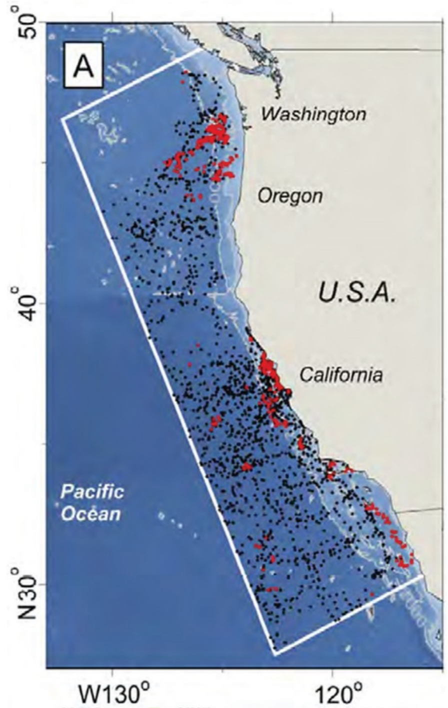


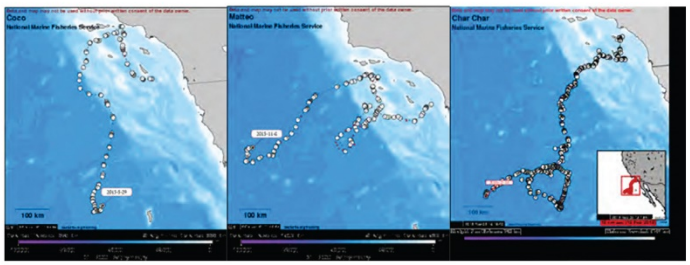
Figure 25. Leatherback telemetry locations with Area Restricted Search behavior (red dots) and transit behavior (black dots) along the U.S. West Coast. Modified from Figure 5 in Benson et al. (2011)[55].

[55] Benson,S.R., T. Eguchi, D.G. Foley, K.A. Forney, H. Bailey, C. Hitipeuw, B.P. Samber, R.F. Tapilatu, V. Rei, P. Ramohia, and J. Pita. 2011. Large-scale movements and high-use areas of western Pacific leatherback turtles, Dermochelys coriacea. Ecosphere. 2(7):1-27.

Although leatherbacks can be found in the southern California bight, this occurs largely as turtles are transiting through the area. No local movements are considered to be 'resident' activity. This species has been documented as killed or injured in fishery entanglements and vessel strikes (NOAA Fisheries 2008[56], Lewison et al. 2014[57], NOAA Fisheries GARFO and NEFSC 2015[58], Hamelin et al. 2017[59]) and thus may face similar threats from aquaculture gear and operations (Price et al. 2017[60], Bath et al. in review[61]).

Loggerhead turtles

Loggerhead distribution and movements along the U.S. west coast are largely confined to waters of the southern California Bight. Data are derived from satellite telemetry (n=3; Fig. 26), NOAA aerial surveys (Fig. 27), NOAA ship-based surveys (Fig. 28), and loggerhead turtle sightings reported by the public (Fig. 29). Additional data are included in the OBIS Seamap database (Fig. 30). Of all sea turtle species, loggerheads are the most likely to occur within the proposed AOAs. However, loggerhead presence in the area is sporadic, and centered on warm water periods. During normal or cool years, the probability of loggerhead presence is low.



[56] NOAA Fisheries (2008) Summary report of the workshop on interactions between sea turtles and vertical lines in fixed-gear fisheries. Schwartz ML (ed.) Rhode Island Sea Grant, Narragansett, RI 54pp

[57] Lewison RL, Crowder LB, Wallace BP, Moore JE, Cox T, Zydelis R, McDonald S, DiMatteo A, Dunn DC, Kot CY, Bjorkland R, Kelez S, Soykan C, Stewart KR, Sims M, Boustany A, Read AJ, Halpin P, Nichols WJ, Safina C (2014) Global patterns of marine mammal, seabird, and sea turtle bycatch reveal taxa-specific and cumulative megafauna hotspots. PNAS USA. 111(14):5271-5276

[58] NOAA Fisheries Greater Atlantic Regional Fisheries Office (2015) Sea turtles and vertical lines in the northeast region: issue statement and research needs. NMFS, GARFO and NEFSC

[59] Hamelin KM, James MC, Ledwell W, Huntington J, Martin K (2017) Incidental capture of leatherback sea turtles in fixed fishing gear off Atlantic Canada. Aquatic Conserv: Mar Freshw Ecosyst 27:631-642

[60] Price CS, Morris JA Jr., Keane E, Morin D, Vaccaro C, Bean D (2017) Protected species and marine aquaculture interactions. US Dep Commer NOAA Tech Memo NOS NCCOS 211

[61] Bath GE, Price CA, Riley KL, Morris JA (In review) Review: Marine aquaculture and the environment: Protected species interactions. Target journal: Aquaculture Environment Interactions

Figure 26. Satellite-tracked movements of 3 juvenile loggerhead turtles encountered in the southern California bight. The turtles 'Coco' and 'Char Char' were rehabilitated individuals, whereas Matteo was caught during NOAA field research.

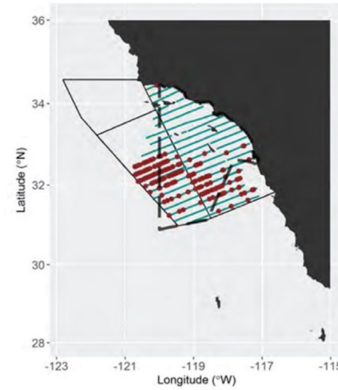
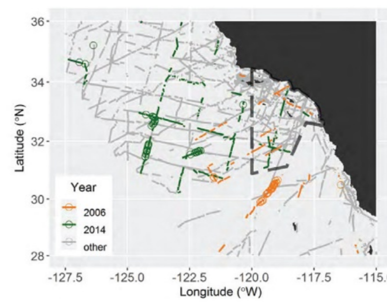


Figure 27. Loggerhead locations determined via NOAA aerial surveys in fall 2015. Blue lines indicate surveyed tracklines. Modified from Eguchi et al. (2018)[62].



[62] Eguchi, T., S. McClatchie, C. Wilson, S.R Benson, R.A. LeRoux, and J.A. Seminoff. 2018 Loggerhead turtles (Caretta caretta) in the Northeast Pacific Ocean; distribution, anomalous warming, and drift gill net fishery closure off southern California. Frontiers in Marine Science. 5:452.

Figure 28. Summary of loggerhead sightings during NOAA 'big-white-ship' cruises to the eastern Pacific.

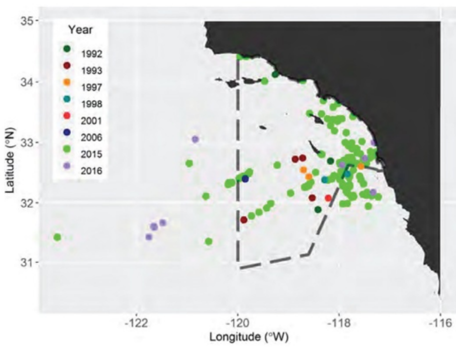


Figure 29. Location and timing of sea turtle sightings (mostly loggerheads) reported by the public to the NOAA sightings hotline. The year 2015 (green) was the time of a large influx of loggerheads into the bight, and most of these data points likely represent loggerheads. Data from Eguchi et al. (2018) Front. Mar. Sci.

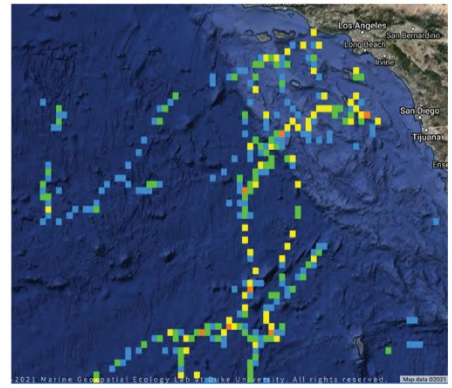


Figure 30. Summary of loggerhead locations reported in the OBIS Seamap database (https://seamap.env.duke.edu/species/173830).

OTHER SPECIES/STOCKS FOR CHARACTERIZATION

Giant Manta Rays

Giant manta rays are a threatened species (recommended score 0.4) that occurs in the Southern California Bight. The giant manta ray is a migratory species, and seasonal visitor along productive coastlines with regular upwelling. The timing of these visits varies by region and seems to correspond with the movement of zooplankton, current circulation and tidal patterns, seasonal upwelling, seawater temperature, and possibly mating behavior. Giant manta rays also appear to exhibit a high degree of plasticity in terms of their use of depths within their habitat. During feeding, giant manta rays may be found aggregating in shallow waters at depths less than 10 meters. However, tagging studies have also shown that the species conducts dives of up to 200 to 450 meters and is capable of diving to depths exceeding 1,000 meters. This diving behavior may be influenced by season and shifts in prey location associated with the thermocline. The giant manta ray is found worldwide in tropical, subtropical, and temperate bodies of water and is commonly found offshore, in oceanic waters, and in productive coastal areas. The species has also been observed in estuarine waters, oceanic inlets, and within bays and intercoastal waterways. As such, giant manta rays can be found in cool water, as low as 19°C, although temperature preference appears to vary by region. Giant manta rays are intentionally and unintentionally caught in fisheries, including purse seine and gillnet fisheries. Aquaculture gear that mimics these types of gear may pose a risk to giant manta rays. Figure 31 shows the range of giant manta rays and indicates their expected presence in the southern California area.

Figure 31. Areas of occurrence (lighter blue) and expected occupancy (darker blue). Excerpted from Figure 3 in: https://doi.org/10.7717/peerj.3027 (Lawson et al 2016)[63] , specific figure is: https://doi.org/10.7717/peerj.3027/fig-3

Scalloped hammerhead shark

The scalloped hammerhead shark can be found in coastal warm temperate and tropical seas worldwide. Distribution in the eastern Pacific Ocean extends from the coast of southern California (U.S.), including the Gulf of California, to Ecuador and possibly Peru (Compagno 1984)[64], and off of the waters of Hawaii (U.S.) and Tahiti. Southern California waters are considered the northernmost extent of the range of the endangered Eastern Pacific DPS (recommended score 0.1). Little information is available on the occurrence of this species in coastal California waters. Major threats include overfishing and bycatch in a variety of fisheries, including trawl, gillnet, purse seine, and longline.

Guadalupe fur seals (and pinnipeds in general)

Guadalupe fur seals (recommended score 0.5) are regular visitors to the Southern California Bight and have been sighted on the Channel Islands, including the presence of newborn pups and juveniles. The species is currently experiencing an Unusual Mortality Event within strandings of sick and emaciated individuals all along the U.S. West Coast.[65]

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63 Lawson JM, Walls RHL, Fordham SV, O'Malley M, Heupel MR, Stevens G, Fernando D, Budziak A, Simpfendorfer C, Davidson LNK, Ender I, Francis M, Notarbartolo di Sciara G, Dulvy NK (2016) Sympathy for the devil: A conservation strategy for devil and manta rays. doi:10.7717/peerj.3027

64 Compagno, L. J. (1984). FAO species catalogue. v. 4:(2) Sharks of the world. An annotated and illustrated catalogue of shark species known to date, pt. 2: Carcharhiniformes.

65 2015–2021 Guadalupe Fur Seal Unusual Mortality Event in California, Oregon and Washington

The range of the species is shown in Figure 32 and indicates the species potential presence throughout the Bight. However, these animals would generally be considered as infrequent visitors in the coastal waters of the Bight.

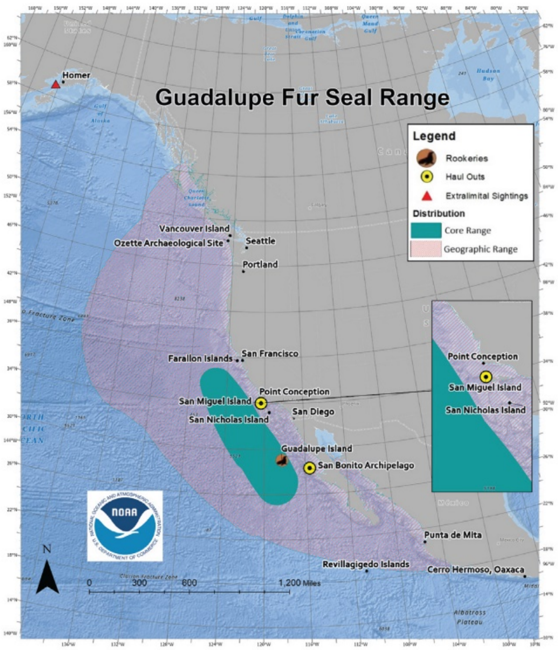


Figure 32. Core and maximum range of the Guadalupe fur seal. NMFS Status Review (in review)

Across the globe, pinnipeds face some level of threat from interactions with various types of aquaculture facilities and operations ranging from little to no threat to killings depending on the nature of the farm and associated operations (Kemper et al. 2003[66], Forrest et al. 2007[67], Price et al. 2017, Callier et al. 2018[68], Bath et al. in review). California sea lions and harbor seals (recommended score 0.8) are two species that are numerous and common occupants in the Bight, especially in nearshore and coastal waters. Both species are frequently seen near fishing operations and have been incidentally caught or entangled in fishing gear (FAO 2021[69]), aquaculture gear (Kemper et al. 2003, Forrest et al. 2007, Clement 2013[70], Callier et al. 2018, Bath et al. in review), and other lines or structures in the water worldwide (Kovacs et al. 2012[71]). Aquaculture operations likely cannot avoid siting within areas that include these species, but special attention should be paid to both the design, maintenance, and operation of facilities to reduce attractants or create conditions that could lead to the death or serious injury of these animals (Clement 2013, Price et al. 2017, Bath et al. in review). All pinnipeds are protected under the MMPA and take is illegal outside of specific exceptions or authorizations.

Common Bottlenose dolphin

This MMPA stock, specifically the Offshore Stock,[72] does occur within the Atlas study area (Figure 33). This stock is highlighted here for several reasons. First, although the recommended score for this stock would be 0.8 per the PR scoring approach, this stock has a relatively low abundance estimate and the Potential Biological Removal level for this stock is 11 animals per year (in comparison, the California/Oregon/Humpback whale stock which includes animals listed as endangered and threatened is currently 16.7 animals in U.S. waters). Bottlenose dolphins have been documented as interacting with aquaculture gear throughout the world, including incidents that have resulted in the death or serious injury of the animals (Clement 2013, Price et al. 2017, Callier et al. 2018, Bath et al. In review). As a result, although it may not be possible to provide specific sighting locations within Federal waters that would avoid or minimize the chances of interactions with common bottlenose dolphins, aquaculture planners and operators should take this species into careful consideration when designing, building, and operating aquaculture facilities as the stock would be vulnerable to declines and increased time

[66] Kemper CM, Pemberton D, Cawthorn M, Heinrich S, Mann J, Würsig B, Shaughnessy P, Gales R (2003) Aquaculture and marine mammals: co-existence or conflict? In: Gales N, Hindell M, Kirkwood R (eds) Marine mammals: fisheries, tourism, and management issues. CSIRO Publishing: Collingwood, Victoria, Australia 208-225

[67] Forrest B, Keeley N, Gillespie P, Hopkins G, Knight B, Govier D (2007) Review of the ecological effects of marine finfish aquaculture: final report. Nelson, NZ: Cawthron Institute Report No 1285

[68] Callier MD, Byron CJ, Bengtson DA, Cranford PJ, Cross SF, Focken U, Jansen HM, Kamermans P, Kiessling A, Landry T, O'Beirn F, Petersson E, Rheault RB, Strand Ø, Sundell K, Svåsand T, Wikfors GH, McKindsey CW (2018) Attraction and repulsion of mobile wild organisms to finfish and shellfish aquaculture: a review. Rev Aquac 10:924-949 https://doi.org/10.1111/raq.12208

[69] FAO (2021) Fishing operations. Guidelines to prevent and reduce bycatch of marine mammals in capture fisheries. FAO Technical Guidelines for Responsible Fisheries No.1, Suppl. 4. Rome. https://doi.org/10.4060/cb2887en

[70] Clement D (2013) Literature review of ecological effects of aquaculture: effects on marine mammals. Nelson, NZ: Cawthron Institute

[71] Kovacs K, Aguilar A, Aurioles D, Burkanov V, Campagna C, Gales N, Gelatt T, Goldsworthy S, Goodman S, Hofmeyr G, Harkonen T, Lowry L, Lydersen C, Schipper J, Sipilä T, Southwell C, Stuart S, Thompson D, Trillmich F (2012) Global threats to pinnipeds. Marine Mammal Science. 28. 414-436. 10.1111/j.1748-7692.2011.00479.x.

[72] https://media.fisheries.noaa.gov/dam-migration/po2016dobn-cowos_508.pdf

to reach its optimum sustainable population if multiple animals are killed or seriously injured each year.

Other species with similar predicted ranges in the study areas are the short-beaked and long-beaked common dolphins and the Risso's dolphin. Of these, only the Risso's dolphin has a PBR (46 animals per year) near the range of the offshore common bottlenose dolphin.

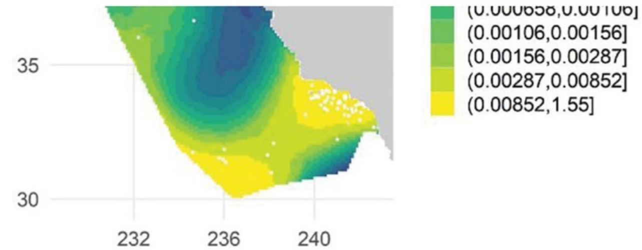


Figure 33. Screen capture excerpt of common bottlenose dolphin density predictions, taken from Becker et al (2020, Figure 2-g). Densities are reported as means in animals/km².

Appendix C

Scoring rationale for data layers used in the spatial analyses for the Gulf of Mexico Aquaculture Opportunity Area analyses. Information for all datasets utilized in submodels for the relative suitability analysis. Key information includes presence or absence within each study area, scores, and the rationale for scoring. Each dataset is listed with an 'x' denoting whether it occurred in the West (W), Central (C), the East (E), or the Southeast (SE) study area. A dash denotes when a dataset did not overlap or intersect a specific study area. Scores are based on a 0 to 1 range, with 0 = unsuitable for aquaculture; 0.5 = potentially unsuitable for aquaculture; 1 = suitable for aquaculture.

Table C-1. National security submodel datasets used in suitability modeling. Each dataset was collected and reviewed by the Department of Defense (DOD) Military Aviation and Installation Assurance Siting Clearinghouse (MAIASC) and designated regional representatives for military and national security interests. The Clearinghouse assisted with coordination across all branches of the military to vet data and address concerns.

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Military Operating Area (MOA) - Corpus Christi	x	-	-	-	0.5	MOA Corpus Christi overlaps the West study area and with SUAs W228A, W228B, W228C, and W228D, is used by Fleet Area Control and Surveillance Facility, and is directly adjacent to five other SUAs. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Military Operating Area (MOA) - Eglin Gulf Test and Training Range (EGTTR)	-	x	x	x	0.5	MOA EGTTR is one of the most heavily instrumented, infrastructure-intensive test ranges in the U.S.[61] No other existing DOD area offers the combination of airspace, water space, and existing infrastructure to support military activities. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

[61] https://www.iadc.org/wp-content/uploads/2018/05/DOD-Offshore-Report.pdf

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Military Operating Area (MOA) - Key West	-	-	-	x	0.5	MOA Key West overlaps with SUAs W465A, W465C, W174B, C, D, and E, contains the Bonefish Air Traffic Control Assigned Airspace (ATCAA), and extends from the surface to the ocean bottom.[62] This area supports Special Warfare Command High Altitude Low Opening operations and other multi-national collaborative or training exercises.[63] Uncertainty exists in the temporal and spatial extent of military training in the area, and how aquaculture operations may interact with them. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Military Operating Area (MOA) - New Orleans	-	x	-	-	0.5	MOA New Orleans overlaps with SUA W92 (used by FACSFAC) and is adjacent to W54A, W54B, and W54C SUAs. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Military Operating Area (MOA) - Pensacola	-	x	x	-	0.5	The Central and East study areas overlap MOA Pensacola. The U.S. Navy Testing and Training Range overlapping W155A is used by the FACSFAC.[64] The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Military Training Routes (MTR) - Flight Corridors	-	x	-	-	0.5	MTRs (areas of low-level combat tactics training) include the required maneuvers and high speeds needed for such tactics. These tactics and this aspect of visual flight rules are more difficult to track without increased vigilance in areas containing such operations.[65] The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (SUA) - A381	-	x	-	-	0.5	This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - not warning areas) - Testing and Training Area EWTA-2A	-	-	x	-	0.5	This SUA overlaps a small portion of the central East study area. The portion of this SUA is not within the danger zone, but is adjacent to W151 and is heavily used. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - not warning areas) - Testing and Training Area EWTA-2B	-	-	x	-	0.5	This SUA overlaps with the central portion of the East study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

62 https://media.defense.gov/2020/Jul/14/2002456770/-1/-1/0/GOMEX-FINAL-EIS-OEIS-VOL1.PDF

63 https://www.iadc.org/wp-content/uploads/2018/05/DOD-Offshore-Report.pdf

64 https://denix.osd.mil/sri/policy/reports/report-to-congress-on-sustainable-ranges/april-2012-appendix-c-maps-and-inventory-of-ranges-range-complexes-military-training-routes-and-special-use-areas-figures/

65 https://www.faa.gov/air_traffic/publications/atpubs/aip_html/part2_enr_section_5.2.html

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Special Use Airspace (over water - not warning areas) - Testing and Training Area EWTA-5	-	-	x	-	0.5	This SUA overlaps with the southern portion of the East study area. This SUA is not within a danger zone or restricted area, but is still a SUA used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - MOA U.S. 02174	-	-	-	x	0.5	This SUA partially overlaps with a restricted area and is used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - MOA U.S. 02416 and 02417	-	x	-	-	0.5	This SUA partially overlaps with the Central study area. It is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (SUA) - W147A and W147B	x	-	-	-	0.5	This SUA overlaps with the eastern portion of the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (SUA) - W147C	x	-	-	-	0.5	This SUA overlaps with the central portion of the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (SUA) - W147D	x	-	-	-	0.5	This SUA overlaps with the central portion of the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W148A and W148B	-	x	-	-	0.5	This SUA overlaps with the eastern portion of the Central study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W155A	-	x	x	-	0.5	This SUA overlaps both the East and Central study areas. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W155B	-	x	-	-	0.5	This SUA overlaps with the eastern portion of the Central study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Special Use Airspace (over water - warning areas) - W228A	x	-	-	-	0.5	This SUA overlaps with the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W228B	x	-	-	-	0.5	This SUA overlaps with the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W228C	x	-	-	-	0.5	This SUA overlaps with the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W228D	x	-	-	-	0.5	This SUA overlaps with the West study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W54A	-	x	-	-	0.5	This SUA partially overlaps with the Central study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W54B and W54C	-	x	-	-	0.5	This SUA partially overlaps with the Central study area. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W59A	x	x	-	-	0.5	This SUA overlaps with the West and Central study areas. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Special Use Airspace (over water - warning areas) - W59B	x	x	-	-	0.5	This SUA overlaps with the West and Central study areas. This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Special Use Airspace (over water - warning areas) - W92	-	x	-	-	0.5	This SUA overlaps with the Central study area. The Naval Air Station Joint Reserve Base New Orleans uses SUA W92 for a multitude of training exercises.[66] This SUA is not within a danger zone or restricted area, but is still used for military training. The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Danger Zones and Restricted Areas (33 CFR § 334.2)	-	-	x	x	0	Areas are, by nature, dangerous and restricted due to the military activities that occur (bombing, missile and torpedo testing, etc.).[67] These areas are generally not compatible with aquaculture infrastructure; therefore, these areas were assigned a score of 0 for complete avoidance.
Military Operating Area (MOA) - Panama City	-	-	x	-	0	This MOA overlaps SUAs W151A and W151B, which are used by the Navy Diving and Salvage Training Center and the Navy School for Explosive Ordnance Disposal, on an almost daily basis (DOD 2018).[68] Additional uses include Weapon Systems Evaluation Programs assessing aircraft against surface targets, including remotely piloted surface boats (i.e. swarms). Due to the known nature of activities, these areas were assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W151A	-	-	x	-	0	This SUA overlaps with the East study area. It lies within a heavily used airspace with training activities that are incompatible with aquaculture and is within a danger zone. It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W151B	-	-	x	-	0	This SUA overlaps with the East study area. It lies within a heavily used airspace with training activities that are incompatible with aquaculture and is within a danger zone. It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W151D	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used airspace with training activities that are incompatible with aquaculture and is within a danger zone. It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W168	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture (DOD 2018). It was assigned a score of 0 for complete avoidance.

[66] https://www.cnic.navy.mil/regions/cnrse/installations/nas_jrb_new_orleans.html

[67] These data represent the location of Danger Zones and Restricted Areas within coastal and marine waters, as outlined by the Code of Federal Regulations (CFR) and the Raster Navigational Charts (RNC). The CFR defines a Danger Zone as: "A defined water area (or areas) used for target practice, bombing, rocket firing or other especially hazardous operations, normally for the armed forces. The danger zones may be closed to the public on a full-time or intermittent basis, as stated in the regulations."

[68] https://www.iadc.org/wp-content/uploads/2018/05/DOD-Offshore-Report.pdf

National Security Dataset	W	C	E	SE	Score	Rationale for Score
Special Use Airspace (over water - warning areas) - W174A	-	-	x	x	0	This SUA overlaps with the East and Southeast study areas. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture and is partially within a restricted area (DOD 2018). It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W174B(A)	-	-	-	x	0	This SUA overlaps with the Southeast study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture and is partially within a restricted area (DOD 2018). It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W470B	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture and is within a danger zone (DOD 2018). It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W470C	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture and is within a danger zone (DOD 2018). It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W470E	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture (DOD 2018). It was assigned a score of 0 for complete avoidance.
Special Use Airspace (over water - warning areas) - W470F	-	-	x	-	0	This SUA overlaps with the East study area. This SUA lies within a heavily used air space with training activities that are incompatible with aquaculture and is within a danger zone (DOD 2018). It was assigned a score of 0 for complete avoidance.
Unexploded Ordnance (UXO) points with 500-m setback	-	-	x	-	0	UXOs are explosive weapons (in this case, depth charges) that did not explode when they were deployed and still pose a risk of detonation. Data received in point format were given a 500-m setback for planning to avoid any interactions with the UXOs. The point and setback area were assigned a score of 0 for complete avoidance.
Unexploded Ordnance (UXO) polygon	x	-	x	-	0	These are areas containing explosive weapons (bombs, bullets, shells, grenades, mines, etc.) that did not explode when they were deployed and still pose a risk of detonation, potentially decades after being discarded. It was assigned a score of 0 for complete avoidance. [69]

[69] https://www.fisheries.noaa.gov/inport/item/54407

Table C-2. Natural and cultural resources submodel datasets used in suitability modeling. Data were collected and reviewed in coordination with multiple agencies, including National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Bureau of Ocean Energy Management (BOEM), and other state agencies. A dash denotes when a dataset did not overlap or intersect a specific study area. The protected resources consideration combined species layer is not listed, but broken down by each species scoring rationale.

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Florida Keys National Marine Sanctuary	-	-	-	x	0.5	The Florida Keys NMS was originally designated in 1990 and in response to concerns about the decline of the coral reef ecosystem in the area.[70] Live rock aquaculture occurs within the Sanctuary, and while other forms of aquaculture are not prohibited, development of any new fishing practices or aquaculture requires extensive coordination with NOAA. The area was assigned a score of 0.5.
Flower Garden Banks National Marine Sanctuary	x	-	-	-	0.5	The existing Flower Garden Banks NMS was originally designated in 1992 and includes the northernmost coral reefs in the continental United States, deep-water reef communities, and other essential habitats for a variety of marine species.[71] While aquaculture is not prohibited, development of aquaculture or any new activities requires extensive coordination with NOAA. The area was assigned a score of 0.5.
Rice's Whale Core Distribution Area[72]	-	x	x	-	0.1	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Based on status and trends, the Rice's whale[73] is predominantly found within the core distribution area. A convex hull polygon[74] was drawn around SEFSC surveys, telemetry tag locations (n = 52), Acousonde™ tag locations (n = 41), and 212 sightings from 1989 - 2018.[75] Subsequent conservation buffers (i.e., 10 km for capture uncertainty and 20 km for positional uncertainty) were applied to define the core distribution area. Due to the endangered, small, and declining population status of this species, the area was assigned a score of 0.1 to provide a more conservative model value.

70 https://floridakeys.noaa.gov/history.html?s=about

71 https://flowergarden.noaa.gov/management/expansionnpr.html

72 https://www.fisheries.noaa.gov/resource/map/gulf-mexico-brydes-whale-core-distribution-area-map-gis-data

73 Rosel et al. (2021)

74 IUCN (2012)

75 Soldevilla et al. In prep.

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Rice's Whale Suitable Habitat (100 m to 400 m depth)[76, 77]	x	x	x	x	0.1	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Rice's whales are protected under the MMPA and are under the ESA. This data layer (Appendix B) represents the distribution of Rice's whales in the greater Gulf of Mexico region. The suitable habitat area was inferred from strategically placed long-term passive acoustic monitors[78], positioned at the median depth range of 122 m, from the core distribution area at the shelf break in the De Soto Canyon, east to Grand Isle, and west at Flower Garden Banks NMS. Using low-frequency acoustic recording packages to detect stereotypical Rice's whale calls, along with survey data and habitat preference models, NOAA NMFS SERO formulated the final area. The final habitat conservation area runs from 100 m to 400 m depth throughout the U.S. Gulf of Mexico. Due to the endangered, small, and declining population status of this species, the area was assigned a score of 0.1 to provide a more conservative model value throughout the range.
Gulf of Mexico Leatherback Sea Turtle High Use Area	x	x	x	x	0.1	This layer was used within the protected resources consideration combined species layer for AOA suitability model. NOAA NMFS Protected Resources identified critical residence data to assess HUAs for leatherback sea turtles within the Gulf of Mexico (Appendix B).[79] To develop the leatherback sea turtle HUAs, satellite telemetry data[80] from resident areas were converted to polygons by buffering the point data by 18.98 km, ultimately defining the HUAs. Due to the endangered and declining population status of this species, the area was assigned a score of 0.1 to provide a more conservative model value throughout the range.

[76] https://www.fisheries.noaa.gov/species/gulf-mexico-brydes-whale#:~:text=For%20the%20past%2025%20years,et%20al.%2C%202015)%20.

[77] https://www.researchgate.net/publication/316315634_Spatial_distribution_and_dive_behavior_of_Gulf_of_Mexico_Bryde%27s_whales_Potential_risk_of_vessel_strikes_and_fisheries_interactions

[78] Soldevilla et al. In prep.

[79] NMFS and USFWS (2020)

[80] Aleksa et al. (2018)

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Gulf of Mexico Hawksbill Sea Turtle Migratory Corridor	-	-	-	x	0.2	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Hawksbill sea turtle migratory corridor data were based on previous satellite telemetry studies.[81,82,83,84,85] The hawksbill sea turtle migratory corridor was assigned a score of 0.2 for conservation purposes based on the species' endangered status and unknown population trends[86,87] (Appendix B).
Gulf of Mexico Kemp's Ridley Sea Turtle High Use Area	x	x	x	x	0.2	This layer was used within the protected resources consideration combined species layer for AOA suitability model. NOAA NMFS Protected Resources evaluated critical residence data to assess HUAs for Kemp's ridley sea turtles within the Gulf of Mexico (Appendix B). To develop the HUAs, satellite telemetry data[88,89,90] from resident areas were converted to polygons by buffering the point data by 18.98 km, ultimately defining the HUAs. Each HUA was assigned a score of 0.2 for conservation purposes based on the species' endangered status and unknown population trends.

81 Phillips et al. (2021)
82 Hart et al. (2021)
83 Foley et al. (2013)
84 Iverson et al. (2020)
85 Shaver et al. (2016)
86 NMFS and USFWS (2013)
87 NMFS and USFWS (1993)
88 NMFS and USFWS (2015)
89 Shaver et al. (2016)
90 Hart et al. (2021)

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
U.S. Distinct Population Segment Smalltooth Sawfish High Use Areas (HUAs)	-	-	x	x	0.3	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Smalltooth sawfish locations in the U.S. Gulf of Mexico were determined from three sources: 1) U.S. Sawfish Recovery Encounter Database[91,92], 2) acoustic tag data[93,94], and 3) satellite tag data[95]. Point data from the three sources were merged into a single dataset and filtered to only locations in the Gulf of Mexico EEZ (Appendix B). A 95% kernel density estimate was generated for the AOA AOI to encompass the smalltooth sawfish HUA polygons. This area was assigned a score of 0.3 given the endangered status of the species, but increasing population trend.
Loggerhead (Northwest Atlantic Ocean DPS) Sea Turtle High Use Area	-	x	x	x	0.4	This layer was used within the protected resources consideration combined species layer for AOA suitability model. NOAA NMFS Protected Resources identified critical residence data to assess HUAs for loggerhead sea turtles within the Gulf of Mexico AOI (Appendix B). To develop the HUAs, satellite telemetry data,[96, 97, 98, 99, 100] representing resident areas were converted to polygons by buffering the point data for presence by 18.98 km, ultimately defining the HUAs. The loggerhead HUA was assigned a score of 0.4 for conservation purposes based on the species' endangered status and unknown population trend.

91 Simpfendorfer and Wiley (2006)
92 International Sawfish Encounter Database, https://www.floridamuseum.ufl.edu/sawfish/ised/, updated through 2017
93 Graham et al. (2021)
94 Graham et al. In prep.
95 Carlson et al. (2014)
96 Conant et al. (2009)
97 Foley et al. (2013)
98 Foley et al. (2014)
99 Hardy et al. (2014)
100 Hart et al. (2014)

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Loggerhead Sea Turtle (Northwest Atlantic DPS) Migratory Corridor	-	-	-	x	0.4	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Loggerhead sea turtle migratory route data and migratory corridor were based on previous satellite telemetry studies.[101, 102, 103,104, 105] The loggerhead sea turtle migratory corridor area was assigned a score of 0.4 for conservation purposes based on the species' threatened status and unknown population trends (Appendix B).
Gulf of Mexico Giant Manta Ray Predicted Species Distribution Model Area Above Median Maximum Probability of Presence	x	x	x	x	0.4	This layer was used within the protected resources consideration combined species layer for AOA suitability model. NOAA NMFS Protected Resources generated a giant manta ray distribution model in the Gulf of Mexico, which was determined through a combined species distribution model (SDM) fitting survey data to monthly distillations of habitat parameters (e.g., water clarity, current speed, bathymetry) from January, 2003 to December, 2019 (Appendix B). The maximum predicted species presence across all months was retained in a final predictive grid (10 x 10 km). To provide meaningful contrast to inform the AOA site identification process, SERO-PRD evaluated several potential cutoffs based on quantiles for maximum probability of presence. Because predictions from the giant manta ray SDM are not normally distributed, the median was used, as it is a better measure of central tendency. The area was assigned a score of 0.4 to areas above the median maximum predicted value from the SDM to provide conservation measures for the species.
Gulf of Mexico Green (North Atlantic Ocean DPS) Sea Turtle High Use Area	x	x	x	x	0.5	This layer was used within the protected resources consideration combined species layer for AOA suitability model. NOAA NMFS Protected Resources identified critical residence data to assess HUAs for green sea turtles within the Gulf of Mexico AOA AOI. To develop the HUAs, satellite telemetry data[106, 107, 108] from resident areas were converted to polygons by buffering the point data by 18.98 km, ultimately defining the HUAs within the AOA AOI. Each green sea turtle HUA was assigned a score of 0.5 for conservation purposes based on the species' threatened status but increasing population trends (Appendix B).

101 Phillips et al. (2021)
102 Hart et al. (2021)
103 Foley et al. (2013)
104 Iverson et al. (2020)
105 Shaver et al. (2016)
106 Seminoff et al. (2015)
107 Hardy et al. (2014)
108 Hart et al. (2021)

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Green Sea Turtle (North Atlantic DPS) Migratory Corridor	-	-	-	x	0.5	This layer was used within the protected resources consideration combined species layer for AOA suitability model. Green sea turtle migratory route data and migratory corridor were based on previous satellite telemetry studies.[109,110,111,112,113] The green sea turtle migratory corridor was assigned a score of 0.5 for conservation purposes based on the species' threatened status and increasing population trends (Appendix B).
Archaeological Sensitive Areas (Florida)	-	-	x	-	0	These areas contain historic and culturally important items that have protections, particularly off the Gulf coast of Florida. These areas were assigned a score of 0 for complete avoidance.
Artificial Reefs with 500-ft setback	x	x	x	-	0	Artificial reefs (e.g., concrete pyramids, shipwrecks) are man-made structures that emulate some functions of natural reefs.[114] They generally fall in fish haven boundaries, but do exist outside of these areas in some cases. Artificial reefs are point data, so a 500-ft setback (i.e., the same setback distance applied to fish havens) was applied to the point data and both were assigned scores of 0 for complete avoidance.
Automated Wreck and Obstruction Information System (AWOIS) Wrecks Polluting, Remedial Underwater Legacy Environmental Threat (RULET) Wrecks, Electronic Navigational Chart Wrecks and Obstructions, Electronic Navigational Chart Danger Wrecks with 500-ft setback	x	x	x	x	0	All shipwrecks were considered incompatible with aquaculture infrastructure and often can be viewed as habitat-building. Shipwrecks are point data, so a 500-ft setback (i.e., same setback distance applied to artificial reefs) was applied to the point data for avoidance of the area, and both were assigned a score of 0.
BOEM No Activity Zones 1000-m setback	x	x	-	-	0	At East and West Flower Garden Banks, Sanctuary boundaries closely follow the original No Activity Zone designations set by Minerals Management Service to restrict oil and gas exploration around the reefs. These areas are incompatible with aquaculture development because of sensitive habitat, and were assigned a score of 0 for complete avoidance.

109 Phillips et al. (2021)
110 Hart et al. (2021)
111 Foley et al. (2013)
112 Iverson et al. (2020)
113 Shaver et al. (2016)
114 https://oceanservice.noaa.gov/facts/artificial-reef.html

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Coral 9 Habitat Area of Particular Concern (HAPC)[115]	x	x	-	-	0	Coral 9 areas are protected coral reef habitats; protection of corals is provided through designation of EFH HAPC, or designating deep-water coral areas via section 303(b)(2)(B). Due to the presence of coral habitat, areas were assigned a score of 0 for complete avoidance given the sensitivity of this habitat to bottom disturbance.
Coral 9 HAPC (Regulated Areas)[116]	x	x	-	x	0	An additional 13 regulated areas for protection of coral areas were established in 2020 as HAPC. Due to the presence of coral habitat, areas were assigned a score of 0 for complete avoidance given the sensitivity of this habitat to bottom disturbance.
Coral, Coral reefs, Live or Hardbottom EFH HAPC	-	-	-	x	0	Due to the presence of coral habitat, live bottom, or hardbottom HAPC (i.e. sensitive habitats), areas were assigned a score of 0 for complete avoidance.
Deep-sea Coral and Sponge Observations (1985 to present) with 1000-m setback	x	x	x	x	0	Deep-sea (i.e., > 40 m in depth) corals and sponges are considered important habitat for conservation purposes within the planning area depth range.[117] Observations are point data, so a 1000-m setback was applied to each point, and both were assigned a score of 0 for complete avoidance given the sensitivity of this habitat to bottom disturbance.
FMA Flower Garden Banks EFH HAPC	x	-	-	-	0	Flower Garden Banks contains coral habitat and protects many ecologically important species.[118] All anchoring is prohibited to protect coral structures; therefore, the data layer was assigned a score of 0 for complete avoidance.
Federally Managed Areas Madison-Swanson, The Edges, and Steamboat Lumps	-	-	x	-	0	These managed areas restrict some fishing and protect coral reef habitat.[119] These FMAs were assigned a score of 0 for complete avoidance.
Federally Managed Area Pulley Ridge EFH HAPC	-	-	x	x	0	Pulley Ridge contains important coral habitat and habitat-forming corals. All anchoring is prohibited to protect coral structures.[120, 121] This area was assigned a score of 0 for complete avoidance.

115 https://gulfcouncil.org/wp-content/uploads/Final-Coral-9-DEIS-20181005_508C.pdf

116 https://portal.gulfcouncil.org/coralhapc.html

117 https://deepseacoraldata.noaa.gov/

118 https://www.ncei.noaa.gov/maps/fgb/mapsFGB.htm

119 https://www.fisheries.noaa.gov/southeast/west-florida-marine-protected-areas

120 https://www.fisheries.noaa.gov/resource/map/pulley-ridge-essential-fish-habitat-efh-habitat-area-particular-concern-hapc-map-gis

121 https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174

Natural and Cultural Resources Datasets	W	C	E	SE	Score	Rationale for Score
Federally Managed Area Tortugas Marine Reserve EFH HAPC	-	-	-	x	0	The Tortugas Marine Reserve contains important coral habitat and habitat-forming corals.[122] All anchoring is prohibited to protect coral structures; therefore, the data layer was assigned a score of 0 for complete avoidance.
Low Relief Structures with 1000-m setback	x	x	-	-	0	Low relief structures represent potentially important habitat that needs to be protected for conservation. A 1000-m setback was applied to each polygon, and both were assigned a score of 0 for complete avoidance.
Natural Reefs (i.e., hardbottom, pinnacles, escarpments, ledges) (NMFS) with 1000-m setback	x	x	x	x	0	Hardbottom areas include a range of biota including a thin veneer of live corals, often covering a rock outcrop or a relic reef, and associated benthos (e.g., sponges, tunicates, holothurians) in an assemblage with low relief. Hardbottom is also called live bottom, hardgrounds, or pinnacles (when found in a non-bank setting). A 1000-m setback was applied to each polygon, and both were assigned a score of 0 for complete avoidance, as recommended by EPA.[123]
NOAA Fish Havens with 500-ft setback	x	x	x	-	0	Fish havens are artificial reefs deliberately constructed or placed on the seabed to emulate some functions of a natural reef.[124] A 500-ft setback was applied to each polygon, and both were assigned a score of 0 for complete avoidance.
Potentially Sensitive Biological Features, Flower Garden Banks National Marine Sanctuary	x	x	-	-	0	The features represent important conservation areas with live bottom habitat. A 1000-m setback was applied to each polygon, and both were assigned a score of 0 for complete avoidance.

[122] https://www.ecfr.gov/cgi-bin/text-idx?SID=f3e475e206bdbddfb545dd420753cf9e&mc=true&node=pt50.12.622&rgn=div5#se50.12.622_174
[123] https://safmc.net/habitat-and-ecosystems/coral-livehard-bottom-habitat/
[124] https://nauticalcharts.noaa.gov/publications/docs/us-chart-1/UnderstandingFishHavens-2016Feb.pdf

Table C-3. Industry, navigation, and transportation submodel datasets used in suitability modeling. Data were collected from multiple sources, including National Oceanic and Atmospheric Administration (NOAA), U.S. Coast Guard (USCG), U.S. Army Corps of Engineers (USACE), Environmental Protection Agency (EPA), Bureau of Ocean Energy Management (BOEM), Bureau of Safety and Environmental Enforcement (BSEE), and other state agencies. “Cont.” denotes continuous data (0 – 1).

Industry, Navigation, and Transportation Datasets	W	C	E	SE	Score	Rationale for Score
Federal Lightering Rendezvous Areas	x	x	-	-	0.5	Federal lightering rendezvous areas in the Gulf of Mexico involve oil and hazardous material transfer operations.[125] Rendezvous areas are where lightering can begin and can continue for a given time and speed of craft. Due to this activity, these areas were assigned a score of 0.5.
AIS Vessel Traffic 2019 – Cargo	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Fishing	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Military	-	x	x	-	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Other	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Passenger	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Pleasure and Sailing	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Tanker	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
AIS Vessel Traffic 2019 – Tug and Tow	x	x	x	x	Cont.	As vessel transits increase, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.

[125] https://www.fisheries.noaa.gov/inport/item/54387

Industry, Navigation, and Transportation Datasets	W	C	E	SE	Score	Rationale for Score
Aids to Navigation (beacons and buoys) with 500-m setback	x	x	x	-	0	Aids to navigation provide a vessel with information in determining location, transiting from one place to another, or avoiding dangerous areas.[126] Aids range from lighthouses to minor lights, day beacons, range lights and sound signals, and lighted or unlighted buoys.[127] Due to the importance of these structures for navigation, a 500-m setback was applied to each structure, and both were assigned as score of 0 for complete avoidance.
Anchorage Areas (Used/Disused)	-	x	-	-	0	An anchorage area is a place where boats and ships can safely drop anchor. A variety of designations refer to types of anchorage areas or restrictions, or even to alerts of potential dangers within an anchorage area.[128] Due to the nature of activities, and the possibility of change in use, these areas were assigned a score of 0 for complete avoidance.
Environmental Sensors and Buoys with 500-m setback	x	x	x	x	0	Marine observation and monitoring infrastructure (i.e., sensors and buoys) provide important information on changing oceanographic and/or meteorological conditions at sea.[129] These buoys and environmental sensors, along with a 500-m setback, and were both assigned a score of 0 for complete avoidance.
Lease Blocks with Significant Sediment Resources	-	x	-	-	0	This BOEM data layer is used to assist in the management of Outer Continental Shelf (OCS) sediment resources, reduce multiple use conflicts, minimize interference with existing oil and gas leases and rights-of-way, and help avoid sensitive areas (e.g., archaeological sites, protected habitat). These OCS blocks represent areas within the OCS protraction grid where sand resources have been identified through reconnaissance and/or design-level OCS studies.[130] These areas were assigned a score of 0 for complete avoidance.
Ocean Disposal Sites	-	x	-	-	0	EPA ocean disposal sites delineate both active areas used for dredged material and discontinued areas where materials are disposed of (e.g., first generation pesticides, contaminated sediment), and are generally described as having an internal setback from those disposed products.[131] These areas were assigned a score of 0 for complete avoidance.

126 https://www.navcen.uscg.gov/pdf/navRules/US_ATON_Guide.pdf

127 https://www.pacificarea.uscg.mil/Portals/8/District_13/dpw/docs/usaidstonavigationbooklet.pdf?ver=2018-10-15-154501-363#:~:text=Aids%20to%20Navigation%20can%20provide,to%20lighted%20or%20unlighted%20buoys

128 https://marinecadastre.gov/news/load.php?url=posts/anchorage-areas.html

129 https://www.ndbc.noaa.gov/

130 https://www.boem.gov/marine-minerals/marine-minerals-mapping-and-data

131 https://www.epa.gov/ocean-dumping/ocean-disposal-sites

Industry, Navigation, and Transportation Datasets	W	C	E	SE	Score	Rationale for Score
Oil and Gas Active Leases	x	x	x	-	0	Active leases are those BOEM OCS lease blocks which are currently leased out to private entities for oil and/or gas mining rights.[132] Active leases include those that are exploratory, non-producing (e.g., suspended), and producing. Due to the nature of activities, as well as oil and gas infrastructure within each active lease block, these areas were assigned a score of 0 for complete avoidance.
Oil and Gas Boreholes, Test Wells, and Wells with 500-m setback	x	x	x	-	0	Surface boreholes are drilled into the ocean floor for purposes of mineral exploration and mining. Some boreholes are angled and all wells (active or inactive) are being considered as oil and gas infrastructure already in place. The point data along with a 500-m setback were both assigned a score of 0 for complete avoidance.
Oil and Gas Drilling Platforms with 500-m setback	x	x	-	-	0	Drilling platforms are structures used to drill into the seabed for mineral exploration or to bring resources to the surface, particularly oil and gas.[133] Due to the nature of this ocean activity, and that drilling platforms are continuously added and modified, these structures and a 500-m setback from the structure were both assigned a score of 0 for complete avoidance.
Oil and Gas Pipelines with 500-m setback	x	x	x	-	0	Submerged structures transporting oil and gas from offshore platforms or terminals to inshore facilities.[134] These structures vary in size and carry hazardous materials. Pipeline areas, along with a 500-m setback, were both assigned a score of 0 for complete avoidance.
Shipping Fairways with a 500-m setback	x	x	x	-	0	These areas delineate activities and regulations for marine vessel traffic. Traffic lanes define specific traffic flow, and separation zones assist opposing streams of traffic. Recommended routes are predetermined routes for shipping adopted for reasons of safety. Due to regulations, high and variable use, and needed avoidance, a 500-m setback was applied to all fairways. Both were assigned a score of 0 for complete avoidance.
Submarine Cables with 500-m setback	x	x	-	-	0	Comprehensive submarine cable data were obtained from the U.S. Naval Seafloor Cable Protection Office. Submarine cables are responsible for many international and national communications as they are quicker than satellites. Many cables are also high voltage. These cable areas, along with a 500-m setback, were both assigned a score of 0 for complete avoidance.

[132] https://metadata.boem.gov/geospatial/GOM_Active_OG_Leases.xml
[133] https://metadata.boem.gov/geospatial/OCSplatforms-GOMR-NAD27.xml
[134] https://metadata.boem.gov/geospatial/OCSpipelines-GOMR-NAD27.xml

Table C-4. Fuzzy logic Z-shaped membership function rescaling for Automatic Identification System (AIS) data. Rescaling of AIS data was conducted using the fuzzy logic Z-shaped membership function from 0 – 1, with the original range of values shown for each dataset, and the ceiling and the foot for each. The Z-shaped membership function (a polynomial equation) allows for rescaling of the data to a normalized scale from 0 – 1. AIS vessel transit data were rescaled for each planning area.

Study Area	Data Set	Range	Ceiling	Foot
West	Cargo	0 - 171.8	0	172.8
West	Fishing	0 - 34.7	0	35.7
West	Other	0 - 161.8	0	162.8
West	Passenger	0 - 103.3	0	104.3
West	Pleasure and Sailing	0 - 15.5	0	16.5
West	Tanker	0 - 299.3	0	300.3
West	Tug and Tow	0 - 41.5	0	42.5
Central	Cargo	0 - 392.6	0	393.6
Central	Fishing	0 - 130.8	0	131.8
Central	Military	0 - 1.5	0	2.5
Central	Other	0 - 5779.3	0	5780.3
Central	Passenger	0 - 3239.3	0	3240.3
Central	Pleasure and Sailing	0 - 88.5	0	89.5
Central	Tanker	0 - 255.6	0	256.6
Central	Tug and Tow	0 - 91.8	0	92.8
East	Cargo	0 - 16.8	0	17.8
East	Fishing	0 - 10.0	0	11.0
East	Military	0 - 2.0	0	3.0
East	Other	0 - 51.5	0	52.5
East	Passenger	0 - 63.3	0	64.3
East	Pleasure and Sailing	0 - 24.8	0	25.8
East	Tanker	0 - 30.8	0	31.8
East	Tug and Tow	0 - 24.5	0	25.5
Southeast	Cargo	0 - 26.0	0	27.0
Southeast	Fishing	0 - 6.8	0	7.8
Southeast	Other	0 - 23.0	0	24.0
Southeast	Passenger	0 - 128.5	0	129.5
Southeast	Pleasure and Sailing	0 - 62.7	0	63.7
Southeast	Tanker	0 - 6.7	0	7.7
Southeast	Tug and Tow	0 - 12.5	0	13.5

Table C-5. Fishing and aquaculture submodel datasets used in suitability modeling. Data were collected from multiple sources across the National Oceanic and Atmospheric Administration, National Marine Fisheries Service. "Cont." denotes continuous data (0 – 1).

Fishing and Aquaculture Datasets	W	C	E	SE	Score	Rationale for Score
Commercial Shrimp Electronic Logbook Data (2004 - 2019)	x	x	x	x	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Highly Migratory Species Pelagic Longline Gear Observer Data (1993 - 2019)	x	x	-	x	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Menhaden Fishery Data (2000 - 2016)	-	x	-	-	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Reef Fish Bandit Gear Fishing Data (2007 - 2019)	x	x	x	x	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Reef Fish Longline Gear Fishing Data (2007 - 2019)	x	x	x	x	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Southeast Region Headboat Survey Data (2014 - 2020)	x	x	x	x	Cont.	As fishing activity increases, compatibility with aquaculture decreases. Rescaling was conducted using the fuzzy logic Z-shaped membership function from 0-1.
Live Rock Aquaculture with 500-m setback	-	-	x	-	0	Live rock aquaculture is already permitted off Florida's Gulf coast. Each live rock site (point data) was used, with a 500-m setback applied, and scored as 0 for avoidance.

Table C-6. Fuzzy logic Z-shaped membership function rescaling for fishing data. Rescaling of fishing data was conducted using the fuzzy logic Z-shaped membership function from 0-1, with the original range of values shown for each dataset, as well as the ceiling and the foot for each. The Z-shaped membership function (a polynomial equation, see methods) allows for rescaling of continuous data to a normalized scale from 0 – 1, and accounts for some uncertainty in the data. Fishing data were rescaled for each planning area for the suitability model.

Study Area	Data Set	Range	Ceiling	Foot
West	Commercial Shrimp Electronic Logbook Data (2004 - 2019)	0 - 303	0	304
West	Highly Migratory Species Pelagic Longline Gear Observer Data (1993 - 2019)	0 - 1	0	2
West	Reef Fish Bandit Gear Fishing Data (2007 - 2019)	0 - 286	0	287
West	Reef Fish Longline Gear Fishing Data (2007 - 2019)	0 - 53	0	54
West	Southeast Region Headboat Survey Data (2014 - 2020)	0 - 230	0	231
Central	Commercial Shrimp Electronic Logbook Data (2004 - 2019)	0 - 480	0	481
Central	Highly Migratory Species Pelagic Longline Gear Observer Data (1993 – 2019)	0 - 2	0	3
Central	Menhaden Fishery Data (2000 – 2016)	0 - 3012	0	3013
Central	Reef Fish Bandit Gear Fishing Data (2007 - 2019)	0 - 1013	0	1014
Central	Reef Fish Longline Gear Fishing Data (2007 - 2019)	0 - 44	0	45
Central	Southeast Region Headboat Survey Data (2014 - 2020)	0 - 43	0	44
East	Commercial Shrimp Electronic Logbook Data (2004 - 2019)	0 - 33	0	34
East	Reef Fish Bandit Gear Fishing Data (2007 - 2019)	0 - 1048	0	1049
East	Reef Fish Longline Gear Fishing Data (2007 - 2019)	0 - 182	0	183
East	Southeast Region Headboat Survey Data (2014 - 2020)	0 - 227	0	228
Southeast	Commercial Shrimp Electronic Logbook Data (2004 - 2019)	0 - 44	0	45
Southeast	Highly Migratory Species Pelagic Longline Gear Observer Data (1993 – 2019)	0 - 1	0	2
Southeast	Reef Fish Bandit Gear Fishing Data (2007 - 2019)	0 - 188	0	189
Southeast	Reef Fish Longline Gear Fishing Data (2007 - 2019)	0 - 89	0	90
Southeast	Southeast Region Headboat Survey Data (2014 - 2020)	0 - 2	0	3

Appendix D

Appendix D: Memoranda from the Department of Defense providing review of Aquaculture Opportunity Area options.

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

September 29, 2020

James Morris, Jr.
Marine Ecologist
National Centers for Coastal Ocean Science
101 Pivers Island Rd.
Beaufort, NC 28516

Dear Dr. Morris,

As requested, the Military Aviation and Installation Assurance Siting Clearinghouse coordinated within the Department of Defense (DoD) an informal review of the NOAA Aquaculture Opportunity Areas in the Gulf of Mexico. The following is a list of points of contact that were identified through this process that request participation in future working groups:

- Andrea Carpenter | andrea.l.carpenter@navy.mil
- Erica Felins | erica.felins@navy.mil
- Maj. Charles Smith | charles.smith.7@us.af.mil
- James Roncaglione | james.roncaglione@us.af.mil
- Lt. Col. Doug Harwell | william.harwell@us.af.mil
- SMSgt. Dodie S. Currera | dodie.currera.1@us.af.mil
- SSgt. Jenny Buendia | jenny.buendia@us.af.mil

Additionally, while the North American Aerospace Defense Command (NORAD) did not identify any impacts to homeland defense radar operations, they do request consultation if large, permanent standing or floating structures are to be constructed. Please contact Mr. Frederick Shepherd of NORAD at frederick.l.shepherd.civ@mail.mil for further discussions.

Thank you for working with us to preserve our military's operational, training, and testing capabilities. We have assigned the tracking code 2020-08-AC-NOA-09 to this project for future discussions. If you have any questions, please contact me at steven.j.sample4.civ@mail.mil or at 703-571-0076.

Sincerely,

Steven J. Sample
Deputy Director
Military Aviation and Installation
Assurance Siting Clearinghouse

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

September 20, 2021

Ken Riley
Marineecologist
National Oceanic and Atmospheric Administration
101 Pivers Island Rd.
Beaufort, NC 28516

Dear Dr. Riley,

As requested, the Military Aviation and Installation Assurance Siting Clearinghouse coordinated within the Department of Defense (DoD) a review of the NOAA Gulf Aquaculture Opportunity Areas Project located off the coast of Gulf of Mexico.

The proposed Aquaculture Opportunity Areas (AOAs) W-1, W-4, W-8, C-3, C-11 and C-13 were reviewed by DoD, and no military concerns were identified.

Our review found that aquaculture development in AOAs E-1, E-3 and E-4 may impact military flight testing and training conducted by the 96th Test Wing at Eglin Air Force Base. This essential mission activity occurs in the military controlled airspace (EWTA-5 and W-174) surrounding these proposed project areas. Due to the hazardous nature of this activity, there are safety concerns regarding the clearing of surface vessels (commercial and private) within the areas. We request that any permit for aquaculture in these areas include stipulations such as a hold-harmless agreement and evacuation procedures. Please contact Ms. Sally Curran (sally.curran@us.af.mil), Chief, Range and Airspace Sustainment, to discuss further.

We encourage you to continue coordinating with the Department of the Air Force and this office as the project proceeds.We have assigned the tracking code 2021-08-AC-NOA-26 to this project for reference in future communications. If you have any questions, please contact me at scott.e.kiernan.civ@mail.mil or at 571-255-9507.

Sincerely,

Scott E. Kiernan
Deputy Director
Military Aviation and Installation
Assurance Siting Clearinghouse

Appendix E

Appendix E. OceanReports analyses supporting characterization of Aquaculture Opportunity Area options.

OceanReports is the most comprehensive web-based spatial assessment tool for the U.S. oceans, designed to improve decision-making and increase transparency for ocean and coastal users and resource managers. The tool contains approximately 100 distinct data layers capable of analyzing energy and minerals, natural resources (including species and habitat), transportation and infrastructure, oceanographic and biophysical conditions, and the local ocean economy for any area of the U.S. Exclusive Economic Zone. OceanReports was developed through a partnership between the Bureau of Ocean Energy Management, the National Oceanic and Atmospheric Administration, and the Department of Energy, and utilizes new and authoritative data from MarineCadastre.gov and other trusted sources.

OceanReports enables informed decisions for ocean industries such as such as energy, shipping and transportation, aquaculture, fisheries, and seabed mining to navigate conflicting uses, analyze environmental considerations, and assess economic opportunity. Herein, we provide OceanReports for Aquaculture Opportunity Area options in the Gulf of Mexico. Readers can navigate and further explore each AOA option using the links provided.

Table E-1. Study area, Aquaculture Opportunity Area final options, coordinates, and some features of the Aquaculture Opportunity Area option including links for a customized OceanReports analysis for each Aquaculture Opportunity Area option. The table presents options listed by geographical distribution rather than any ranked order.

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-1	-96.6387	26.7004	2,000	91	https://bit.ly/3jSXPPB
		-96.6405	26.726			
		-96.612	26.7276			
		-96.6101	26.702			
West	W-4	-96.12292	27.71421	2,000	84	https://bit.ly/3dGlZc2
		-96.12469	27.73983			
		-96.09588	27.74139			
		-96.09412	27.71577			
West	W-8	-94.940947	27.997986	500	81	https://bit.ly/2ToyiCZ
		-94.9417	28.010805			
		-94.927257	28.011473			
		94.926506	27.998654			
Central	C-3	-92.1548	28.31758	2,000	61	https://bit.ly/3jDId1Y
		-92.1557	28.34325			
		-92.12671	28.34405			
		-92.12581	28.31838			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
Central	C-11	-90.08456	28.375922	2,000	76	https://bit.ly/3heWYqp
		-90.08501	28.401598			
		-90.05599	28.401997			
		-90.05555	28.376321			
Central	C-13	-89.18816	28.90386	500	62	https://bit.ly/3jFT6Ao
		-89.18829	28.91671			
		-89.17371	28.91682			
		-89.17358	28.90398			
East	E-4	-83.93697	27.7661	2,000	51	https://bit.ly/3hcoAN2
		-83.9361	27.79175			
		-83.90723	27.79097			
		-83.90813	27.76531			
East	E-3	-83.62981	27.24644	2,000	51	https://bit.ly/3dFMZlw
		-83.62886	27.27209			
		-83.60013	27.27124			
		-83.60108	27.2456			
East	E-1	-83.153637	26.141176	500	51	https://bit.ly/3hyA0JL
		-83.153119	26.153996			
		-83.138889	26.153528			
		-83.139408	26.140709			

Appendix F

Appendix F. Highest scoring AOA option from each of the high-high clusters within each study area.

Table F-1. Highest scoring AOA option from each of the high-high clusters distributed across the Gulf of Mexico. For more information on the precision siting model workflow steps, please refer to the methods section within the Atlas publication and specifically Figure 2.20. Website links are provided for a customized OceanReports analysis for each Aquaculture Opportunity Area option. The table presents options listed by geographical distribution rather than any ranked order.

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-1	-96.6387024	26.70039940	2000	91	https://bit.ly/2YTFp8B
		-96.6405029	26.72599983			
		-96.6119995	26.72760010			
		-96.6100998	26.70199966			
West	W-2	-96.6095963	27.04210091	500	98	https://bit.ly/2YODUIP
		-96.6104965	27.05489922			
		-96.5961990	27.05579948			
		-96.5952988	27.04299927			
West	W-3	-96.2298965	27.70389938	500	79	https://bit.ly/3nxfv53
		-96.2307968	27.71669960			
		-96.2164001	27.71750069			
		-96.2154999	27.70470047			
West	W-4	-96.1229019	27.71419907	2000	84	https://bit.ly/3ny4Pmv
		-96.1247025	27.73979950			
		-96.0959015	27.74139977			
		-96.0941010	27.71579933			
West	W-5	-95.8051987	27.76199913	2000	69	https://bit.ly/3CgBsJy
		-95.8069000	27.78759956			
		-95.7780991	27.78910065			
		-95.7763977	27.76350021			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-6	-95.6307983	27.79150009	2000	74	https://bit.ly/3nC5Mui
		-95.6324005	27.81719971			
		-95.6035995	27.81859970			
		-95.6018982	27.79299927			
West	W-7	-94.9667969	27.95759964	2000	88	https://bit.ly/3kcaoVK
		-94.9682999	27.98320007			
		-94.9393997	27.98460007			
		-94.9378967	27.95890045			
West	W-8	-94.9409027	27.99799919	500	81	https://bit.ly/3964iQu
		-94.9417038	28.01079941			
		-94.9272995	28.01149940			
		-94.9264984	27.99869919			
West	W-9	-94.7032013	27.94199944	500	94	https://bit.ly/3nzJMjz
		-94.7039032	27.95479965			
		-94.6894989	27.95540047			
		-94.6887970	27.94260025			
West	W-10	-94.3515015	27.96290016	1000	90	https://bit.ly/3EmVbt9
		-94.3525009	27.98100090			
		-94.3320999	27.98189926			
		-94.3311005	27.96369934			
West	W-11	-94.3317032	28.03140068	500	73	https://bit.ly/3AlfHrK
		-94.3323975	28.04420090			
		-94.3179016	28.04479980			
		-94.3172989	28.03199959			
West	W-12	-94.3272018	28.08300018	500	60	https://bit.ly/3nBozGa
		-94.3279037	28.09580040			
		-94.3134995	28.09639931			
		-94.3127975	28.08359909			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-13	-94.2832031	28.07200050	500	61	https://bit.ly/3EoyDZ4
		-94.2838974	28.08480072			
		-94.2694016	28.08539963			
		-94.2832031	28.07200050			
West	W-14	-94.2115021	27.92070007	500	95	https://bit.ly/3tGRiu9
		-94.2121964	27.93359947			
		-94.1977005	27.93420029			
		-94.1970978	27.92130089			
West	W-15	-94.1179962	27.95929909	500	84	https://bit.ly/3AeUakl
		-94.1186981	27.97209930			
		-94.1042023	27.97270012			
		-94.1035995	27.95989990			
West	W-16	-94.1042023	28.02799988	500	73	https://bit.ly/39oN2Gp
		-94.1047974	28.04080009			
		-94.0904007	28.04140091			
		-94.0896988	28.02849960			
West	W-17	-93.9353027	27.94720078	1000	91	https://bit.ly/3A9JyTL
		-93.9362030	27.96540070			
		-93.9157028	27.96619987			
		-93.9148026	27.94799995			
West	W-18	-93.8217010	28.03980064	2000	76	https://bit.ly/3tGIKDw
		-93.8229980	28.06550026			
		-93.7939987	28.06660080			
		-93.7928009	28.04089928			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-19	-93.8515015	28.21789932	500	66	https://bit.ly/3Ae9Fc1
		-93.8520966	28.23069954			
		-93.8376999	28.23130035			
		-93.8369980	28.21850014			
West	W-20	-93.7937012	28.25230026	500	63	https://bit.ly/3AgCS6b
		-93.7944031	28.26510048			
		-93.7798996	28.26569939			
		-93.7792969	28.25279999			
West	W-21	-93.7023010	28.16200066	500	67	https://bit.ly/396zglh
		-93.7029037	28.17480087			
		-93.6884995	28.17530060			
		-93.6878967	28.16250038			
West	W-22	-93.7245026	28.05190086	1500	75	https://bit.ly/3tJ8X46
		-93.7256012	28.07410049			
		-93.7005005	28.07500076			
		-93.6995010	28.05279922			
West	W-23	-93.6280975	28.15710068	1000	65	https://bit.ly/3kdtWZL
		-93.6289978	28.17519951			
		-93.6084976	28.17600060			
		-93.6075974	28.15789986			
West	W-24	-93.6496964	28.25970078	2000	61	https://bit.ly/396A001
		-93.6510010	28.28529930			
		-93.6220016	28.28639984			
		-93.6207962	28.26079941			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-25	-93.5026016	28.20030022	500	61	https://bit.ly/3k8ONgR
		-93.5031967	28.21310043			
		-93.4888000	28.21360016			
		-93.4881973	28.20079994			
West	W-26	-93.4524002	28.18020058	500	62	https://bit.ly/3kduLlj
		-93.4530029	28.19309998			
		-93.4384995	28.19359970			
		-93.4380035	28.18079948			
West	W-27	-93.3629990	28.09779930	1000	80	https://bit.ly/39beXte
		-93.3638992	28.11590004			
		-93.3433990	28.11660004			
		-93.3425980	28.09849930			
West	W-28	-93.4033966	28.01180077	2000	96	https://bit.ly/39gmHtH
		-93.4046021	28.03739929			
		-93.3757019	28.03849983			
		-93.3744965	28.01280022			
West	W-29	-93.2800980	28.02989960	1000	97	https://bit.ly/3tGXmTn
		-93.2808990	28.04800034			
		-93.2604980	28.04870033			
		-93.2596970	28.03059959			
West	W-30	-93.3121033	28.12229919	500	77	https://bit.ly/3zdAHPE
		-93.3126984	28.13509941			
		-93.2982025	28.13570023			
		-93.2975998	28.12280083			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-31	-93.2294998	28.05579948	500	94	https://bit.ly/3AdSZ4w
		-93.2300034	28.06870079			
		-93.2155991	28.06920052			
		-93.2149963	28.05640030			
West	W-32	-93.2626038	28.11639977	500	79	https://bit.ly/2VHmDjA
		-93.2631989	28.12919998			
		-93.2487030	28.12969971			
		-93.2481003	28.11689949			
West	W-33	-93.2621002	28.21980095	2000	61	https://bit.ly/3EnpSOT
		-93.2632980	28.24539948			
		-93.2342987	28.24650002			
		-93.2332001	28.22080040			
West	W-34	-93.0837021	28.18479919	2000	70	https://bit.ly/3hD0Npf
		-93.0848007	28.21050072			
		-93.0559006	28.21150017			
		-93.0548019	28.18580055			
West	W-35	-93.1026993	28.07049942	500	91	https://bit.ly/3tGPX6q
		-93.1032028	28.08329964			
		-93.0887985	28.08379936			
		-93.0882034	28.07099915			
West	W-36	-93.0205994	28.06360054	2000	91	https://bit.ly/2VMJ0Ek
		-93.0216980	28.08930016			
		-92.9927979	28.09020042			
		-92.9916992	28.06459999			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-37	-92.9076996	28.08250046	1000	86	https://bit.ly/3AjQ4Yj
		-92.9084015	28.10059929			
		-92.8880005	28.10129929			
		-92.8871994	28.08309937			
West	W-38	-92.9117966	28.14620018	500	77	https://bit.ly/2XoHDML
		-92.9123001	28.15909958			
		-92.8979034	28.15950012			
		-92.8973007	28.14669991			
West	W-39	-92.7483978	28.13669968	2000	78	https://bit.ly/39dBFRl
		-92.7494965	28.16239929			
		-92.7204971	28.16329956			
		-92.7194977	28.13759995			
West	W-40	-92.5709991	28.13899994	500	78	https://bit.ly/3kiwuGf
		-92.5715027	28.15180016			
		-92.5570984	28.15229988			
		-92.5566025	28.13940048			
West	W-41	-92.4070969	28.11249924	1000	84	https://bit.ly/39d49e7
		-92.4076996	28.13069916			
		-92.3872986	28.13129997			
		-92.3865967	28.11310005			
West	W-42	-92.3085022	28.16990089	500	73	https://bit.ly/3AqEPgM
		-92.3089981	28.18269920			
		-92.2945023	28.18309975			
		-92.2939987	28.17029953			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
West	W-43	-92.1815033	28.04630089	1000	96	https://bit.ly/2VPD91d
		-92.1820984	28.06450081			
		-92.1616974	28.06500053			
		-92.1610031	28.04689980			
Central	C-1	-92.1918030	28.21640015	2000	68	https://bit.ly/3nJ3zgG
		-92.1927032	28.24200058			
		-92.1638031	28.24279976			
		-92.1629028	28.21719933			
Central	C-2	-92.1615982	28.26339912	2000	64	https://bit.ly/3hHlCQe
		-92.1624985	28.28910065			
		-92.1334991	28.28989983			
		-92.1325989	28.26420021			
Central	C-3	-92.1548004	28.31760025	2000	61	https://bit.ly/3nLClAq
		-92.1557007	28.34329987			
		-92.1267014	28.34399986			
		-92.1258011	28.31839943			
Central	C-4	-92.0727005	28.20940018	2000	68	https://bit.ly/3hJUBvA
		-92.0736008	28.23500061			
		-92.0446014	28.23579979			
		-92.0438004	28.21019936			
Central	C-5	-91.9881973	28.26110077	500	67	https://bit.ly/3CpjS66
		-91.9887009	28.27389908			
		-91.9741974	28.27429962			
		-91.9737015	28.26149940			

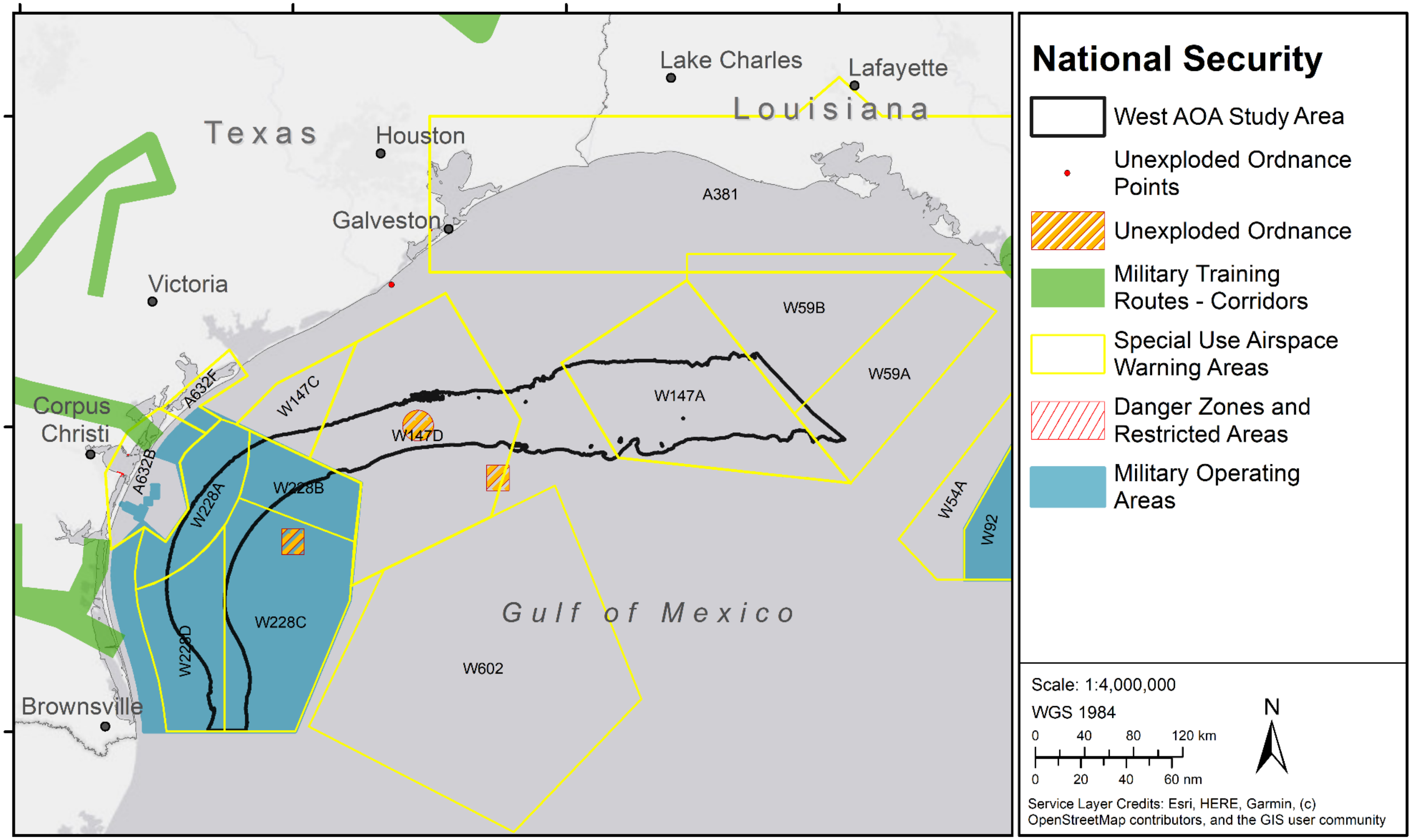
Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
Central	C-6	-91.9475021	28.29940033	500	63	https://bit.ly/3hFc600
		-91.9478989	28.31220055			
		-91.9334030	28.31259918			
		-91.9329987	28.29980087			
Central	C-7	-91.8981018	28.18829918	2000	73	https://bit.ly/3lBJupB
		-91.8989029	28.21400070			
		-91.8700027	28.21470070			
		-91.8691025	28.18910027			
Central	C-8	-91.8933029	28.05179977	1000	86	https://bit.ly/3lC1wrS
		-91.8938980	28.06999969			
		-91.8733978	28.07049942			
		-91.8728027	28.05229950			
Central	C-9	-91.7714996	28.10230064	500	90	https://bit.ly/3nF8fE3
		-91.7718964	28.11510086			
		-91.7574005	28.11549950			
		-91.7570038	28.10269928			
Central	C-10	-90.1146011	28.31320000	500	90	https://bit.ly/3CkjIgv
		-90.1148987	28.32609940			
		-90.1004028	28.32629967			
		-90.1000977	28.31340027			
Central	C-11	-90.0846024	28.37590027	2000	76	https://bit.ly/2XyAn16
		-90.0849991	28.40159988			
		-90.0559998	28.40200043			
		-90.0554962	28.37630081			

Study Area	Option	Latitude	Longitude	Size (acres)	Depth Average (m)	OceanReports
Central	C-12	-90.02120210	28.44930077	500	88	https://bit.ly/3lrWCxu
		-90.02149960	28.46220016			
		-90.00700380	28.46240044			
		-90.00669860	28.44949913			
Central	C-13	-89.18820190	28.90390015	500	62	https://bit.ly/3jFT6Ao
		-89.18830110	28.91670036			
		-89.17369840	28.91679955			
		-89.17359920	28.90399933			
East	E-1	-83.15360260	26.14119911	500	51	https://bit.ly/3tNSNGQ
		-83.15309906	26.15399933			
		-83.13890076	26.15349960			
		-83.13939667	26.14069939			
East	E-2	-83.31960297	26.14080048	2000	57	https://bit.ly/3tWu43i
		-83.31860352	26.16640091			
		-83.29019928	26.16550064			
		-83.29119873	26.13979912			
East	E-3	-83.62979889	27.24640083	2000	51	https://bit.ly/3AnEXgI
		-83.62889862	27.27210045			
		-83.60009766	27.27120018			
		-83.60109711	27.24559975			
East	E-4	-83.93699646	27.76609993	2000	51	https://bit.ly/3AnFnUk
		-83.93609619	27.79179955			
		-83.90720367	27.79100037			
		-83.90809631	27.76530075			

Appendix G

Appendix G: Large format maps to aid in viewing and interpretation.

National Security



Unexploded Ordnance Polygons and Points: NOAA OCM & BOEM (2018)
Military Training Routes - Corridors: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Special Use Airspace Warning Areas: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Danger Zones and Restricted Areas: NOAA OCM & BOEM (2018)
Military Operating Areas: NOAA OCM & BOEM (2018)

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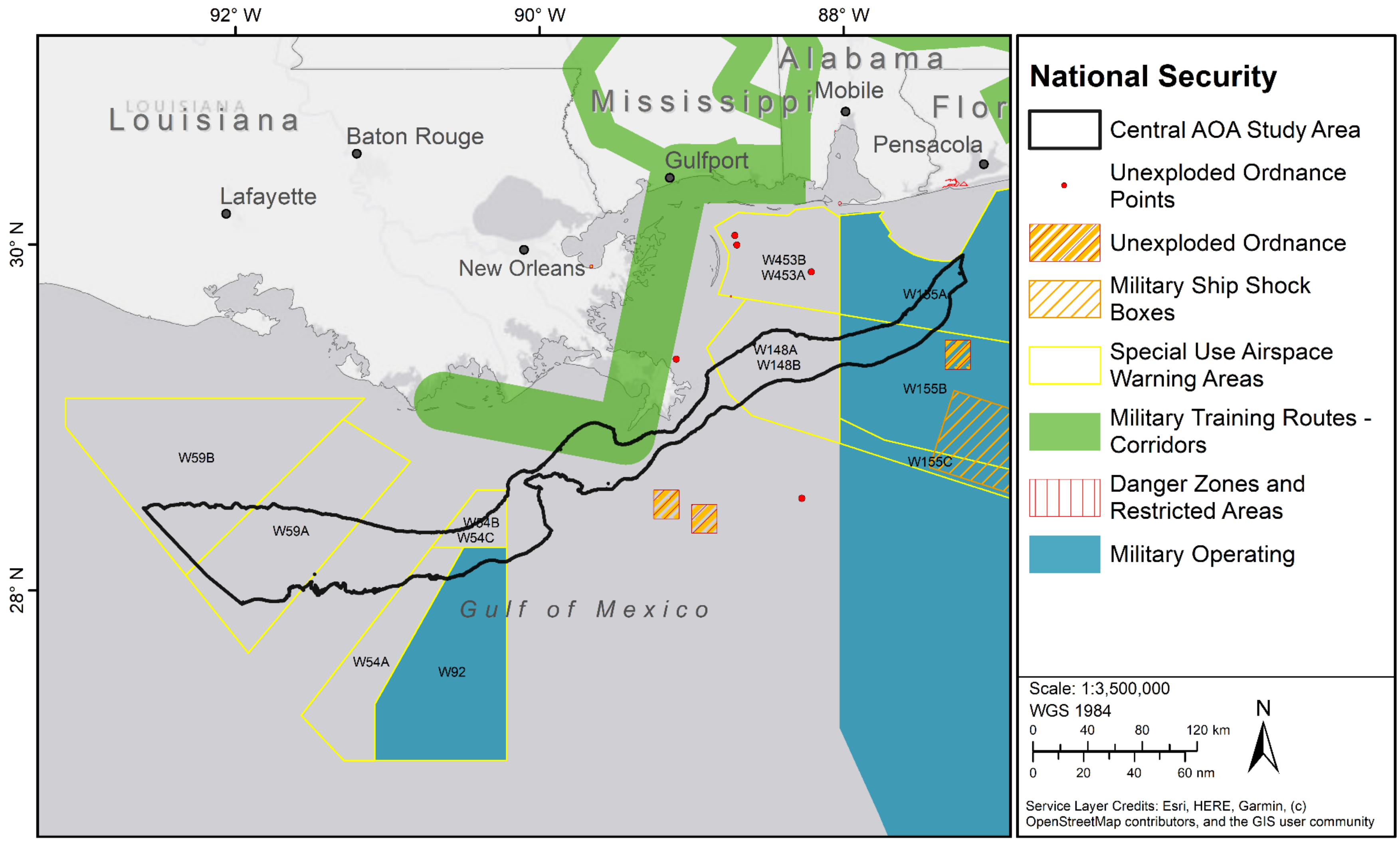

Unexploded Ordnance (UXO) polygons, Unexploded Ordnance points: NOAA OCM & BOEM (2018)
Ship Shock Boxes: NOAA OCM & BOEM (2018)
Special use Airspace Warning Areas: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Military Training Routes: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Danger Zones and Restricted Areas: NOAA OCM & BOEM (2018)
Military Operating Areas: NOAA OCM & BOEM (2019)

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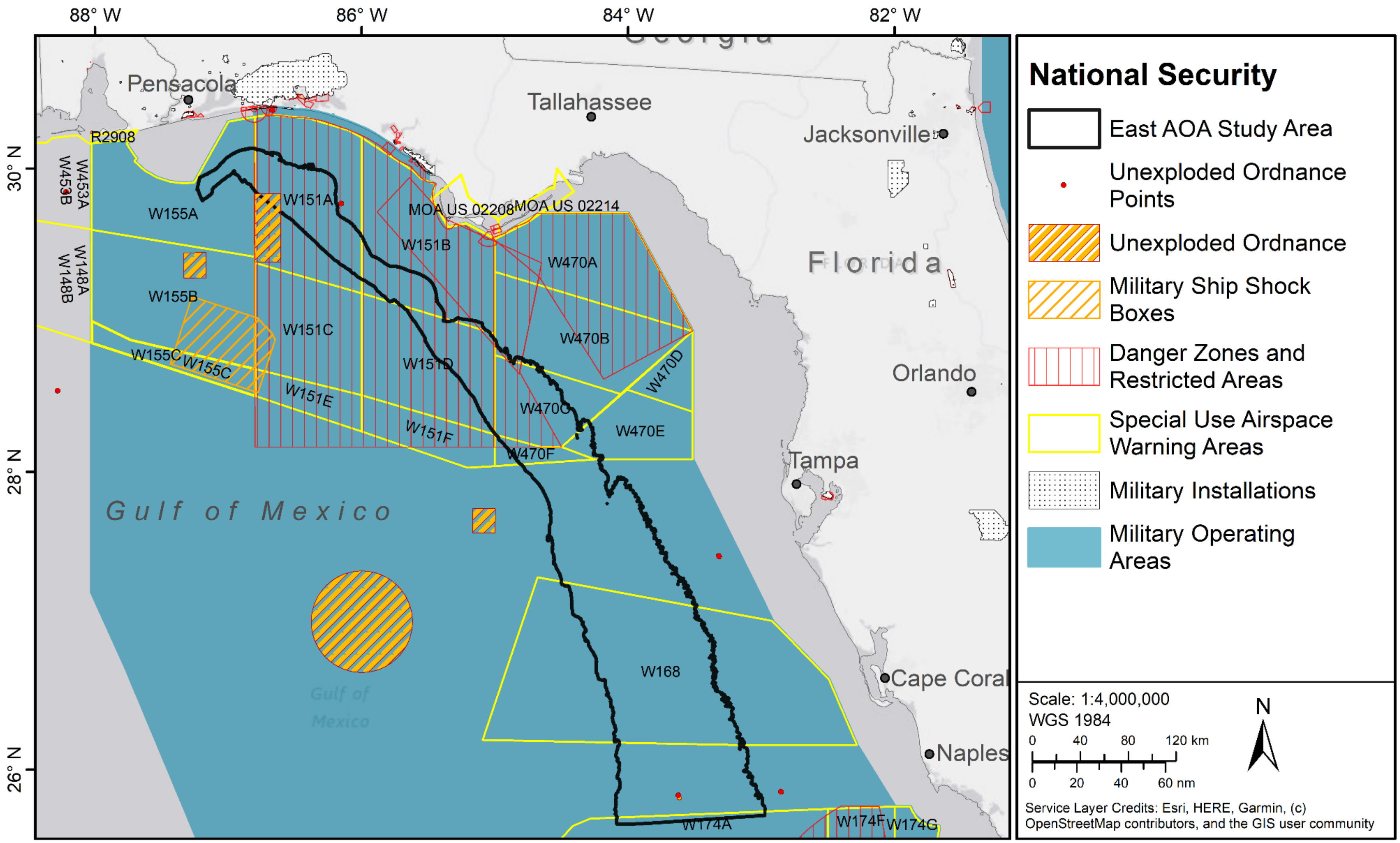

Unexploded Ordnance Polygons and Points: NOAA OCM & BOEM (2018)
Military Ship Shock Boxes & Danger Zones and Restricted Areas: NOAA OCM & BOEM (2018)
Special Use Airspace Warning Areas: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Danger Zones and Restricted Areas: NOAA OCM & BOEM (2018)
Military Installations: NOAA OCM & BOEM (2018)
Military Operating Areas: NOAA OCM & BOEM (2018)

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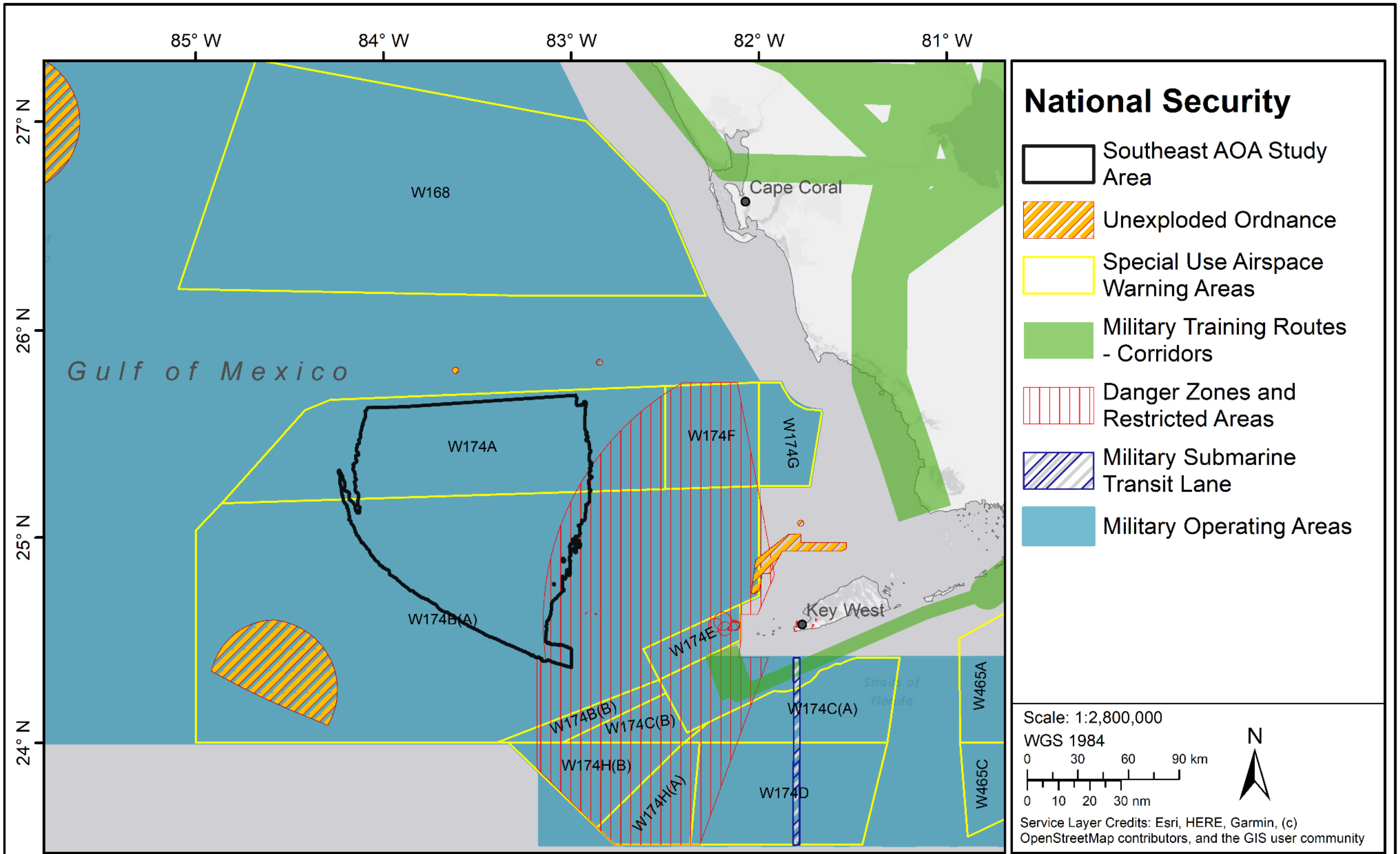

Unexploded Ordnance: NOAA OCM & BOEM (2018)
Danger Zones and Restricted Areas & Submarine Transit Lane: NOAA OCM & BOEM (2018)
Special Use Airspace Warning Areas: Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Military Training Corridor (MTRs): Military Aviation & Installation Assurance Siting Clearinghouse (2019)
Danger Zones and Restricted Areas: NOAA OCM & BOEM (2018)
Military Operating Areas: NOAA OCM & BOEM (2018)

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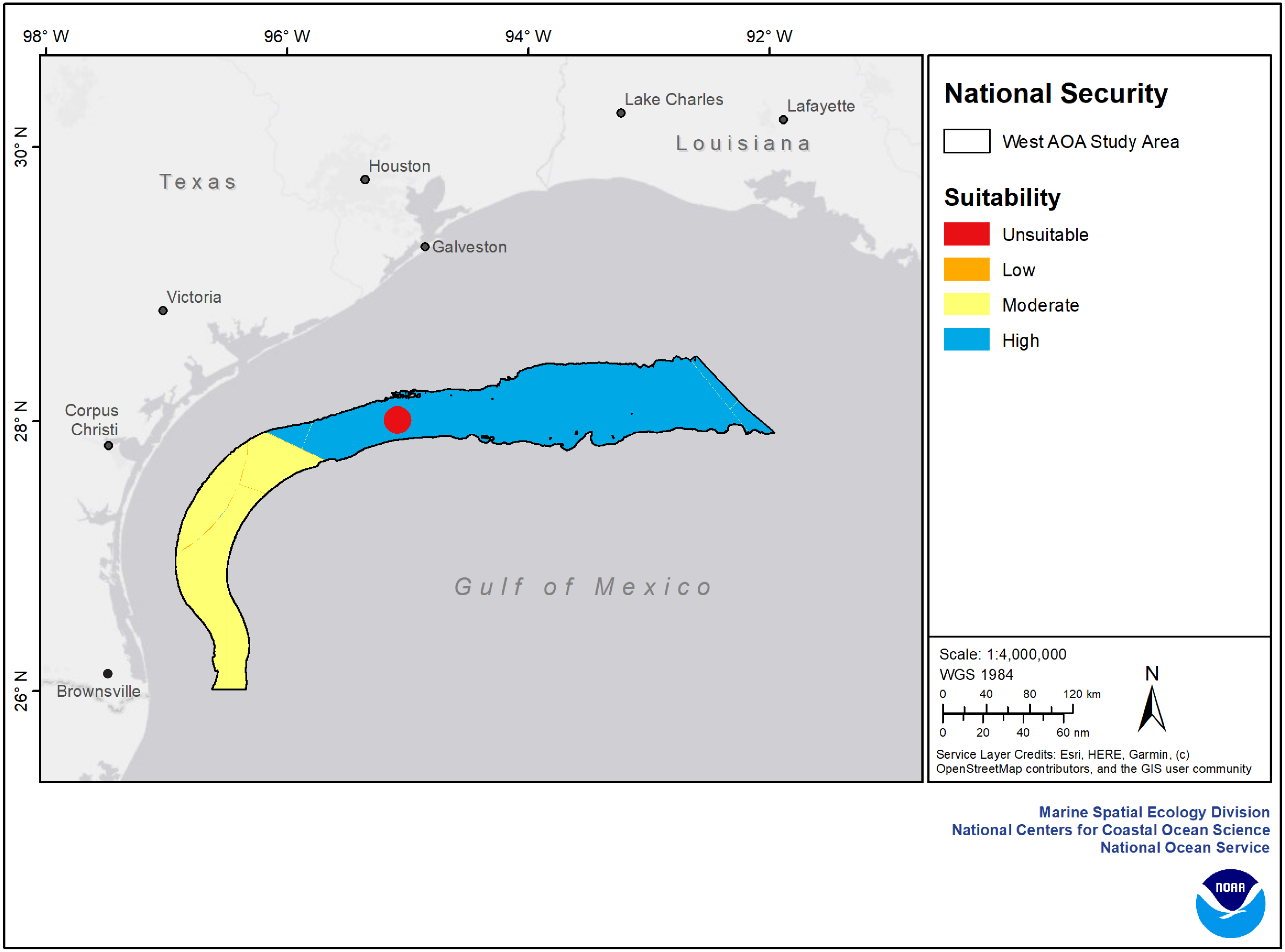
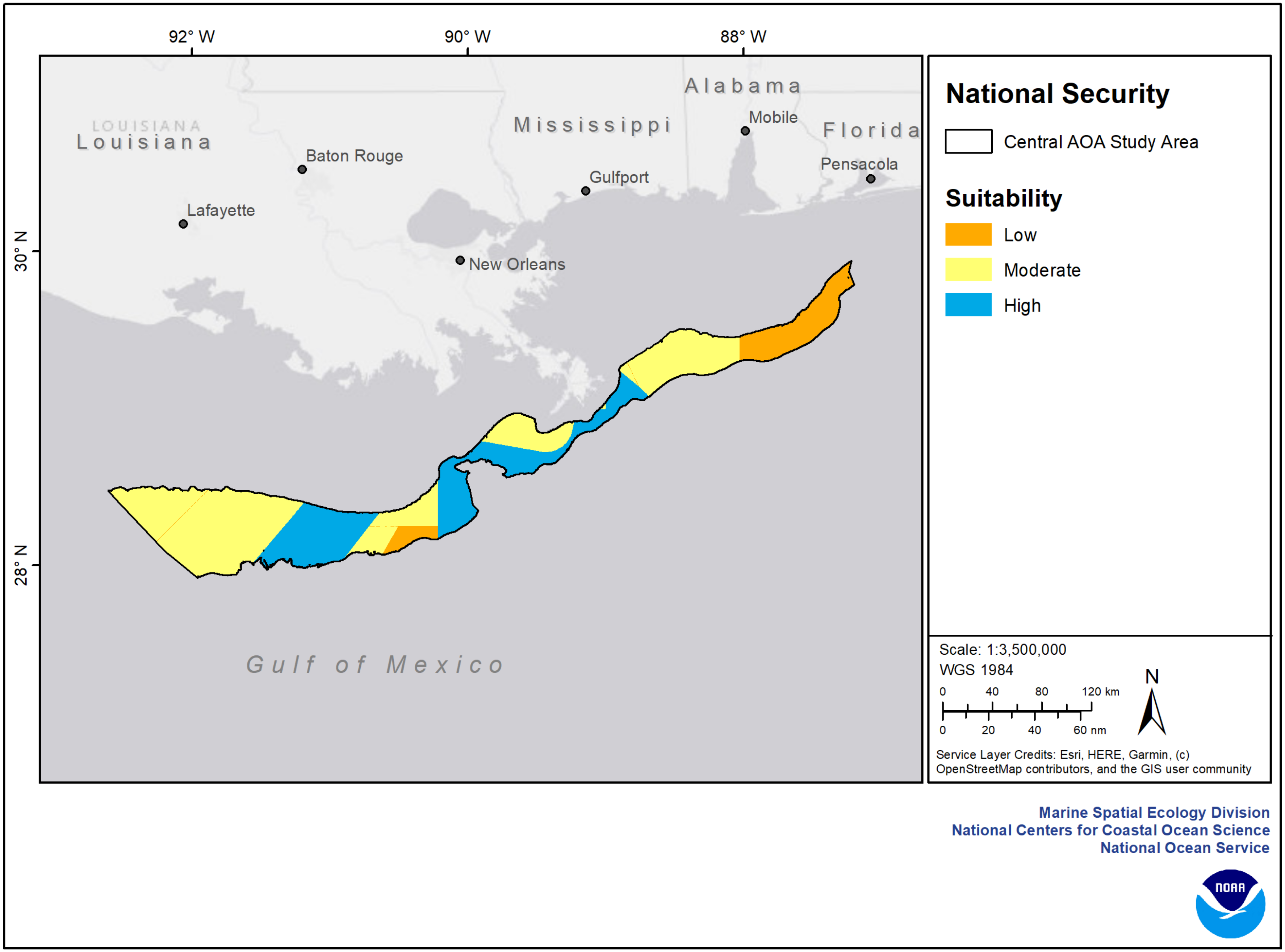

98° W
96° W
94° W
92° W
30° N
28° N
26° N
Lake Charles
Lafayette
Louisiana
Texas
Houston
Galveston
Victoria
Corpus Christi
Brownsville
Gulf of Mexico
National Security
West AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:4,000,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



92° W
90° W
88° W
30° N
28° N
Alabama
Mississippi
Florida
LOUISIANA
Louisiana
Mobile
Pensacola
Baton Rouge
Gulfport
Lafayette
New Orleans
Gulf of Mexico
National Security
Central AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:3,500,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
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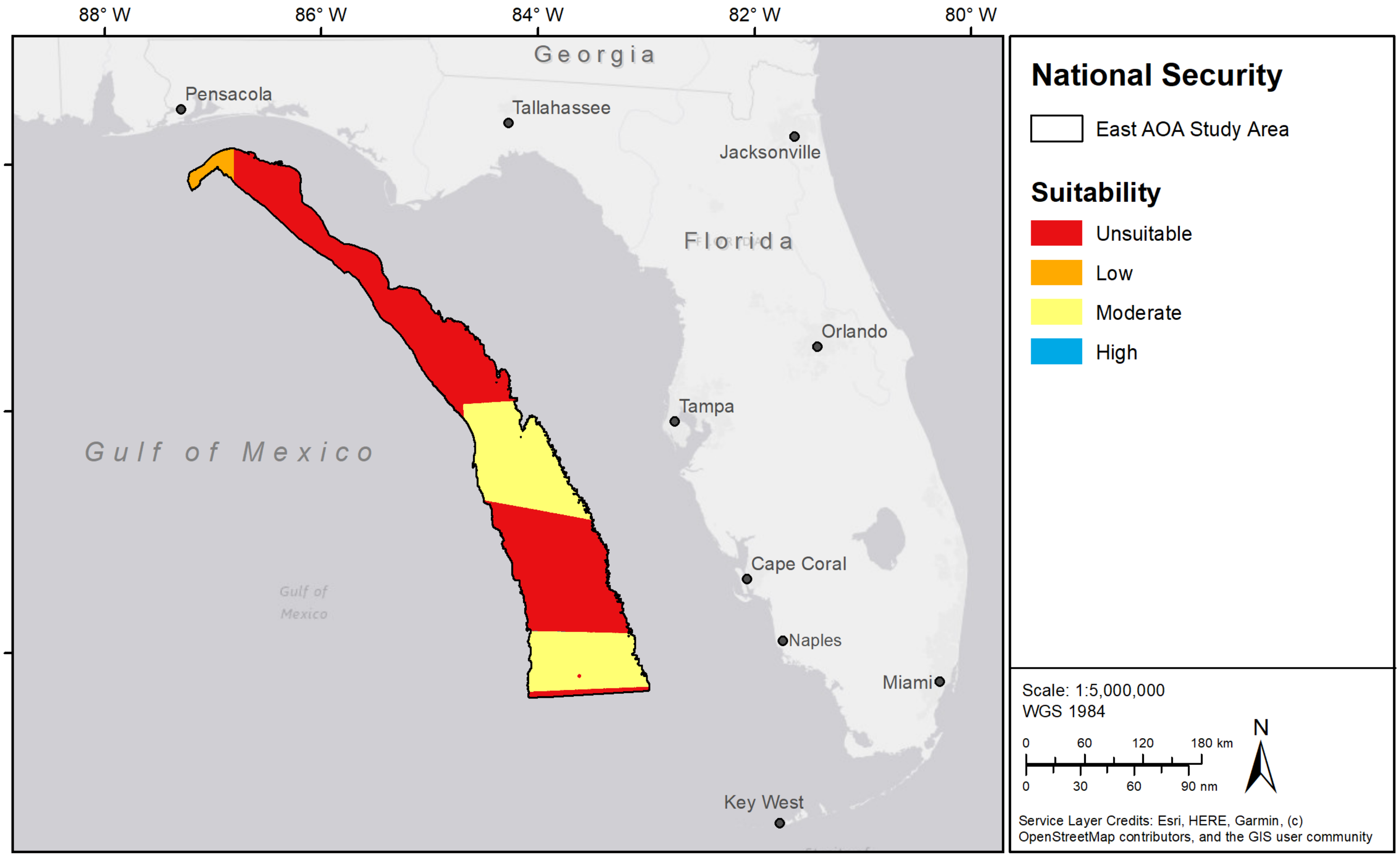

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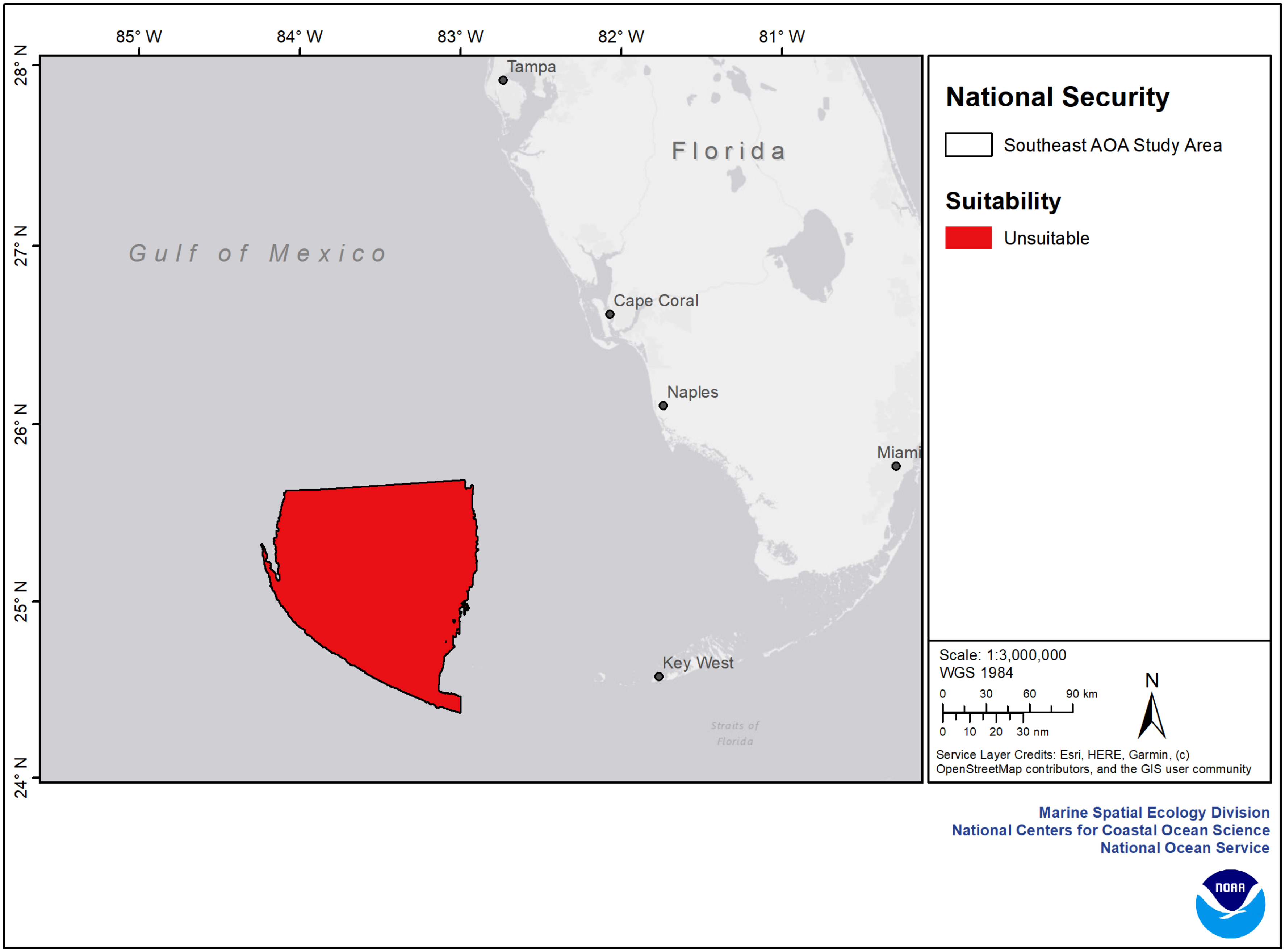
85° W
84° W
83° W
82° W
81° W
28° N
27° N
26° N
25° N
24° N
Tampa
Florida
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Straits of Florida
National Security
Southeast AOA Study Area
Suitability
Unsuitable
Scale: 1:3,000,000
WGS 1984
0 30 60 90 km
0 10 20 30 nm
N
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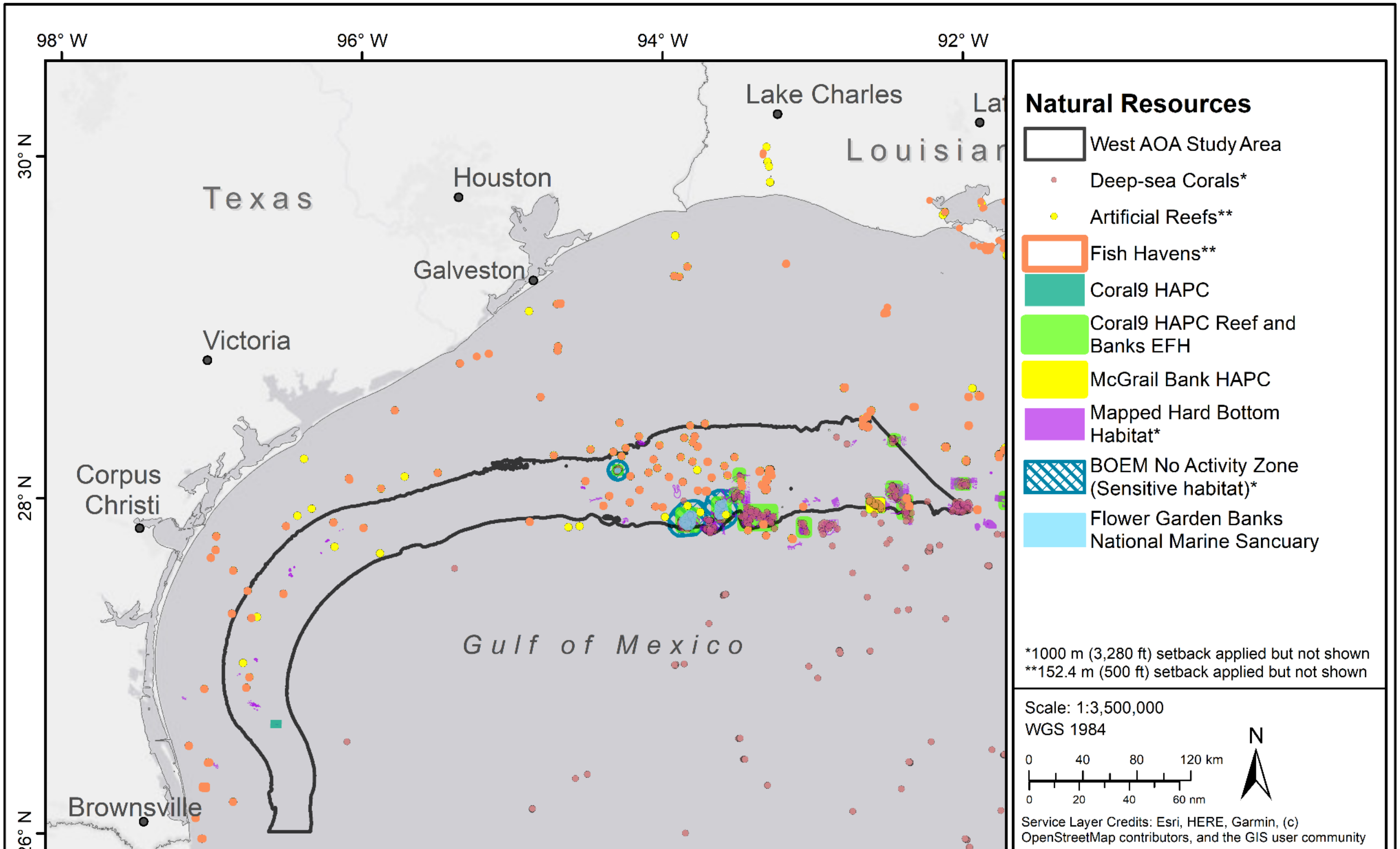
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA

Natural and Cultural Resources



Deep-sea Corals (1985 - present): NOAA Deep-sea Coral Research &Technology Program (2021)
Artificial Reefs: NOAA OCM & BOEM (2018), Texas Parks & Wildlife (2020)
Fish Havens: NOAA Electronic Navigation Chart (2020)
Flower Garden Banks National Marine Sanctuary: NOAA National Marine Sanctuaries (2021)
Coral9 Habitat Areas of Particular Concern (HAPC): Gulf Fisheries Management Council & NOAA (2020)
Coral9 Reef and Banks & McGrail Bank Habitat Areas of Particular Concern: NOAA Fisheries (2020)
Mapped Hard Bottom Habitat: NOAA Fisheries (2020)

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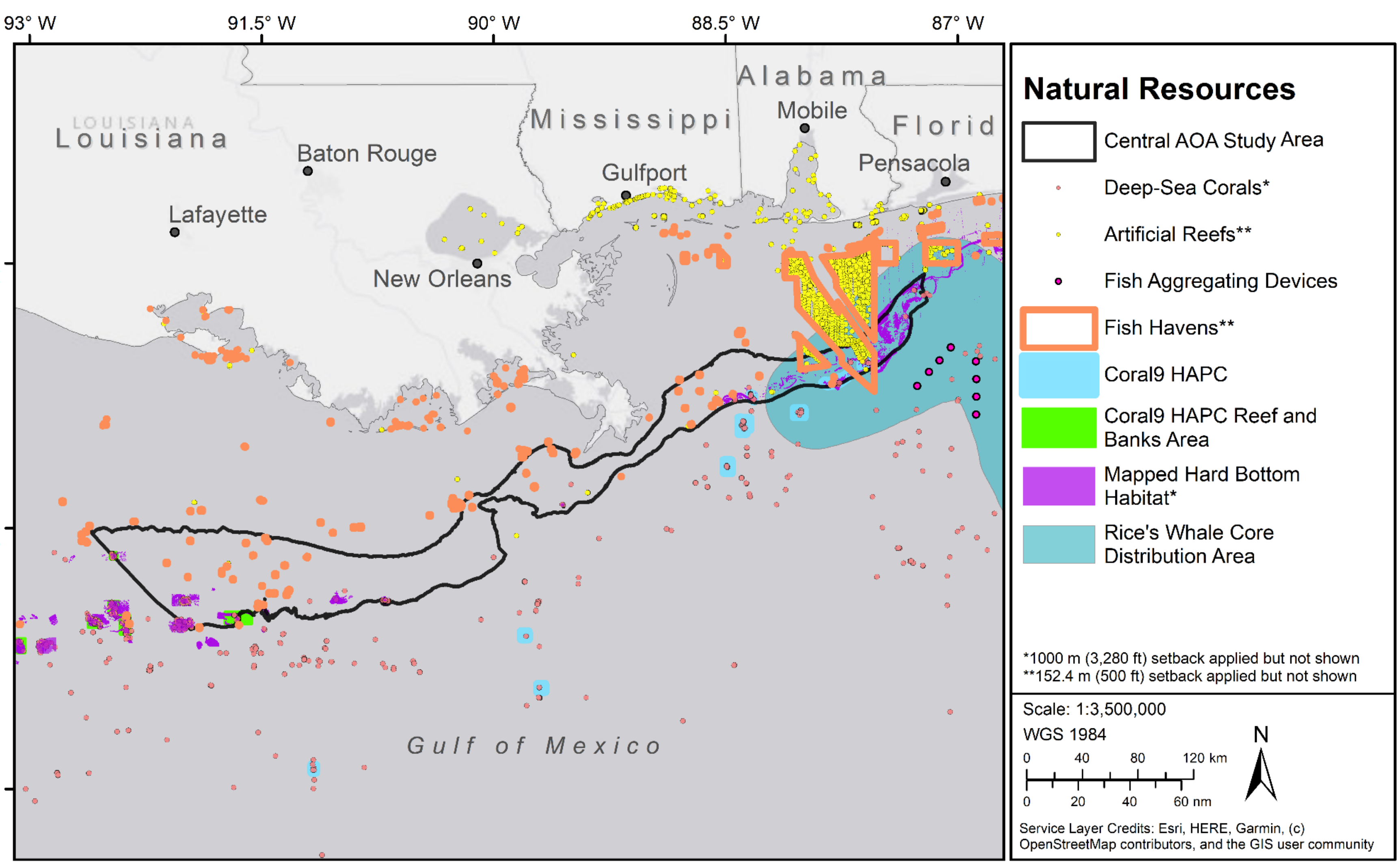

Deep-sea Corals (1985 - present): NOAA Deep-Sea Coral Research &Technology Program (2021)
Artificial Reefs: NOAA OCM and BOEM (2018)
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Fish Havens: NOAA Eletronic Navigation Chart (2019)
Coral9 HAPC Reef and Banks: NOAA Fisheries (2020)
Mapped Hard Bottom Habitat: NOAA Fisheries (2020)
Rice's Whale Core Distribution Area: NOAA Fisheries (2019)

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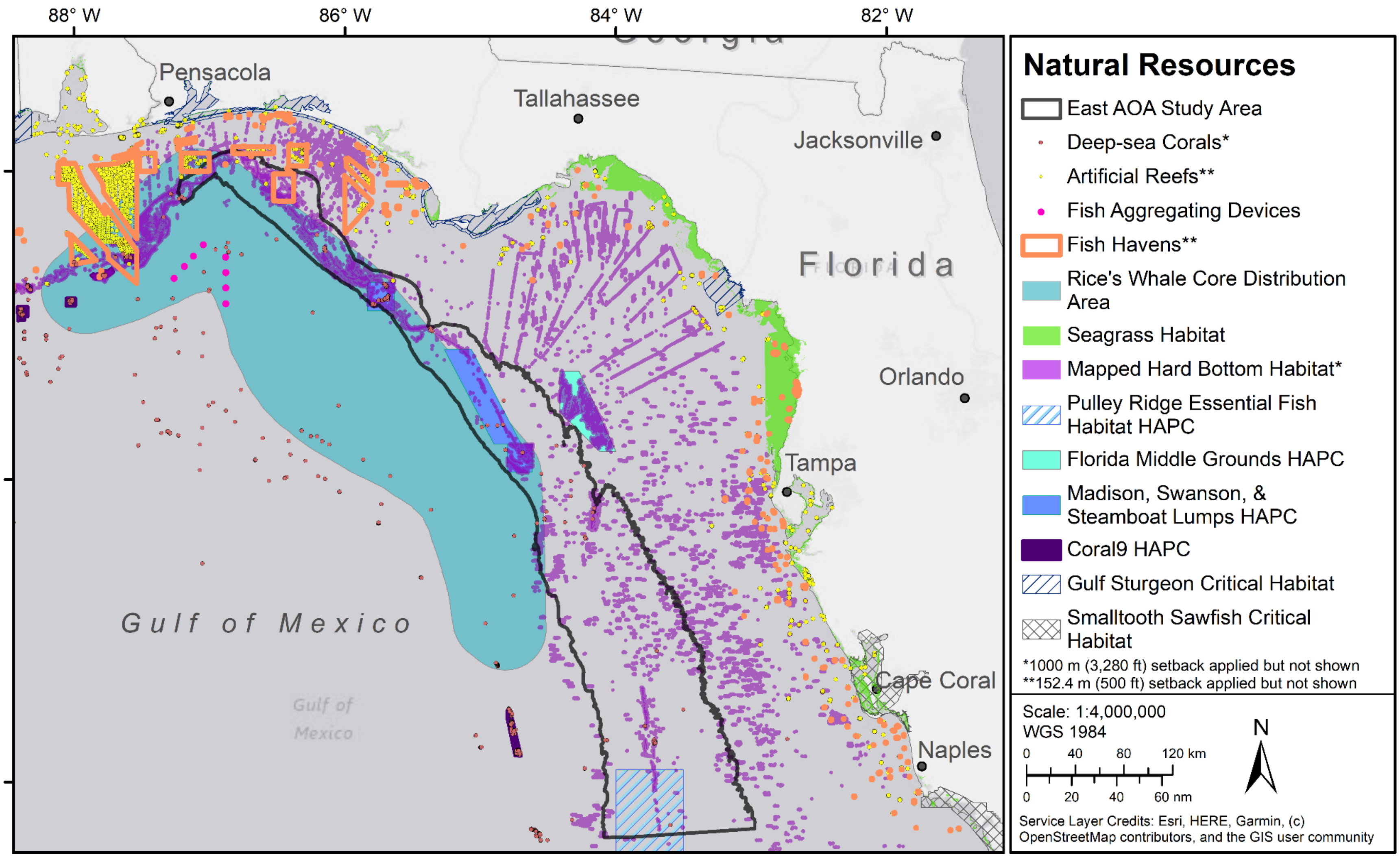

Deep-sea Corals (1985 - present): NOAA Deep-Sea Coral Research &Technology Program (2021)
Artificial Reefs: NOAAA OCM & BOEM (2018)
Seagrass Habitat: FWC SIMM Program (2019)
Madison, Swanson, the Edges, and Steamboat Lumps, FL Middle Grounds Habitat Area of Particular Concern: NOAA Fisheries (2019)
Pulley Ridge EFH Habitat Area of Particular Concern: NOAA Fisheries (2019)
Fish Havens: NOAA Electronic Navigation Chart (2019)
Mapped Hard Bottom Habitat: NOAA Fisheries (2020)
Rice's Whale Core Distribution Area: NOAA Fisheries (2019)
Gulf Sturgeon and Smalltooth Sawfish Critical Habitat: NOAA Fisheries (2019)

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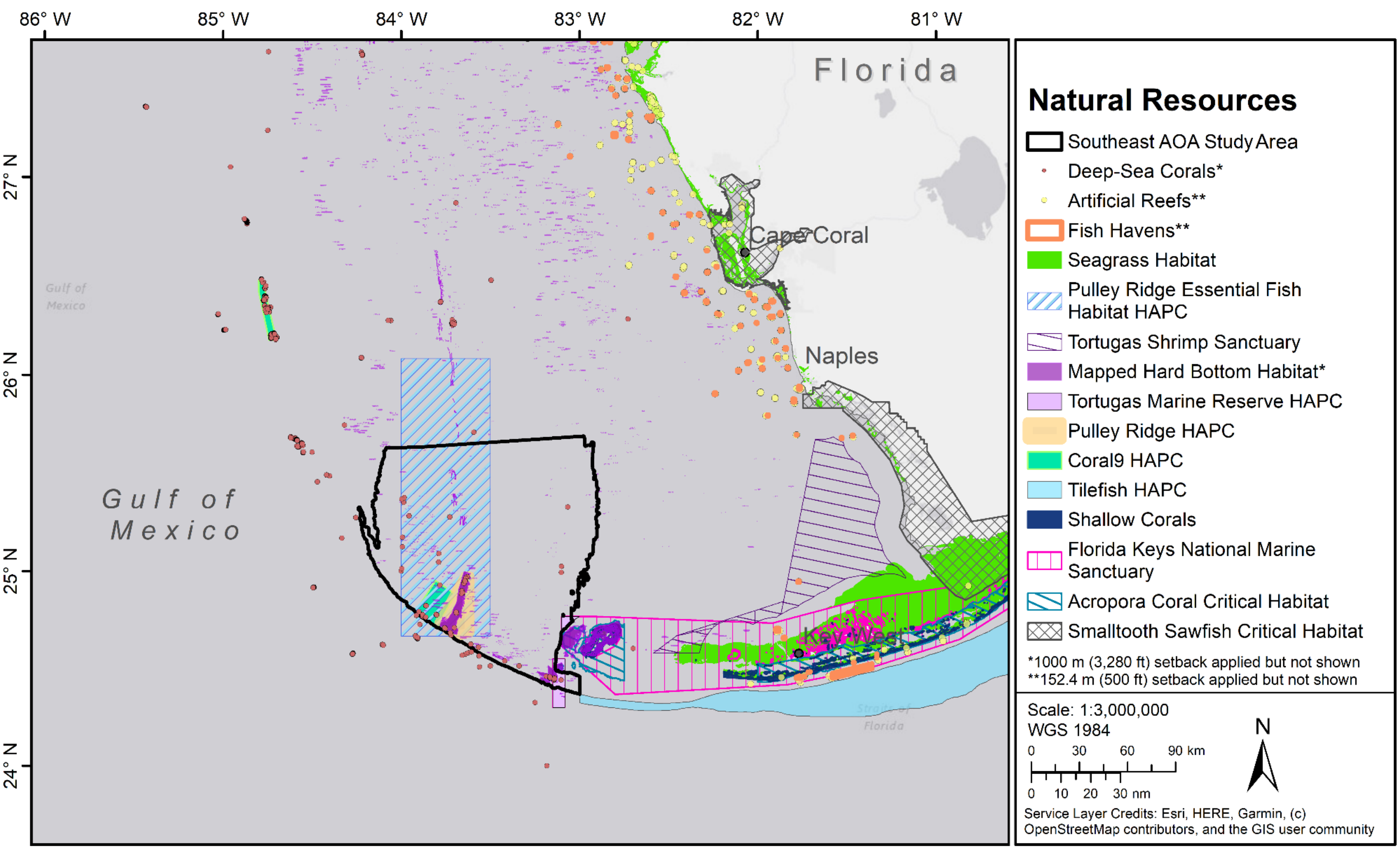

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Artificial Reefs: Florida Fish and Wildlife Conservation Commission (2020)
Seagrass Habitat: FWC SIMM Program (2019)
Coral9 Habitat Area of Particular Concern: Gulf Fisheries Management Council & NOAA (2020)
Pulley Ridge & Tortugas Marine Reserve HAPCs: NOAA Fisheries (2019)
Fish Havens: NOAA Electronic Navigation Chart (2019)
Shallow Corals: NOAA Fisheries (2018)
Florida Keys National Marine Sanctuary: NOAA National Marine Sanctuaries (2004)
Mapped Hard Bottom Habitats: NOAA Fisheries (2020)
Smalltooth Sawfish & Acropora Coral Critical Habitats: NOAA Fisheries (2019)

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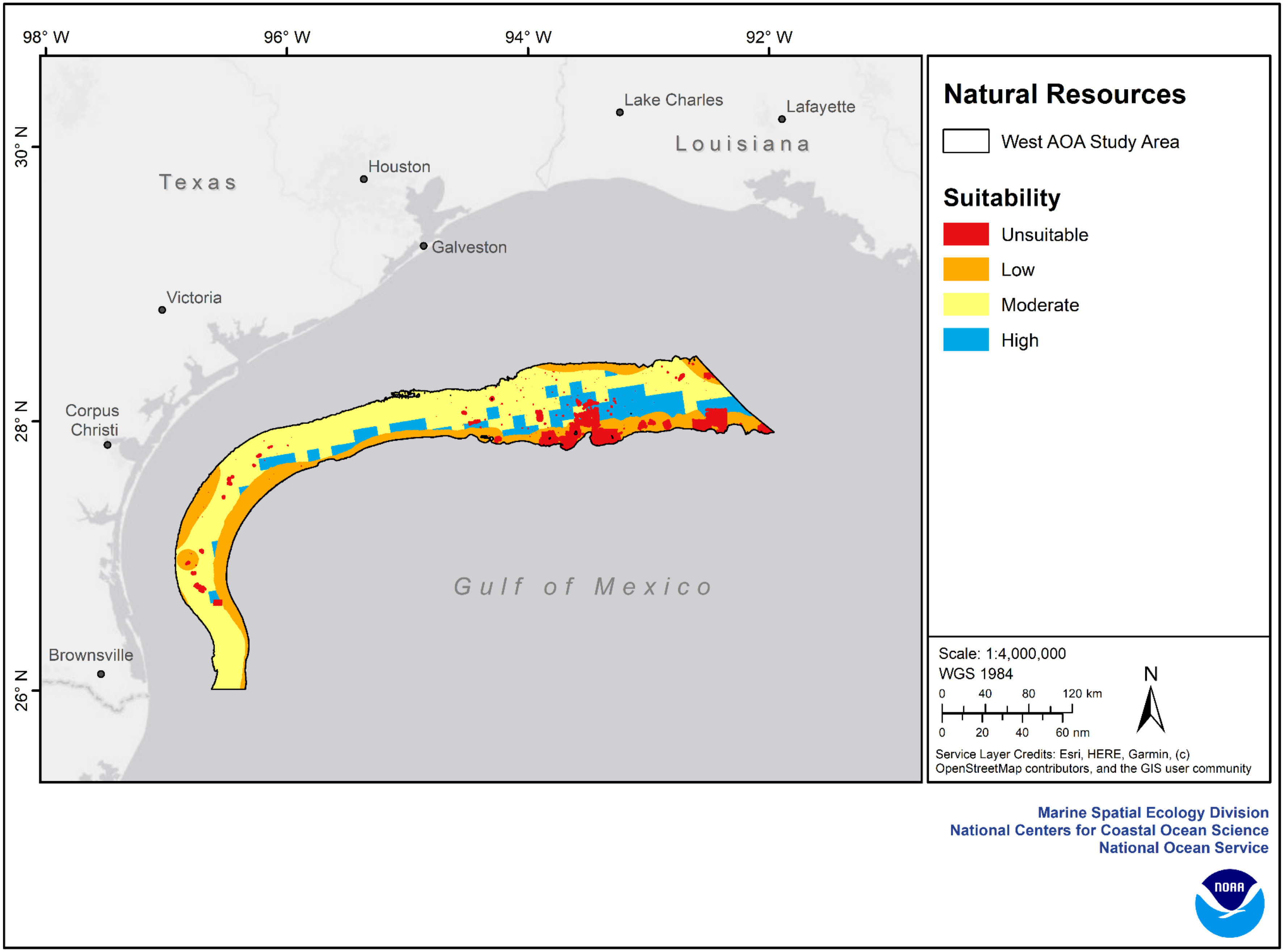
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96° W
94° W
92° W
30° N
28° N
26° N
Lake Charles
Lafayette
Louisiana
Texas
Houston
Galveston
Victoria
Corpus Christi
Brownsville
Gulf of Mexico
Natural Resources
West AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:4,000,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
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Marine Spatial Ecology Division
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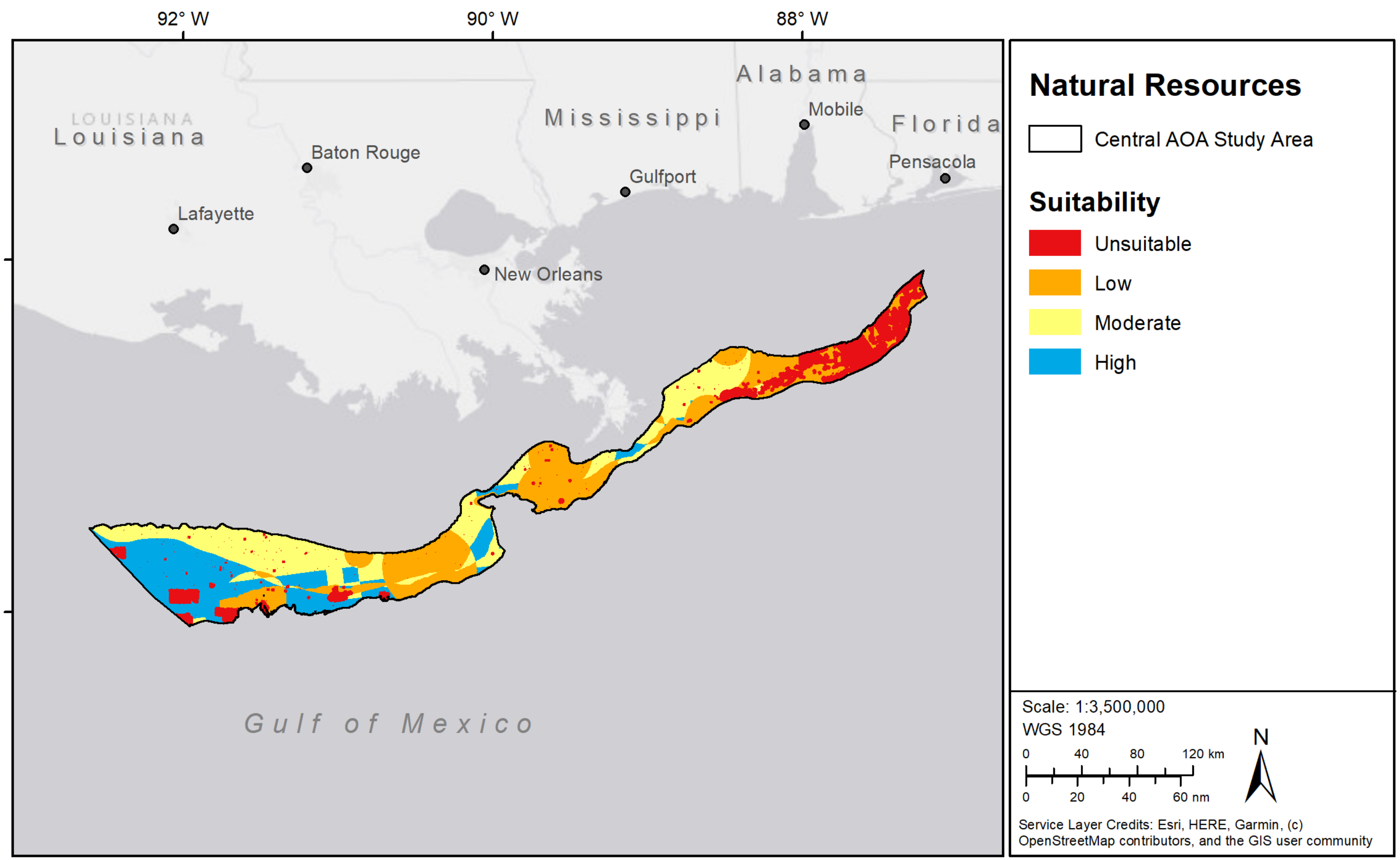

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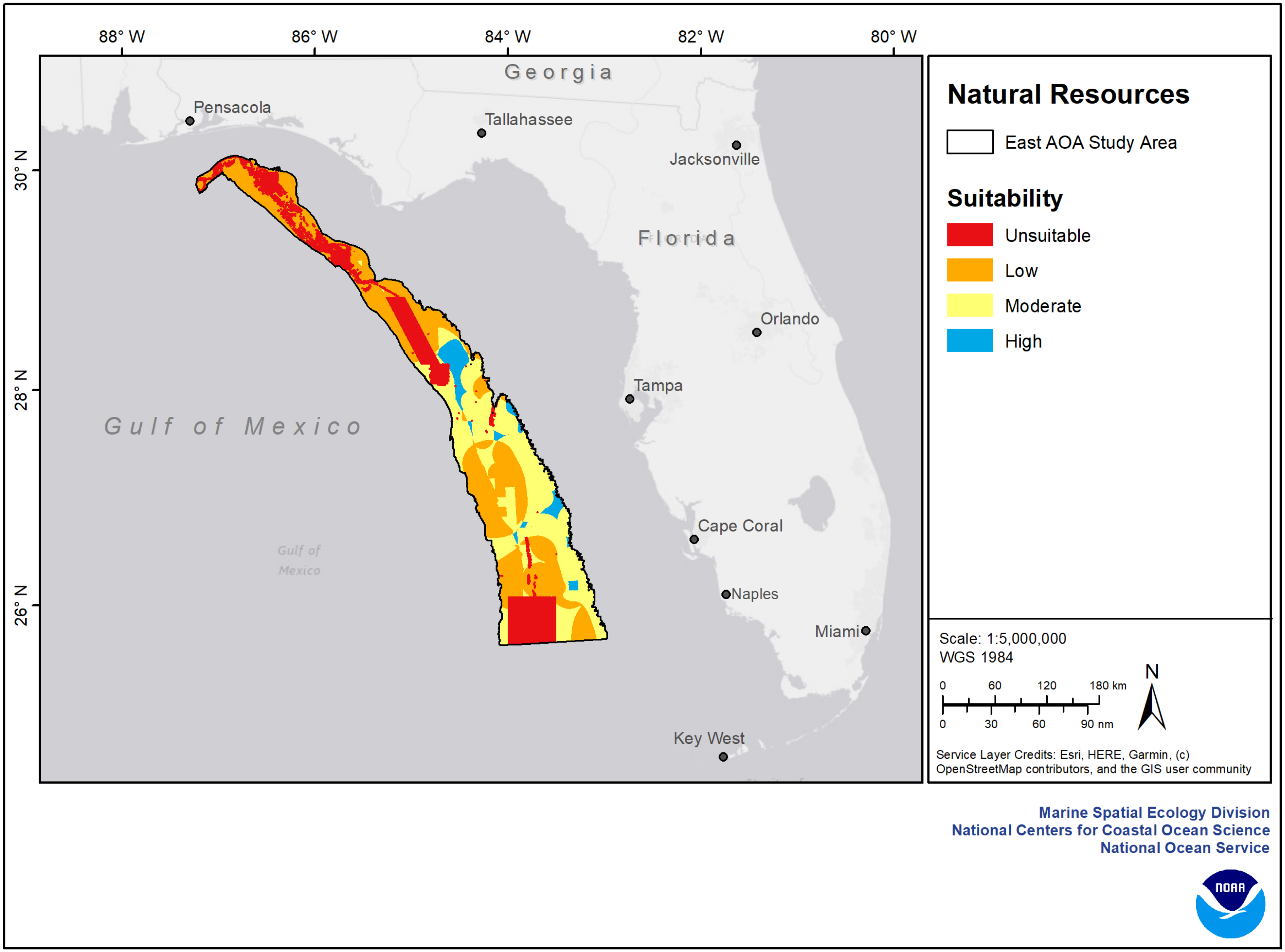
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86° W
84° W
82° W
80° W
30° N
28° N
26° N
Georgia
Pensacola
Tallahassee
Jacksonville
Florida
Orlando
Tampa
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Natural Resources
East AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:5,000,000
WGS 1984
0 60 120 180 km
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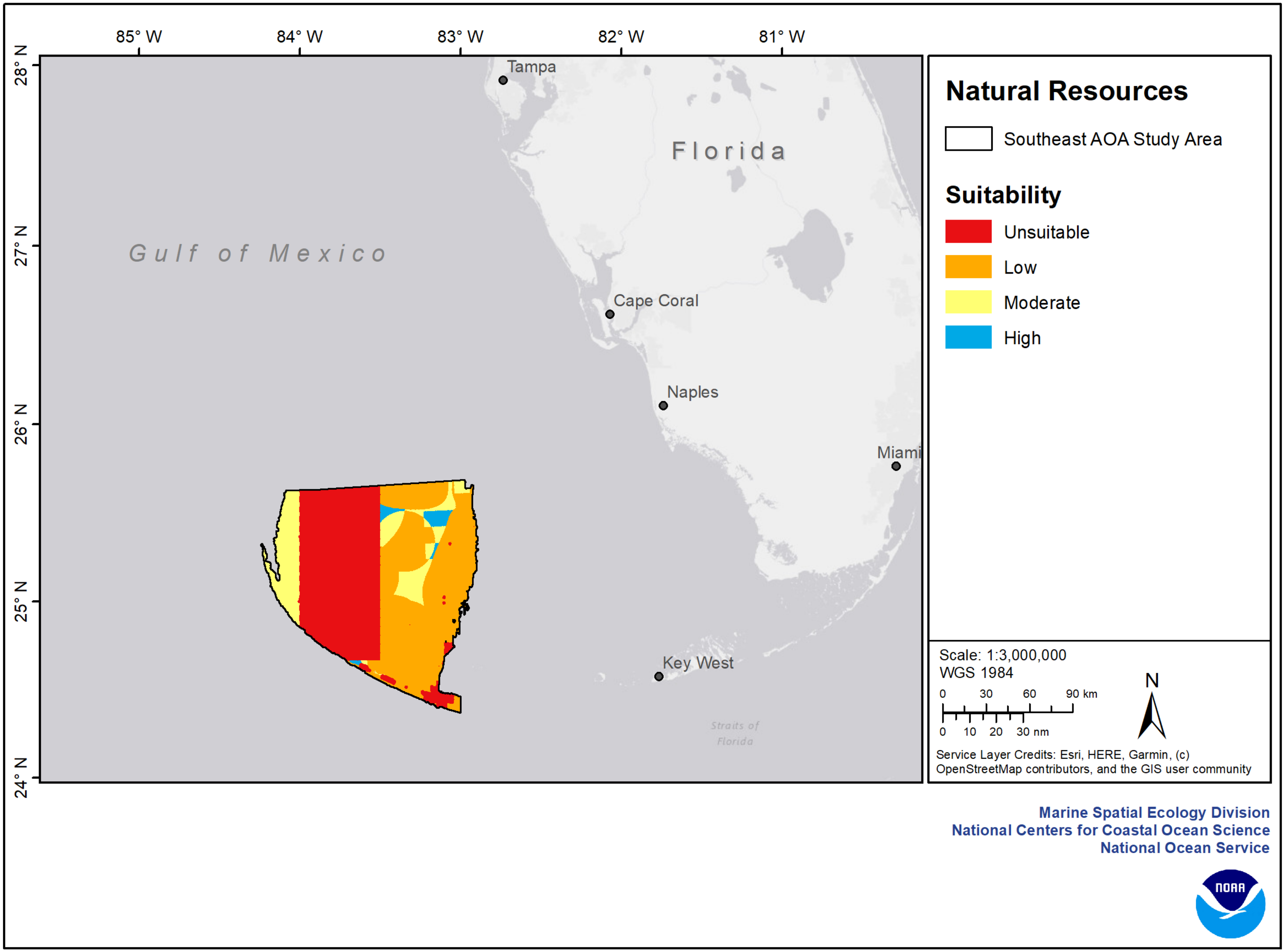
National Ocean Service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24° N
Tampa
Florida
Gulf of Mexico
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Straits of Florida
Natural Resources
Southeast AOA Study Area
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Scale: 1:3,000,000
WGS 1984
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0 10 20 30 nm
N
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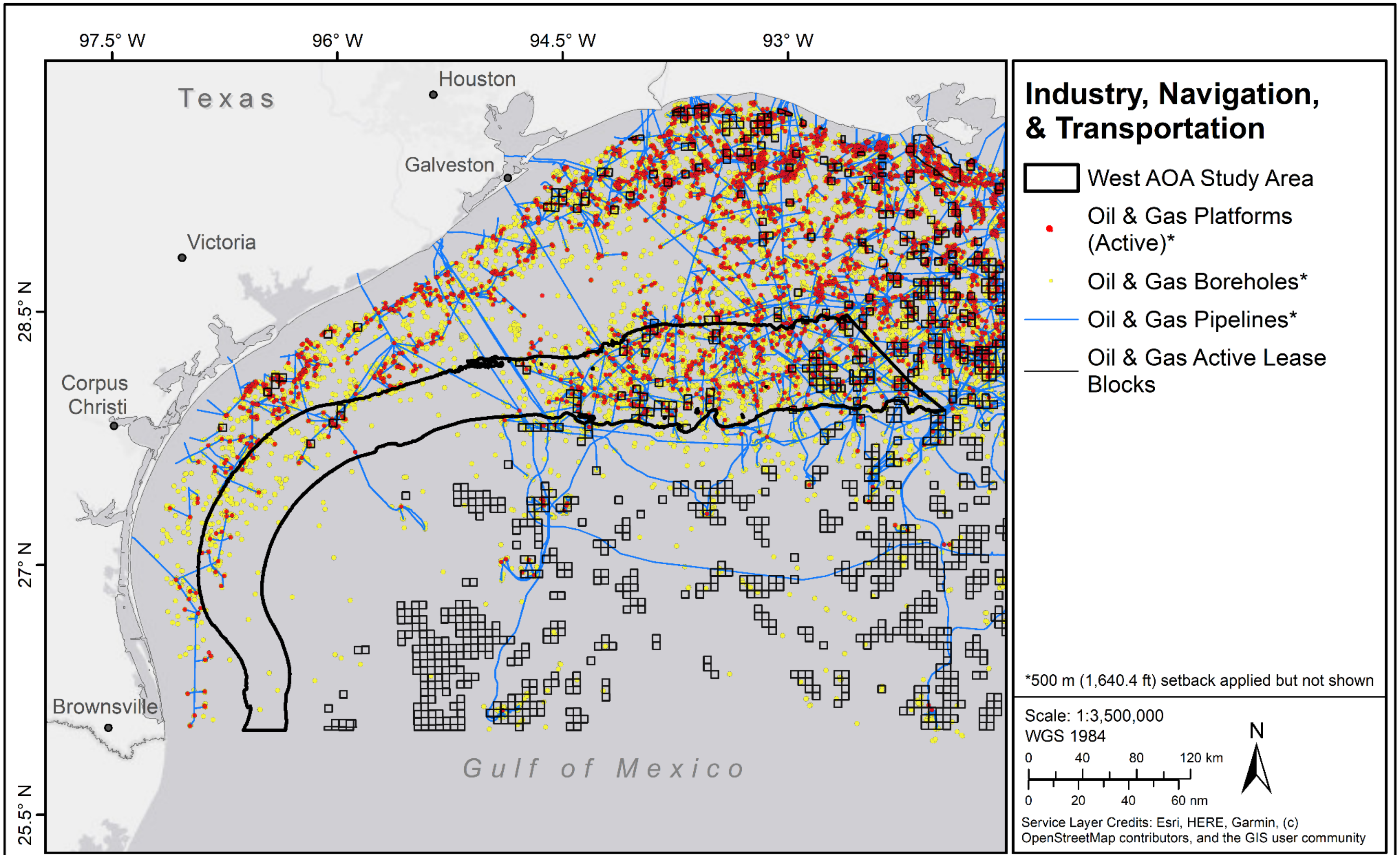
National Ocean Service

Industry, Navigation, and Transportation



Oil & Gas Platforms: Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement (2021)
Oil & Gas Boreholes: Bureau of Safety and Environmental Enforcement (2021)
Oil & Gas Pipelines: Bureau of Safety and Environmental Enforcement (2021)
Oil & Gas Active Lease Blocks: Bureau of Ocean Energy Management (2021)

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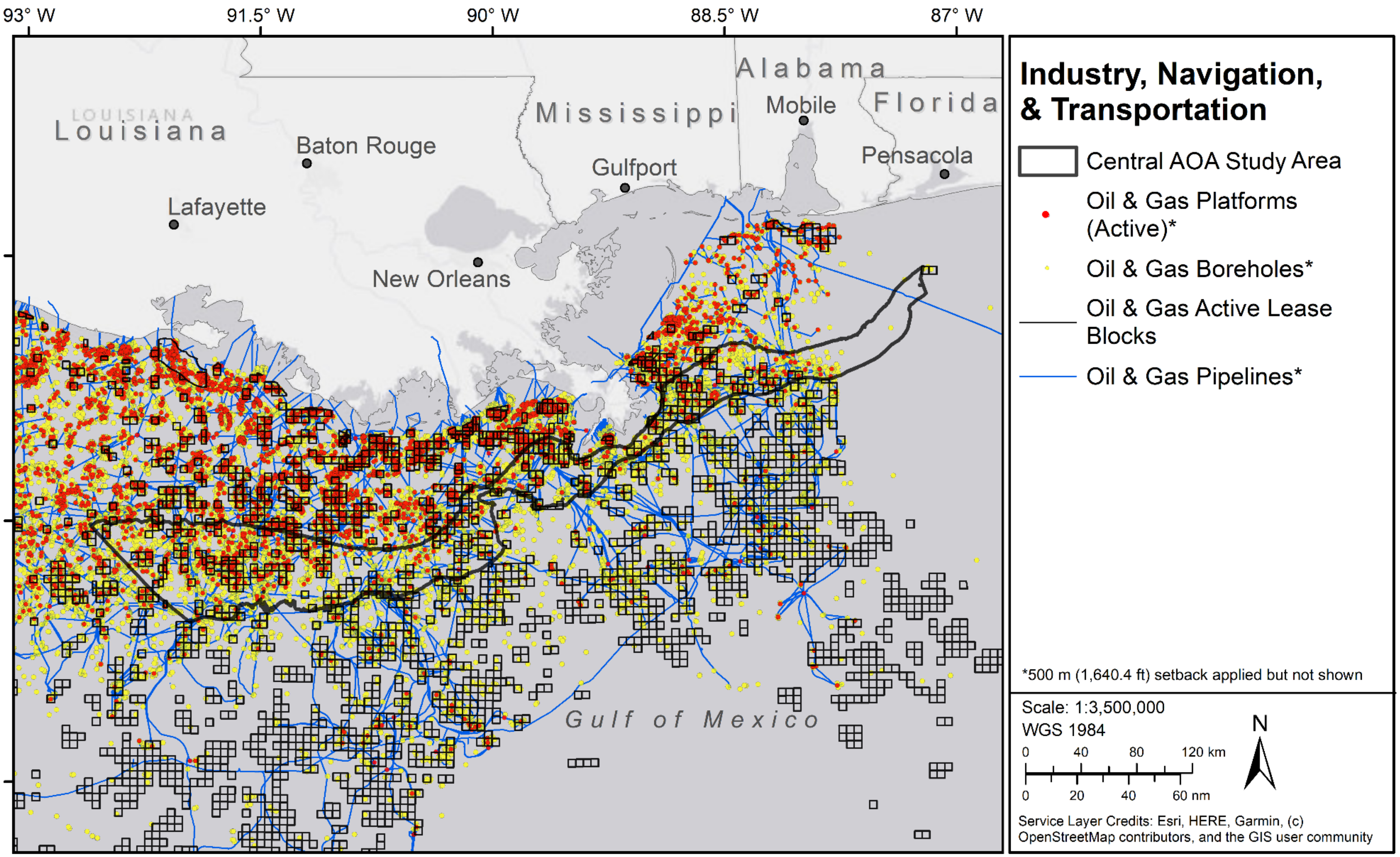

Oil & Gas Platforms: Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement (2021)
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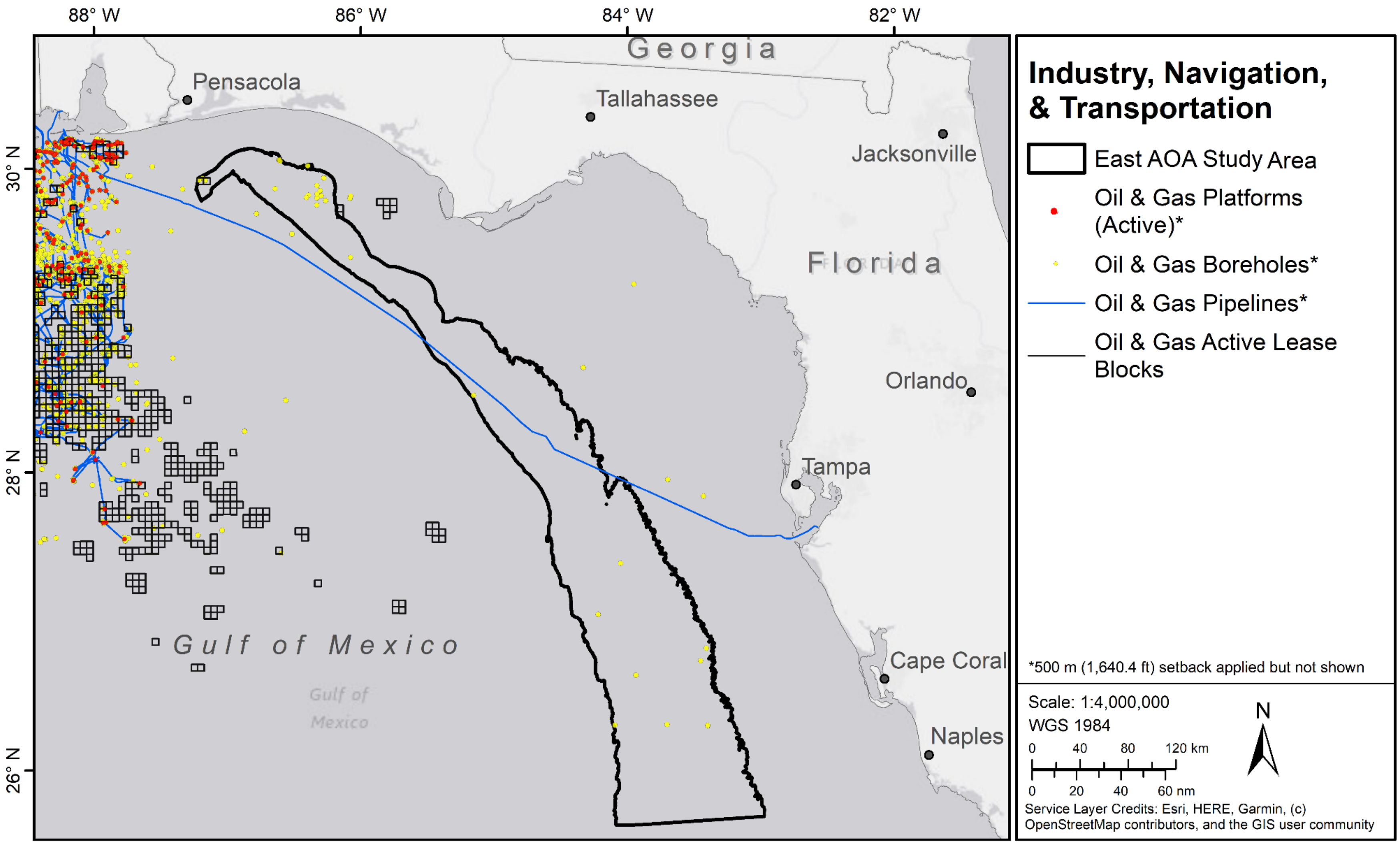

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Oil & Gas Boreholes: Bureau of Safety and Environmental Enforcement (2021)
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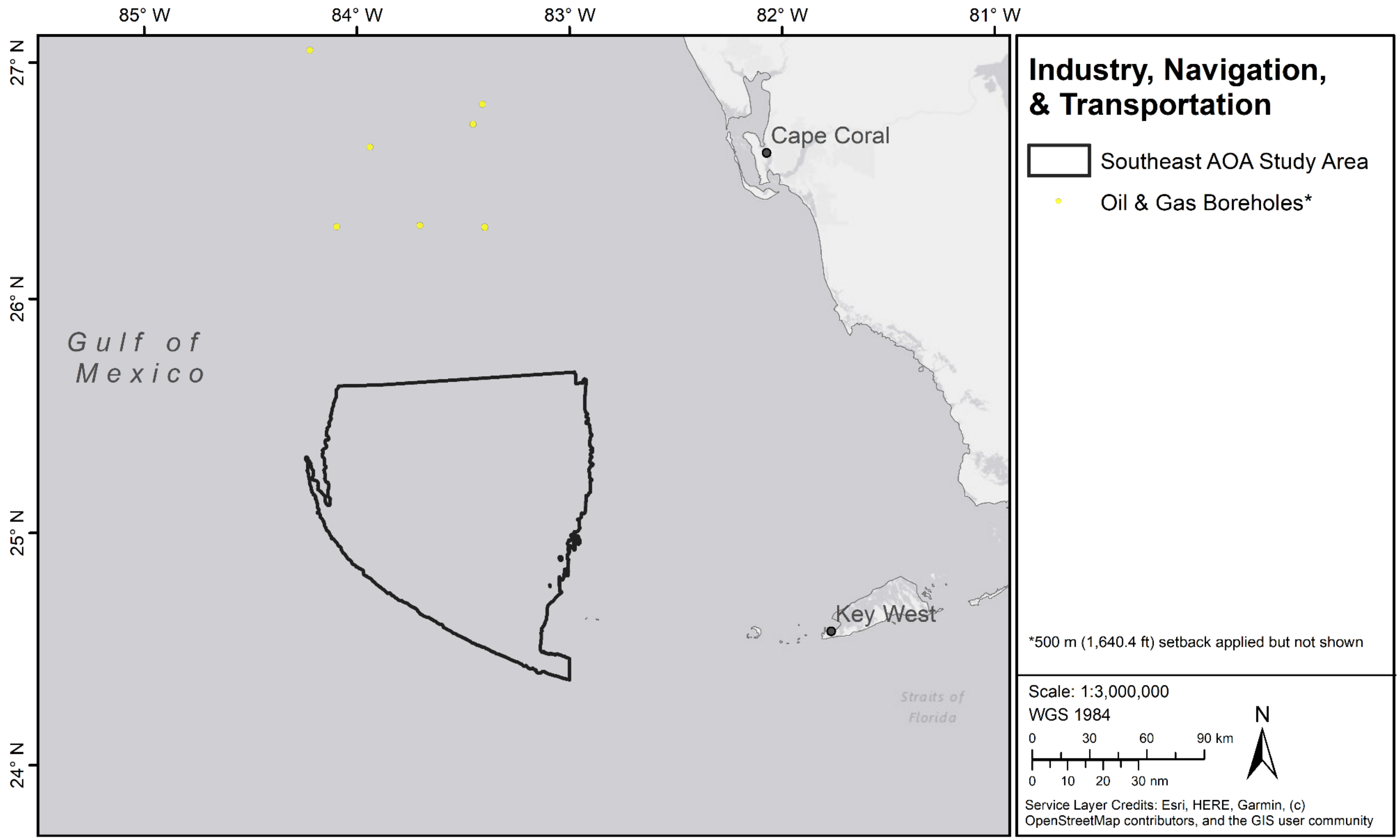

Oil & Gas Boreholes: Bureau of Safety and Environmental Enforcement (2021)

Marine Spatial Ecology Division
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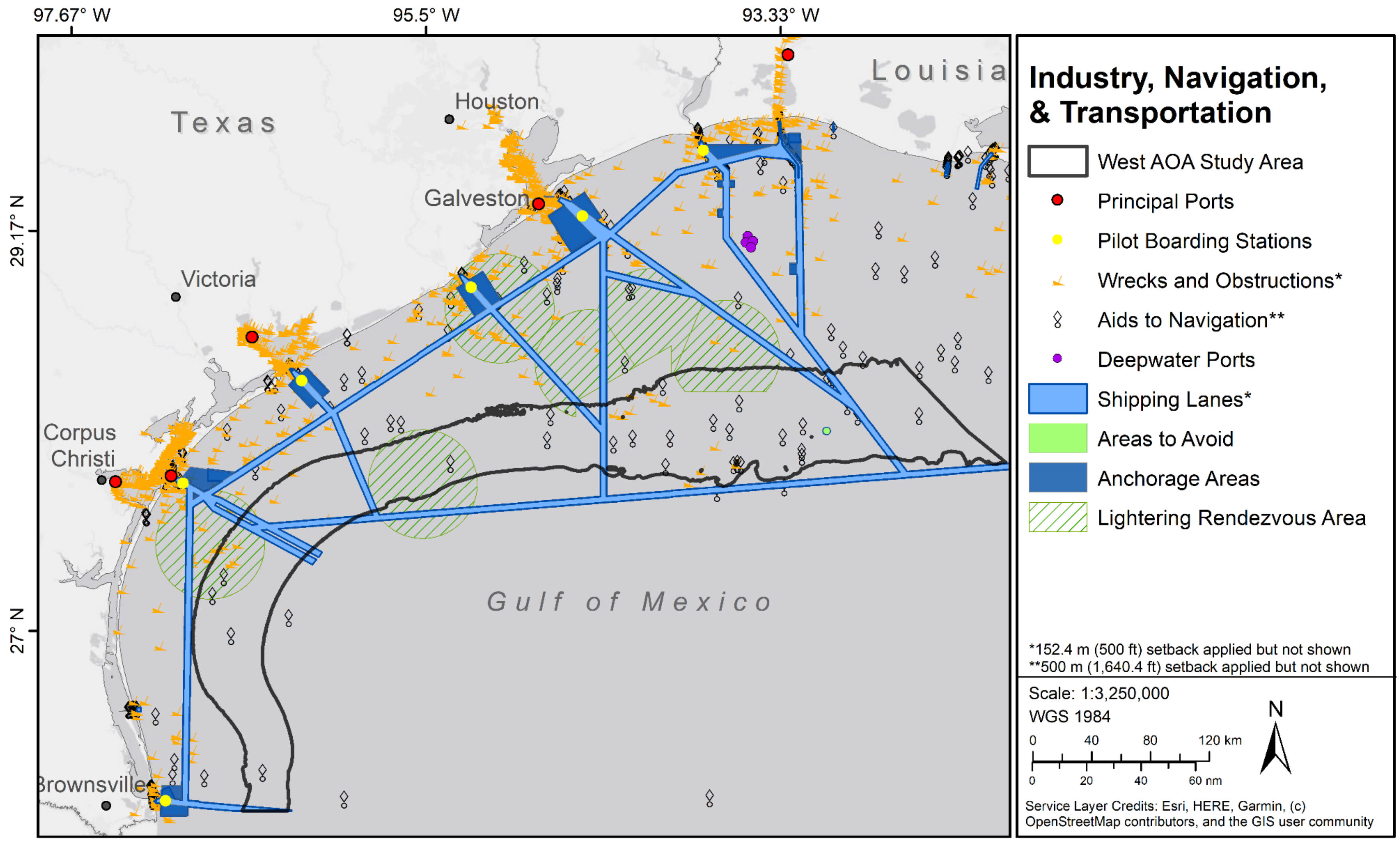

Principal Ports: NOAA OCM and BOEM (2018)
Pilot Boarding Stations: NOAA OCM and BOEM (2018)
Wrecks and Obstructions: NOAA OCM and BOEM (2018)
Aids to Navigation: NOAA OCM and BOEM (2018)
Deepwater Ports NOAA OCM and BOEM (2018)
Areas to Avoid: NOAA OCM and BOEM (2018)
Anchorage Areas: NOAA OCM and BOEM (2018)
Shipping Lanes: NOAA OCM and BOEM (2018)
Lightering Redezvous Areas: NOAA OCM and BOEM (2018)

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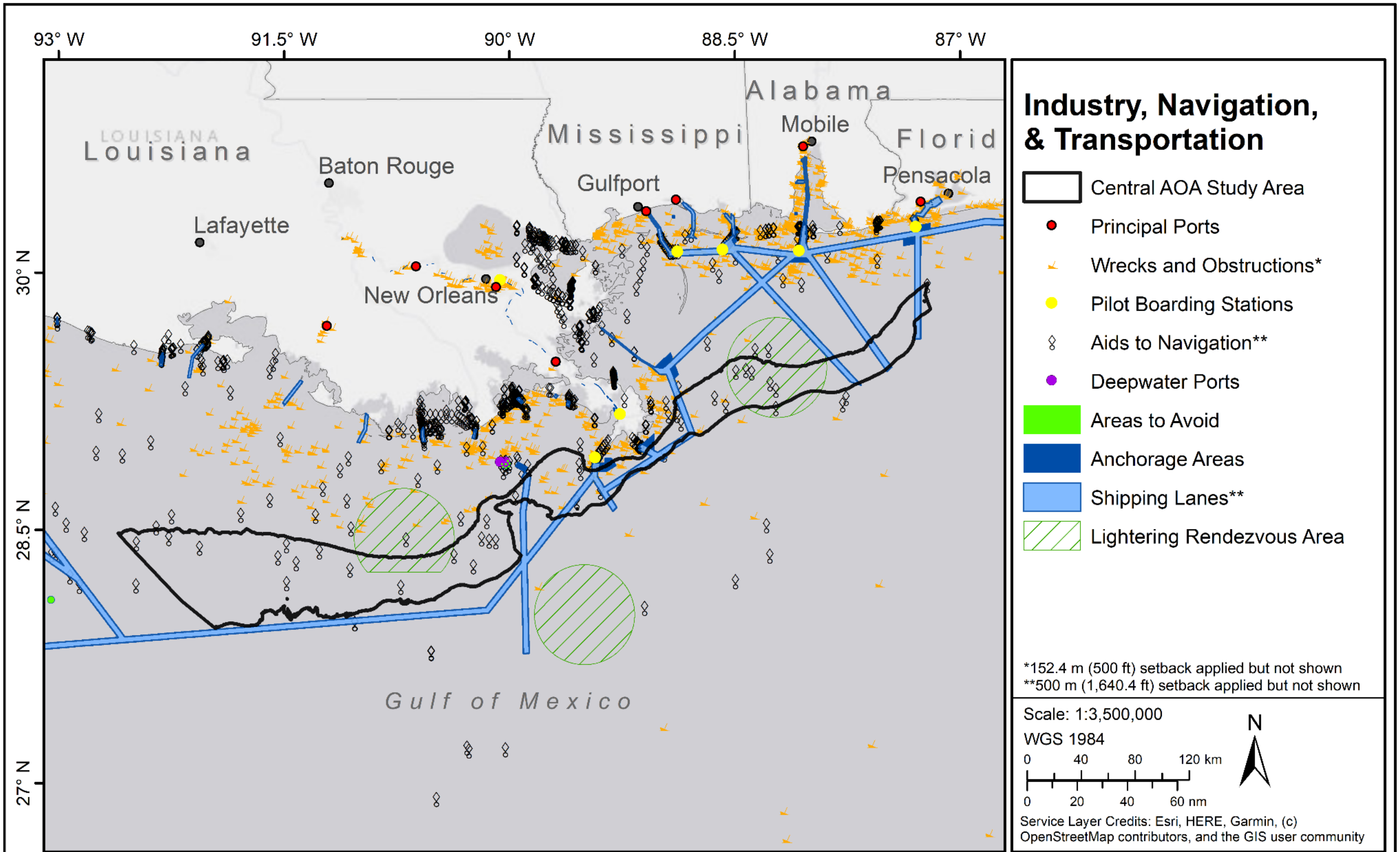

Principal Ports: NOAA OCM and BOEM (2018)
Deepwater Ports NOAA OCM and BOEM (2018)
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Areas to Avoid: NOAA OCM and BOEM (2018)
Lightering Rendezvous Areas: NOAA OCM and BOEM (2018)

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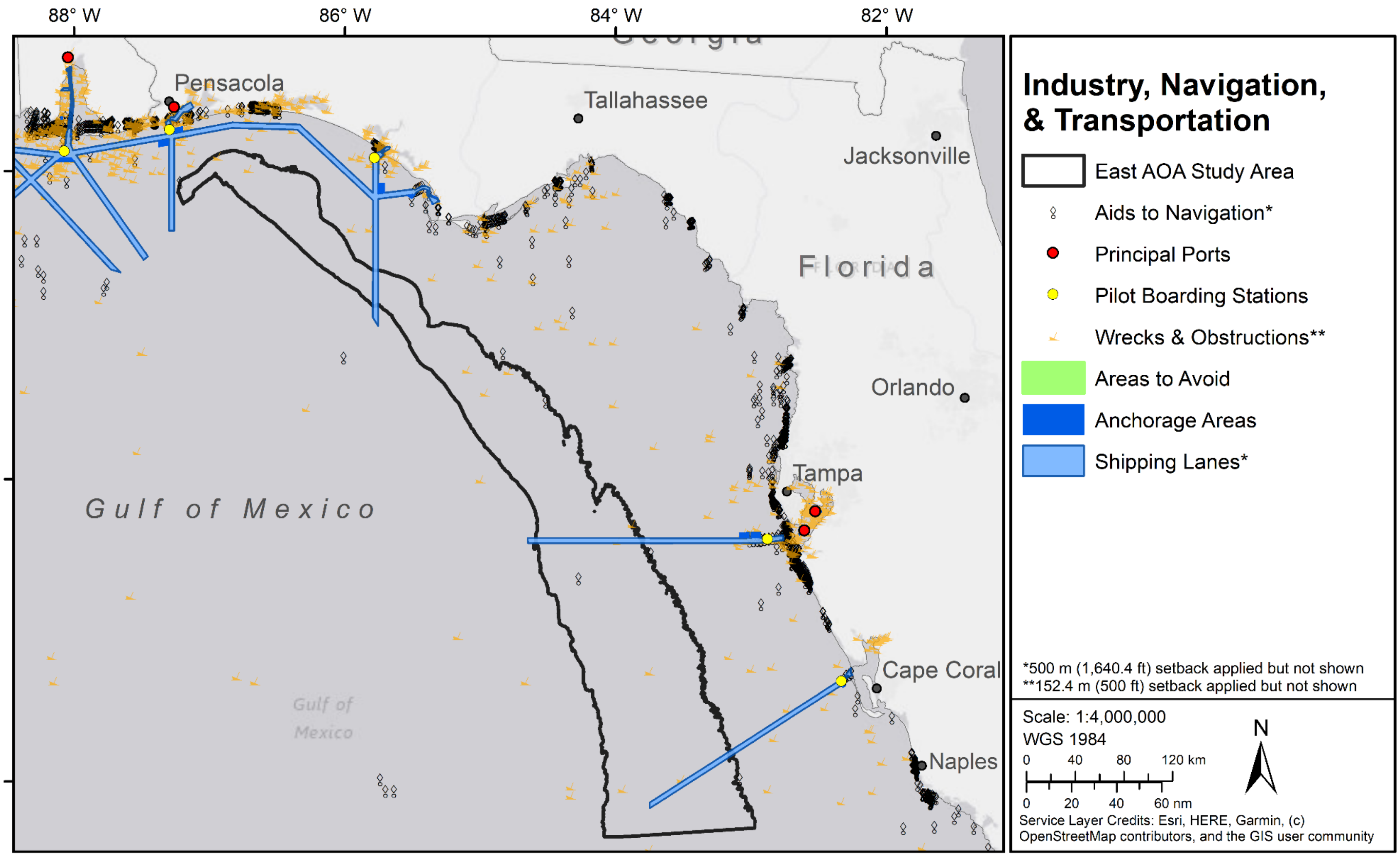

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Pilot Boarding Stations: NOAA OCM and BOEM (2018)
Aids to Navigation: NOAA OCM and BOEM (2018)
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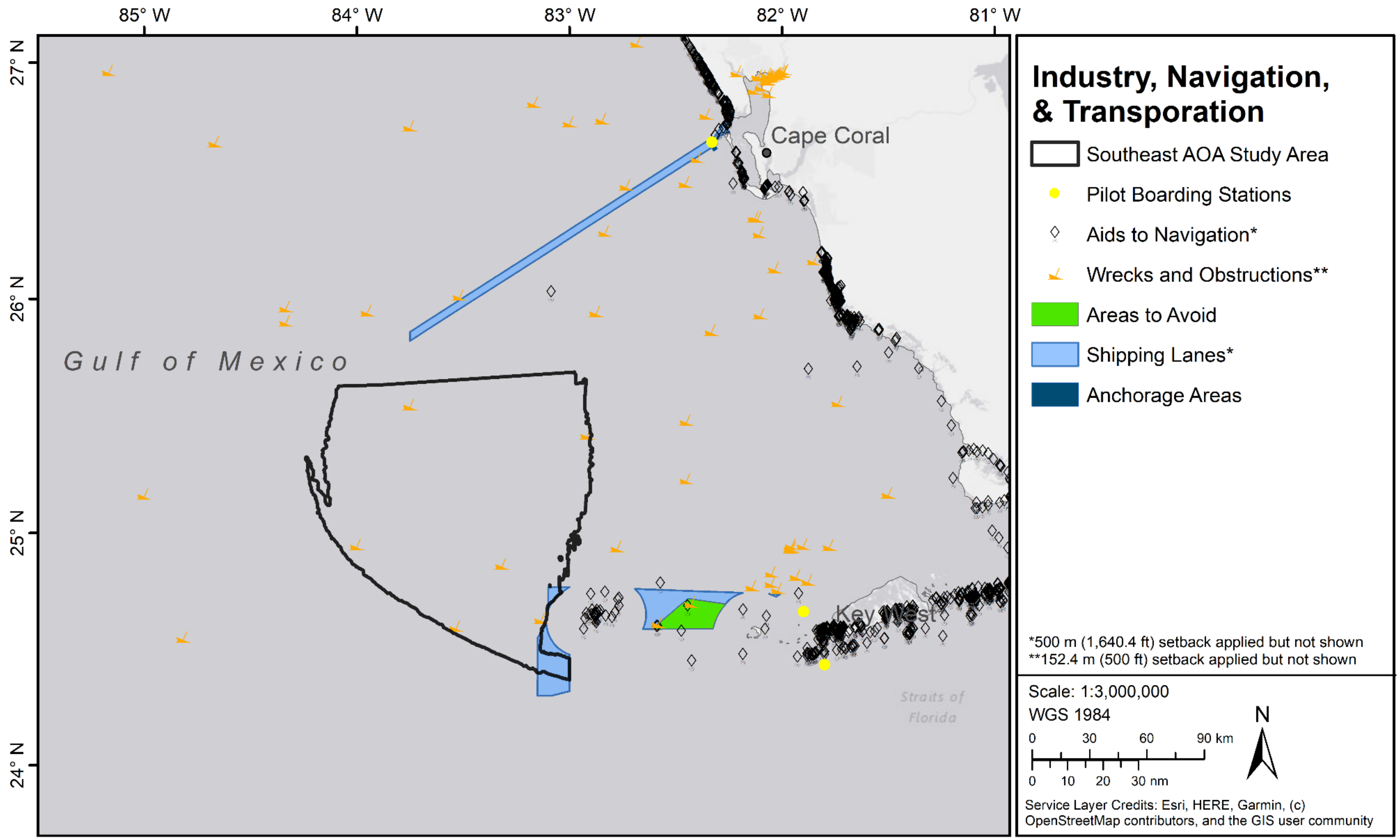

Pilot Boarding Stations: NOAA OCM and BOEM (2018)
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Wrecks and Obstructions: NOAA OCM and BOEM (2018)
Anchorage Areas: NOAA OCM and BOEM (2018)
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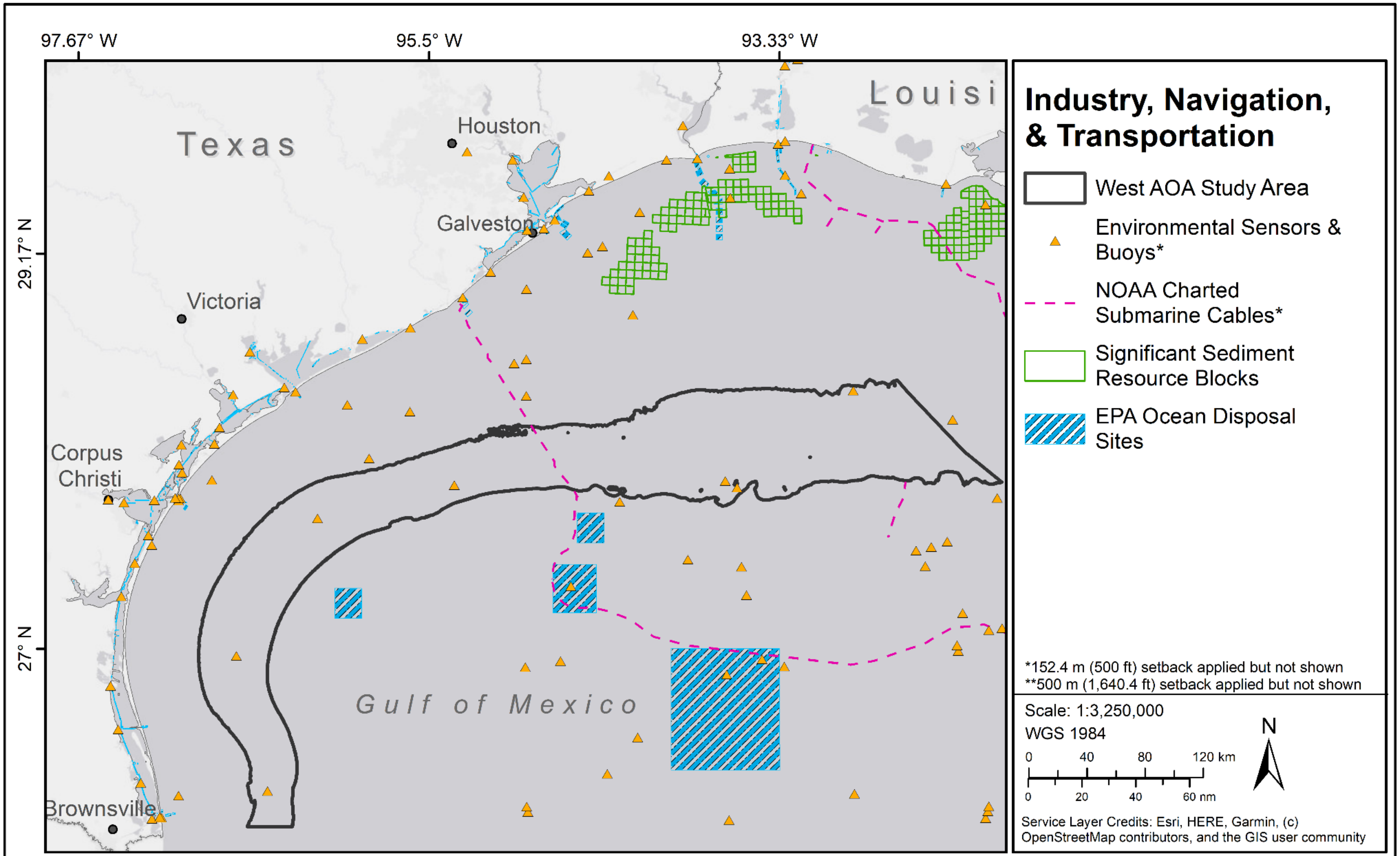

Environmental Sensors & Buoys: National Data Buoy Center (2019)
NOAA Charted Submarine Cables: NOAA OCM & BOEM (2018)
Environmental Protection Agency Ocean Disposal Sites: NOAA OCM & BOEM (2018)
Significant Sediment Resource Blocks: NOAA OCM & BOEM (2018)

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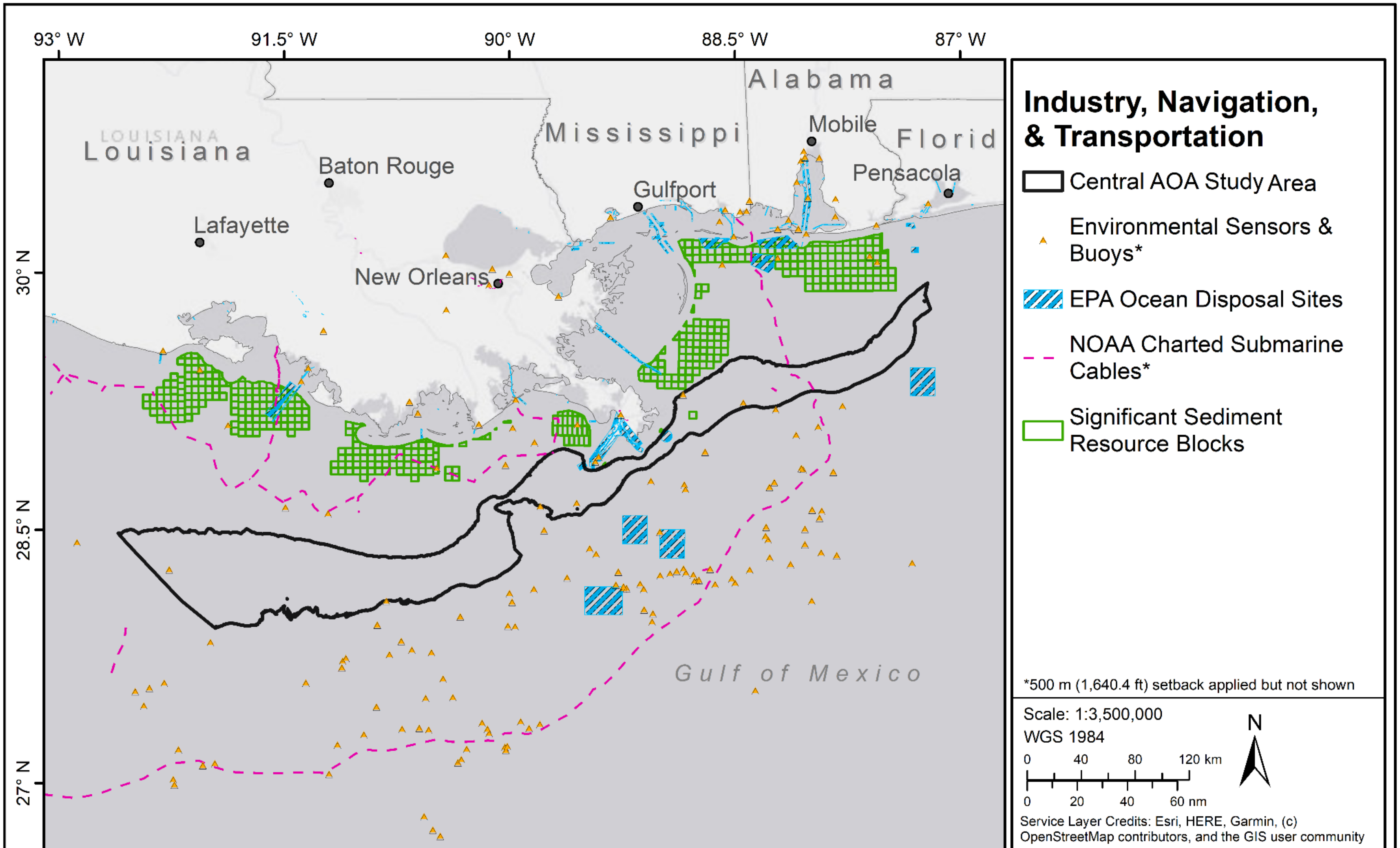

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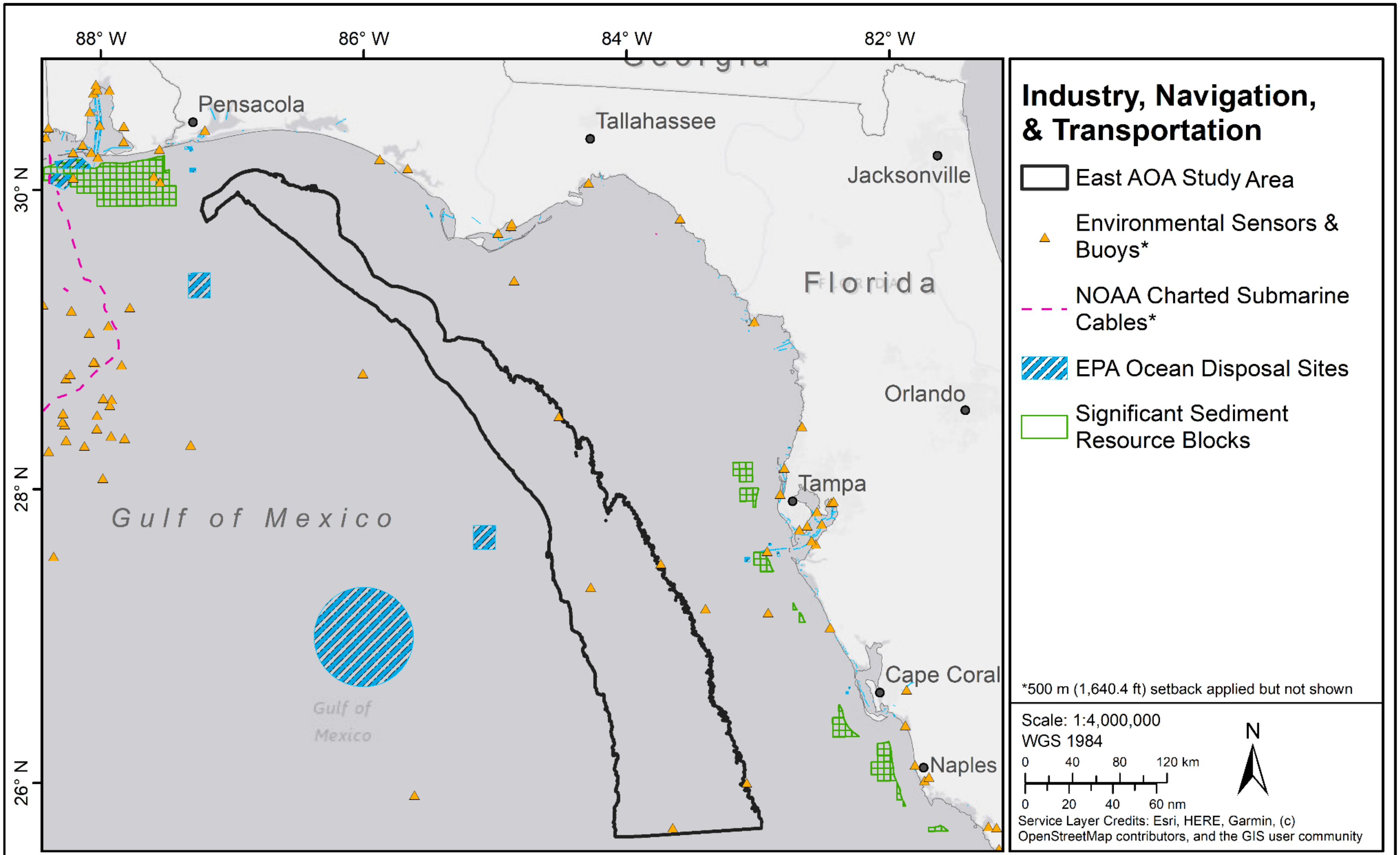

Environmental Sensors & Buoys: National Data Buoy Center (2019)
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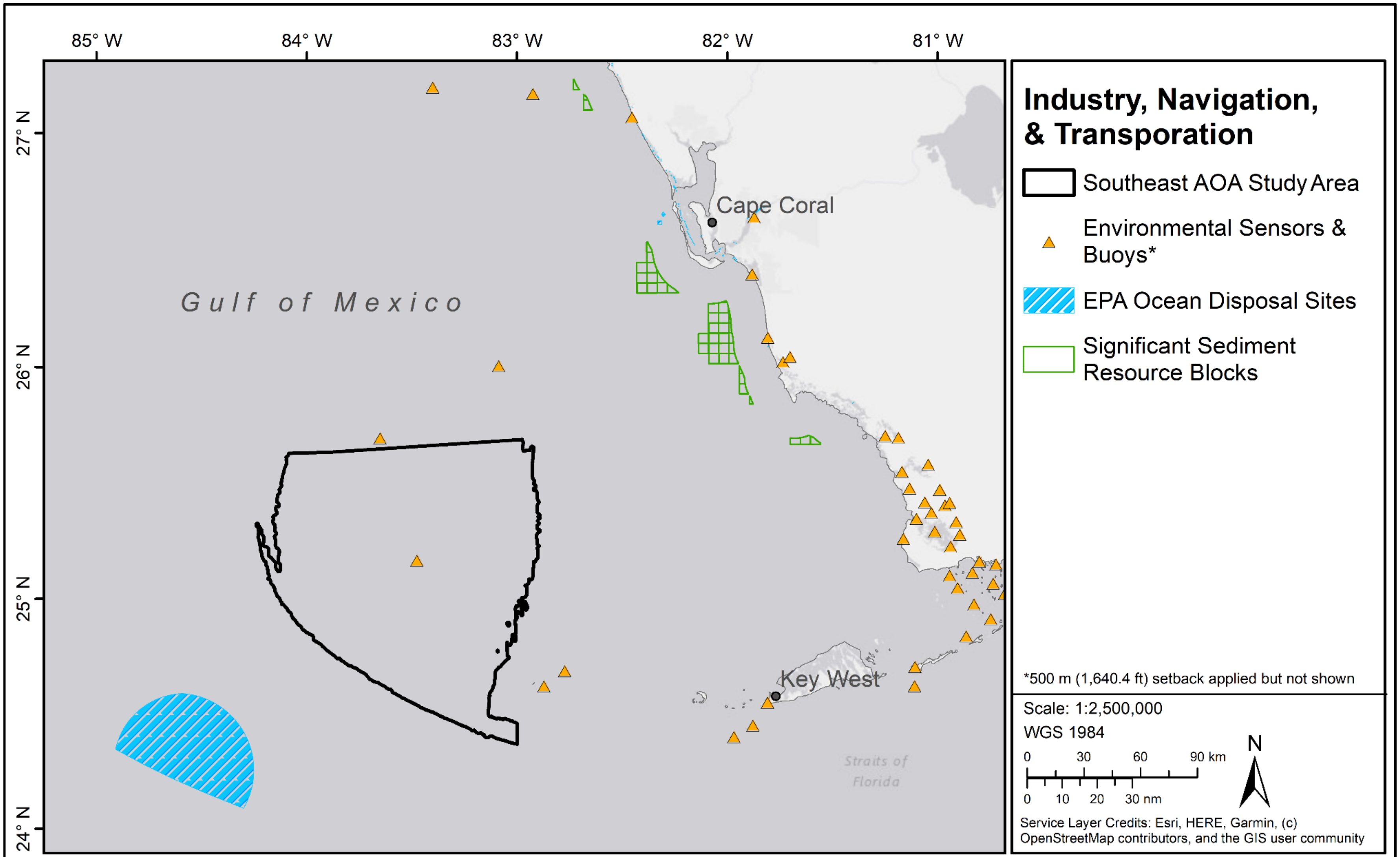

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Marine Spatial Ecology Division
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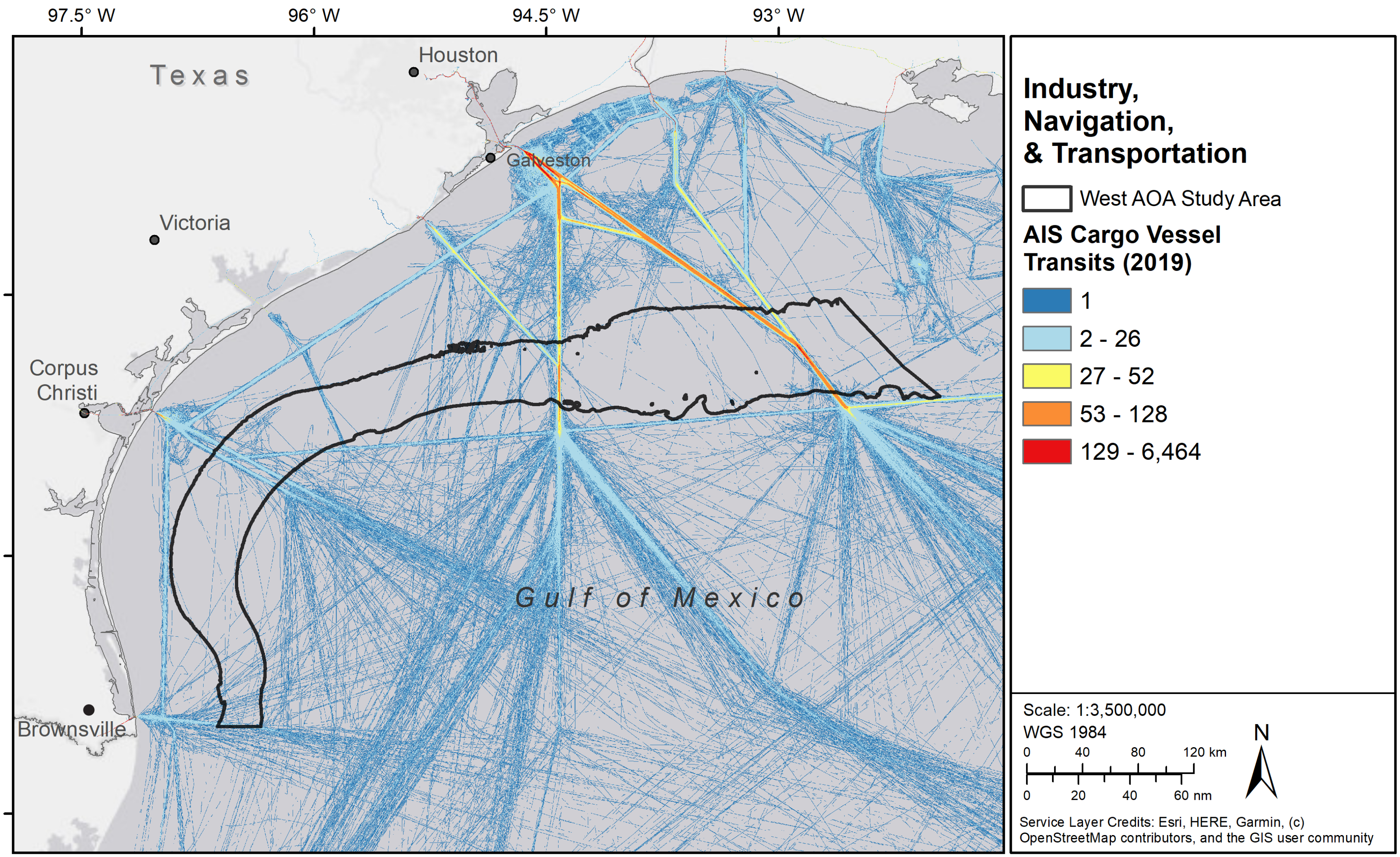

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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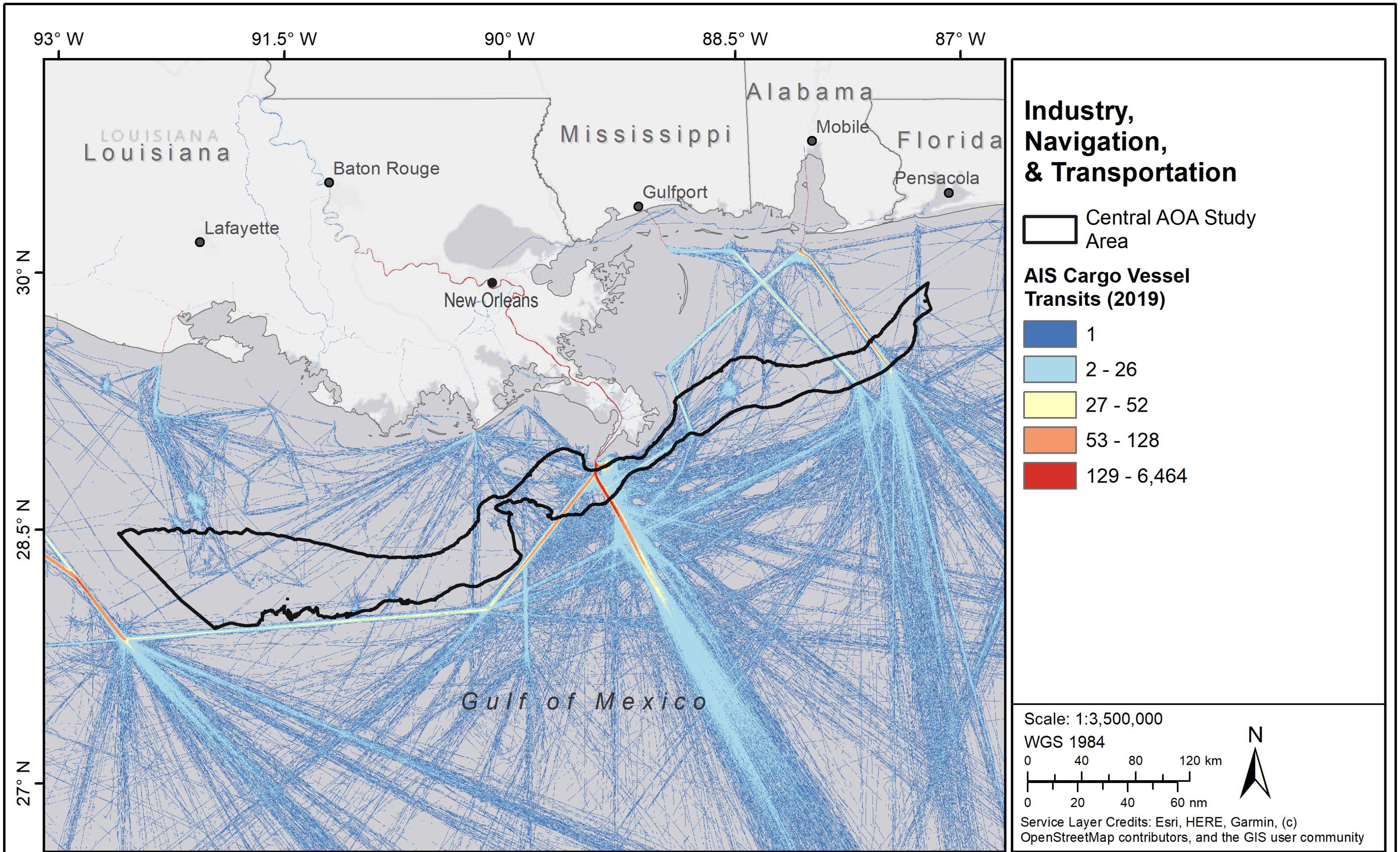

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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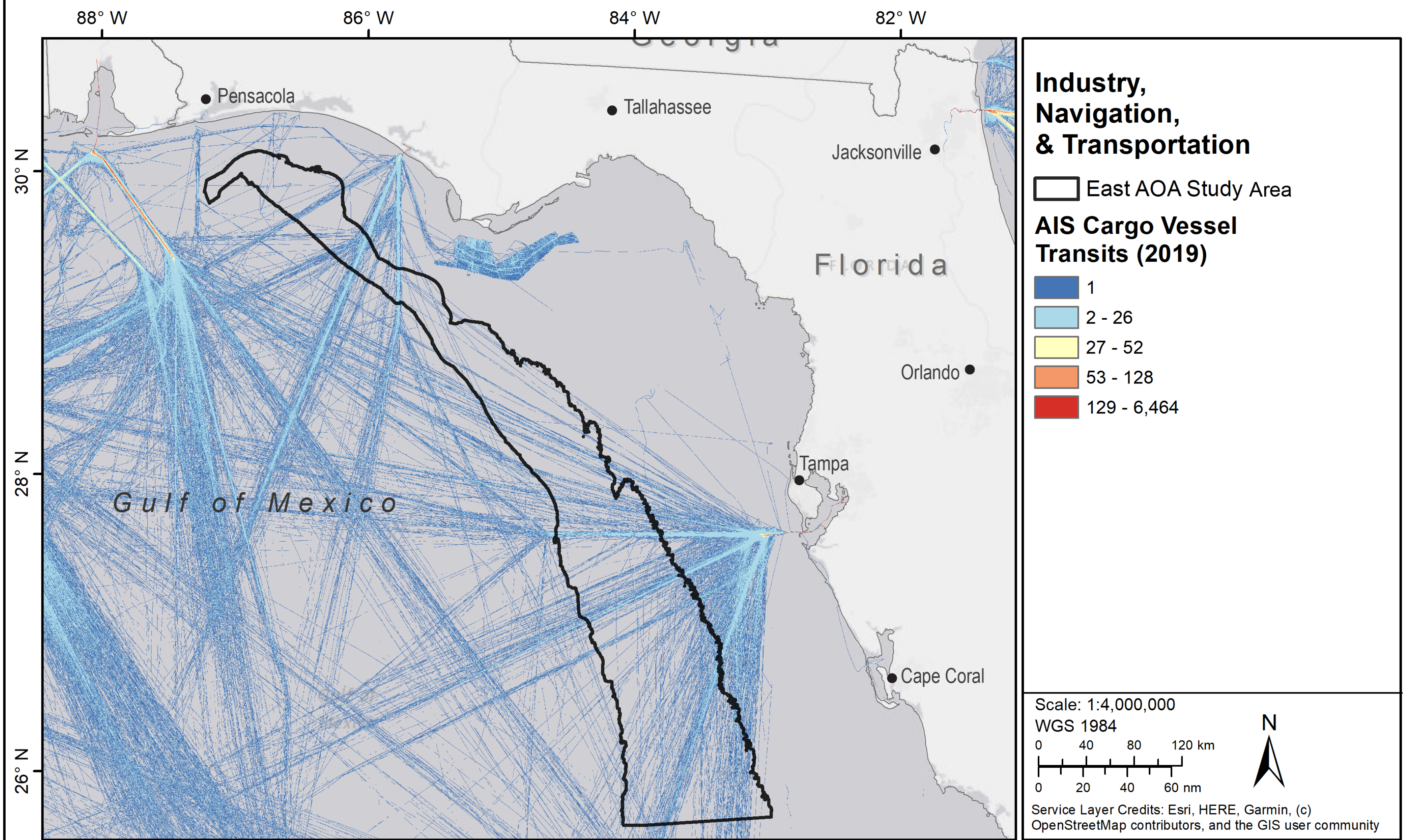

Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

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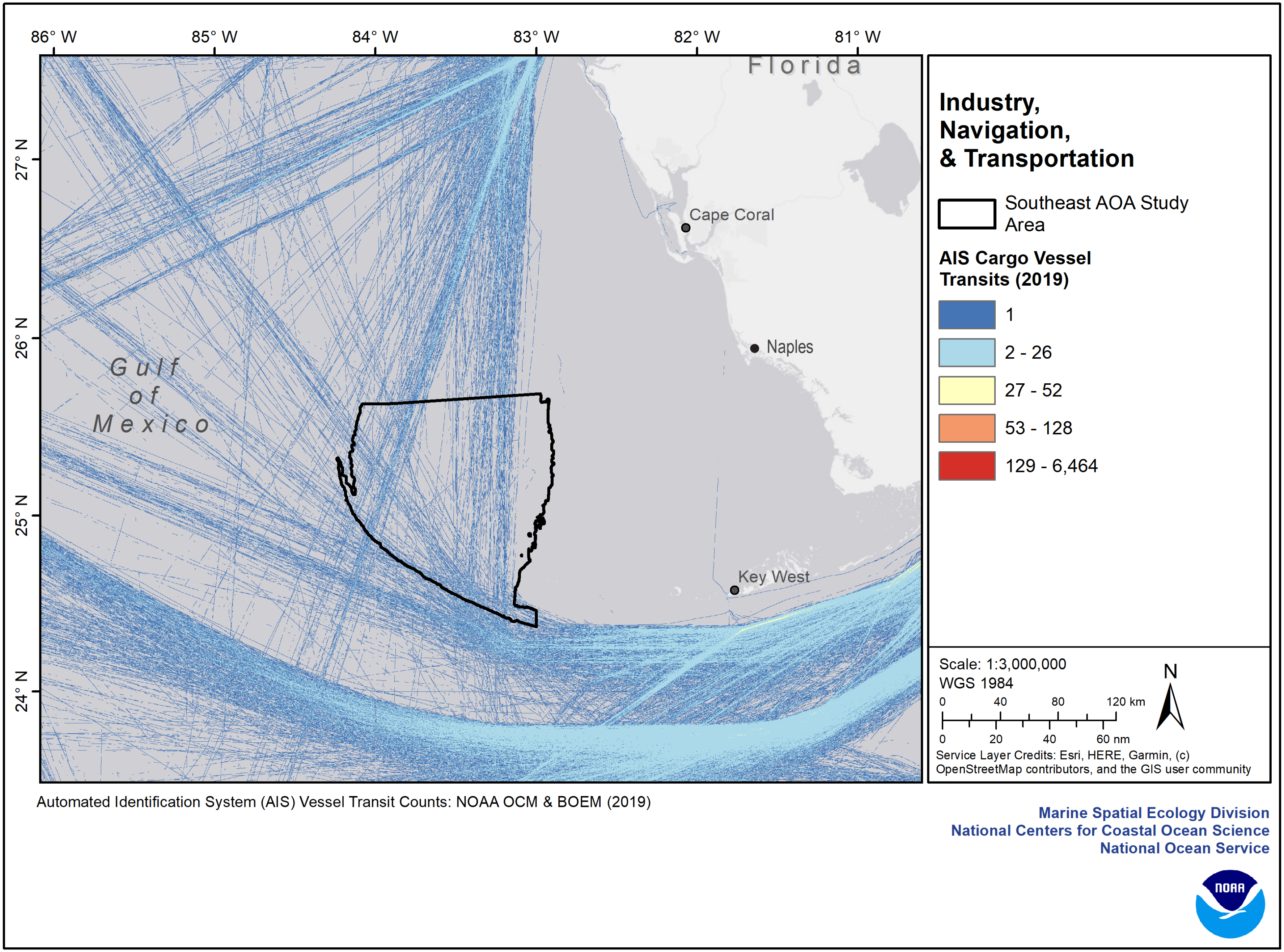
86° W
85° W
84° W
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26° N
25° N
24° N
Florida
Cape Coral
Naples
Key West
Gulf of Mexico
Industry, Navigation, & Transportation
Southeast AOA Study Area
AIS Cargo Vessel Transits (2019)
1
2 - 26
27 - 52
53 - 128
129 - 6,464
Scale: 1:3,000,000
WGS 1984
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0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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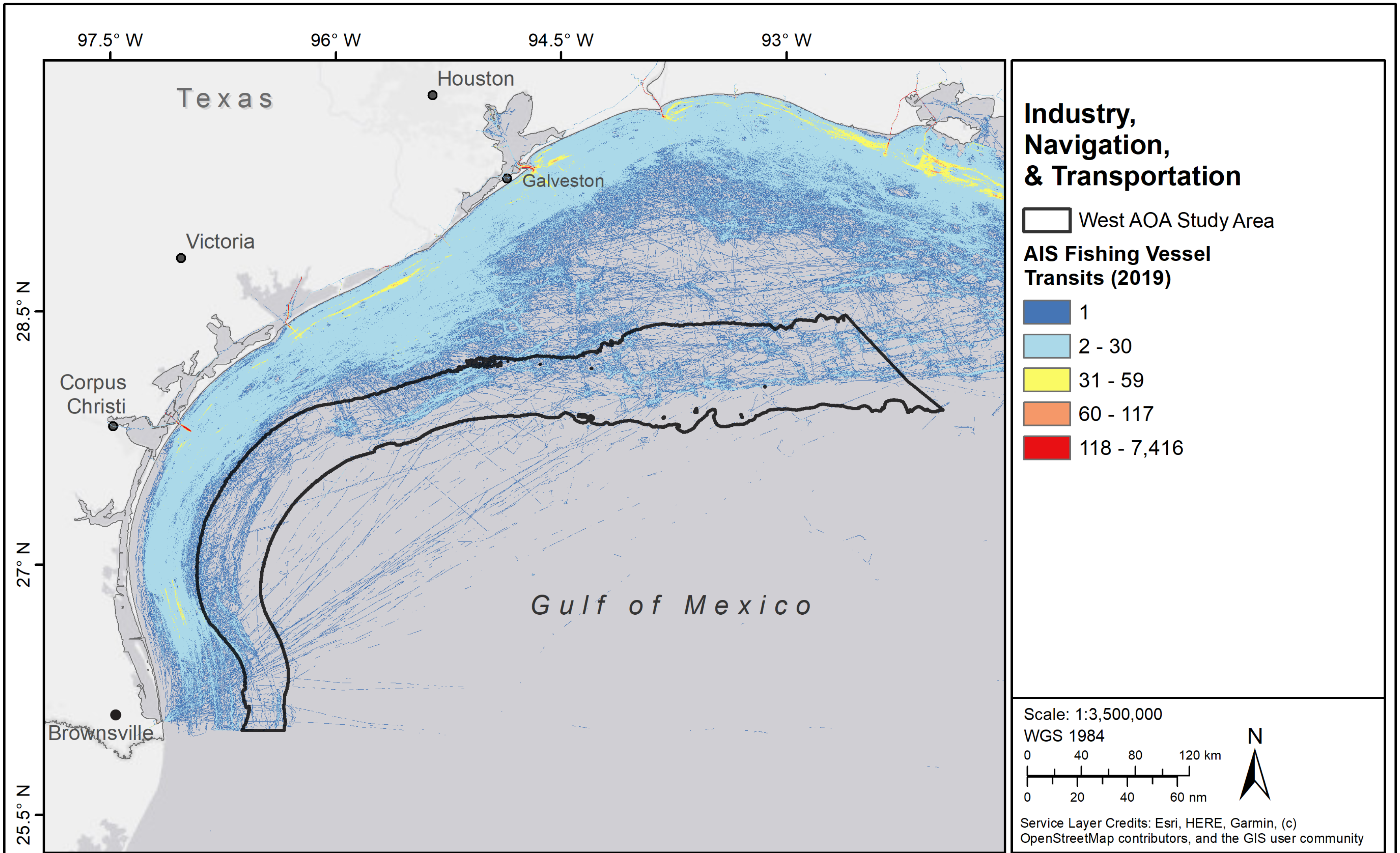

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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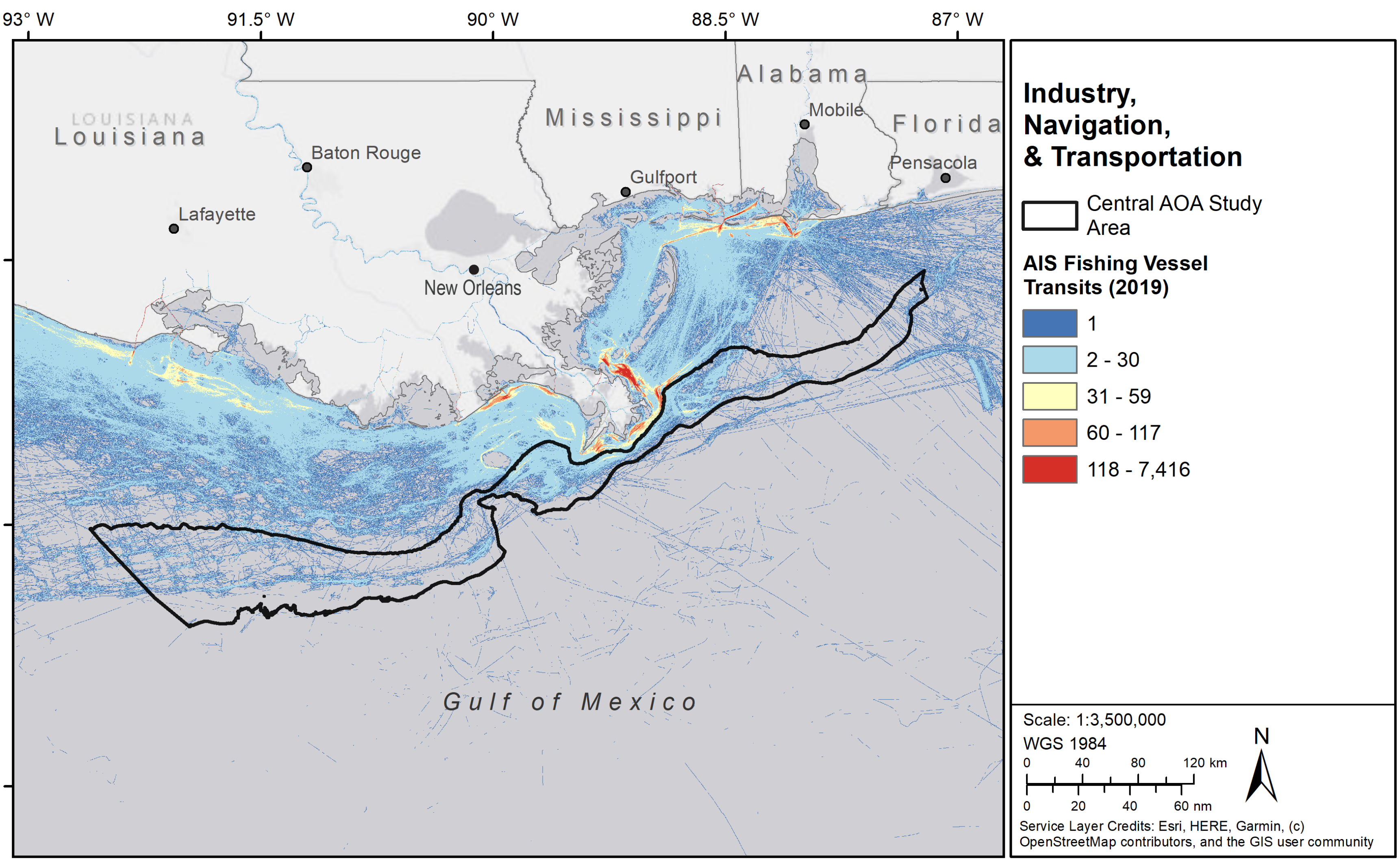

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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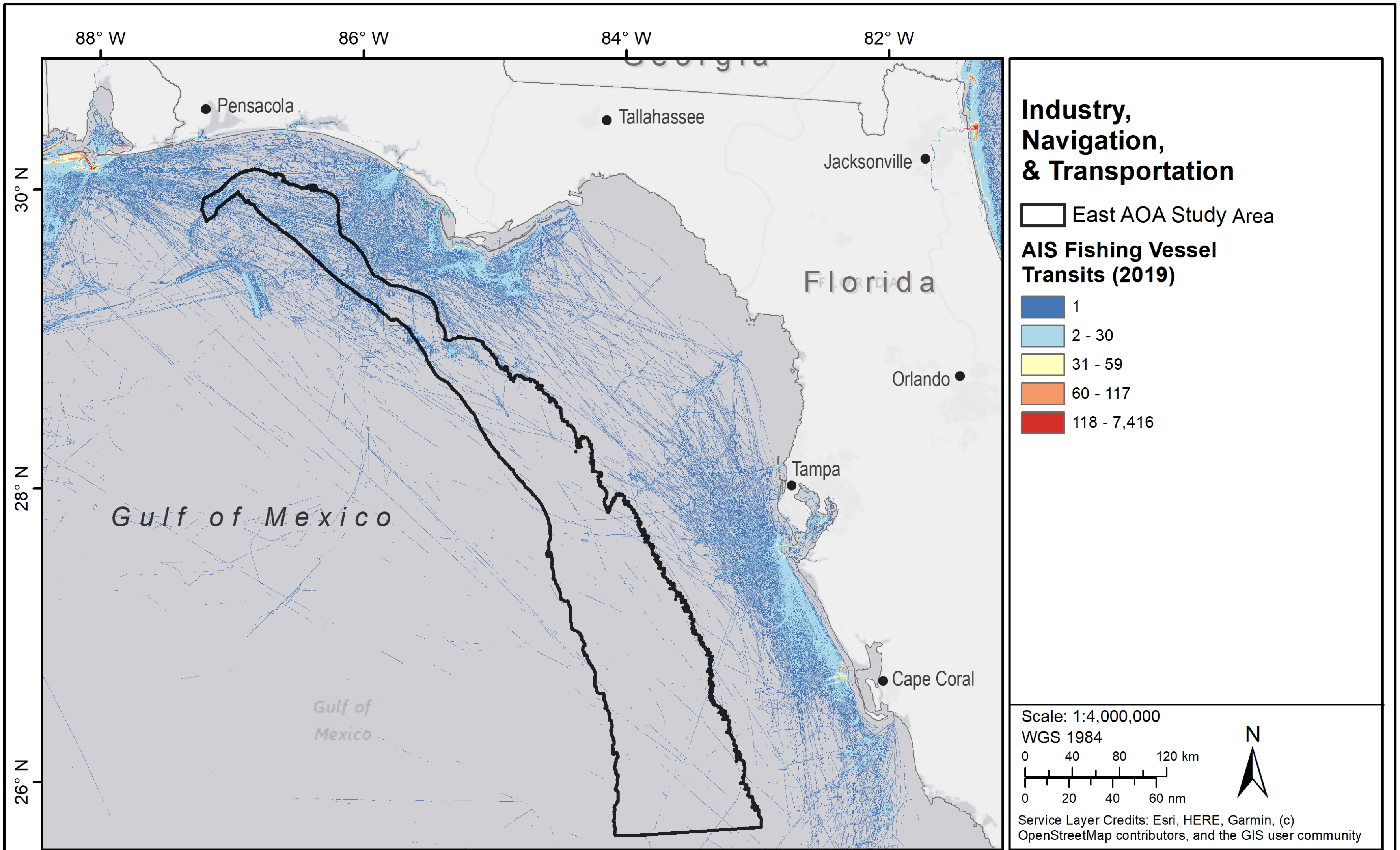

Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

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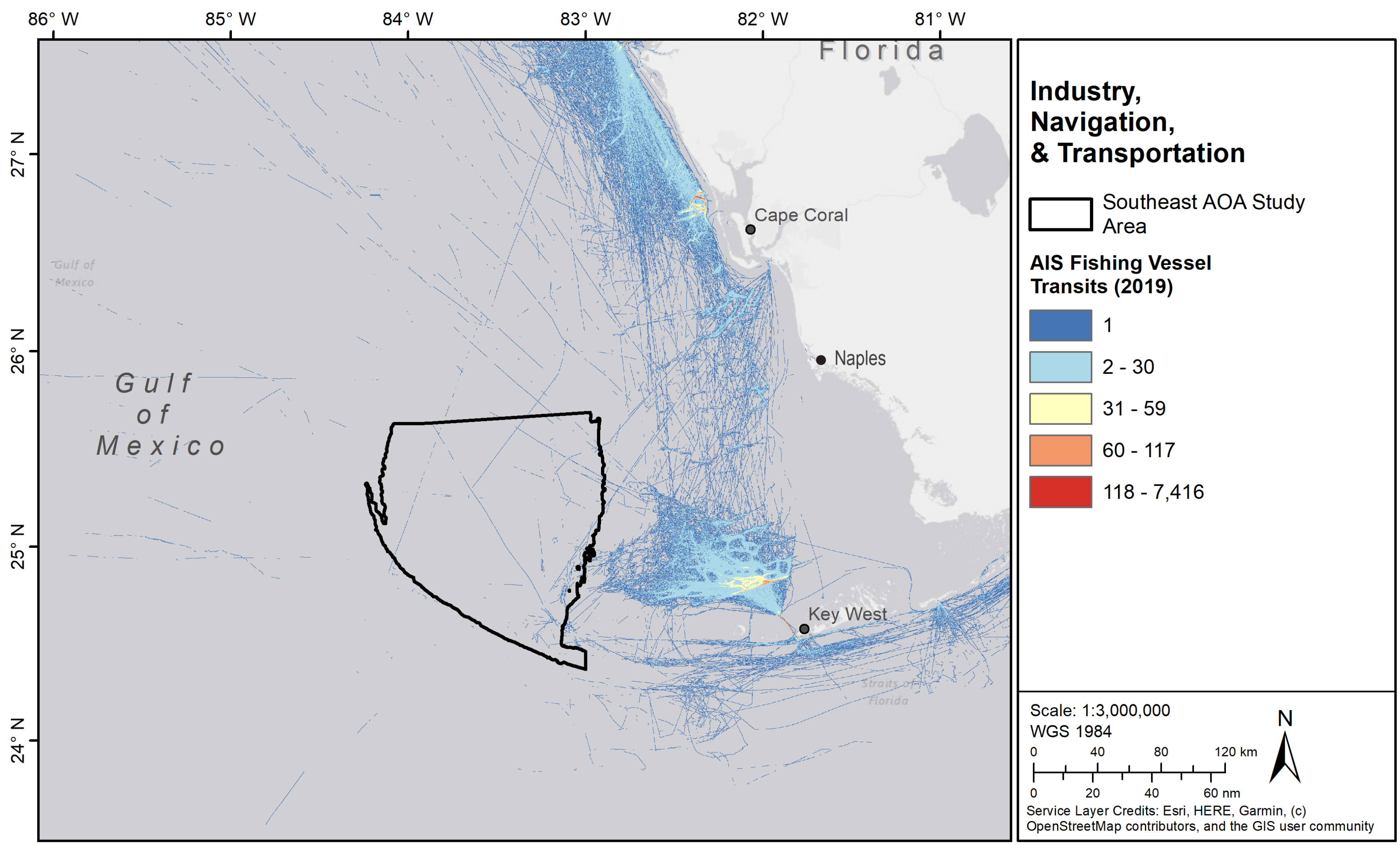

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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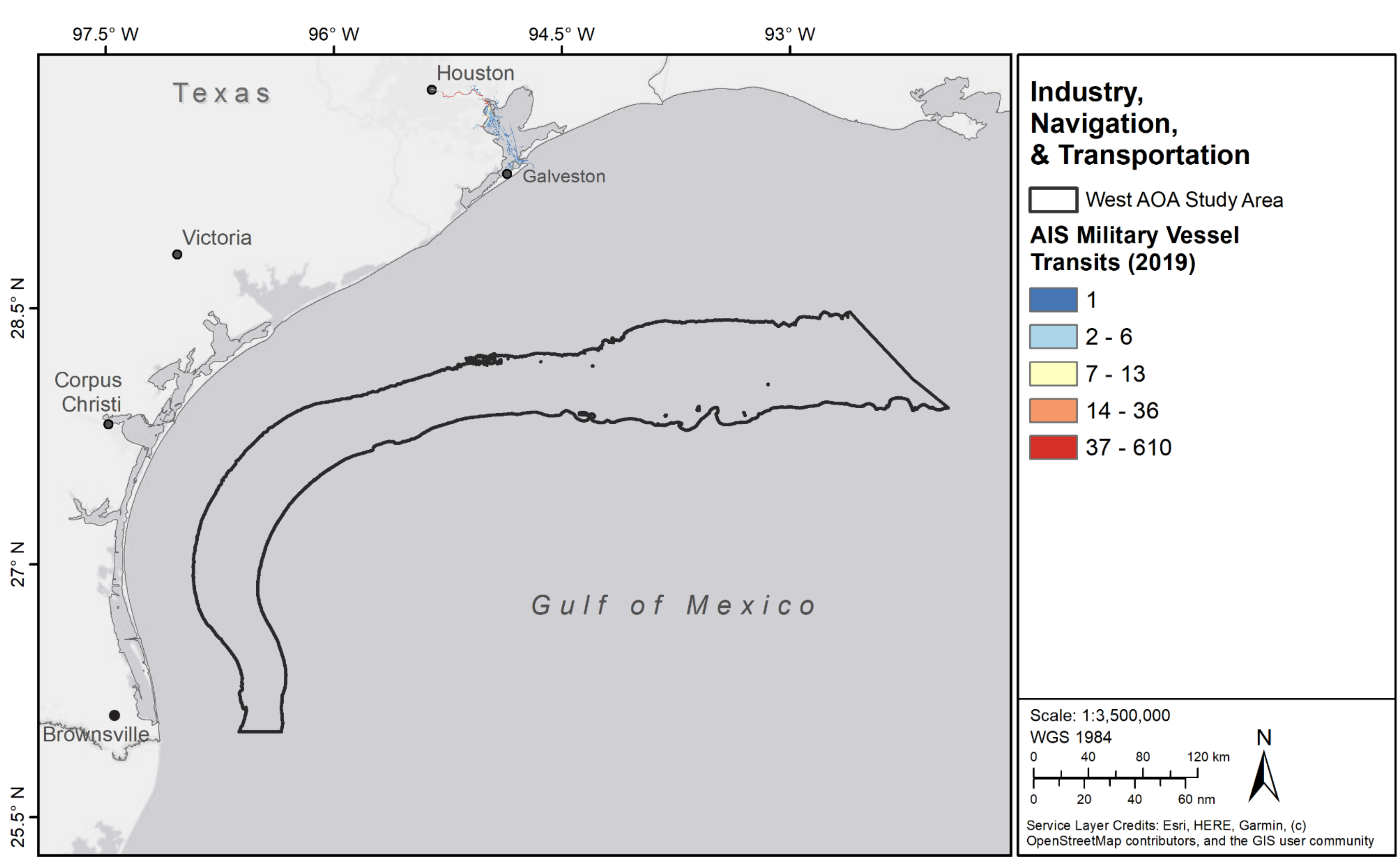
National Ocean Service



Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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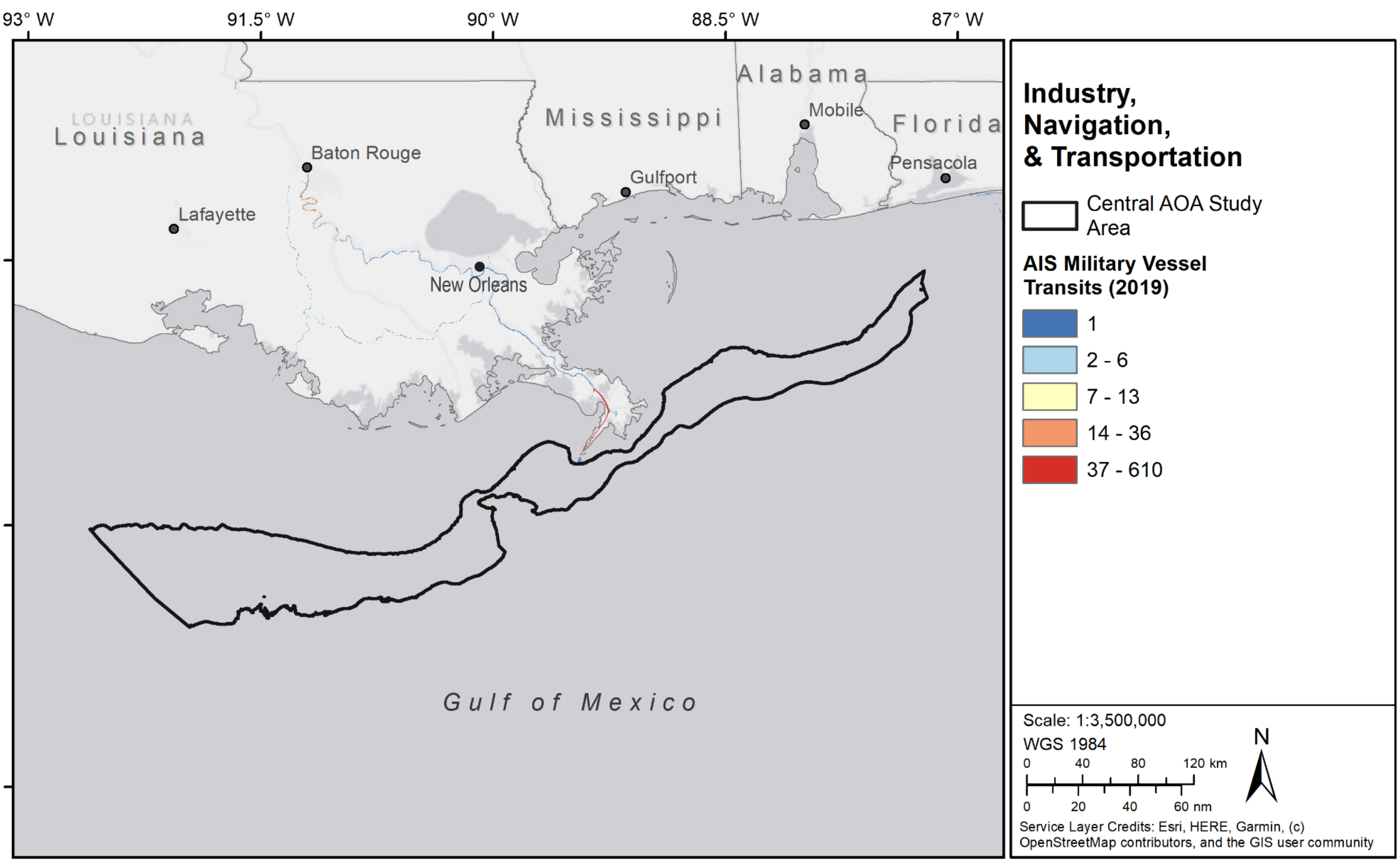
National Ocean Service



Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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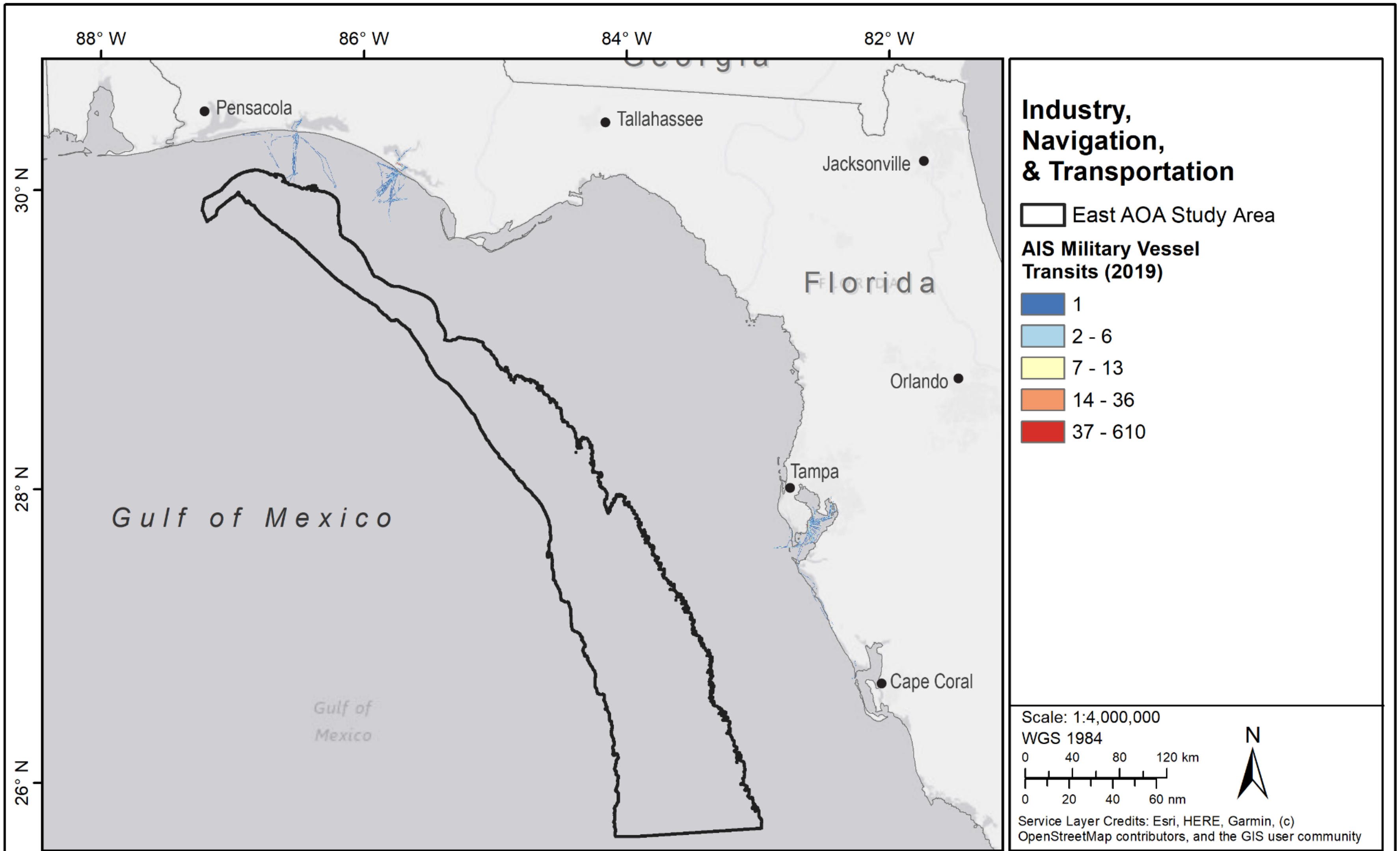

Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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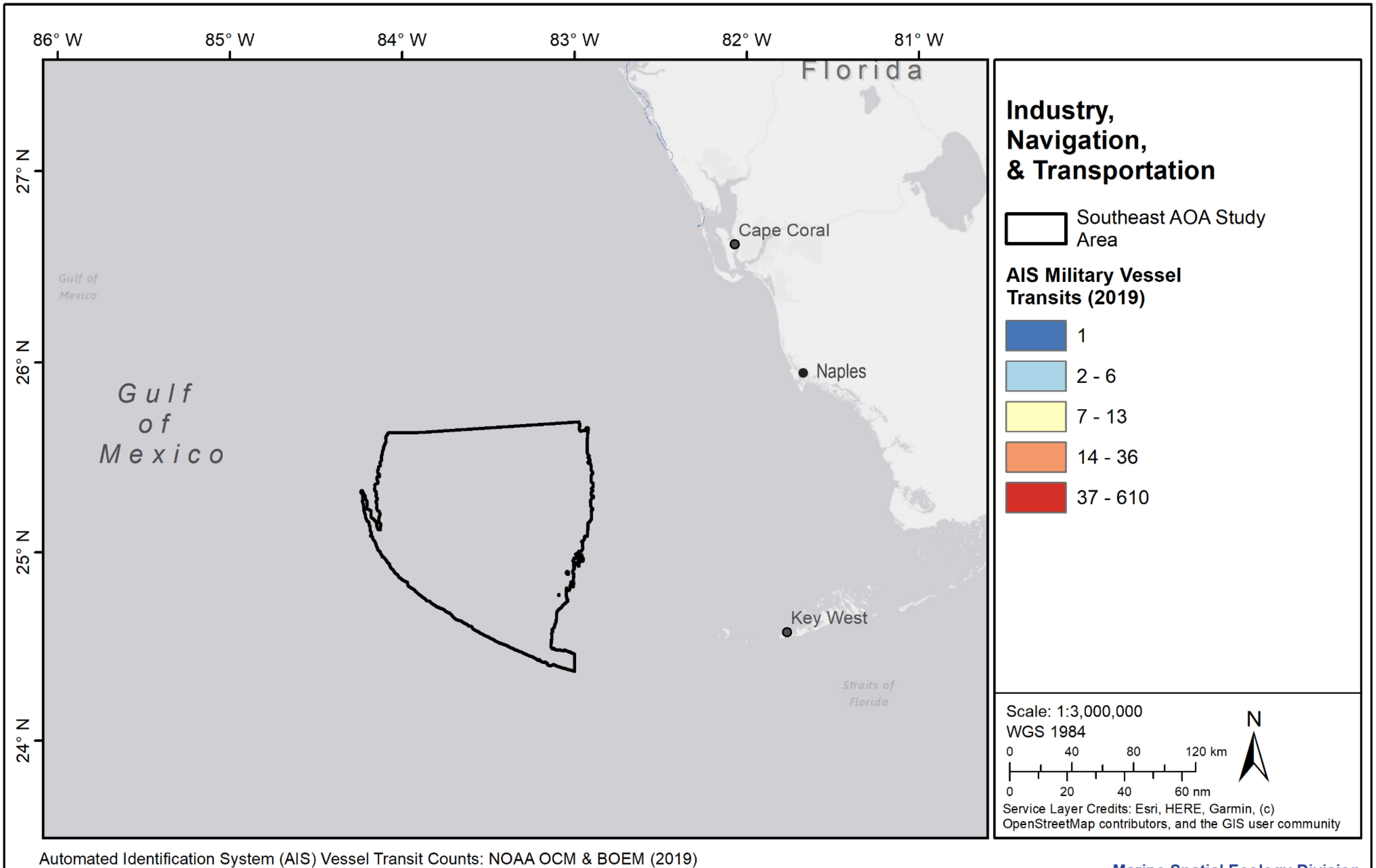

Marine Spatial Ecology Division
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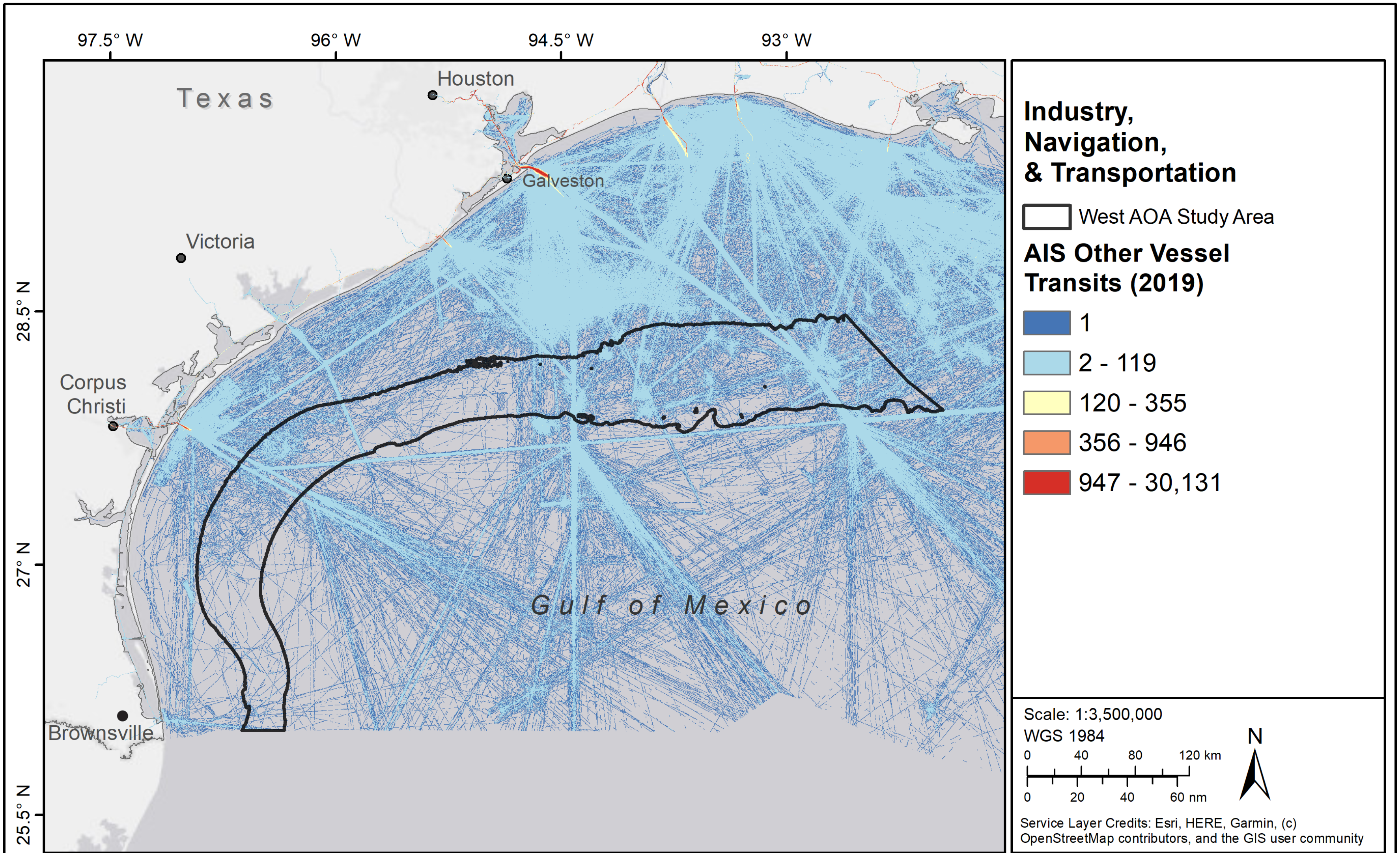
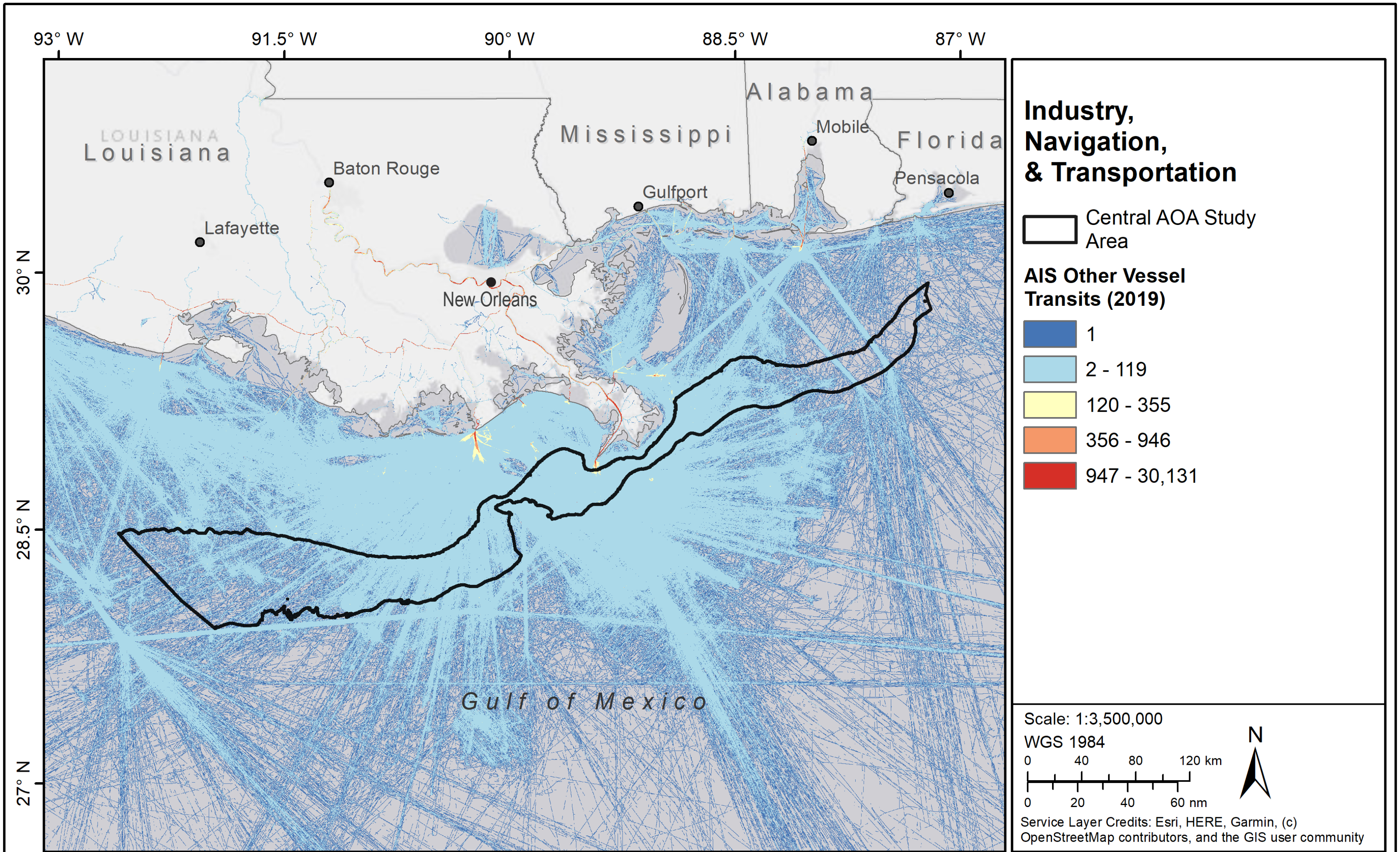


Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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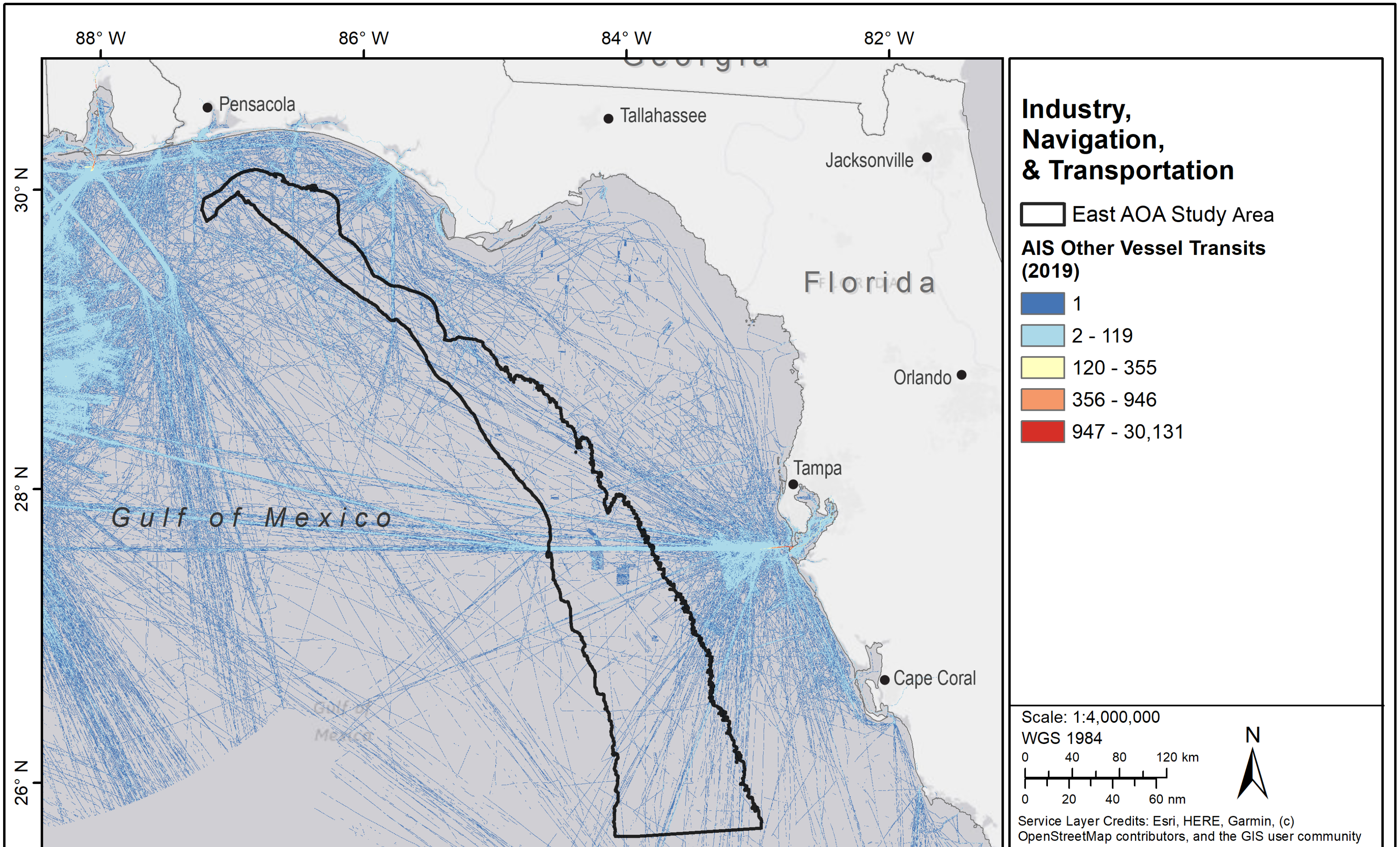

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National Centers for Coastal Ocean Science
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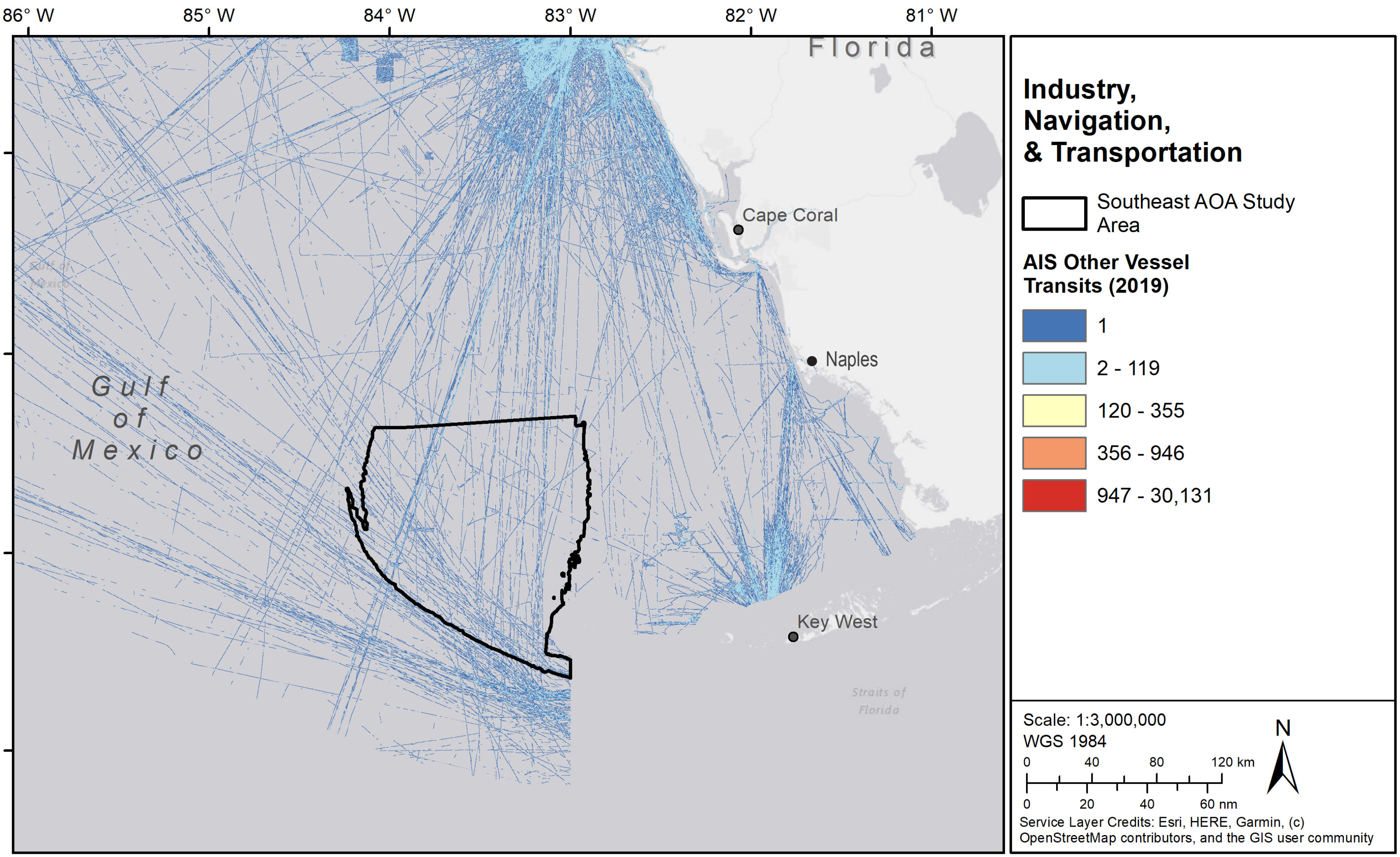

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
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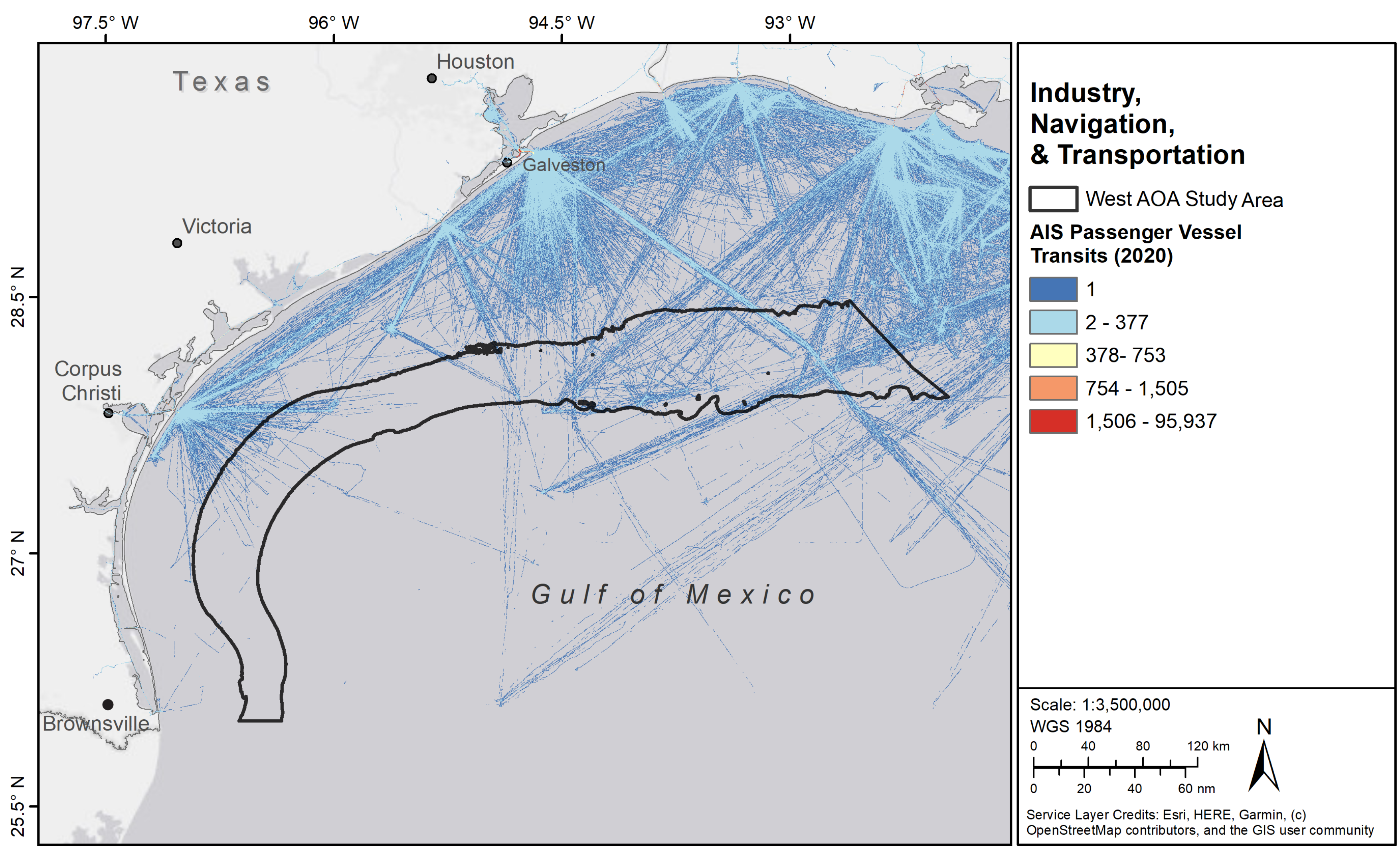

Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

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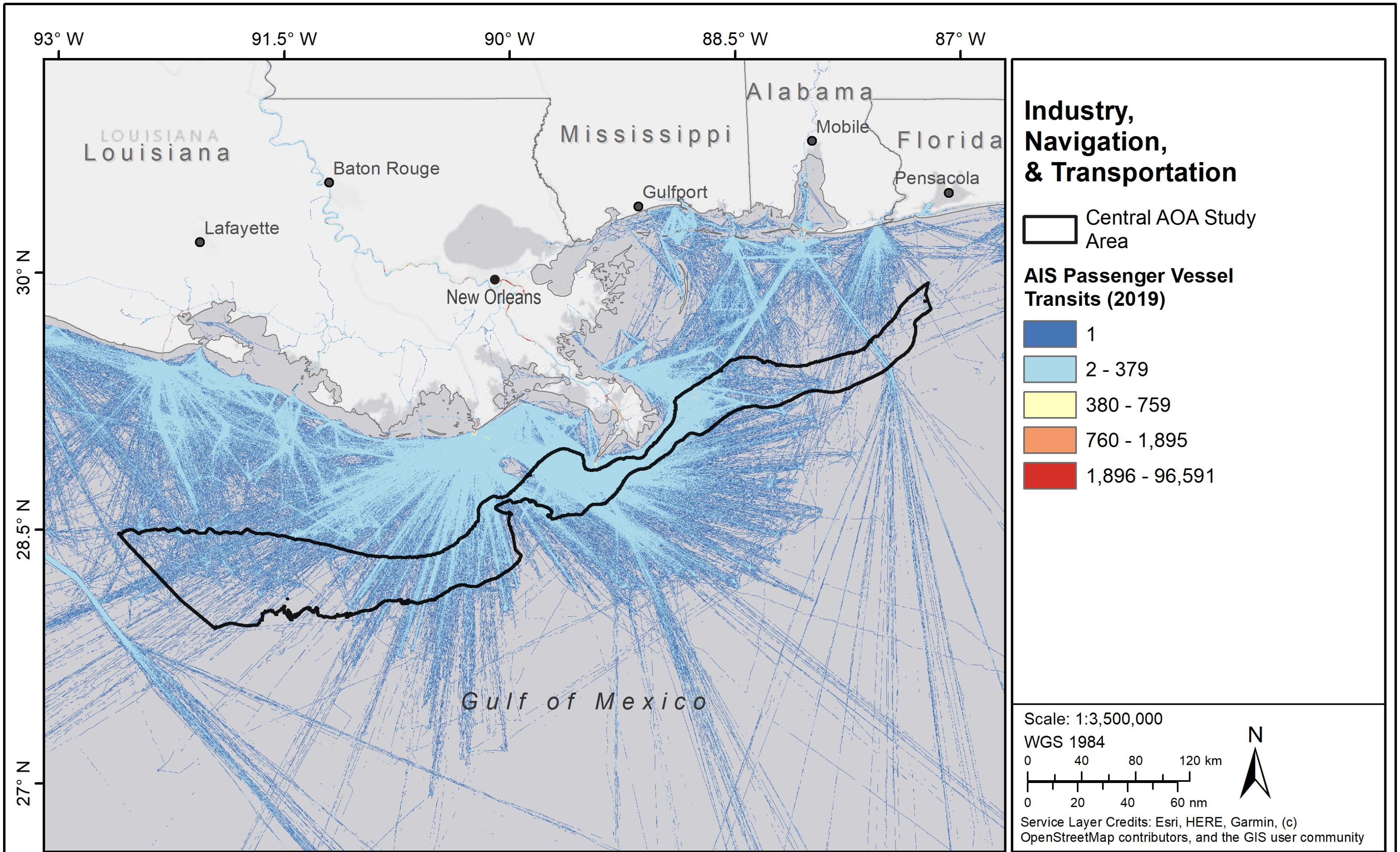

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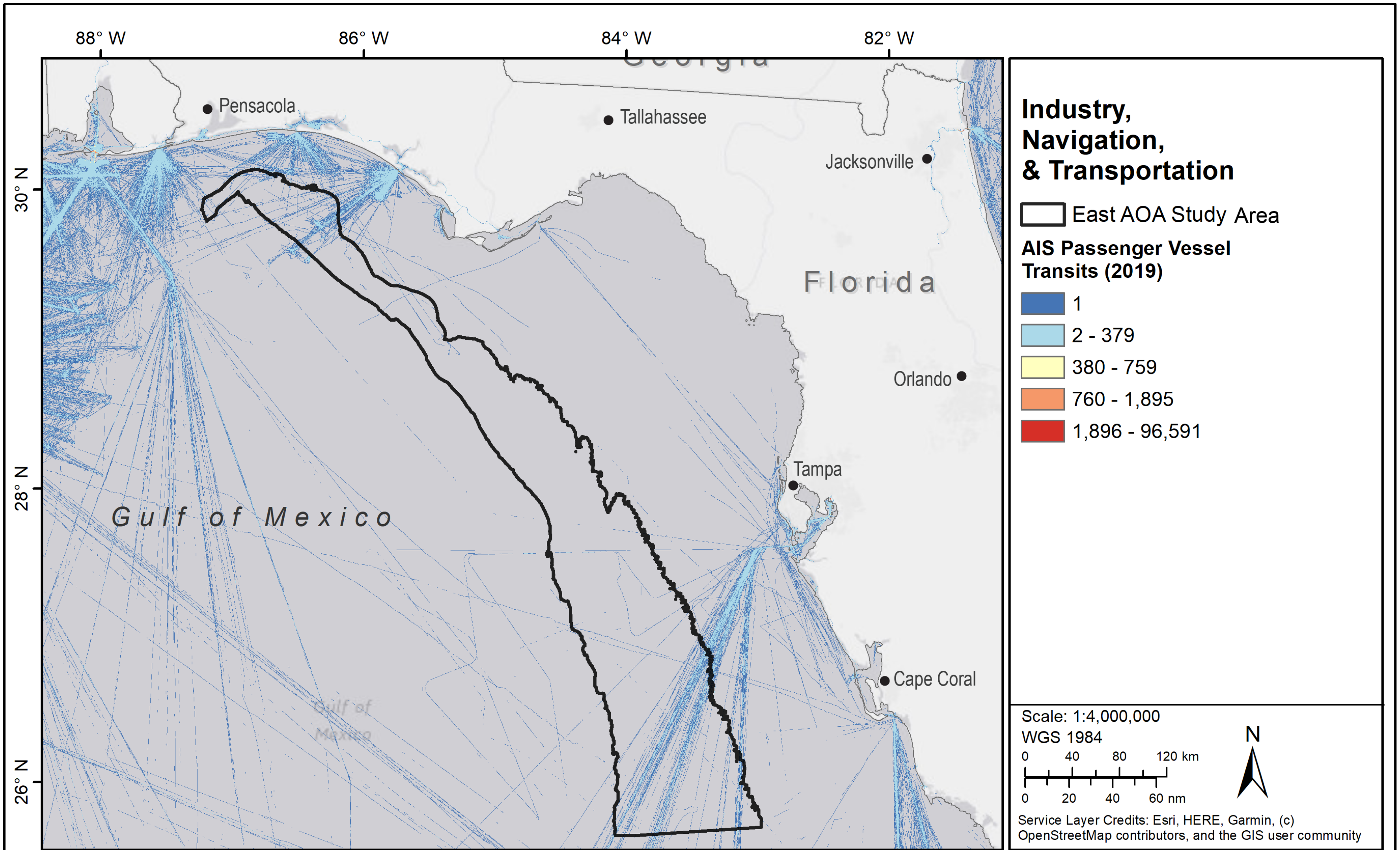
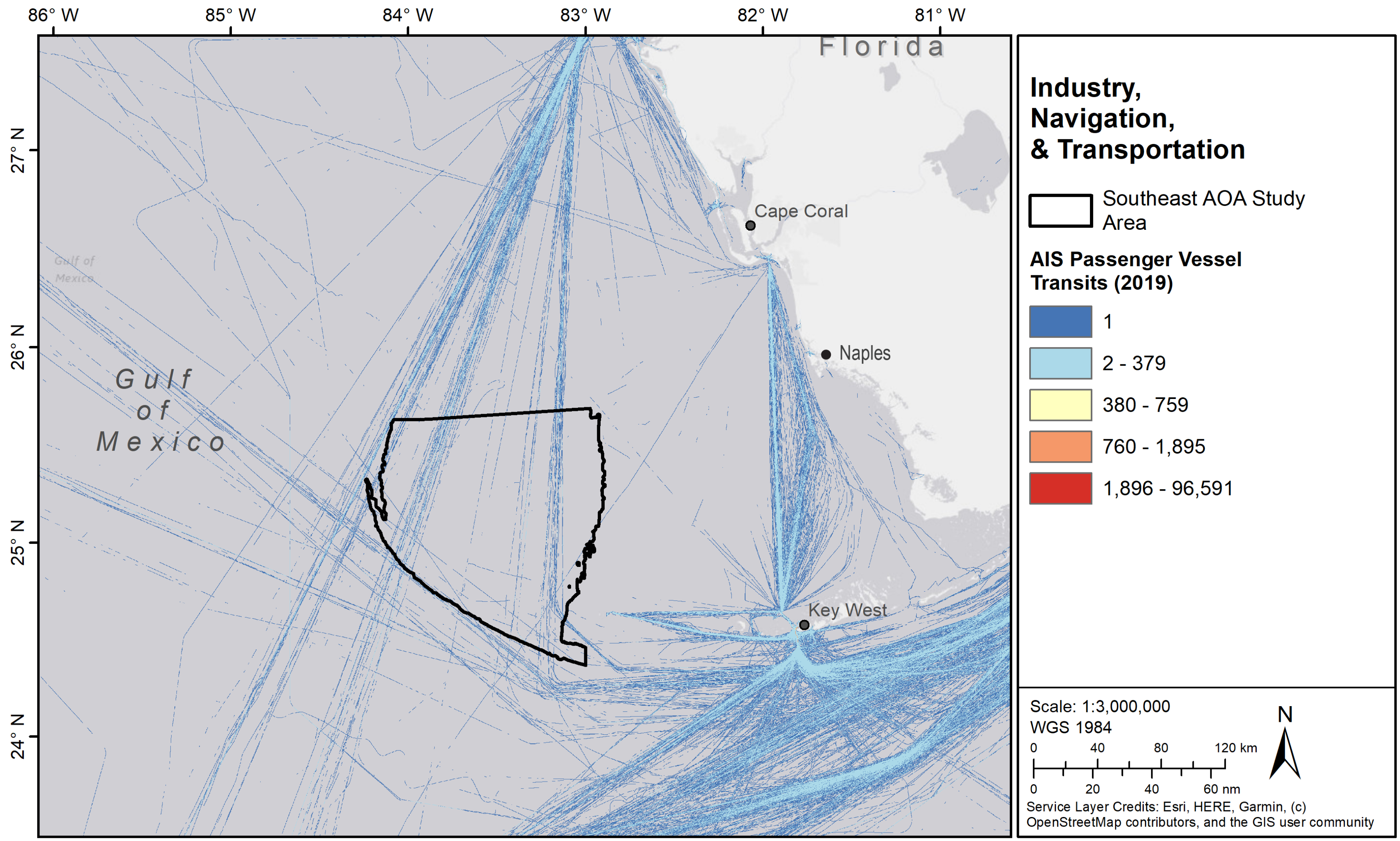
National Centers for Coastal Ocean Science
National Ocean Service



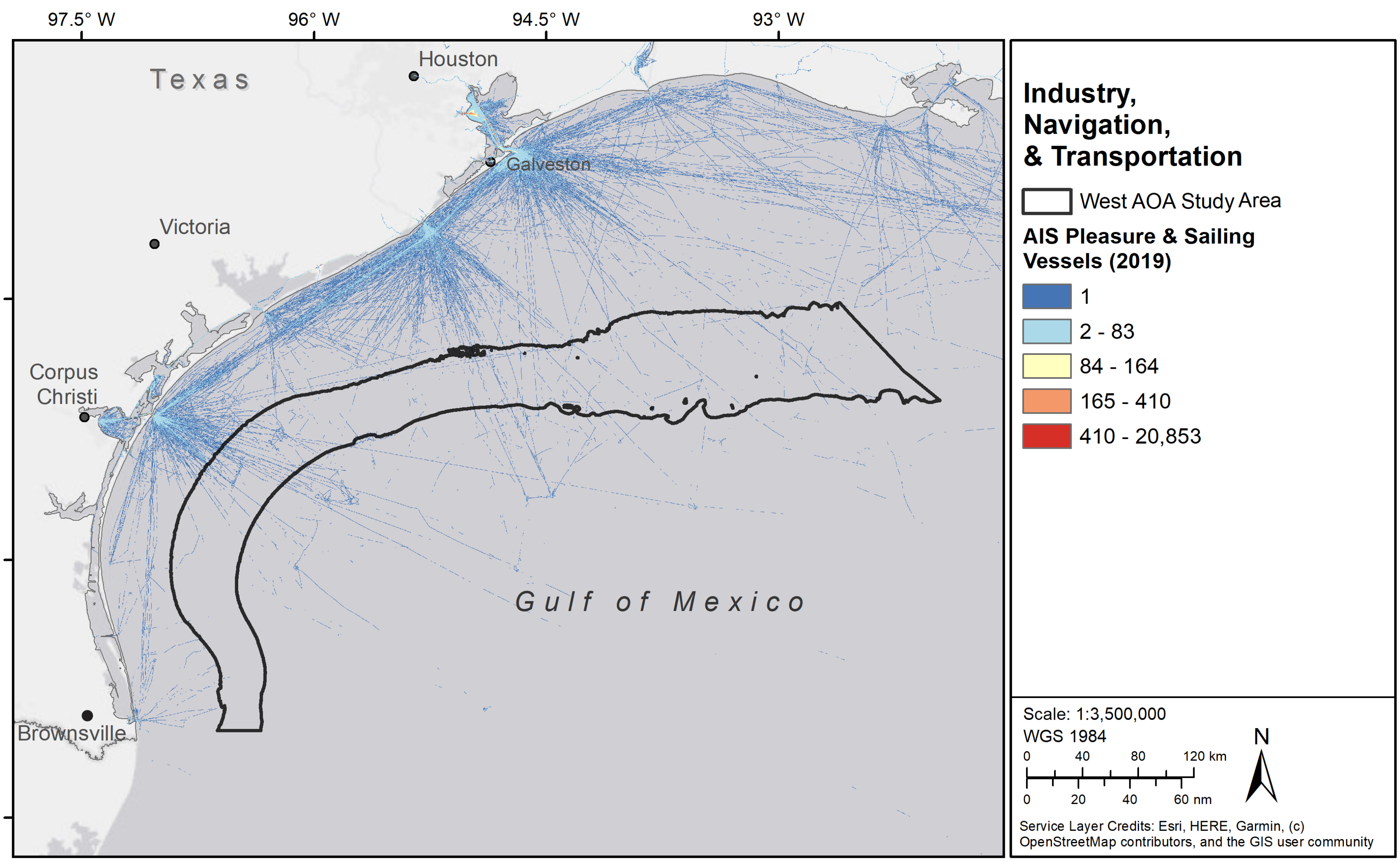
Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



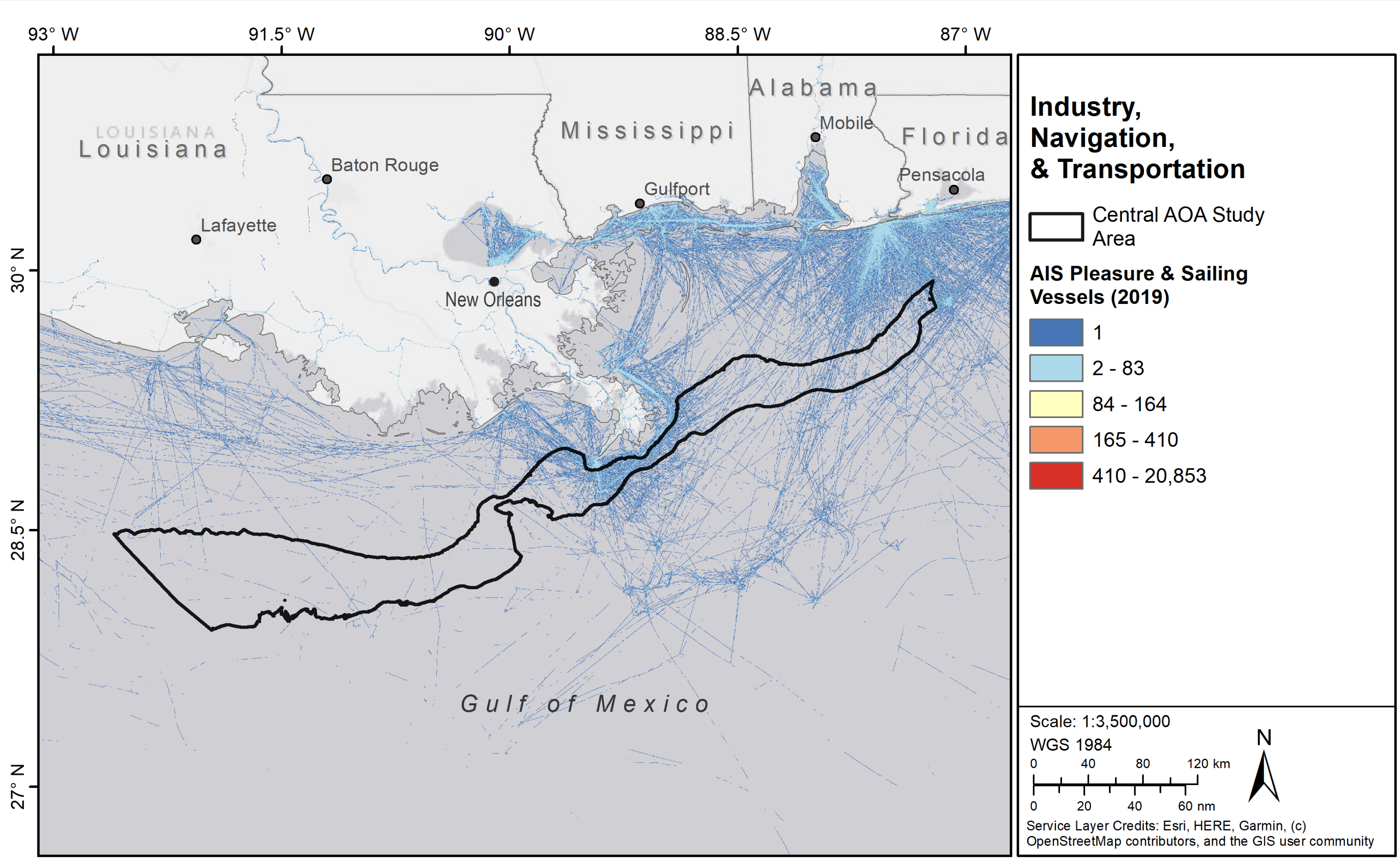
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



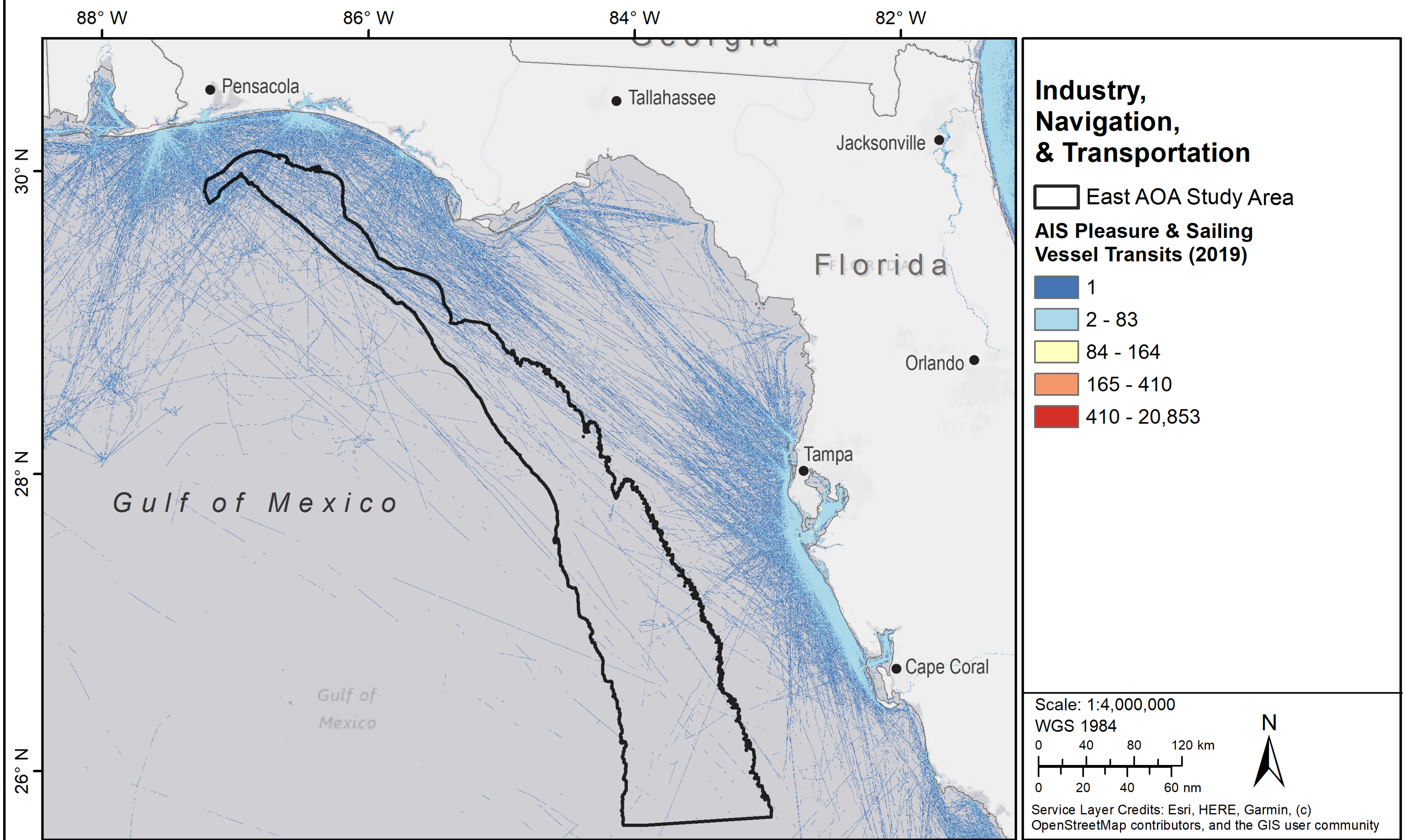
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



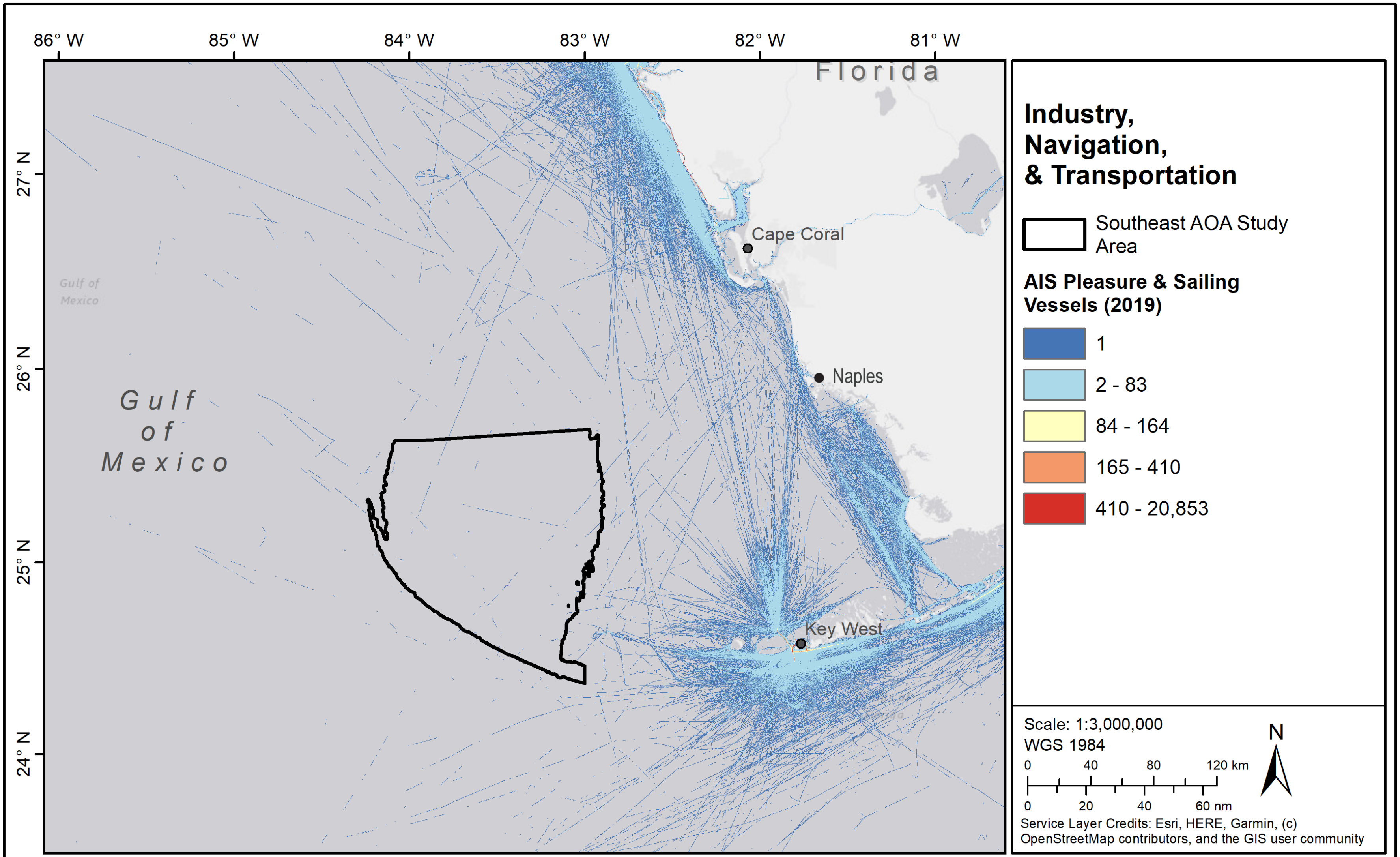
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



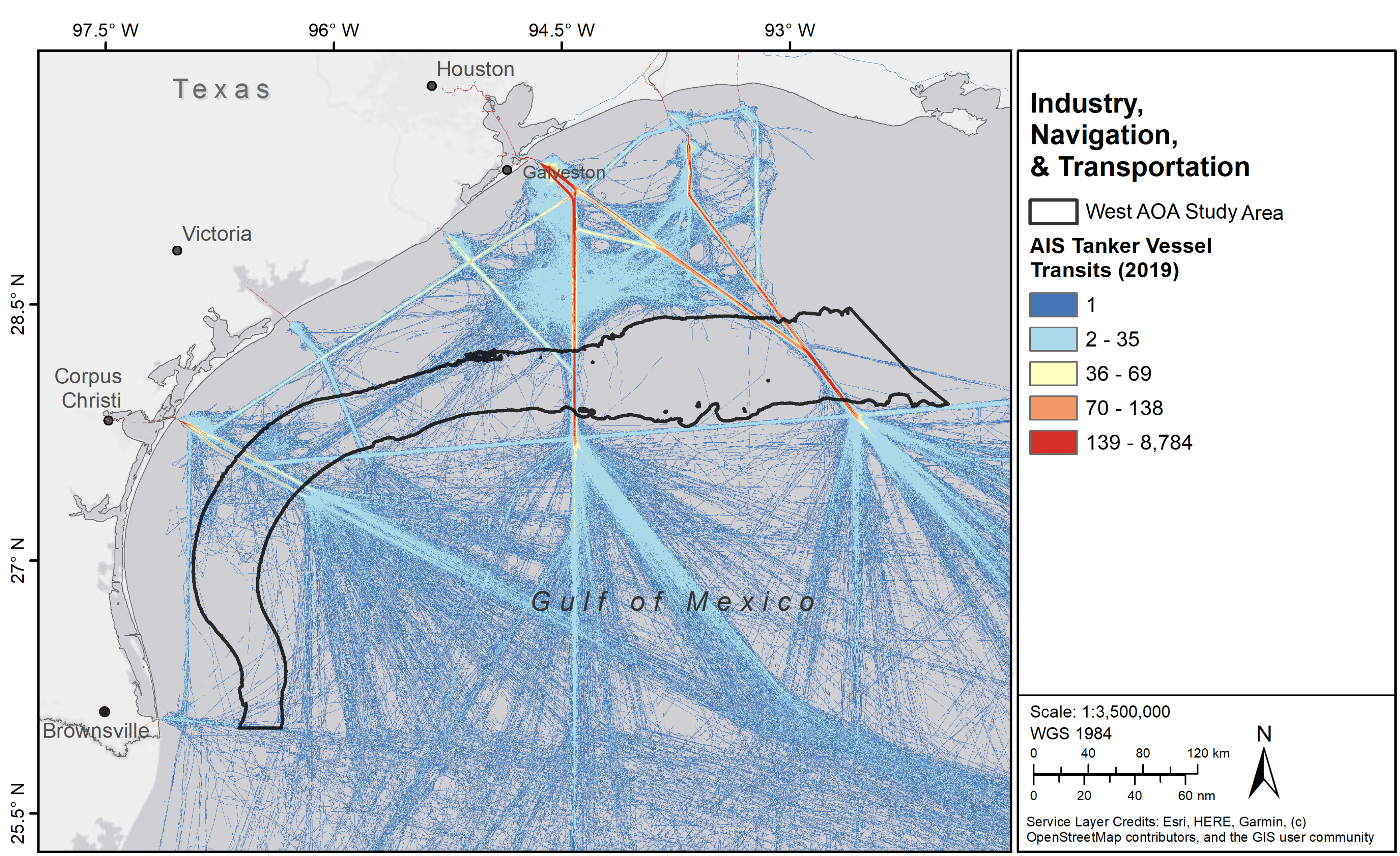
Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



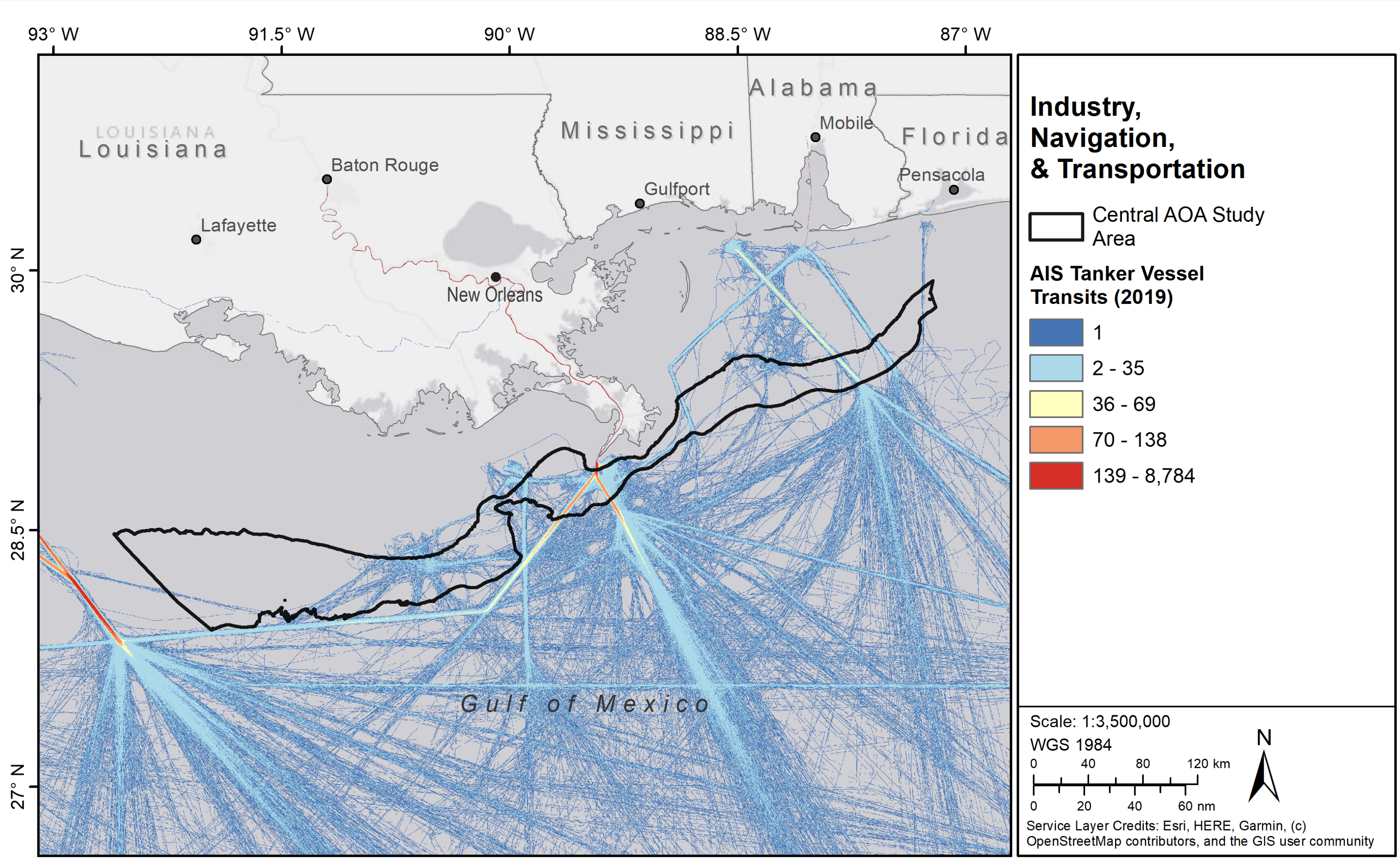
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



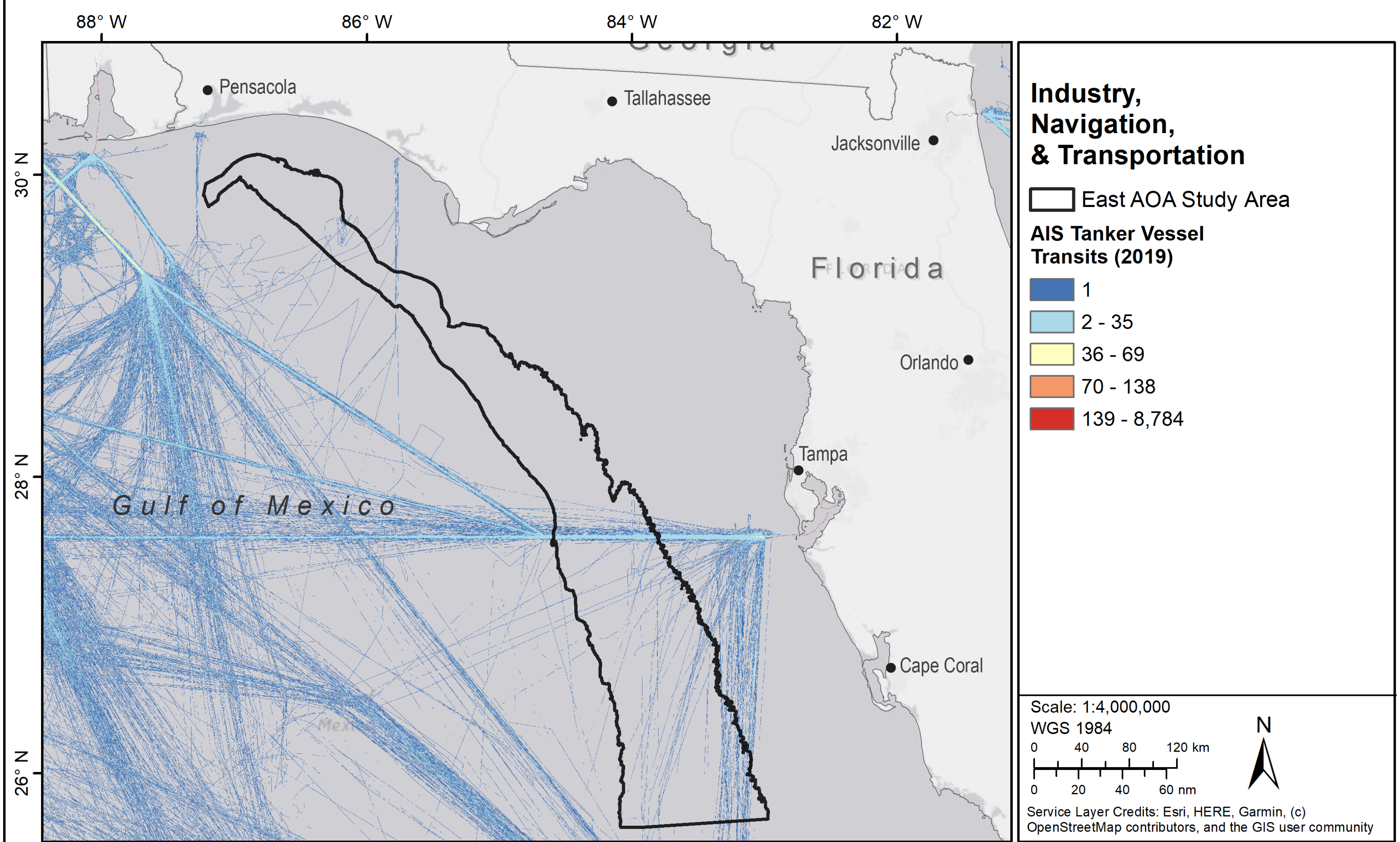
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



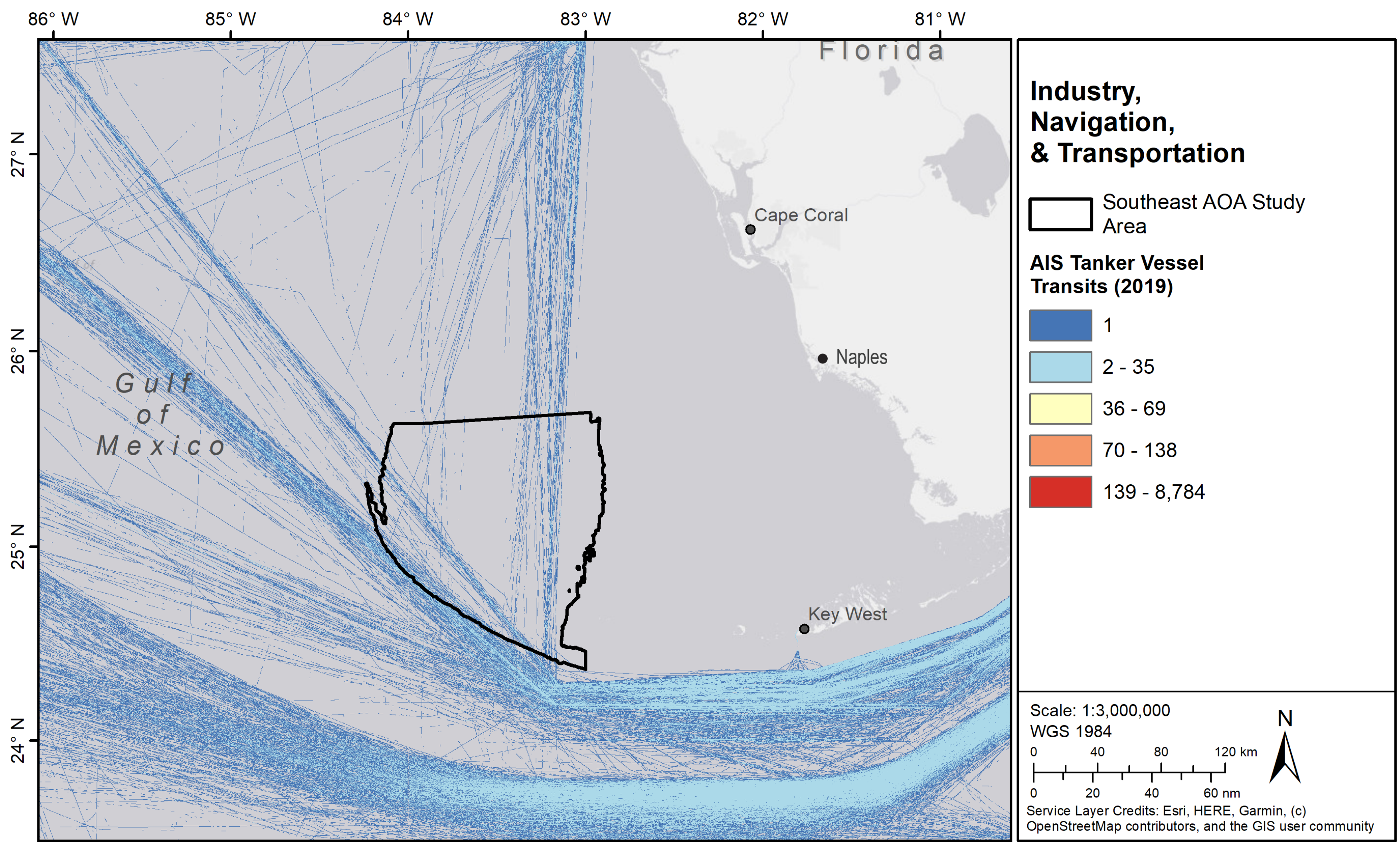
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



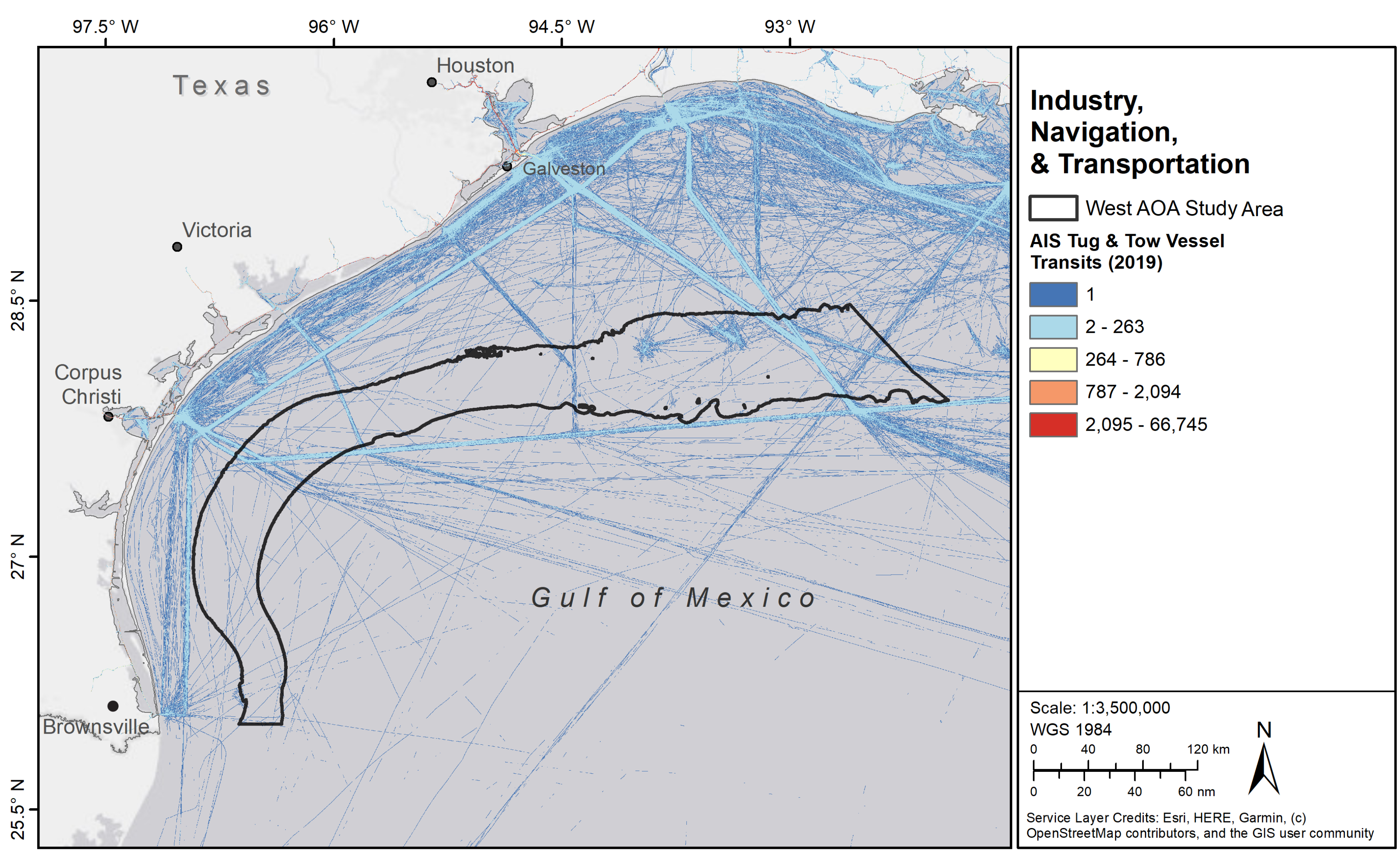
Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



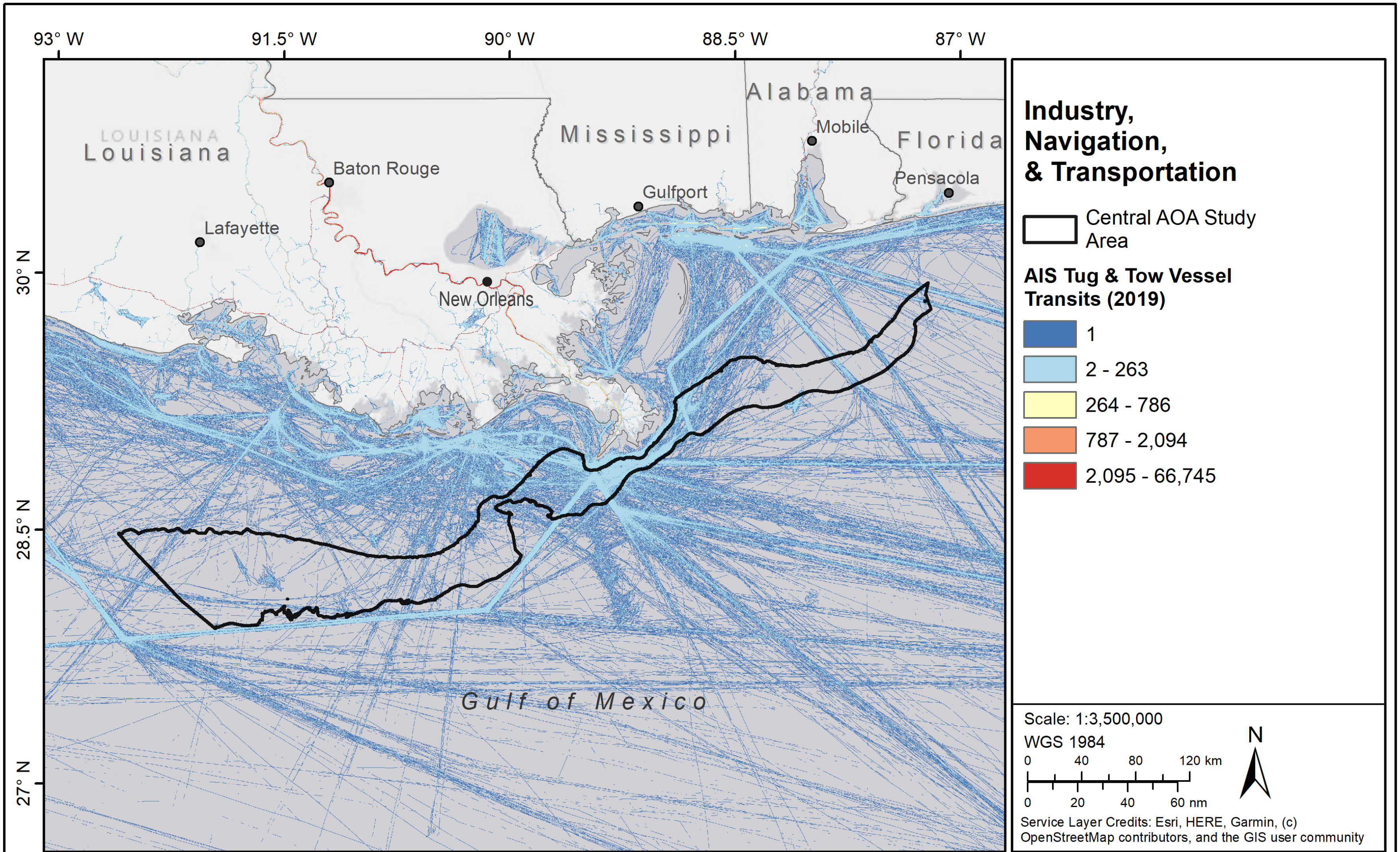
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



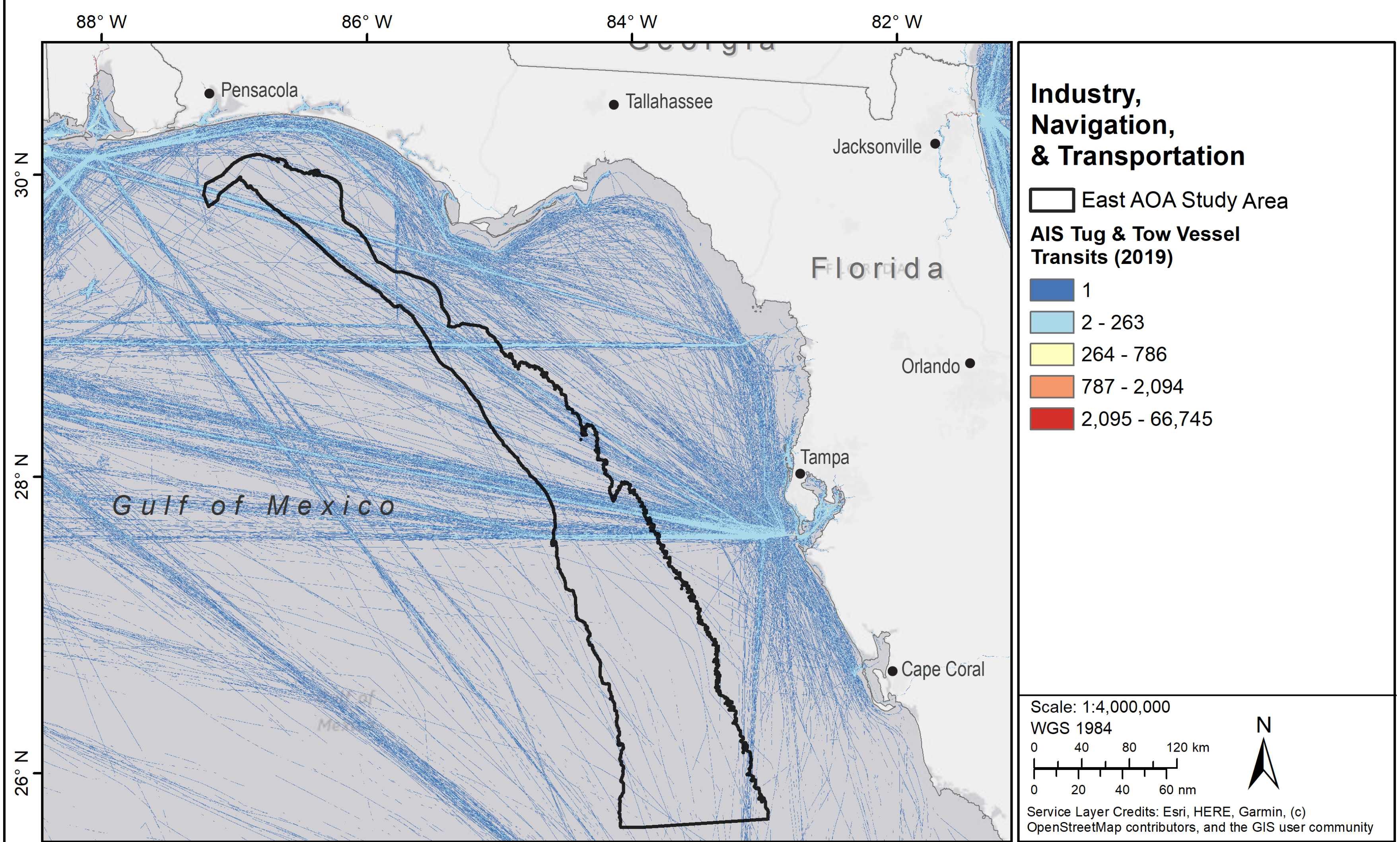
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



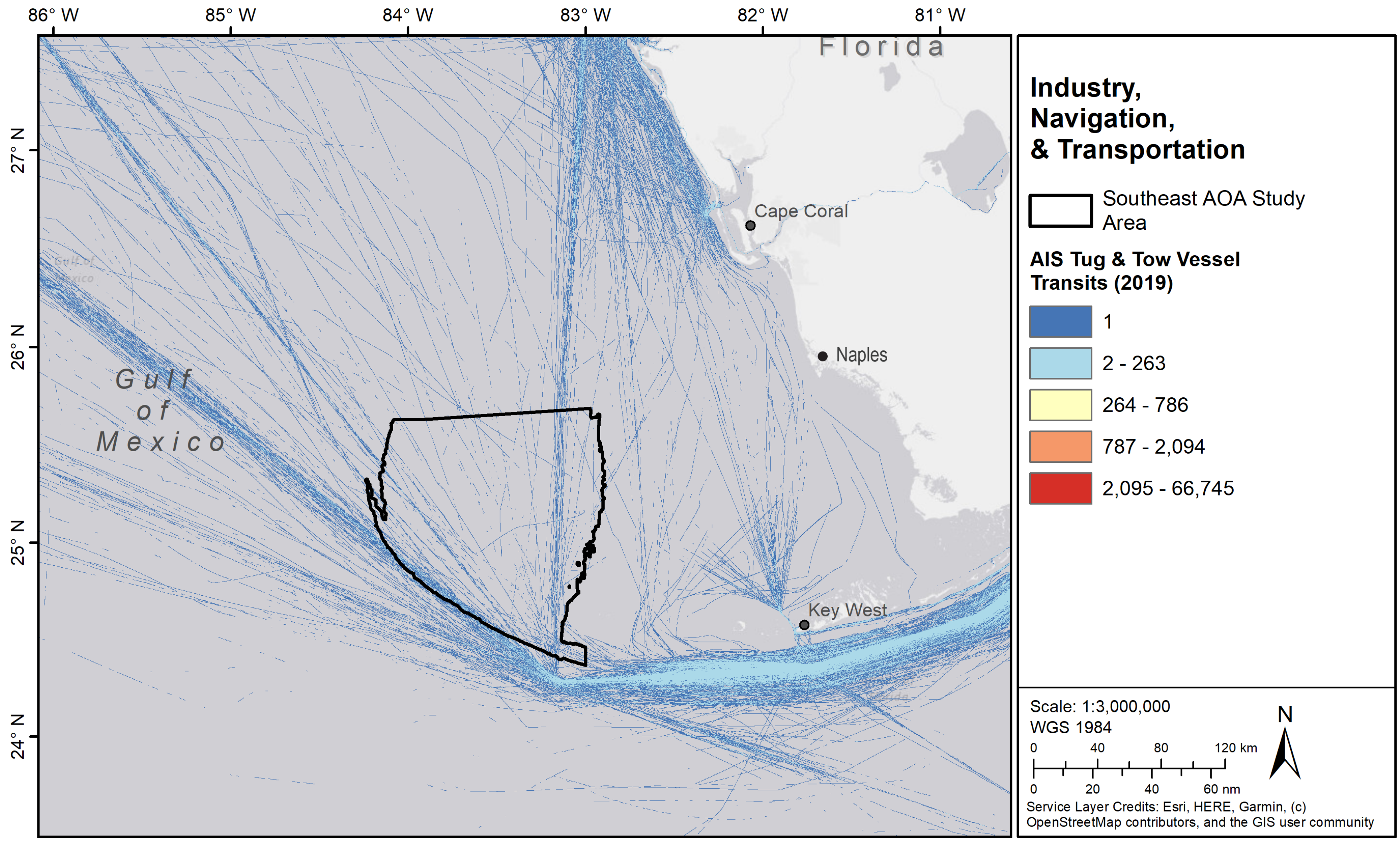
Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



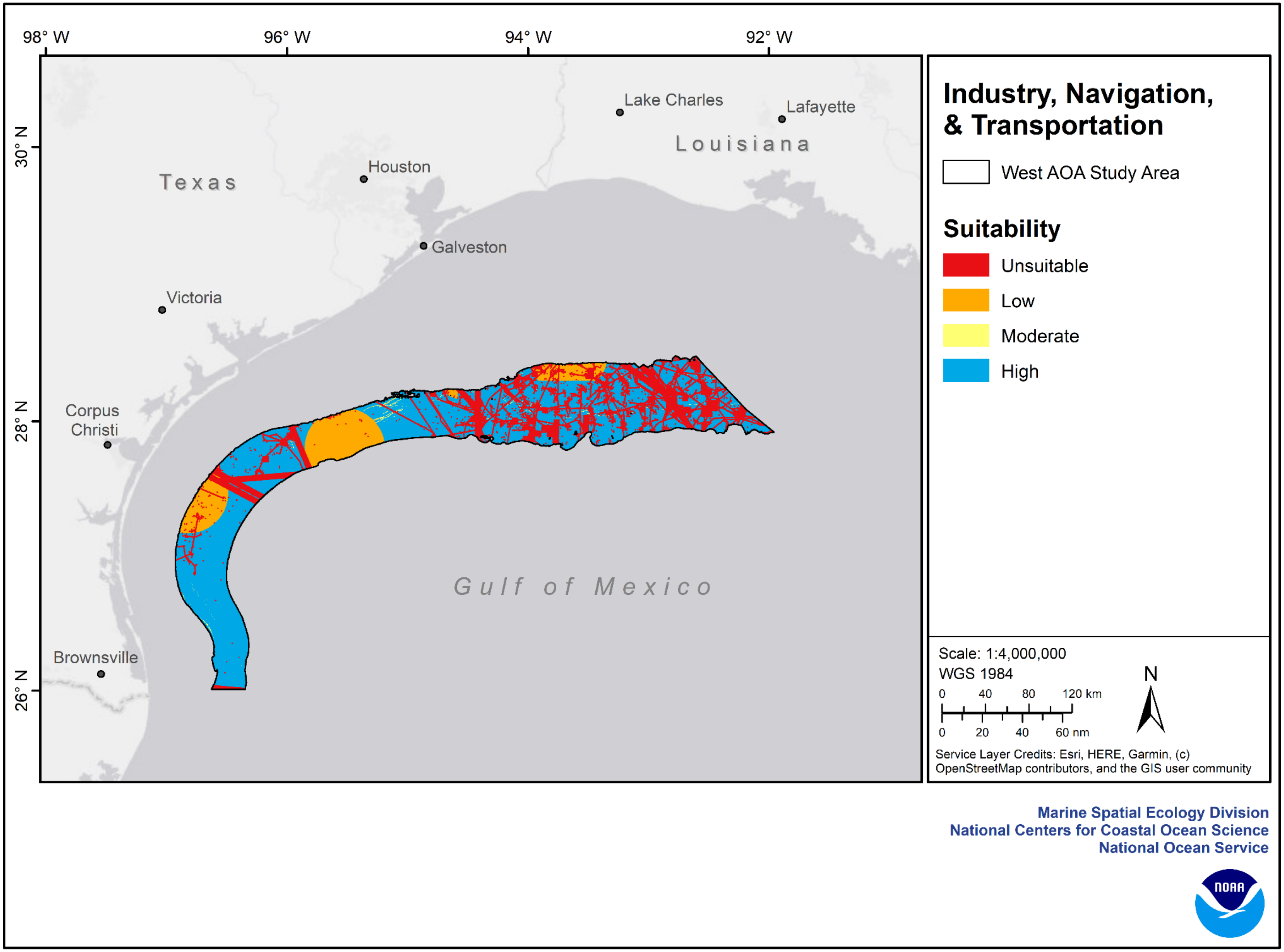
Automated Identification System (AIS) Data: NOAA OCM & BOEM (2019)

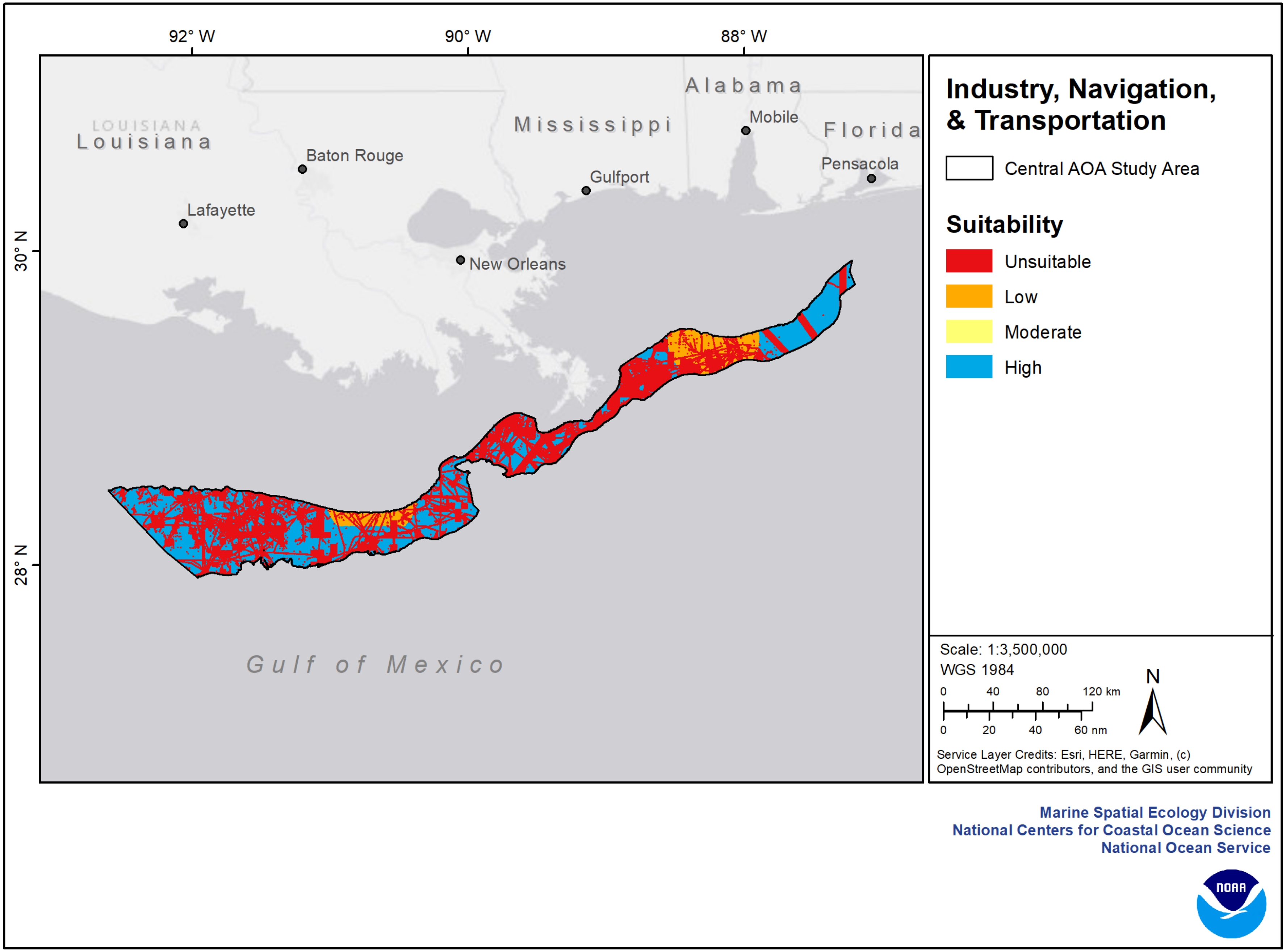
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

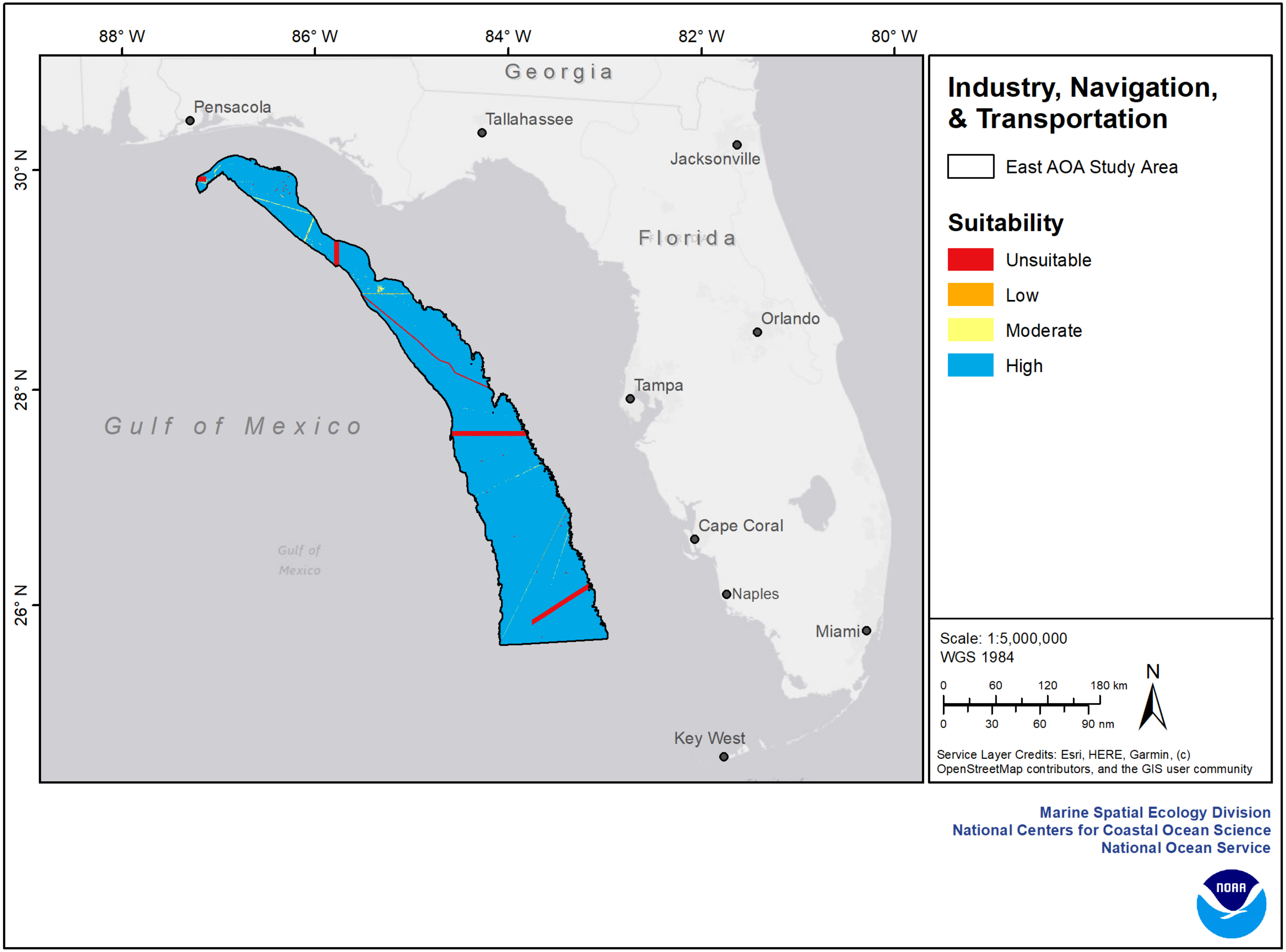


Automated Identification System (AIS) Vessel Transit Counts: NOAA OCM & BOEM (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


98° W
96° W
94° W
92° W
30° N
28° N
26° N
Lake Charles
Lafayette
Louisiana
Texas
Houston
Galveston
Victoria
Corpus Christi
Gulf of Mexico
Brownsville
Industry, Navigation, & Transportation
West AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:4,000,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


92° W
90° W
88° W
30° N
28° N
Alabama
Louisiana
Mississippi
Florida
Mobile
Baton Rouge
Gulfport
Pensacola
Lafayette
New Orleans
Gulf of Mexico
Industry, Navigation, & Transportation
Central AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:3,500,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


88° W
86° W
84° W
82° W
80° W
30° N
28° N
26° N
Georgia
Pensacola
Tallahassee
Jacksonville
Florida
Orlando
Tampa
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Gulf of Mexico
Industry, Navigation, & Transportation
East AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:5,000,000
WGS 1984
0 60 120 180 km
0 30 60 90 nm
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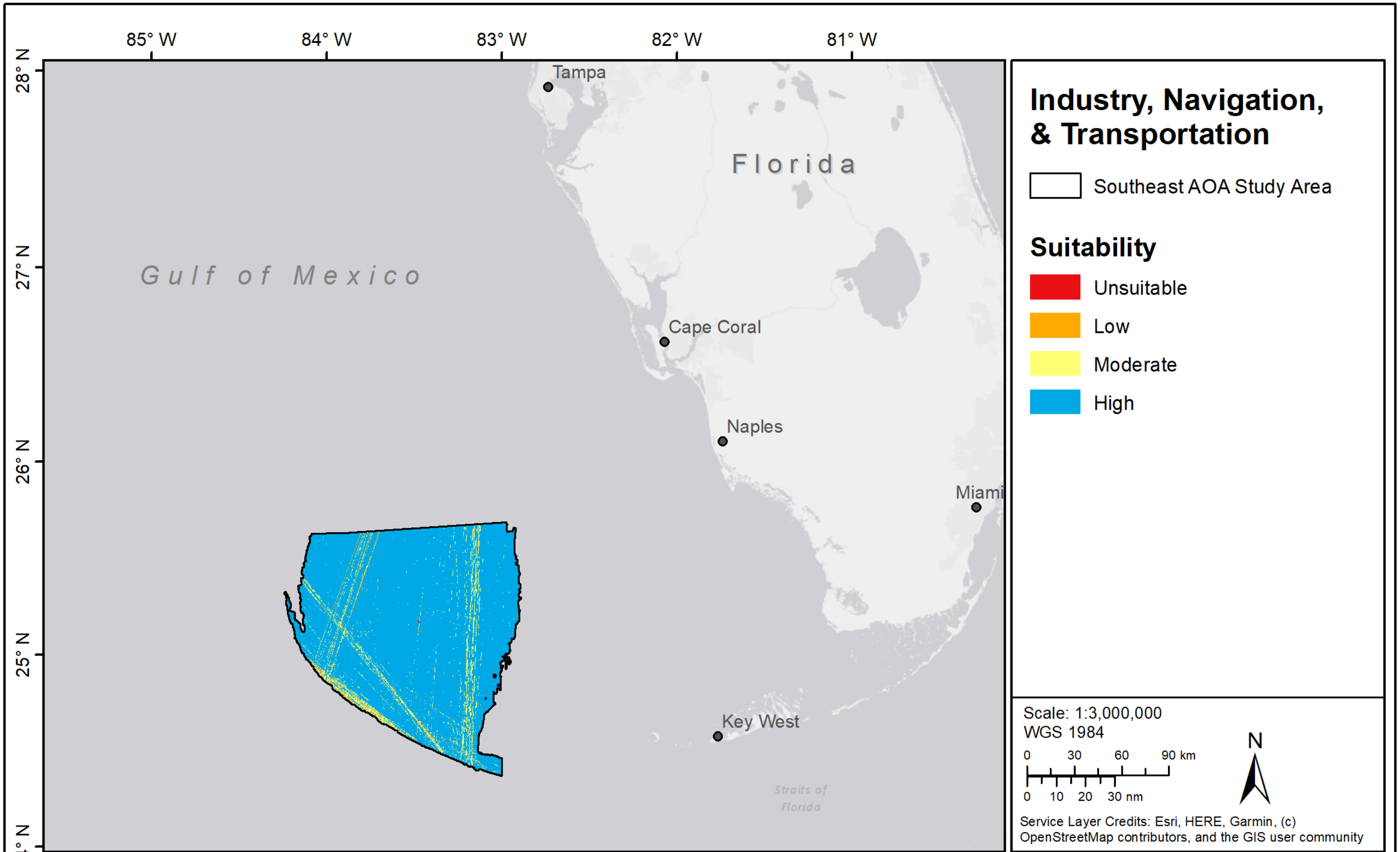
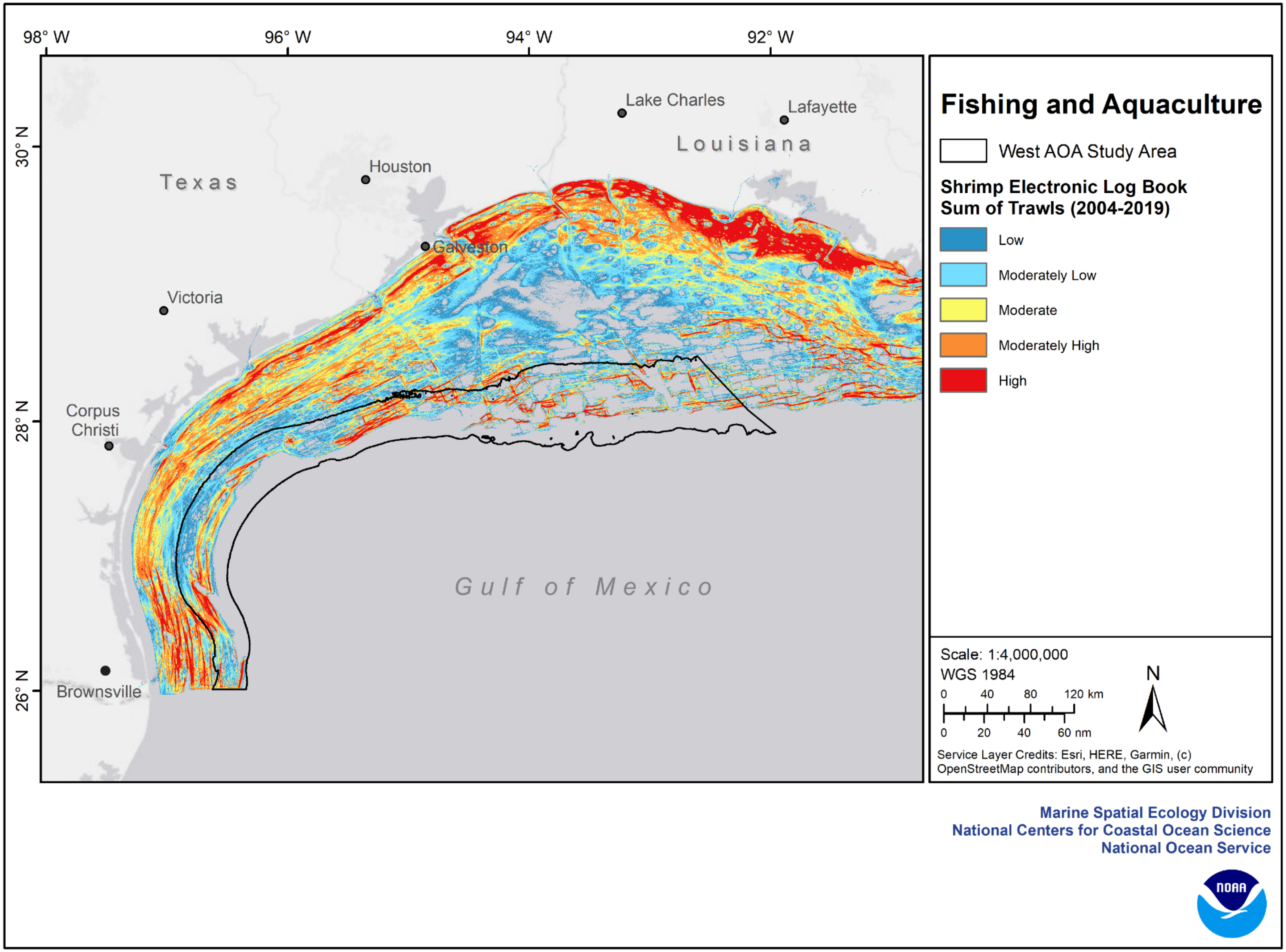
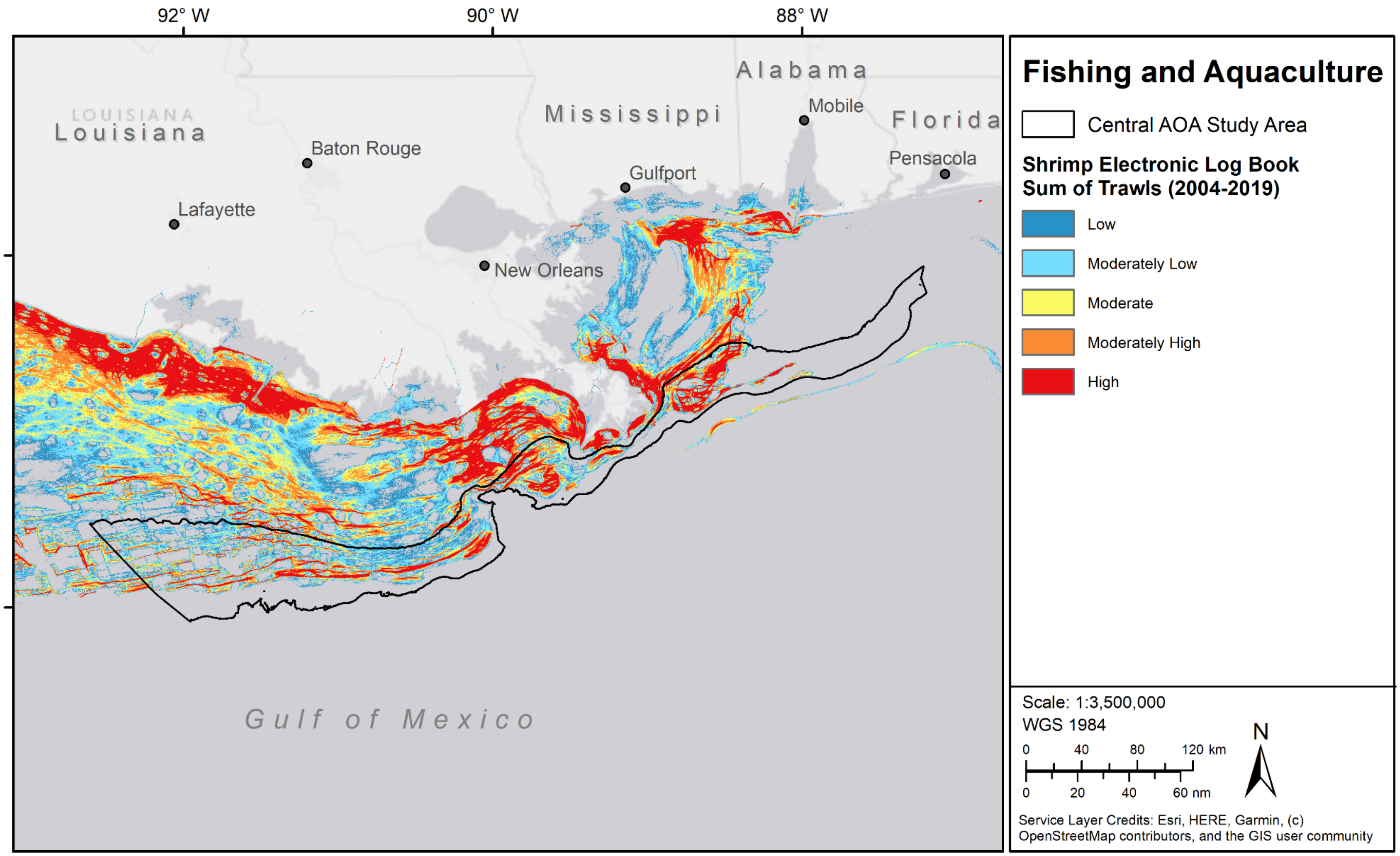
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



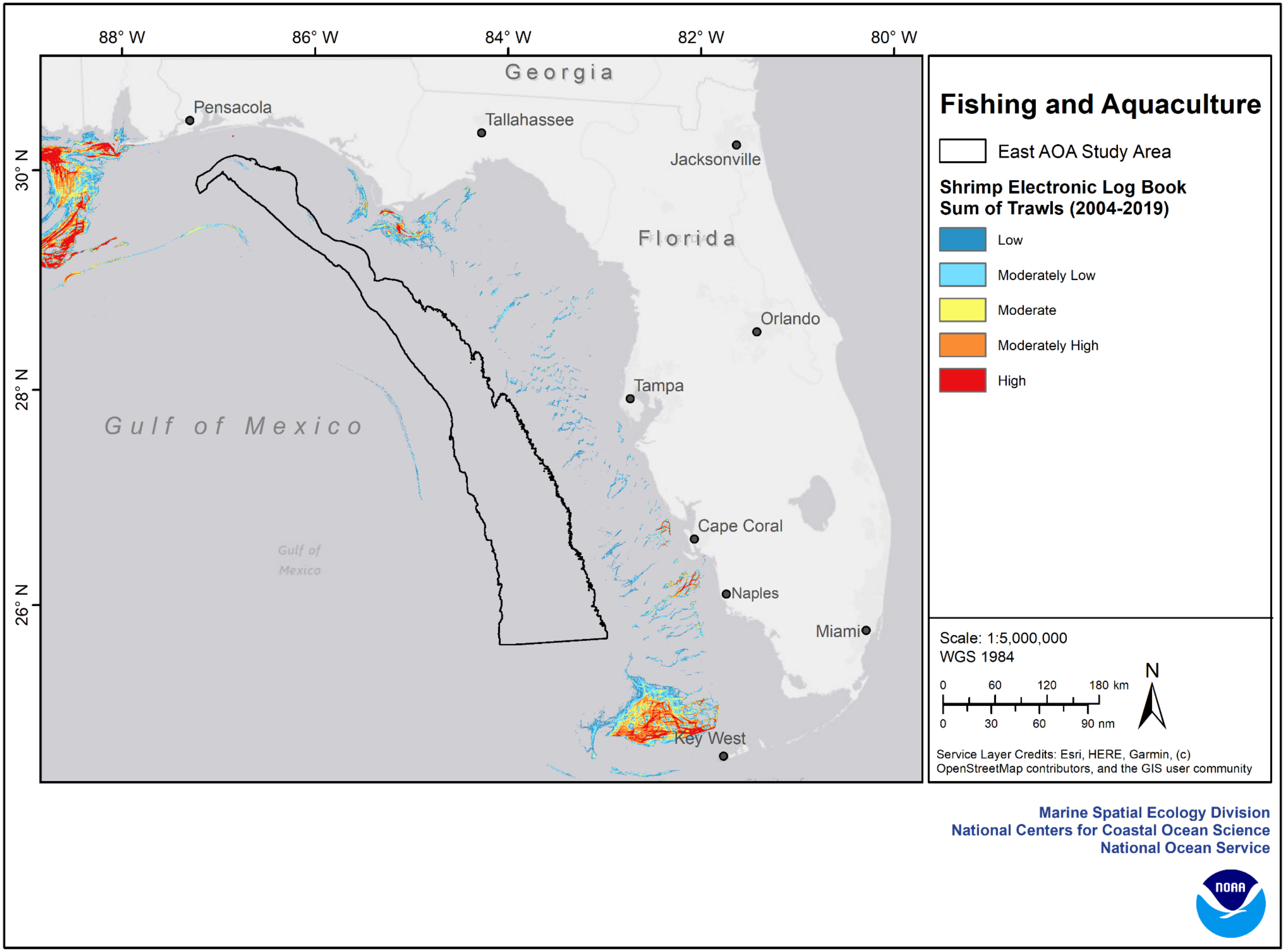
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

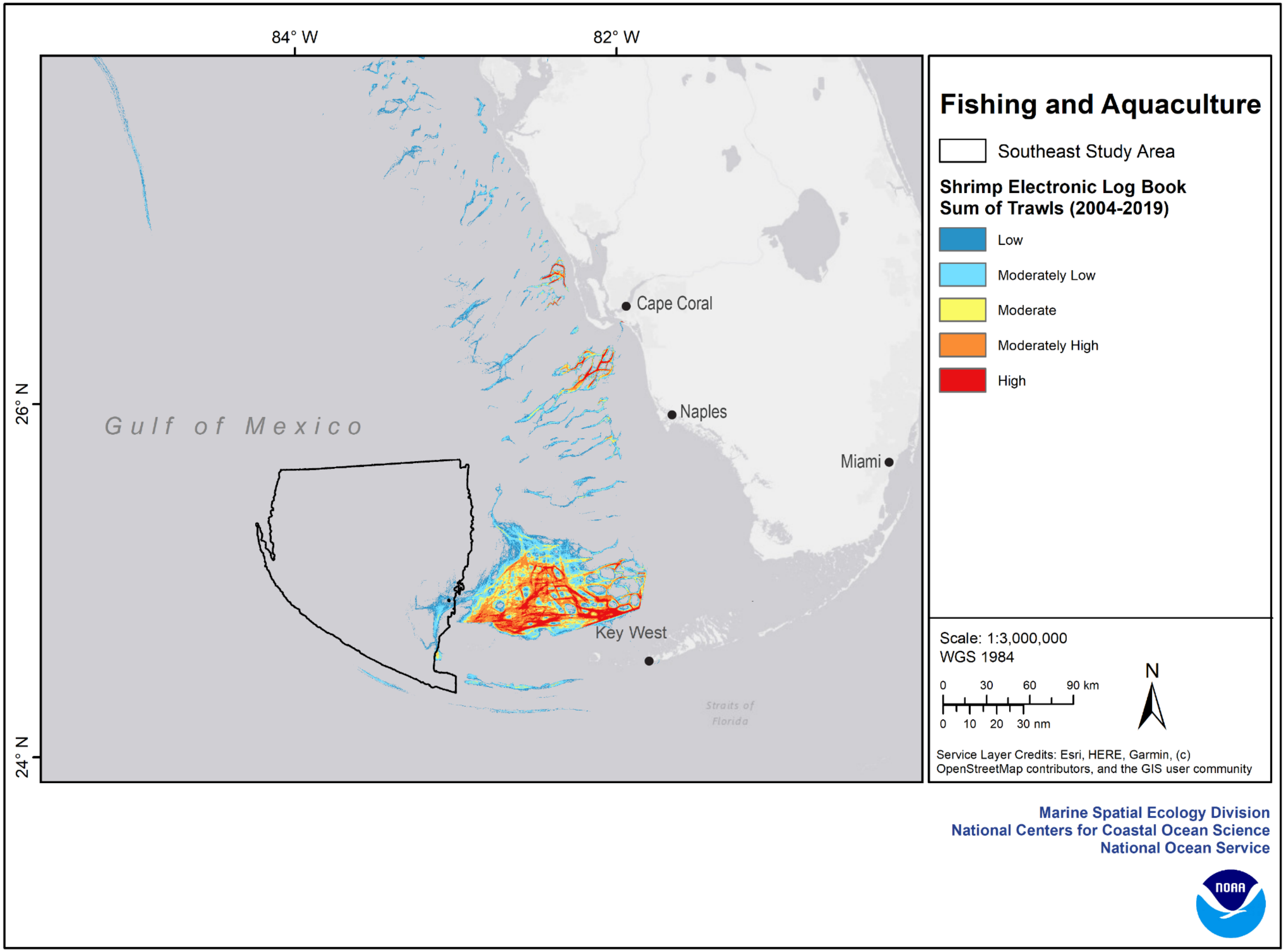
Fishing and Aquaculture

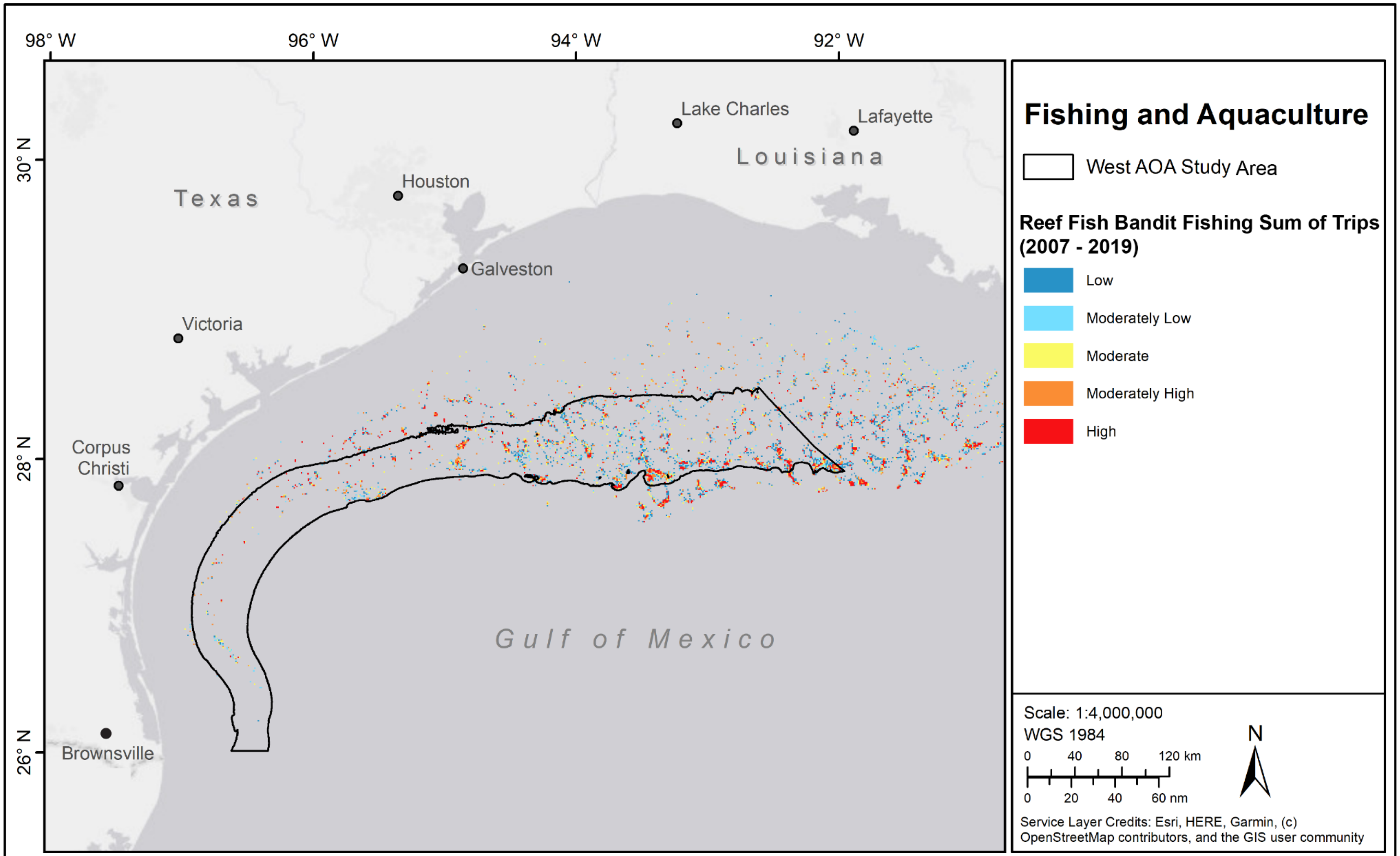




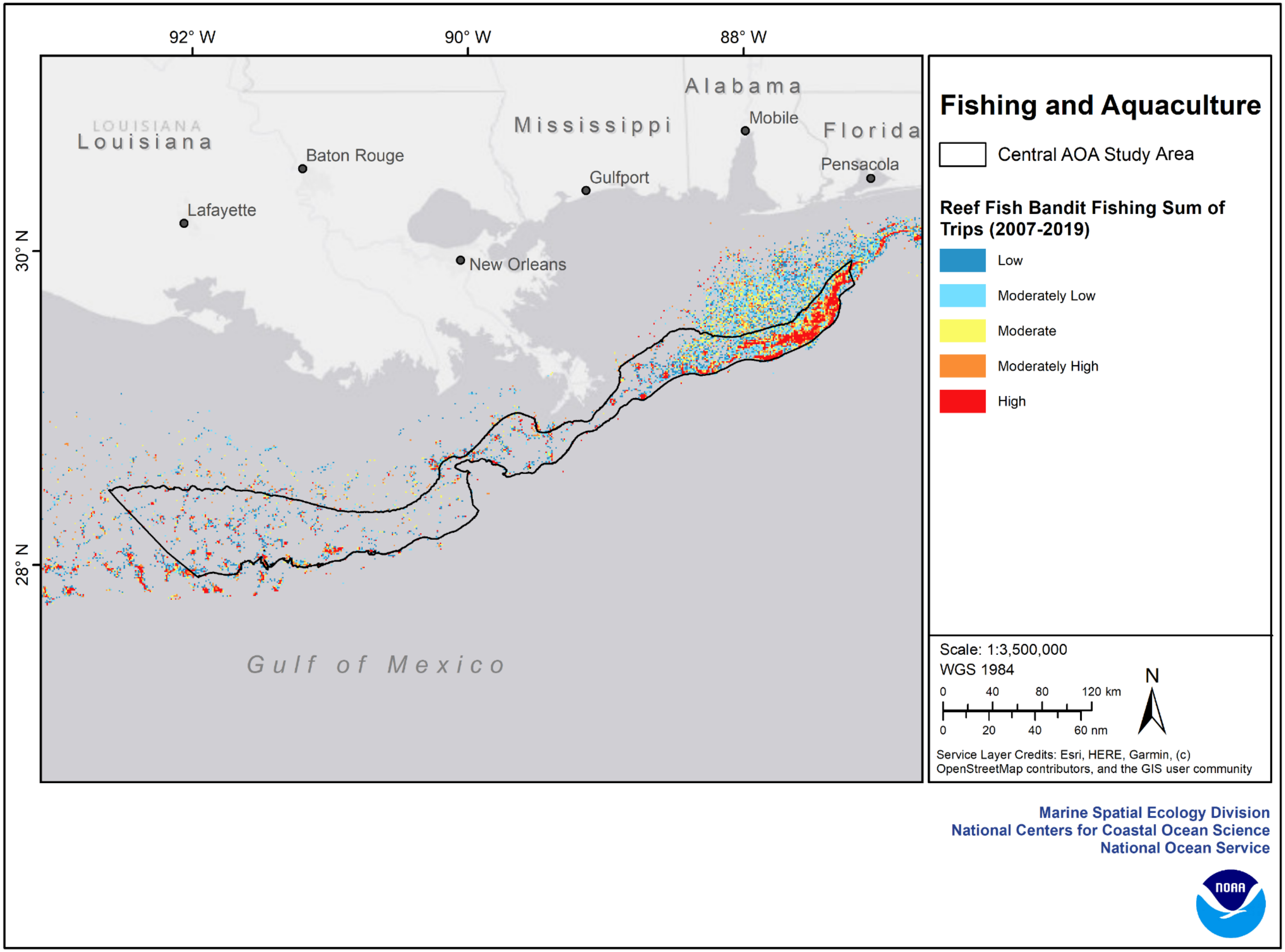
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


88° W
86° W
84° W
82° W
80° W
30° N
28° N
26° N
Georgia
Pensacola
Tallahassee
Jacksonville
Florida
Orlando
Tampa
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Fishing and Aquaculture
East AOA Study Area
Shrimp Electronic Log Book
Sum of Trawls (2004-2019)
Low
Moderately Low
Moderate
Moderately High
High
Scale: 1:5,000,000
WGS 1984
0 60 120 180 km
0 30 60 90 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


84° W
82° W
26° N
24° N
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Straits of Florida
Fishing and Aquaculture
Southeast Study Area
Shrimp Electronic Log Book
Sum of Trawls (2004-2019)
Low
Moderately Low
Moderate
Moderately High
High
Scale: 1:3,000,000
WGS 1984
0 30 60 90 km
0 10 20 30 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA



Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


92° W
90° W
88° W
30° N
28° N
Alabama
Louisiana
Mississippi
Florida
Mobile
Baton Rouge
Gulfport
Pensacola
Lafayette
New Orleans
Gulf of Mexico
Fishing and Aquaculture
Central AOA Study Area
Reef Fish Bandit Fishing Sum of Trips (2007-2019)
Low
Moderately Low
Moderate
Moderately High
High
Scale: 1:3,500,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
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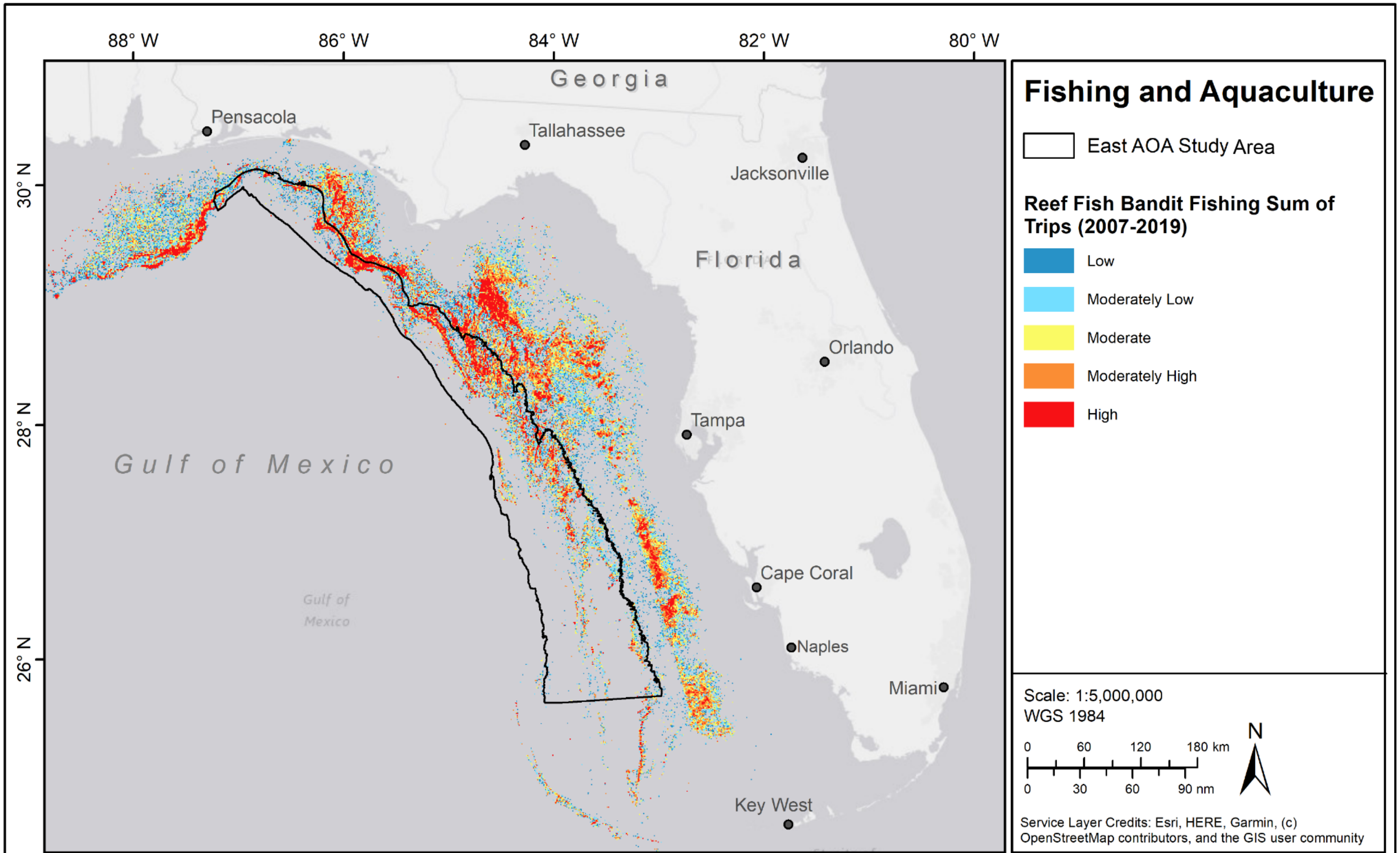
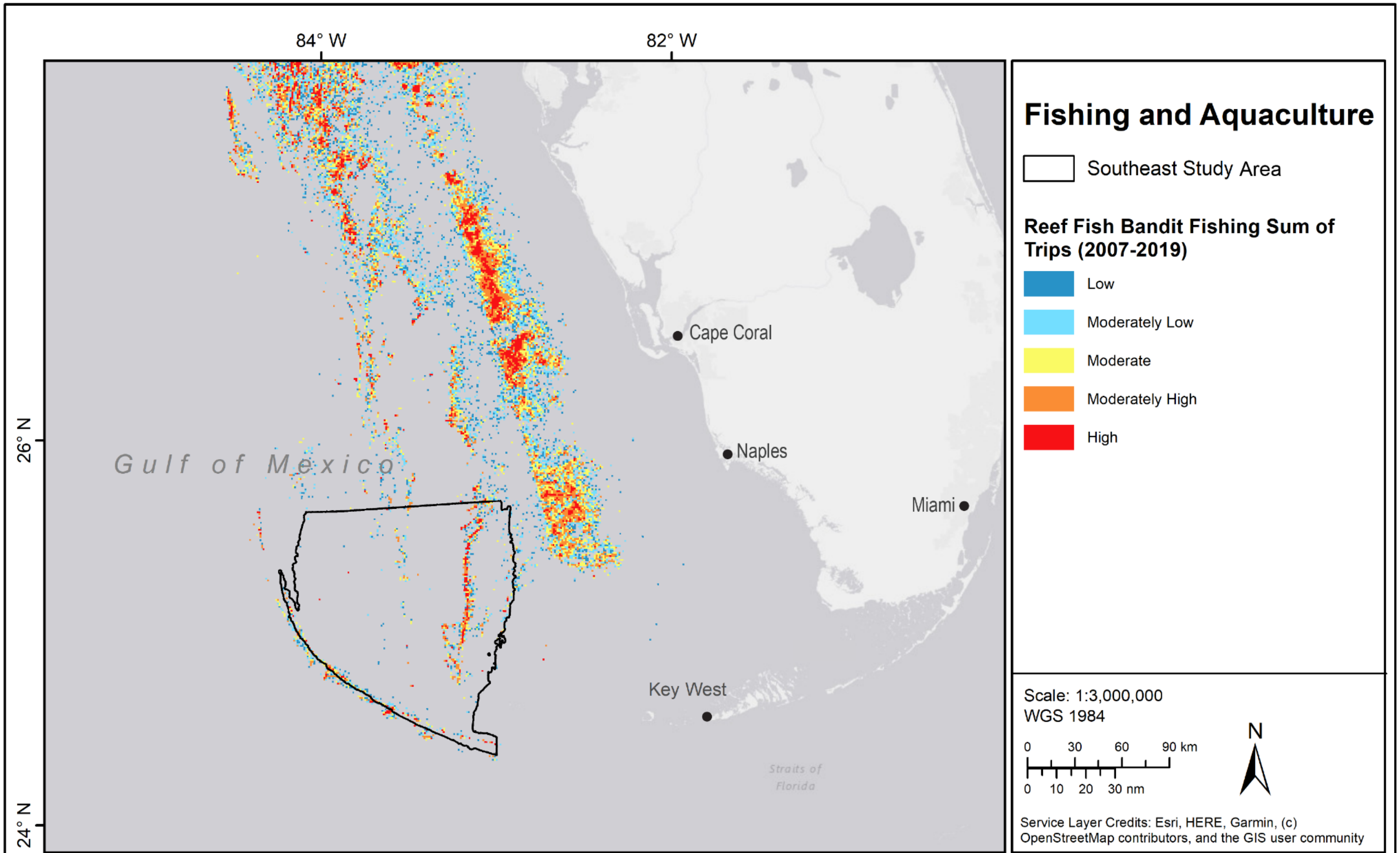
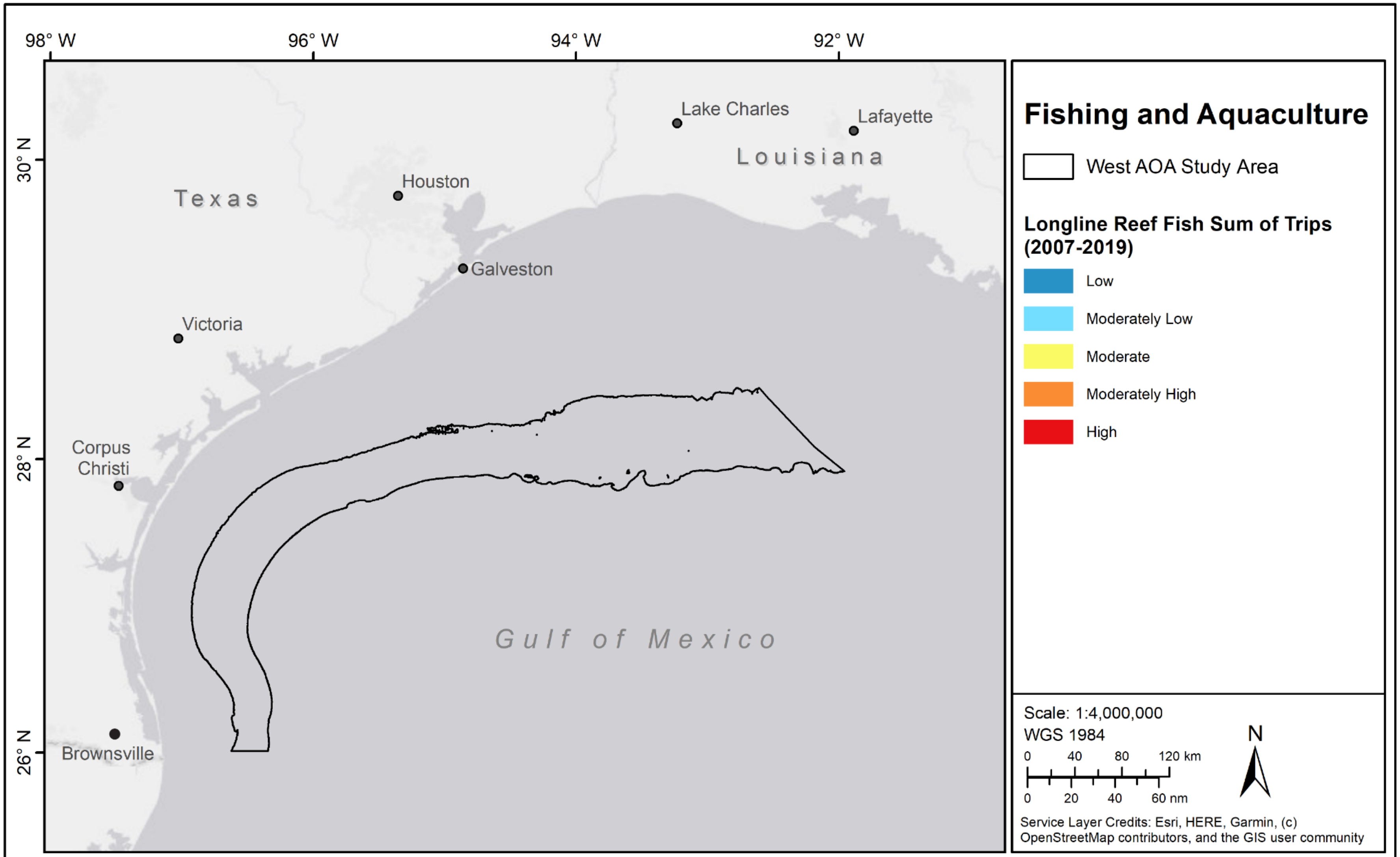
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



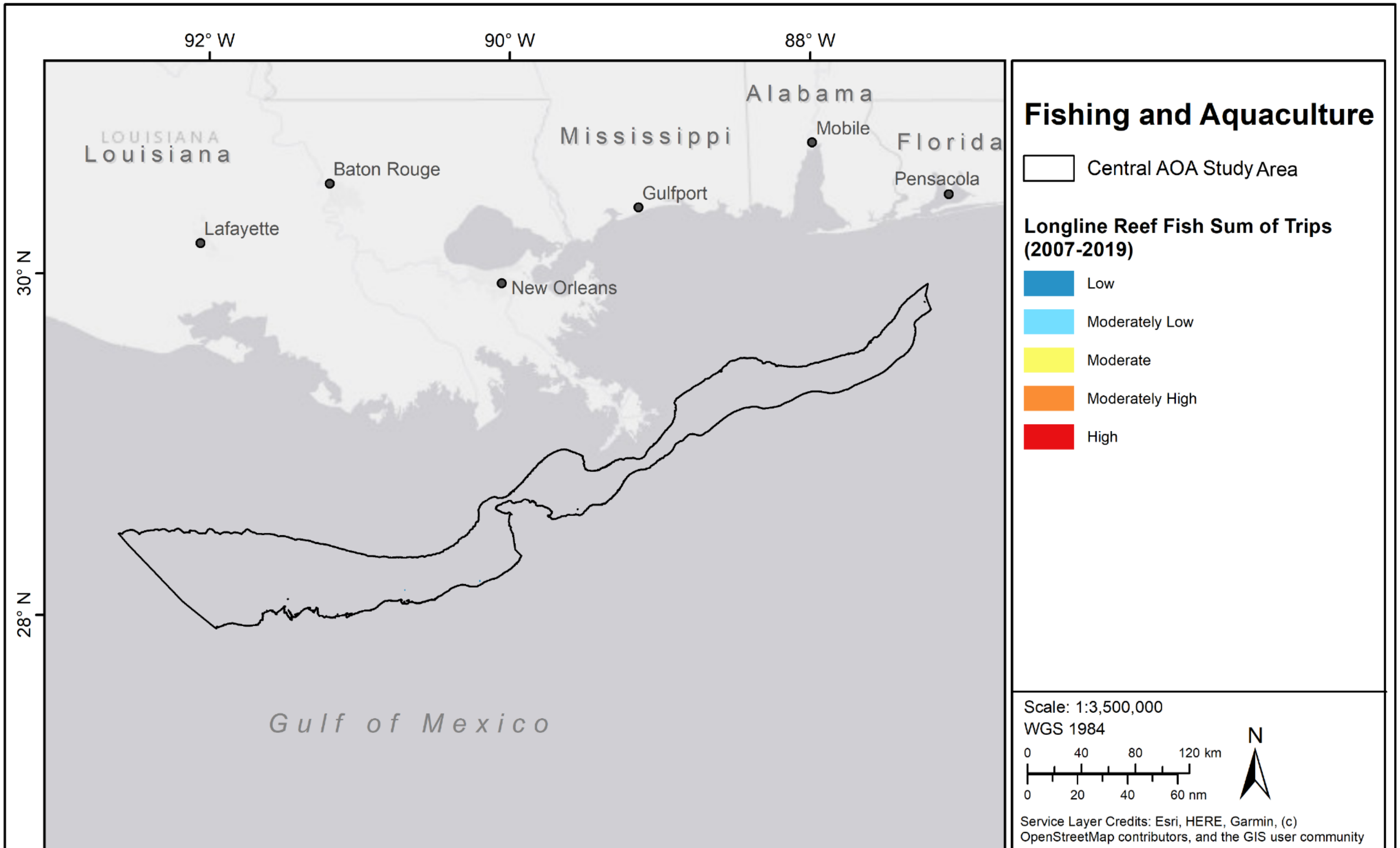
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



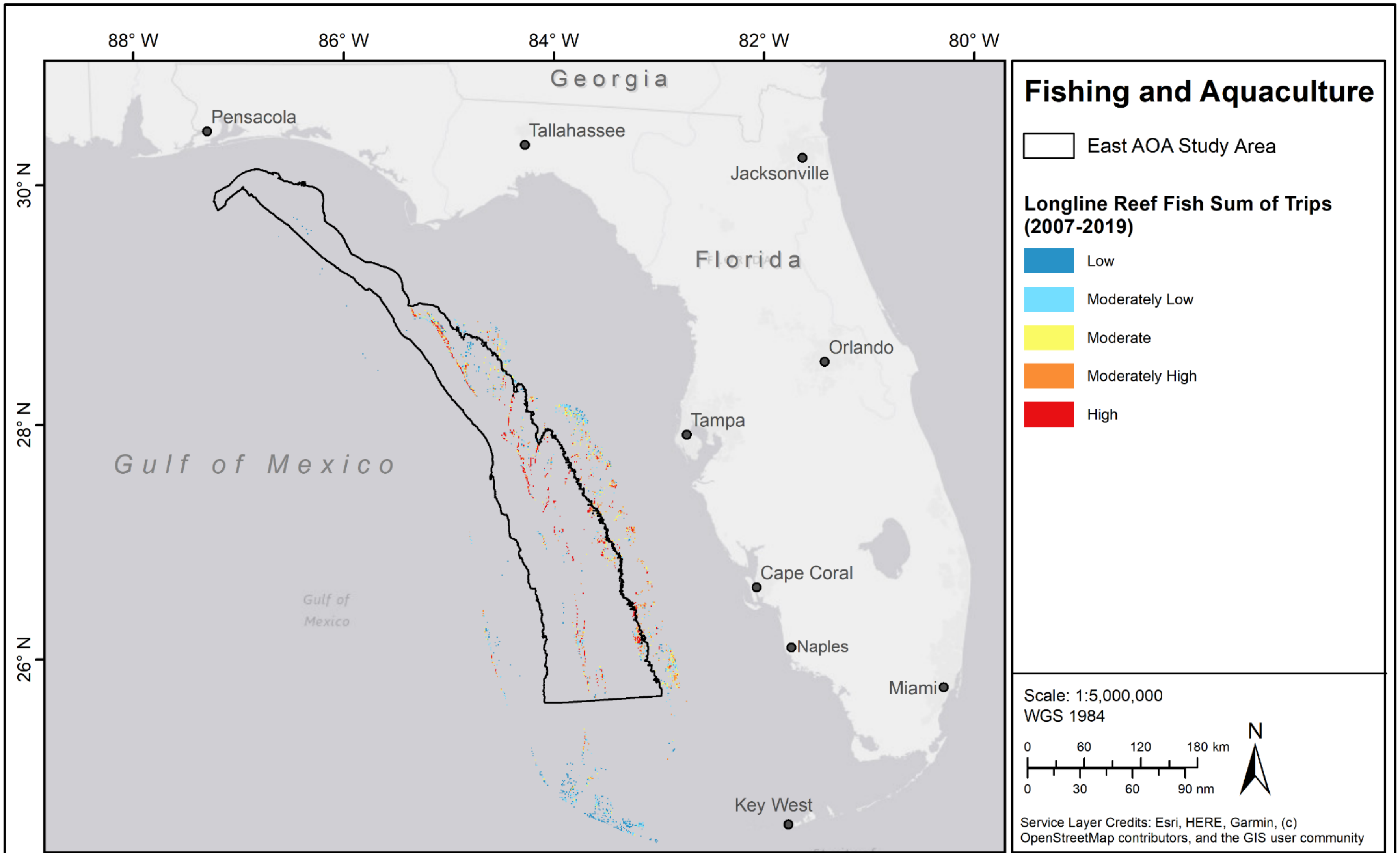
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



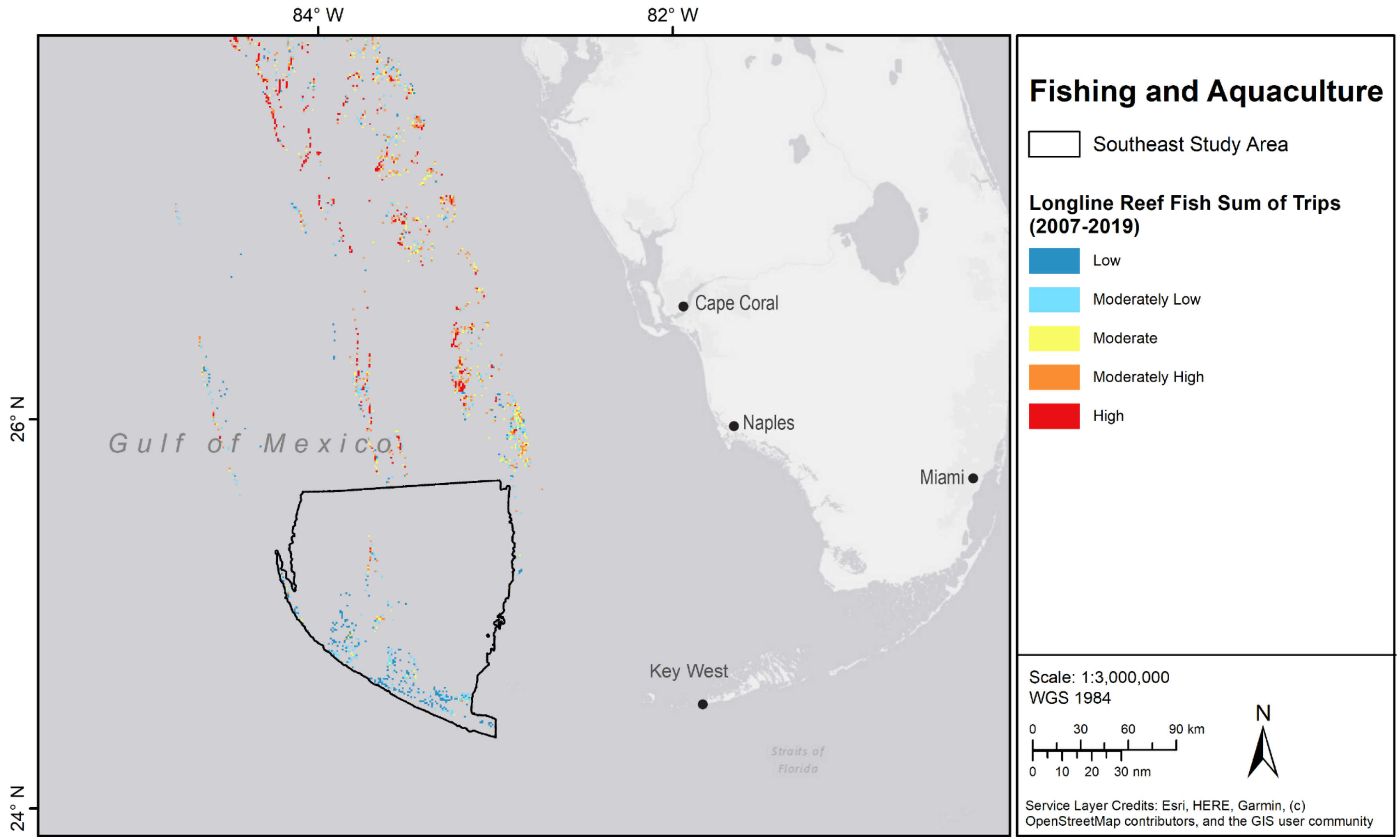
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



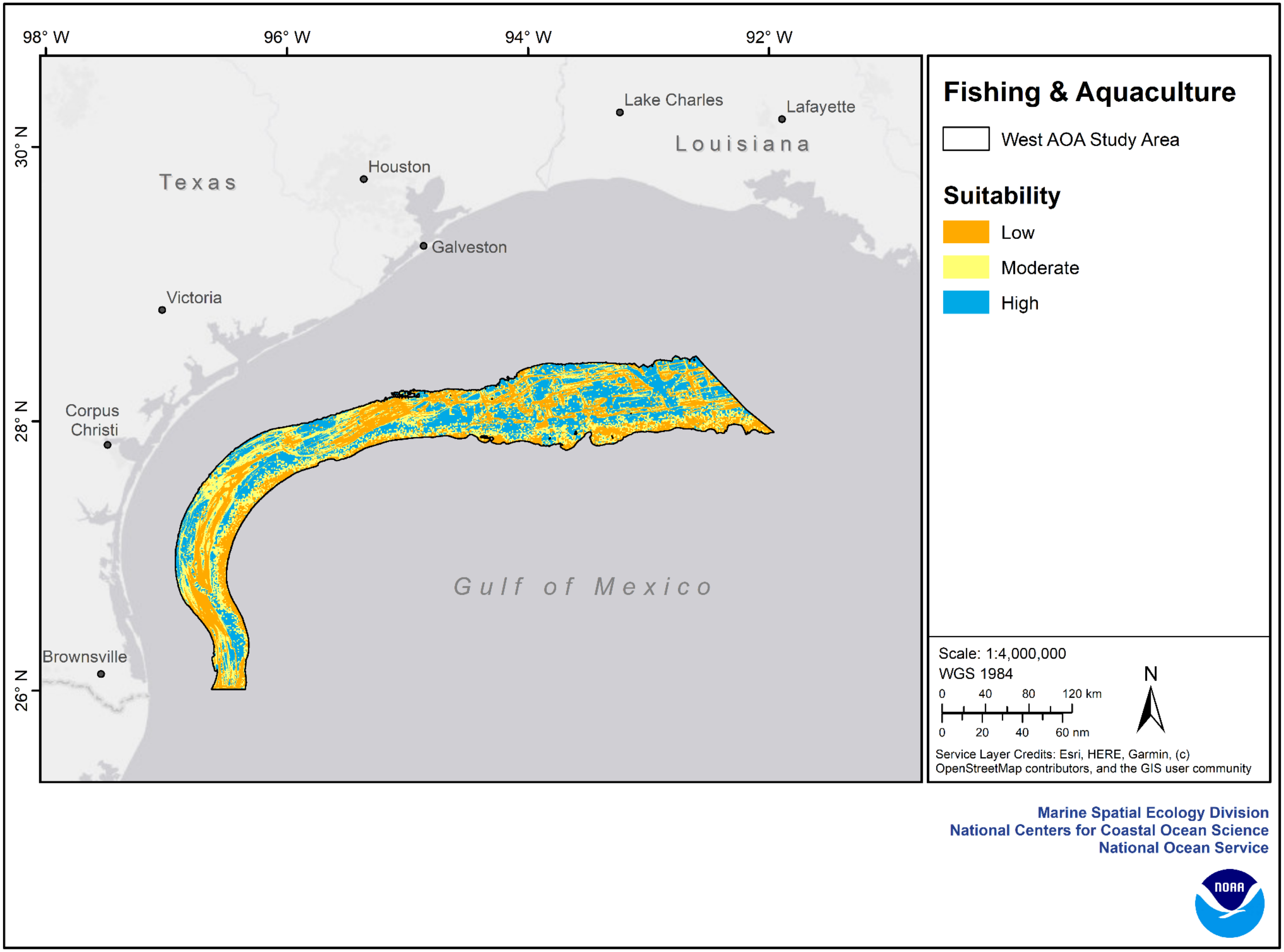
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

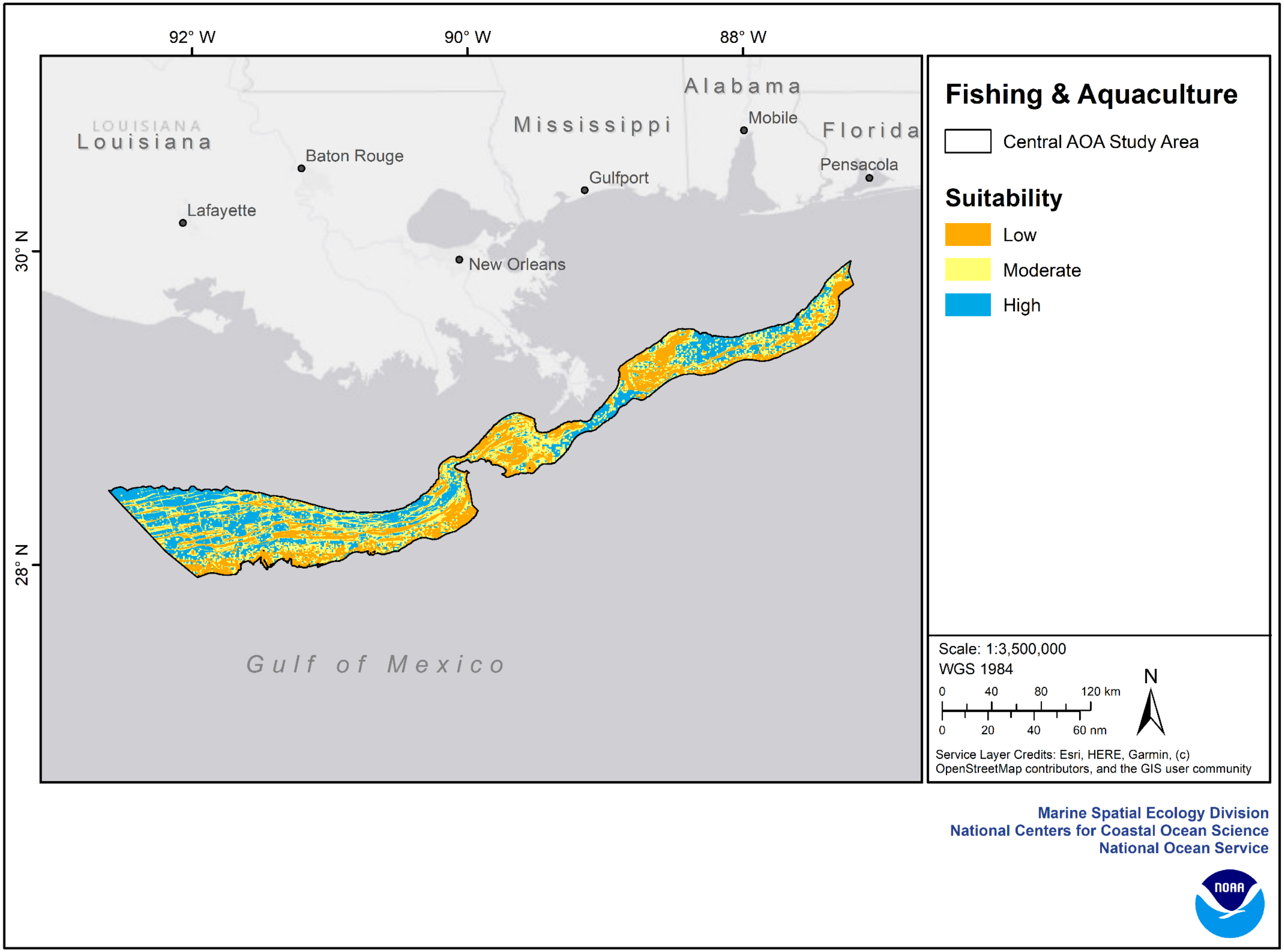


Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

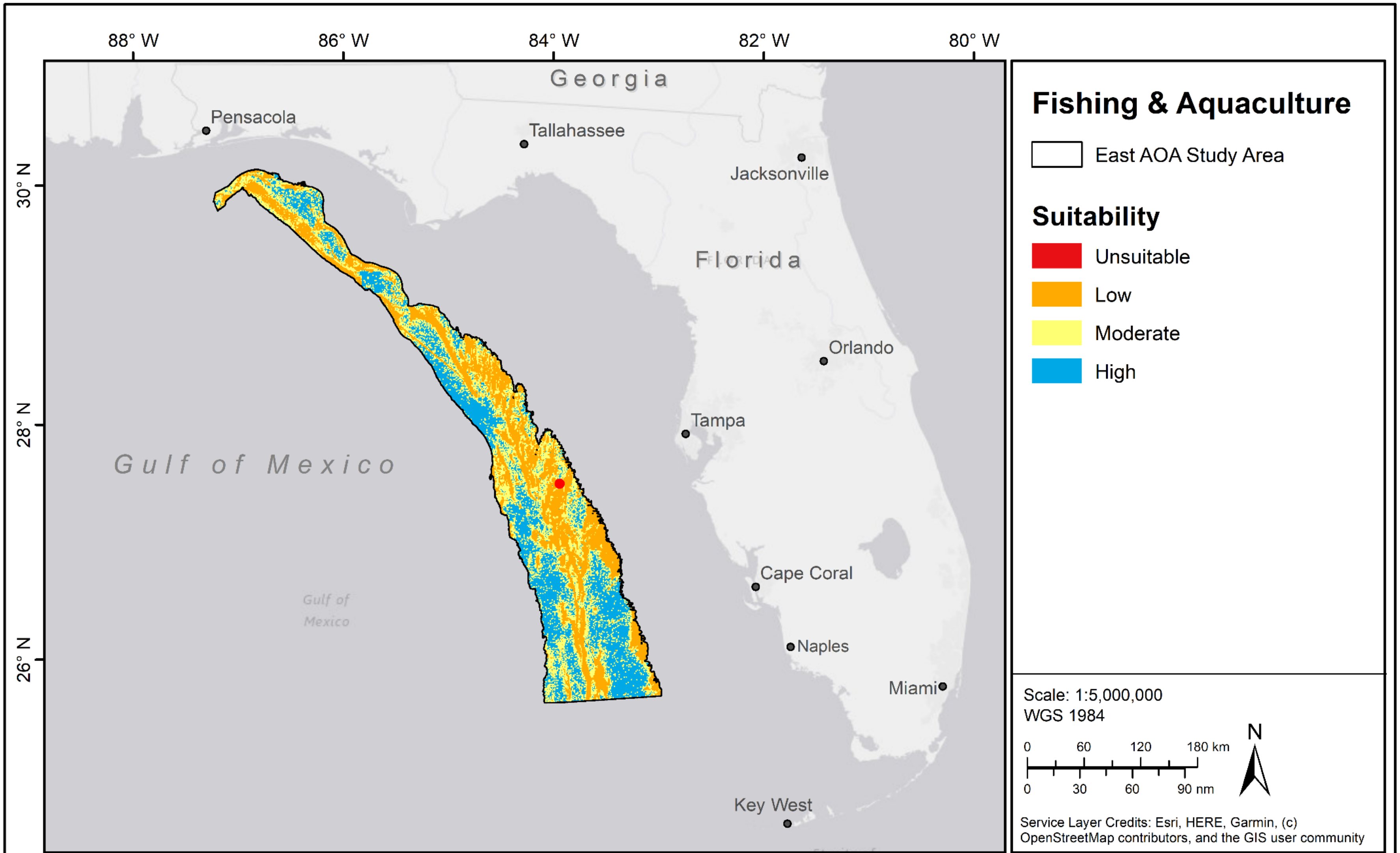


Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

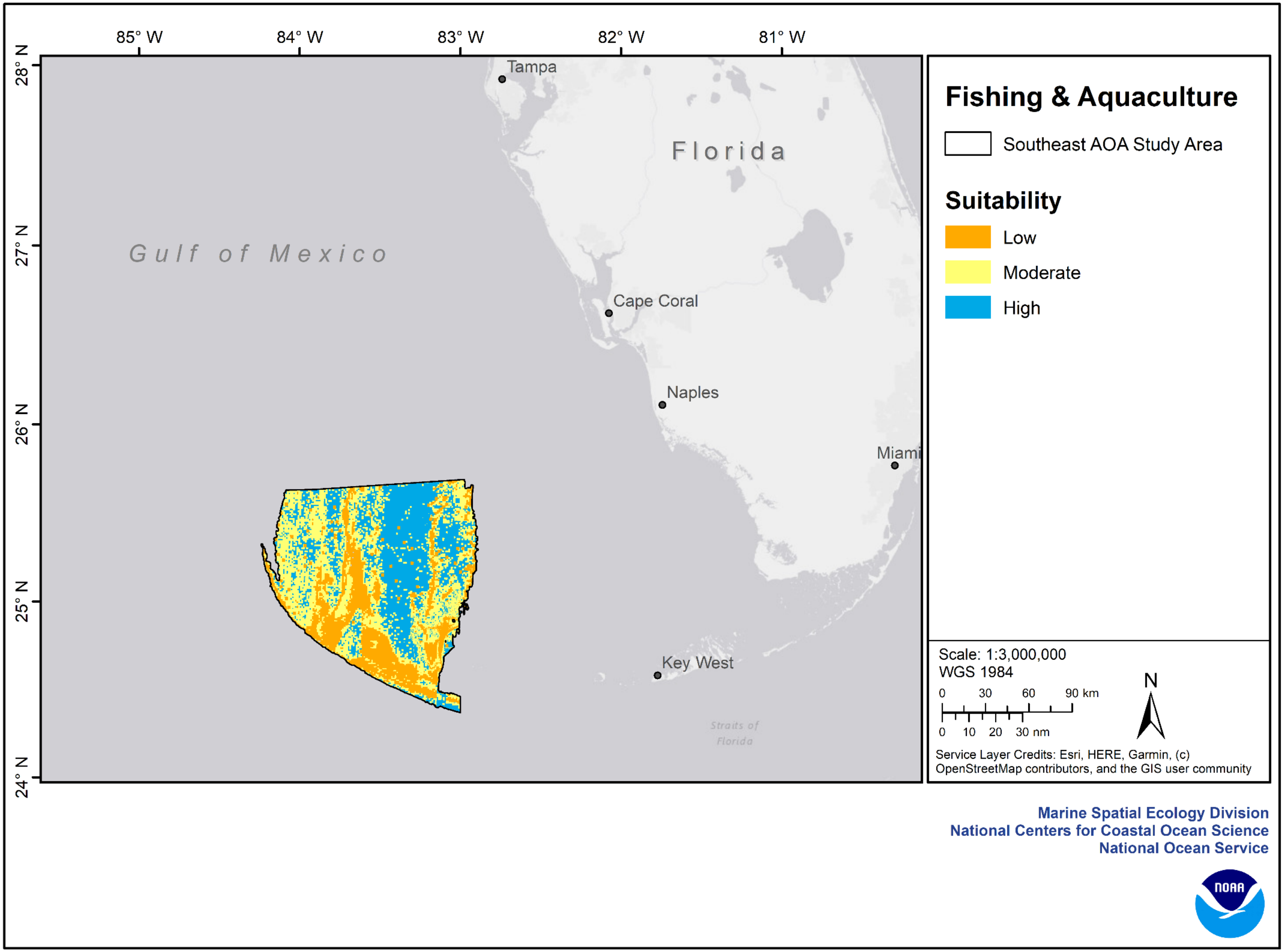

98° W
96° W
94° W
92° W
30° N
28° N
26° N
Lake Charles
Lafayette
Louisiana
Texas
Houston
Galveston
Victoria
Corpus Christi
Brownsville
Gulf of Mexico
Fishing & Aquaculture
West AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:4,000,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



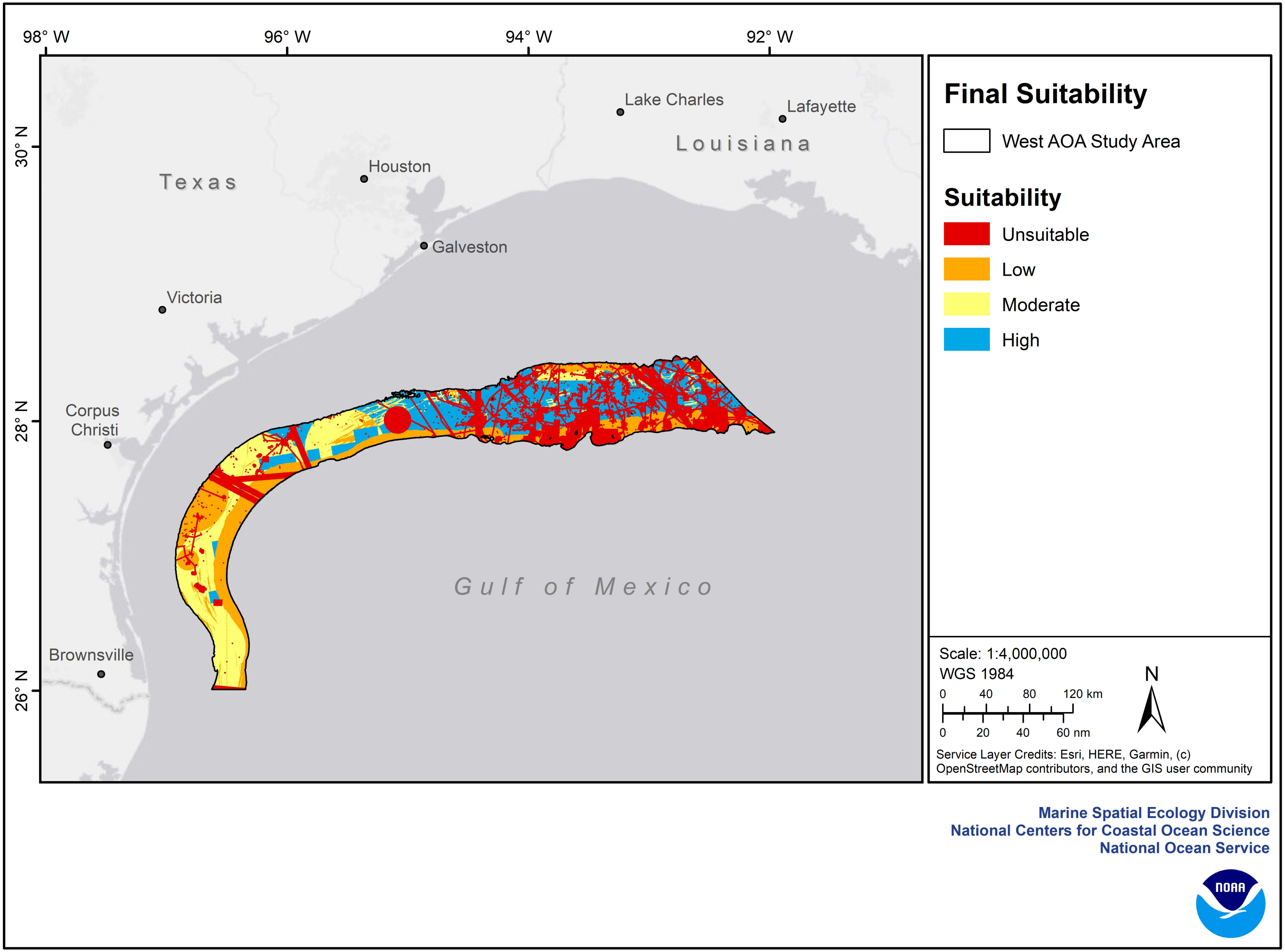
92° W
90° W
88° W
30° N
28° N
Alabama
Mississippi
Louisiana
Florida
Mobile
Pensacola
Baton Rouge
Gulfport
Lafayette
New Orleans
Gulf of Mexico
Fishing & Aquaculture
Central AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:3,500,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

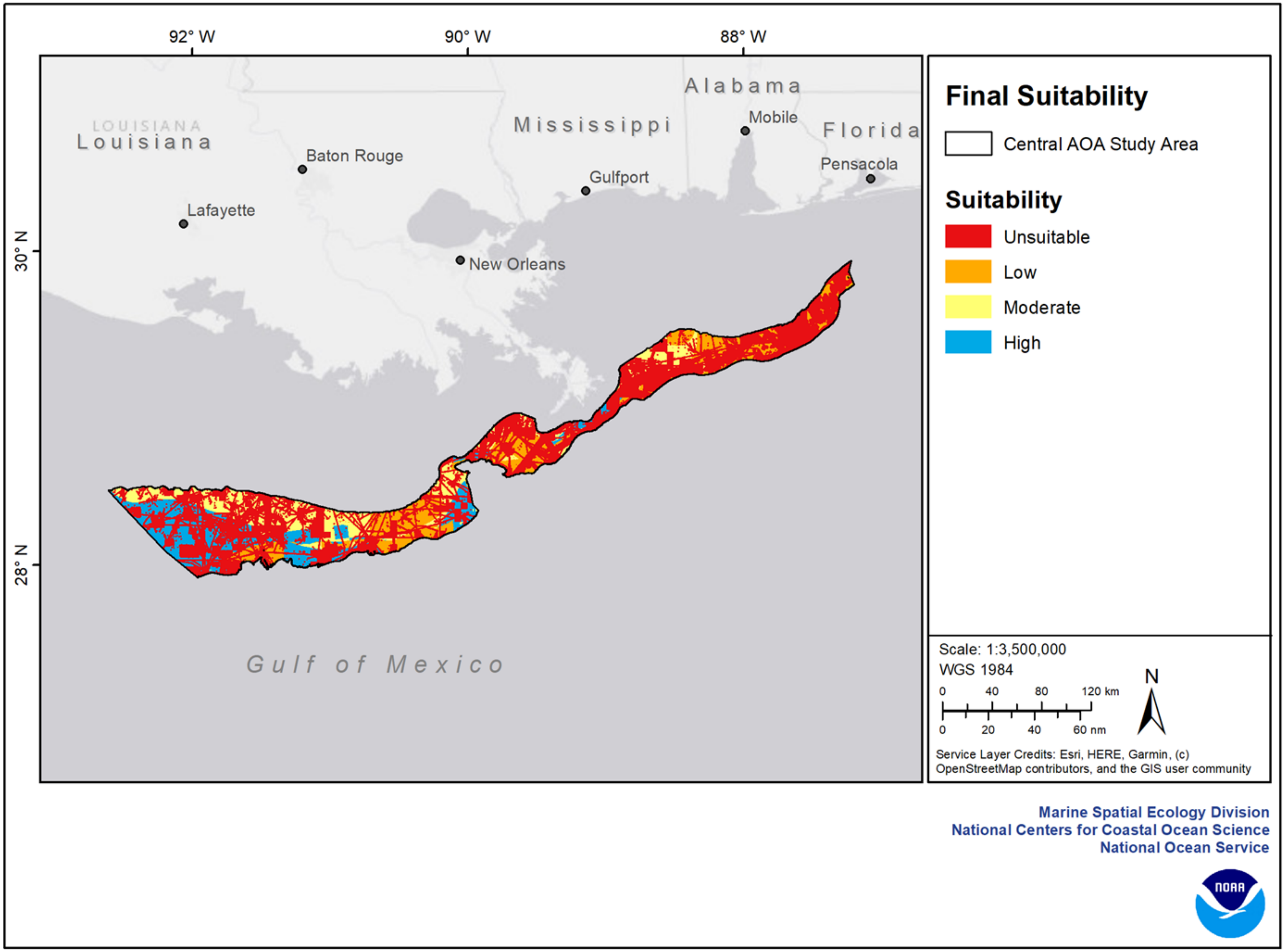


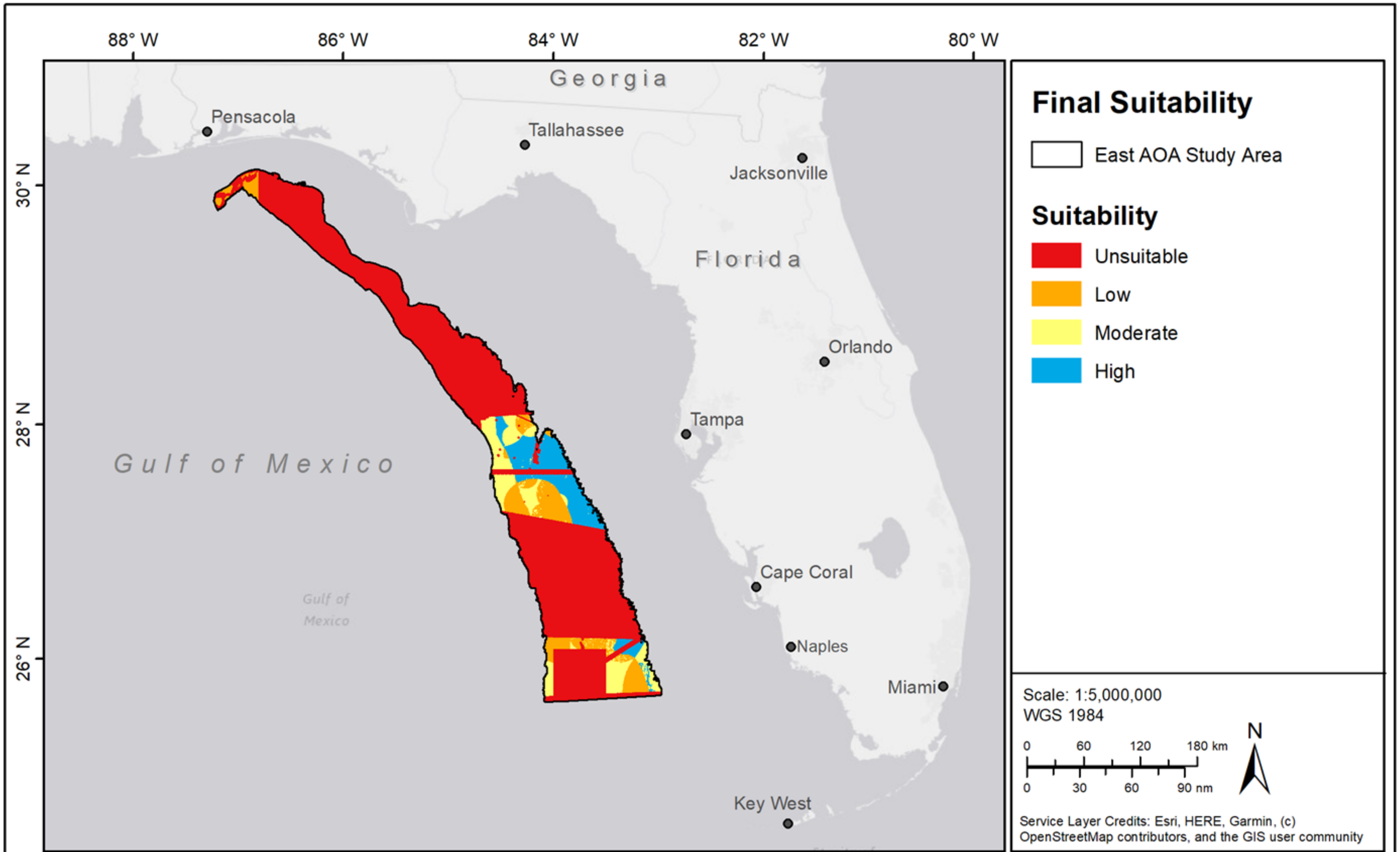
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


85° W
84° W
83° W
82° W
81° W
28° N
27° N
26° N
25° N
24° N
Tampa
Florida
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Straits of Florida
Fishing & Aquaculture
Southeast AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:3,000,000
WGS 1984
0 30 60 90 km
0 10 20 30 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

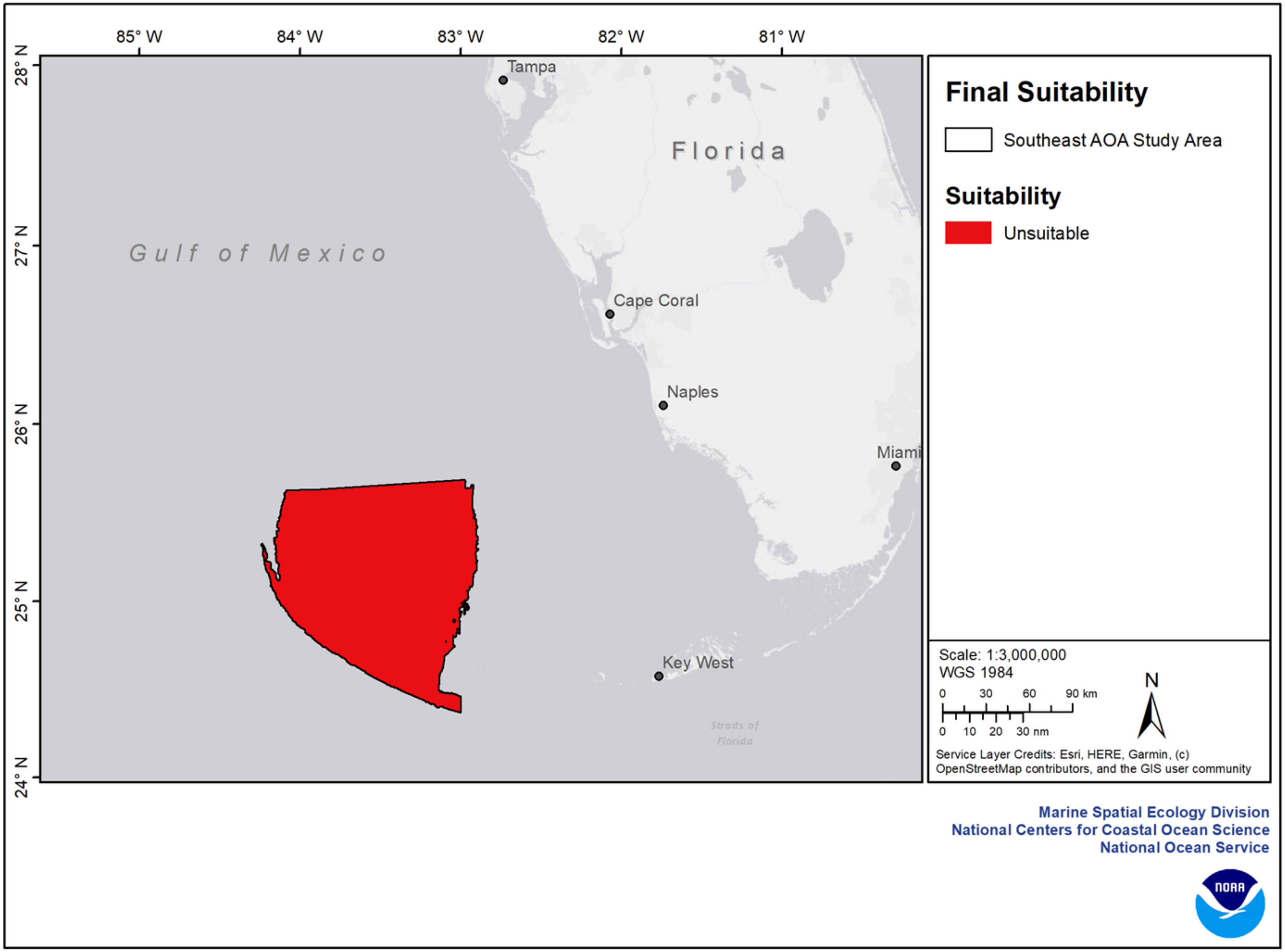
Final Suitability




92° W
90° W
88° W
30° N
28° N
Louisiana
LOUISIANA
Mississippi
Alabama
Florida
Baton Rouge
Lafayette
New Orleans
Gulfport
Mobile
Pensacola
Gulf of Mexico
Final Suitability
Central AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:3,500,000
WGS 1984
0 40 80 120 km
0 20 40 60 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA



Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


85° W
84° W
83° W
82° W
81° W
28° N
27° N
26° N
25° N
24° N
Tampa
Florida
Gulf of Mexico
Cape Coral
Naples
Miami
Key West
Straits of Florida
Final Suitability
Southeast AOA Study Area
Suitability
Unsuitable
Scale: 1:3,000,000
WGS 1984
0 30 60 90 km
0 10 20 30 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA

Gina Raimondo, Secretary
United States Department of Commerce

Dr. Richard Spinrad, Under Secretary for Oceans and Atmosphere
National Oceanic and Atmospheric Administration

Nicole LeBoeuf, Assistant Administrator
National Ocean Service