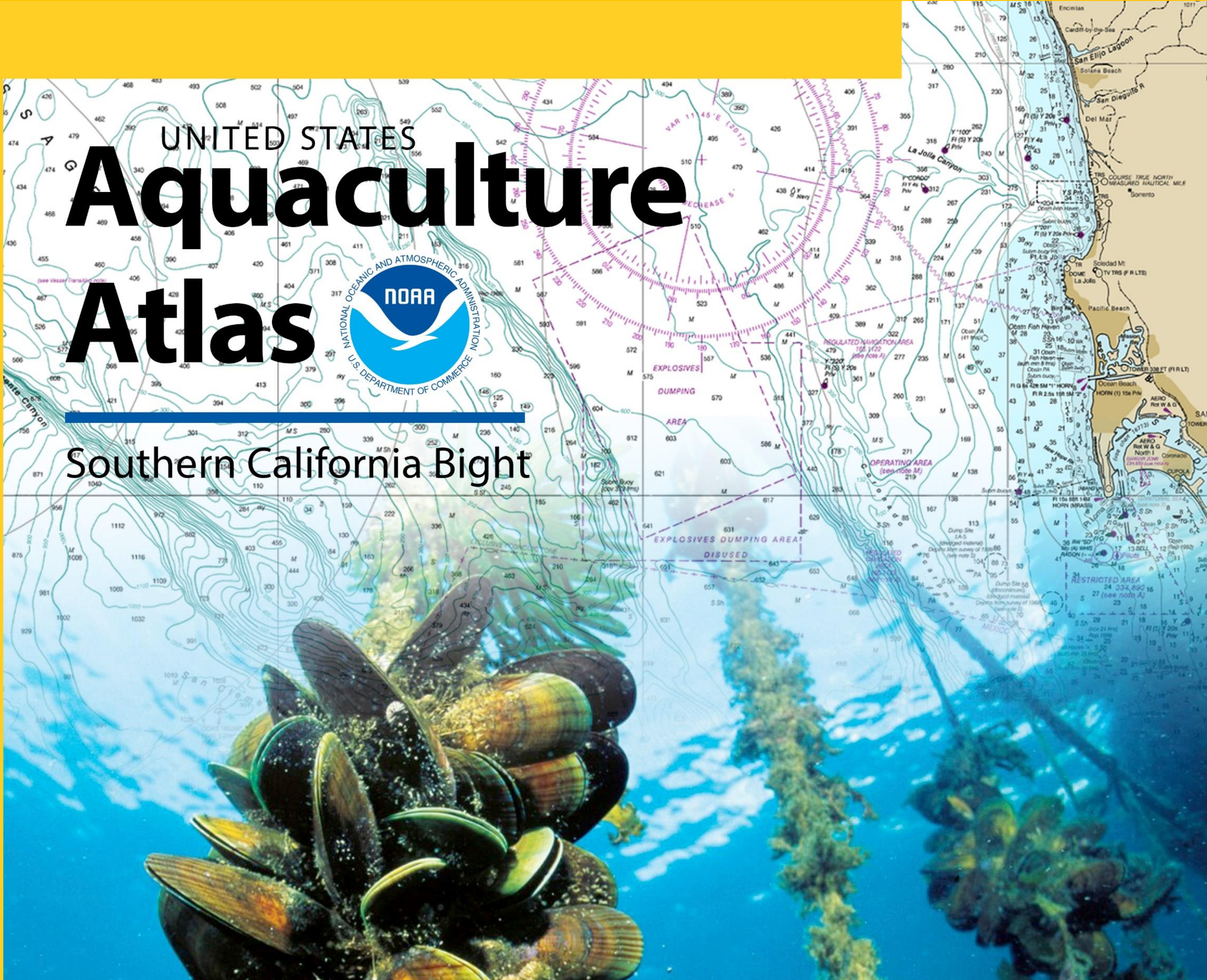
UNITED STATES

Aquaculture Atlas

Southern California Bight



An Aquaculture Opportunity Area Atlas for the Southern California Bight

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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 habitat to help meet our Nation's economic, social, and environmental needs. 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. 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 NOS and works to help NOAA meet its coastal stewardship and management responsibilities. NOAA's 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 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 Riley et al. (2021) Atlas for the Gulf of Mexico. As such, both Atlases share common authorship, methodologies, and text. Some sections are intentionally identical given the relevance to both regions.

Acknowledgements

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We thank the Pacific Fishery Management Council, Pacific States Marine Fisheries Commission, West Coast Ocean Alliance, and Southern California Coastal Ocean Observing System.

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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 U.S.-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 analyses utilize 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.

Presidential Executive Order 13921 (E.O.), Promoting American Seafood Competitiveness and Economic Growth (May 7, 2020), called for the expansion of sustainable seafood production in the U.S. to ensure food security; provide environmentally safe and sustainable seafood; support American workers; establish coordinated, predictable, and transparent federal action; and remove unnecessary regulatory burdens. The directive requires the Secretary of Commerce, in consultation with relevant federal agencies, to identify Aquaculture Opportunity Areas (AOAs) 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 E.O. requirement to identify AOAs, NOAA's National Centers for Coastal Ocean Science (NCCOS) collaborated with NOAA's 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. Southern California Bight (SCB). The Areas of Interest for spatial analyses were identified using a series of public engagement approaches including a Request for Information published in the Federal Register (85 FR 67519; October 23, 2020) and one-on-one meetings with stakeholders. The AOIs were delineated based on bathymetric data, political boundaries associated with offshore policies and regulation of submerged lands, outer continental shelf boundary, state and federal water demarcations, and Marine Protected Areas (MPAs).

Four distinct study areas were identified in the Southern California Bight: North, Central North, South, and Central South. 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 203 data layers included in this analysis, the maps, models, and descriptions provide the most comprehensive marine spatial modeling in the U.S. Southern California Bight 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 Southern California Bight that meet the industry and engineering requirements for 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. From 296 possibilities of the highest scoring ocean spaces in the two northern study areas, ten of the highest-ranking AOA options were identified (Figure 3.44 reprinted from Results below). Spatial modeling was performed at 10-ac (4.05-ha) grid cell resolution providing high contrast of suitability. Modeling results identified eight AOA options in the North study area off Santa Barbara, California, and two AOA options in the Central North study area off Santa Monica, California. Major constraints in the Central South and South study areas, principally interactions with ports and military activities, presented limitations for AOA consideration. Offshore aquaculture development in areas south of Long Beach, California, will have to contend with these constraints, which may continue to affect siting and permitting efficiency.

Eight AOA options were identified for the North study area (Figure page vii). Six of the options are located within 10 nm of fishing docks, which could provide shore-based infrastructure for aquaculture. Five of the AOA options are closest to Ventura Harbor with the closest option (N2-E) located just 4.6 nm offshore; the other options range from 6.3 to 14.9 nm offshore. The AOA options in this study area could also be accessed from the ports/harbors of Santa Barbara and Hueneme with distances ranging from 7.5 to 17.9 nm. The mean depth for all eight of the AOA options ranges from 25 m down to 95 m with the shallowest sites being N2-E (25.4 m), N2-D (31.5 m), and N2-C (48.1 m). Predominant currents are from the east-southeast with mean velocities ranging from 0.3 m/sec to upwards of 1.3 m/sec. The area consists of a mild wave climate with wave heights averaging 0.6 to around 1 m with 7 to 10 second wave periods predominantly from the west or west-southwest.

Two AOA options were identified for the Central North study area (Figure page vii). These AOA options are two of the smaller options with the largest being 1,000 acres. The nearest two harbors are Marina del Rey and Redondo Beach (King Harbor). AOA option CN1-B is the closest option, located just 5.3 nm from Marina del Rey, whereas CN1-A is approximately 6 nm away from the same harbor. Redondo Beach is 10.5 nm from CN1-B and 11.3 nm from CN1-A. These two harbors already support some commercial fishing landings, with Redondo Beach reporting over 264,000 pounds of seafood in 2019, whereas Marina del Rey reported over 230,000 pounds the same year. It is uncertain if either location could support expansion of aquaculture-related shore-based infrastructure. Marina del Rey was once the largest man-made small craft harbor in the United States and today provides nearly 5,000 boat slips supporting the greater Los Angeles metro area. Similarly, Redondo Beach is primarily a harbor for pleasure and sailing vessels. Further consideration could be given for shore-based infrastructure farther south within the Port of Los Angeles complex. While this area is nearly 30 nm from the two Central North AOA options, some types of aquaculture may accommodate this distance from port.

As the U.S. embarks on the identification of AOAs, offshore siting decisions must be based on rigorous marine spatial planning (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.

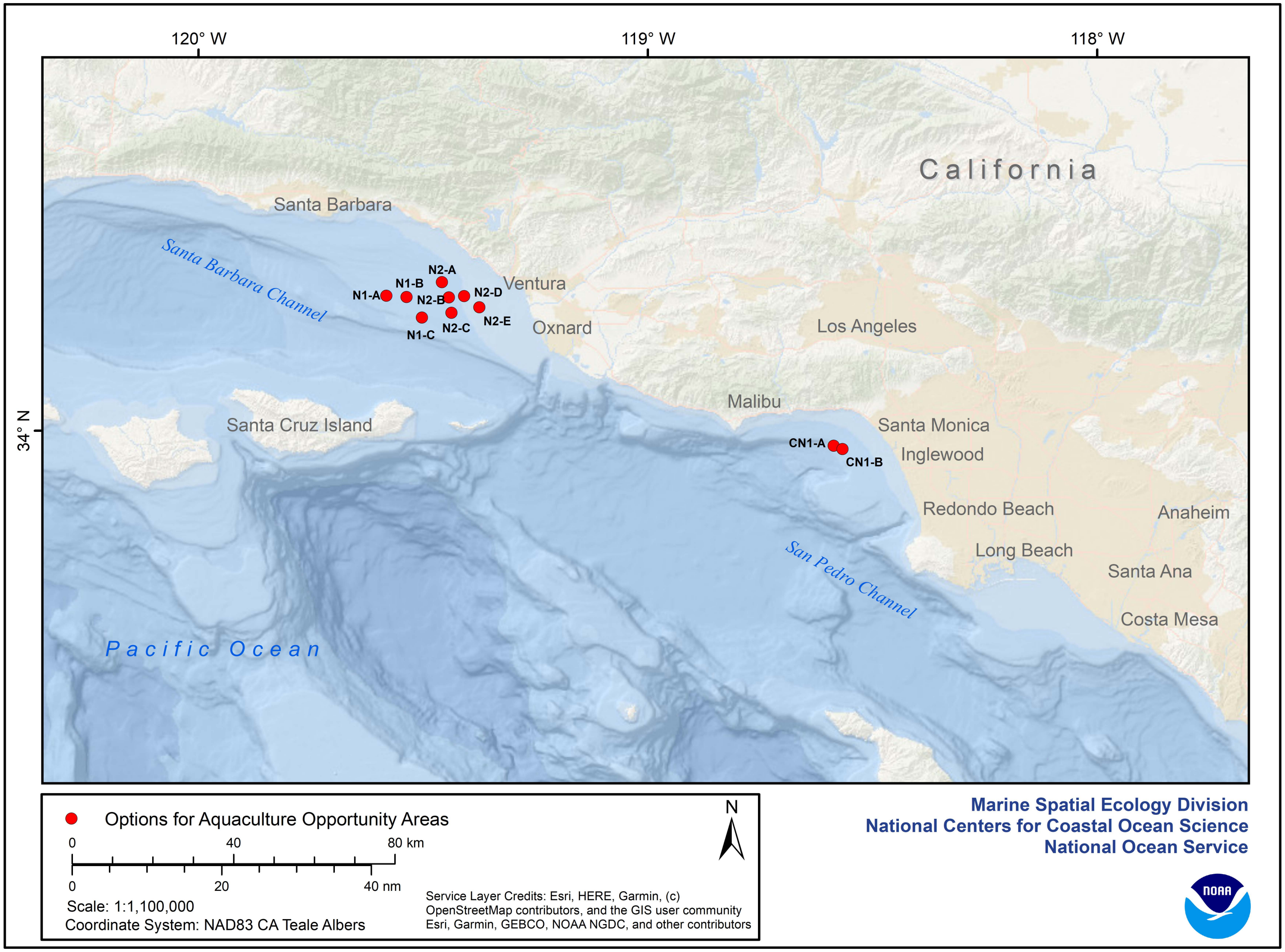

Figure 3.44 (reprinted from Results). Distribution of options for Aquaculture Opportunity Areas in U.S. federal waters of the Southern California Bight. Red circles represent the options, but do not reflect the size of the options.

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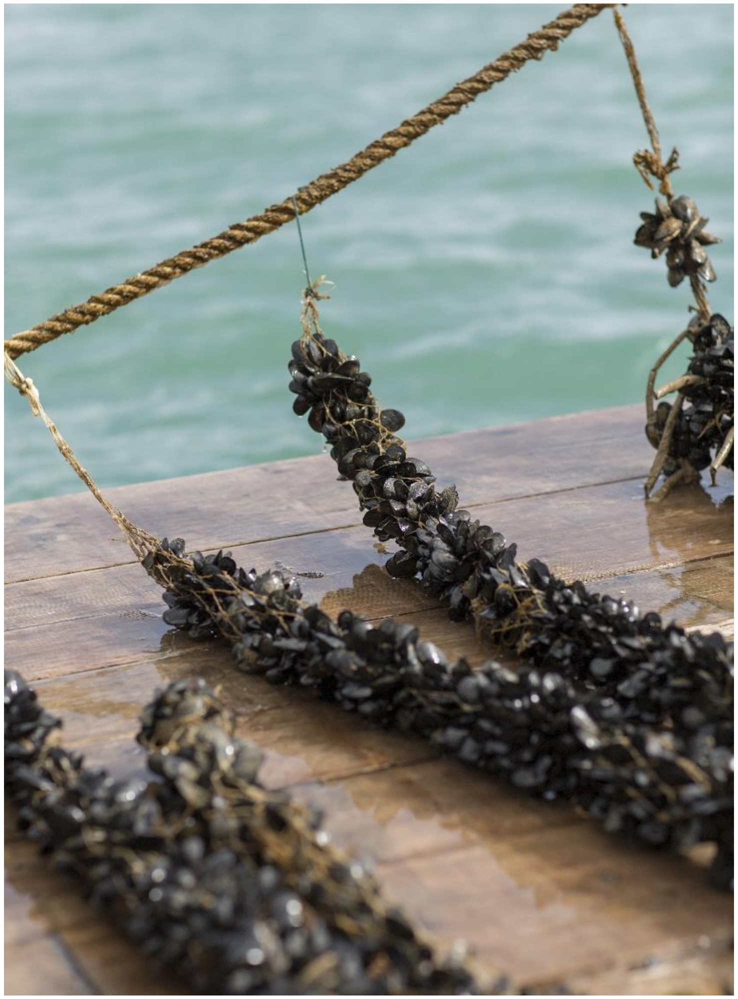


Appendices

Acronyms and Abbreviations

ac	acre
ADCP	Acoustic Doppler Current Profiler
AIS	Automated Identification System
AOA	Aquaculture Opportunity Area
AOI	Area of Interest
ARPA-E	Advanced Research Projects Agency-Energy
ASBPA	American Shore and Beach Preservation Association
AWOIS	Automated Wreck and Obstruction Information System
BIA	Biologically Important Area
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
BTS	Bureau of Transportation Statistics
CA	California
CADPH	California Department of Public Health
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CAMLPAI	California Marine Life Protection Act Initiative
C-HARM	California Harmful Algae Risk Mapping
CDAS	Computerized Database Analysis System
CDFW	California Department of Fish and Wildlife
CENCOOS	Central and Northern California Ocean Observing System
CFR	Code of Federal Regulations
CN	Central North
COLREGs	Convention on the International Regulations for Preventing Collisions at Sea
CoNED	Coastal National Elevation Database
CPS	Coastal Pelagic Species
CPFV	Commercial Passenger Fishing Vessel
CRFS	California Recreational Fisheries Survey
CRM	Coastal Relief Model
CS	Central South
CSMP	California Seafloor Mapping Program
CTD	Conductivity, Temperature, and Depth
CUI	Controlled Unclassified Information
DDT	dichloro-diphenyl-trichloroethane
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOT	Department of Transportation
DPS	Distinct Population Segment
DSCRTP	Deep-sea Coral Research and Technology Program
DTL	Daily Trip Limit
EAA	Ecosystem Approach to Aquaculture
EEZ	Exclusive Economic Zone

EFH	Essential Fish Habitat
EIMS	Environmental Information Management System
ENC	Electronic Navigational Chart
ENOW	Economics: National Ocean Watch
E.O.	Executive Order
ERS	Economic Research Service
ESA	Endangered Species Act
Esri	Environmental Systems Research Institute
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization of the United Nations
FDA	Food and Drug Administration
FMP	Fishery Management Plan
FR	Federal Register
ft	feet
FUDS	Formerly Used Defense Sites
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
ha	hectare
HAB	Harmful Algal Bloom
HAPC	Habitat Areas of Particular Concern
HMS	Highly Migratory Species
H_s	Significant Wave Height
IFQ	Individual Fishing Quota
JOFLO	Joint Oil Fisheries Liaison Office
JPL	Jet Propulsion Laboratory
Kd	Diffuse Light Attenuation Coefficient
km	kilometer
LE	Limited Entry
LISA	Local Index of Spatial Association
m	meter
MAIASC	Military Aviation and Installation Assurance Siting Clearinghouse
MARINER	Macroalgae Research Inspiring Novel Energy Resources
MCDA	Multi-Criteria Decision Analysis
MEOWs	Marine Ecoregions of the World
mg/m^3	milligrams per meter cubed
mi	statute mile
$mmol/m^3$	millimoles per cubic meter
MMPA	Marine Mammal Protection Act
MOA	Military Operating Area
MPA	Marine Protected Area
MSP	Marine Spatial Plan/Planning
MT	metric ton
MTR	Military Training Routes
N	North
NAA	National Aquaculture Act
NAD	North American Datum
NASA	National Aeronautics and Space Administration

NCCOS	National Centers for Coastal Ocean Science
NCEI	National Centers for Environmental Information
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
nm	nanometer (Kd light attenuation)
nm	nautical mile
NMS	National Marine Sanctuaries
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWFSC	Northwest Fisheries Science Center
OA	Open Access
OBIS	Ocean Biodiversity Information System
OCM	Office for Coastal Management
OCS	Office of Coast Survey
OCS	Outer Continental Shelf
ODIS	Ocean Data Information System
ORR	Office of Response and Restoration
PAR	Photosynthetic Active Radiation (Kd)
PCBs	polychlorinated biphenyls
PEIS	Programmatic Environmental Impact Statement
PMSR	Point Mugu Sea Range
PNNL	Pacific Northwest National Laboratory
POA	Pacific Ocean AquaFarms
PRD	Protected Resources Division
QA/QC	Quality Assurance/Quality Control
ROMS	Regional Ocean Modeling System
RSM	Regional Sediment Management
RULET	Remediation of Underwater Legacy Environmental Threats
s	second
S	South
S.B.	Senate Bill (California)
SCB	Southern California Bight
SCCWRP	Southern California Coastal Water Research Project
SCOOS	South California Coastal Ocean Observing System
SE	Species Evenness
SLC	State Lands Commission
SMI	Standard Mapped Image
SPCOA	San Pedro Channel Operating Area
SUA	Special Use Airspace
SWAN	Simulating WAves Nearshore
SWFSC	Southwest Fisheries Science Center
SWRCB	California State Water Resources Control Board
TNC	The Nature Conservancy
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UCLA	University of California Los Angeles
UN	United Nations
U.S.	United States of America

USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USDON	U.S. Department of the Navy
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UXO	Unexploded Ordnance
VMS	Vessel Monitoring System
WCR	West Coast Region

Species List

Common name	Scientific name
albacore tuna	*Thunnus alalunga*
arrowtooth flounder	*Atheresthes stomias*
Atlantic salmon	*Salmo salar*
aurora rockfish	*Sebastes aurora*
Baird's beaked whale	*Berardius bairdii*
bank rockfish	*Sebastes rufus*
bigeye tuna	*Thunnus obesus*
big skate	*Beringraja binoculata*
black abalone	*Haliotis cracherodii*
Black-and-yellow rockfish	*Sebastes chrysomelas*
black rockfish	*Sebastes melanops*
blackgill rockfish	*Sebastes melanostomus*
blue rockfish	*Sebastes mystinus*
blue shark	*Prionace glauca*
blue whale	*Balaenoptera musculus*
bocaccio	*Sebastes paucispinis*
bronzespotted rockfish	*Sebastes gilli*
brown rockfish	*Sebastes auriculatus*
butter sole	*Isopsetta isolepis*
cabezon	*Scorpaenichthys marmoratus*
calico rockfish	*Sebastes dallii*
California halibut	*Paralichthys californicus*
California market squid	*Doryteuthis opalescens*
California mussel	*Mytilus californianus*
California scorpionfish	*Scorpaena guttata*
California sea cucumber	*Apostichopus californicus*
California sea lion	*Zalophus californianus*
California sheephead	*Semicossyphus pulcher*
California skate	*Beringraja inornata*
California spiny lobster	*Panulirus interruptus*

Common name	Scientific name
canary rockfish	*Sebastes pinniger*
chameleon rockfish	*Sebastes phillipsi*
chilipepper rockfish	*Sebastes goodei*
China rockfish	*Sebastes nebulosus*
chinook salmon	*Oncorhynchus tshawytscha*
coho salmon	*Oncorhynchus kisutch*
common bottlenose dolphin	*Tursiops truncatus*
common thresher shark	*Alopias vulpinus*
copper rockfish	*Sebastes caurinus*
cowcod	*Sebastes levis*
curlfin sole	*Pleuronichthys decurrens*
Cuvier’s beaked whale	*Ziphius cavirostris*
Dall's porpoise	*Phocoenoides dalli*
darkblotched rockfish	*Sebastes crameri*
dorado (dolphinfish)	*Coryphaena hippurus*
Dover sole	*Microstomus pacificus*
Dungeness crab	*Metacarcinus magister*
dusky rockfish	*Sebastes ciliatus*
dwarf-red rockfish	*Sebastes rufinanus*
dwarf sperm whale	*Kogia sima*
eelgrass	*Zostera marina*
English sole	*Parophrys vetulus*
fin whale	*Balaenoptera physalus*
finescale codling (Pacific flatnose)	*Antimora microlepis*
flag rockfish	*Sebastes rubrivinctus*
flathead sole	*Hippoglossoides elassodon*
freckled rockfish	*Sebastes lentiginosus*
giant kelp	*Macrocystis pyrifera*
giant manta ray	*Manta birostris*
gopher rockfish	*Sebastes carnatus*

Common name	*Scientific name*
grass rockfish	*Sebastes rastrelliger*
gray whale	*Eschrichtius robustus*
greenblotched rockfish	*Sebastes rosenblatti*
green sea turtle	*Chelonia mydas*
greenspotted rockfish	*Sebastes chlorostictus*
greenstriped rockfish	*Sebastes elongatus*
Guadalupe fur seal	*Arctocephalus townsendi*
gulf grouper	*Mycteroperca jordani*
halfbanded rockfish	*Sebastes semicinctus*
harbor seal	*Phoca vitulina*
harlequin rockfish	*Sebastes variegatus*
hawksbill sea turtle	*Eretmochelys imbricata*
honeycomb rockfish	*Sebastes umbrosus*
humpback whale	*Megaptera novaeangliae*
Japanese scallop	*Patinopecten yessoensis*
kelp greenling	*Hexagrammos decagrammus*
kelp rockfish	*Sebastes atrovirens*
Kemp’s ridley sea turtle	*Lepidochelys kempii*
killer whale	*Orcinus orca*
krill	*Thysanoessa spinifera*
leopard shark	*Triakis semifasciata*
leatherback sea turtle	*Dermochelys coriacea*
lingcod	*Ophiodon elongatus*
loggerhead sea turtle	*Caretta caretta*
long-beaked common dolphin	*Delphinus capensis*
longnose skate	*Beringraja rhina*
longspine thornyhead	*Sebastolobus altivelis*
Mediterranean mussels	*Mytilus galloprovinicialis*
Mexican rockfish	*Sebastes macdonaldi*
minke whale	*Balaenoptera acutorostrata*
northern fur seal	*Callorhinus ursinus*
northern right whale dolphin	*Lissodelphis borealis*

Common name	*Scientific name*
North Pacific krill	*Euphausia pacifica*
North Pacific right whale	*Eubalaena japonica*
oceanic whitetip shark	*Carcharhinus longimanus*
olive ridley sea turtle	*Lepdochelys olivacea*
olive rockfish	*Acanthoclinus fuscus*
Pacific bluefin tuna	*Thunnus orientalis*
Pacific cod	*Gadus macrocephalus*
Pacific Ocean perch	*Sebastes alutus*
Pacific rattail	*Coryphaenoides acrolepis*
Pacific sanddab	*Citharichthys sordidus*
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*
Pacific whiting (Pacific hake)	*Merluccius productus*
petrale sole	*Eopsetta jordani*
pink salmon	*Oncorhynchus gorbuscha*
pink shrimp	*Pandalus borealis*
pinkrose rockfish	*Sebastes simulator*
pygmy rockfish	*Sebastes wilsoni*
pygmy sperm whale	*Kogia breviceps*
quillback rockfish	*Sebastes maliger*
redbanded rockfish	*Sebastes babcocki*
red sea urchin	*Mesocentrotus franciscanus*
redstripe rockfish	*Sebastes proriger*
rex sole	*Glyptocephalus zachirus*
ridgeback prawn	*Sicyonia ingentis*
Risso's dolphin	*Grampus griseus*
rock sole	*Lepidopsetta bilineata*
rosethorn rockfish	*Sebastes helvomaculatus*
rosy rockfish	*Sebastes rosaceus*
rougheye rockfish	*Sebastes aleutianus*
sablefish	*Anoplopoma fimbria*
sand sole (Pacific sand sole)	*Psettichthys melanostictus*
scalloped hammerhead shark	*Sphyrna lewini*

Common name	*Scientific name*
sei whale	*Balaenoptera borealis*
sharpchin rockfish	*Sebastes zacentrus*
short-beaked common dolphin	*Delphinus delphis*
shortbelly rockfish	*Sebastes jordani*
short-finned pilot whale	*Globicephala macrorhynchus*
shortfin mako shark	*Isurus oxyrinchus*
shortraker rockfish	*Sebastes borealis*
shortspine thornyhead	*Sebastolobus alascanus*
silvergray rockfish	*Sebastes brevispinis*
soupfin shark	*Galeorhinus galeus*
speckled rockfish	*Sebastes ovalis*
sperm whale	*Physeter macrocephalus*
spiny dogfish (Pacific spiny dogfish)	*Squalus suckleyi*
splitnose rockfish	*Sebastes diploproa*
spotted ratfish	*Hydrolagus colliei*
squarespot rockfish	*Sebastes hopkinsi*
starry flounder	*Platichthys stellatus*
starry rockfish	*Sebastes constellatus*
striped dolphin	*Stenella coeruleoalba*
stripetail rockfish	*Sebastes saxicola*
swordspine rockfish	*Sebastes ensifer*
tiger rockfish	*Sebastes nigrocinctus*
treefish	*Sebastes serriceps*
vermilion rockfish	*Sebastes miniatus*
white abalone	*Haliotis sorenseni*
widow rockfish	*Sebastes entomelas*
yelloweye rockfish	*Sebastes ruberrimus*
yellowfin tuna	*Thunnus albacares*
yellowmouth rockfish	*Sebastes reedi*
yellowtail jack	*Seriola lalandi*
yellowtail rockfish	*Sebastes flavidus*

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

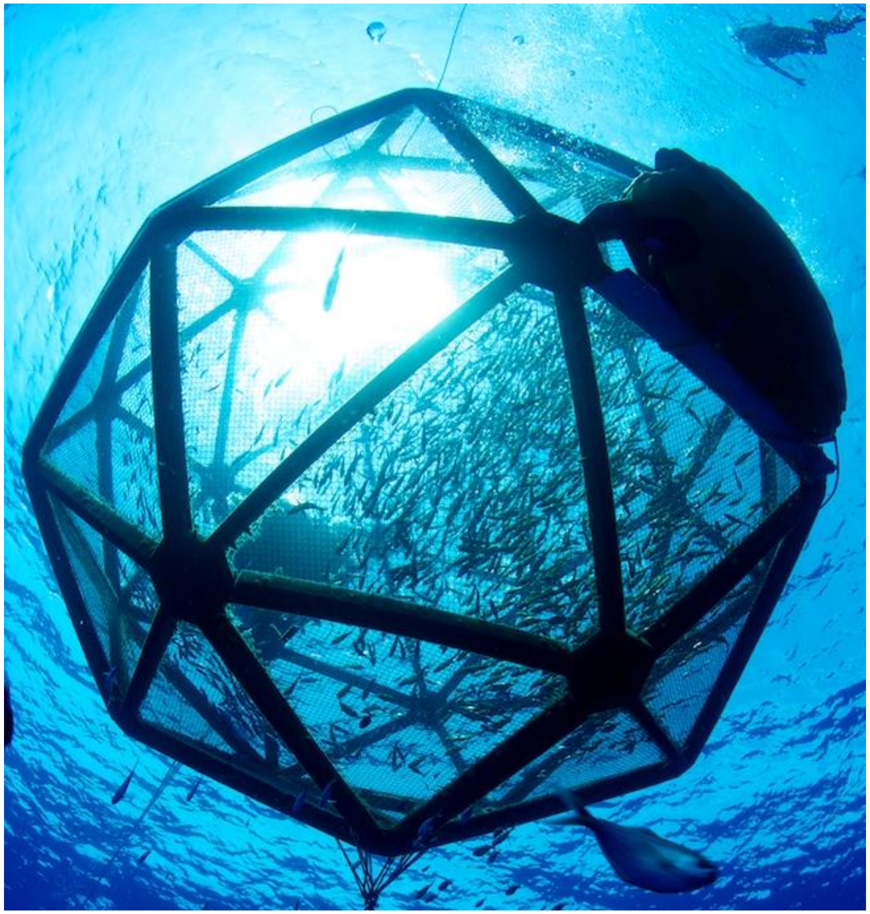
Background

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 (UN 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 teetering between 86 and 93 million metric tonnes (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 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 Technology Policy, and 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. Working in partnership with the U.S. Department of Agriculture, Food and Drug Administration, Department of the Interior, and the Joint Subcommittee on Aquaculture, the policy intent was “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, NOAA’s 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’s National Marine Fisheries Service (NMFS) is also responsible for protecting habitat, vulnerable species, and sustainable fisheries, and thus has responsibility for considering, preventing, and mitigating potential adverse environmental impacts

[1]https://media.fisheries.noaa.gov/2021-01/doc-aquaculture-policy-2011.pdf?

[2] https://media.fisheries.noaa.gov/2021-01/2011-noaa-marine-aquaculture-policy.pdf?null

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 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, 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 (UN) 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 U.S. Department of Agriculture (USDA) and the 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. 2021). As of December 2019, before the COVID-19 pandemic,[6] USDA (2019) reported that 89.5% of U.S. households were food secure; the remaining 10.5%

[3] https://www.federalregister.gov/documents/2020/05/12/2020-10315/promoting-american-seafood-competitiveness-and-economic-growth
[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
[6] https://www.who.int/emergencies/diseases/novel-coronavirus-2019

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 our 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, which exacerbates 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).

U.S. Offshore Aquaculture Opportunity

A study by the United Nations (UN) 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, or 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 northeastern 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; Holm et al. 2017; Lester et al. 2018; FAO 2020). 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 either farmed overseas or harvested by American fishermen, exported overseas for processing, and then imported back into the U.S. for consumption (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 (2018), 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 and 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 Southern California Bight

Historically, there has been minimal offshore aquaculture development in the Southern California Bight despite having calm seas, low storm frequency, and a temperate climate. Presently, there are two farms permitted to grow Mediterranean mussels (*Mytilus galloprovincialis*) in the open ocean including state (< 3 miles; 5 km) and federal waters (> 3 miles; 5 km), and an algae farm and a finfish farm pursuing permits in federal waters. In 1979, researchers and a consulting firm began harvesting wild-set Mediterranean mussels and the sea mussel (*Mytilus californianus*) from oil-production platforms in the Santa Barbara Channel. This activity was stimulated by the need to control biofouling on platform submerged support structures and lasted well into the 1990s with as much as one-half million pounds of mussels harvested per year. There have been forays into several types of small-scale experimental aquaculture endeavors in the southern California coastal ocean, including mussels, abalone, and kelp on a tire-reef experiment.

There have been efforts by the California state legislature and government to address ocean-based aquaculture. The Sustainable Oceans Act (S.B. 201) provided two provisions to establish a permitting framework for finfish aquaculture: 1) the requirement that the California Department of Fish and Wildlife prepare a Programmatic Environmental Impact Report and 2) authorization for the California Fish and Game Commission to lease state water bottoms or the water column for marine finfish aquaculture. More recently, the California Ocean Protection Council initiated an effort to develop the "California Aquaculture Action Plan," a statewide strategic plan for a comprehensive, consistent, and science-based framework and policy for marine aquaculture (OPC 2020). This new plan focuses on marine macroalgae, shellfish, and multi-trophic aquaculture in state marine waters (including coastal ocean waters). The goal of the action plan was to provide guidance for minimizing environmental impacts to wild fisheries, habitat, and biodiversity, and to evaluate socioeconomic considerations.

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 (MPAs), navigation and transportation management, and energy development. For example, Wind Energy Areas 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 (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 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). The application of marine spatial planning is central to an ecosystem approach to aquaculture (EAA) to ensure accountability and equitable shared use of resources (Stelzenmüller et al. 2017). 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 those seeking a permit.

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 aquaculture infrastructure management challenges while strengthening community resilience and works to site specific 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 analysis (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 Aquaculture Opportunity Areas (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 NCCOS in collaboration with NOAA NMFS to identify potential AOA options for offshore aquaculture development in the Southern California Bight. 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 have potential to be greatly suitable for developing offshore AOAs in the Southern California Bight are presented in this Atlas, which documents the science and results of this effort. The potential AOA options resulting from this analysis may 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 development process. Areas identified as AOAs will have characteristics that are expected 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., shipping), 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.

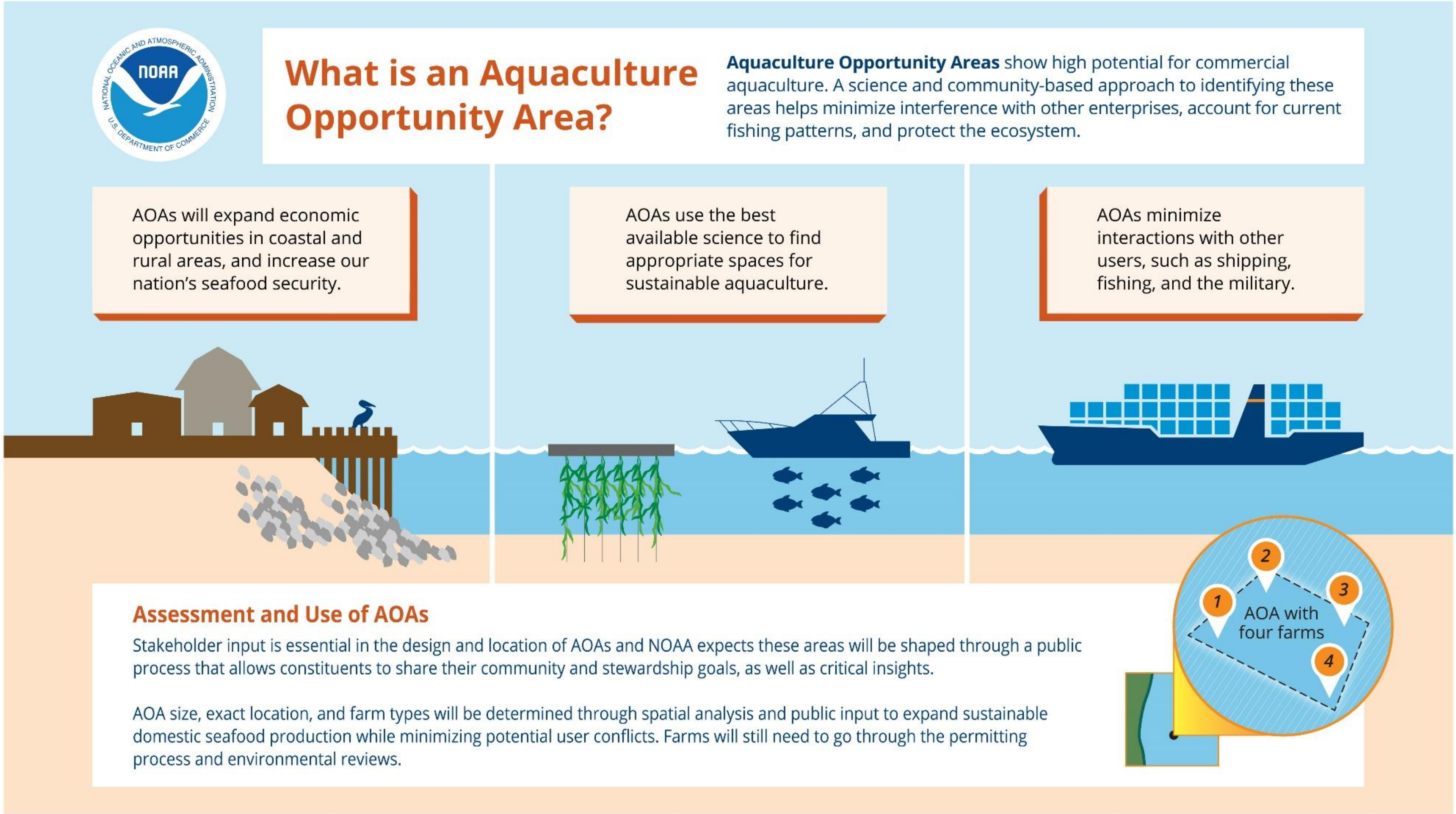


Figure 1.1. Infographic explaining how Aquaculture Opportunity Areas show high potential for commercial aquaculture.

Southern California Study Region

Area of Interest

Federal waters off southern California, south of Point Conception to the U.S. and Mexico border, were selected as one of the first regions for AOA evaluation due to preexisting spatial data availability, previous analyses in the region, and industry interest in developing sustainable offshore aquaculture operations. NOAA further narrowed the criteria for aquaculture planning in southern California using a combination of spatial mapping approaches, scientific review, and stakeholder input. As described above, the southern California AOA AOI includes federal waters between 5.6 km (3 nautical miles [nm]) and 46.3 km (25 nm) offshore within the EEZ at depths ranging between 10 m (33 ft) and 150 m (492 ft).

Physical Description and Scale

Bathymetric features of the southern California AOI region include the continental shelf, steep and eroded continental slope, continental rise, and deep-sea floor. The continental shelf off southern California extends from the shore to depths of approximately 200 m (Tomczak and Godfrey 2003). Along the continental slope, the upper slope ranges from 200 - 800 m (656 - 2,625 ft) adjacent to the shelf break. The mid-slope ranges from 800 - 1,400 m (2,625 - 4,593 ft) and the lower slope occurs at depths between 1,400 - 4,000 m (4,593 - 13,123 ft). Below the lower slope, the flat abyssal plain stretches out to depths between 3,500 - 6,500 m (11,483 - 21,326 ft). Bottom topography in the Southern California Bight undulates between broad expanses of continental shelf to the Santa Rosa Cortes Ridge down to the deep shelf basins including Tanner, Santa Cruz, Santa Catalina, East Cortez, San Pedro, Santa Monica, and Santa Barbara basins as well as the San Diego Trough (NRC 1990). Other bathymetric features associated with the AOI include two important channels (Santa Barbara and San Pedro) and a series of escarpments, canyons, banks, and seamounts (NRC 1990). Additionally, the volcanic Channel Islands archipelago (Moody 2000) occurs within the southern California AOA AOI, which is located off Santa Barbara, Ventura, Los Angeles, Orange, and San Diego counties.

Marine Ecoregion and Habitat

The southern California AOI occurs within the Southern California Bight (SCB) Level I ecoregion, which extends from Point Conception to the southern tip of Baja California, Mexico (Wilkinson et al. 2009). Level I marine ecoregions capture large-scale ecosystem differences, such as large water masses and currents and regions of consistent sea surface temperature (Spalding et al. 2007; Wilkinson et al. 2009). The SCB ecoregion is characterized by the transition zone where the warm northward-flowing Davidson Current collides with the cold south-flowing California Current (Schiff et al. 2016). Abundant nutrients and sunlight promote high biological productivity supporting diverse cold- and warm-water species (Wilkinson et al. 2009). The SCB is a unique ecological environment that provides a range of habitat types for approximately 350 fish and 5,000 invertebrate species native to the region (Schiff et al. 2016). The southern California AOI includes diverse habitat types including rocky reefs, submarine canyons, and seamounts, to broader-scale habitat features, including the continental shelf break, that share certain features coastwide (PFMC 2013).

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 (ICF et al. 2013). 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 are capable of providing scientific or humanistic understanding of past human behavior or cultural adaptation.

Coastal communities of seafaring Paleoindians lived along the shores and on the islands of California from as early as the Pleistocene (8,600 years ago) (Erlandson and Jew 2009). Over 100 submerged artifacts and dwelling sites have been identified in southern California (Masters 2003). Most prehistoric habitation areas are found within the inner continental shelf. Evidence from numerous archaeological sites along the coast suggests an exploitation of bay and estuary kelp beds, rocky areas, and offshore environments (USDON 2018). Daisy Cave, located on San Miguel Island in the Northern Channel Islands, represents the oldest known human settlement on the California coast. Settlements along estuaries, bays, and sloughs with middens containing the remains of fish, marine invertebrates, and marine mammals, as well as other maritime artifacts recovered from the region, indicate extensive maritime resource use well into the Holocene (nearly 12,000 years ago) (Rick et al. 2001; Erlandson et al. 2007). By the time of early European contact, Spanish voyages traveled northward from Mexico in the 1530s, and by 1578 the British were encroaching on the Spanish occupation of coastal California. Undiscovered sunken vessels from early Spanish and British exploration, colonization, and trade may be present in coastal southern California (USDON 2018). Evidence of the nation's rich maritime and economic history along the West Coast is represented by records of 5,813 shipwrecks representative of each time period from the 16th to the 20th centuries (ICF et al. 2013).

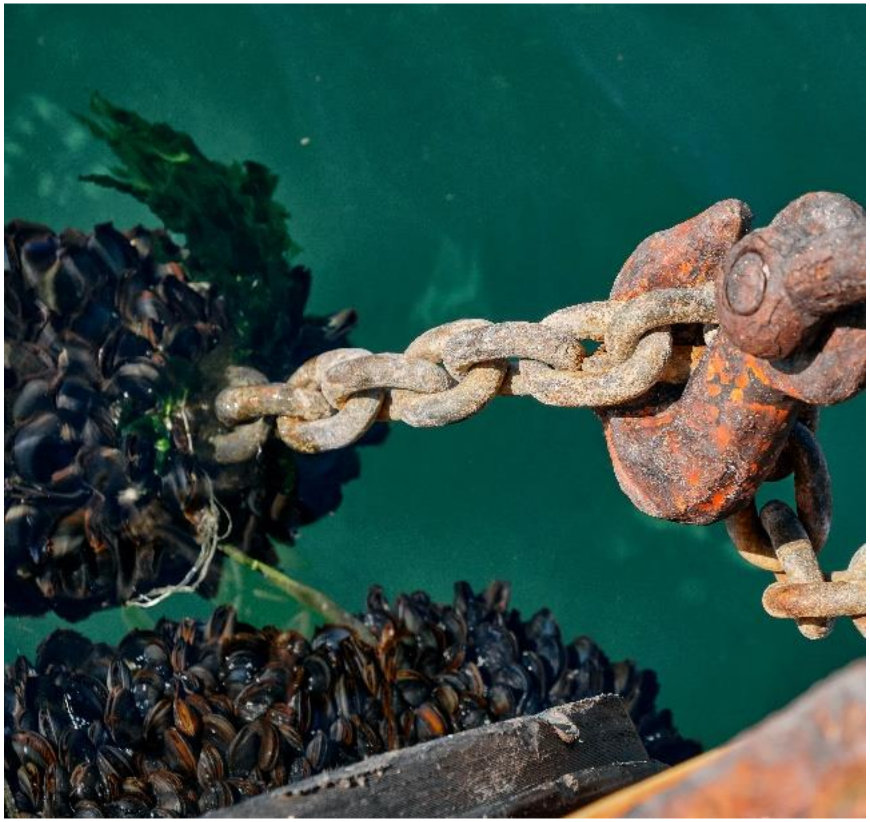
Maritime Economy

The vibrant California economy is valued at $3.1 trillion and ranks the state among the world's top ten wealthiest nations (NOEP 2020). California is the largest ocean-based economy in the U.S., which in 2018 was valued at $49.1 billion annually and employed over half a million people (NOAA OCM 2018). Of the five largest California counties, four are adjacent to the Pacific Ocean and account for 48 percent of the state's gross domestic product (GDP). California's ocean economy is dominated by tourism, recreation, and marine transportation sectors, which account for 94 percent of California's coastal workforce (NOAA OCM 2018). California's diverse living marine resources also support fishing communities that supply seafood to the state and region, and for international export. In 2012, approximately 1,900 commercial fishing vessels operated in California (Sievanen et al. 2018) and in 2017, over 150,000 jobs were supported by the seafood industry (NMFS 2021b).

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. As described above, the AOI here is federal waters between 5.6 km (3 nm) and 46.3 km (25 nm) offshore within the EEZ at depths ranging between 10 m (33 ft) and 150 m (492 ft). 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 stakeholder meetings and listening sessions initiated through NOAA's Request for Information in the Federal Register (85 FR 67519; October 23, 2020)[7] to solicit public input in order to support the identification of project requirements for offshore aquaculture (finfish, macroalgae, shellfish, or a combination of species) (Table 2.1). Based on 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 southern California. 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 Marine Protected Areas. Within the Southern California Bight 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 the state of California. This is coterminous with the boundary of most coastal states at 5.6 km (3 nm). The outer boundary, established by Presidential Proclamation 5030[8] and consistent with the UN Convention of the Law of the Sea, extends out to the 370-km (200-nm) limit (Reed 2000).



[7] https://www.federalregister.gov/documents/2020/10/23/2020-23487/aquaculture-opportunity-areas
[8] 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

NOAA's planning goal for this study was to identify AOA options for the waters of the Southern California Bight 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 (Table 2.1) suggested that study areas focus on aquaculture development off southern California at depths from 10 to 150 m (33 to 492 ft) with a maximum distance from shore of 46 km (25 nm) (Figure 2.1). Water depths were extracted using NOAA's U.S. Coastal Relief Model, which provides comprehensive bathymetric data at 3 arc-second horizontal resolution (~90 x 90 m pixels). The northern extent of the AOI was determined using a biogeographical break at Point Conception, which also corresponds to the Marine Ecoregions of the World (MEOWs) approach established by Spalding et al. (2007). The southern extent was delineated based on the southern extent of the U.S. EEZ and the U.S.-Mexico border (Figure 2.2). Four distinct study areas were identified for spatial analysis including the North (N) study area estimated at 700 km^2 (270 mi^2), Central North (CN) study area estimated at 173 km^2 (67 mi^2), Central South (CS) study area estimated at 230 km^2 (89 mi^2), and the South (S) study area estimated at 269 km^2 (104 mi^2) (Figure 2.3).

Table 2.1. Aquaculture Opportunity Area study area spatial planning and siting boundary rules.

AOA Boundary Rules	Description
Depth Range	10 - 150 m (33 ft - 492 ft)
Size Range	500 - 2,000 ac (202 - 809 ha)
Maximum Distance from Shore	46.3 km (25 nm)
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

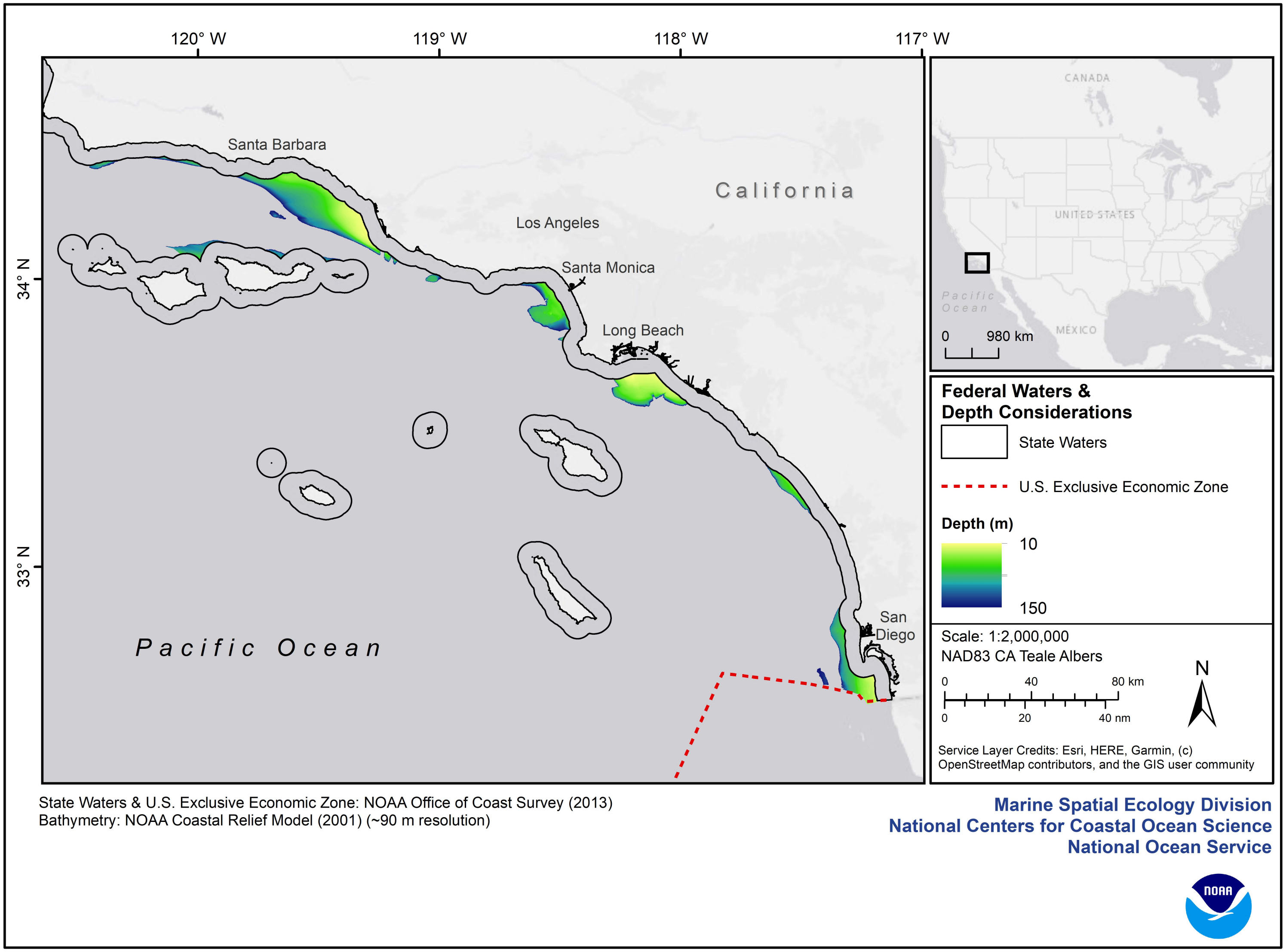


Figure 2.1. Depths from 10 to 150 m in U.S. federal waters of the Southern California Bight.

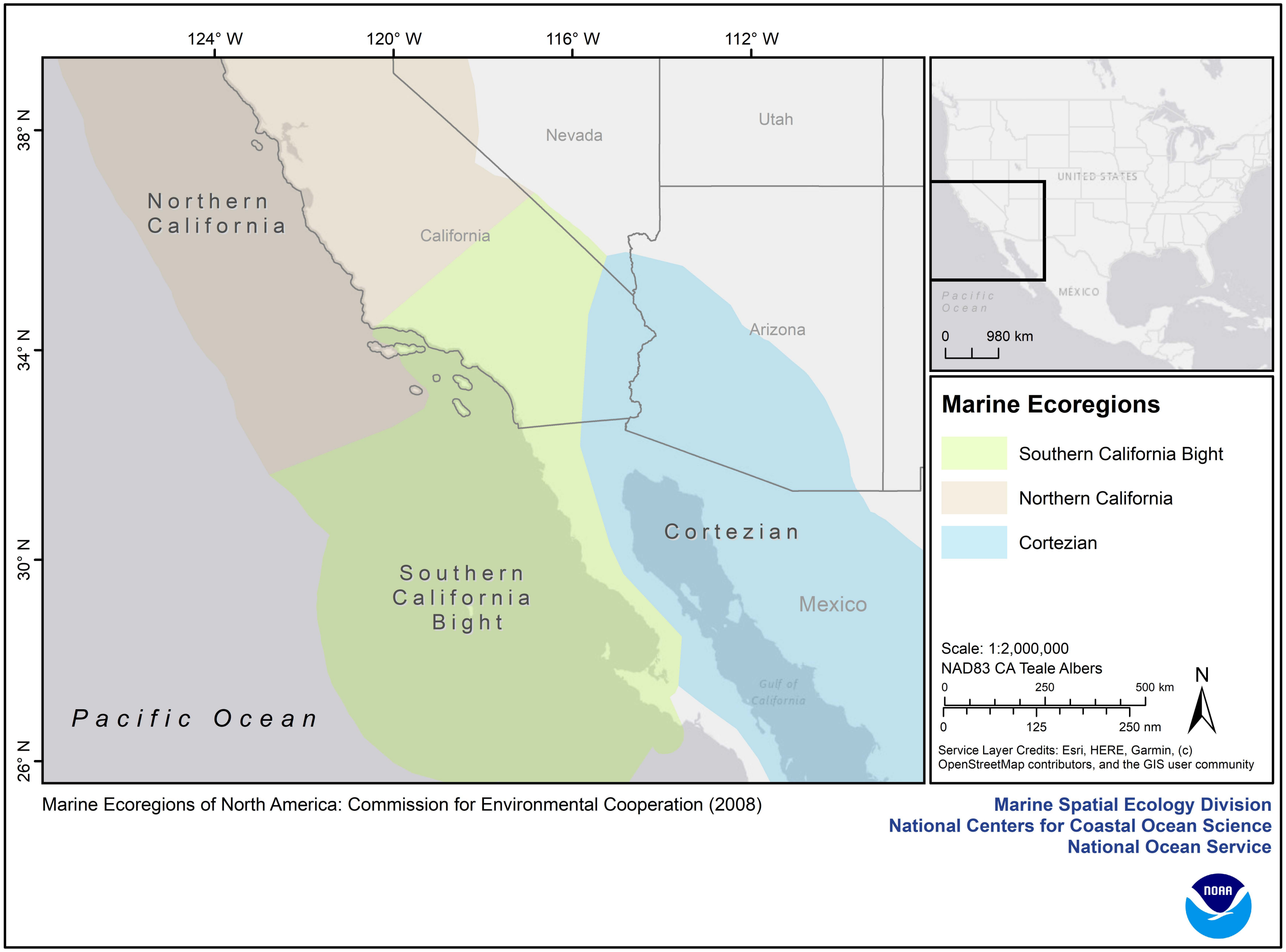


Figure 2.2. Area of Interest was determined using a biogeographical break at Point Conception, which also corresponds to the Marine Ecoregions of the World approach established by Spalding et al. (2007). The southern extent was delineated based on the U.S. Exclusive Economic Zone and the U.S.-Mexico border.

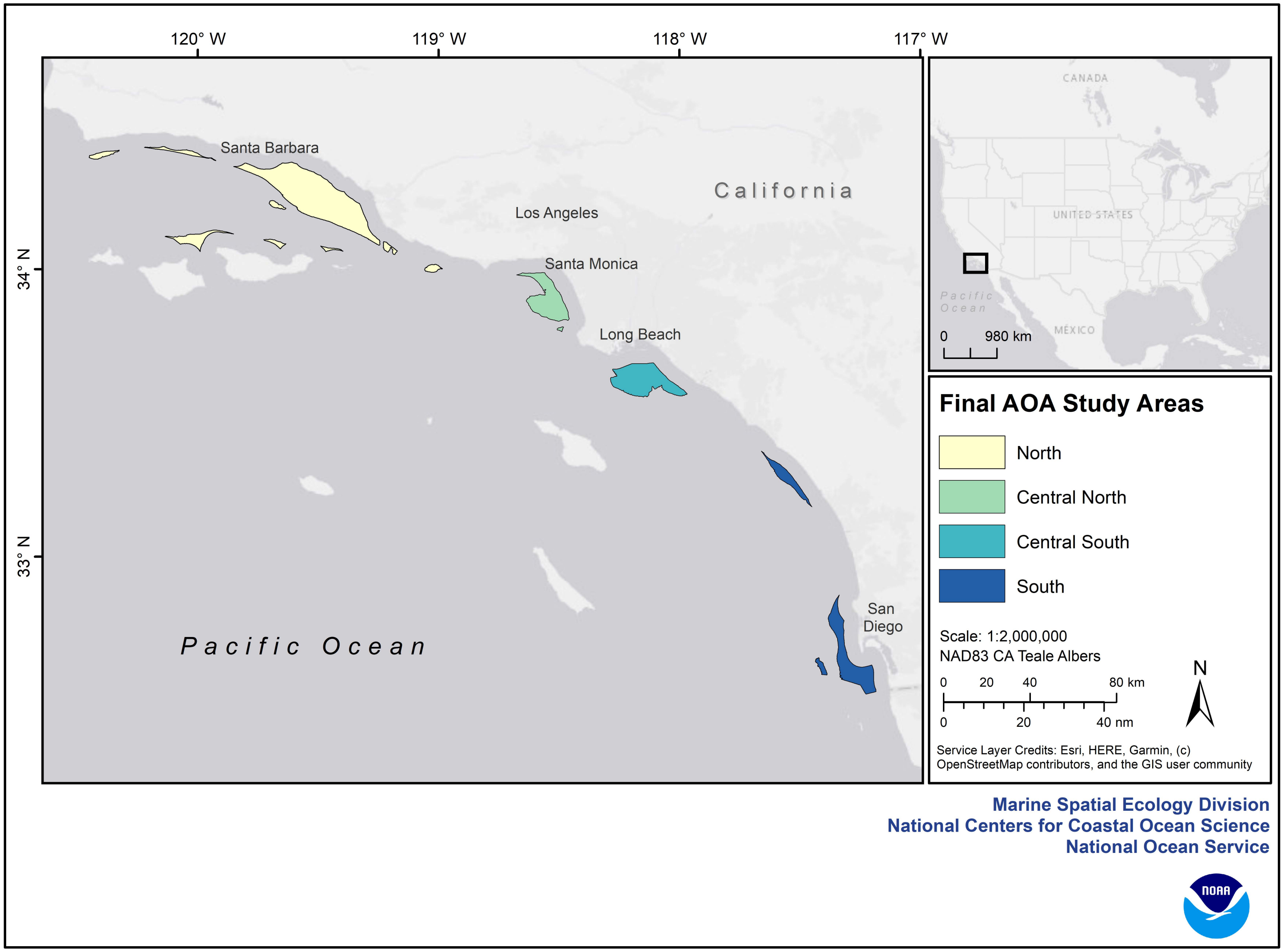


Figure 2.3. Study areas for identification of Aquaculture Opportunity Areas (AOAs) include North (yellow polygon), Central North (green polygon), Central South (light blue polygon), and South (dark blue polygon).

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 practical requirements for aquaculture development (Table 2.1). By any measure, developing an atlas for an expansive ocean region 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 2.4).

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 202 - 809 ha (500 - 2,000 ac), a gridded overlay with 4.05-ha (10-ac) grid cell size was used for each study area (Figure 2.5).

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 2.5).

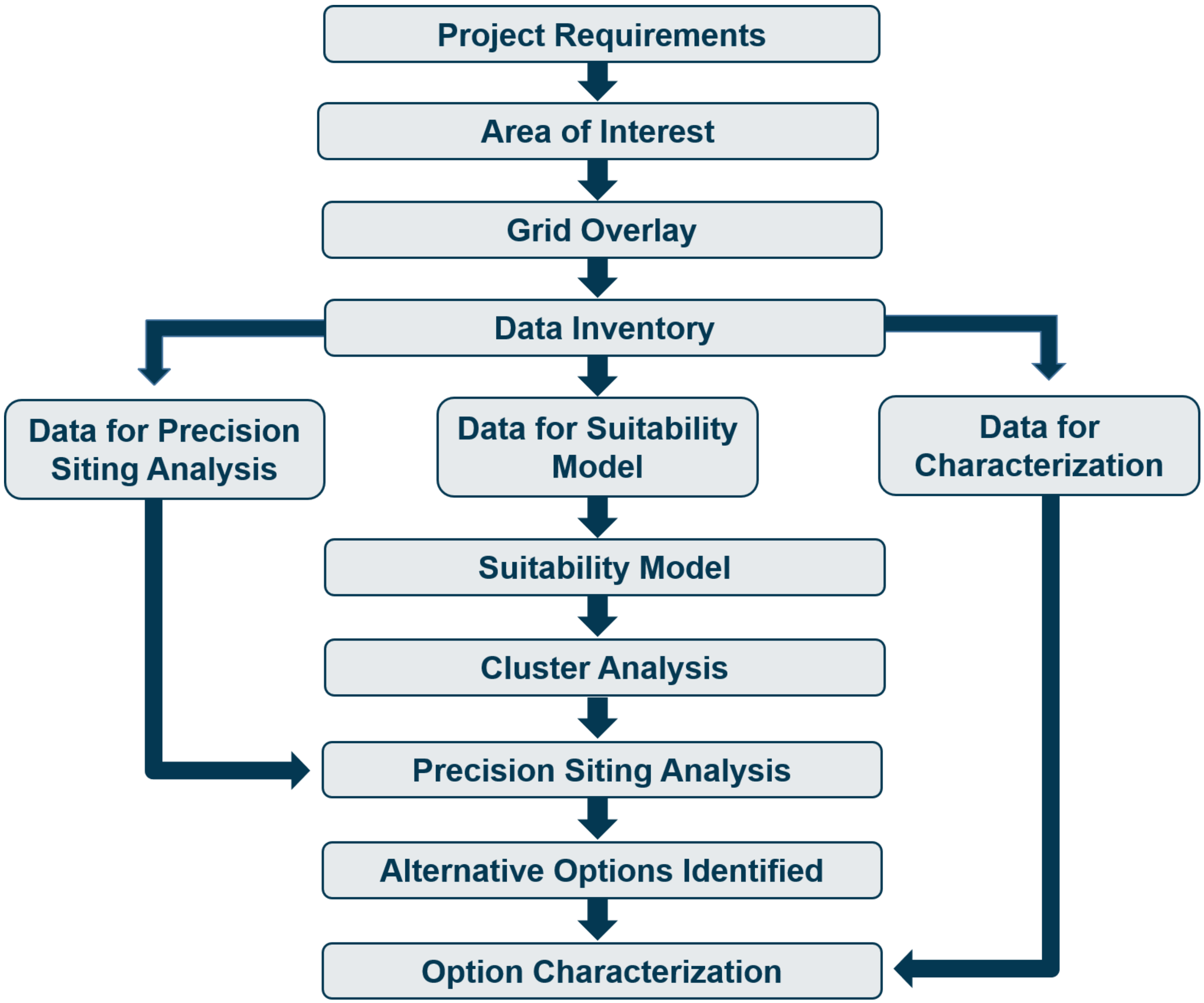


Figure 2.4. Workflow overview for the Aquaculture Opportunity Areas site suitability analysis within the Southern California Bight.

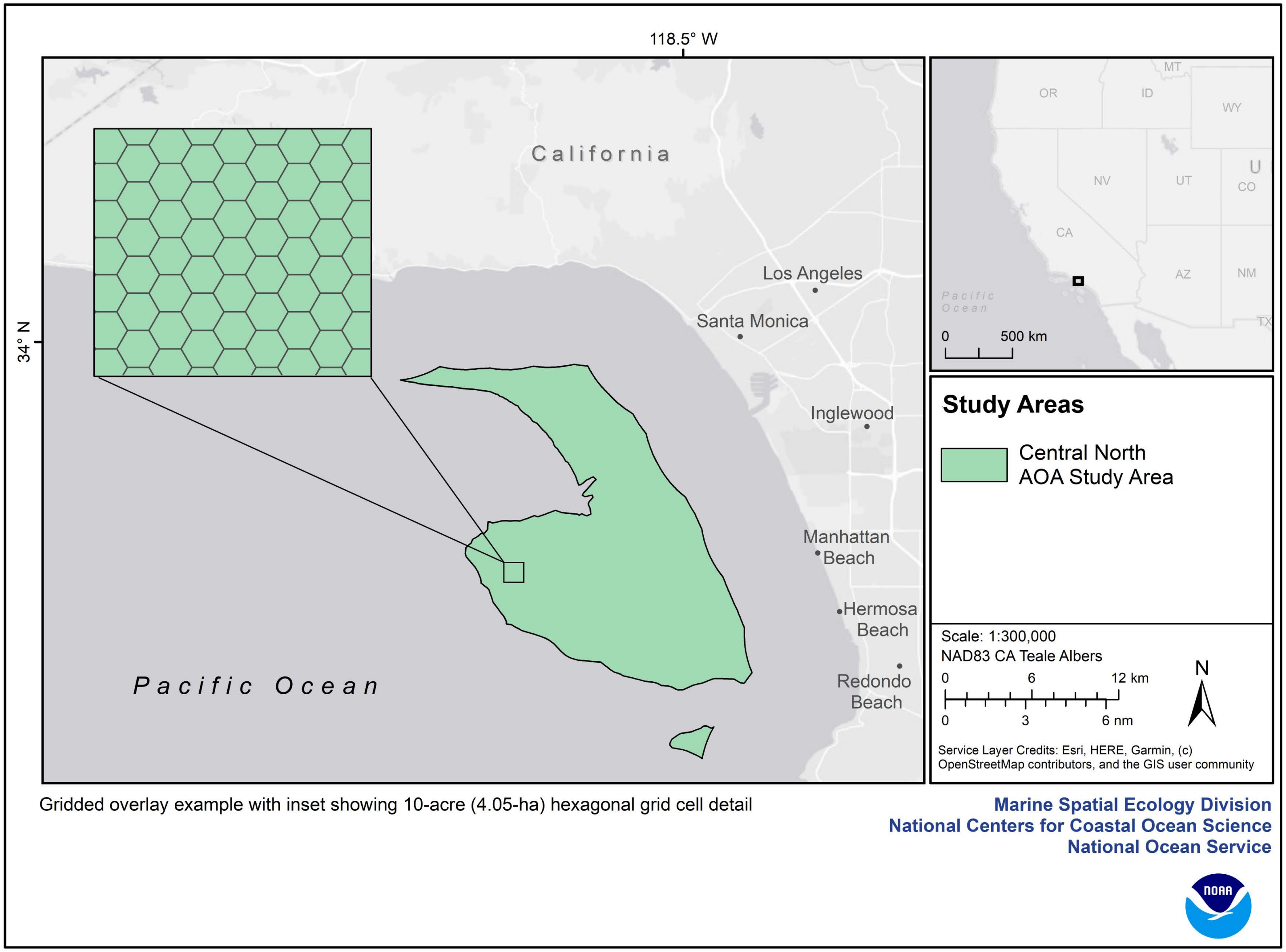


Figure 2.5. An example of the grid cells formulated for each study area. Each cell is a 10-acre or 4.05-ha hexagon.

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 relationship among the data input into the models and to organize information into appropriate submodels for relative suitability modeling. Data categorization was based on a 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 marine aquaculture 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 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 224 engagements related to data acquisition and interpretation occurred during 2020 and 2021, encompassing stakeholder interest related to military (24), natural resources (81), regional planning and regulatory (13), industry (21), navigation (12), governance and boundaries (40), social and cultural (8), research (6), environmental non-governmental organizations (5), and human health (14) were held. Approximately 1,200 individuals 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 North American Datum (NAD - 1983), California (Teale) Albers projection for southern California (Projection: Albers, False Easting: -0.0, False Northing: -4,000,000.0, Central Meridian: -120.0, Standard Parallel 1: 34.0, Standard Parallel 2: 40.5.0, Latitude of Origin: 0.0) with the NAD 1983 coordinate system EPSG 4269).[9] 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 (see provided sources, data download locations, and metadata in Appendix A). Setbacks (i.e., buffers) were applied when required by governance, policy, and

[9] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=109326&inline

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 West Coast Region and NMFS Office of Protected Resources (Appendix B). A scoring table (Table 2.2) was developed to assign relative suitability scores to protected species data based on species status, population size, and trajectory. 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, and because a more generalized approach was transferable across regions. This submodel contains only highly vulnerable protected species, so there are a number of protected species, especially marine mammals, that were excluded from this analysis. Those species will need to be considered during the PEIS stage to determine overall suitability of potential AOA options. 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. 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.

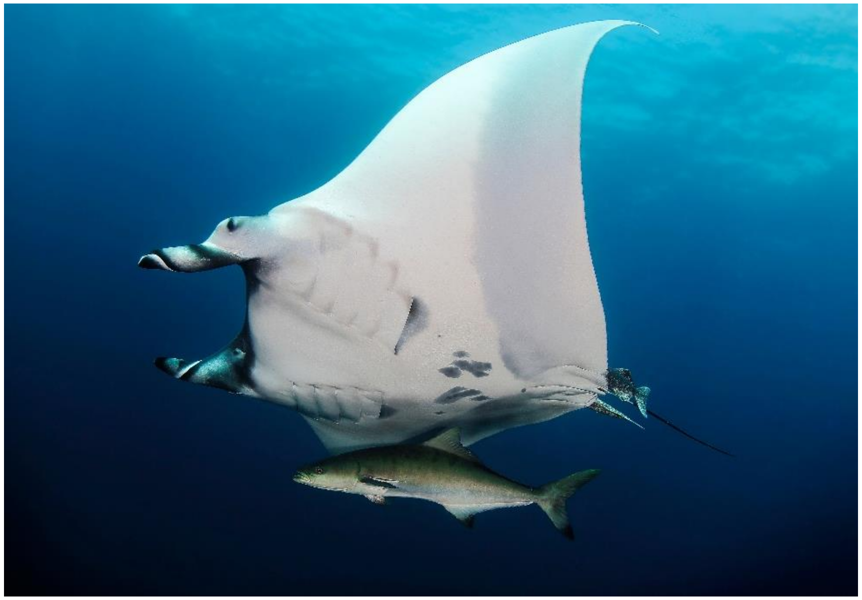


Table 2.2. Scoring system from the National Marine Fisheries Service for protected resources for the Southern California Bight Aquaculture Opportunity Area study areas.

Status	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).		

A total of three data layers including humpback whale Biologically Important Areas (BIAs), blue whale BIAs, and Critical Habitat for humpback whales were combined into a single data layer. Table 2.3 provides the species, status and trend, and score. Justification for scores used in suitability modeling can be found in Appendix B.

Data layers provided for these species provide resolution and contrast that will influence the cell score within the study areas. Table 2.4 and Table 2.5 list species (including their population status and trend and suitability score) which are too widely distributed to influence cell scores within the study area during suitability modeling. This list of species and scores is provided to inform characterization and should be considered for early awareness regarding the potential presence of species of lower or higher concern for protected species interaction at the regional scale or within specific AOAs.

NMFS used the product method to combine these data layers, which assumes a lower scoring variable cannot be compensated by a higher scoring variable (Equation 2.1).

Equation 2.1. Equation for the product method used to determine scoring values.

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

$$x_1 = \textit{variable 1}$$
$$x_2 = \textit{variable 2}$$
$$x_i = \textit{additional variables}$$

Table 2.3. Score and justification for Endangered Species Act-listed species known to occur within the Southern California Bight to be used in suitability modeling.

Species	Status and Trend	Score
Blue Whale BIA (feeding)	Endangered, stable	0.2
Humpback Whale BIA (feeding)	Endangered, unknown	0.2
Humpback Whale Critical Habitat	Endangered, unknown	0.2

Table 2.4. Species, status and trend, and score for Endangered Species Act-listed species known to occur within the Southern California Bight for consideration during characterization. Species list and status and trend data obtained from NMFS 2021c.

Species	Status and Trend	Score
Western North Pacific Gray Whale DPS	Endangered, small	0.1
North Pacific Right Whale	Endangered, small	0.1
Sei Whale	Endangered, small	0.1
Leatherback Sea Turtle	Endangered, declining	0.1
Scalloped Hammerhead Shark	Endangered, declining	0.1
White Abalone	Endangered, declining	0.1
Black Abalone	Endangered, declining	0.1
Blue Whale	Endangered, stable or unknown	0.2
Fin Whale	Endangered, stable or unknown	0.2
Sperm Whale	Endangered, stable or unknown	0.2
Loggerhead Sea Turtle	Endangered, unknown	0.2
Gulf Grouper	Endangered, unknown	0.2
Humpback Whale - Central America DPS	Endangered, unknown	0.2
Olive Ridley Sea Turtle	Endangered, increasing	0.3
Humpback Whale, Mexico DPS	Threatened, unknown	0.4
Oceanic Whitetip Shark	Threatened, declining	0.4
Giant Manta Ray	Threatened, declining	0.4
Guadalupe Fur Seal	Threatened, increasing	0.5
Green Sea Turtle	Threatened, increasing	0.5

Table 2.5. Species, population size, and score for Marine Mammal Protection Act stocks known to occur within the Southern California Bight for consideration during site characterization. Species list and status and population size obtained from NMFS 2021c.

Species	Population Size	Score
Dwarf Sperm Whale	Unknown	0.7[10]
Coastal Bottlenose Dolphin	Small	0.7
Minke Whale	Small	0.7
Short-finned Pilot Whale	Small	0.7
Transient Killer Whale	Small	0.7
Baird's Beaked Whale	Large	0.8
Harbor Seal	Large	0.8
California Sea Lion	Large	0.8
Cuvier's Beaked Whale	Large	0.8
Dall's Porpoise	Large	0.8
Eastern North Pacific Gray Whale DPS	Large	0.8
Long-beaked Common Dolphin	Large	0.8
Northern Fur Seal	Large	0.8
Northern Right Whale Dolphin	Large	0.8
Pacific White-sided Dolphin	Large	0.8
Pygmy Sperm Whale	Large	0.8
Risso's Dolphin	Large	0.8
Short-beaked Common Dolphin	Large	0.8
Striped Dolphin	Large	0.8

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 southern California coast. For full bathymetric coverage of southern California waters, the CRM requires download of the Southern California, Volume 2 CRM (2003).[11] Once AOA options were identified, the U.S. Geological Survey (USGS) Coastal National Elevation Database (CoNED) 1-m resolution bathymetric dataset for southern California was used for

[10] A score of 0.7 was assigned to dwarf sperm whales due to the unknown population size and rarity of sightings or other stock-specific information. However, it is not considered a "strategic stock" under the MMPA, which is why it did not receive a score of 0.6.
[11] https://www.ngdc.noaa.gov/mgg/coastal/crm.html

characterization and further bathymetric analysis (Danielson et al. 2016). Bathymetry data were clipped (i.e., data not overlapping the study areas were removed) from 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 that are part of 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 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.[12]

Vessel traffic data from 2015 to 2020 were acquired and processed for the AOI.[13] Tracklines for each vessel were created from the transmission points, with points not being connected if greater than 1 mile apart or longer than 30 minutes apart in time. The vessel traffic tracklines were categorized by vessel type (cargo, tanker, tug and tow, pleasure and sailing, passenger, fishing, military, and other).[14] 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 precision siting models, mean vessel traffic from 2015 through 2019 for transits through the option was utilized. The COVID-19 pandemic, beginning in late February of 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 in 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.

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

Deep-sea Coral Observational Data

Deep-sea coral observations for southern California were obtained from NOAA's Deep-sea Coral Data Portal.[15] NOAA Deep-sea Coral Research and Technology Program (DSCRTP) recommended use of the post-1985 presence data on all species reported except for sea pens, as they are associated with soft bottom habitat which is far more ubiquitous than hardbottom habitat in the study area. A setback of 500 m (1,640 ft) was applied, as deep-sea corals are associated with ecologically-sensitive habitat.

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" (UN Environment Programme 2009; NOAA 2016). Fish haven boundary data were extracted from NOAA's 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. A setback of 500 ft (152 m) was applied to preserve ecosystems associated with fish havens and artificial reefs for AOA planning.

Oceanographic Conditions

The University of California Los Angeles (UCLA) California Regional Ocean Modeling System (ROMS) was used to characterize current speed and direction, temperature, and salinity.[16] Data were provided by the Central and Northern California Ocean Observing System (CENCOOS) for 2016 - 2020 at a 6-hour interval. The representative zonal (U) and meridional (V) velocities were combined using a Python script to display the magnitude and direction of currents. The Naval Research Laboratory Coupled Ocean/ Atmosphere Mesoscale Prediction System was used to characterize wind speed and direction.[17] Data were provided by CENCOOS for 2016 - 2020 at a 1-hour interval. The representative zonal (U) and meridional (V) velocities were combined using a python script to display the magnitude and direction of wind. The Pacific Northwest National Laboratory (PNNL) Simulating WAves Nearshore (SWAN) model was used to characterize significant wave height (H_s) (the average wave height, from trough to crest, of the highest one-third of the waves), period, and direction.[18] Data represent annual and monthly averages for a 32-year period from 1979 to 2010.

[15] https://deepseacoraldata.noaa.gov/metadata-records/iso-dscrtp-national-db
[16] https://atmos.ucla.edu/research/roms
[17] https://www.nrlmry.navy.mil/coamps-web/web/view
[18] https://www.pnnl.gov/publications/high-resolution-regional-wave-resource-characterization-us-west-coast

Water Quality

Water quality for each AOA option was assessed by examining chlorophyll-*a* and water clarity. Chlorophyll-*a* is a specific chlorophyll pigment observed in photosynthesizing organisms such as phytoplankton. Measurements of chlorophyll-*a* concentration are a common approximation for phytoplankton presence. Chlorophyll-*a* monthly climatological means from 2016 to 2020 were estimated using satellite data from NASA[19] and were evaluated for seasonal variance. Similarly, satellite data were used to assess the 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).[20] High Kd(490) values indicate shallow attenuation depth and lower clarity of ocean water. Kd(490) monthly mean data were downloaded from NASA from 2010 to 2018 at a 750-m resolution, and an overall monthly mean dataset was created by averaging each month for all years. The diffuse light attenuation coefficient of photosynthetic active radiation (PAR) at wavelengths 400 - 700 nm, Kd(PAR), is useful for determining the amount of light that is available for photosynthesis. Kd(PAR) is represented as percent light transmissivity at 1 m. To calculate the percentage, raw data from 2010 to 2018 for Kd(PAR) were downloaded from NASA[21] and the ratio of radiance at 1 m and solar radiance was calculated. Nutrient data for nitrate, phosphate, and dissolved oxygen were also reported for each cluster. Data from 1997 to 2000 were provided by the southern California Coastal Water Research Project (SCCWRP) at 0.3 km resolution using the methods developed by Kessouri et al. (2021). Data in a monthly network Common Data Form format at 10, 20, 50, and 100 m depths were processed to create average monthly mean values from the yearly data.

Commercial and Recreational Fishing Data

Commercial and recreational fishing are important economic drivers for southern California (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 and the California Department of Fish and Wildlife (CDFW).[22] Fishing data are considered

[19] https://modis.gsfc.nasa.gov/data/dataprod/chlor_a.php
[20] https://oceancolor.gsfc.nasa.gov/atbd/kd_490/
[21] https://oceancolor.gsfc.nasa.gov/data/viirs-snpp/
[22] CDFW collects data from various sources for fisheries management purposes, and data may be modified at any time to improve accuracy and as new data are acquired. CDFW may provide data upon request under a formal agreement. Data are provided as-is and in good faith, but CDFW does not endorse any particular analytical methods, interpretations, or conclusions based upon the data it provides. Unless otherwise stated, use of CDFW's data does not constitute CDFW's professional advice or formal recommendation of any given analysis. CDFW recommends users consult with CDFW prior to data use regarding known limitations of certain data sets.

Controlled Unclassified Information (CUI) requiring specific measures for handling, safeguarding, and controlled dissemination.[23] Data and maps within this technical report reflect the resolution at which data can be displayed to the public to ensure protection of confidential data components. Under NOAA Administrative Order 216-100 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.

Vessel Monitoring System Declaration Codes

Vessel Monitoring System (VMS) data from 18 fisheries were processed by California Polytechnic State University and BOEM from data provided by NMFS Office of Law Enforcement. Raw point data were extracted from records from 2010 to 2018 and were converted into tracklines using a conservative approach to determine which vessels were traveling at fishing speeds (i.e., when fishing was occurring).

Squid Landing Microblocks

Squid commercial fishery landings data by microblock (1 nm x 1 nm) were provided by CDFW from 2000 to 2019. An average landing per year was calculated and examined for the EEZ.

California Recreational Fisheries Surveys

California Recreational Fisheries Survey (CRFS) private and rental boat fishing and party and charter boat fishing data were provided by CDFW. The private and rental vessel data consisted of dockside surveys recorded at the microblock (1 nm x 1 nm) and block (10 nm x 10 nm) resolution from 2010 to 2019. The surveys represent a subsection of the total recreational fishing effort; these surveys are

[23] https://www.archives.gov/cui/about

conducted at public docks and by phone with licensed anglers.[24] Microblock data were extracted and a count per month for each microblock was performed. The total of the counts was summarized by year to represent the average number of vessels per year per microblock.

The party and charter vessel data contained information on locations fished, ports of landing, number of anglers, hours fished, species, number of fish kept, and interactions with marine mammals. Global positioning system (GPS) records of fishing activities were extracted from the 2010 to 2019 dataset. The start and end locations were joined to create tracklines for use within the suitability analysis.

Suitability Analysis

A gridded relative suitability analysis, commonly used in a multi-criteria decision analysis (MCDA), 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 fishing and aquaculture. Data layers with no compatibility with aquaculture development (e.g., shipping fairways) were captured in the constraints submodel (Figure 2.6). This model structure ensures that each submodel is given equal representation in the final suitability model regardless of how many data layers are present in each submodel.

Final suitability scores are presented in 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 maps, standardized colors were used to depict categories, with orange representing “Low,” yellow representing “Moderate,” and blue representing “High” suitability and coinciding with each quantile. With all suitability maps, the categories still represent values ranging from 0 to 1, with the “Low” category representing the lowest quantile of the data, “Moderate” representing the middle quantile, and “High” representing the upper quantile. Presenting categories rather than actual suitability scores simplifies interpretation of results and provides optimal contrast among categories. Further, the 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.

[24] https://wildlife.ca.gov/Conservation/Marine/CRFS

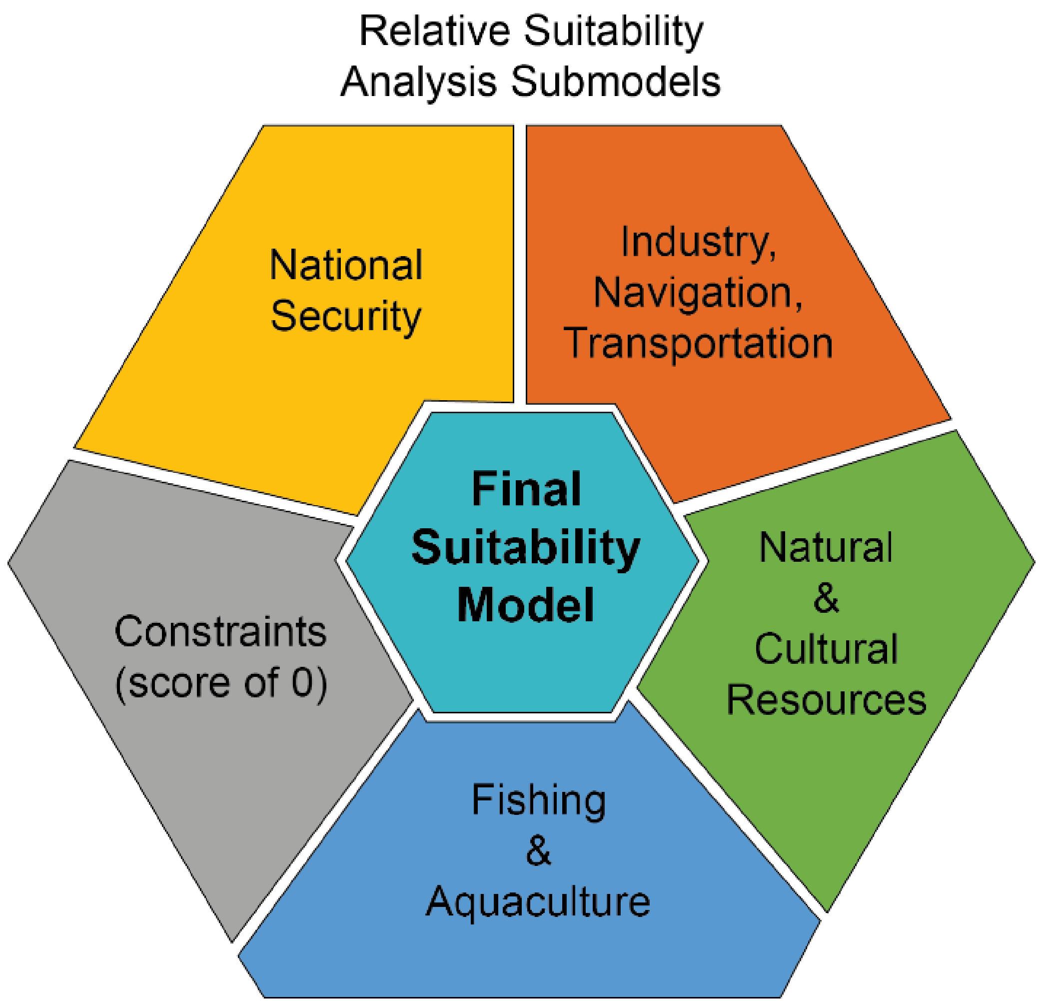


Figure 2.6. Overview of relative suitability model design and the submodel components. The constraints submodel includes all data layers with a score of 0; these data layers were removed before the remaining submodel scores were calculated.

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 the setback (e.g., a 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, while 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 remained as to what that interaction is with aquaculture, 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) 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 ranges 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 unsuitable with aquaculture.

The distance to shore parameter is the only dataset where a standard linear function was used, due to the high certainty that the closer it is to shore the more suitable an aquaculture operation is regarding logistics and cost (Gentry et al. 2017). All other numerical datasets 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 2.7).

Categorical and numerical datasets used in scoring for the relative suitability analysis are in Tables 2.6, 2.7, 2.8, and 2.9, with a detailed list and rationale for each score found in Appendix C.

Equation 2.2. Equation of the Z-shaped membership function used, based on the MathWorks documentation example (MathWorks 2021).

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

$x =$ *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)*

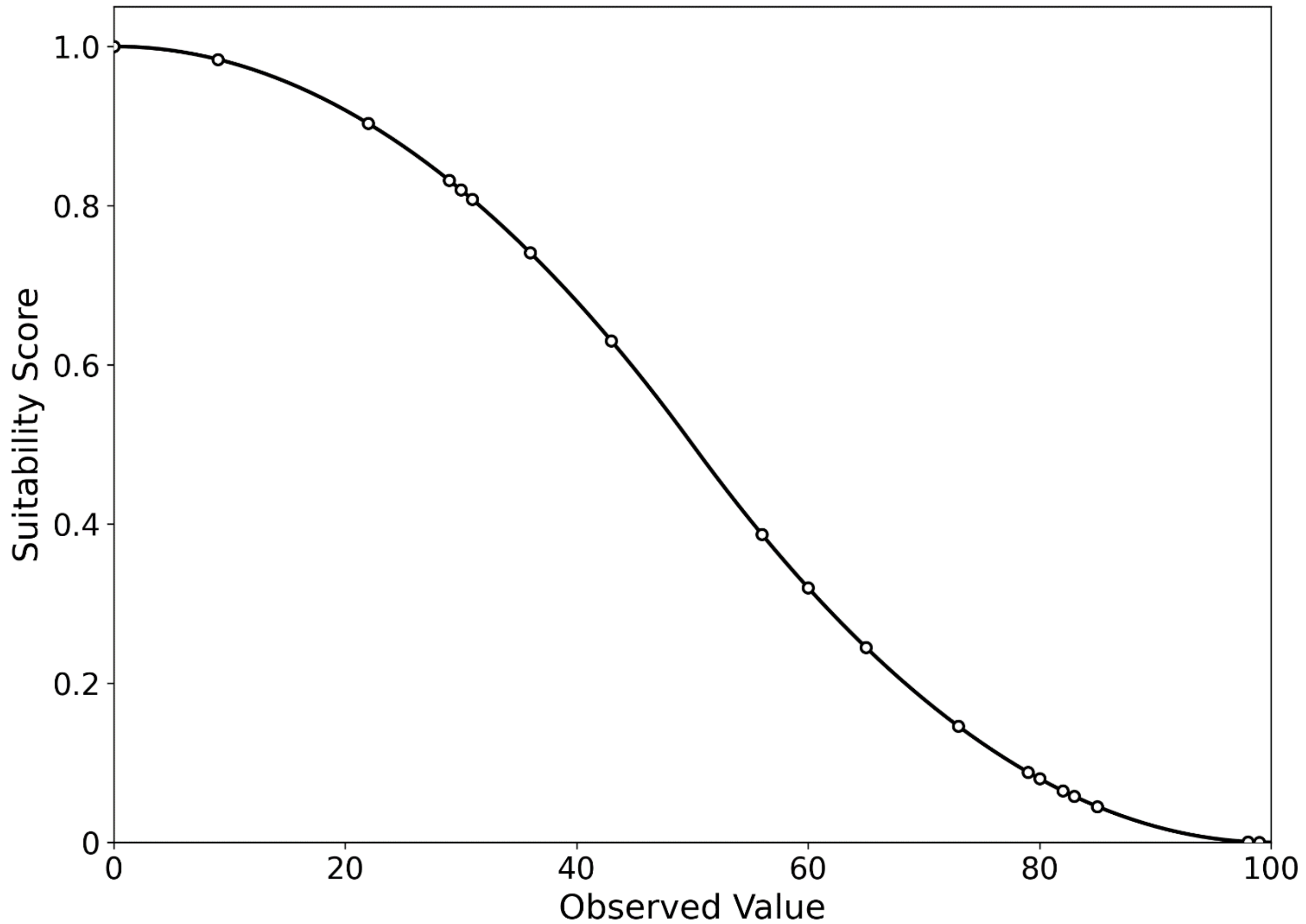


Figure 2.7. Example of a hypothetical Z-shaped membership function, with the minimum observed value being 0 and the maximum observed value being 99. However, the total range of the function goes to 100, as 1 was added to 99 when creating the function to ensure no observed values would be rescaled to 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.

Table 2.6. National security considerations 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 North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel.

National Security Dataset	Score	N	CN	CS	S
Camp Pendleton and San Diego Military Areas	0.5	-	-	-	x
Encinitas Naval Electronic Test Area	0.5	-	-	-	x
Military Training Routes (MTR)	0.5	x	-	-	-
Point Mugu Sea Range (PMSR)	0.5	x	-	-	-
San Pedro Channel Operating Area (SPCOA)	0.5	x	x	x	-
Special Use Airspace (SUA) (W-412 and W-289E)	0.5	x	-	-	-
Unexploded Ordnance Formerly Used Defense Sites (UXO FUDS)	0.5	x	-	x	x
Camp Pendleton and San Diego Military Exclusion Areas	0	-	-	-	x
- Dash indicates that the data layer did not overlap the study area.					

Table 2.7. Natural and cultural resources considerations 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 North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel.

Natural and Cultural Resources Dataset	Score	N	CN	CS	S
BOEM Preserve	0.5	x	-	-	-
Cetacean BIAs - Blue Whale Feeding Area*	0.2	x	x	x	x
Cetacean BIAs - Humpback Whale Feeding Area*	0.2	x	-	-	-
Critical Habitat - Humpback Whale*	0.2	x	-	-	-
Deep-sea Coral and Sponge Observations (1985 to present) with 500-m setback	0	x	x	x	x
Hardbottom Habitat - with 500-ft setback	0	x	x	x	x
National Marine Sanctuaries (NMS)	0	x	-	-	-
NMFS EFH Habitat Area of Particular Concern (Rocky) - with 500-ft setback	0	x	x	x	-
NOAA Fish Havens - with 500-ft setback	0	-	-	x	x
- Dash indicates that the data layer did not overlap the study area. * Data layers were combined and scores calculated using the product method.					

Table 2.8. Industry, navigation, and transportation considerations 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 North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel. Continuous data (0 - 1) are denoted in the table as "cont."

Industry, Navigation and Transportation Dataset	Score	N	CN	CS	S
BOEM Active Lease Blocks	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	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 Vessels	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	x	-
AWOIS Wrecks Polluting, RULET Wrecks, ENC Wrecks and Obstructions, ENC Danger Wrecks with 500-ft setback	0	x	x	x	x
Boreholes, Test Wells, and Wells with 500-m setback	0	x	-	x	-
California Cooperative Oceanic Fisheries Investigations (CalCOFI) Sampling Sites with 500-m setback	0	x	x	-	-
Environmental Sensors and Buoys with 500-m setback	0	-	-	x	x
Joint Oil Fisheries Liaison Office (JOFLO) Corridors	0	x	-	-	-
NOAA Charted Submarine Cables with 500-m setback	0	x	x	x	x
Ocean Disposal Sites	0	x	-	x	x
Oil and Gas Pipelines with 500-m setback	0	x	-	x	-
Oil and Gas Platforms with 500-m setback	0	x	-	x	-
Outfall Pipes and Diffusers with 3-mi setback	0	x	x	x	x
Pilot Boarding Areas	0	-	x	-	-
Pilot Boarding Stations with 500-m setback	0	-	-	x	-

Industry, Navigation and Transportation Dataset	Score	N	CN	CS	S
Shipping Fairways with 500-m setback	0	x	-	x	-
Southern California Ferry Routes with 500-m setback	0	x	-	x	-

- Dash indicates that the data layer did not overlap the study area.
* Data layers represent continuous data scored using a fuzzy logic Z-shaped membership function.

Table 2.9. Fishing and aquaculture considerations 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 North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel. Continuous data (0 - 1) are denoted in the table as "cont."

Fishing and Aquaculture Dataset	Score	N	CN	CS	S
Ocean Rainforest Aquaculture with 500-m setback	0.5	x	-	-	-
Pacific Ocean AquaFarms (POA) San Diego Aquaculture with 500-m setback	0.5	-	-	x	x
California Recreational Fisheries Surveys (CRFS) 2010 - 2019	Cont.*	x	x	x	x
Commercial Passenger Fishing Vessels (CPFV) 2010 - 2019	Cont.*	x	x	x	x
Divelog 1998 - 2016	Cont.*	x	x	x	x
Emergency Exemption VMS 2010 - 2017	Cont.*	x	x	x	x
Haul Out Exemption VMS 2010 - 2017	Cont.*	x	-	-	x
Lobster Log 2016 - 2019	Cont.*	x	x	x	x
Long Term Departure Exemption VMS 2010 - 2017	Cont.*	x	x	x	x
Non-groundfish Trawl Gear for California Halibut VMS 2010 - 2017	Cont.*	x	-	x	x
Non-groundfish Trawl Gear for Pink Shrimp VMS 2010 - 2017	Cont.*	x	x	x	x
Non-groundfish Trawl Gear for Ridgeback Prawn VMS 2010 - 2017	Cont.*	x	-	x	x
Non-groundfish Trawl Gear for California Sea Cucumber VMS 2010 - 2017	Cont.*	x	x	x	x
Open Access California Gillnet Complex Gear VMS 2010 - 2017	Cont.*	x	x	x	x
Open Access California Halibut Line Gear VMS 2010 - 2017	Cont.*	x	-	x	x
Open Access Dungeness Crab Trap or Pot Gear VMS 2010 - 2017	Cont.*	x	-	x	x
Open Access Groundfish Trap or Pot Gear VMS 2010 - 2017	Cont.*	x	x	x	x
Open Access Highly Migratory Species Line Gear VMS 2010 - 2017	Cont.*	x	x	x	x

Fishing and Aquaculture Dataset	Score	N	CN	CS	S
Open Access Line Gear for Groundfish VMS 2010 - 2017	Cont.*	x	x	x	x
Open Access Longline Gear for Groundfish VMS 2010 - 2017	Cont.*	x	-	x	x
Open Access Prawn Trap or Pot Gear VMS 2010 - 2017	Cont.*	x	-	x	-
Open Access Sheephead Trap or Pot Gear VMS 2010 - 2017	Cont.*	x	-	-	x
Other Gear Not Listed VMS 2010 - 2017	Cont.*	x	x	x	x
Squid Landing Microblocks 2000 - 2019	Cont.*	x	x	x	x
Limited Entry Fixed Gear Not Including Shorebased IFQ VMS 2010 - 2017	Cont.*	x	x	x	x
Pacific Mariculture with 500-m setback	0	-	-	x	-
- Dash indicates that the data layer did not overlap the study area. * Data layers represent continuous data scored using a fuzzy logic Z-shaped membership function.					

Calculation of Suitability Scores

All data within the gridded area for each study area were scored or rescaled on a 0 to 1 range, with scores approaching 0 representing low suitability and scores approaching 1 representing high suitability relative to the other grid cells for aquaculture. The final suitability score was calculated using a geometric mean for each of the four submodels, and then the geometric mean of those four scores was calculated to determine the final score for each grid cell. Last, the constraints layers (all 0 scoring data layers) were used to remove any areas deemed unsuitable for aquaculture. The geometric mean (Equation 2.3) was chosen as the most representative scoring statistic for the analysis (Bovee 1986; Longdill et al. 2008; Silva et al. 2011; Muñoz-Mas et al. 2012). Equal weights were applied to data layers or submodels.

The geometric mean was taken for each submodel, then the geometric mean was taken for all the final submodel scores to produce the final suitability score.

Suitability Constraints

After the suitability scores were determined for each study area, an analysis was performed to describe the data most influential in removing 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 allowed determination of how each constraining factor ultimately affected the submodel and 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 were not considered further (Figure 2.6). 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 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 suitable 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 and Cluster Analysis

All data layers utilized in the suitability and subsequent cluster analysis were considered authoritative and were from federal or state agencies, or oceanographic or biophysical models that had been calibrated and validated (Tables 2.6, 2.7, 2.8, 2.9; Appendix A). A quality assurance/quality control (QA/QC - check for data spatial accuracy and temporal and spatial completeness) was performed on all data layers before data were utilized in the final submodels and models. Layers that did not meet these specifications, or did not overlap study areas, were not included in the suitability model. Some data were included in the characterization data inventory to provide supplemental information beyond the scope of this study, and those data may be useful during the PEIS process.

Data Not Included in the Suitability Model and Cluster Analysis

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 including influencing the accuracy, output resolution, and robustness of the data (Ramírez Villegas and Jarvis 2010; Porporato et al. 2020). Lastly, some layers were considered, but simply did not overlap or intersect the study area. Table 2.10 lists data layers that were reviewed, but were not included in the suitability model.

Equation 2.3. Geometric mean equation implemented for final suitability model scoring, after 0 values (constraints submodel) were removed.

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

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

Table 2.10. Examples of data layers 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, they were considered in the characterization of Aquaculture Opportunity Area options.

National Security Datasets		
Military Training Routes	Military Installations	Military Operating Areas
Less Impact Navy Mission	Unexploded Ordnance Points	Submarine Transit Lanes
Special Use Airspace	Accident Potential Zone	-
Natural and Cultural Resources Datasets		
Kelp Canopy Extent	Eelgrass Survey Version 2.0	Coastal Wetlands
Black Abalone Critical Habitat	Areas of Special Biological Significance	Fish Ranges
Industry, Navigation, and Transportation Datasets		
State Oil and Gas Platforms	Deepwater Ports	Coastal Maintained Channels
Marine Hydrokinetic Projects	Lighthouses	Renewable Energy Planning Areas
Fishing and Aquaculture Datasets		
CDFW Trawl Grid	NMFS Observer	Halibut Trawl Grounds

Suitability Modeling Approach, Assumptions, and Limitations

Models, in general, can help 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, often assumptions must be made within a modeling framework. For instance, we assume that 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 a coastal 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). An attempt was made to minimize bias among submodels 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 statistic 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, primary socio-economic data available, and assignments of setback distances from structures to reduce interference with other ocean activities. Further, we consistently chose the most conservative approach for scoring assignments and other judgements to ensure a high level of accuracy for aquaculture compatibility within the constraints of the data and model.

AOA Suitability Approach and Alternative Suitability Approaches

There are multiple approaches for determining aquaculture site suitability based on the planning goal. 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 done in this analysis (Figure 2.8). Additionally, a cumulative effects assessment could be used to assess multiple synergistic or conflicting activities occurring in an area (Menegon et al. 2018). Weighted approaches have shown aquaculture experts with similar backgrounds may not be consistent 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 (Levings et al. 1995; Nath et al. 2000; Longdill et al. 2008). Although expert panels can successfully be used to assign weights in some cases (e.g., Vincenzi et al. 2006, Theuerkauf et al. 2019a, 2019b), it is important 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 used to date 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, significant wave height) (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, NOAA fisheries-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 southern California region.

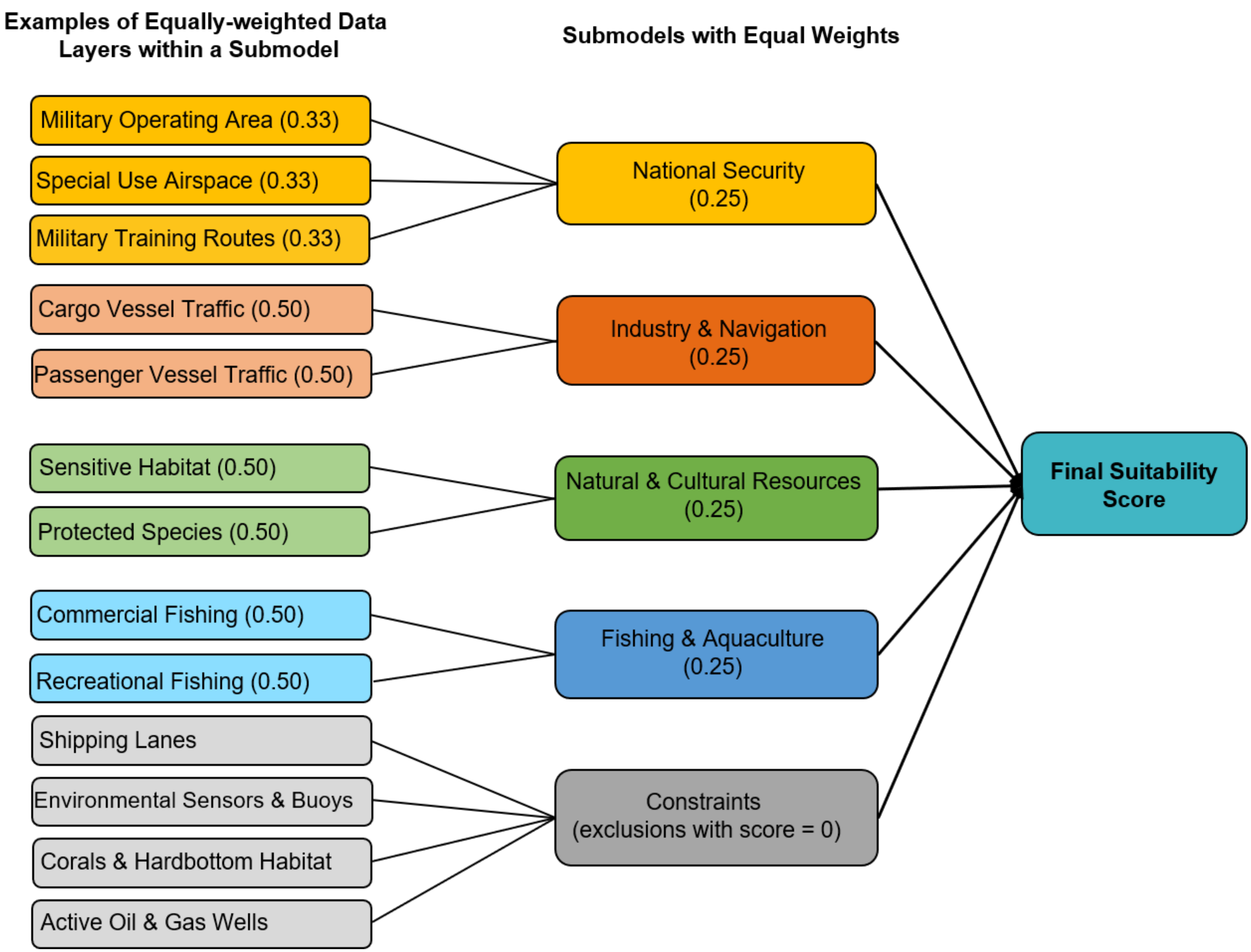


Figure 2.8. A generalized equally-weighted approach to a Multi-Criteria Decision Analysis suitability model with equally-weighted data layers in the submodels and final suitability model.

Precision Siting Model

A precision siting model was developed using custom rules and an adapted version of the 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; Díaz and Soares 2021). Often, after suitable areas within an MCDA framework are determined (Figure 2.8), 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 from the LISA cluster analysis and refined each cluster to accommodate at minimum a square option that is 500 ac (i.e., the minimum AOA size requirement) (Figure 2.9). For each of those 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 2.9). 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, 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 parts of the precision siting model.

Within-cluster Model and Final Precision Modeling Output

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 2.8, 2.10). 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 closest port in order to account for potential economic impacts related to travel distance. The distance from a potential AOA to the closest port was calculated for all options. Distance to port 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 2.11). Therefore, the closer an option is to a port the higher the score it will receive, while lower scores are given to options farther from a port.

The commercial fishing submodel in the within-cluster model contains all California VMS fishing data. The fuzzy logic Z-shaped membership function was used to rescale each of the variables to the 0 to 1 range (Table 2.11). Thus, options where fishing effort 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 - 2019) of vessel transits for each vessel type was calculated for each potential option. This is different from the suitability model where only 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 2.11).

After all the 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 site with the highest score was then considered to be the optimal option for that cluster. This operation was performed for each individual high-high cluster.

Site options with the highest scores were then considered for AOA options. Non-overlapping AOA options were identified, ranked by suitability score, and selected for characterization.

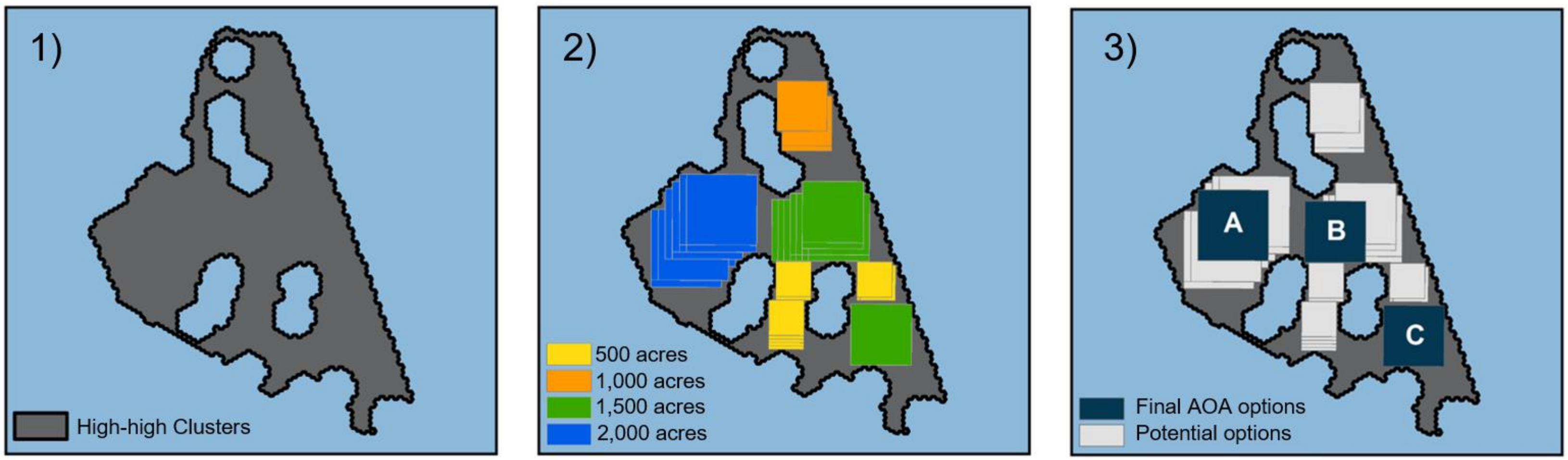


Figure 2.9. Precision siting model workflow steps illustrated within a spatial context. Step 1) illustrates one high-high cluster (dark gray polygon with black outline) determined from the suitability model and subsequent Local Indicators of Spatial Association cluster analysis. Step 2) illustrates how within each high-high cluster, options were identified for 500 ac (yellow boxes), 1,000 ac (orange boxes), 1,500 ac (green boxes), and 2,000 ac (light blue boxes) in size (options of the same size could overlap each other). Step 3) shows all potential options (light gray boxes) within each cluster and scored using the within-cluster model. The within-cluster model identified the most suitable option (dark blue boxes) for each high-high cluster.

Precision Siting Model – Within-Cluster Model

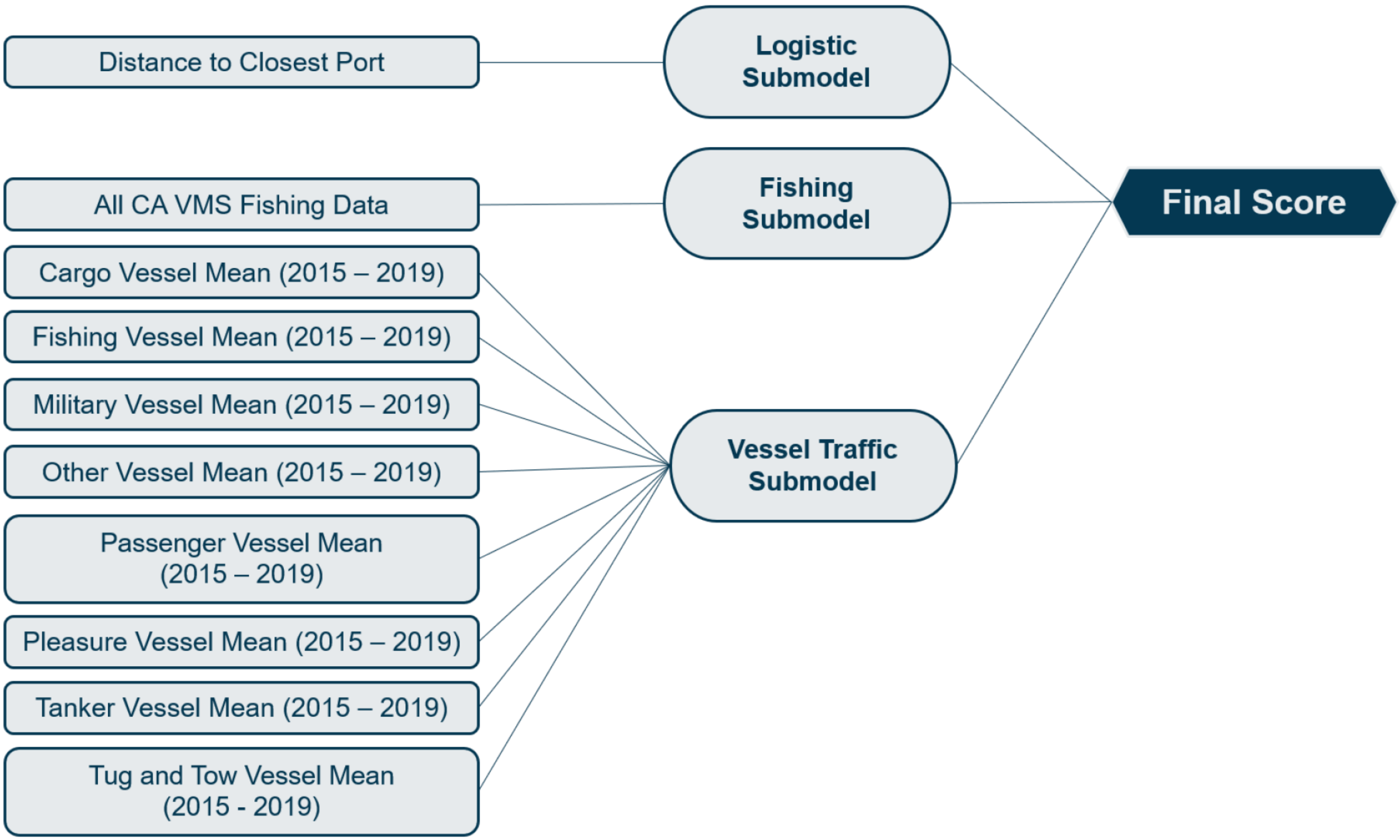


Figure 2.10. Precision siting model workflow for within-cluster comparisons.

Table 2.11. Precision siting model submodel datasets with the function used to rescale the data.

Submodel	Data Layer	Rescale Function
Logistics	Distance to Port	Linear
Commercial Fishing	Limited Entry Fixed Gear Not Including Shore Based IFQ VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Longline Gear for Groundfish VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Groundfish Trap or Pot Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Line Gear for Groundfish VMS 2010 - 2017	Z function
Commercial Fishing	Non-groundfish Trawl Gear for Ridgeback Prawn VMS 2010 - 2017	Z function
Commercial Fishing	Non-groundfish Trawl Gear for Pink Shrimp VMS 2010 - 2017	Z function
Commercial Fishing	Non-groundfish Trawl Gear for California Halibut VMS 2010 - 2017	Z function
Commercial Fishing	Non-groundfish Trawl Gear for California Sea Cucumber VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Prawn Trap or Pot Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Dungeness Crab Trap or Pot Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access California Halibut Line Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Sheephead Trap or Pot Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access Highly Migratory Species Line Gear VMS 2010 - 2017	Z function
Commercial Fishing	Open Access California Gillnet Complex Gear 2010 - 2017	Z function
Commercial Fishing	Other Gear Not Listed VMS 2010 - 2017	Z function
Commercial Fishing	Haul Out Exemption VMS 2010 - 2017	Z function
Commercial Fishing	Emergency Exemption VMS 2010 - 2017	Z function
Commercial Fishing	Long Term Departure Exemption VMS 2010 - 2017	Z function
Vessel Traffic	Cargo Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Tanker Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Tug and Tow Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Passenger Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Pleasure and Sailing Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Other Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Fishing Mean Vessel Transits 2015 - 2019	Z function
Vessel Traffic	Military Mean Vessel Transits 2015 - 2019	Z function

Characterization of AOA Options

Some data layers were not appropriate for suitability modeling or the precision siting model but are still important in the final decision-making process. For example, some data were at a resolution too coarse to include in the two 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.

This characterization included consideration of the relevance of the data set to inform aquaculture planning and permitting. A subset of data layers in Table 2.12 provides examples of data that were examined to characterize the AOA option (i.e., distance to closest port, significant wave height, current speed and direction, temperature, salinity, vessel traffic, and fishing interactions). OceanReports[25] was utilized to further enhance the characterization of each AOA option, and custom reports are provided for each AOA option.

Table 2.12. A sample of data considered for characterization of Aquaculture Opportunity Area options. For more information on data sources and an exhaustive data inventory, please refer to Appendix A.

National Security Datasets				
Less Impact Navy Mission	Military Operating Areas	Silver Strand Training Complex Boat Lanes	Military Installations	Unexploded Ordnance Polygons
Natural and Cultural Resources Datasets				
Abrahms Blue Whale Suitability (5 km)	Baird's Beaked Whale Abundance, SE, coefficient of variation	Beaked Whales (Guild)[26] Abundance, SE, coefficient of variation	Blue Whale Abundance, SE, coefficient of variation	Common Bottlenose Dolphin Abundance, SE, coefficient of variation
Dall's Porpoise Abundance, SE, coefficient of variation	Fin Whale Abundance, SE, coefficient of variation	Humpback Whale Abundance, SE, coefficient of variation	Long-beaked Common Dolphin Abundance, SE, coefficient of variation	Natural Hydrocarbon Seeps
Fish Ranges	West Coast Canopy-forming Kelp	Habitat CA Eelgrass	Coastal Wetlands	AquaMaps Northern Fur Seal
Northern Right Whale Dolphin Abundance, SE, coefficient of variation	Pacific White-sided Dolphin Abundance, SE, coefficient of variation	Risso's Dolphin Abundance, SE, coefficient of variation	Short-beaked Common Dolphin Abundance, SE, coefficient of variation	Sperm Whale Abundance, SE, coefficient of variation
Striped Dolphin Abundance, SE, coefficient of variation	CDAS Bird Surveys	ODIS - Cetacean and Turtle Points (various species)	Fish Biomass	NOAA Essential Fish Habitat

[25] https://www.marinecadastre.gov/oceanreports
[26] The beaked whale guild includes *Mesoplondon* spp. and Cuvier's beaked whale.

Protected Seas Marine Managed Areas	Areas of Special Biological Significance	Habitat Kelp Administration Regions	Coastal Marsh	Scuba Diving Sites
Boat Launch Sites	Coastal National Monuments	Audubon Important Bird Areas	Deep-sea Coral Presence/Absence Data	Marine Economic Gross Domestic Product
Fishing Piers	Fish Ranges	NOAA EFH Conservation Area	Kelp Canopy	Coastal RSM Plan Identified Sensitive Areas
Coastal Critical Habitat Designation	Seagrasses in the United States	Social Indicators Fishing Communities	-	-
Industry, Navigation, and Transportation Datasets				
Fish Houses	Marine Information for Safety and Law Enforcement	Lighthouses	Navigable Waters	USACE Coastal Maintained Channels
Principal Ports	Oil and Gas Platforms	Draft of Ship and Maneuverability of Vessel Type for AIS Vessel Data	Airports	-
Fishing and Aquaculture Datasets				
Fishing Blocks	Lobster Fishing Blocks	Halibut Trawl Grounds	Commercial Passenger Fishing Vessels (CPFV) 2010 - 2019	Observer Data - LE Fixed Gear DTL
Observer Data - OA Fixed Gear	California Recreational Fisheries Surveys (CRFS) 2010 - 2019	Observer Data - Fixed Gear 2010 - 2019	Observer Data - Trawl 2010 - 2019	Squid Landing Microblocks 2000 - 2019
Observer Data - Nearshore	Observer Data - Ridgeback Prawn (Trawl)	Lobster Microblocks 2016 - 2019	Divelog 1998 - 2016	State Managed Trawl VMS 2010 - 2016
Observer Data - Catch Shares	Observer Data - OA CA Halibut (Trawl)	Observer Data - CA Sea Cucumber (Trawl)	-	-
Physical, Chemical, and Biological Datasets				
Percent Transmissivity of Light (1-m Depth)	Slope Over Distance Across Options	High -resolution Bathymetry	Kd(490)	Nutrients (Nitrate, Phosphate, Silicate) and Dissolved Oxygen
Chlorophyll-*a*	Iron Concentration	Temperature Profile at Depth	Salinity	Significant Wave Height (m)
Current Speed (m/s) Direction at Depth	Surface Wind Speed and Direction	Sea Surface Height	Aragonite Saturation State	High-resolution Side-scan Sonar
High Frequency Radar Current Speeds (m/s)	Regions of Upwelling	Sea Floor Characteristics	-	-

Public Health Indicators Datasets				
Bight Regional Survey - Sediment Toxicity and Marine Debris	Dissolved Oxygen	C-HARM HABs - cellular and particulate	-	-
Boundaries Datasets				
U.S. EEZ	State and State Waters Boundaries	California Coastline NAD83	EPA Regional Boundaries	NMFS Regional Boundaries
USCG Districts	COLREGs Demarcation Line	USACE Districts	USFWS Regions	Marine Ecoregions of the World (MEOWs)

Final Considerations

Each study area is independent within the planning process, and scores and statistics can only be compared within a distinct study area. 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 operational areas and areas of national security interest were reviewed in and around the final AOA study areas. The waters of southern California are of strategic importance to military readiness, research, development, and testing and evaluation (10 U.S.C. § 5062). There are several areas of strategic importance for national security within the AOA study areas (Figure 3.1). The North AOA study area is within portions of the Point Mugu Sea Range (PMSR), which is the largest instrumented over-water test range in the U.S. at approximately 95,000 km² (36,679 mi²). PMSR provides controlled sea space and airspace for the Vandenberg Air Force Base and Naval Base Ventura County (Port Hueneme, Point Mugu, and San Nicolas Island). Completely overlapping both the Central North (CN) and Central South (CS) study areas, the San Pedro Channel Operating Area (SPCOA) is 8,165 km² (36,679 mi²) and is used for conducting fleet and mine countermeasure training. The South study area off the coast of San Diego County is within or in close proximity to several mission-critical U.S. Department of Defense (DOD) areas, including Naval Bases in Point Loma and San Diego. Data layers for this area were combined and named Camp Pendleton and San Diego Military Exclusion Areas (USDON 2018). Guidance on compatibility of aquaculture operations in the study areas with DOD activities was provided through consultations with the Military Aviation and Installation Assurance Siting Clearinghouse (MAIASC - Appendix D).

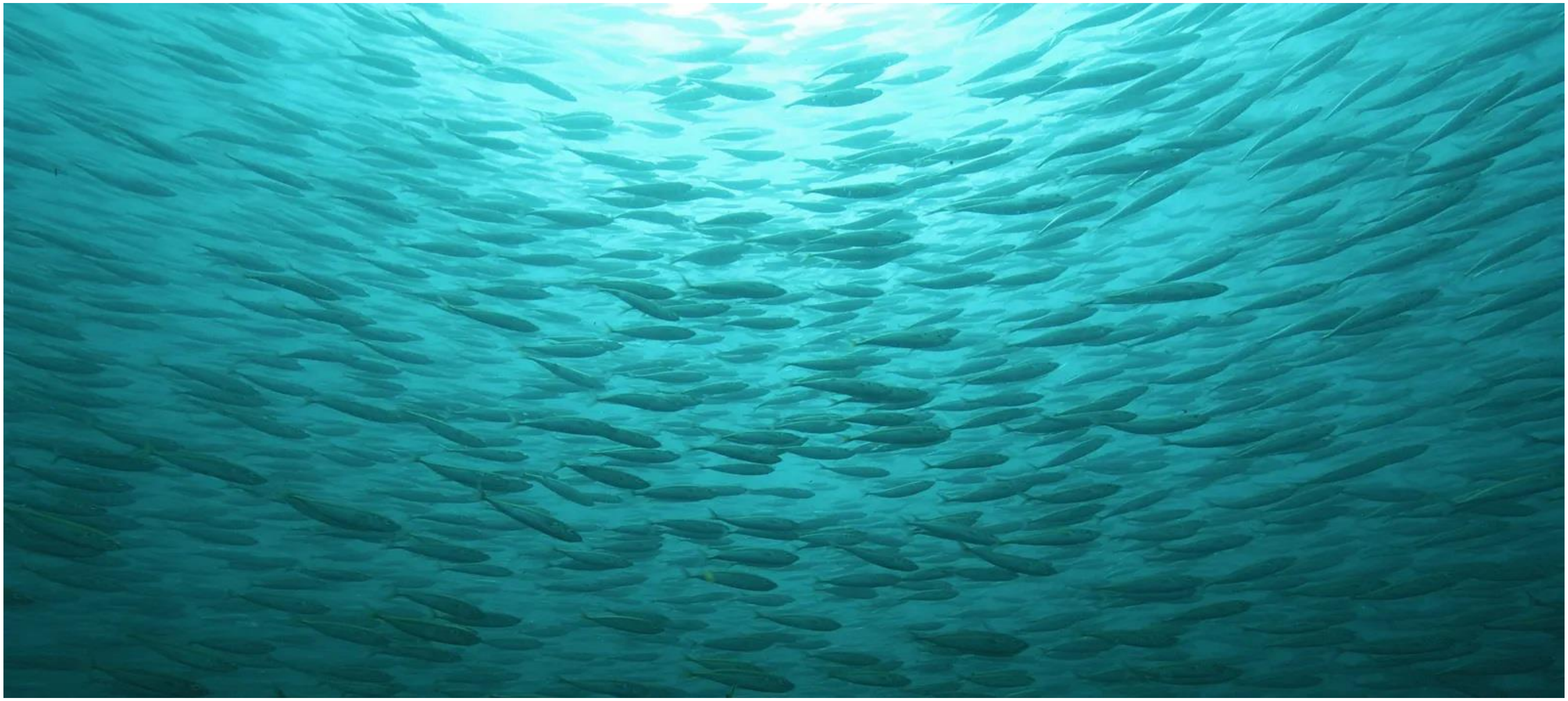
Additional military activities that overlap the AOA study areas (Table 3.1; Figure 3.1) include the Military Training Route (MTR) program, which is a collaboration between the DOD and the Federal Aviation Administration (FAA). MTR allows for military aircraft to conduct training exercises at low altitudes and at high speeds (FAA 2021). A portion of the MTR extends across several sections of the North study area; however, there are no other MTR overlaps in the other study areas. Similarly, special use airspace (SUA) imposes limitations on civilian aircraft operations. SUA has interactions with a small portion of the North study area (FAA 2021). Formerly Used Defense Sites (FUDS) are part of the Military Munitions Response Program that addresses unexploded ordnance (UXO), discarded military munitions, and munitions constituents at DOD sites (USACE 2019). FUDS overlap the entire Central South and a portion of the South study areas. The South study area has the highest number of interactions with DOD activities (Table 3.1).

Scoring of national security areas for suitability modeling efforts was led through communications with MAIASC (aka. DOD Siting Clearinghouse).[27] Many military use area data layers were moved to the constraints submodel and scored as a 0 value (i.e., no suitability) due to their potential incompatibility with aquaculture (Table 3.1; Figure 3.2). Some layers were scored as 0.5 within the analysis to account for any uncertainty within that area and unknown types of training activities occurring or that may occur within a space.

[27] https://www.acq.osd.mil/dodsc/

The North study area overlapped the MTR, PMSR, SPCOA, SUA, and FUDS; each of these layers was given a score of 0.5 as there is uncertainty of the impact to DOD activities in the area. No 0 value constraints occurred in the North study area; however, final site options were submitted for a preliminary MAIASC assessment. The Central North study area is entirely within the SPCOA and was scored 0.5. The Central South study area is also entirely within the SPCOA and FUDS and was scored 0.5.

The South study area had a 98.7% overlap with the Camp Pendleton and San Diego Military Exclusion Areas; those areas were scored 0 and deemed incompatible with aquaculture. Additionally, the South study area had a 27.9% overlap with the FUDS data layer and was scored 0.5. These interactions left most of the South study area deemed incompatible for aquaculture development.



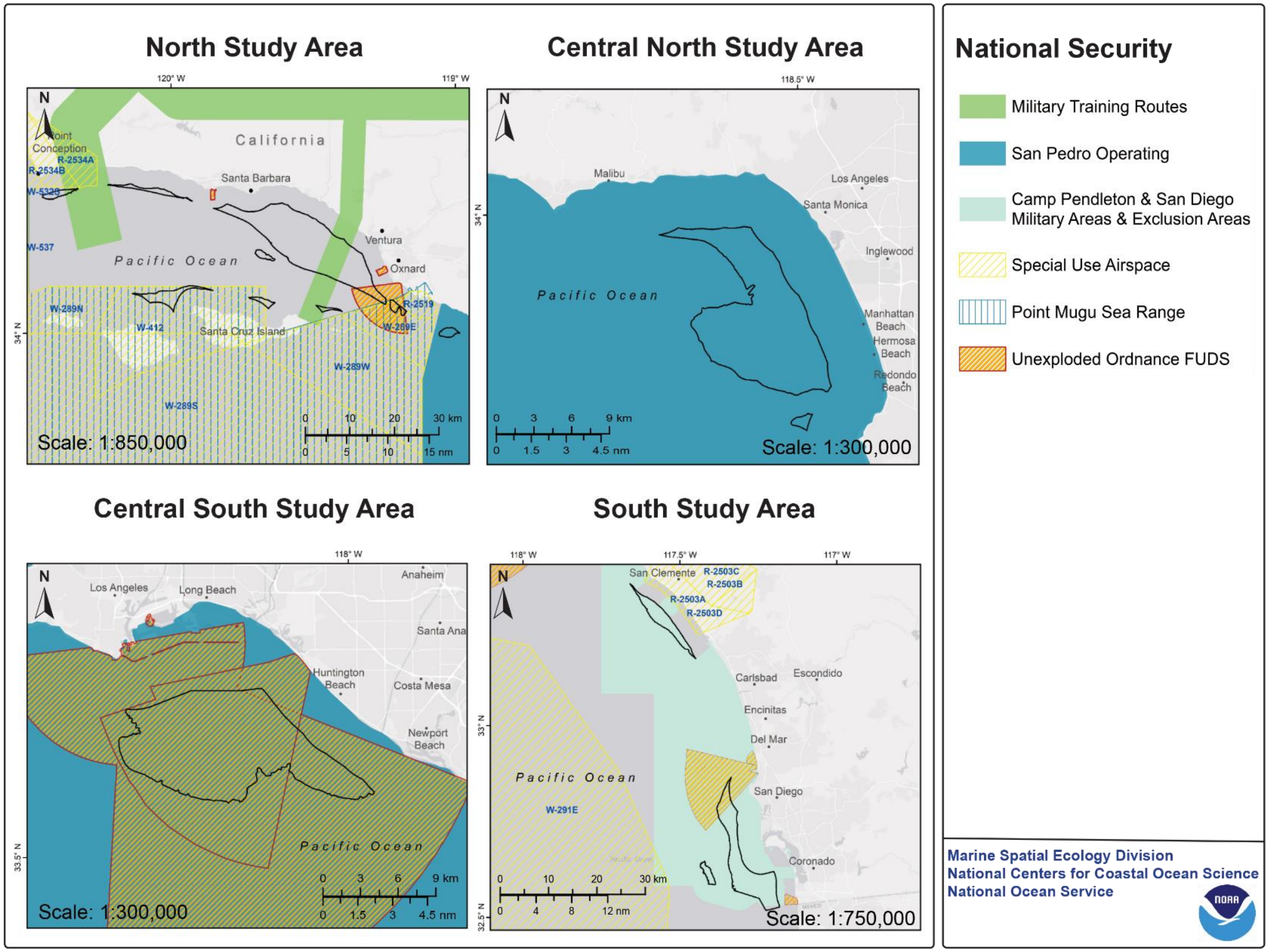


Figure 3.1. National security considerations for the North, Central North, Central South, and South study areas. Considerations include military training routes, the San Pedro Operating Area, the Camp Pendleton and San Diego military areas and exclusion areas, special use airspace, Point Mugu Sea Range, and unexploded ordnance Formerly Used Defense Sites.

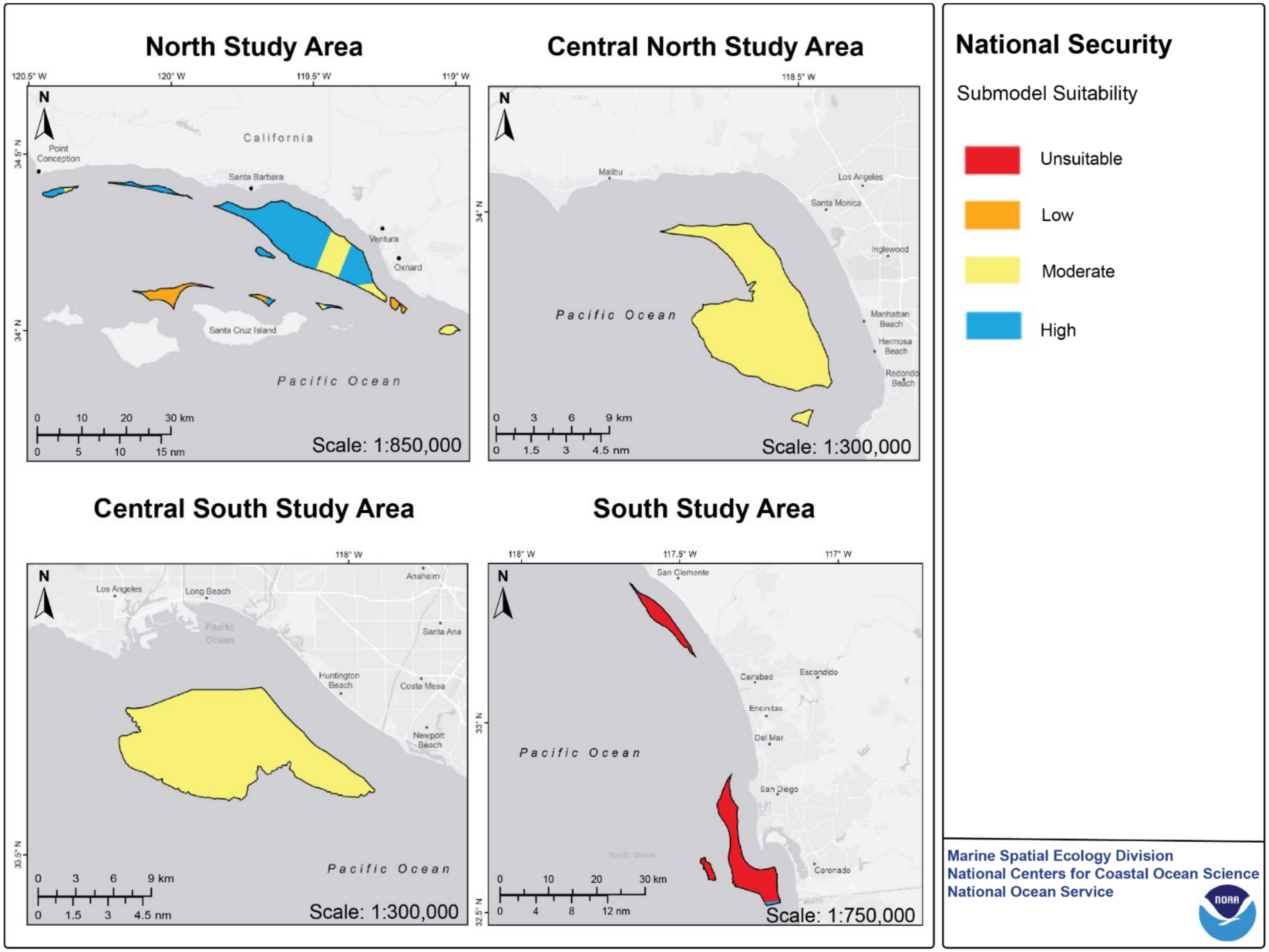


Figure 3.2. National security submodel utilized in the suitability model for (from top to bottom, left to right) the North, Central North, Central South, and South study areas.

Table 3.1. National security considerations included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with percent overlap that occurred in the North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel.

National Security Dataset	Score	Percent Overlap			
		N	CN	CS	S
Camp Pendleton and San Diego Military Areas	0.5	-	-	-	51.1%
Military Training Routes (MTR)	0.5	14.6%	-	-	-
Point Mugu Sea Range (PMSR)	0.5	9.9%	-	-	-
San Pedro Channel Operating Area (SPCOA)	0.5	1.9%	100%	100%	-
Special Use Airspace (SUA) (W-412 and W-289E)	0.5	9.8%	-	-	-
Unexploded Ordnance Formerly Used Defense Sites (UXO FUDS)	0.5	4.6%	-	100%	27.9%
Camp Pendleton and San Diego Military Exclusion Areas	0	-	-	-	98.7%
- Dash indicates that the data layer did not overlap the study area.					

Natural and Cultural Resources

Natural resource data layers were assessed to determine biologically important and sensitive habitat, culturally and archaeologically sensitive areas, and designated protected areas that are incompatible with aquaculture (Figure 3.3). Most layers in this submodel were moved to the constraints model due to their ecological importance and need for avoidance (Table 3.2; Figure 3.4). Data layers that received a score of 0 included deep-sea coral and sponge observations with a 500-m setback, hardbottom habitat with a 500-ft setback, NMFS Essential Fish Habitat (EFH) Habitat Areas of Particular Concern (HAPC) for rocky reefs, fish havens with a 500-ft setback, and National Marine Sanctuaries (NMS). Other considerations included a Bureau of Ocean Energy Management (BOEM) preserve established in 1969 that was scored as 0.5, and the combined data layer of Cetacean Biologically Important Areas (BIAs) and Critical Habitat, which received scores of 0.008 to 0.2 depending on the number of overlapping layers.

The North study area overlapped deep-sea coral, hardbottom habitat, HAPC, and the Channel Islands NMS; these interactions required a score of 0 and the areas were deemed incompatible with aquaculture development. The BOEM preserve, also found within the North study area, was scored a 0.5. Overall, the protected resources data layer overlapped with 74.6% of the study area.

The Central North study area overlapped deep-sea coral observations, hardbottom habitat, and HAPC rocky reefs in the southern section of the study area. Similarly, the BIA for blue whale feeding, with a score of 0.2, overlaps 58.6% of the southern section of the study area.

The Central South study area overlaps several natural resource submodel data layers. The deep-sea coral, hardbottom, HAPC rocky reefs, and fish havens were all found within the study area and were given a 0 score, removing that area from consideration for AOAs. The BIA for blue whale feeding, scored 0.2, was part of the Protected Resources Division (PRD) combined data layer and had significant overlap with the study area (90.9%). The South study area contained deep-sea coral observations, hardbottom habitat, and a small section of a fish haven. All three data layers received a score of 0, and these areas were deemed unsuitable for AOA development. The BIA for blue whale feeding had a 37.9% overlap with the study area.

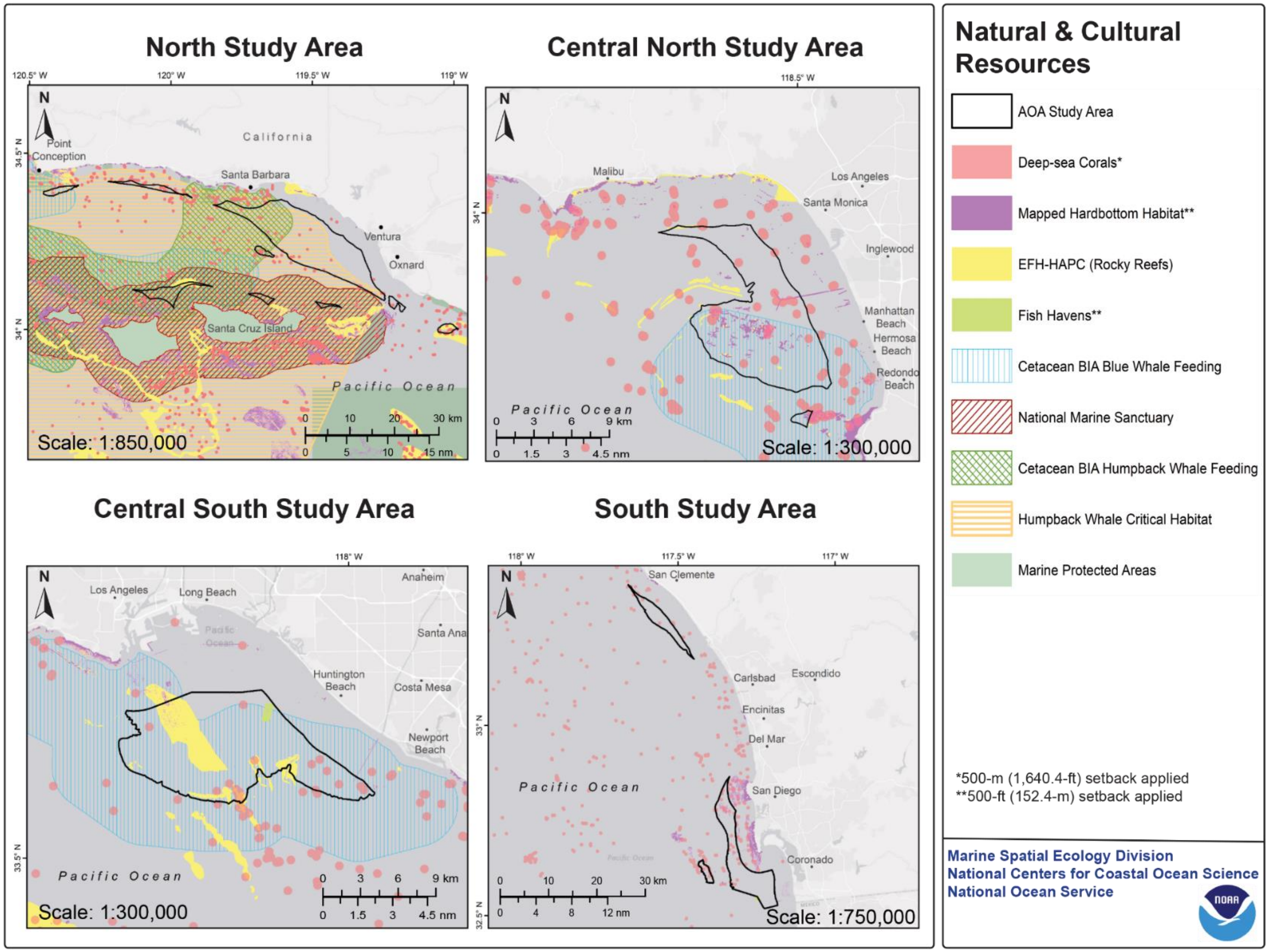


Figure 3.3. Natural and cultural resources for the North, Central North, Central South, and South study areas including corals, hardbottom habitat, fish havens, cetaceans, and protected areas.

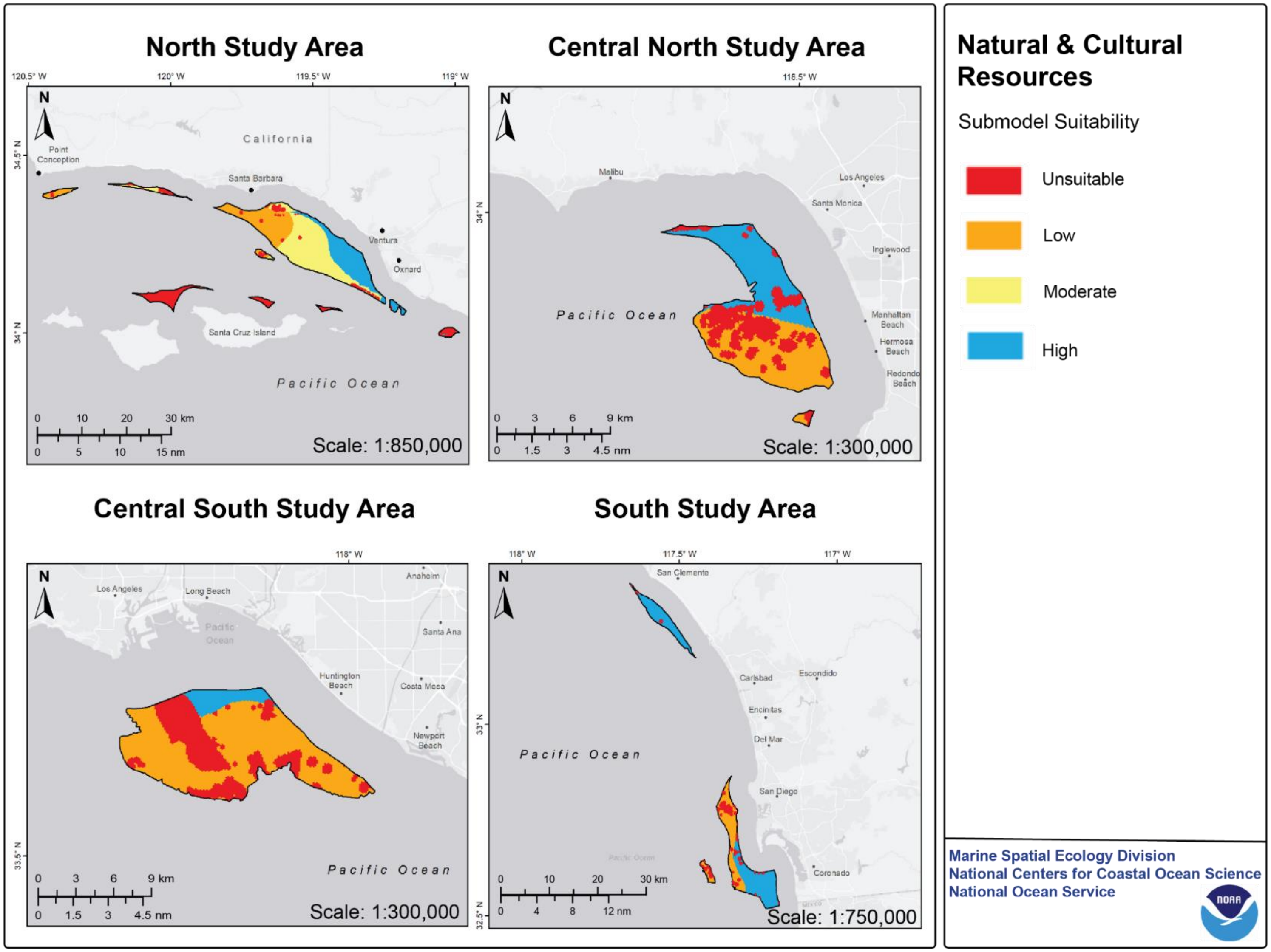


Figure 3.4. Final natural and cultural resources submodel utilized in the suitability model for (from top to bottom, left to right) the North, Central North, Central South, and South study areas.

Table 3.2. Natural and cultural resources considerations included in the relative suitability analysis and the score assigned to each dataset. Percent overlap of each dataset is provided for the North (N), Central North (CN), Central South (CS), or the South (S) study area. All zero values were included in the constraints submodel rather than the natural and cultural resources submodel.

Natural and Cultural Resources Dataset	Score	Percent Overlap			
		N	CN	CS	S
BOEM Preserve	0.5	12.8%	-	-	-
Cetacean BIAs - Blue Whale Feeding Area*	0.2	74.6%	58.6%	90.9%	37.9%
Cetacean BIAs - Humpback Whale Feeding Area*	0.2	2.5%	-	-	-
Critical Habitat - Humpback Whale*	0.2	2.5%	-	-	-
Deep-sea Coral and Sponge Observations (1985 to present) - with 500-m setback	0	3.8%	9.7%	4.1%	9.5%
Hardbottom Habitat - with 500-ft setback	0	4.0%	20.7%	8.2%	7.1%
National Marine Sanctuaries (NMS)	0	9.6%	-	-	-
NMFS EFH HAPC (Rocky)	0	2.5%	16.9%	24.9%	-
NOAA Fish Havens - with 500-ft setback	0	-	-	1.2%	0.1%

- Dash indicates that the data layer did not overlap the study area.
* Data layers were combined and scores calculated using the product method.

Industry, Navigation, and Transportation

The ocean economy in California contributed an estimated $84 billion to the 2018 gross state product and comprises six distinct sectors, including offshore mineral extraction and marine transportation (LAEDC 2020). Of the major industries identified in the study areas, oil and gas extraction was one of the most prevalent, with several data layers depicting different aspects of the industry. These layers include platforms, pipelines, wells, and lease blocks, which were scored according to their compatibility with aquaculture development and operations. In federal waters, two agencies are responsible for regulations around oil and gas development offshore. The Bureau of Ocean Energy Management (BOEM) is responsible for the leasing policy and program development for oil, gas, and other marine minerals, and the Bureau of Safety and Environmental Enforcement (BSEE) is responsible for regulatory programs for the safety, maintenance, inspection, and environmental protections of current oil and gas operations. The offshore oil and gas industries in California have been in a state of transition as no new platform installations have occurred since 1994, and many of the current platforms are at the end of their operational lifespan, with installation dates between 1960 and 1980. A total of 23 platforms are found in the Pacific Outer Continental Shelf Region, with 7 structures being considered for decommissioning (BSEE 2020).

Current oil and gas platform, well, and pipeline data layers were given a 500-m (1,640-ft) setback to provide conservative estimates of distance needed for the development and operation of aquaculture sites in proximity to existing ocean infrastructure. These layers and the Joint Oil Fisheries Liaison Office (JOFLO) corridors, which are defined corridors used for oil and gas service vessels to transit and within which certain types of commercial fishing should be avoided, were given a score of 0, and moved to the constraints submodel for analysis (Table 3.3; Figure 3.5). BOEM lease blocks were scored 0.5 and were used in the industry submodel. The North study area is within California's largest offshore oil and gas development area, with further development in the Central South study area; no oil and gas developments are found within the Central North and South study areas (Figure 3.5). Of the oil and gas development data layers, pipelines had the highest percent overlap with the study area, with 9.3% in the North and 9.3% in the Central South (Table 3.3).

Within AOA study areas, other industry infrastructure is also present on the seafloor, including vital fiber optic cables, submarine power cables, and outfall pipes and diffusers (Table 3.3; Figure 3.5). Fiber optic cables provide high speed data transmission connecting California cities, California to Hawaii, and the U.S. to other countries across the Pacific Ocean. Submarine power cables provide shore-based power to several offshore oil platforms. NOAA charted submarine cables include both fiber optic and submarine power cables and were given a 500-m (1,640-ft) setback, scored 0, and moved to the constraints submodel, as they are vital infrastructure. Outfall pipes and diffusers are also found within and in close proximity to the AOA study areas. These structures are found on the seafloor and function to transport and diffuse treated wastewater from onshore treatment plants. A 3-mi (4.8-km) setback was applied to outfall pipes and diffusers as a conservative measure consistent with setbacks used in the area by the California Department of Public Health pursuant to the National Shellfish Sanitation Program (CADPH 2012). Outfall structures and diffusers with a 3-mi setback were scored 0 and moved to the constraints submodel. All four study areas interact with outfall structures and diffusers with 3-mi setbacks, and this data layer overlapped significantly in the Central North and South study areas.

The remaining data layers include aids to navigation, anchorage areas, wrecks and obstructions, California Cooperative Oceanic Fisheries Investigations (CalCOFI) sampling sites, pilot boarding areas and stations, shipping fairways, and ferry routes. These data layers were all scored 0 and moved to the constraints submodel as they are essential to existing navigation-based industries and should be avoided by aquaculture operations as well as associated vessel activity. Shipping lanes accounted for the largest overlap in the Central South region due to the close proximity to the ports of Long Beach and Los Angeles.

Vessel traffic data, or Automatic Identification System (AIS) data, are collected in real time by the U.S. Coast Guard (USCG) using very high frequency maritime-band transponders, capable of handling over 4,500 reports per minute, which update as often as every two seconds (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; MarineCadastre 2021).

AIS data were used as a proxy for potential transit conflicts within the study areas. Specifically, AIS data from 2019, available from NOAA Office for Coastal Management, were analyzed to determine the relative vessel transit counts (i.e., vessel traffic) of eight vessel groups (i.e., cargo, fishing, military, passenger, pleasure and sailing, tanker, tug and tow, and other vessels) within the study areas (Table 3.4; Figures 3.6 - 3.13). The COVID-19 pandemic, beginning in February of 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.

Examining each of the eight vessel groups (Table 3.4; Figures 3.6 - 3.13), the North study area contained the highest percent overlap with other, passenger, and pleasure and sailing vessels, each with over 90%. The highest number of vessel transits were from the passenger vessel category, with 517,330 transits. The next highest value, 46,915, was from the other vessel category. The lowest percent overlap was from tanker and military vessels, with 2.1% and 1.7% overlap accounting for 71 and 109 transits, respectively. Distinct patterns of travel for cargo vessels were observed within the designated traffic lanes and to and from Port Hueneme. Passenger vessel transits can be found dispersed throughout the North study area with distinct traffic routes to and from the area's oil platforms and with regular daily ferry service to Santa Cruz Island. The 2019 fishing vessel transits are focused from the harbors of Ventura, Santa Barbara, and Channel Islands with distinct traffic along the coast and to the Channel Islands. Tug and tow vessel transits occur within the shipping lanes.

The Central North study area is within Santa Monica Bay and has a high percent overlap, greater than 90%, with pleasure and sailing and passenger vessel categories, as well as an 80% overlap with the other vessel category. Cargo transits in the area rarely enter the bay, with the vast majority of transits found within the shipping lanes. Tanker traffic is higher throughout the southern region of the study area, with 4,392 transits. There appear to be distinct patterns as tankers exit the shipping lanes to offload oil at the Chevron El Segundo marine terminal. Fishing transits are relatively low, with 59 transits found mainly in the southern portion of the study area. Tug and tow transits mirrored the large tanker transits to the marine terminal. Transits from the other vessel group were dispersed in the study area with no distinct transit routes. No military vessel transits were found in the study area.

Within the Central South study area, vessel traffic is concentrated from the commercial ports of Long Beach and Los Angeles, and the recreational ports of Newport Beach. A total of 6,000 cargo and 2,381 tanker vessel transits occurred in the study area in 2019; most transits connected the commercial ports to the shipping lanes. Fishing vessels transit the study area from the ports in different directions, some directed at Catalina Island. Similar to other study areas, tug and tow traffic appears to be correlated to cargo and tanker transits. A total of 23,677 passenger vessel transits occurred through the study area; patterns emerged for transits to and from the oil platforms and regular daily ferry service transits to Catalina Island. Pleasure and sailing vessel transits were evenly distributed throughout the study area, with no distinct transit routes or patterns. The other vessel traffic group depicts distinct patterns of transits to the oil platforms within the study area. AIS data suggest there are minimal military transits through the study area.

The South study area is in close proximity to the Port of San Diego and Mission Bay. Cargo and tanker vessel transits bisect the study area as vessels travel to and from the Port of San Diego. Fishing vessel traffic occurs at highest values along the shore between Mission Bay and the Port of San Diego, with 1,013 transits through the study area. Tug and tow vessel transit patterns from 2019 mirror patterns of the cargo and tanker vessel groups. Passenger, pleasure and sailing, and other vessel categories had the highest number of transits through the study area, with 18,215, 12,796, and 19,254 transits, respectively. Military transits were the highest of all study areas, with 956 transits; this could be due to the area’s proximity to Naval Base San Diego.

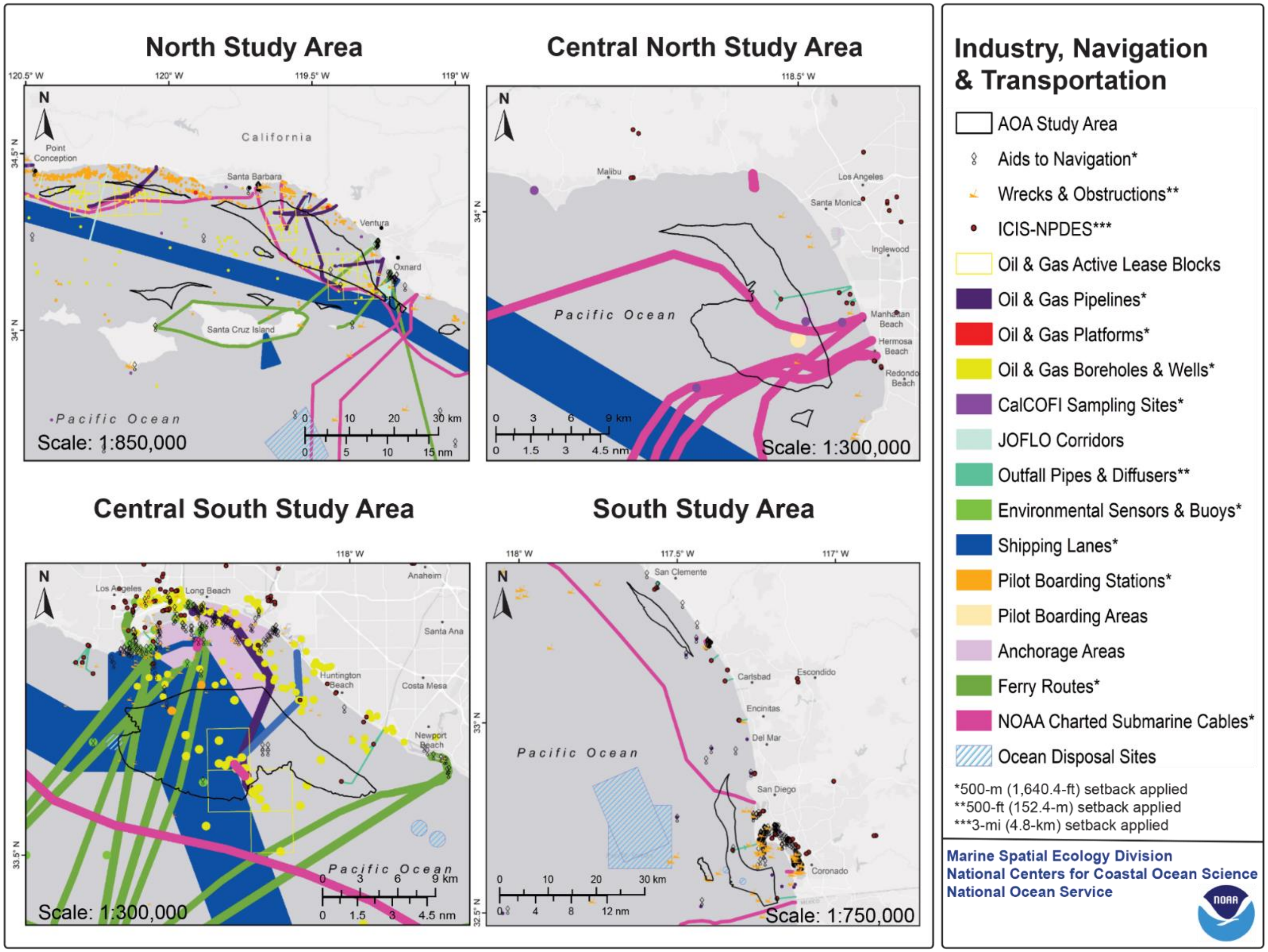


Figure 3.5. Industry, navigation, and transportation considerations for the North, Central North, Central South, and South study areas. Considerations include energy infrastructure (e.g., oil and gas lease blocks, pipelines, platforms, and boreholes and wells), shipping infrastructure and routes (e.g., aids to navigation, shipping lanes, pilot boarding stations and areas, anchorage areas, and ferry routes).

Table 3.3. Industry, navigation, and transportation considerations included in the relative suitability analysis and the score assigned to each dataset. Each dataset is listed with percent overlap that occurred in the North (N), Central North (CN), Central South (CS), or South (S) study area. All zero values were included in the constraints submodel.

Industry, Navigation, and Transportation Dataset	Score	Percent Overlap			
		N	CN	CS	S
BOEM Active Lease Blocks	0.5	36.1%	-	18.7%	-
AIS Vessel Traffic 2019 - Cargo	Cont.*	31.1%	4.7%	59.0%	52.4%
AIS Vessel Traffic 2019 - Fishing	Cont.*	69.2%	41.2%	83.2%	84.2%
AIS Vessel Traffic 2019 - Military	Cont.*	1.7%	0.0%	4.7%	41.7%
AIS Vessel Traffic 2019 - Other	Cont.*	96.1%	80.2%	94.9%	94.5%
AIS Vessel Traffic 2019 - Passenger	Cont.*	95.3%	95.4%	100%	96.3%
AIS Vessel Traffic 2019 - Pleasure and Sailing Vessels	Cont.*	98.1%	99.3%	100%	99.9%
AIS Vessel Traffic 2019 - Tanker	Cont.*	2.1%	55.0%	57.7%	36.0%
AIS Vessel Traffic 2019 - Tug and Tow	Cont.*	24.4%	46.3%	92.0%	79.8%
Aids to Navigation (Beacons and Buoys) with 500-m setback	0	0.2%	-	2.4%	0.5%
Anchorage Areas (Used/Disused)	0	-	0.8%	3.9%	-
AWOIS Wrecks Polluting, RULET Wrecks, ENC Wrecks and Obstructions, ENC Danger Wrecks with 500-ft setback	0	0.1%	0.1%	0.1%	0.3%
Boreholes, Test Wells, and Wells with 500-m setback	0	10.6%	-	7.0%	-
California Cooperative Oceanic Fisheries Investigations (CalCOFI) Sampling Sites with 500-m setback	0	0.3%	0.7%	-	-
Contingency Anchorage Area with 2-mi setback	0	-	-	24.9%	-
Environmental Sensors and Buoys with 500-m setback	0	-	-	0.5%	0.4%
Joint Oil Fisheries Liaison Office (JOFLO) Corridors	0	2.3%	-	-	-
NOAA Charted Submarine Cables with 500-m setback	0	9.4%	22.6%	-	1.1%
Ocean Disposal Sites	0	0.1%	-	0.3%	1.3%
Oil and Gas Pipelines with 500-m setback	0	9.3%	-	9.3%	-
Oil and Gas Platforms with 500-m setback	0	1.3%	-	0.8%	-

Industry, Navigation, and Transportation Dataset	Score	Percent Overlap			
		N	CN	CS	S
Outfall Pipes and Diffusers with 3-mi setback	0	-	42.2%	12.3%	27.9%
Pilot Boarding Areas	0	-	1.9%	-	-
Pilot Boarding Stations with 500-m setback	0	-	-	0.5%	-
Shipping Fairways with 500-m setback	0	2.1%	-	66.5%	-
Southern California Ferry Routes with 500-m setback	0	2.7%	-	15.8%	-

- Dash indicates that the data layer did not overlap with the study area.
* Data layers represent continuous data scored using a fuzzy logic Z-shaped membership function.

Table 3.4. Scoring approach and number of transits for each type of vessel traffic by study area.

Vessel Traffic Dataset	Score	Number of Transits			
		N	CN	CS	S
AIS Vessel Traffic 2019 - Cargo	Cont.*	3,485	5	6,000	3,084
AIS Vessel Traffic 2019 - Fishing	Cont.*	1,297	59	934	1,013
AIS Vessel Traffic 2019 - Military	Cont.*	109	-	14	956
AIS Vessel Traffic 2019 - Other	Cont.*	46,915	650	5,213	19,254
AIS Vessel Traffic 2019 - Passenger	Cont.*	517,330	1,686	23,677	18,215
AIS Vessel Traffic 2019 - Pleasure and Sailing Vessels	Cont.*	5,973	2,667	5,264	12,796
AIS Vessel Traffic 2019 - Tanker	Cont.*	61	4,392	2,381	546
AIS Vessel Traffic 2019 - Tug and Tow	Cont.*	891	338	2,219	1,249

- Dash indicates that the data layer did not overlap with the study area.
* Data layers represent continuous data scored using a fuzzy logic Z-shaped membership function.

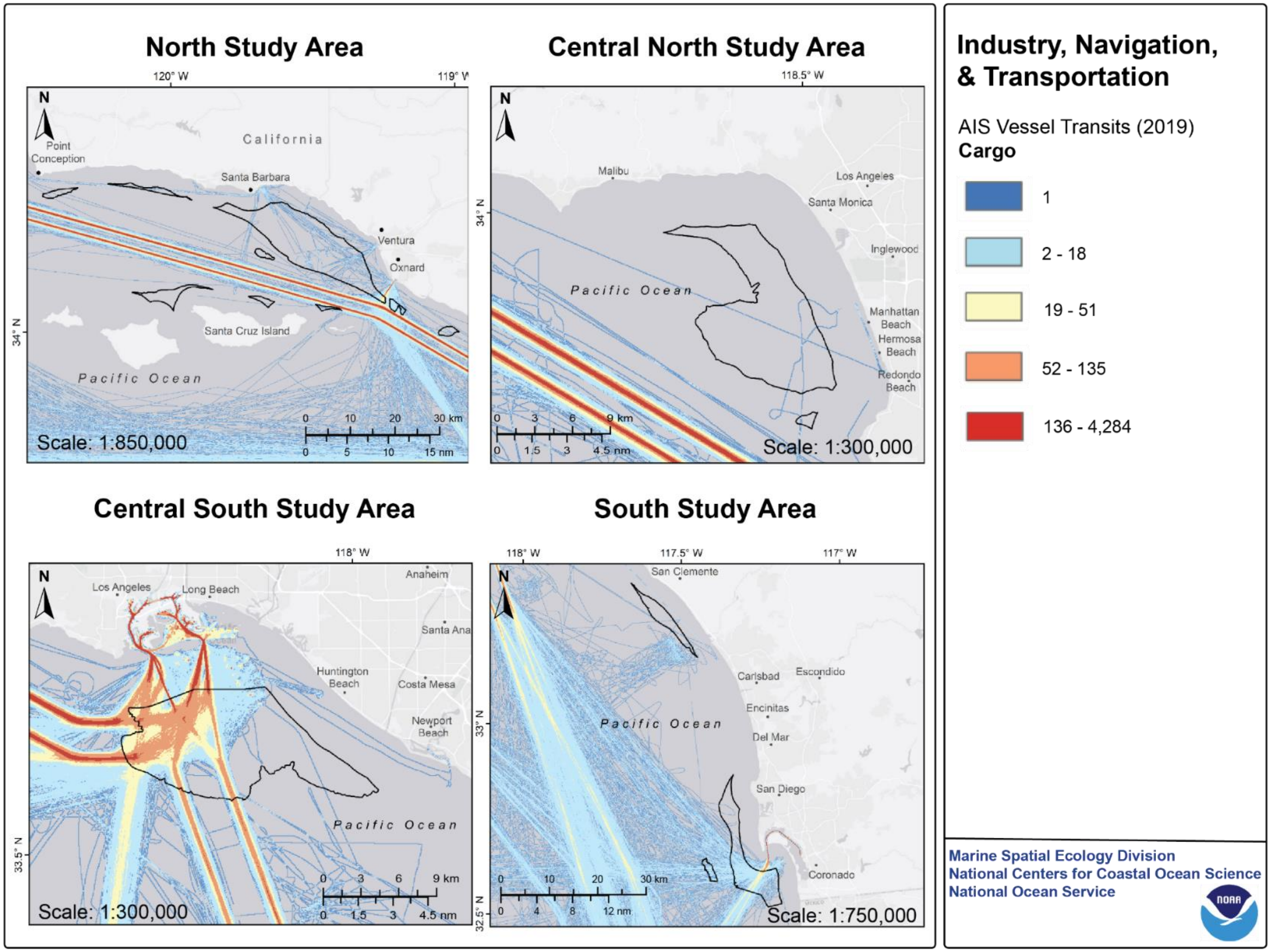


Figure 3.6. Automatic Identification System vessel transit data from 2019 for cargo vessels in the North, Central North, Central South, and South study areas.

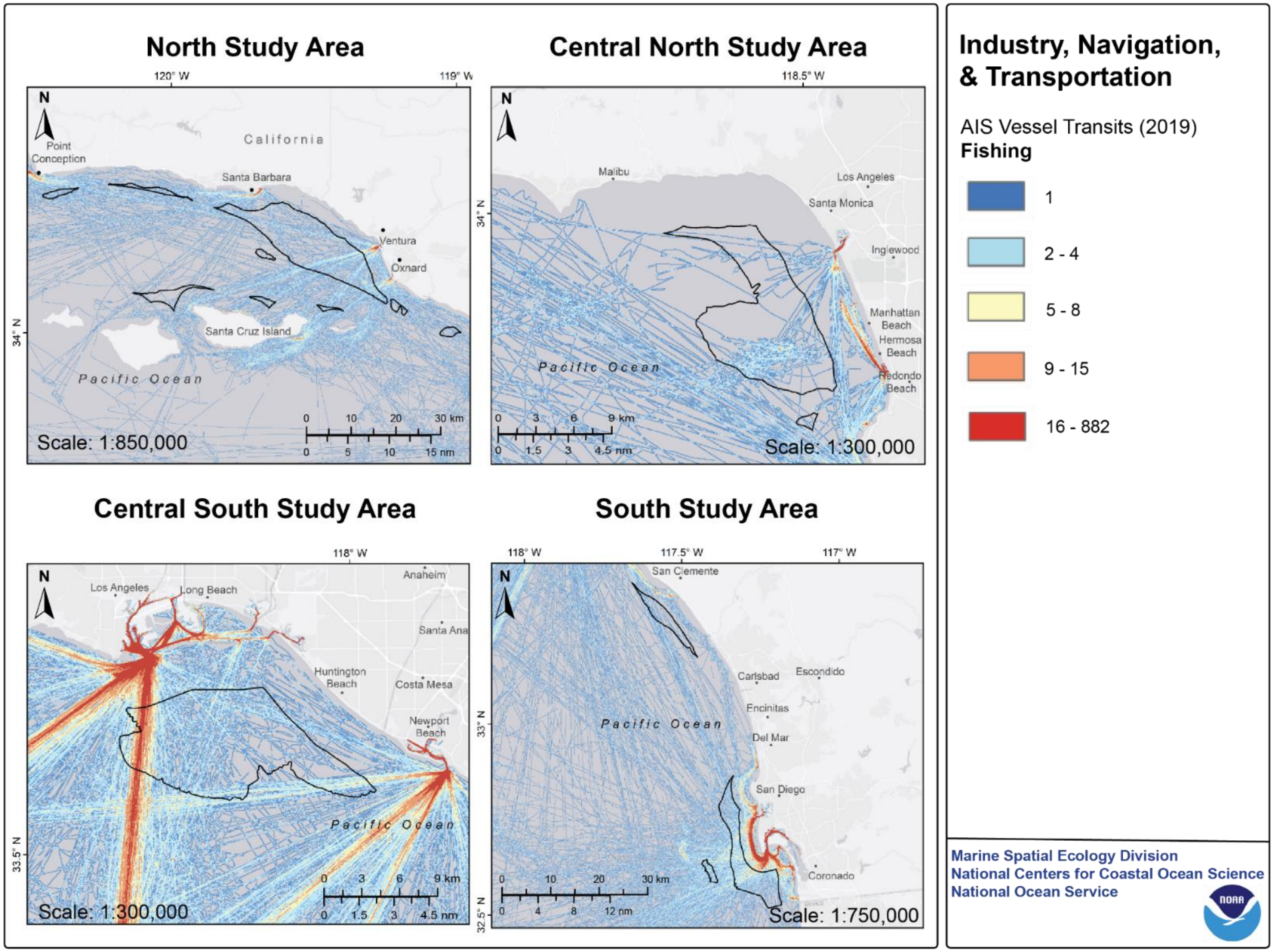


Figure 3.7. Automatic Identification System vessel transit data from 2019 for fishing vessels with very high frequency transponders in the North, Central North, Central South, and South study areas.

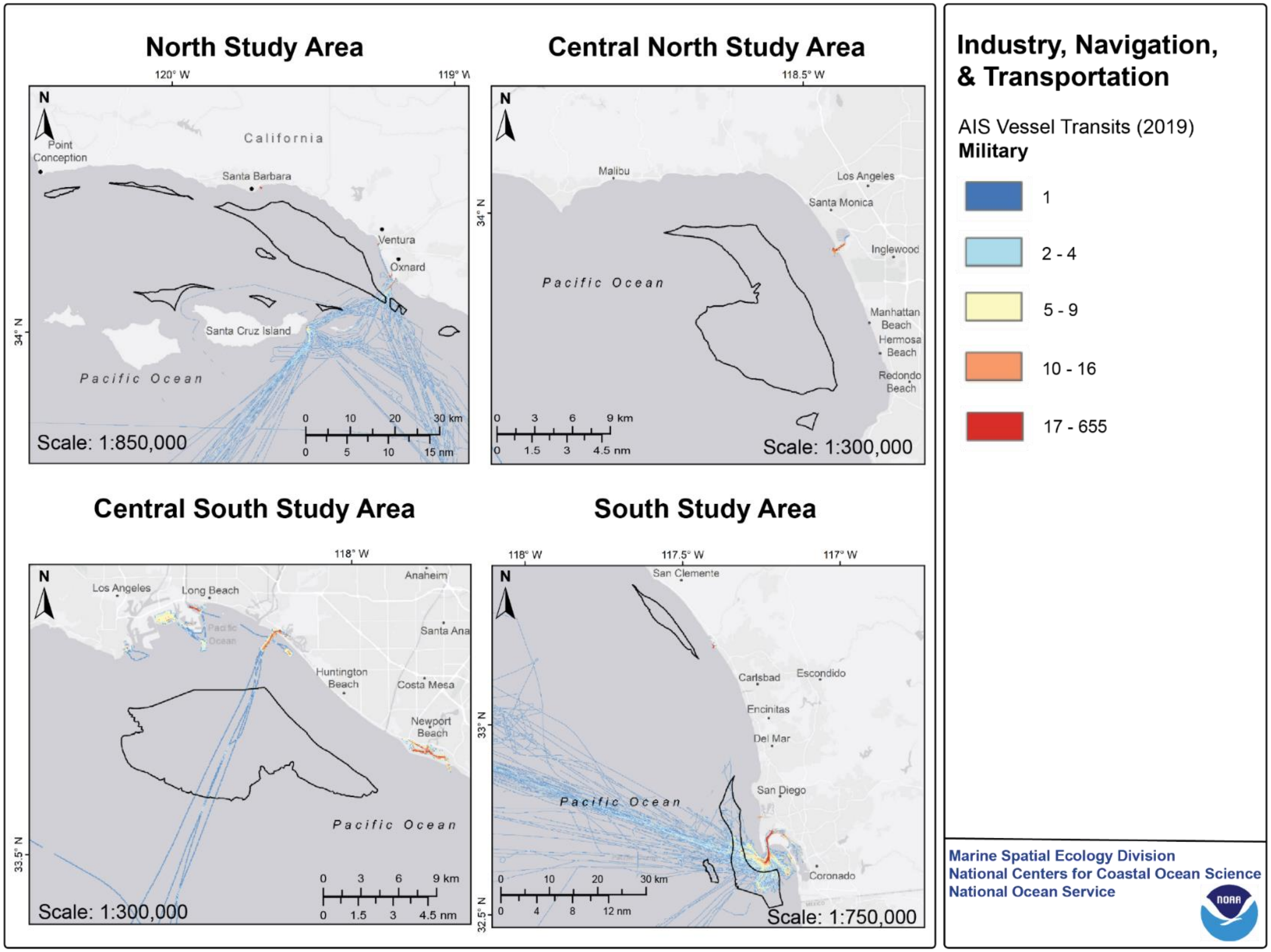


Figure 3.8. Automatic Identification System vessel transit data from 2019 for military vessels in the North, Central North, Central South, and South study areas.

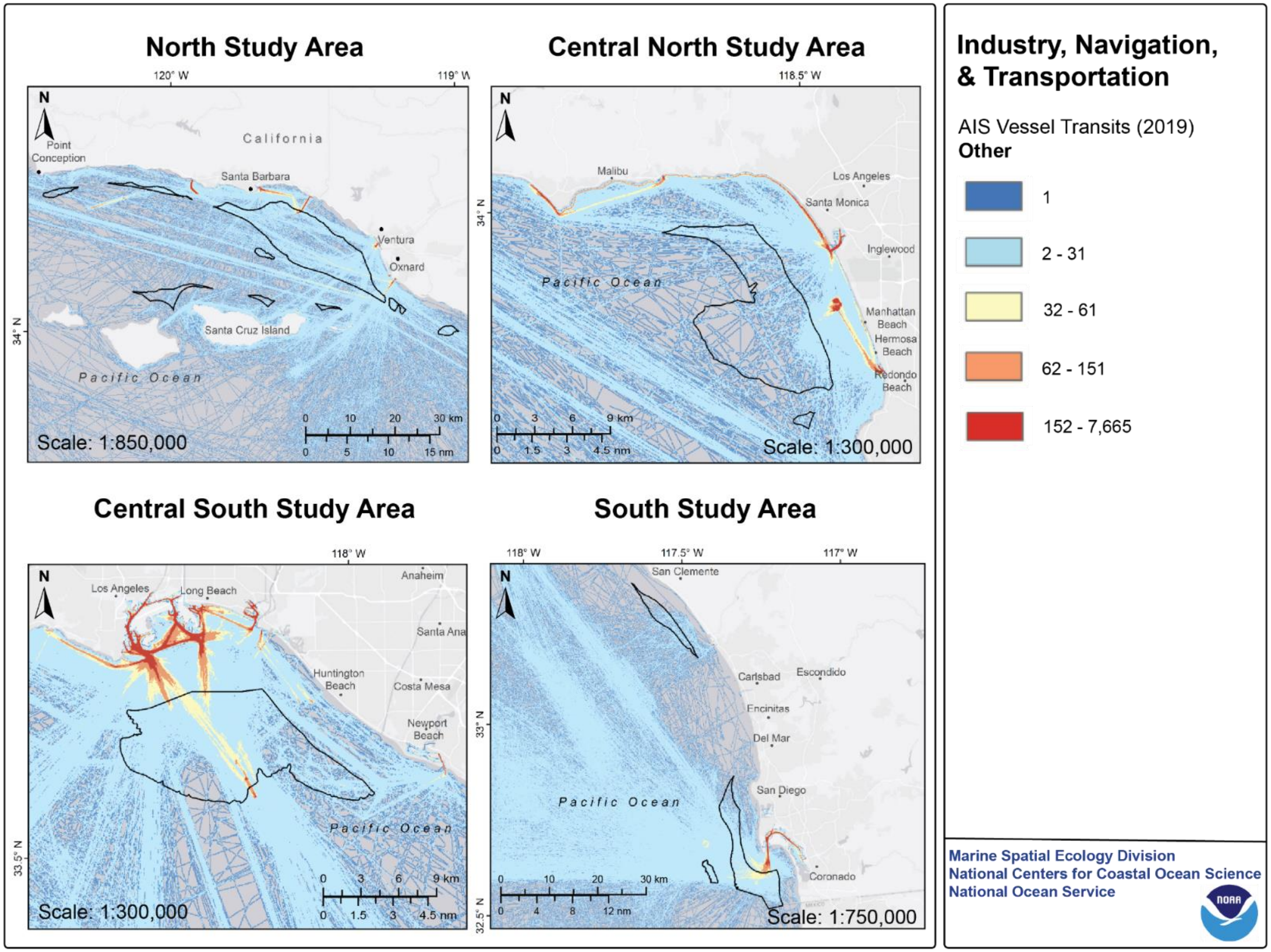


Figure 3.9. Automatic Identification System vessel transit data from 2019 for vessels classified as other in the North, Central North, Central South, and South study areas.

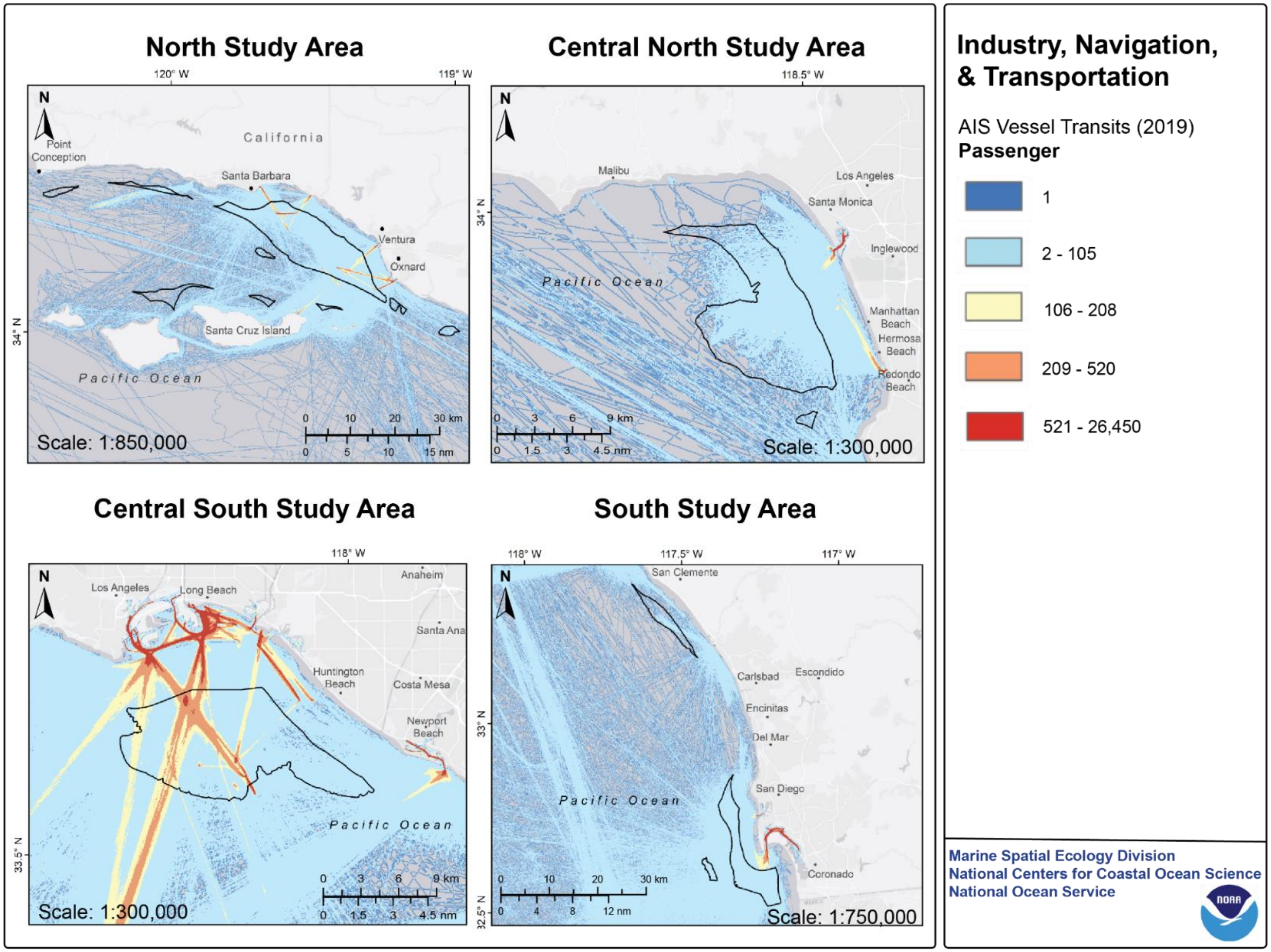


Figure 3.10. Automatic Identification System vessel transit data from 2019 for passenger vessels in the North, Central North, Central South, and South study areas.

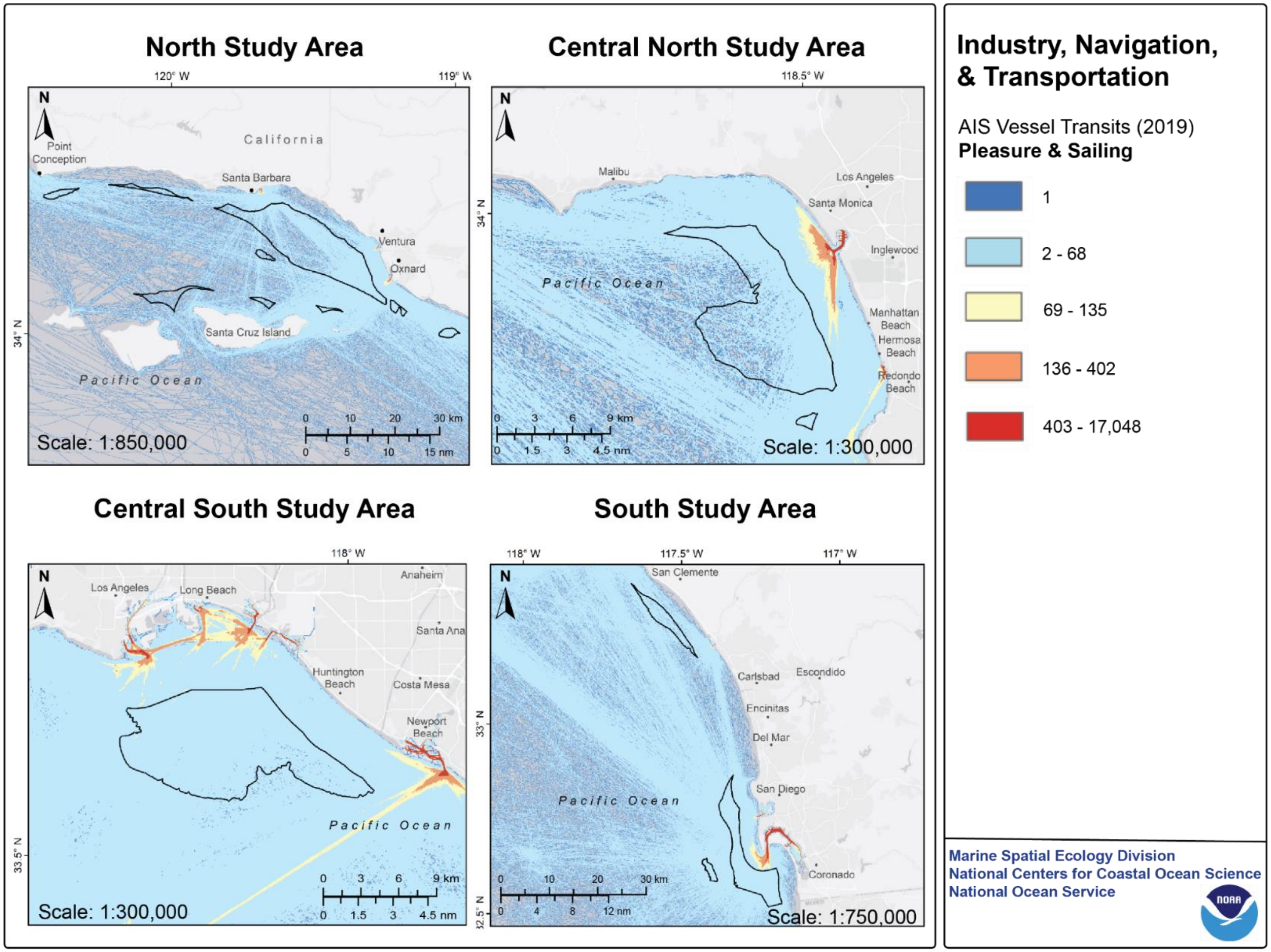


Figure 3.11. Automatic Identification System vessel transit data from 2019 for pleasure and sailing vessels in the North, Central North, Central South, and South study areas.

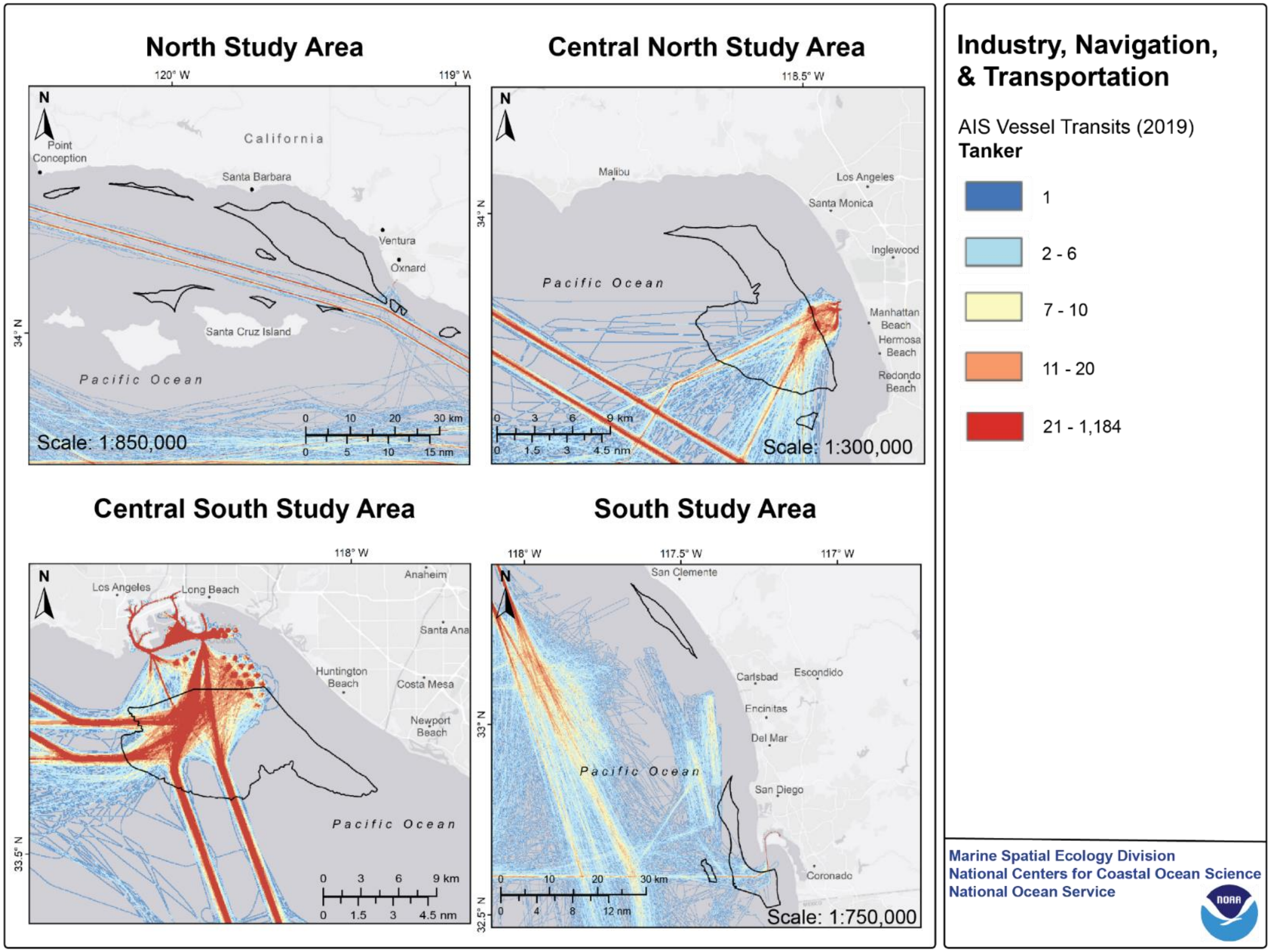


Figure 3.12. Automatic Identification System vessel transit data from 2019 for tanker vessels in the North, Central North, Central South, and South study areas.

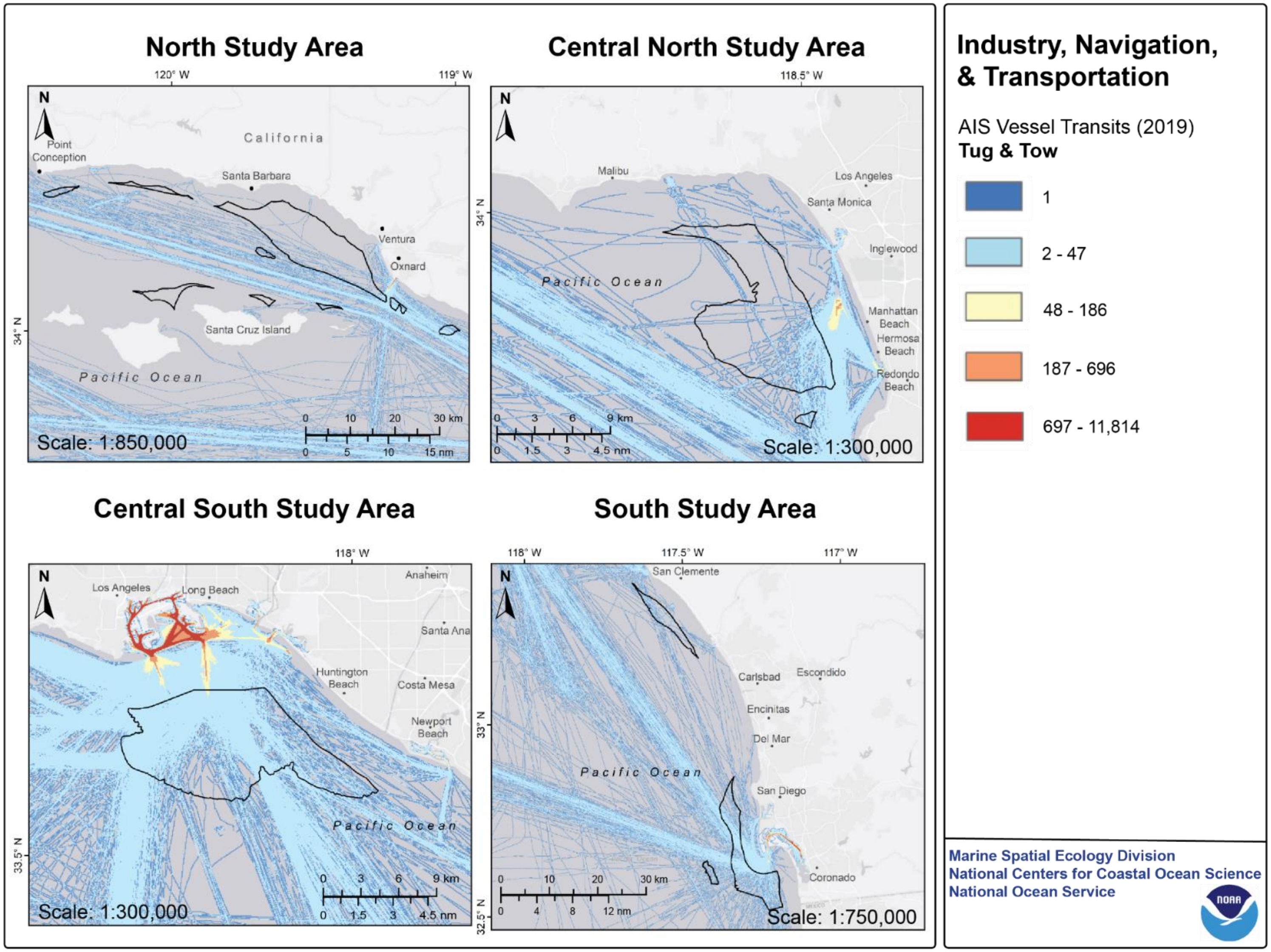


Figure 3.13. Automatic Identification System vessel transit data from 2019 for tug and tow vessels in the North, Central North, Central South, and South study areas.

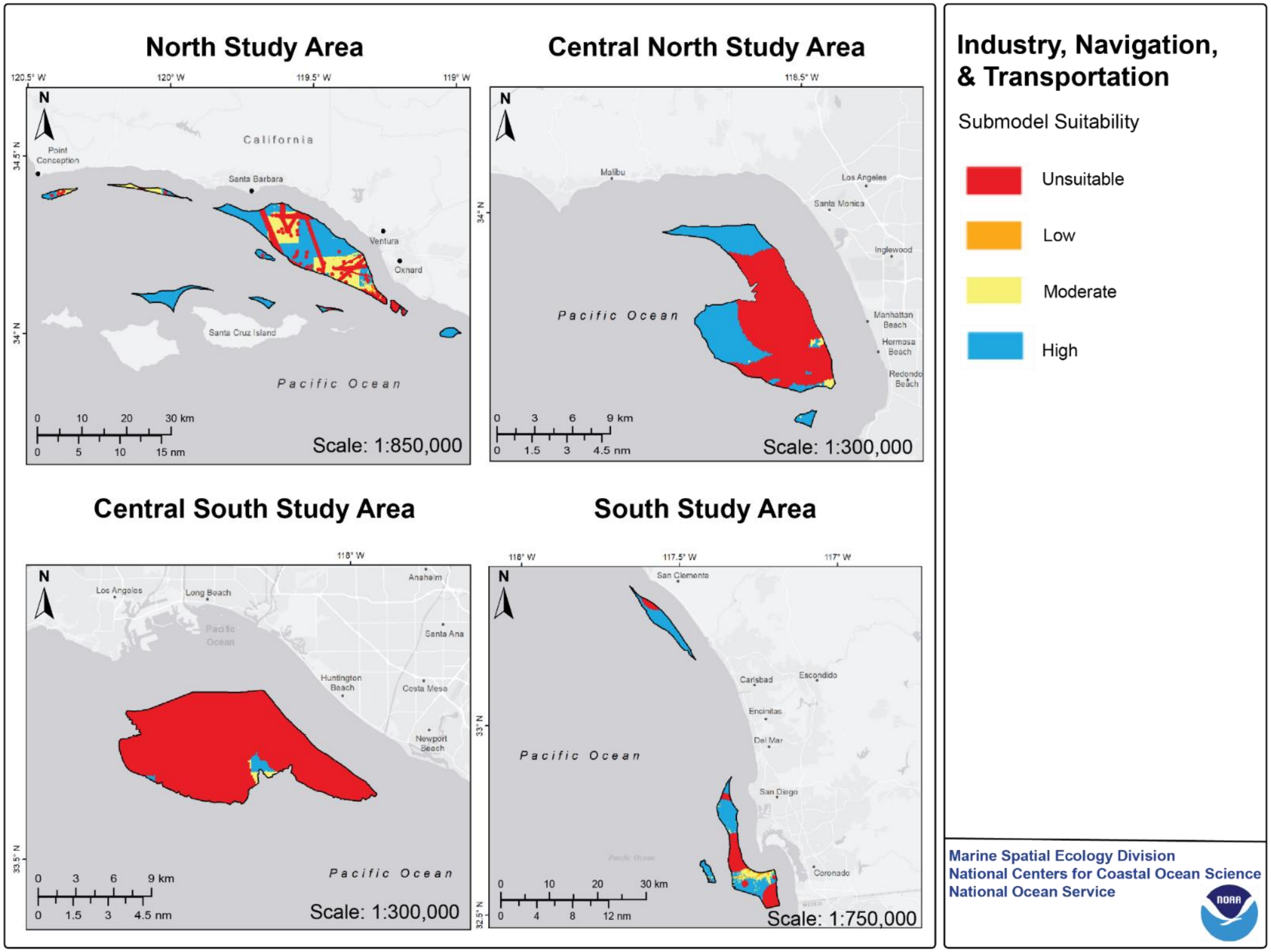


Figure 3.14. Industry, navigation, and transportation suitability submodel utilized in the Aquaculture Opportunity Area suitability model (from top to bottom, left to right) for the North, Central North, Central South, and South study areas.

Fishing and Aquaculture

Data layers representing fishing and aquaculture activity were provided by authoritative sources for southern California (Tables 3.5, 3.6; Figures 3.15 - 3.35) including six main data sources for a total of 23 data layers to provide the best available representation of commercial and recreational fishing activity. Commercial and recreational fishing activity represent major economic drivers for the region. According to CDFW data, in 2019, a total of 19,051 MT (42 million pounds) of fish were landed in the waters of southern California. Recreational fishing is both an economic driver as well as an important social consideration for the region. Also, within the study areas there are a total of three aquaculture farm sites at various stages of the permitting process or operational status.

The North study area overlapped both sources of recreational fishing data with a 63.9% overlap with the CRFS dataset and 8.65% overlap with the 1,581 CPFV transits. Of the VMS transits, the highest overlap and number of transits typically occurred with VMS declaration codes related to trawl fisheries of different target species (ridgeback prawn, pink shrimp, California halibut, and California sea cucumber). The North study area had the highest value of total VMS transits. The Central North study area had a 92.5% overlap with the CRFS dataset and a 13% overlap with the 560 CPFV transits. The Central study area had the lowest overlap and number of transits of commercial fishing data due to restrictions within Santa Monica Bay for specific commercial fisheries. Within the Central South study area, overlaps occur with both recreational fishing data layers, with a 29% overlap with the 1,013 CPFV transits and a 98.5% overlap with the CRFS dataset. Commercial fishing occurs within the study area with high overlap with trawl fisheries and groundfish with a total of 4,813 transits for VMS data. The South study area had the highest percent overlap with the 880 CPFV transits and a 95.8% overlap with the CRFS dataset. A total of 3,735 VMS transits occurred within the study area, with the highest number of transits from pink shrimp trawls.

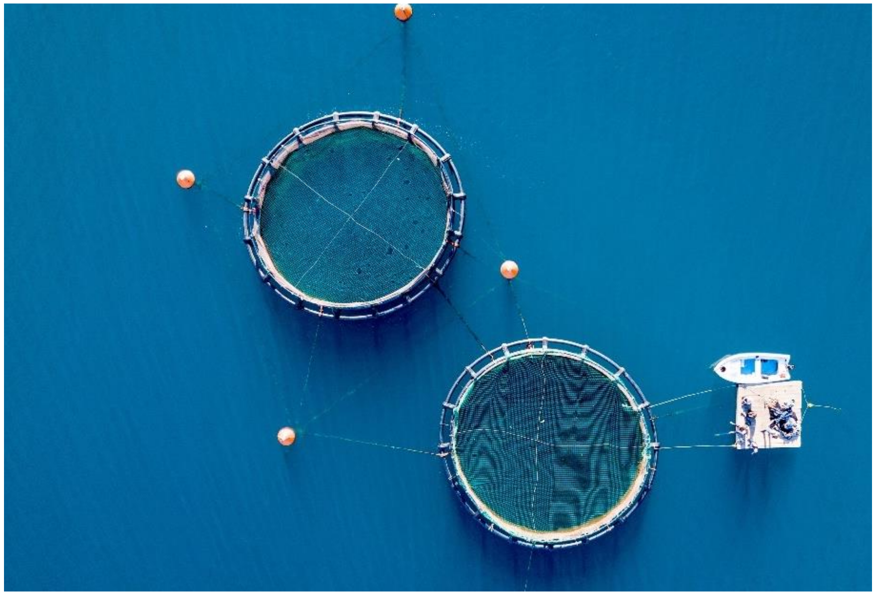
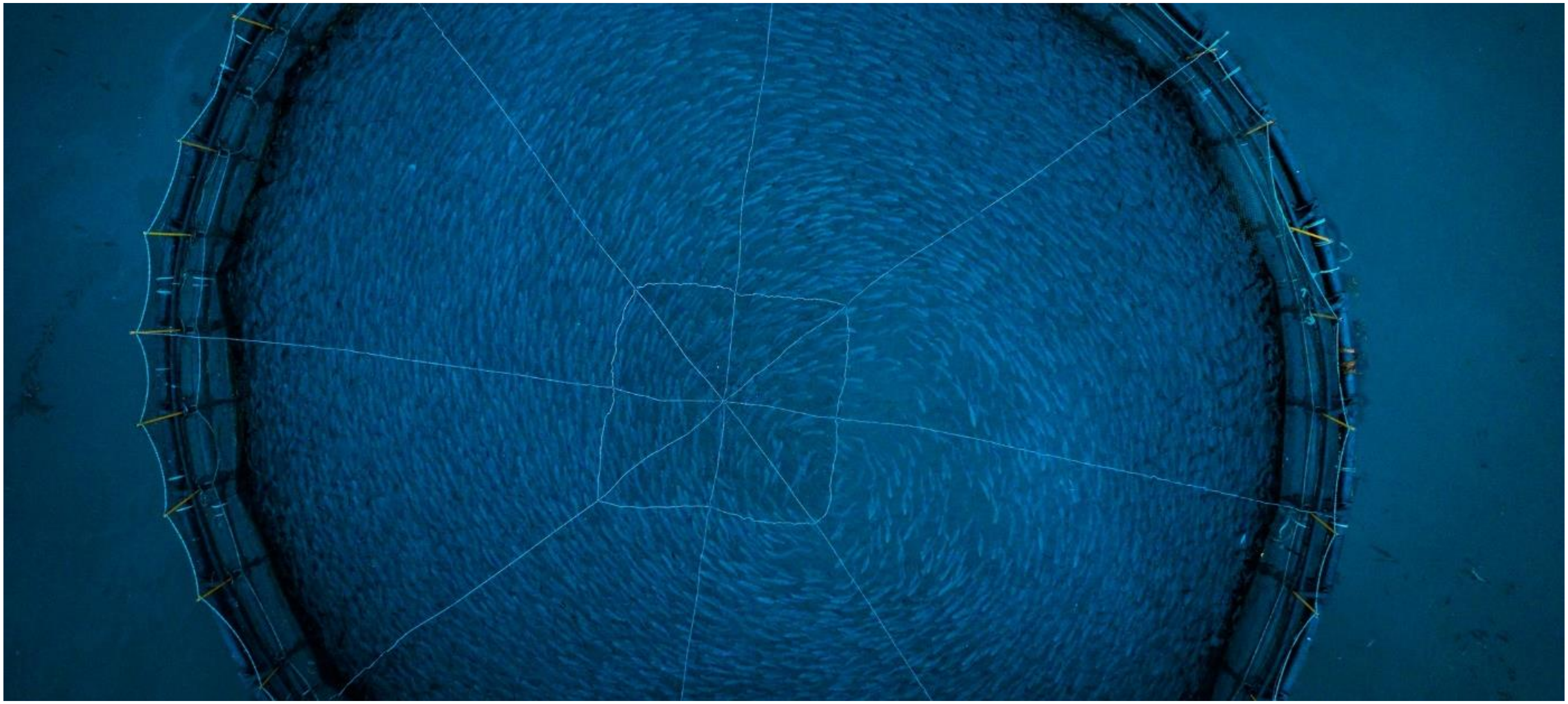


Table 3.5. Percent overlap for each study area for fishing and aquaculture activities.

Fishing and Aquaculture Dataset	Score	Percent Overlap			
		N	CN	CS	S
Ocean Rainforest Aquaculture with 500-m setback	0.5	0.5%	-	-	-
Pacific Ocean AquaFarms (POA) San Diego Aquaculture with 500-m setback	0.5	-	-	-	3.4%
California Recreational Fisheries Surveys (CRFS) 2010 - 2019	Cont.*	63.9%	92.5%	98.5%	95.8%
Commercial Passenger Fishing Vessels (CPFV) 2010 - 2019	Cont.*	8.7%	13.0%	29.0%	30.1%
Divelog 1998 - 2016	Cont.*	0.1%	0.6%	0.7%	0.3%
Lobster Log 2016 - 2019	Cont.*	0.1%	0.1%	0.0%	0.8%
Squid Landing Microblocks 2000 - 2019	Cont.*	23.7%	23.8%	77.4%	12.3%
VMS 210 Limited Entry Fixed Gear Not Including Shore-Based IFQ 2010 - 2017	Cont.*.	5.4%	7.9%	40.5%	7.0%
VMS 233 Open Access Longline Gear for Groundfish 2010 - 2017	Cont.*	7.0%	-	22.0%	6.0%
VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	Cont.*	16.7%	0.7%	39.3%	30.3%
VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	Cont.*	21.5%	35.8%	45.6%	49.6%
VMS 240 Non-groundfish Trawl Gear for Ridgeback Prawn 2010 - 2017	Cont.*	45.8%	-	20.3%	9.9%
VMS 241 Non-groundfish Trawl Gear for Pink Shrimp 2010 - 2017	Cont.*	32.2%	20.2%	45.5%	14.8%
VMS 242 Non-groundfish Trawl Gear for California Halibut 2010 - 2017	Cont.*	61.1%	-	1.8%	15.2%
VMS 243 Non-groundfish Trawl Gear for California Sea Cucumber 2010 - 2017	Cont.*	67.5%	0.8%	42.8%	10.8%
VMS 260 Open Access Prawn Trap or Pot Gear 2010 - 2017	Cont.*	50.3%	-	1.5%	-
VMS 261 Open Access Dungeness Crab Trap or Pot Gear 2010 - 2017	Cont.*	29.9%	-	0.7%	24.2%
VMS 264 Open Access California Halibut Line Gear 2010 - 2017	Cont.*	55.6%	-	41.2%	10.7%
VMS 265 Open Access Sheephead Trap or Pot Gear 2010 - 2017	Cont.*	1.1%	-	-	7.7%
VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	Cont.*	1.5%	0.9%	0.5%	13.7%
VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	Cont.*	22.1%	15.7%	53.1%	27.8%
VMS 269 A Gear That Is Not Listed Above 2010 - 2017	Cont.*	25.7%	15.9%	45.7%	44.7%
VMS 310 Haul Out Exemption 2010 - 2017	Cont.*	0.3%	-	-	5.0%
VMS 330 Emergency Exemption 2010 - 2017	Cont.*	13.7%	8.2%	10.6%	2.6%

Fishing and Aquaculture Dataset	Score	Percent Overlap			
		N	CN	CS	S
VMS 340 Long-term Departure Exemption 2010 - 2017	Cont.*	19.4%	3.3%	12.4%	0.1%
Pacific Mariculture Aquaculture With 500-m setback	0	-	-	1.5%	-

- Dash indicates that the data layer did not overlap with the study area.
* Data layers represent continuous data scored using a fuzzy logic Z-shaped membership function.



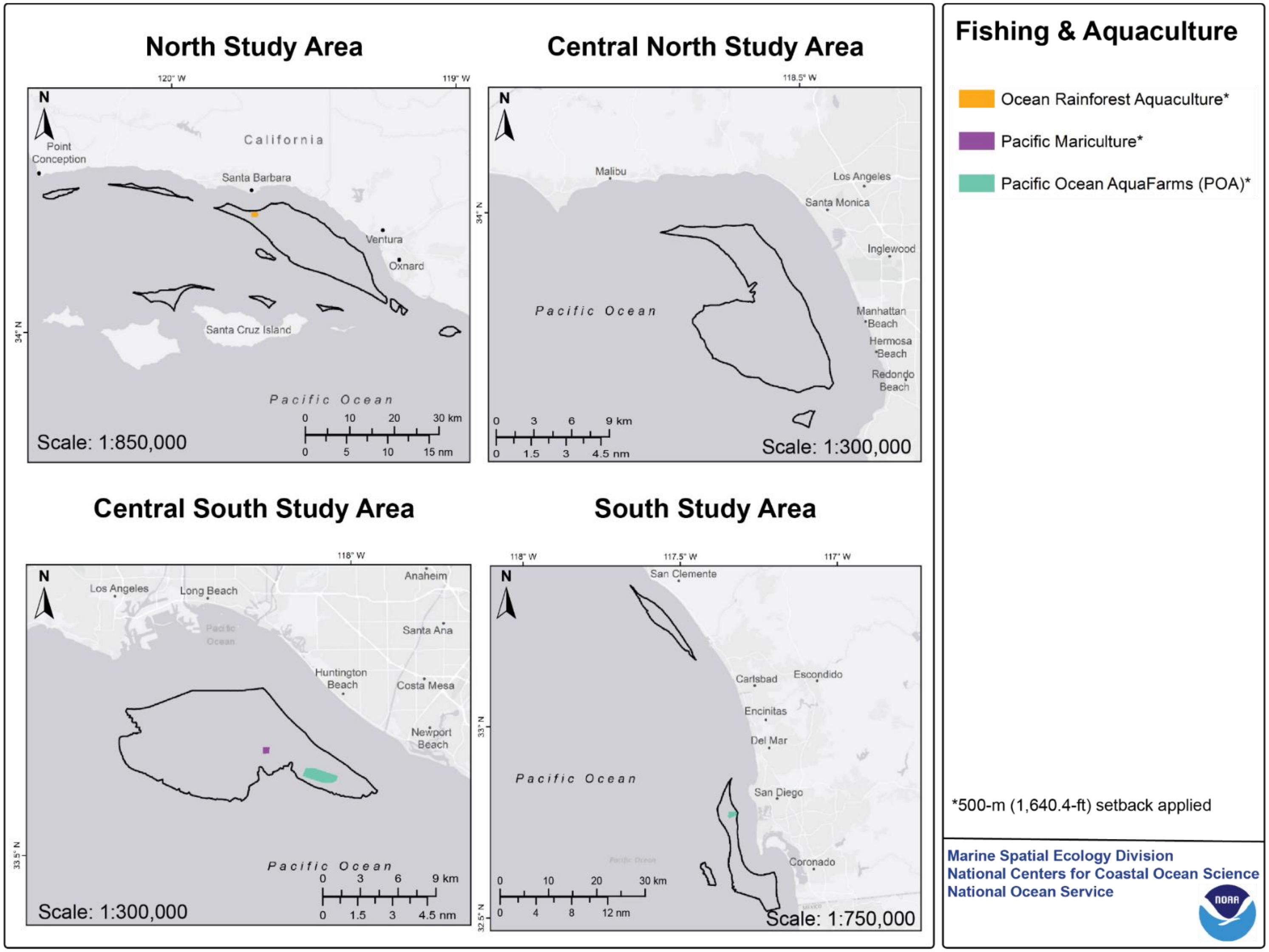


Figure 3.15. Fishing and aquaculture considerations for the North, Central North, Central South, and South study areas.

Commercial and Recreational Fisheries

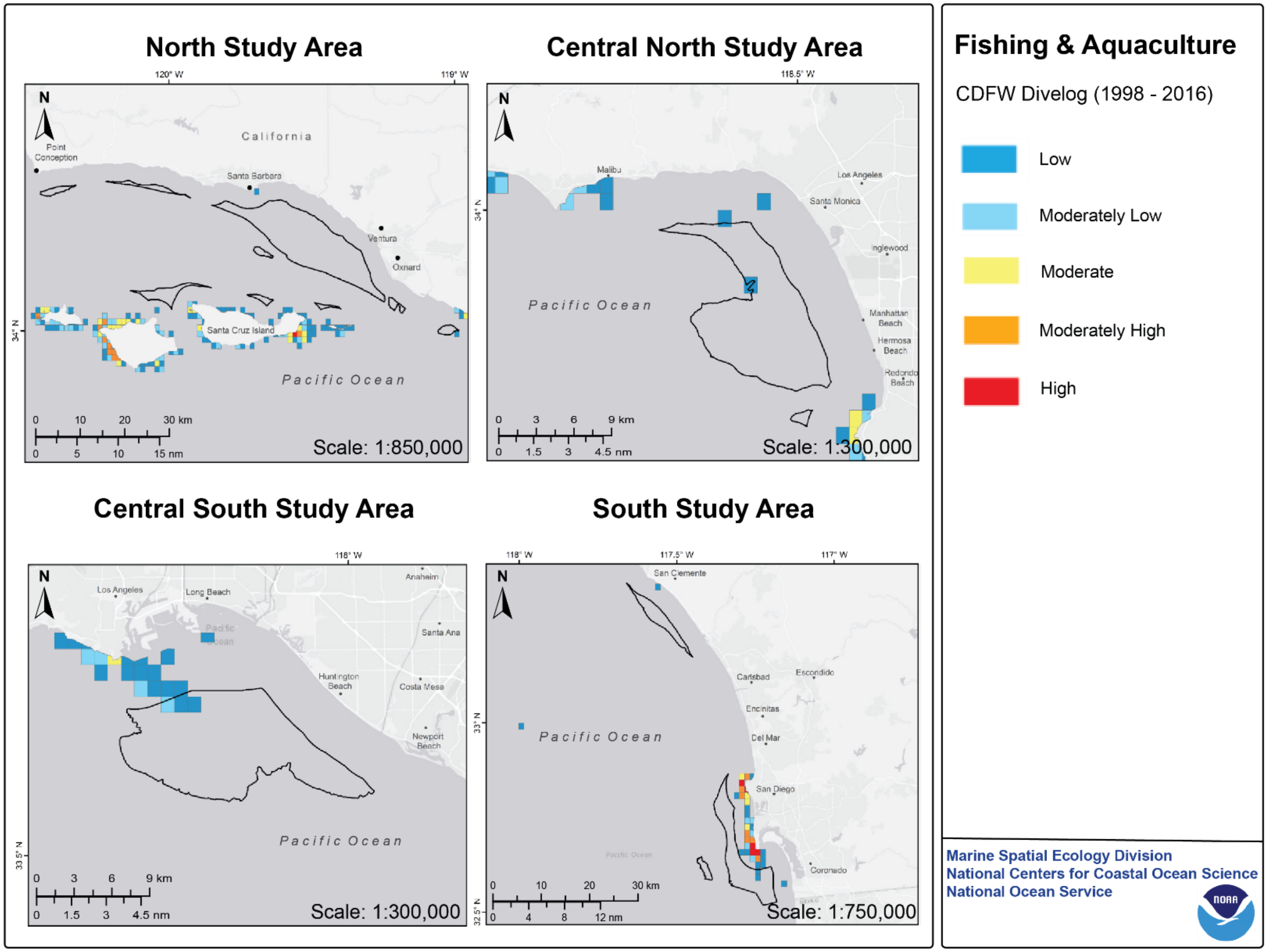


Figure 3.16. Aggregated California Department of Fish and Wildlife divelog data (1998 - 2016) for the North, Central North, Central South, and South study areas. Blue colors represent lower numbers of vessels in the time period examined, while orange and red colors represent relatively higher numbers of vessels.

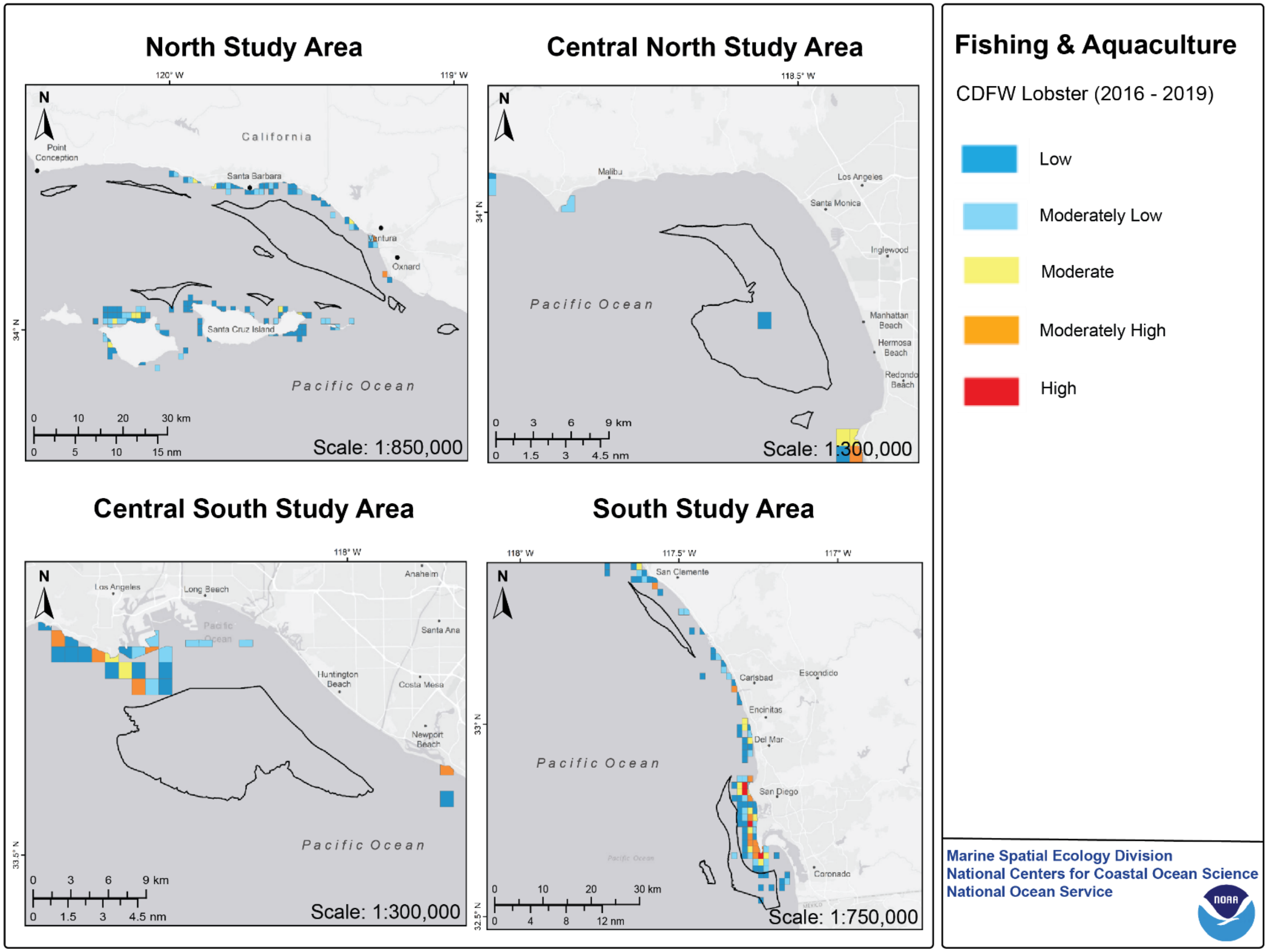


Figure 3.17. Aggregated California Department of Fish and Wildlife lobster data (2016 - 2019) for the North, Central North, Central South, and South study areas. Blue colors represent lower numbers of vessels in the time period examined, while orange and red colors represent relatively higher numbers of vessels.

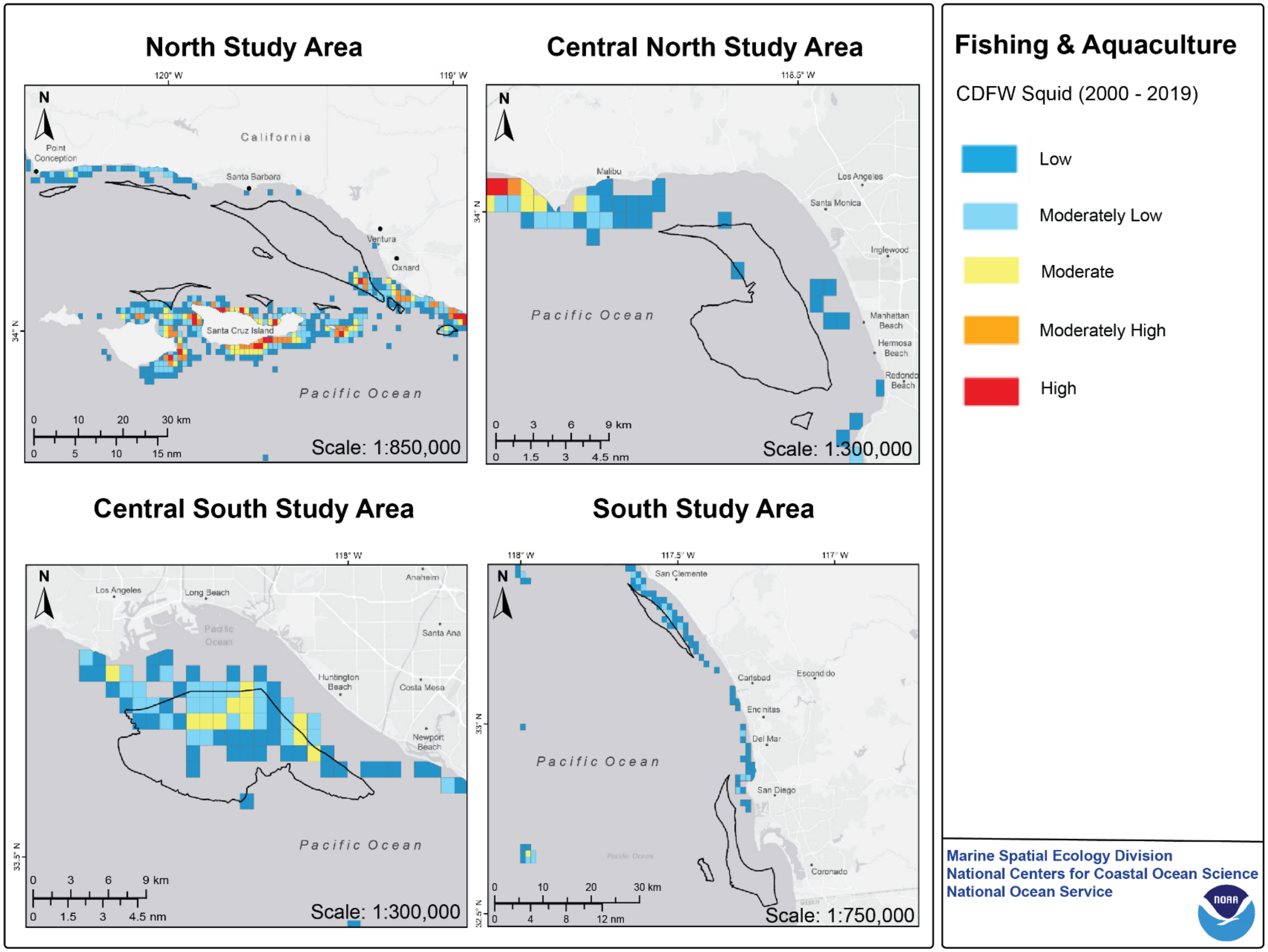


Figure 3.18. Aggregated California Department of Fish and Wildlife squid data (2000 - 2019) for the North, Central North, Central South, and South study areas. Blue colors represent lower catch estimates in the time period examined, while orange and red colors represent relatively higher catch estimates.

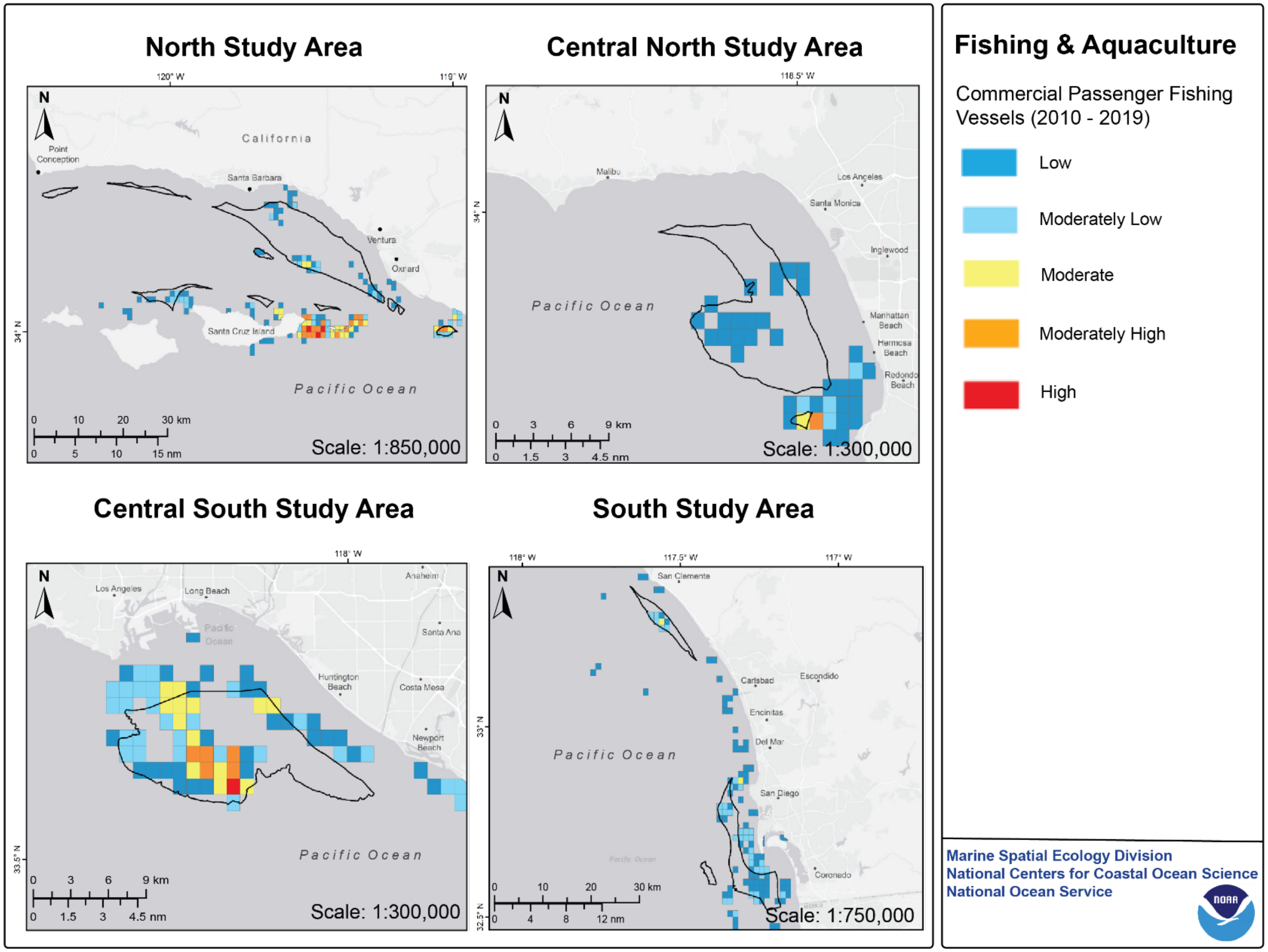


Figure 3.19. Aggregated California Department of Fish and Wildlife commercial passenger fishing vessels data (2010 - 2019) for the North, Central North, Central South, and South study areas. Blue colors represent lower numbers of distinct vessels in the time period examined, while orange and red colors represent relatively higher numbers of distinct vessels.

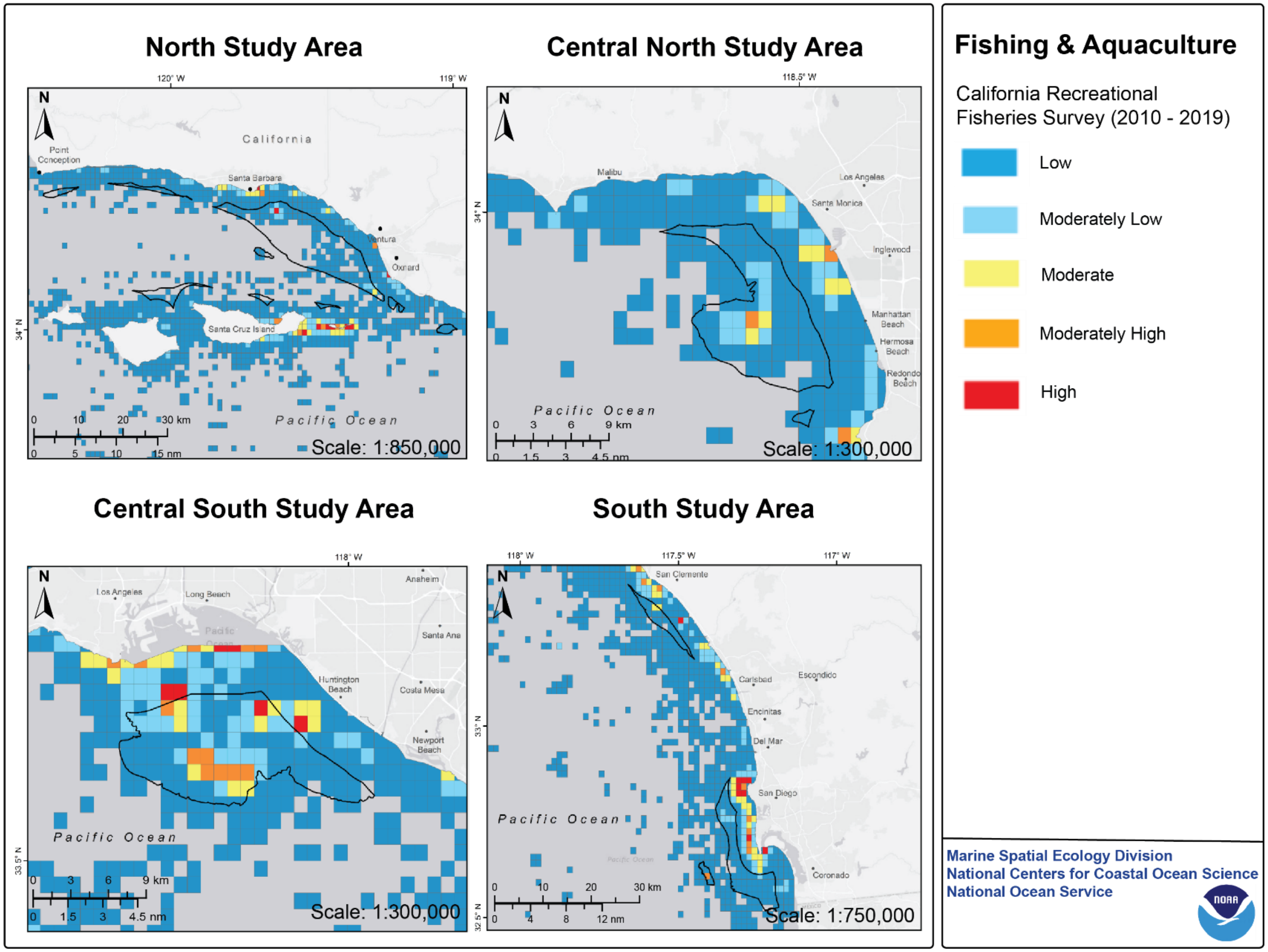


Figure 3.20. California Recreational Fisheries Survey data (2010 - 2019) for the North, Central North, Central South, and South study areas. Blue colors represent lower numbers of vessels in the time period examined, while orange and red colors represent relatively higher fishing effort.

VMS Traffic

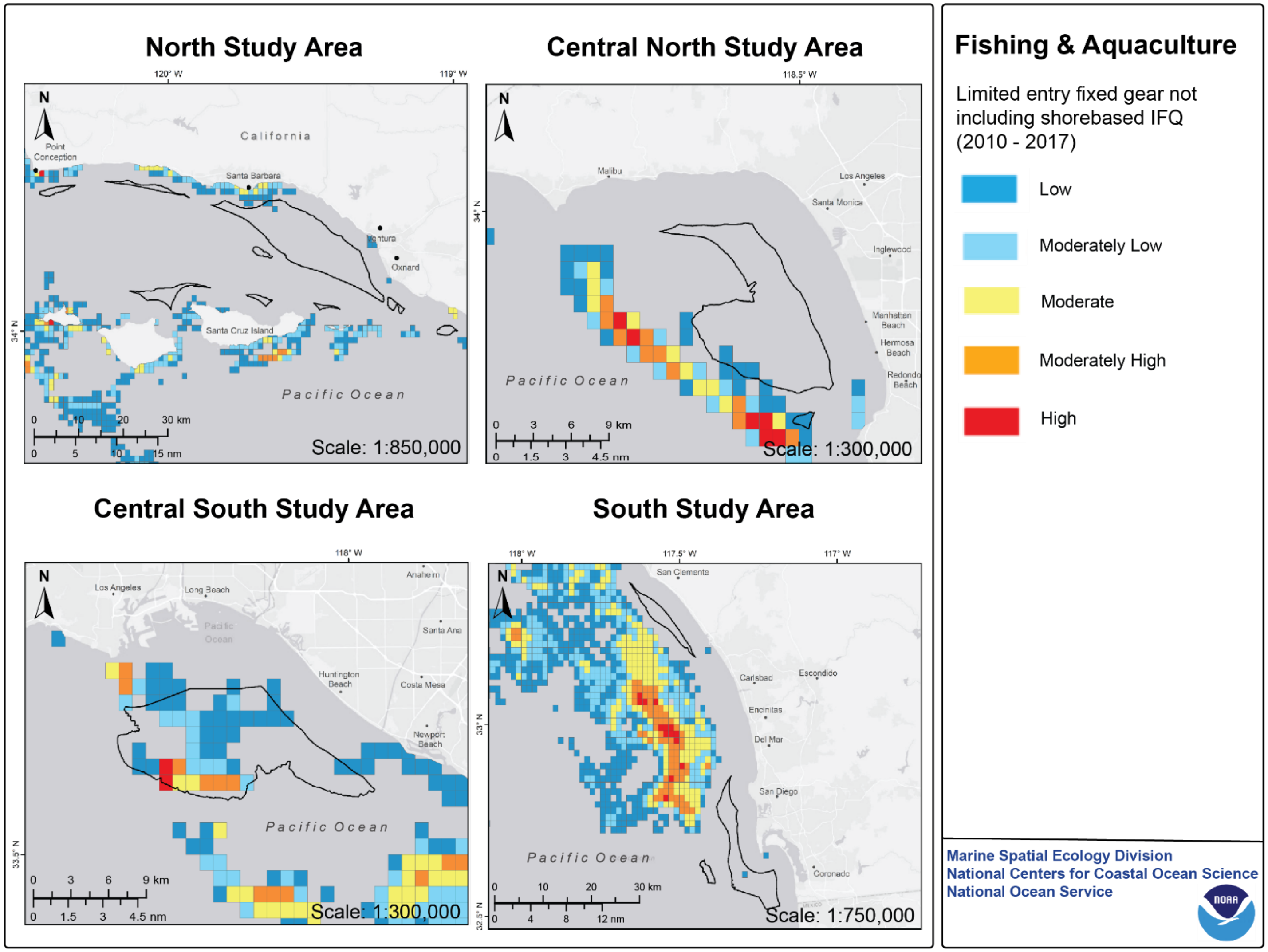


Figure 3.21. Aggregated limited entry fixed gear not including shore-based individual fishing quota data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

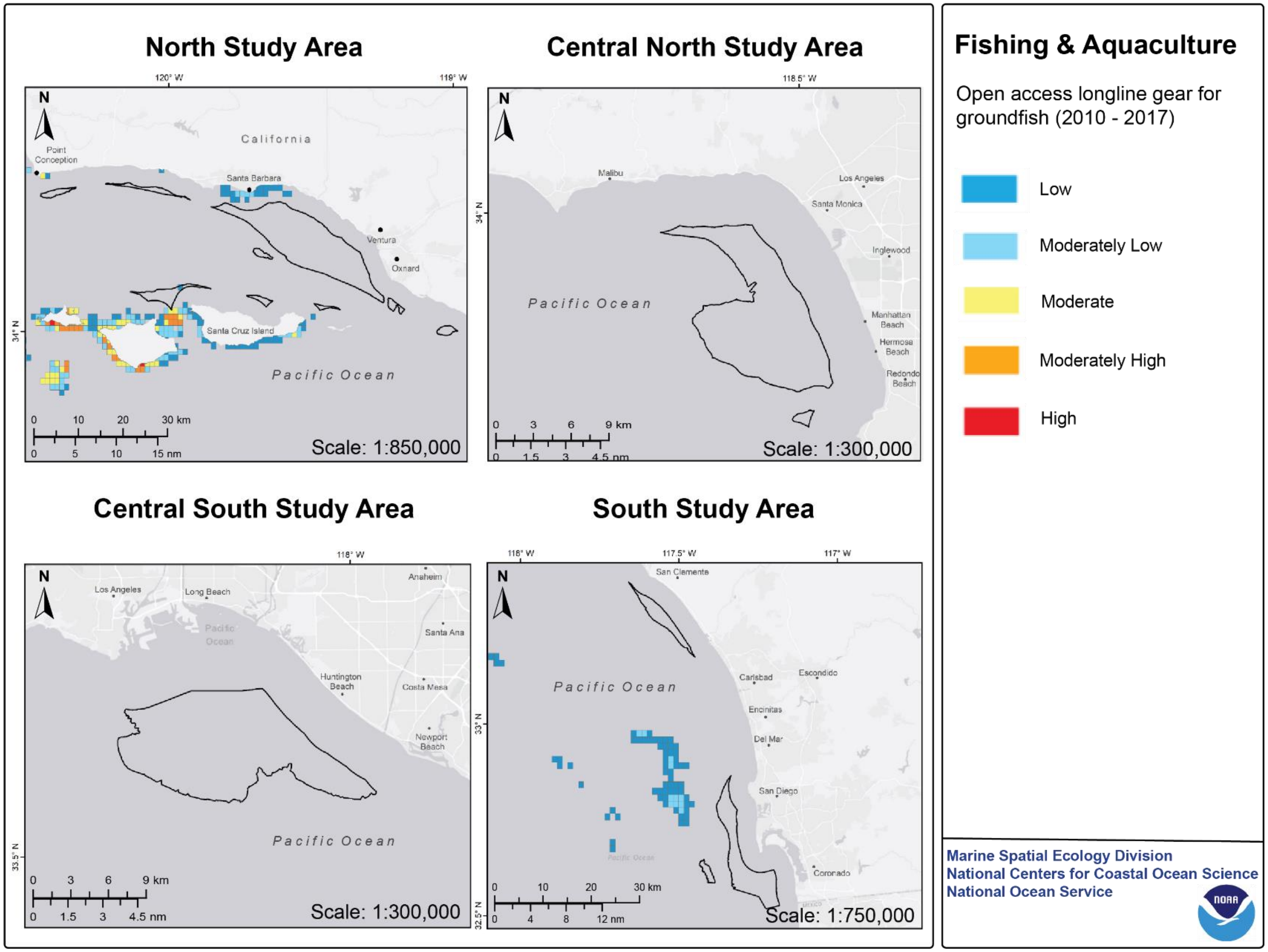


Figure 3.22. Aggregated open access longline gear for groundfish data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

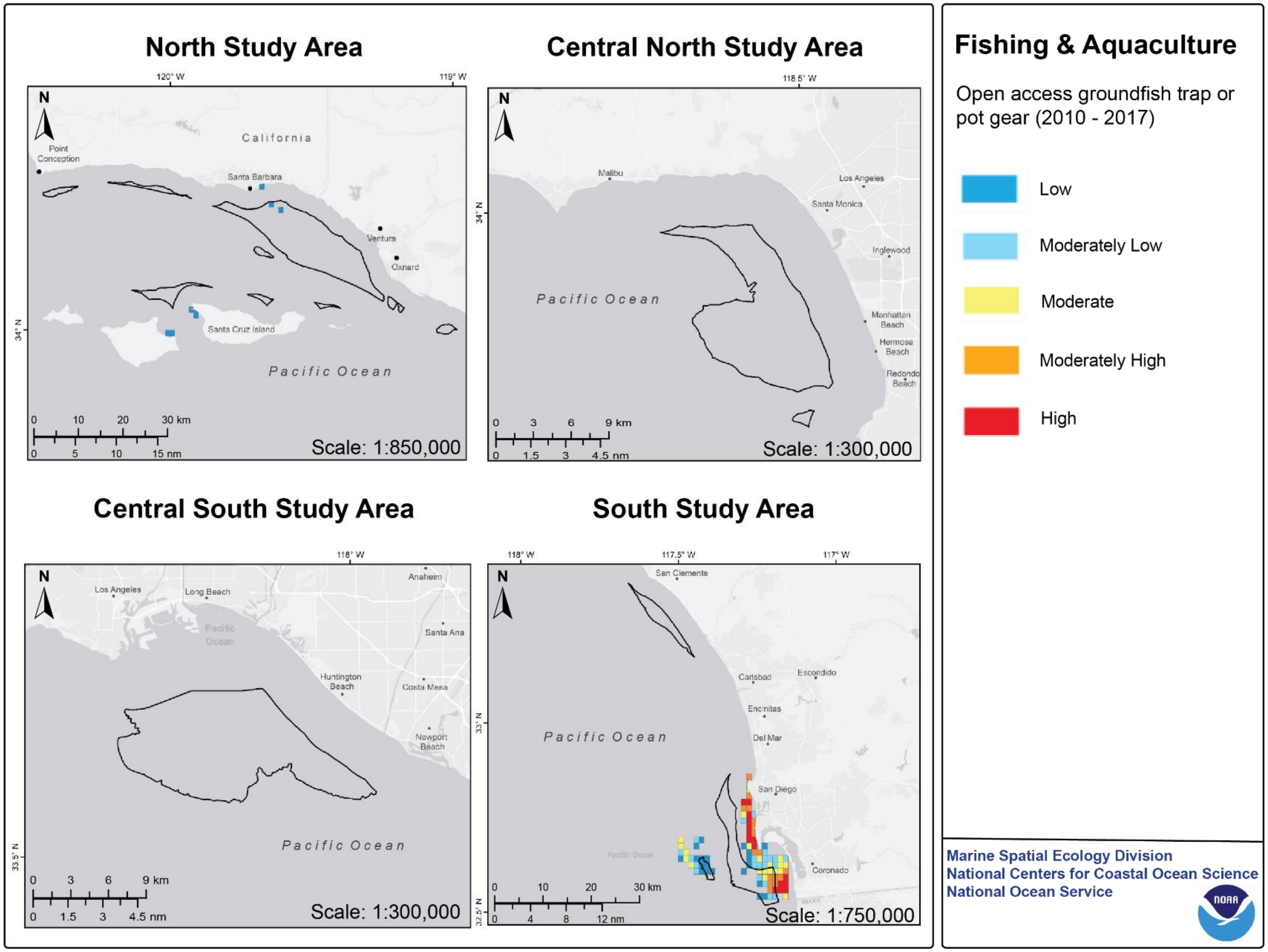


Figure 3.23. Aggregated open access groundfish trap or pot gear data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

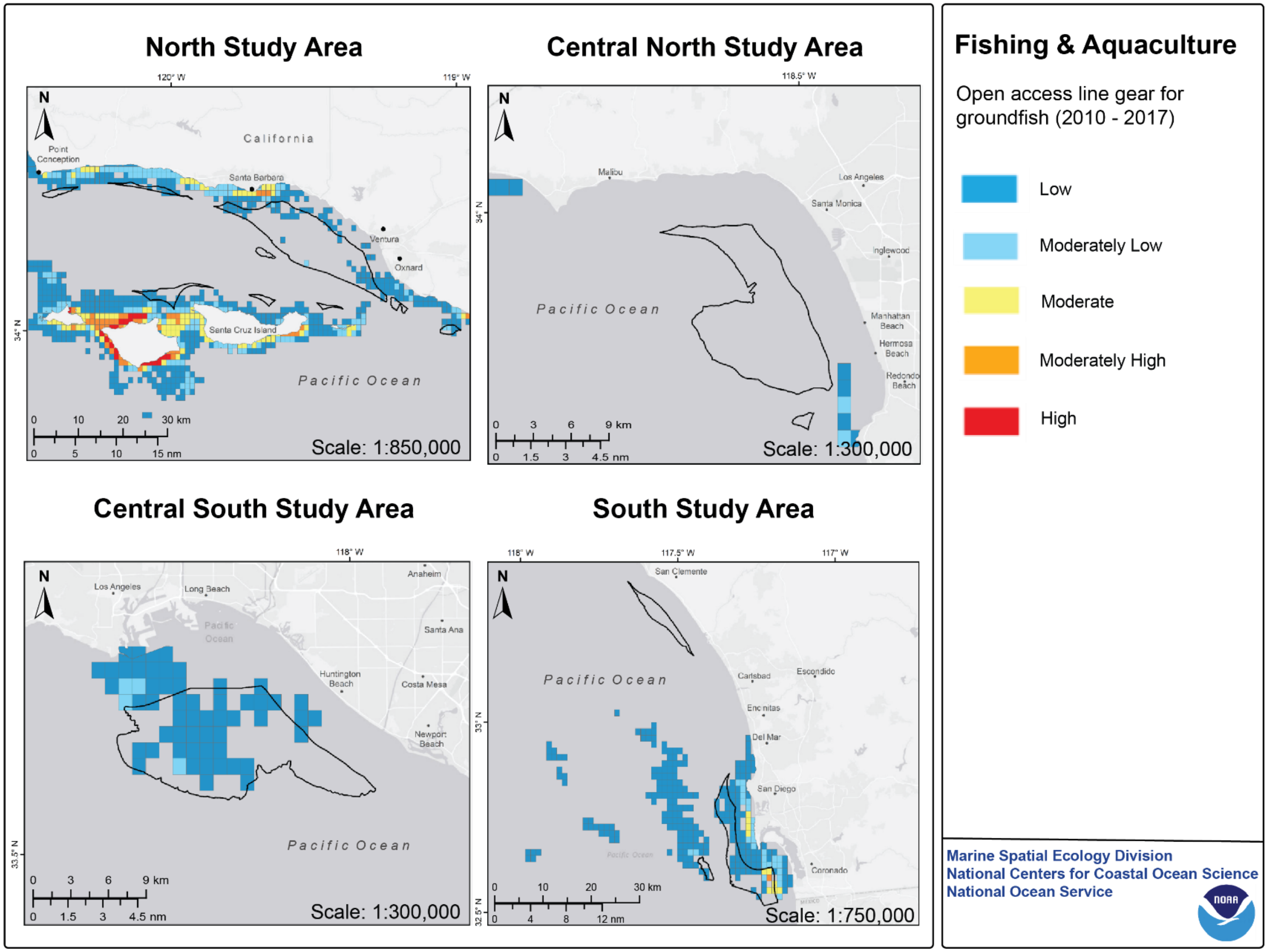


Figure 3.24. Aggregated open access line gear for groundfish data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

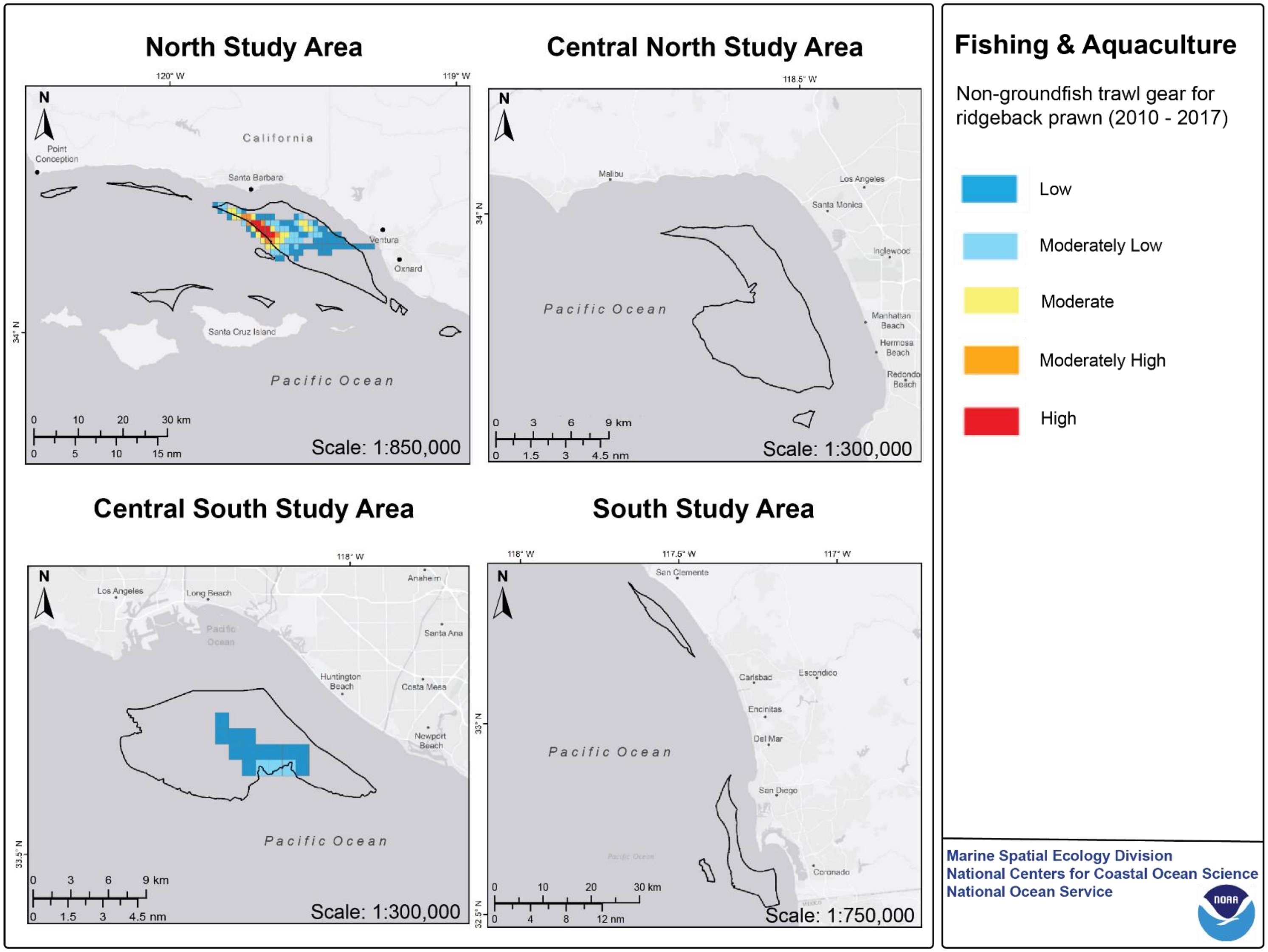


Figure 3.25. Aggregated non-groundfish trawl gear for ridgeback prawn data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

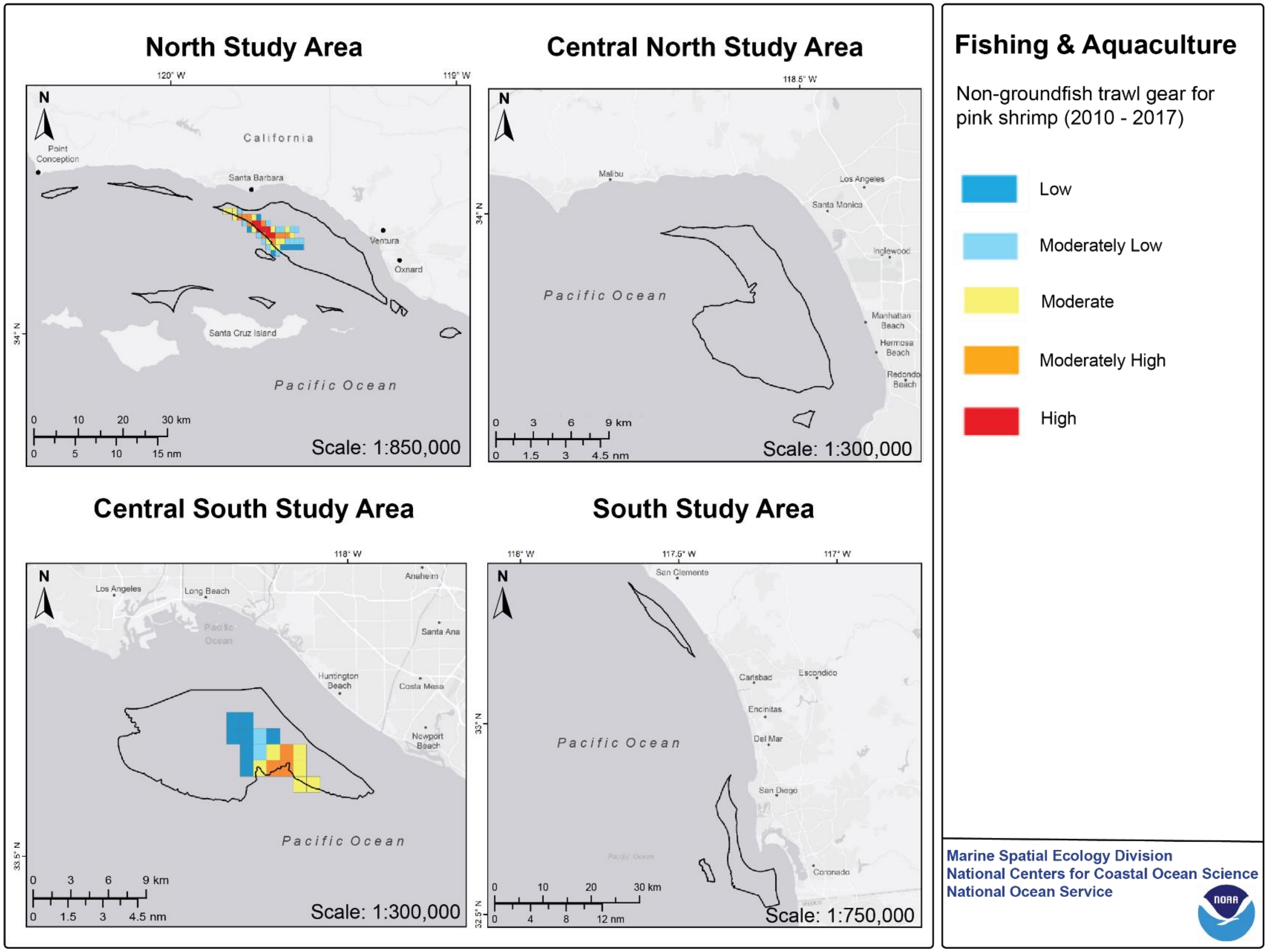


Figure 3.26. Aggregated non-groundfish trawl gear for pink shrimp data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

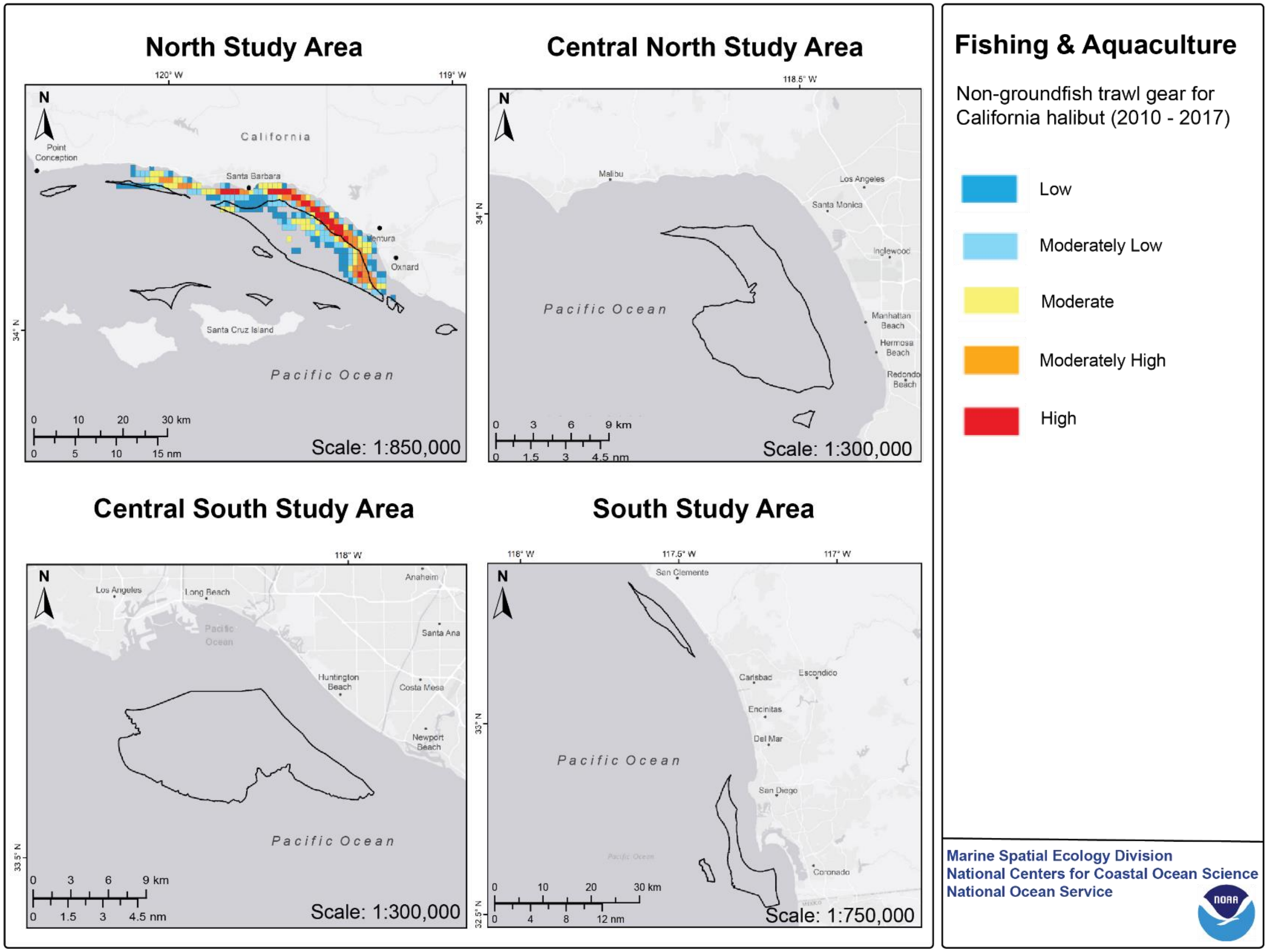


Figure 3.27. Aggregated non-groundfish trawl gear for California halibut data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

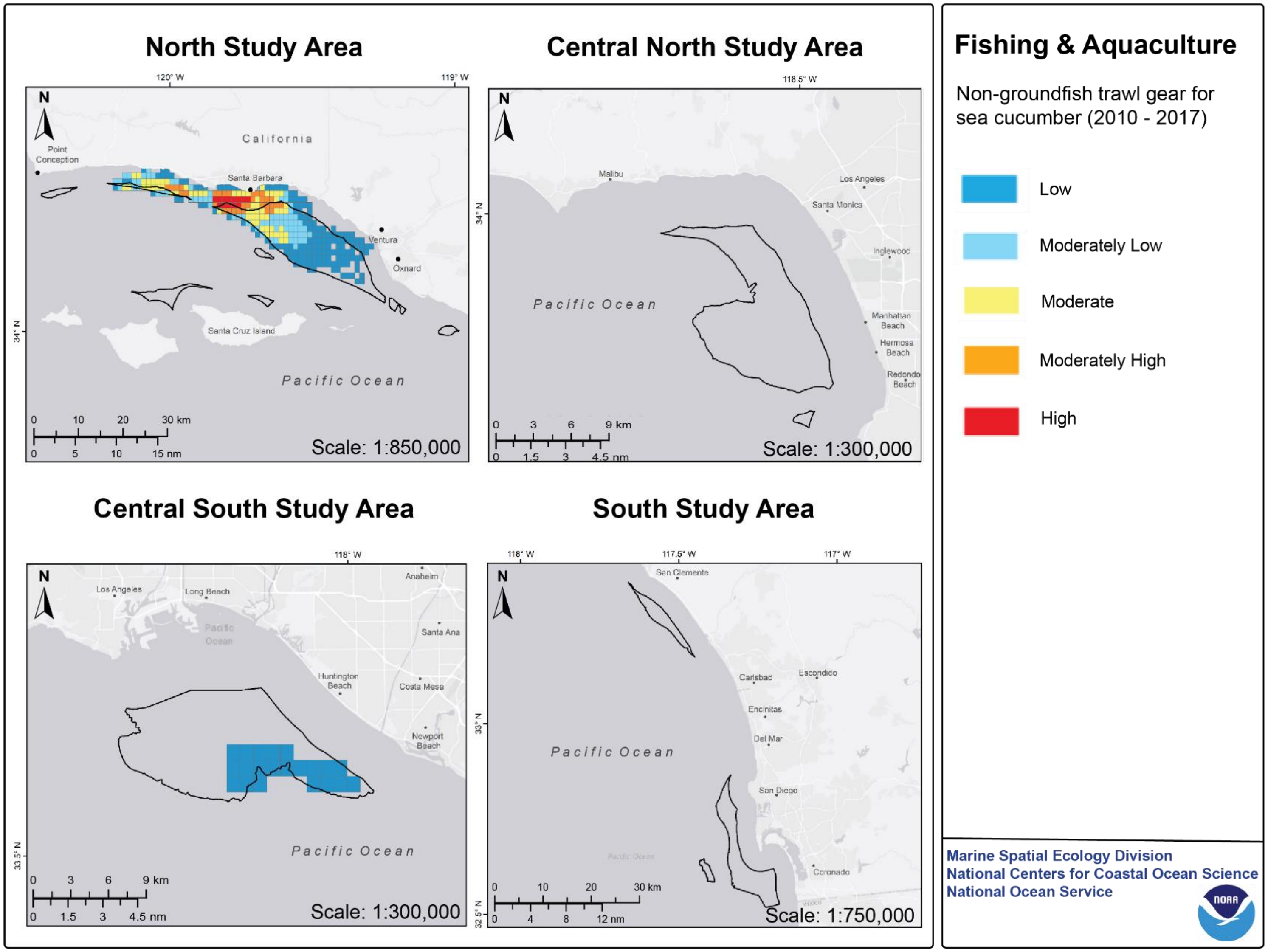


Figure 3.28. Aggregated non-groundfish trawl gear for California sea cucumber data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

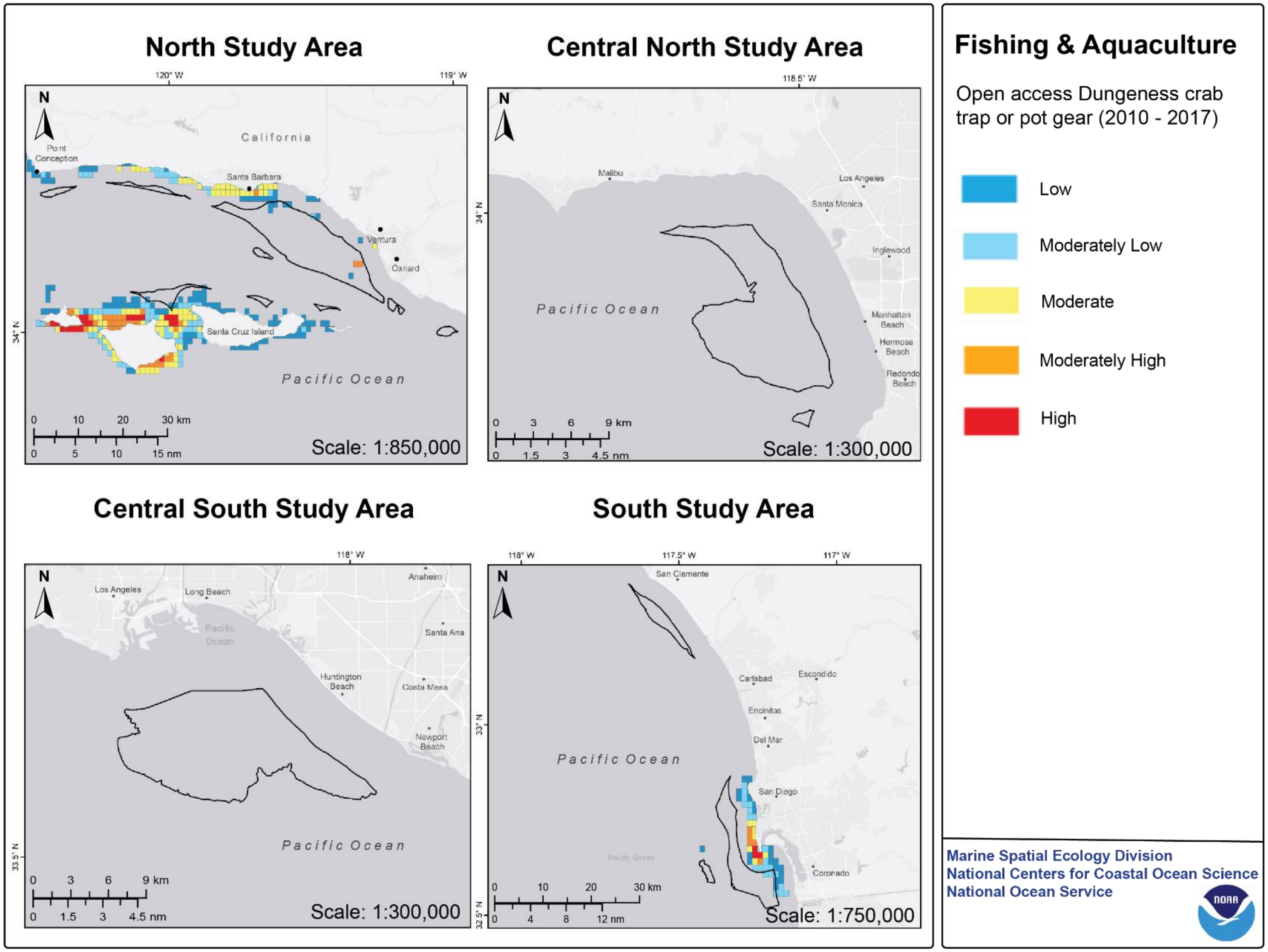


Figure 3.29. Aggregated open access Dungeness crab trap or pot gear data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

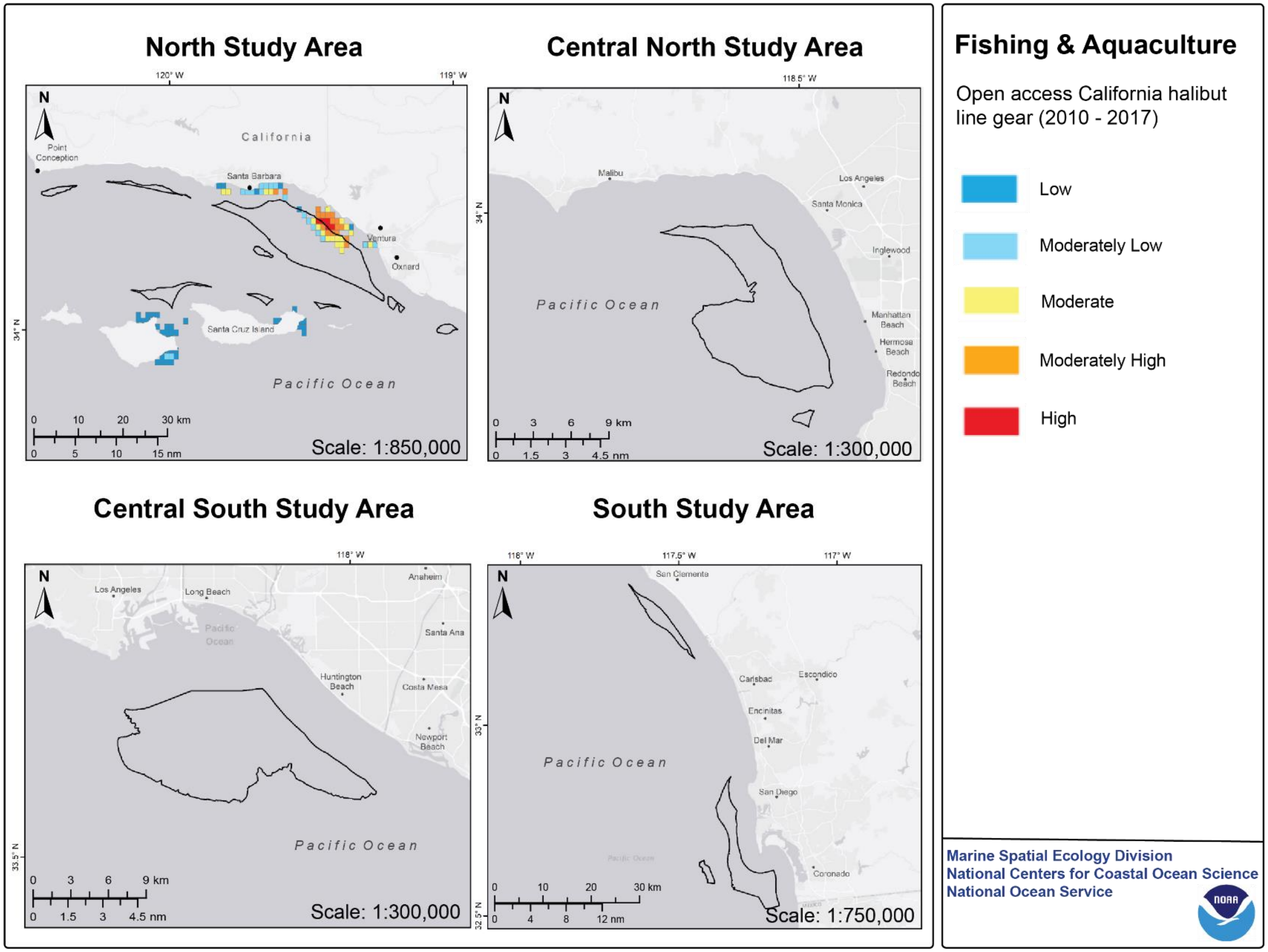


Figure 3.30. Aggregated open access California halibut line gear data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

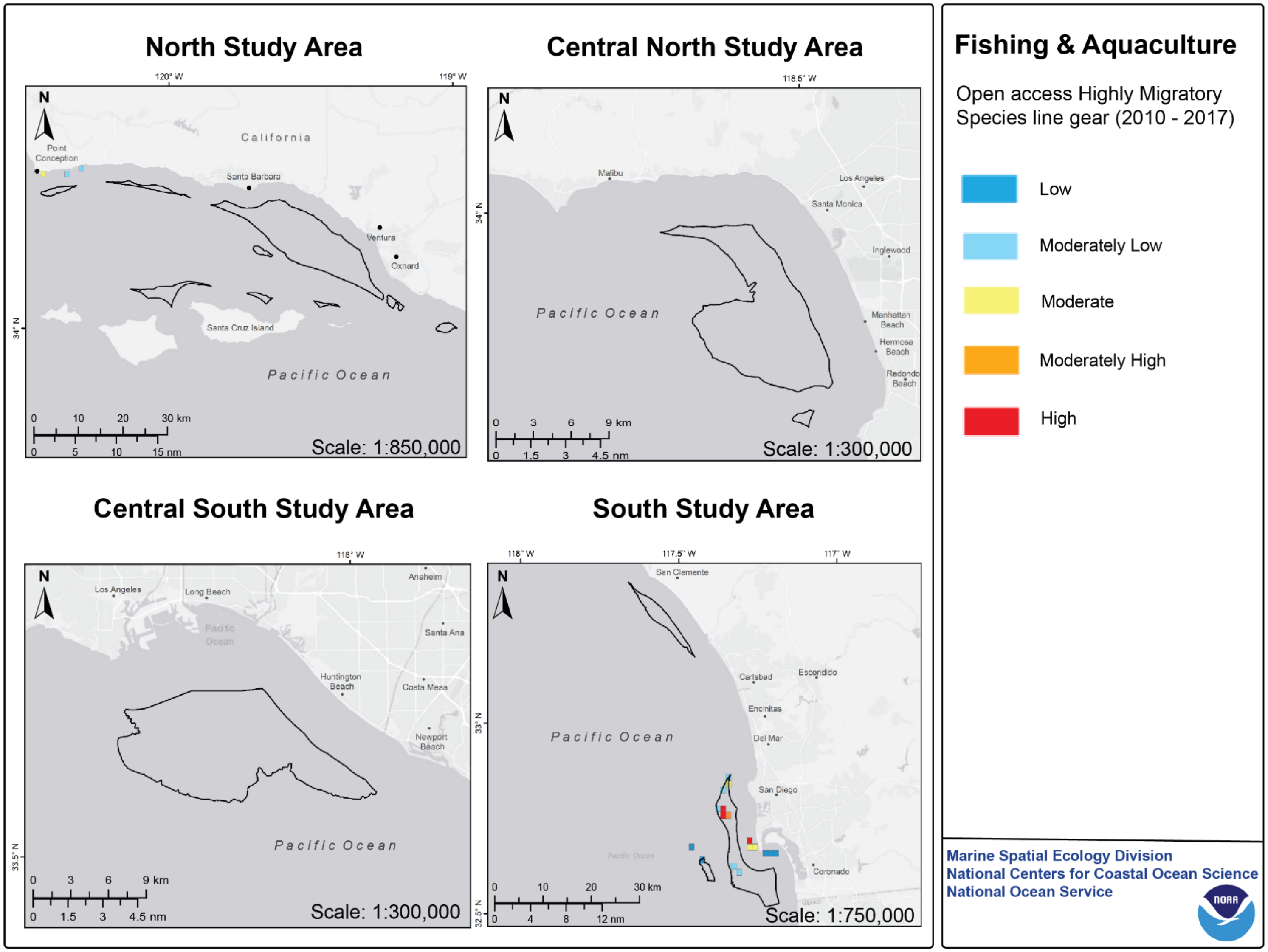


Figure 3.31. Aggregated open access Highly Migratory Species line gear data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

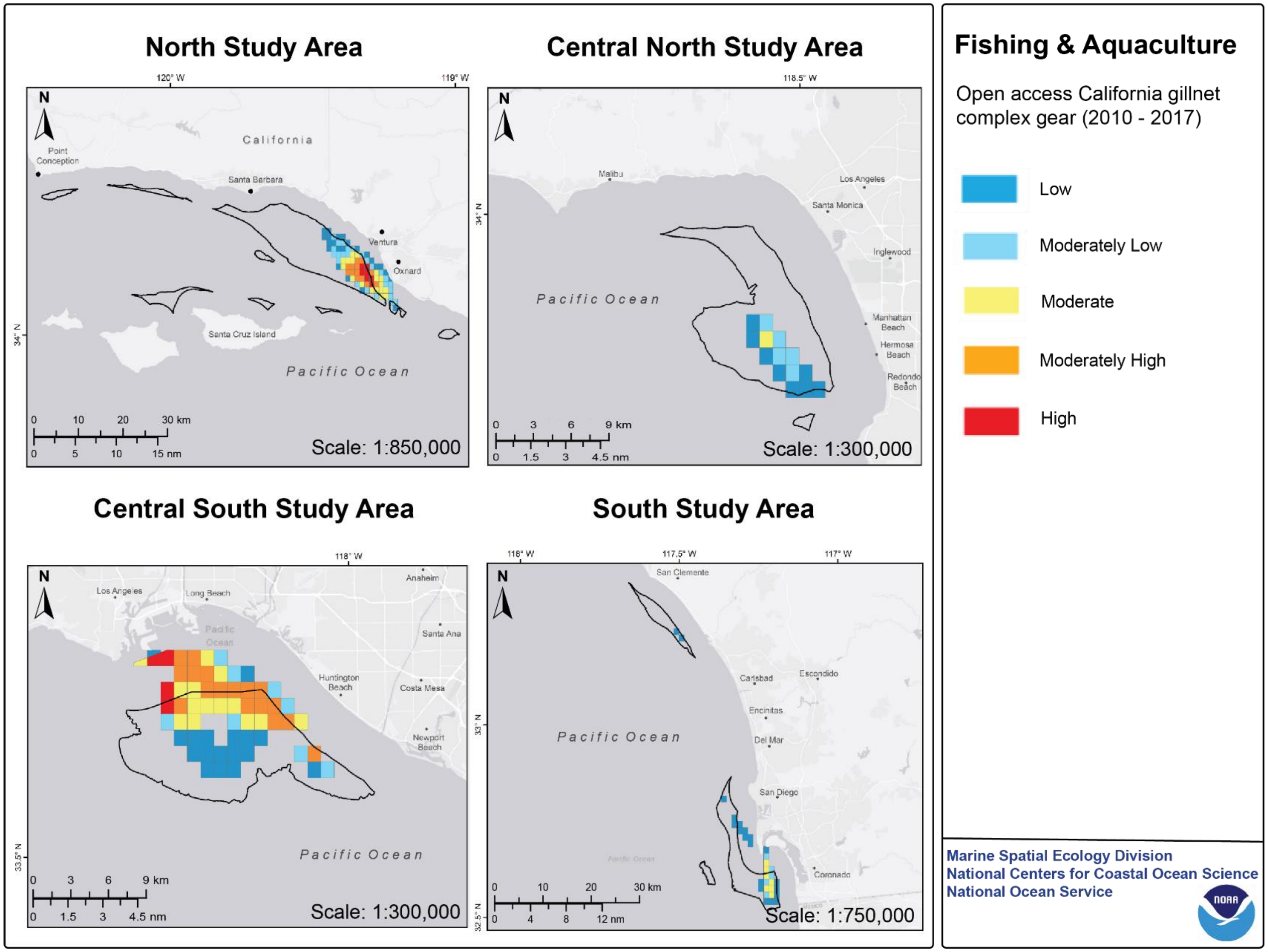


Figure 3.32. Aggregated open access California gillnet complex gear data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

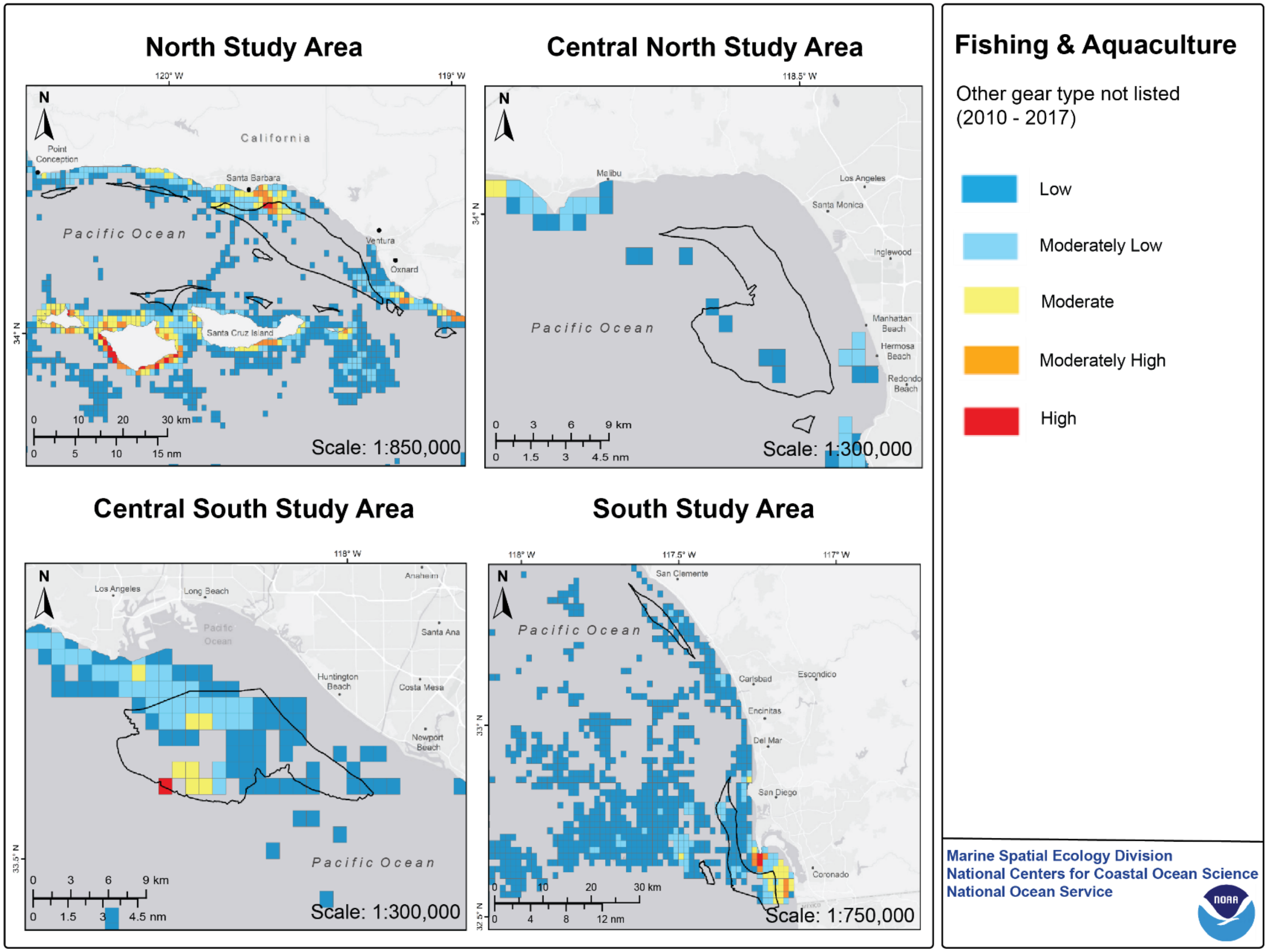


Figure 3.33. Aggregated other gear type not listed data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

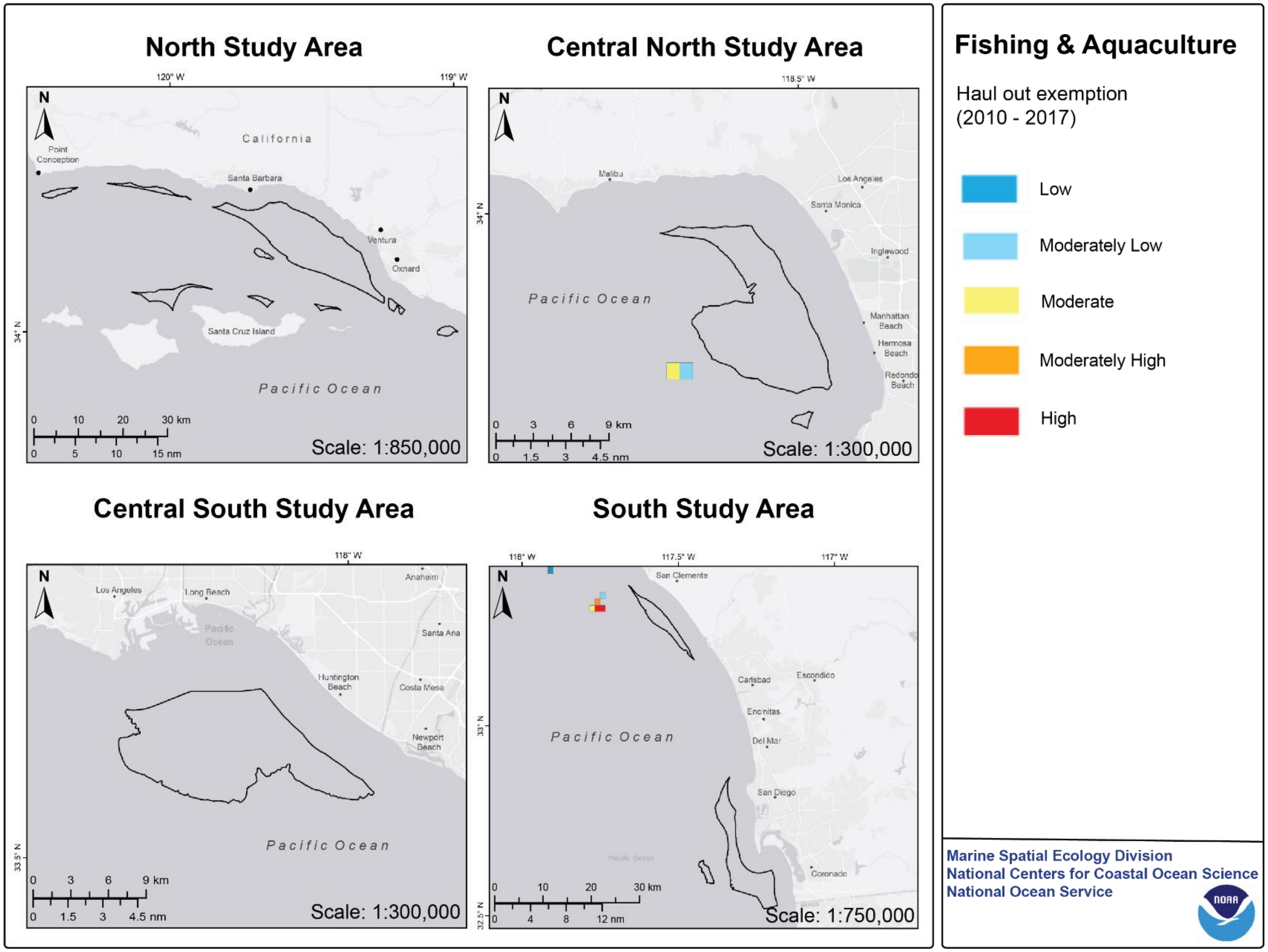


Figure 3.34. Aggregated haul out exemption data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

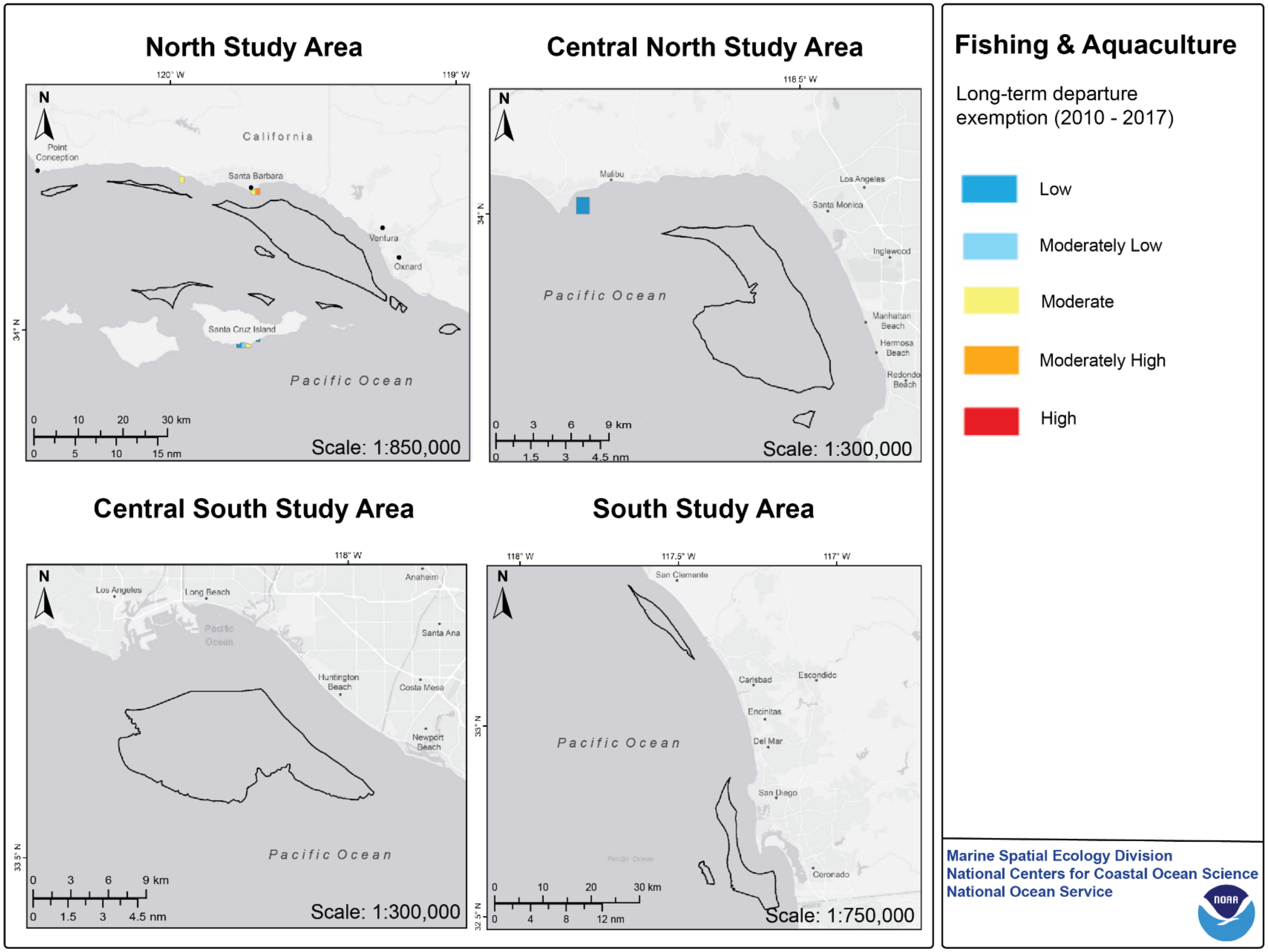


Figure 3.35. Aggregated long-term departure exemption data (2010 - 2017) for the North, Central North, Central South, and South study areas. Blue colors represent less effort in the time period examined, while orange and red colors represent relatively higher fishing effort.

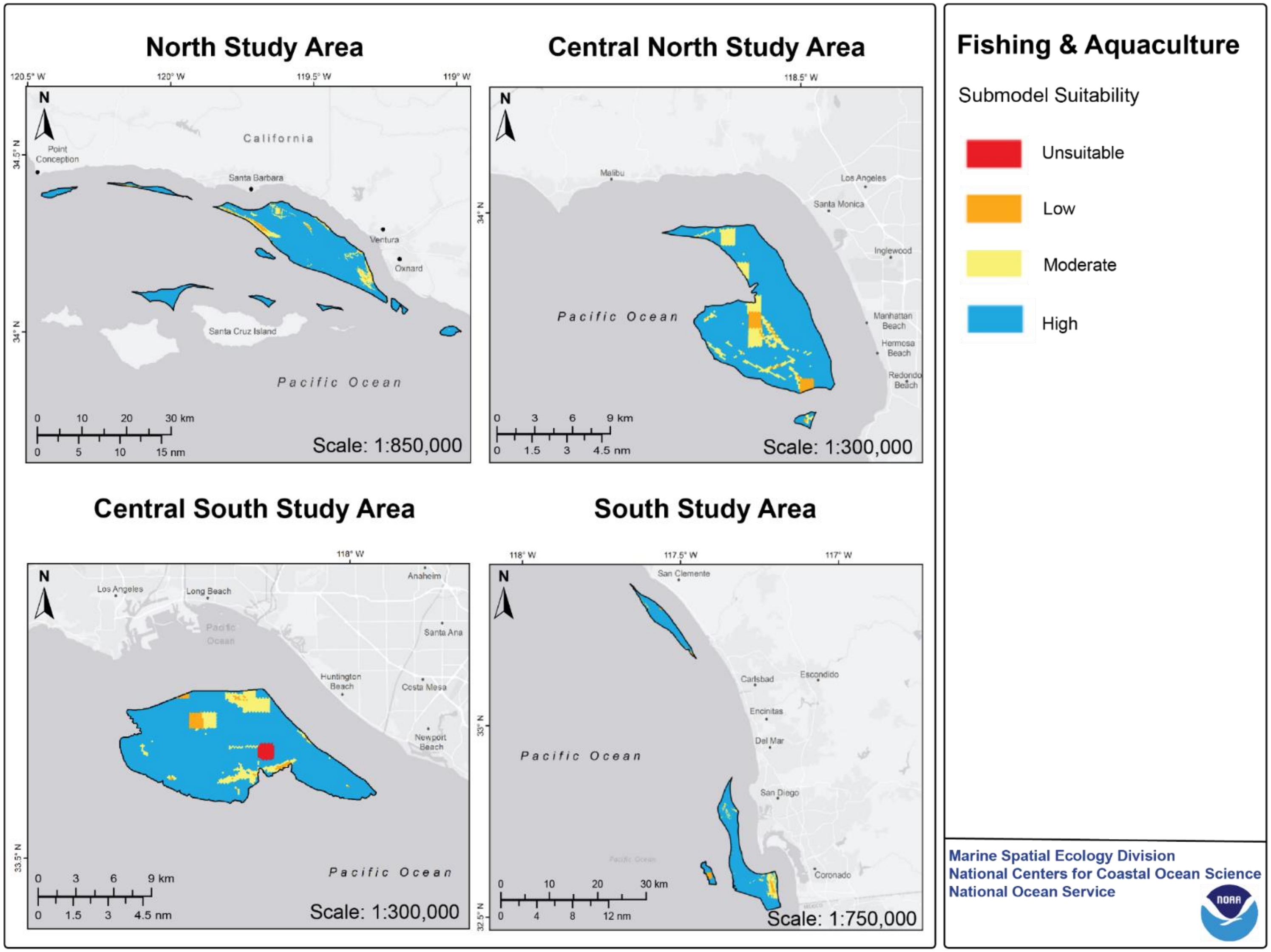


Figure 3.36. Final fishing and aquaculture submodel utilized in the suitability model for (from top to bottom, left to right) the North, Central North, Central South, and South study areas.

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 3.6). It is important to note that many constraints overlap and the total area removed may not sum to 100% due to overlapping constraints. The fishing and aquaculture datasets are comprised of continuous data with the exception of a permitted aquaculture site in the Central South study area. Continuous data were not scored 0 and therefore were not included in the constraints submodel (e.g., fisheries datasets).

Overall, the North study area had 43.2% of the area removed due to constraints. Industry, navigation, and transportation constraints removed 28.9% of the area, while the natural and cultural resources constraints removed 17.2%.

In the Central North study area, 76.3% of the area was removed overall due to constraints. The industry, navigation, and transportation constraints alone accounted for 63.3% of the area removed. This was predominantly due to the presence of wastewater outfall structures and submarine cables in the study area. In addition, natural and cultural resources constraints removed 29.8% of the Central North study area. The Central South study area had 99.3% of the area removed; this was largely a result of the proximity to the nation's largest ports including the ports of Los Angeles and Long Beach. For this study area, industry, navigation, and transportation constraints removed 97.6%, whereas natural and cultural resources constraints removed another 29.9%.

In the South study area, national security constraints alone removed 98.7% of the area, with 100% of the study area removed when combining other constraints. In summary, 43.2% of the North study area, 76.3% of the Central North study area, 99.3% of the Central South study area, and 100% of the South study area were impacted by constraints.

Final Suitability

Final suitability results for all submodels are presented in Figure 3.37. The highest suitable areas are identified in the North and Central North study areas with a small area of moderate suitability identified in the Central South study area. The South study area was not included in subsequent analyses given the incompatibility of this study area for consideration for an AOA.

Table 3.6. 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.

Constraints Submodel	N	CN	CS	S
National Security Constraints	0%	0%	0%	98.7%
Industry, Navigation, and Transportation	28.9%	63.3%	97.6%	31.7%
Natural and Cultural Resources	17.2%	29.8%	29.9%	14.0%
Fishing and Aquaculture	0%	0%	1.5%	0%
Total Area Removed	43.2%	76.3%	99.3%	100.0%

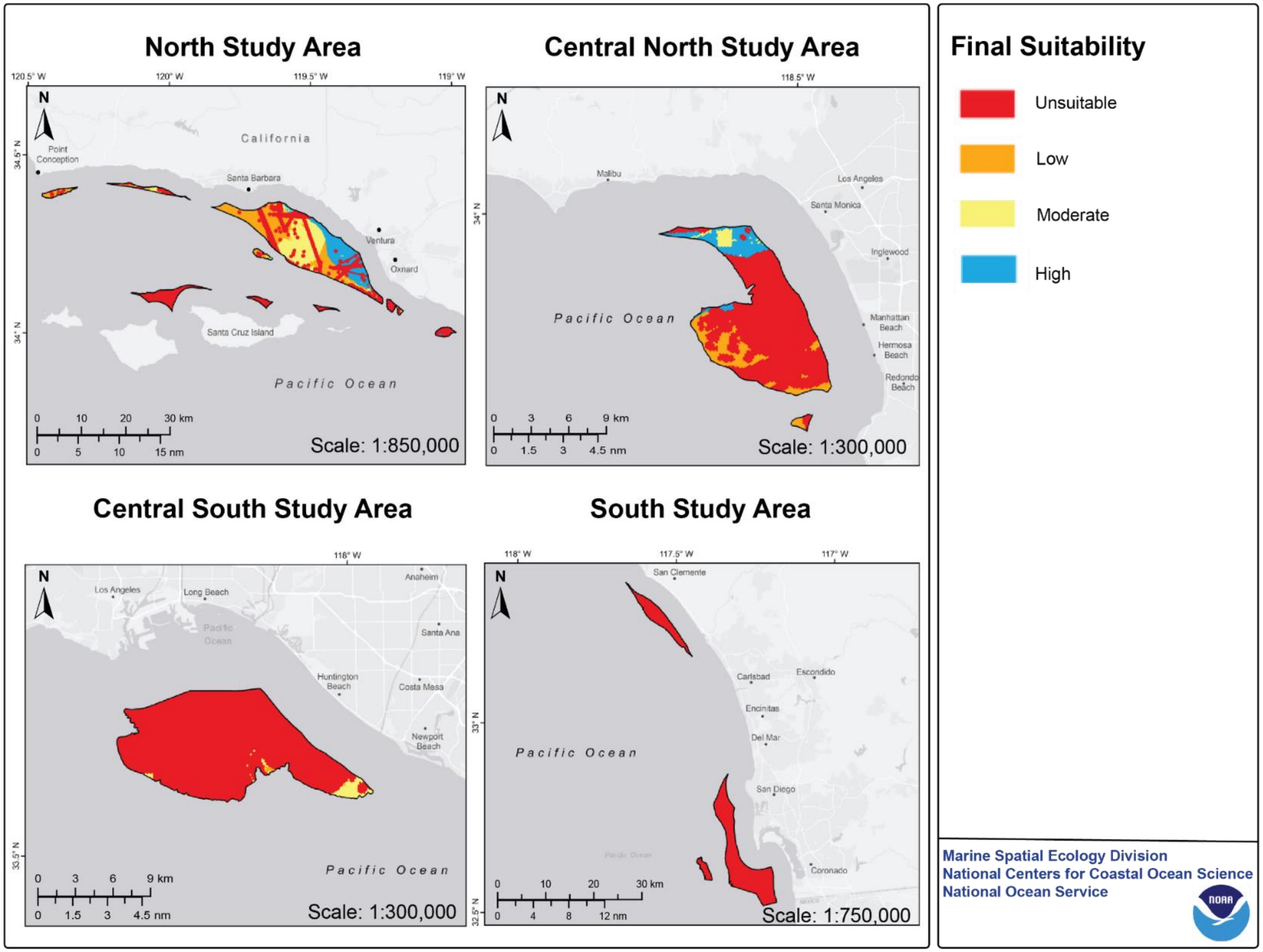


Figure 3.37. Final suitability analysis results for the North, Central North, Central South, and South study areas.

Cluster Analysis and AOA Options

Using the suitability values for each grid cell, a LISA cluster analysis was performed to identify statistically significant areas for the North, Central North, and Central South study areas. The cluster analysis identified contiguous areas of high-high clusters at a p-value < 0.05. Seven clusters with a total area of 60,347 acres were identified in the North study area (Figure 3.38). Only three of the seven clusters were large enough to accommodate AOA options, and after consultation with DOD MAIASC, one of the clusters was deemed incompatible with military operations. The remaining two clusters are referred to as North study area cluster 1 (N1) and North study area cluster 2 (N2) (Figure 3.38). The results of the cluster analysis for the Central North study area identified a single cluster with a total area of 4,665 acres that met the minimum area requirement (Figure 3.39). This single cluster is referred to as Central North study area cluster 1 (CN1). The results of the Central South cluster analysis did not identify any clusters that met the minimum threshold size of 500 acres. There were no options identified in the South study area because the entire area was removed based on the constraints submodel.

Of all the viable clusters for both study areas, a total of 296 AOA options were identified including 284 for the North study area (Figure 3.40) and 12 for the Central North study area (Figure 3.41). Cluster N1 lies offshore of Santa Barbara and Ventura counties in the Santa Barbara Channel. N1 is 21,173 acres in size with a total of 38 AOA options, including 11 at the 2,000-acre size, 14 at the 1,500-acre size, 3 at the 1,000-acre size, and 10 at the 500-acre size. Cluster N2 also lies offshore of Ventura county in the Santa Barbara Channel and comprises 11,679 acres. N2 contained a total of 246 site options, of which 241 were 2,000-acre size and the remaining 5 were 500-acre size. Cluster CN1 lies to the south and offshore of Los Angeles county in Santa Monica Bay. CN1 is 4,665 acres in size with a total of 12 AOA options, including 9 at the 1,000-acre size and 3 at the 500-acre size.

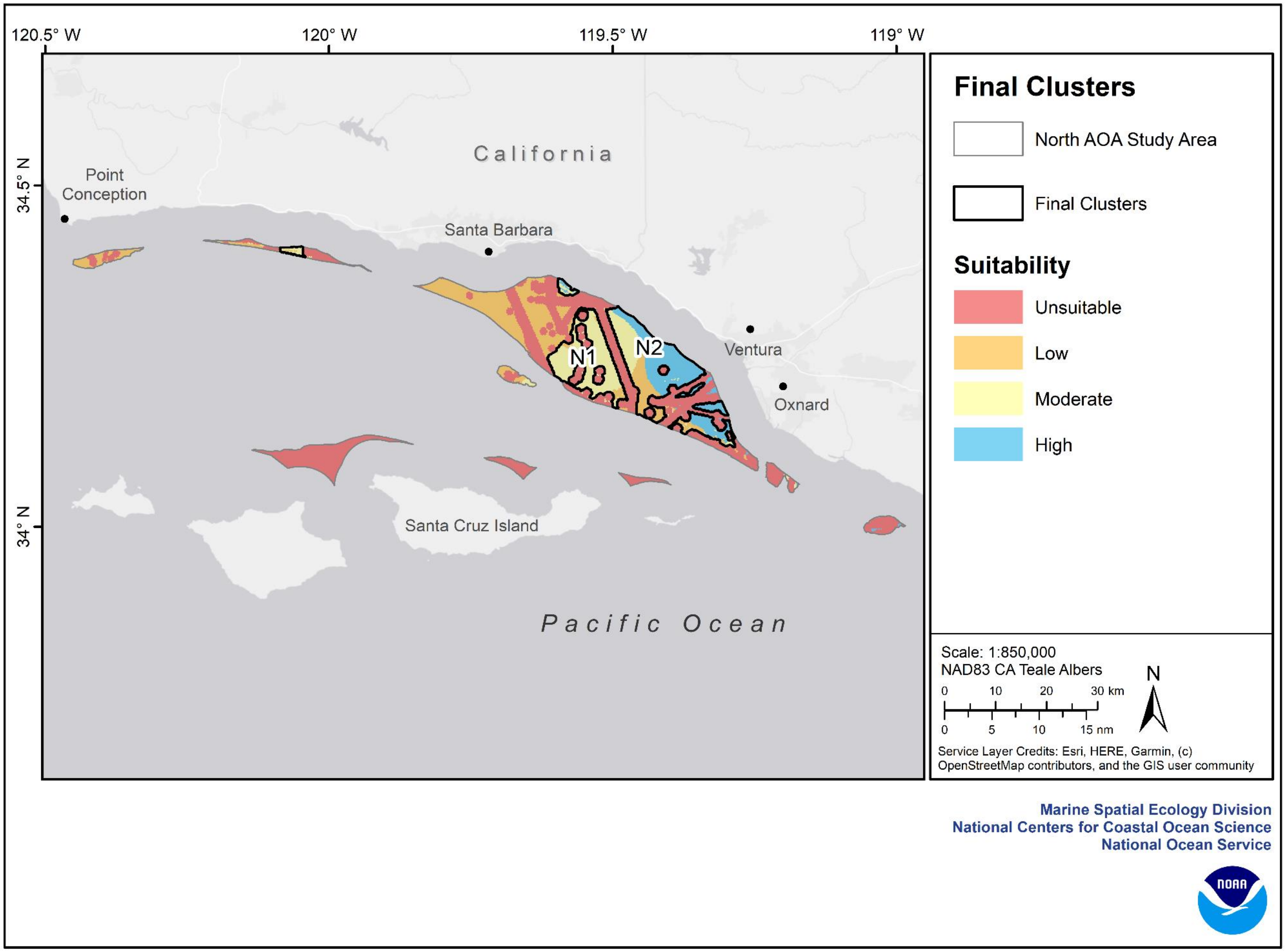


Figure 3.38. Cluster analysis results for the North study area using a Local Indicators of Spatial Association cluster analysis which identified areas of high-high clusters ($p < 0.05$). Only two of the clusters (N1 and N2) were large enough to assess Aquaculture Opportunity Area options.

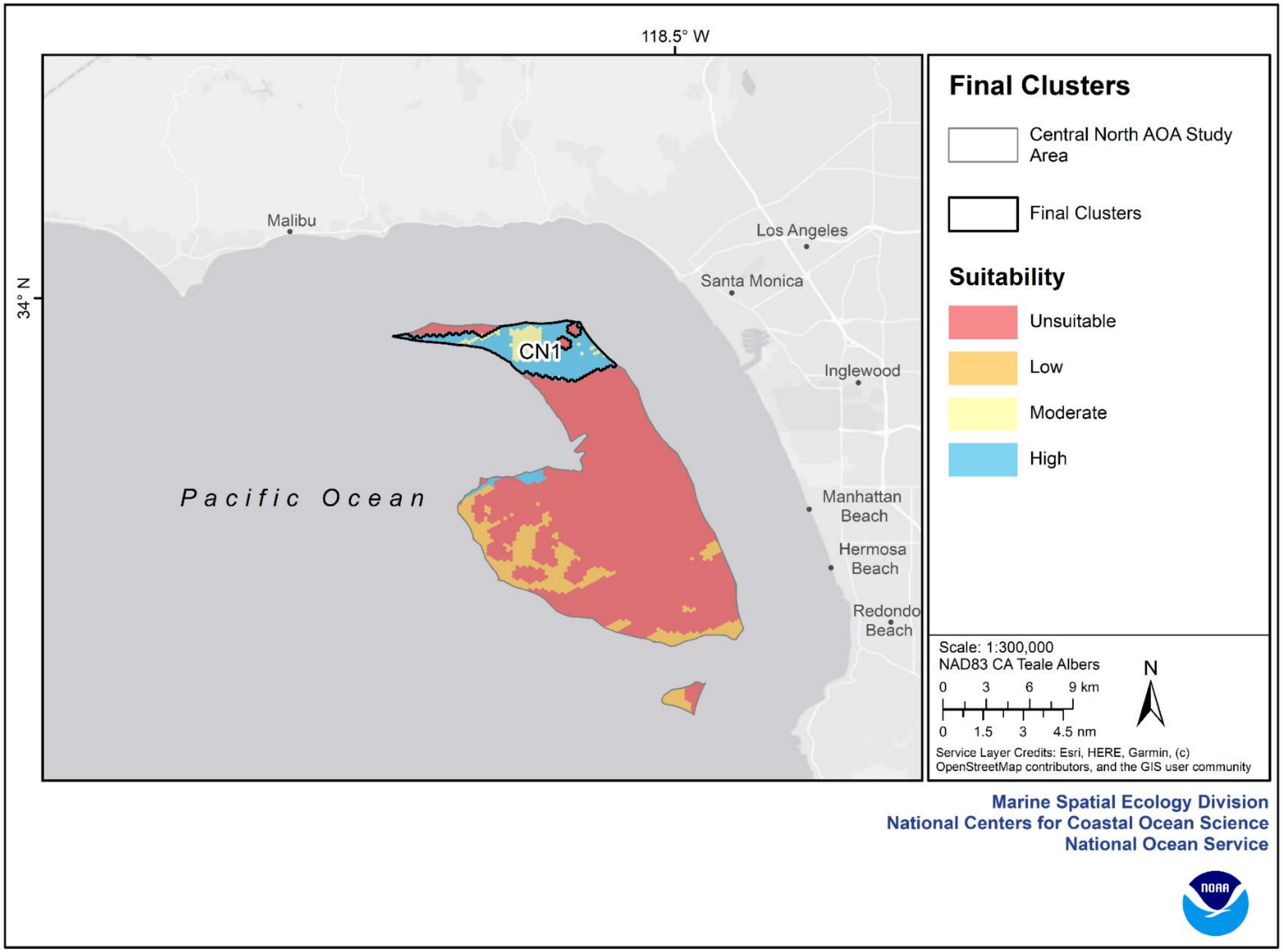


Figure 3.39. Cluster analysis results for the Central North study area using an Aquaculture Opportunity Area cluster analysis which identified areas of high-high clusters ($p < 0.05$). Only one cluster (CN1) was identified.

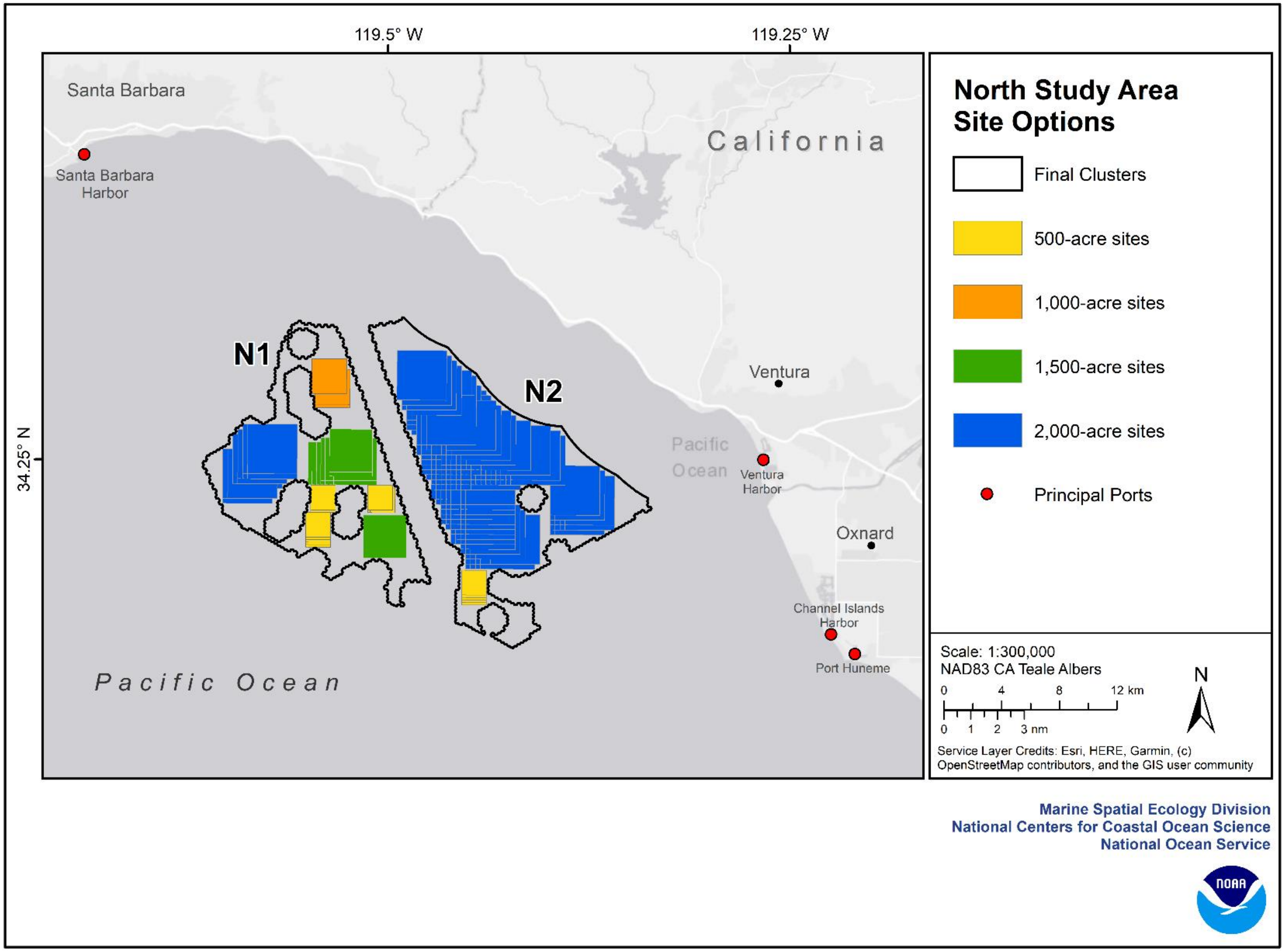


Figure 3.40. Cluster N1 and N2 displaying the total number of Aquaculture Opportunity Area options (n = 284).

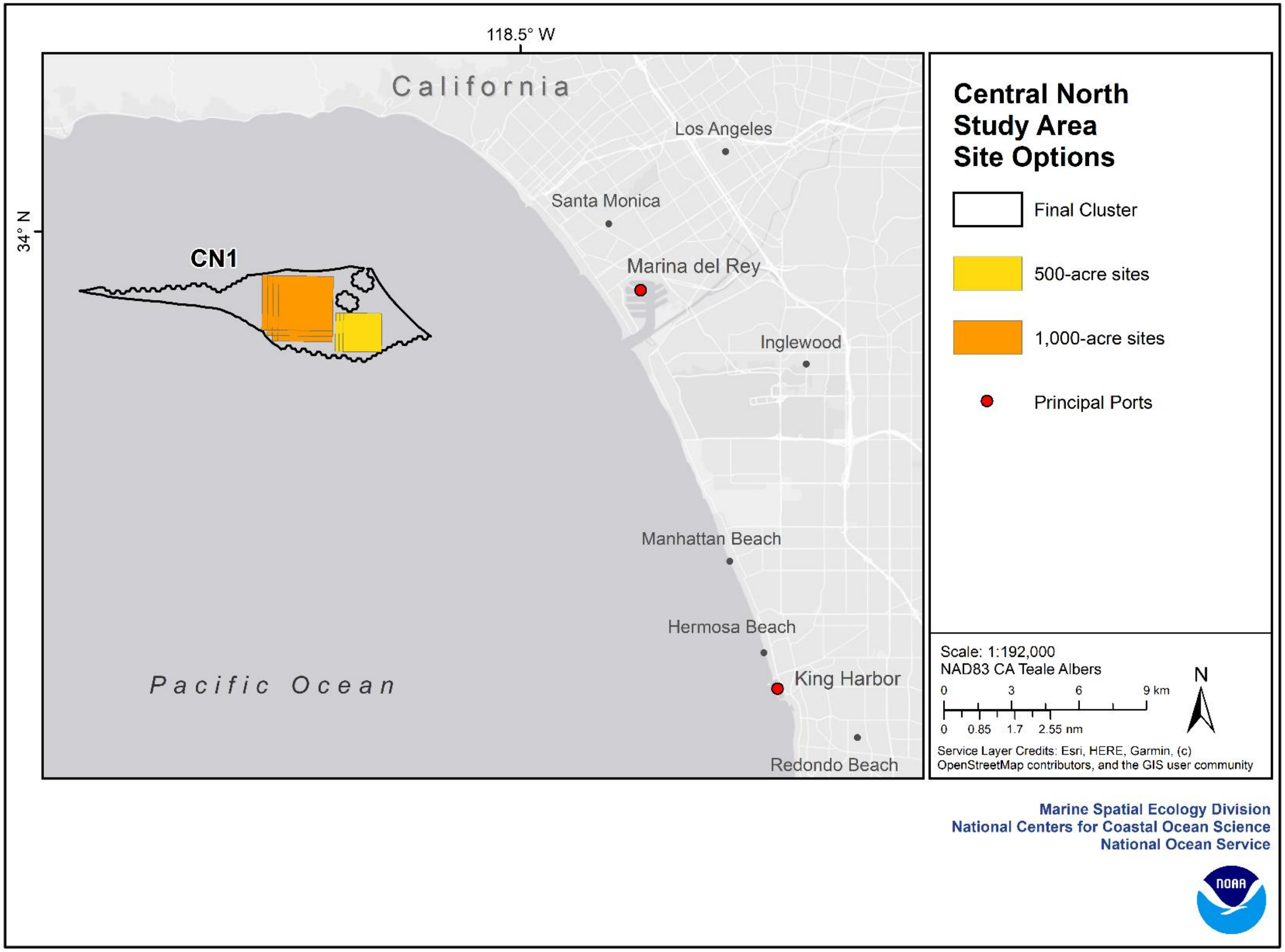


Figure 3.41. Cluster CN1 displaying the total number of Aquaculture Opportunity Area options (n = 12).

Ranking and Characterization of AOA Clusters and Options

Of the 296 AOA options identified from all three clusters, the locations of the top 10 ranked AOA options are provided in Figures 3.42 - 3.44. Three options are located in cluster N1, five options in N2, and two options in CN1. Below we provide detailed characterizations for each of the 10 highest ranked AOA options. The characterizations provide site specific detail regarding the geographic location, national security, natural and cultural resources, and environmental quality. Additional characterization details for the general locations are provided in Appendix E, which includes links for customized analyses from the OceanReports spatial analysis tool. OceanReports provides characterization of ocean neighborhoods for each of the AOA options, pulling from more than 100 data sources. Lastly, Appendix F provides coordinates and OceanReports links for up to 50 of the highest scoring AOA options for each cluster and Appendix G provides large format maps to aid in viewing and interpretation of data.

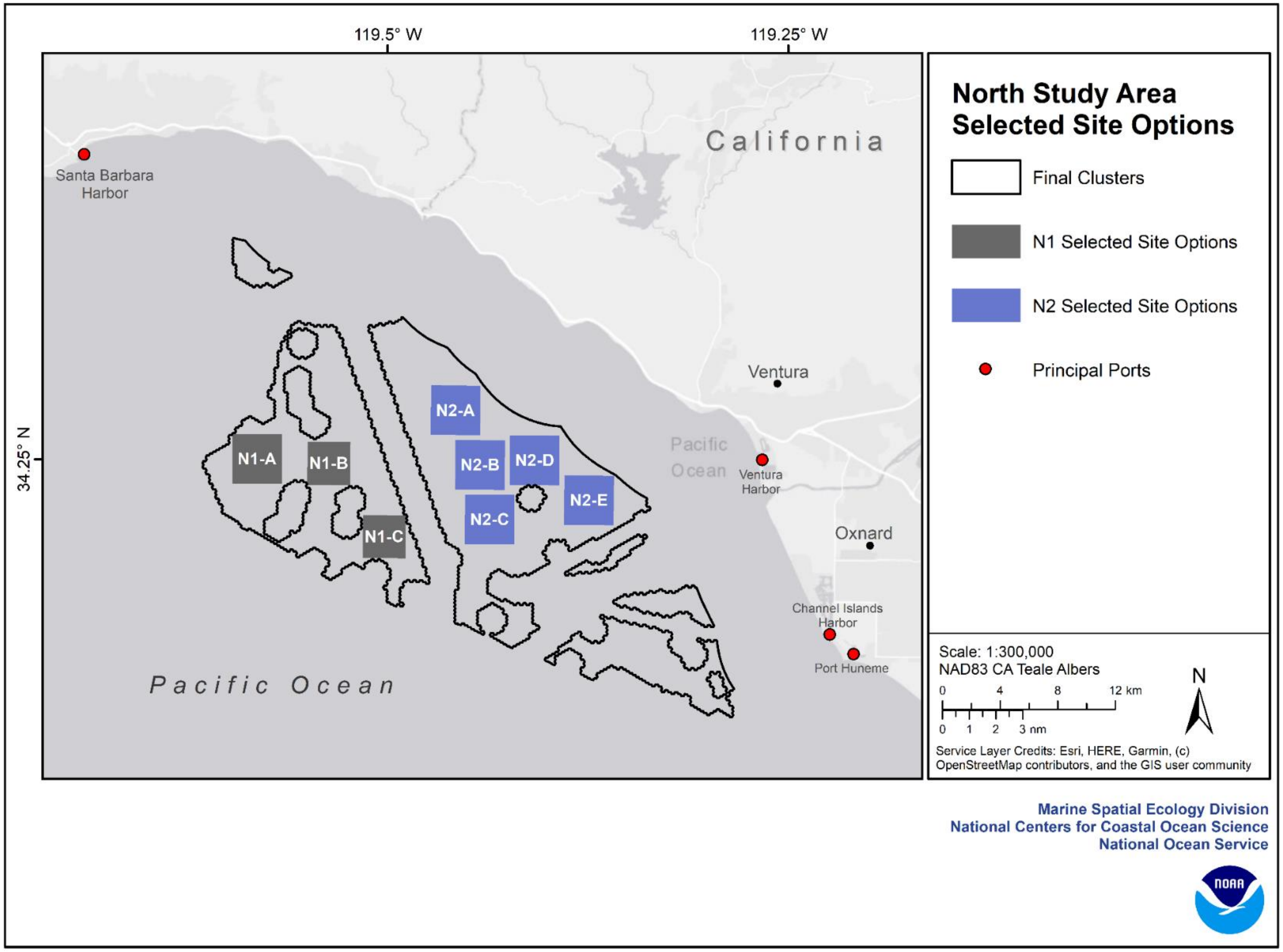


Figure 3.42. Top ranked Aquaculture Opportunity Area options for the North study area.

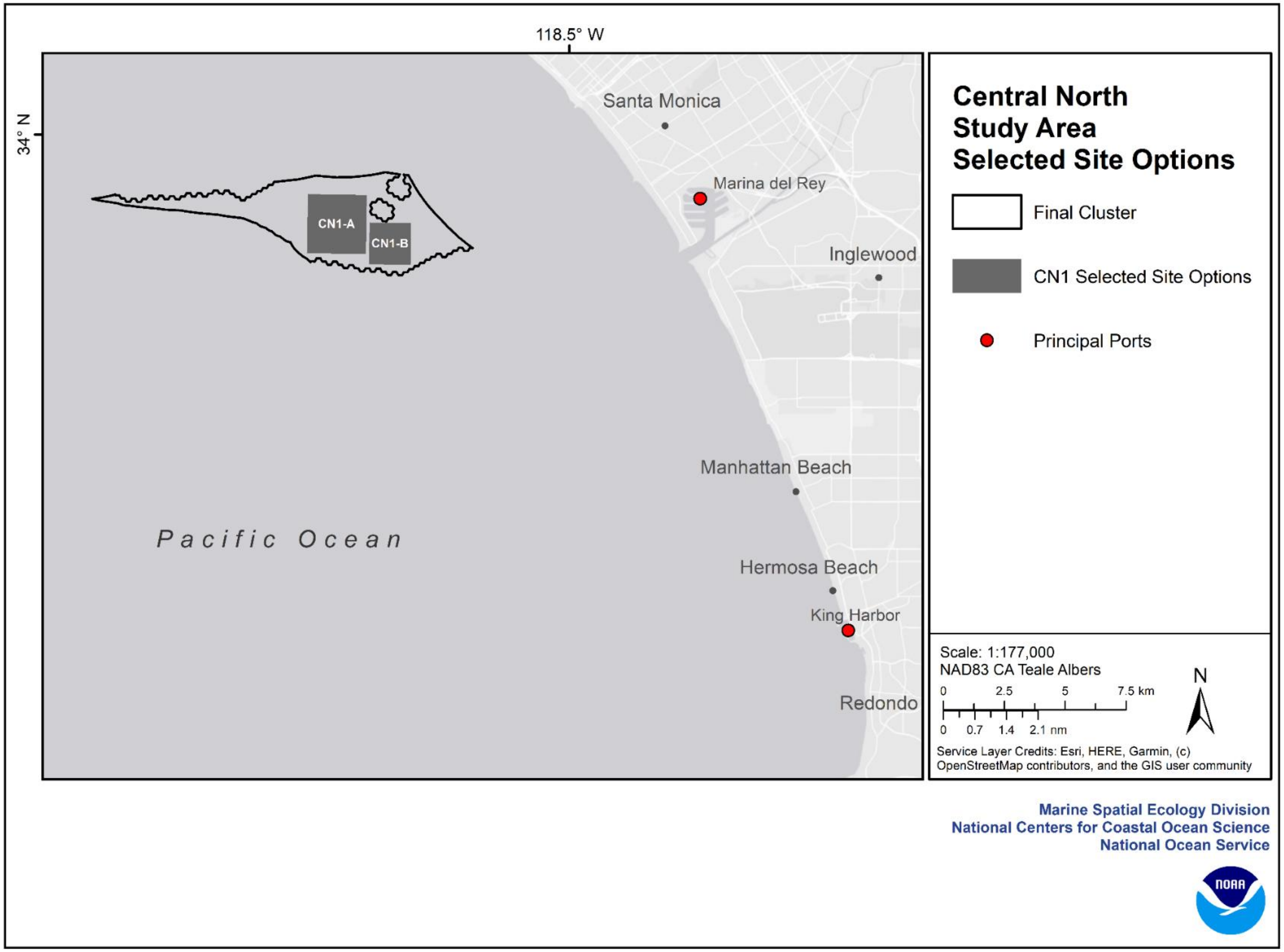


Figure 3.43. Top ranked Aquaculture Opportunity Area options for the Central North study area.

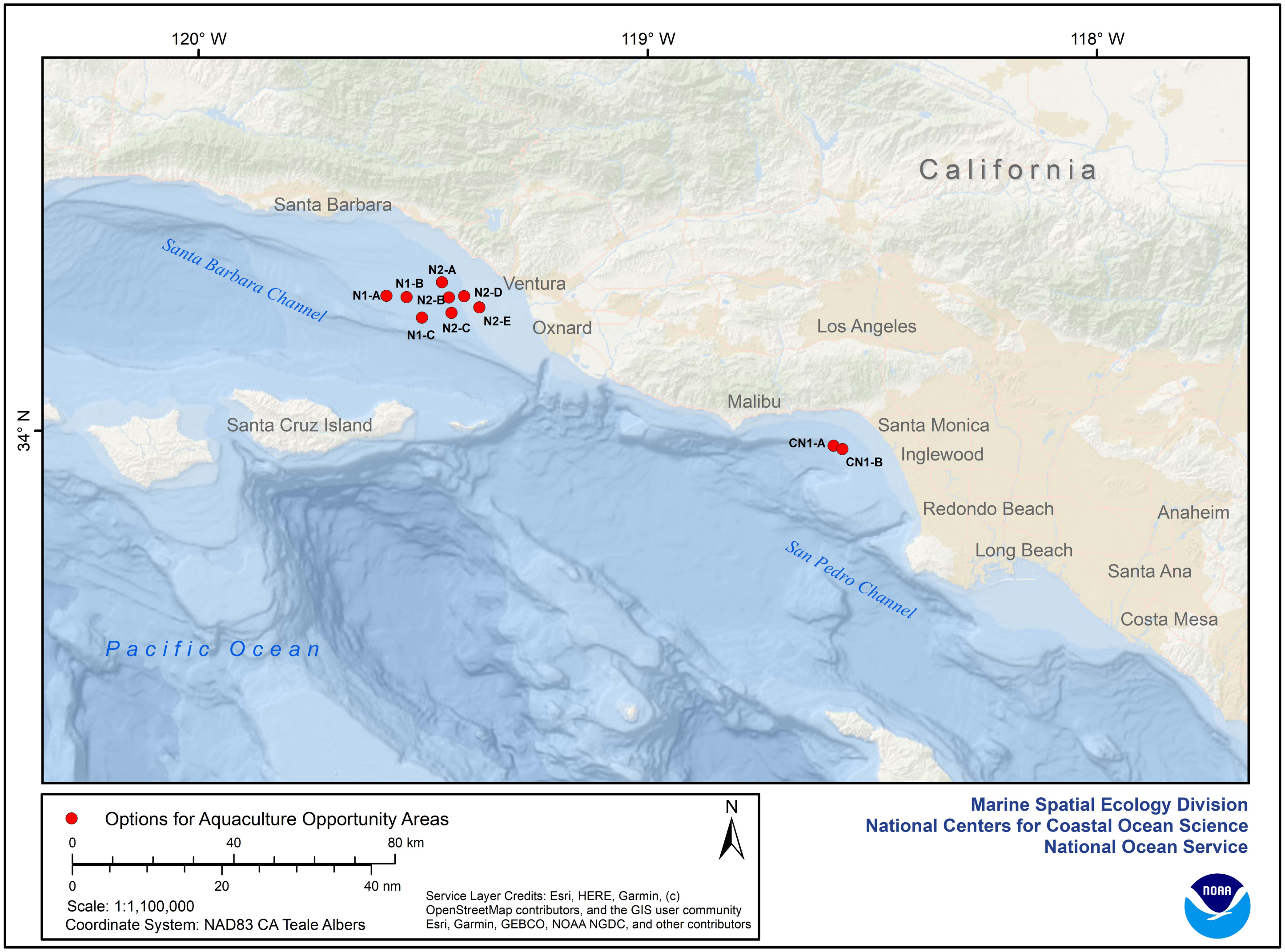


Figure 3.44. Distribution of options for Aquaculture Opportunity Areas in U.S. federal waters of the Southern California Bight. Red circles represent the options, but do not reflect the size of the options.

Characteristics of AOA Cluster N1

The following characteristics are similar among all of the AOA options within cluster N1 including N1-A, N1-B, and N1-C. Descriptive data (Table 3.7), maps, and figures are provided for the general location of the cluster (Figure 3.45), bathymetry (Figure 3.46), interactions with industry (Figure 3.47), interactions with natural resources (Figure 3.48), water temperature (Figure 3.49), current velocity and direction (Figures 3.50 - 3.52), wind velocity and direction (Figure 3.53), wave height and period (Figure 3.54), nutrient concentrations (Figure 3.55), chlorophyll-*a* concentration (Figure 3.56), light attenuation characteristics (Figure 3.57), and light transmissivity (Figure 3.58).

Water Temperature and Salinity

Water temperatures in the Southern California Bight fluctuate seasonally with episodic storm events and shifting current patterns. The mean water temperature at the surface between 2016 - 2020 was 16.4°C with a minimum of 11°C and maximum of 22.9°C (Figure 3.49). The average temperature decreased to 15.8°C at 10-m depth and was the lowest at 75-m depth (11.2°C). Seasonally, temperature at the surface peaked in late July and was lowest in April. Years with the highest surface water temperatures were 2016 and 2017. The surface salinity was consistent throughout the year and among sites with an average of 33.6 psu.

Current Speed and Direction, Wind Speed and Direction, and Significant Wave Height

Current speed and direction vary by month and depth with a west-northwest direction at the surface. The annual average current velocity from the CA ROMS model from 2016 - 2020 at the surface was 0.14 m/s, with a minimum and maximum of 0 m/s and 0.53 m/s, respectively (Figure 3.50). Current speed decreased with depth with average current speeds of 0.12 m/s at 10-m depth and 0.09 m/s at 75-m depth. The current speed did not exceed 1 m/s over the 5-year period. Wind velocity at the site averaged 5.1 m/s, with a minimum of 0 m/s and a maximum of 19.8 m/s. Wind was predominantly from the west (Figure 3.53). The average significant wave height from 1979 to 2010 was 0.98 m with a period of 11.9 seconds, with waves predominantly from the west (Figure 3.54).

Water Quality Considerations

Mean nutrient concentration for nitrate, phosphate, and dissolved oxygen at depth is an indicator of ocean health. Nitrate ranged from 1.03 mmol/m^3 at 10-m depth to 7.85 mmol/m^3 at 50-m depth (Figure 3.55). Phosphate ranged from 0.51 mmol/m^3 at 10-m depth to 0.95 mmol/m^3 at 50-m depth. Dissolved oxygen decreased from 262 mmol/m^3 at 10-m depth to 221 mmol/m^3 at 50-m depth.

Chlorophyll-*a* concentration (mg/m^3), which is an indicator of phytoplankton abundance, was highest in April (2.70 mg/m^3) and lowest in October (0.96 mg/m^3) (Figure 3.56). The diffuse light coefficient at 490 nm, Kd(490), is an indicator of water turbidity. Kd(490) was lowest for the month of October (Kd(490) = 0.08 m^{-1}) and was highest in May (Kd(490) = 0.28 m^{-1}) (Figure 3.57). Percent light transmissivity was calculated at 1-m depth, providing the percent of light that reaches that depth. Percent light transmissivity was highest in October at 87.8% and lowest in May at 74.8% (Figure 3.58).

Table 3.7. Characterization summary for southern California Aquaculture Opportunity Area options N1-A, N1-B, and N1-C.

North 1 (N1)	N1-A	N1-B	N1-C
General Characteristics			
Corner Coordinates (latitude, longitude) (decimal degrees)	34.237, -199.566	34.236, -199.523	34.198, -199.489
	34.237, -199.597	34.236, -199.550	34.198, -199.515
	34.263, -199.587	34.259, -199.550	34.221, -199.515
	34.262, -199.566	34.258, -199.523	34.221, -199.489
Size (acres)	2000	1500	1500
Santa Barbara Harbor (km to port, nm to port)	18.1 (9.8)	20.8 (11.2)	26.1 (14.1)
Ventura Harbor (km to port, nm to port)	27.6 (14.9)	23.7 (12.8)	20.7 (11.2)
Port Hueneme (km to port, nm to port)	34.3 (18.5)	30.6 (16.5)	26.4 (13.4)
Depth (m) (minimum, maximum, mean), Average slope (°)	(88.6, 108.5, 95), 1	(78, 92.6, 84.7), 0.7	(77.3, 101.3, 90), 1
Industry, Navigation, and Transportation (within 5 km)			
Oil and Gas Platform Name and Status	Habitat (Shut-in) (2.6 km)	Habitat (Shut-in) (4.7 km)	Grace (Shut-in) (2.8 km)
Number of Boreholes	46 (1.0 km)	44 (0.9 km)	70 (0.8 km)
BOEM Oil and Gas Active Lease Block	No	No	No
Oil and Gas Pipelines	Yes (2.6 km)	Yes (2.3 km)	Yes (0.8 km)
Submarine Cables	Yes (2.0 km)	Yes (4.7 km)	Yes (2.8 km)
CalCOFI Sampling Site	No	No	No
CDFW Block Number and Average Catch 2010 - 2019 (pounds)	666	666	666
	329,875	329,875	329,875
	-	-	665
	-	-	964,450
National Security			
Overlap with MOAs (yes/no)	No	No	No
Overlap with MTR (yes/no)	No	No	No
Natural Resources (within 5 km)			
Habitat - Hardbottom Substrate	No	No	No
Habitat - Deep-sea Coral Observations	Yes (1.0 km)	Yes (1.1 km)	Yes (3.2 km)
HAPC - Rocky Reef	No	No	No
Important Bird Areas	Santa Barbara Basin	Santa Barbara Basin	Santa Barbara Basin
Cetacean Biologically Important Areas	Gray Whale - Migration	Gray Whale - Migration	Gray Whale - Migration
	Humpback Whale - Feeding (0.25 km)	Humpback Whale - Feeding (3.6 km)	
Critical Habitat - Humpback Whale	Yes	Yes	Yes
- Dash indicates that the data layer did not overlap the study area.			

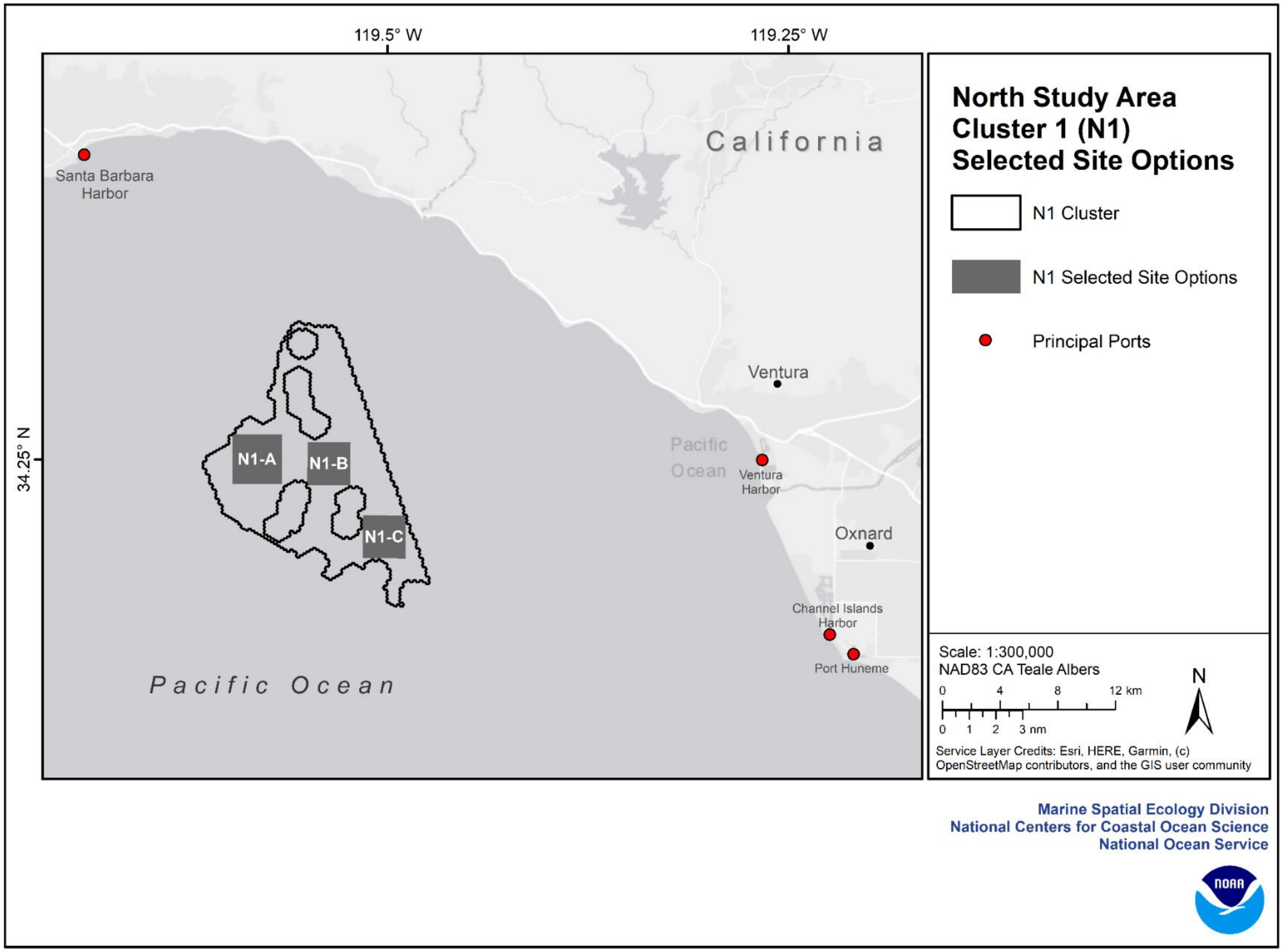


Figure 3.45. Cluster N1 with three top ranked Aquaculture Opportunity Area options including N1-A, N1-B, and N1-C.

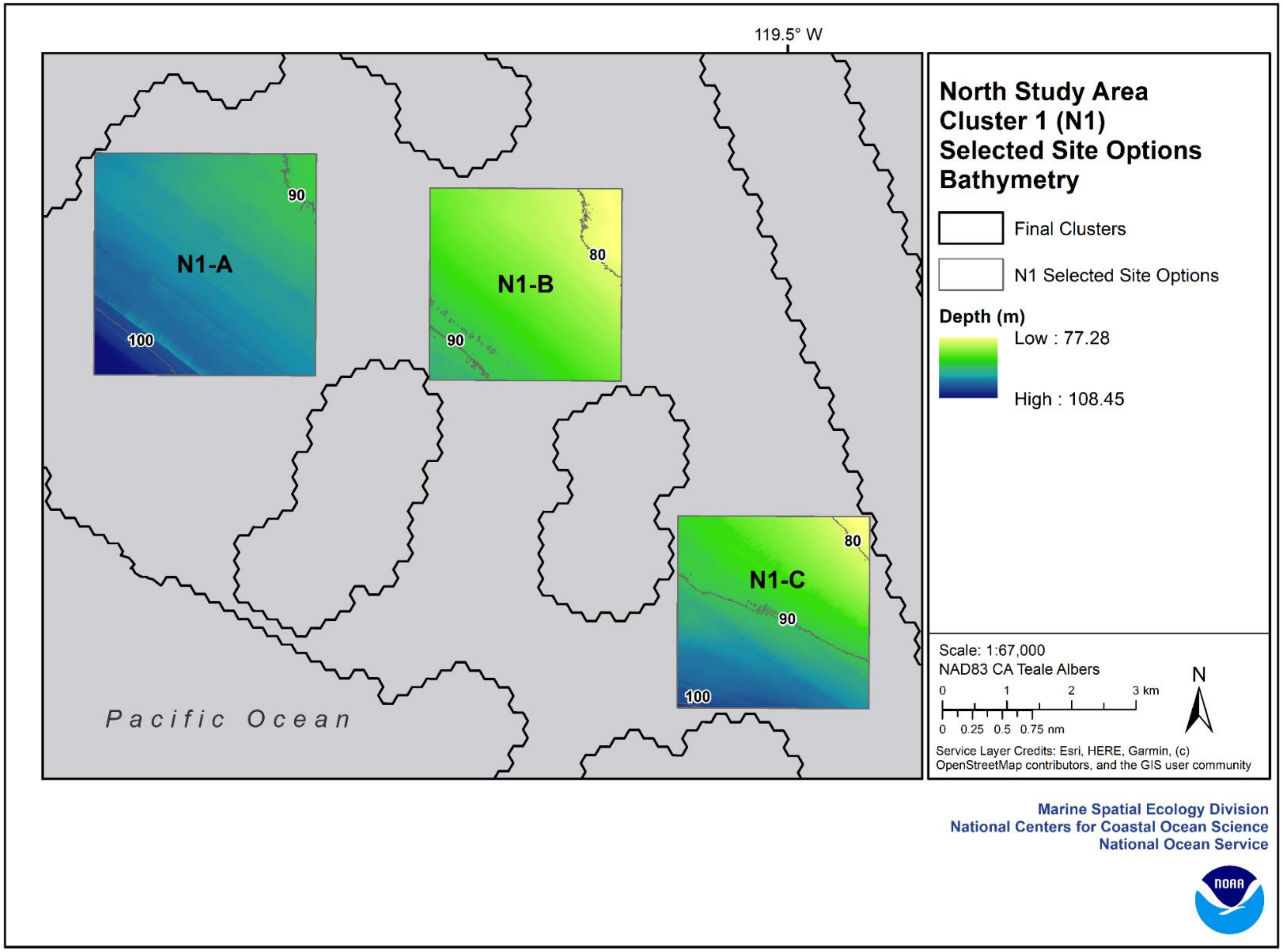


Figure 3.46. Bathymetry for Aquaculture Opportunity Area options N1-A, N1-B, and N1-C.

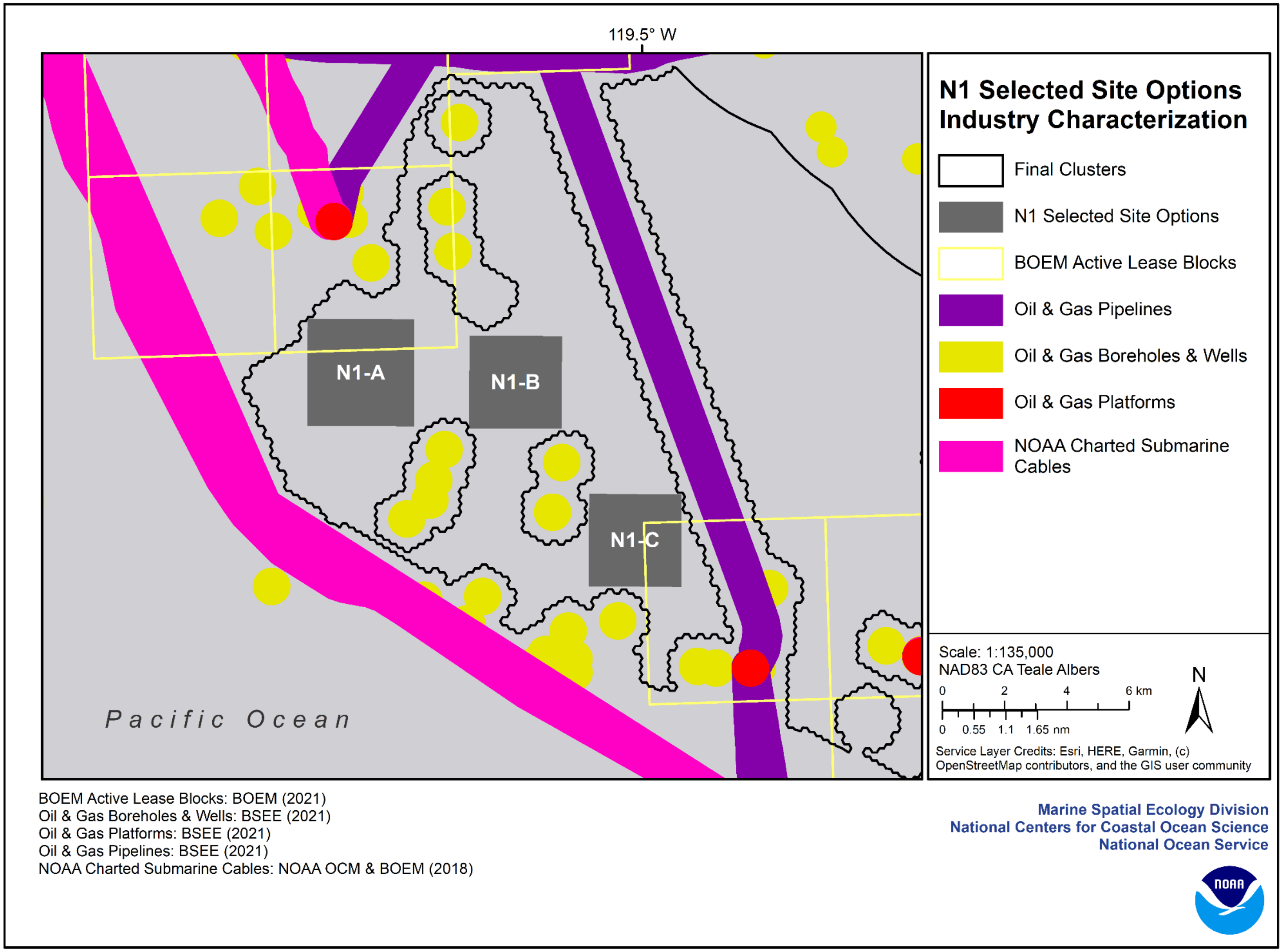


Figure 3.47. Industry interactions for Aquaculture Opportunity Area options N1-A, N1-B, and N1-C.

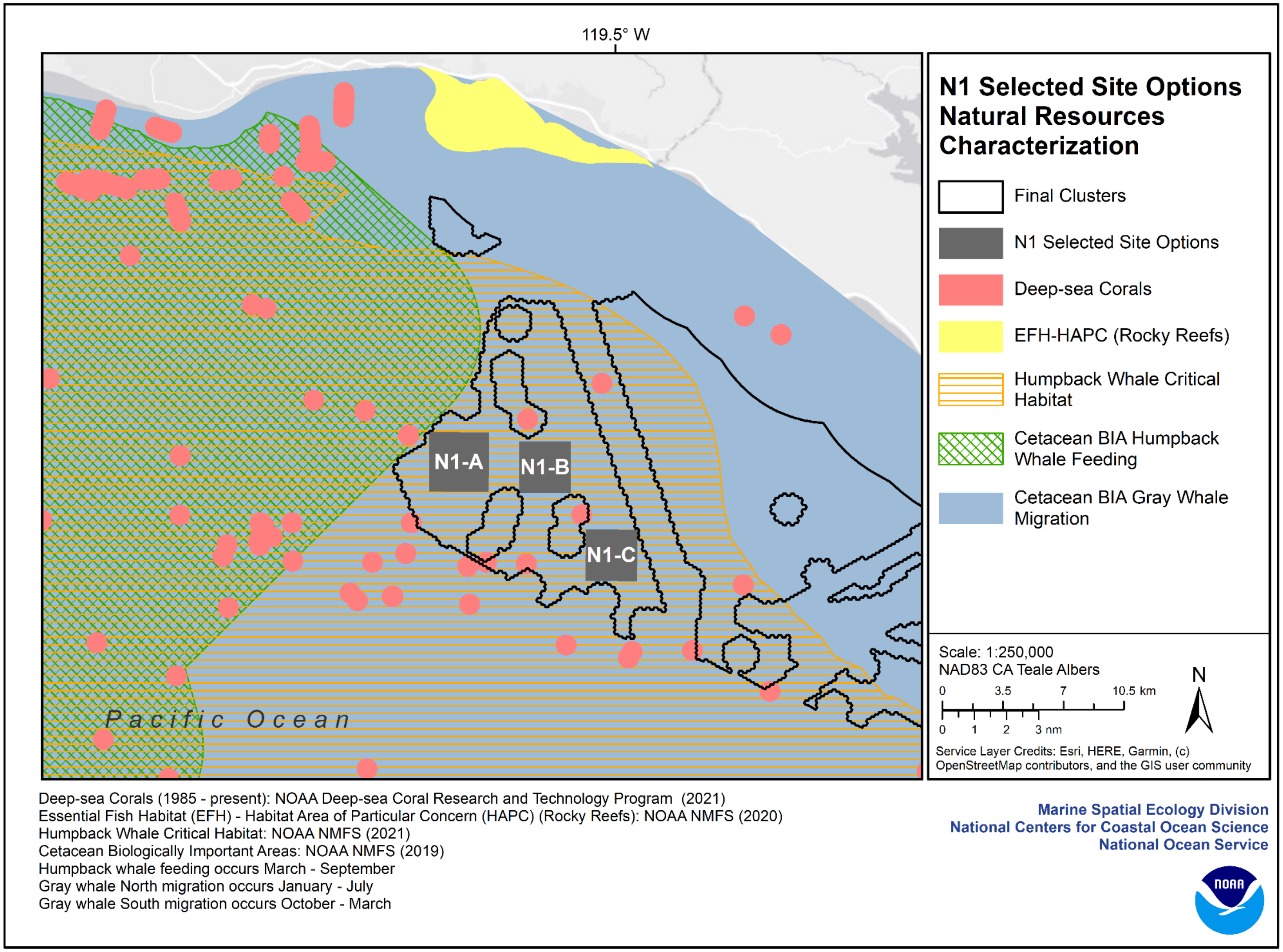


Figure 3.48. Natural resources considerations for N1-A, N1-B, and N1-C.

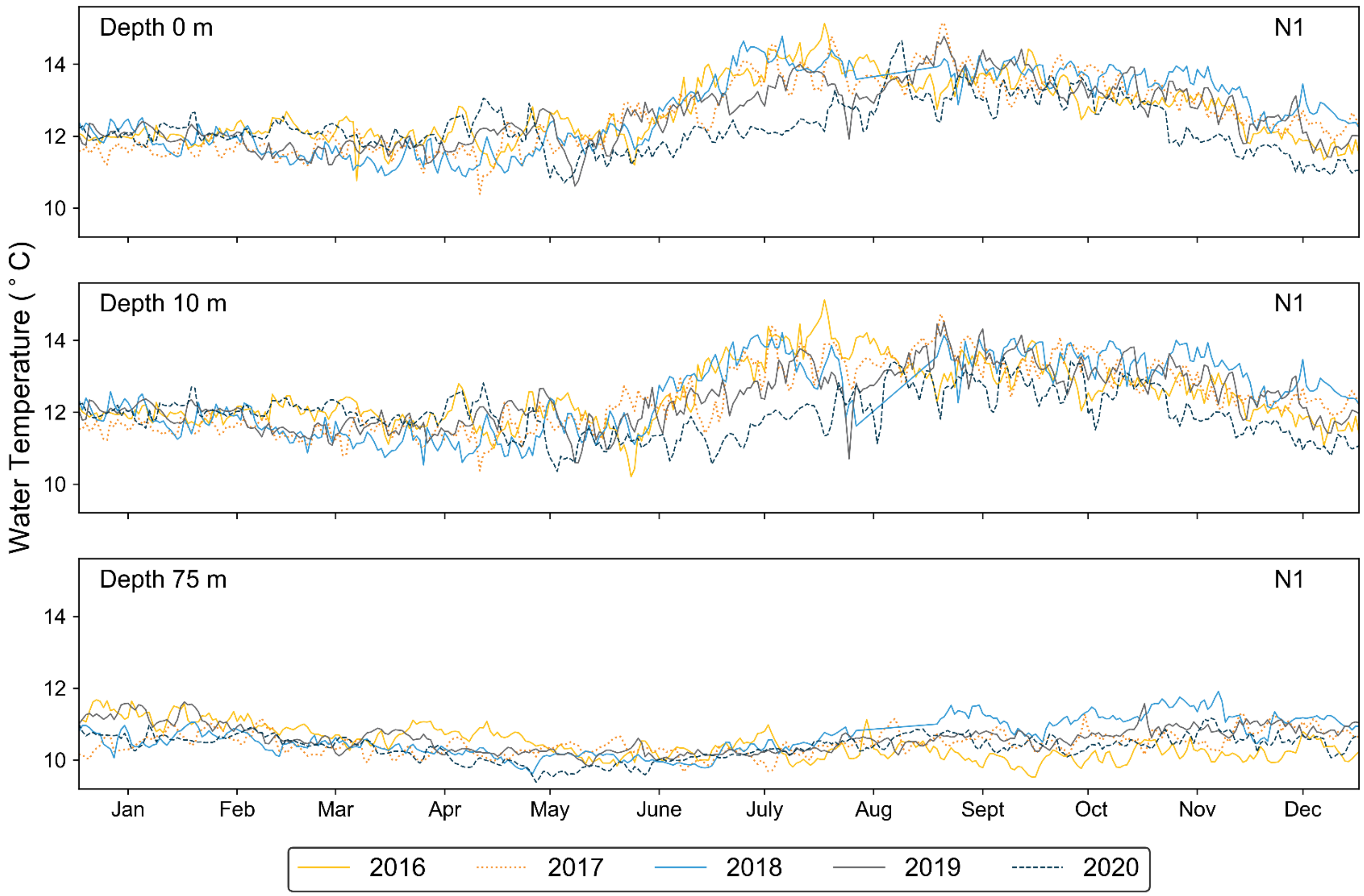


Figure 3.49. Water temperature at 0 m, 10 m, and 75 m for cluster N1 from the California Regional Ocean Modeling System model (2016 - 2020).

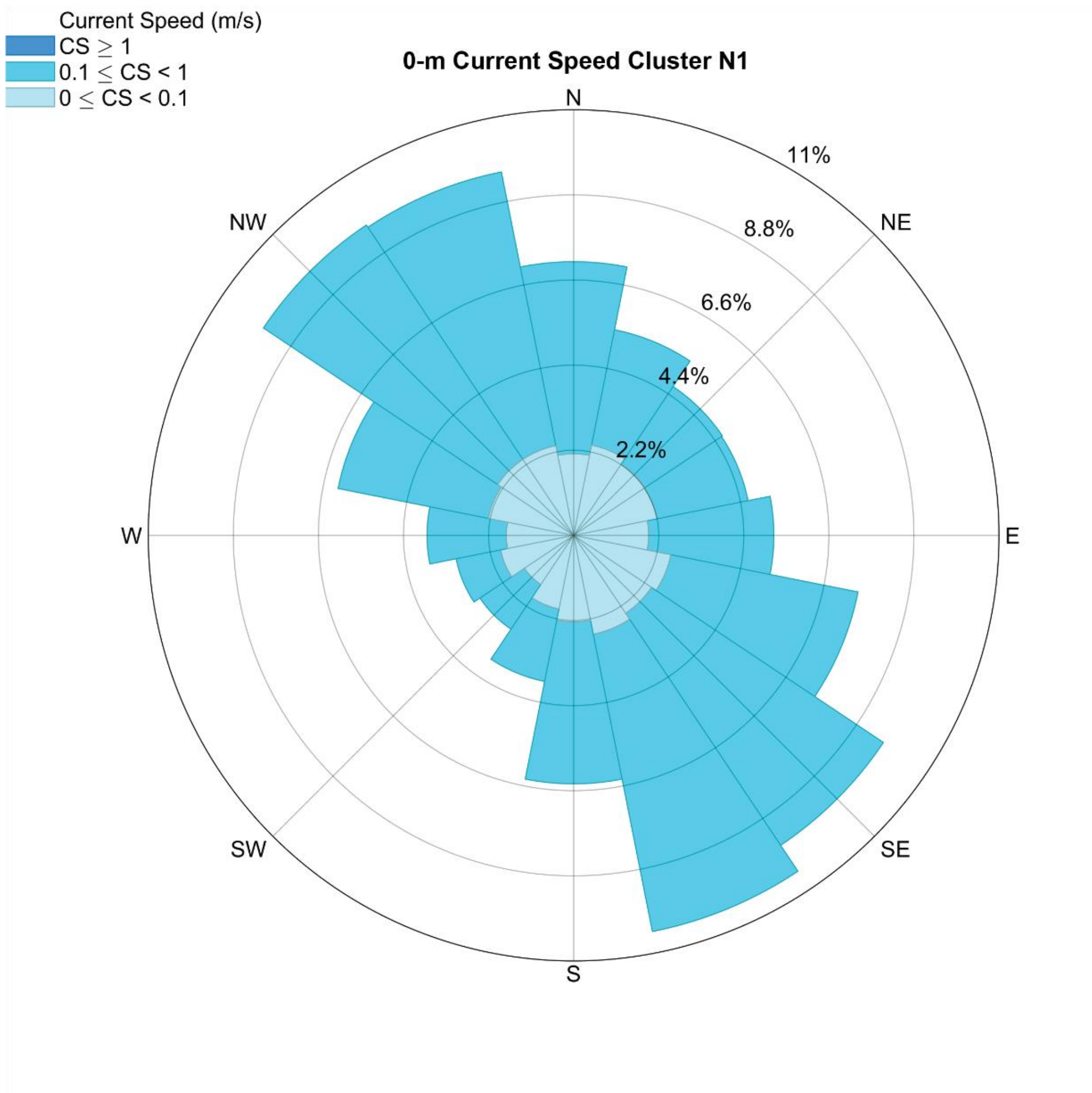


Figure 3.50. Ocean current magnitude and direction for cluster N1 at the ocean surface. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

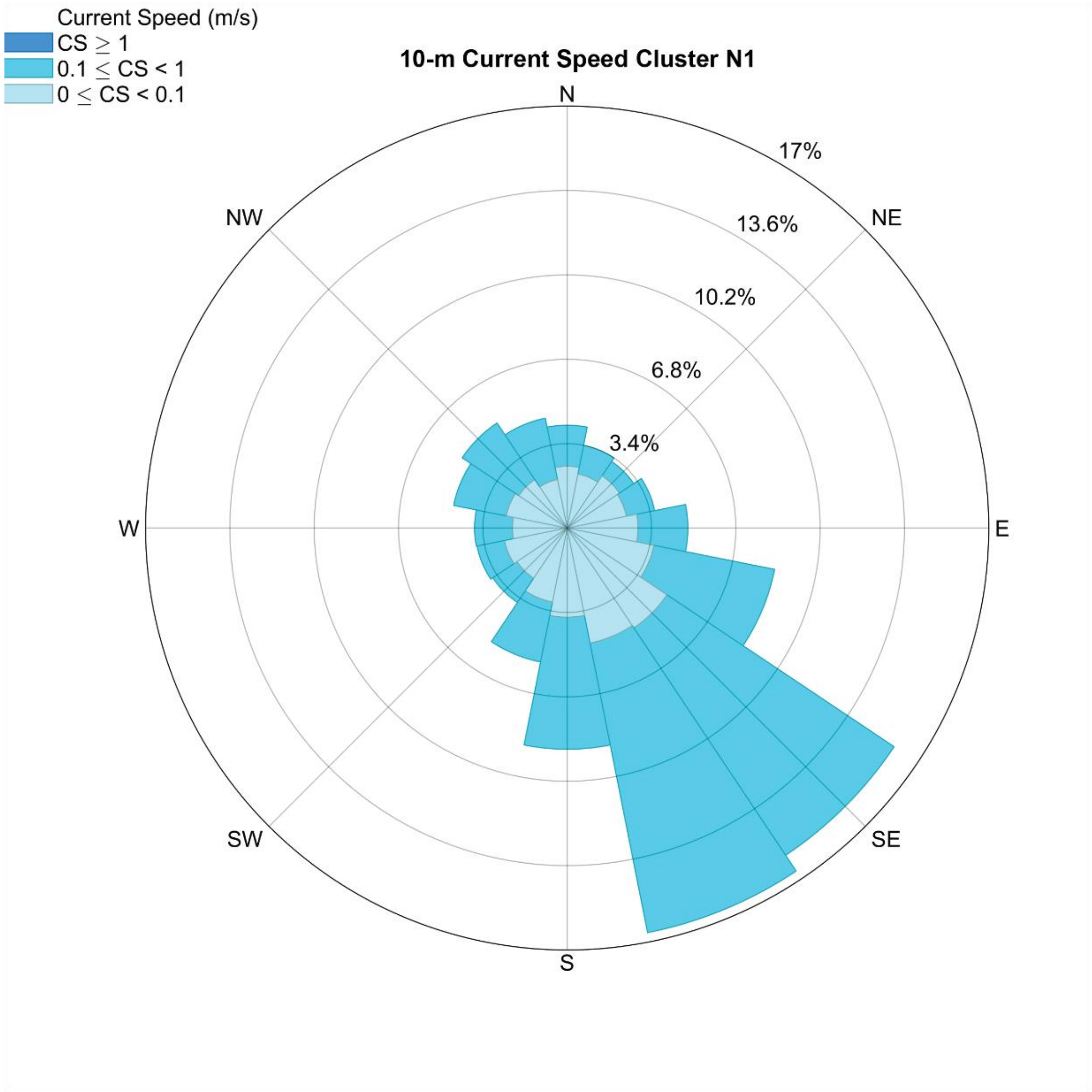


Figure 3.51. Ocean current magnitude and direction for cluster N1 at 10-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

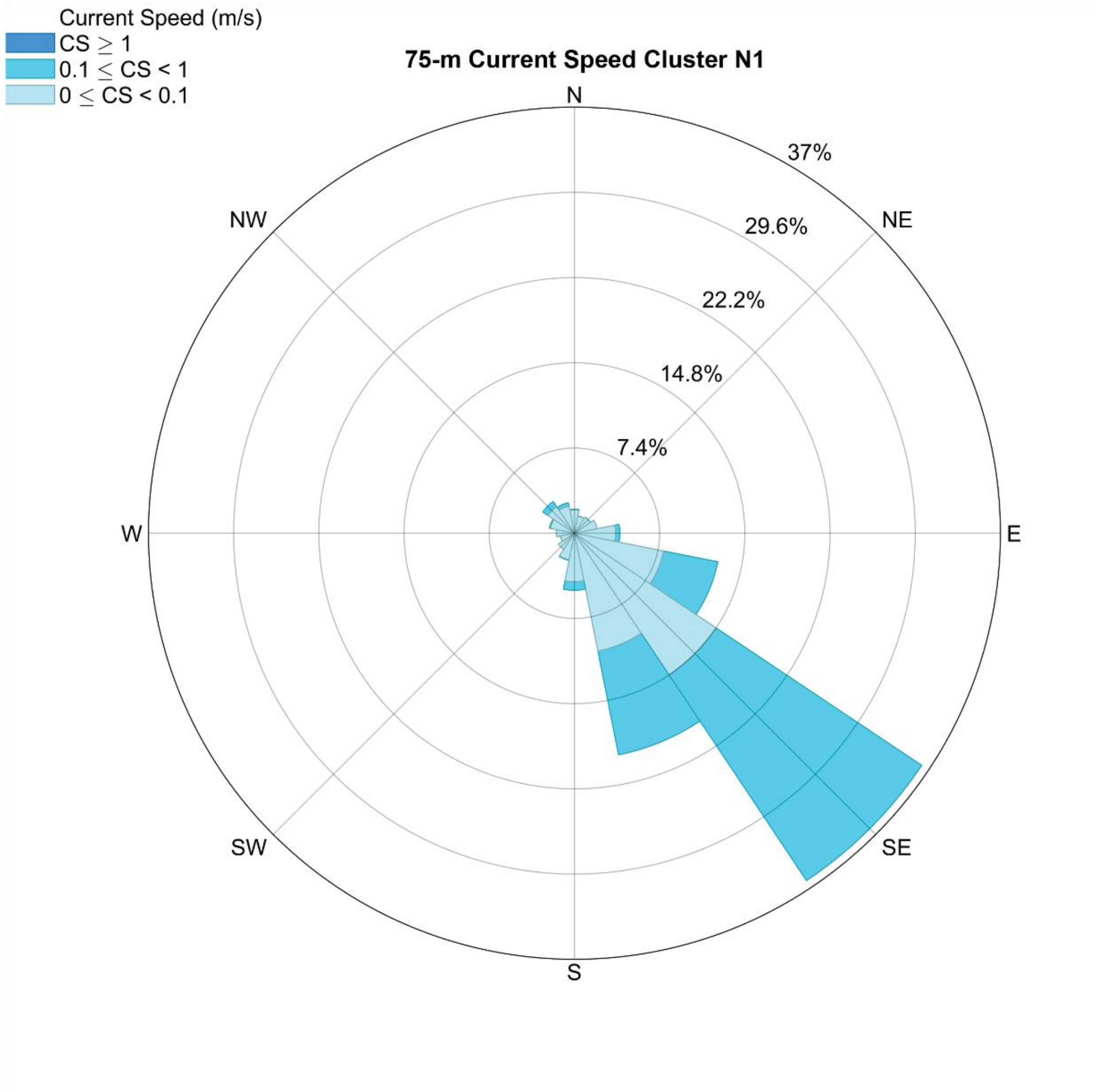


Figure 3.52. Ocean current magnitude and direction for cluster N1 at 75-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

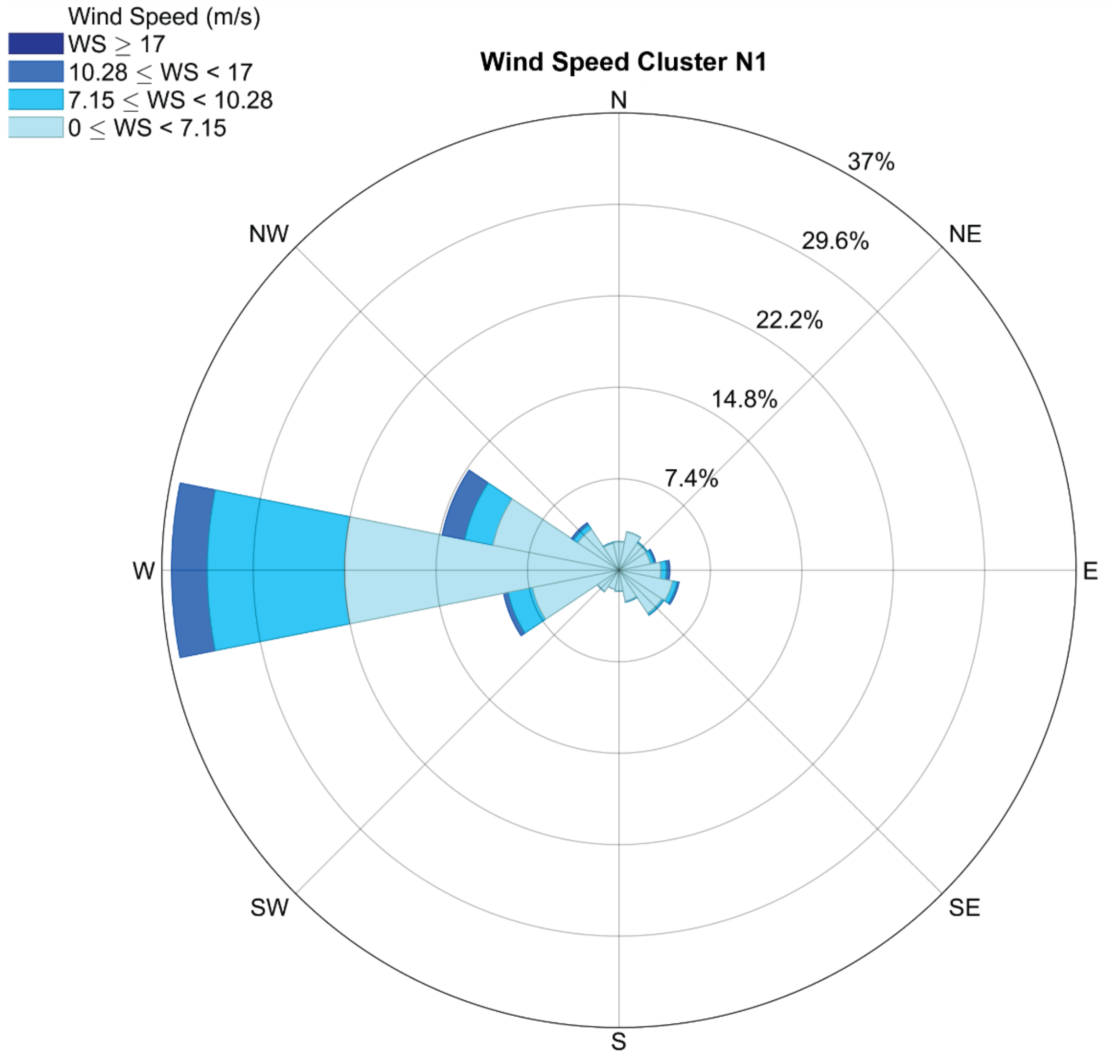


Figure 3.53. Wind velocity and direction at 10-m above sea level for cluster N1. The rose diagram provides percent occurrence for each wind speed (WS) category. Wind direction is displayed as the origin. Wind data are from the Coupled Ocean/Atmosphere Mesoscale Prediction System model (2016 - 2020).

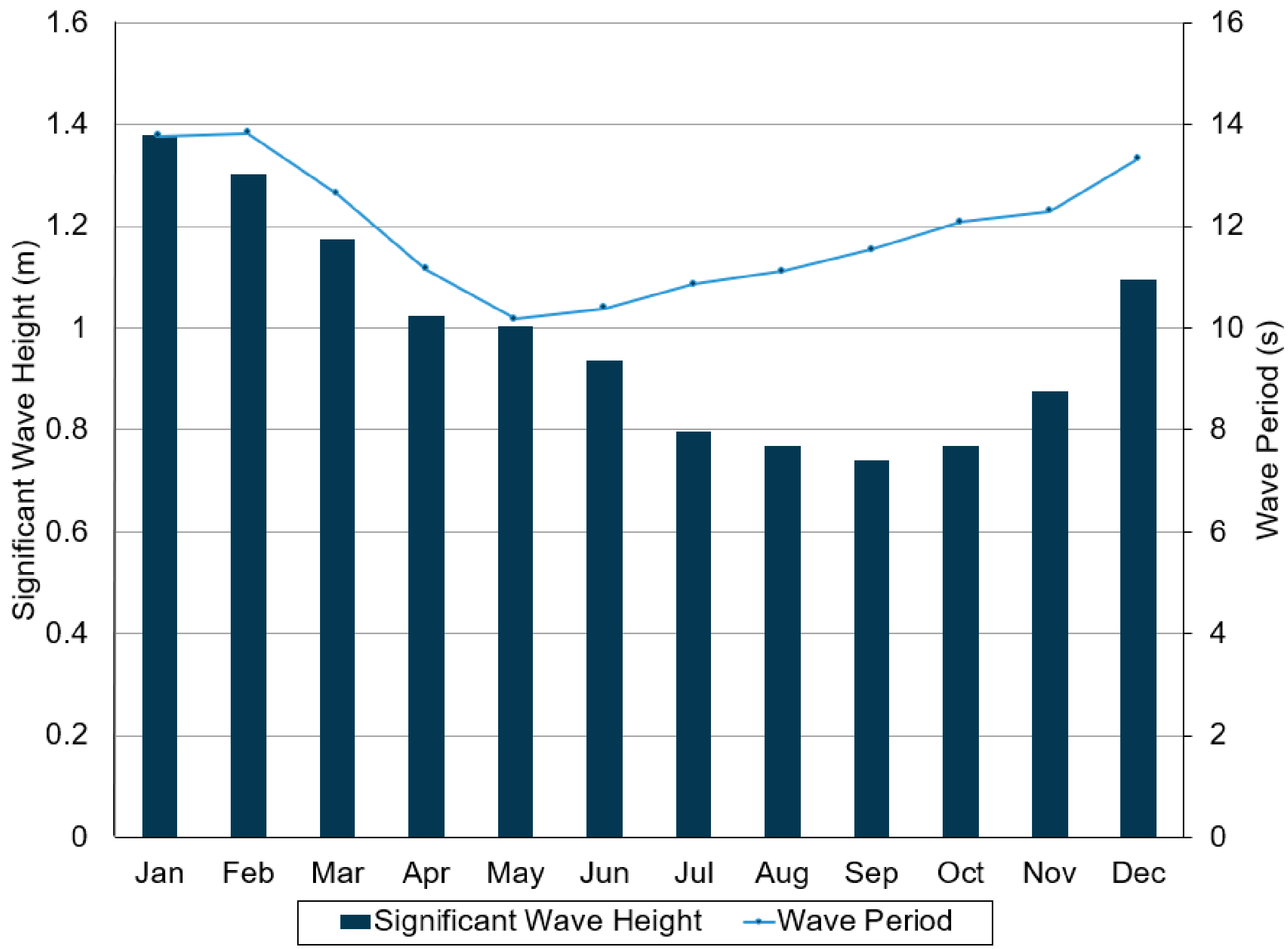


Figure 3.54. Wave height and period for cluster N1 from the Pacific Northwest National Laboratory Simulating WAves Nearshore wave model (1979 - 2010).

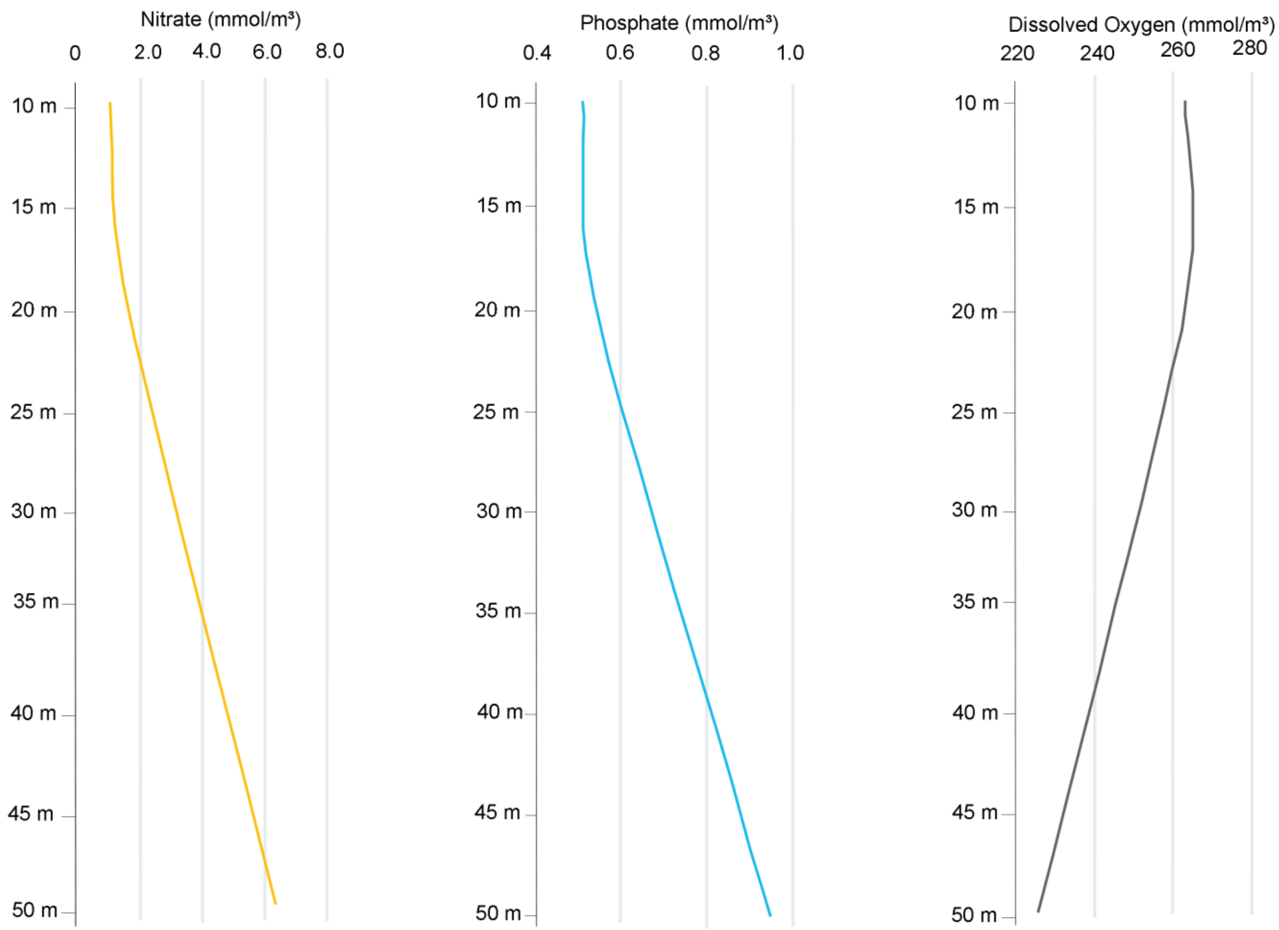


Figure 3.55. Cluster N1 concentration of nitrate, phosphate, and dissolved oxygen at depth (Kessouri et al. 2021).

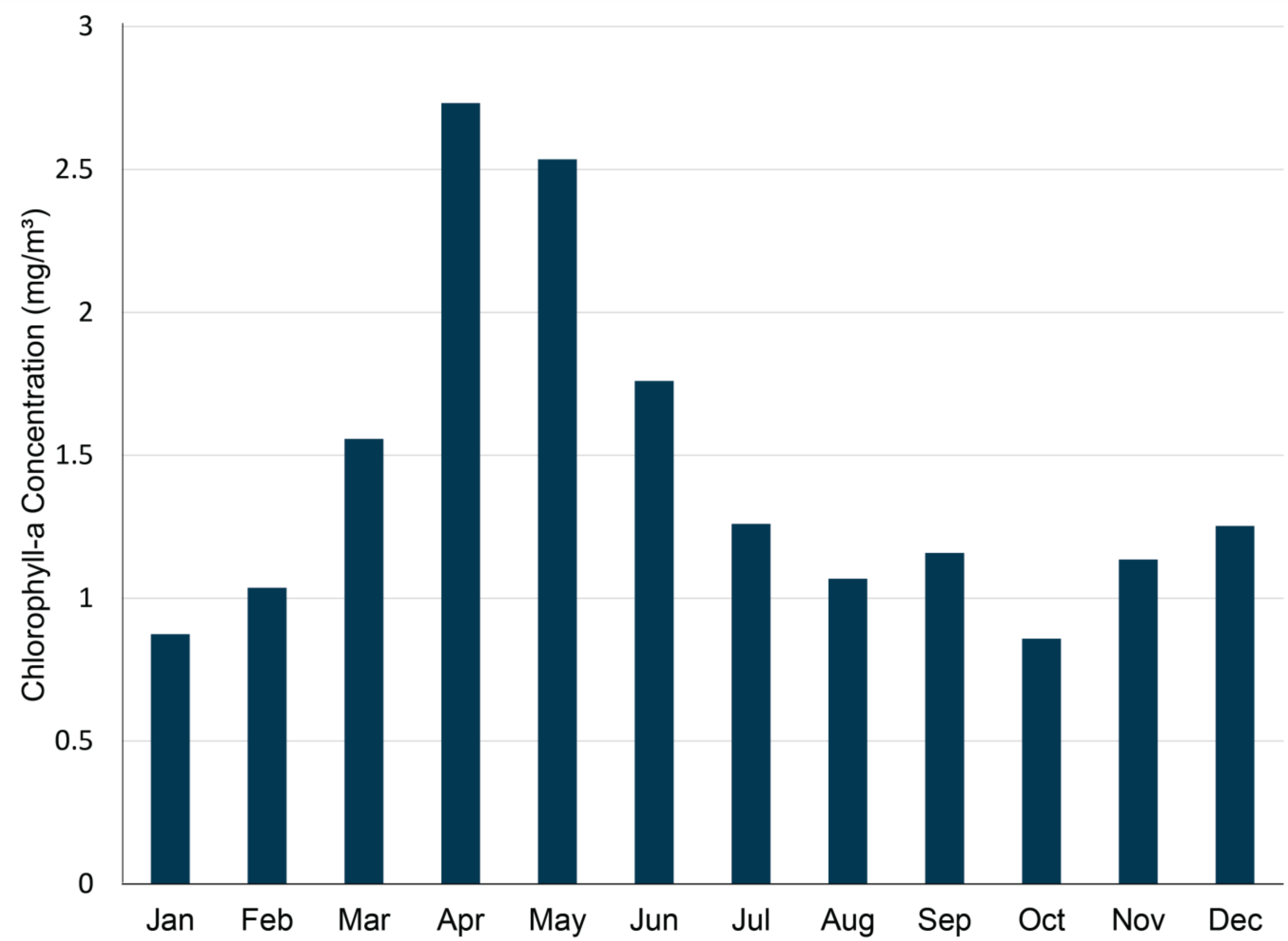


Figure 3.56. Cluster N1 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

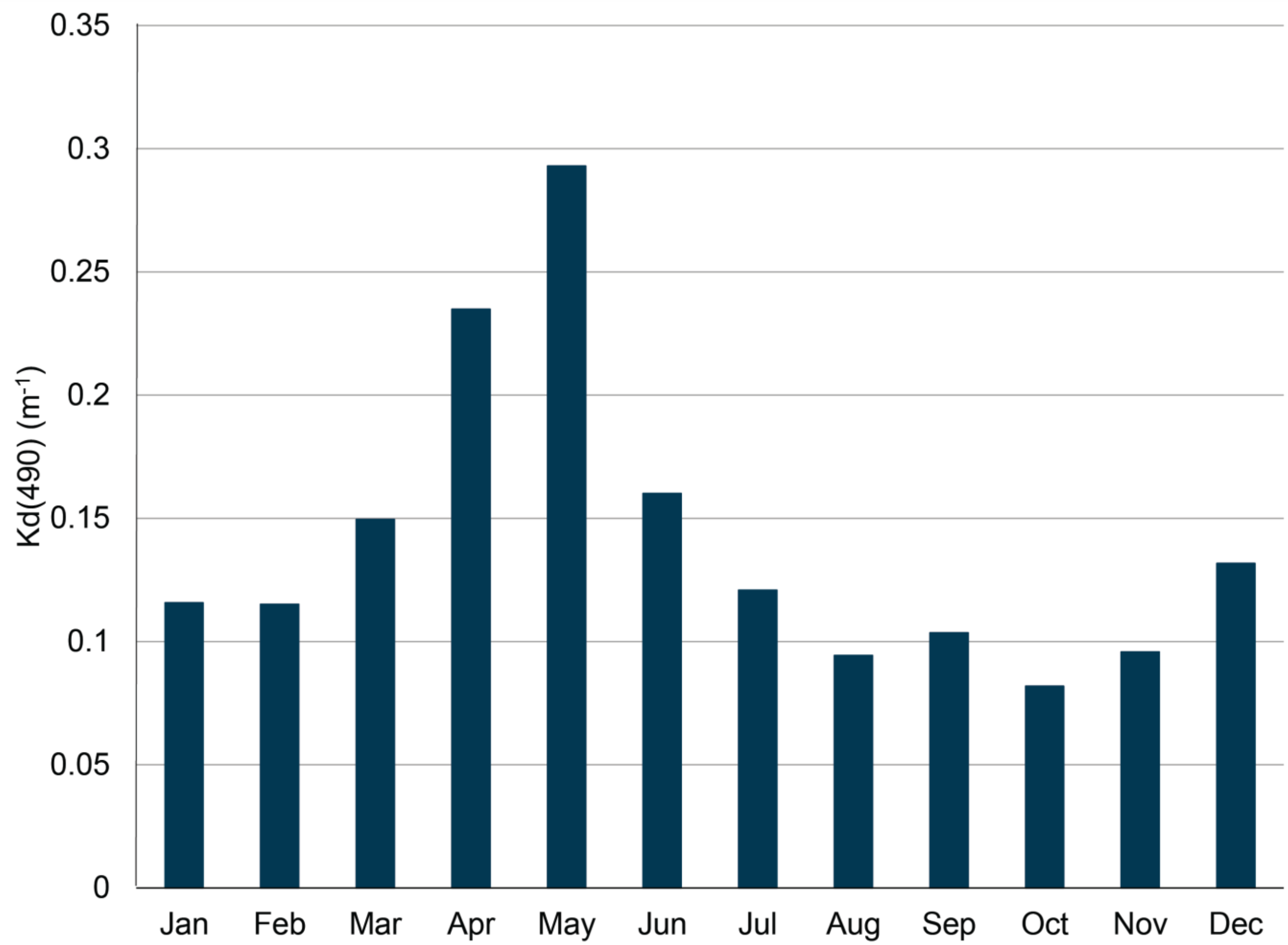


Figure 3.57. Cluster N1 monthly climatological mean (2010 - 2018) for light attenuation Kd(490) at the sea surface produced by Visible Infrared Imaging Radiometer Suite 750-m data.

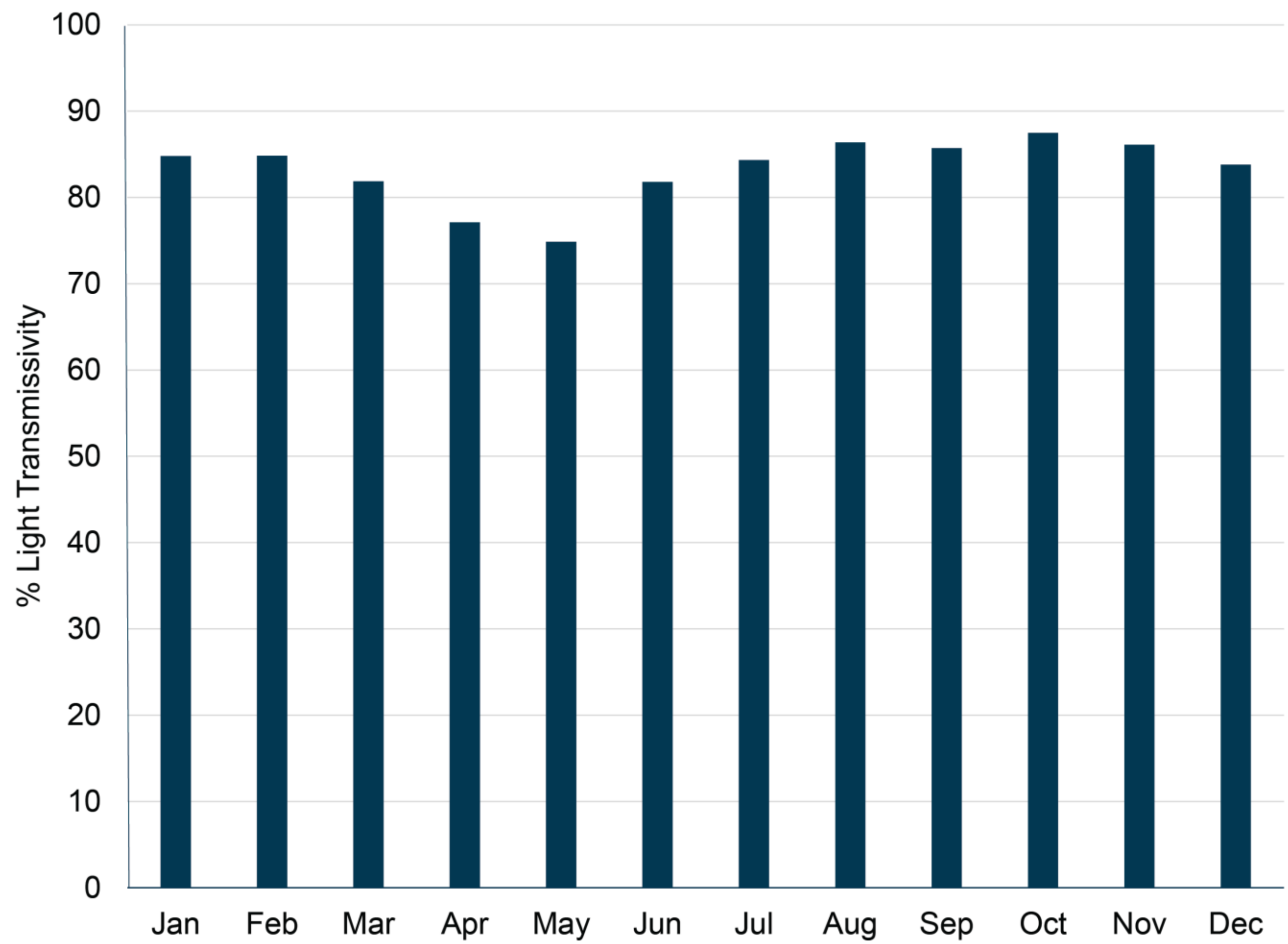


Figure 3.58. Cluster N1 monthly climatological mean (2010 - 2018) for percent light transmissivity at 1 m produced by Visible Infrared Imaging Radiometer Suite 750-m data.

AOA Option N1-A

AOA option N1-A is the most westerly site in the North study area. This 2000-acre site lies within the Santa Barbara Channel and offshore of the city of Carpinteria and the counties of Santa Barbara and Ventura. The site is 18.1 km (9.8 nm) from Santa Barbara Harbor, 27.6 km (14.9 nm) from Ventura Harbor, and 34.3 km (18.5 nm) from Port Hueneme (Table 3.7; Figure 3.59).

Depth and Substrate Type

The site ranges in depth from 88.6 m to 108.5 m with an average depth of 95 m (Figure 3.46). Option N1-A slopes gently with an average slope of one degree. The shallowest section of the site is found in the northeast corner and the deepest in the southwest corner.

Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California,[28] the sediment of N1-A is composed of approximately 70% mud-like (medium silt) substrate. As proximity increases to the bathymetric rise in the southwest corner, sediment changes to predominantly very fine sand which covers the remaining 30% of the site area. The mean sediment grain diameter is approximately 0.03 mm in N1-A, indicating silt to very fine sand as the predominant substrate throughout the site. According to the data, no grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

This site is within an inactive BOEM oil and gas lease block (234) and within 2.6 km of platform habitat, currently in a state of preservation (Figure 3.47). This effort is part of the first campaign of decommissioning in the region (BSEE 2020). Oil and gas infrastructure are found outside the site within a 5-km radius, this includes wells (1 km), pipelines (2.6 km), and submarine power cables (2.6 km). There are also submarine fiber optic cables near the southwest corner, approximately 2 km from the site.

Vessel transits are found within the site with the highest number of transits from the other vessel category, followed by passenger and pleasure and sailing transits (Table 3.8). VMS fishing figures show that the highest number of transits occurred from the California sea cucumber trawl fishery, followed by ridgeback prawn, and California halibut trawl fisheries. The site is within CDFW commercial landing block 666 with an average annual landing of 329,875 pounds from 2010 to 2019 (Figures 3.16 - 3.35).

[28] https://coastalscience.noaa.gov/project/predictive-benthic-habitat-suitability-modeling-of-deep-sea-biota-on-the-us-pacific-outer-continental-shelf/

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, which removed these areas from the remainder of the analysis. The nature of military activities varies over space and time, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site is within the BIA for gray whale migration and the newly established Critical Habitat for humpback whale Central America and Mexico distinct population segments (DPS). The site is also 0.25 km from the BIA for humpback whale feeding and 1 km from a deep-sea coral observation (Figure 3.48). The site also lies within the Santa Barbara Basin Important Bird Area.

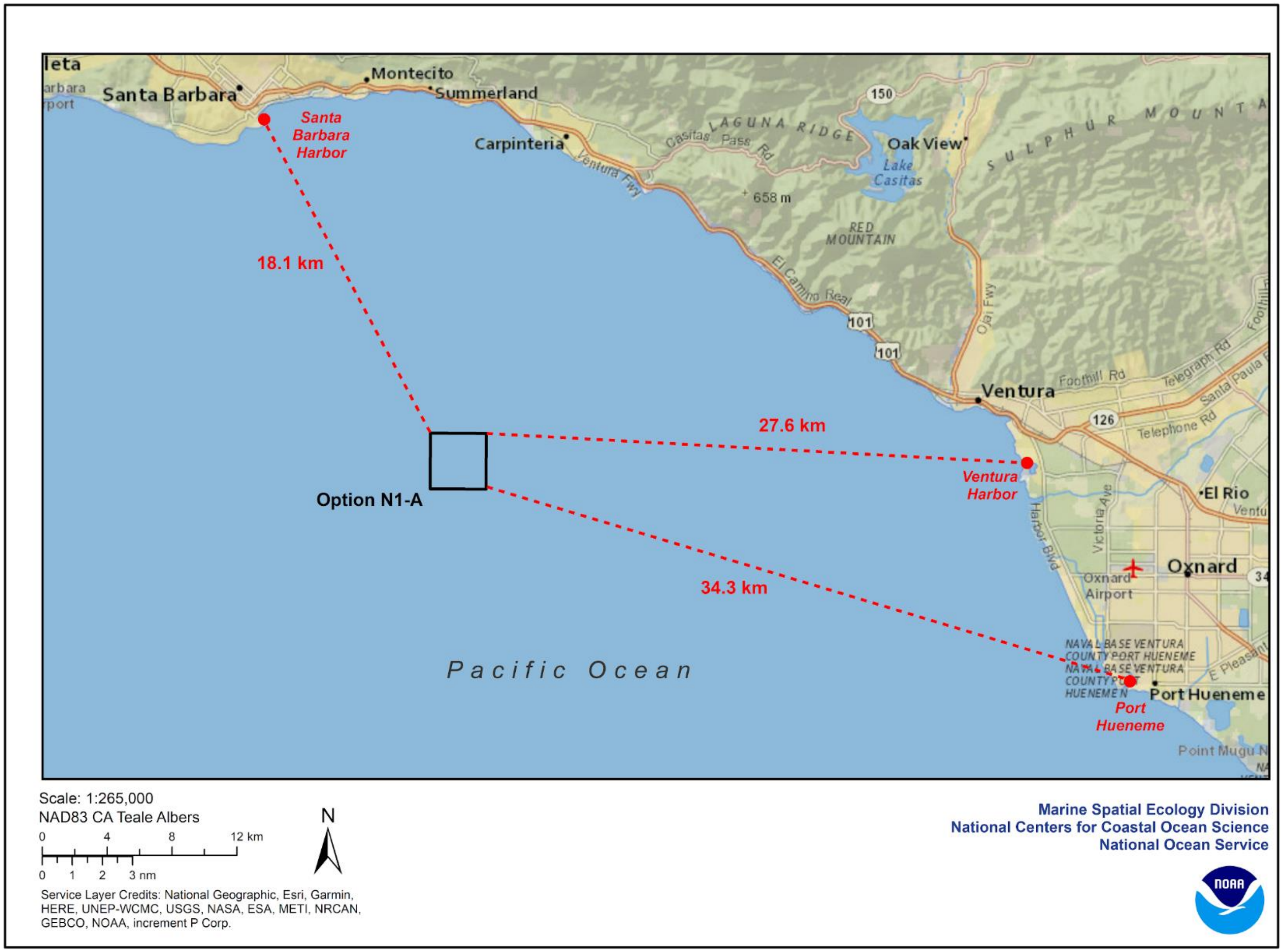


Figure 3.59. Option N1-A (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.8. Automatic Identification System vessel traffic transits by year for the N1-A option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N1-A	Cargo	35.50	0	0	0	0.50	0
N1-A	Fishing	4.00	10.00	2.75	4.75	4.00	2.25
N1-A	Military	0	0	0	0	0	0
N1-A	Other	31.00	15.25	17.75	29.50	51.75	37.50
N1-A	Passenger	24.75	19.75	19.75	18.00	21.75	7.75
N1-A	Pleasure and Sailing	9.50	10.75	10.50	16.75	17.25	10.25
N1-A	Tanker	0	0	0	0	0	0
N1-A	Tug and Tow	0.25	0.75	0.25	1.00	1.25	1.00

AOA Option N1-B

AOA option N1-B is a 1,500-acre site within the Santa Barbara Channel and offshore of the city of Carpinteria and the counties of Santa Barbara and Ventura. The site is 20.8 km (11.2 nm) from Santa Barbara Harbor, 23.7 km (12.8 nm) from Ventura Harbor, and 30.6 km (16.5 nm) from Port Hueneme (Table 3.7; Figure 3.60).

Depth and Substrate Type

The site ranges in depth from 78 m to 92.6 m with an average depth of 84.7 m. N1-B slopes gently with an average slope of 0.7 degrees (Figure 3.46). The shallowest section of the site is found in the northeast corner and the deepest in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N1-B is composed of approximately 95% mud-like (coarse silt) substrate. As proximity increases to the bathymetric rise in the southwest corner, sediment changes to predominantly very fine sand, which covers the remaining 5% of the site area. The mean sediment grain diameter is approximately 0.06 mm in N1-B, indicating coarse silt to very fine sand as the predominant substrate throughout the site. According to the data, no grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

Site N1-B is outside any active or inactive BOEM oil and gas lease blocks, but oil and gas infrastructure is found outside the site within a 5-km radius. The site is 4.7 km from platform habitat that is currently in a state of preservation (Figure 3.47). This effort is part of the first campaign of platform decommissioning in the region (BSEE 2020). Inactive oil and gas wells can be found 0.9 km from the site and an oil and gas pipeline 2.3 km from the site (Figure 3.47). There are also submarine fiber optic cables 4.7 km from the southwest corner of the site.

Vessel transits are found within the site with the highest from the other vessel category, followed by passenger then pleasure and sailing (Table 3.8). VMS fishing data show that the highest number of transits occurred from the California sea cucumber trawl fishery, followed by ridgeback prawn and prawn trap or pot gear fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 666, with an average annual landing of 329,875 pounds from 2010 to 2019 (Table 3.9).

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, which removed these areas from the remainder of the analysis. The nature of military activities varies over space and time as well, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site is within the BIA for gray whale migration and the newly established Critical Habitat for humpback whale Central America and Mexico DPS. The site is also 3.2 km from a deep-sea coral observation (Figure 3.48) and lies within the Santa Barbara Basin Important Bird Area.

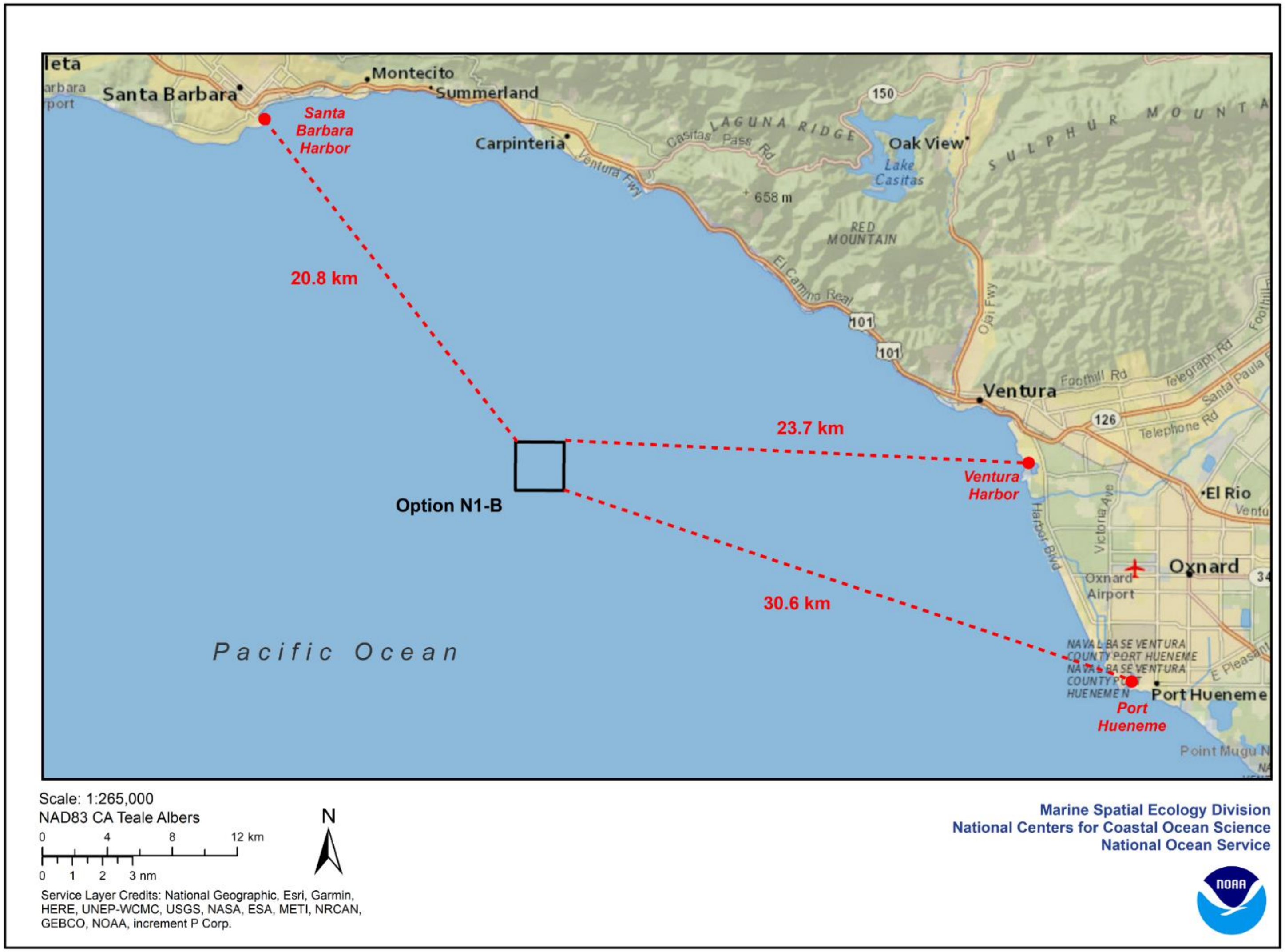


Figure 3.60. Option N1-B (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.9. Automatic Identification System vessel traffic transits by year for the N1-B option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N1-B	Cargo	21.00	0.67	0	0	1.33	0.00
N1-B	Fishing	2.67	10.00	2.33	3.33	4.00	1.67
N1-B	Military	0	0	0	0	0	0
N1-B	Other	27.33	12.67	16.67	27.00	53.67	29.33
N1-B	Passenger	25.00	14.33	15.67	14.67	31.67	12.00
N1-B	Pleasure and Sailing	9.33	10.33	10.00	17.33	13.00	8.67
N1-B	Tanker	0	0	0	0	0	0
N1-B	Tug and Tow	0.33	0.67	0	1.00	1.00	1.33

AOA Option N1-C

AOA option N1-C is a 1500-acre site within the Santa Barbara Channel and offshore of Rincon Point and Ventura County. From the site, it is 26.1 km (14.1 nm) to Santa Barbara Harbor, 20.7 km (11.2 nm) to Ventura Harbor, and 26.4 km (14.3 nm) to Port Hueneme (Table 3.7; Figure 3.61).

Depth and Substrate Type

The site ranges in depth from 77.3 m to 101.3 m with an average depth of 90 m. N1-C slopes gently with an average slope of 1.0 degree (Figure 3.46). The shallowest section of the site is found in the northeast corner and the deepest in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N1-C is composed of approximately 70% mud-like (coarse silt) substrate. As proximity increases to the bathymetric rise in the southwest corner, sediment changes to predominantly very fine sand, which covers the remaining 30% of the site area. The mean sediment grain diameter is approximately 0.03 mm in N1-C, indicating silt to very fine sand as the predominant substrate throughout the site. According to the data, less than 1% of grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

N1-C is within an inactive BOEM oil and gas lease block (217) and within 2.8 km of platform Grace, currently shut-in and part of the first campaign of platform decommissioning in the region (Figure 3.47) (BSEE 2020). Oil and gas infrastructure is found outside the site within a 5-km radius; this includes inactive wells (0.8 km) and pipelines (0.8 km). There are also submarine fiber optic cables 2.8 km from the site.

Vessel transits within the site are the highest by vessels from the other vessel category, followed by passenger then pleasure and sailing transits (Table 3.10). VMS fishing data show that the highest number of transits occurred from the California sea cucumber trawl fishery, followed by ridgeback prawn, and groundfish trap or pot gear fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing blocks 665 and 666 with average annual landings of 964,450 and 329,875 pounds, respectively, from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, which removed these areas from the remainder of the analysis. The nature of military activities varies over space and time as well, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site is within the BIA for gray whale migration and the newly established Critical Habitat for humpback whale Central America and Mexico DPS. The site is also 3.2 km from a deep-sea coral observation (Figure 3.48) and lies within the Santa Barbara Basin Important Bird Area.

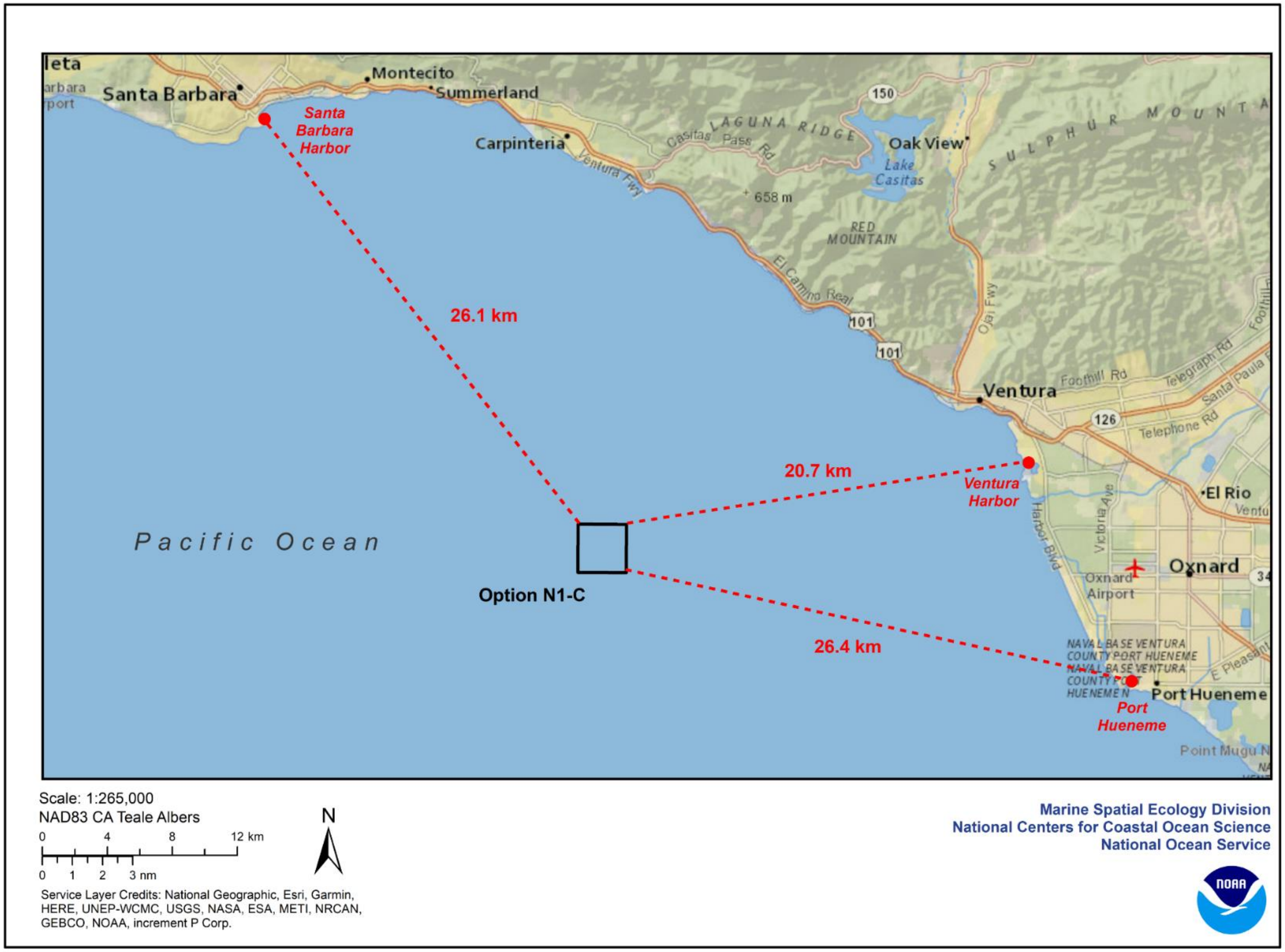


Figure 3.61. Option N1-C (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.10. Automatic Identification System vessel traffic transits by year for the N1-C option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N1-C	Cargo	64.00	0	0.33	0.33	5.00	0
N1-C	Fishing	4.00	11.33	6.67	7.33	6.00	4.00
N1-C	Military	0	0	0.33	0	0	0
N1-C	Other	134.00	72.33	50.33	42.33	69.33	57.67
N1-C	Passenger	44.33	31.67	28.00	31.67	40.33	47.00
N1-C	Pleasure and Sailing	10.33	8.33	10.00	20.33	19.00	16.00
N1-C	Tanker	0	0	0	0	0	0
N1-C	Tug and Tow	1.00	0.67	1.33	1.67	2.67	1.00

Characteristics of AOA Cluster N2

The following characteristics are similar among all AOA options within cluster N2 including N2-A, N2-B, N2-C, N2-D, and N2-E. Descriptive data (Table 3.11), maps, and figures are provided for the general location of the cluster (Figure 3.62), bathymetry (Figure 3.63), interactions with industry (Figure 3.64), national security (Figure 3.65), interactions with natural resources (Figure 3.66), water temperature (Figure 3.67), current velocity and direction (Figures 3.68 - 3.70), wind velocity and direction (Figure 3.71), wave height and period (Figure 3.72), nutrient concentrations (Figure 3.73), chlorophyll-*a* concentration (Figure 3.74), light attenuation characteristics (Figure 3.75), and light transmissivity (Figure 3.76).

Water Temperature and Salinity

Water temperature in southern California fluctuates seasonally with a mean water temperature at the surface of 16.4°C, a minimum of 11°C, and a maximum of 22.4°C between 2016 and 2020 (Figure 3.67). The average temperature decreases to 15.6°C at 10-m depth and is the lowest at 40-m depth (12.7°C). Seasonally, temperature at the surface peaks in August and is lowest in April. Years with the highest surface water temperatures were 2016 and 2017. The surface salinity was consistent throughout the year and among sites, with an average of 33.6 psu.

Current Speed and Direction, Wind Speed and Direction, and Significant Wave Height

Current speed and direction vary by month and depth with a southeasterly direction on the surface. The annual average current velocity from the CA ROMS model from 2016 to 2020 at the surface was 0.14 m/s, with a minimum of 0 m/s and a maximum of 0.58 m/s, respectively (Figure 3.64). Current speed decreases with depth, with average current speeds of 0.11 m/s at 10-m depth and 0.08 m/s at 40-m depth. The current speed did not exceed 1 m/s over the five-year period. Wind velocity at the site averaged 4.5 m/s, with a minimum of 0 m/s and a maximum of 19.1 m/s. Wind was predominantly from the west (Figure 3.65). The average significant wave height from 1979 to 2010 was 0.97 m with a period of 12.1 seconds, with waves predominantly from the west (Figure 3.66).

Water Quality Considerations

Mean nutrient concentration for nitrate, phosphate, and dissolved oxygen at depth is an indicator of ocean health. Nitrate ranged from 0.98 mmol/m^3 at 10-m depth to 6.35 mmol/m^3 at 50-m depth (Figure 3.73). Phosphate ranged from 0.51 mmol/m^3 at 10-m depth to 0.91 mmol/m^3 at 50-m depth. Dissolved oxygen decreased from 263 mmol/m^3 at 10-m depth to 225 mmol/m^3 at 50-m depth. Chlorophyll-*a* concentration (mg/m^3), which is an indicator of phytoplankton abundance, was highest in May (3.0 mg/m^3) and lowest in October (0.97 mg/m^3) (Figure 3.74). The diffuse light coefficient at 490 nm, Kd(490), is an indicator of water turbidity. Kd(490) was lowest for the month of October (Kd(490) = 0.09 m^{-1}) and was highest in April (Kd(490) = 0.24 m^{-1}) (Figure 3.75). Percent light transmissivity was calculated at 1-m depth, providing the percent of light that reaches that depth. Percent light transmissivity was highest in October at 86.8% and lowest in April at 77.1% (Figure 3.76).

Table 3.11. Characterization summary for Aquaculture Opportunity Area options N2-A, N2-B, N2-C, N2-D, and N2-E.

North 2 (N2)	N2-A	N2-B	N2-C	N2-D	N2-E
General Characteristics					
Corner Coordinates (latitude, longitude) (decimal degrees)	34.262, -199.442	34.234, -199.427	34.205, -199.421	34.236, -199.393	34.215, -199.359
	34.262, -199.473	34.234, -199.458	34.206, -199.452	34.236, -199.424	34.216, -199.390
	34.288, -199.473	34.259, -199.458	34.231, -199.452	34.262, -199.424	34.241, -199.390
	34.288, -199.442	34.259, -199.427	34.231, -199.421	34.262, -199.393	34.241, -199.359
Size (acres)	2000	2000	2000	2000	2000
Santa Barbara Harbor (km to port, nm to port)	23.8 (12.9)	26.8 (14.5)	29.2 (15.8)	29.2 (15.8)	33.1 (17.9)
Ventura Harbor (km to port, nm to port)	16.3 (8.8)	14.8 (8.0)	14.3 (7.8)	11.7 (6.3)	8.6 (4.6)
Port Hueneme (km to port, nm to port)	24.9 (13.4)	22.2 (12.0)	20.5 (10.2)	19.5 (9.6)	15.7 (7.5)
Depth (m) (minimum, maximum, mean), Average slope (°)	(41.9, 60.5, 51.2), 0.7	(38.9, 56.0, 47.3), 0.7	(34.8, 63.7, 48.1), 0.8	(25.5, 39, 31.5), 0.8	(23.1, 29.8, 25.4), 1.0
Industry, Navigation, and Transportation (within 5 km)					
Oil and Gas Platforms, Name, and Status (within 5 km)	No	No	Gilda (producing) Grace (Shut-in)	No	Gilda (producing)
Number of Boreholes	12 (1.7 km)	5 (4.0 km)	181 (1.4 km)	13 (3.8 km)	134 (1.8 km)
BOEM Oil and Gas Active Lease Block	No	No	216	No	215, 216
Oil and Gas Pipelines	Yes (2.1 km)	Yes (2.3 km)	Yes (1.8 km)	No	Yes (3.2 km)
Submarine Cables	No	No	Yes (2.6 km)	No	Yes (3.2 km)
CalCOFI Sampling Site	Yes (4.5 km)	Yes (1.5 km)	Yes (1 km)	Yes (0.7 km)	Yes (1.8, 3.9 km)
CDFW Block Number and Average Catch 2010 - 2019 (pounds)	665	665	665	665	665
	964,450	964,450	964,450	964,450	964,450
National Security					
Overlap with MOAs (yes/no)	No	No	No	No	No
Overlap with MTR (yes/no)	Yes	Yes	Yes	Yes	Yes
Natural and Cultural Resources (within 5 km)					
Habitat - Hardbottom Substrate	Yes (2.3 km)	Yes (4.3 km)	No	No	Yes (3.5 km)
Habitat - Deep-sea Corals	No	No	No	No	No
HAPC - Rocky Reef	No	No	No	No	No
Important Bird Areas	Santa Barbara Basin	Santa Barbara Basin	Santa Barbara Basin	Santa Barbara Basin	Santa Barbara Basin
Cetacean Biologically Important Areas	Gray Whale - Migration	Gray Whale - Migration	Gray Whale - Migration	Gray Whale - Migration	Gray Whale - Migration
Critical Habitat - Humpback Whale	Yes	Yes	Yes	No	No

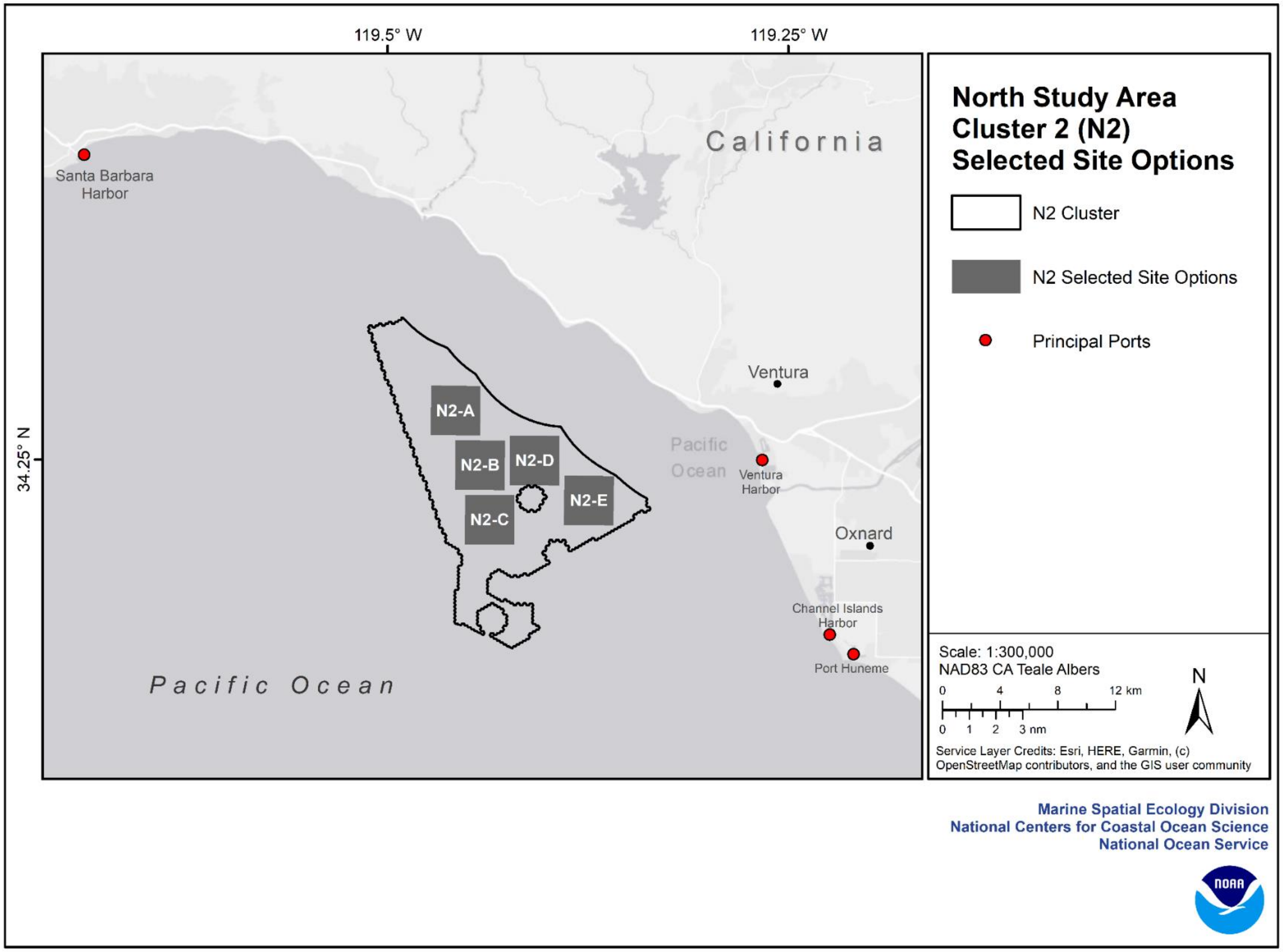


Figure 3.62. North study area cluster N2 with five of the top-ranked southern California Aquaculture Opportunity Area options, N2-A, N2-B, N2-C, N2-D, and N2-E.

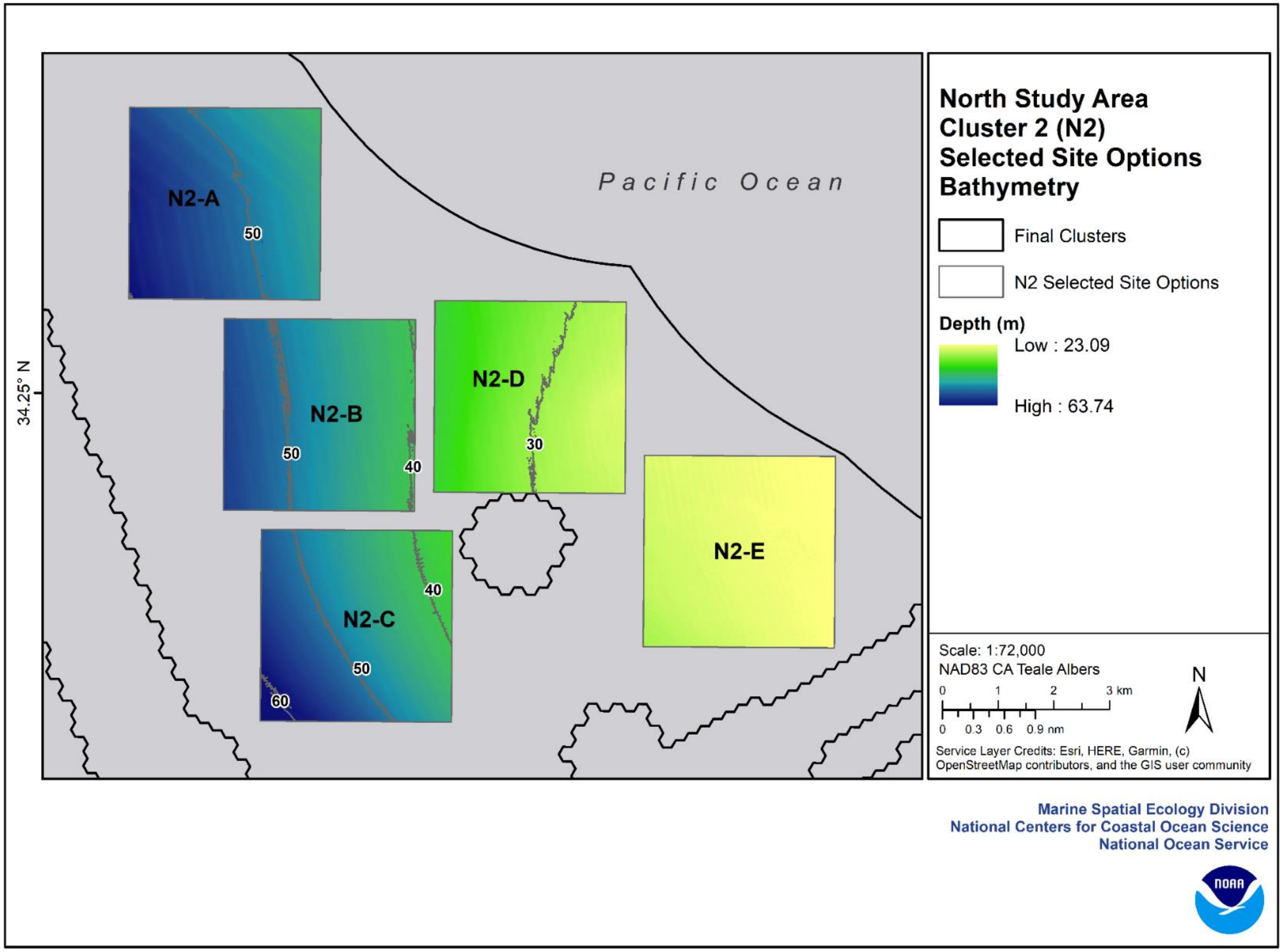


Figure 3.63. Bathymetry for southern California Aquaculture Opportunity Area options N2-A, N2-B, N2-C, N2-D, and N2-E.

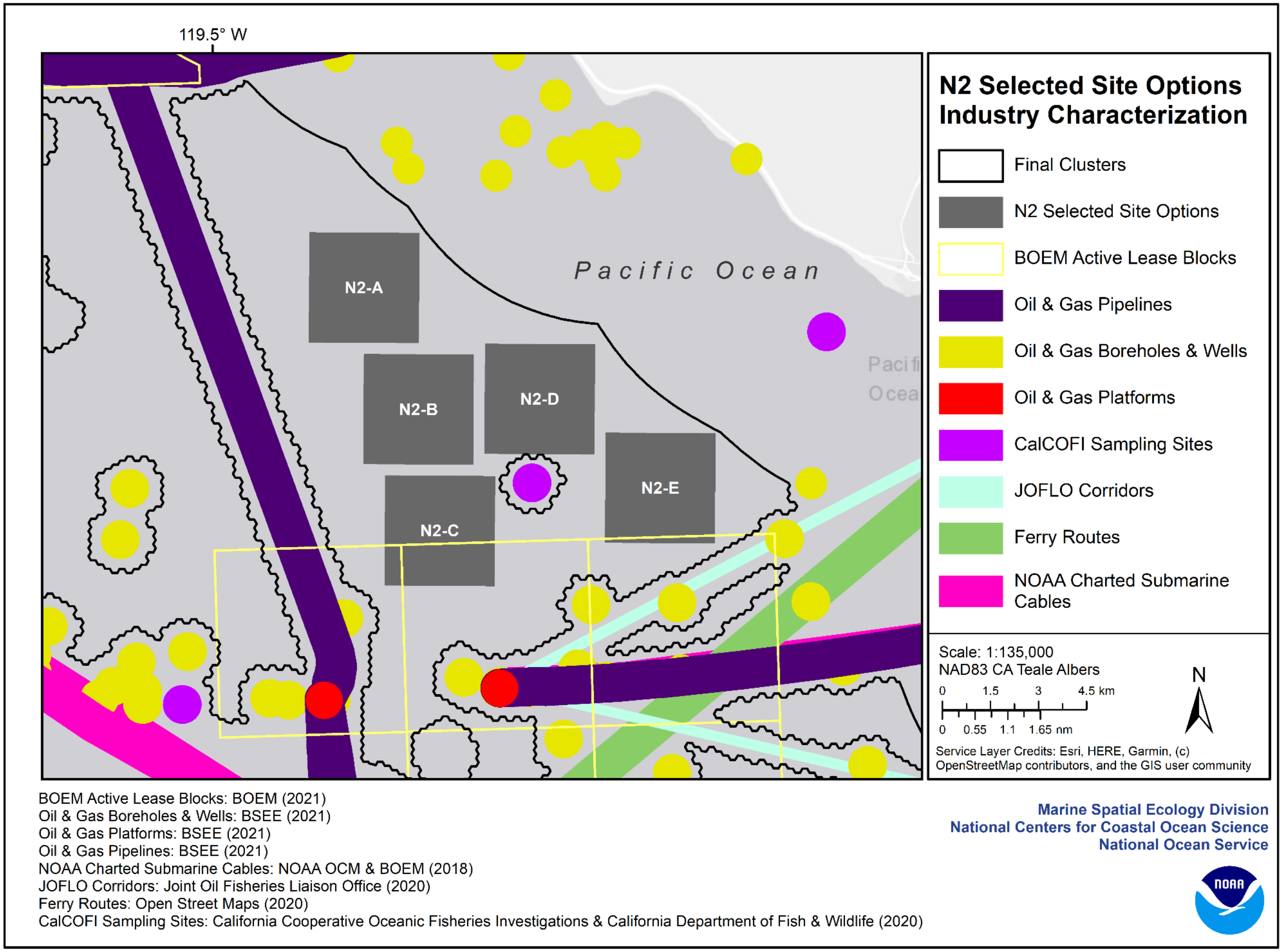


Figure 3.64. Industry interactions for southern California Aquaculture Opportunity Area options N2-A, N2-B, N2-C, N2-D, and N2-E.

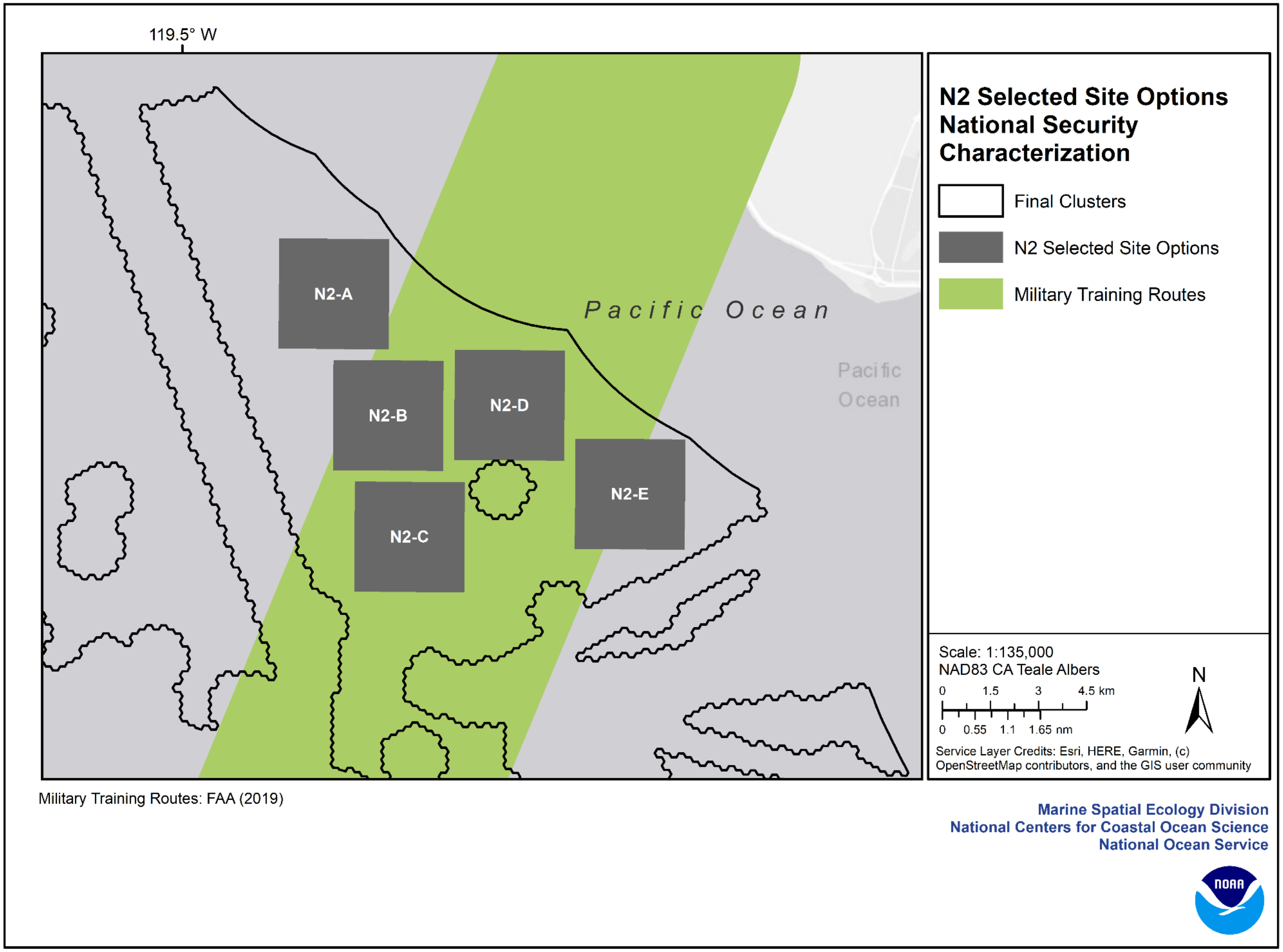


Figure 3.65. National security interactions with southern California Aquaculture Opportunity Area options N2-A, N2-B, N2-C, N2-D, and N2-E.

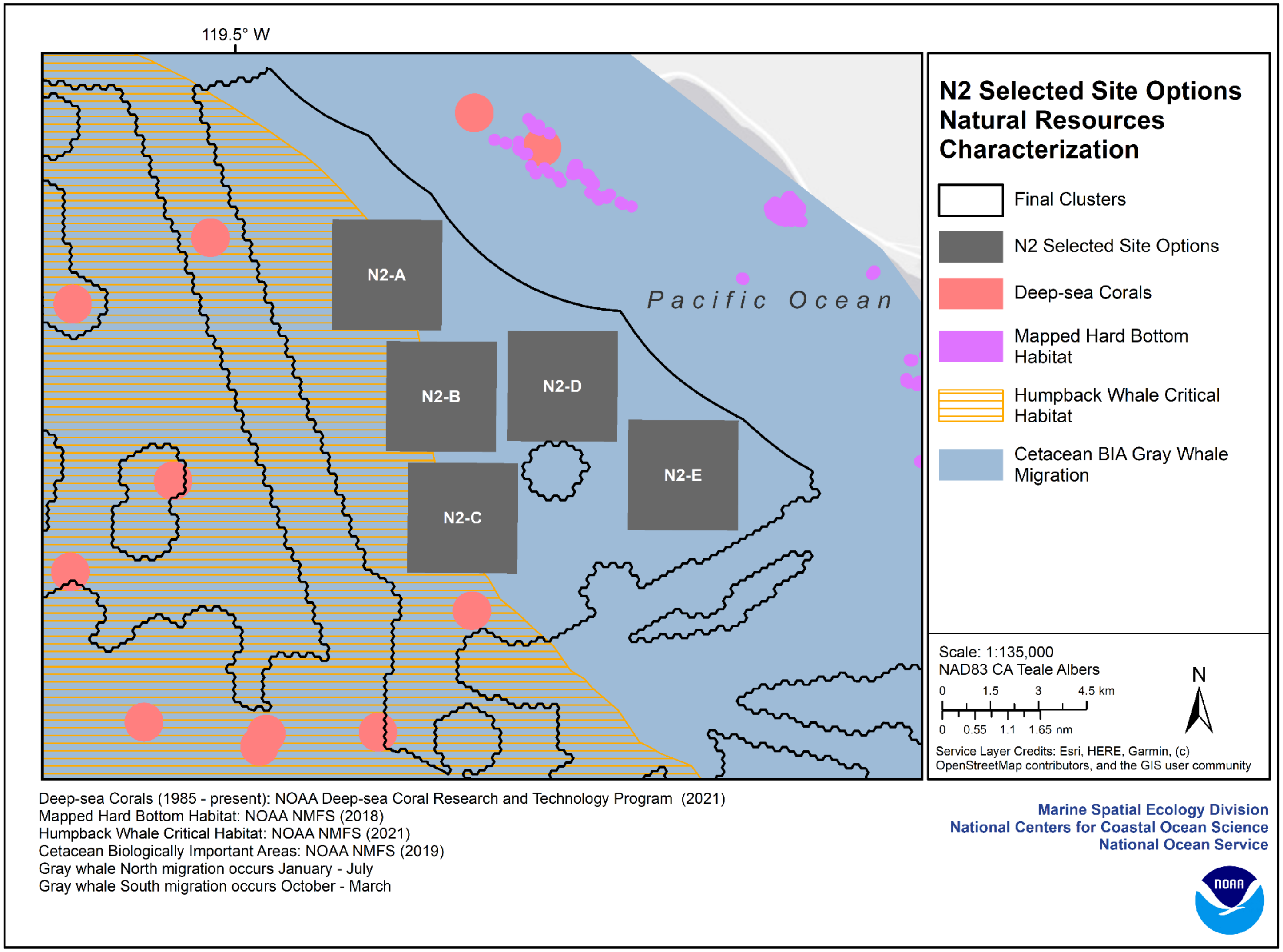


Figure 3.66. Natural resource overlap with Aquaculture Opportuity Area options N2-A, N2-B, N2-C, N2-D, and N2-E.

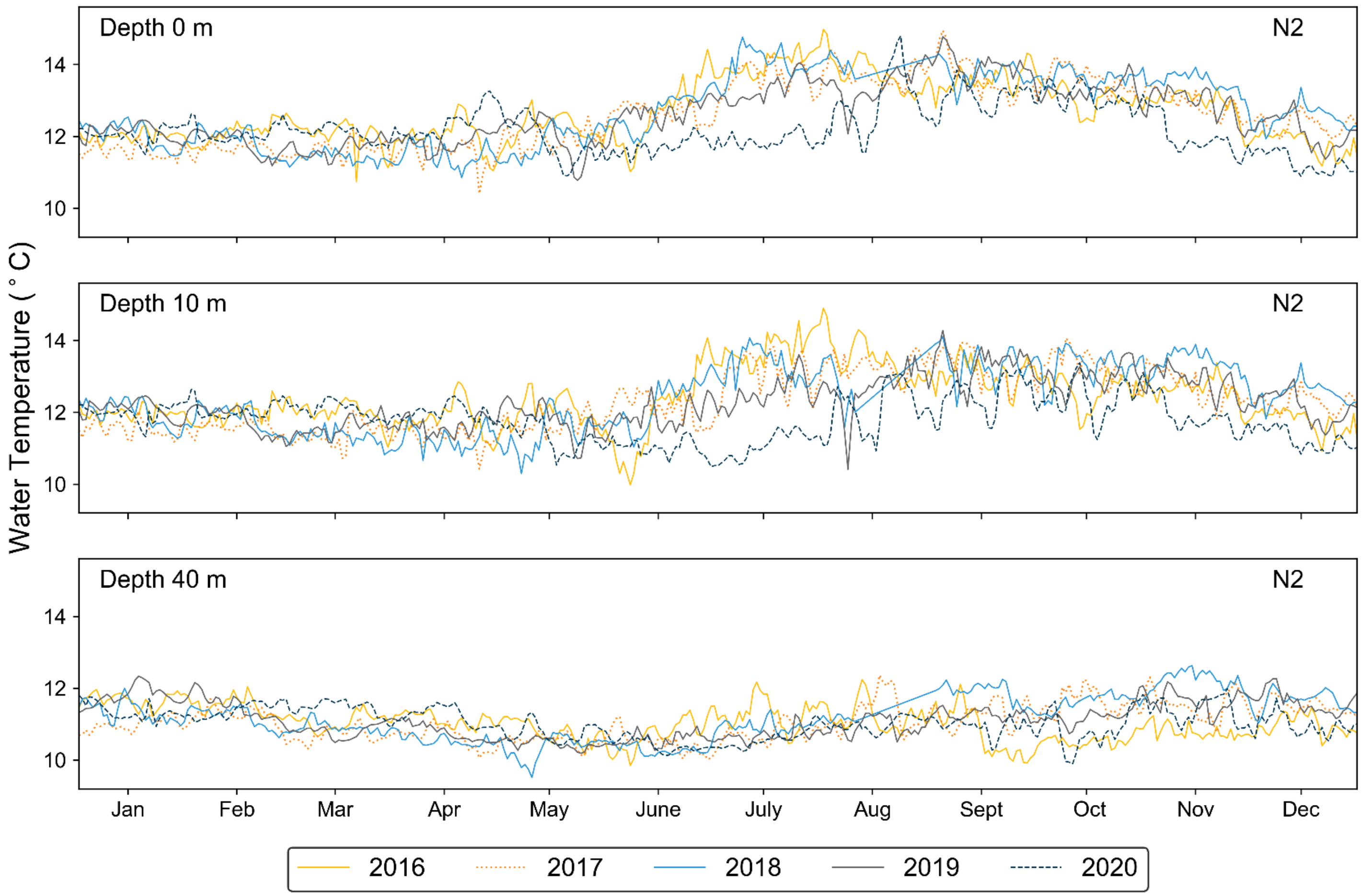


Figure 3.67. Water temperature at 0 m, 10m, and 40 m for cluster N2 from the California Regional Ocean Modeling System model (2016 - 2020).

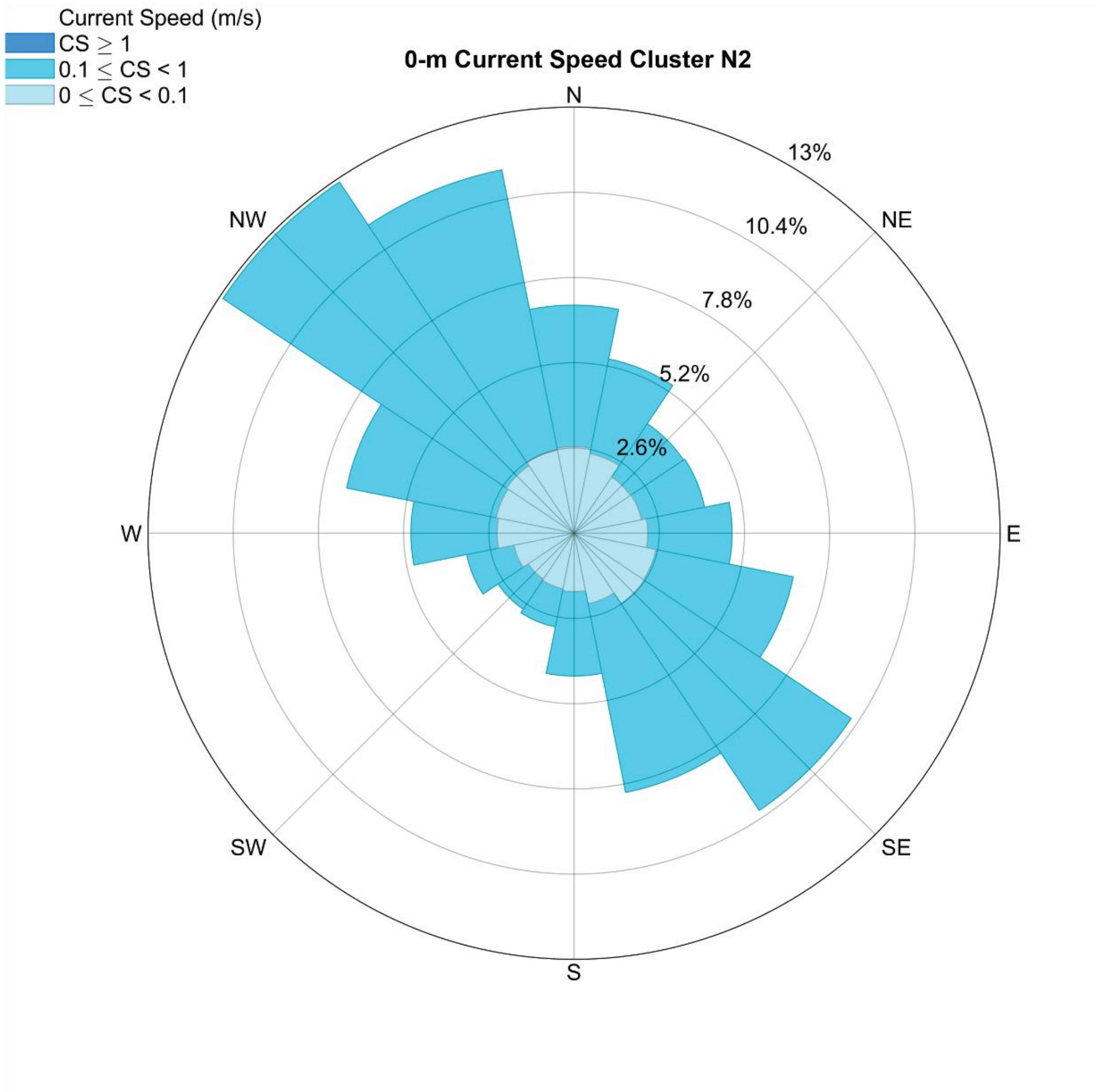


Figure 3.68. Ocean current magnitude and direction for cluster N2 at the ocean surface. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

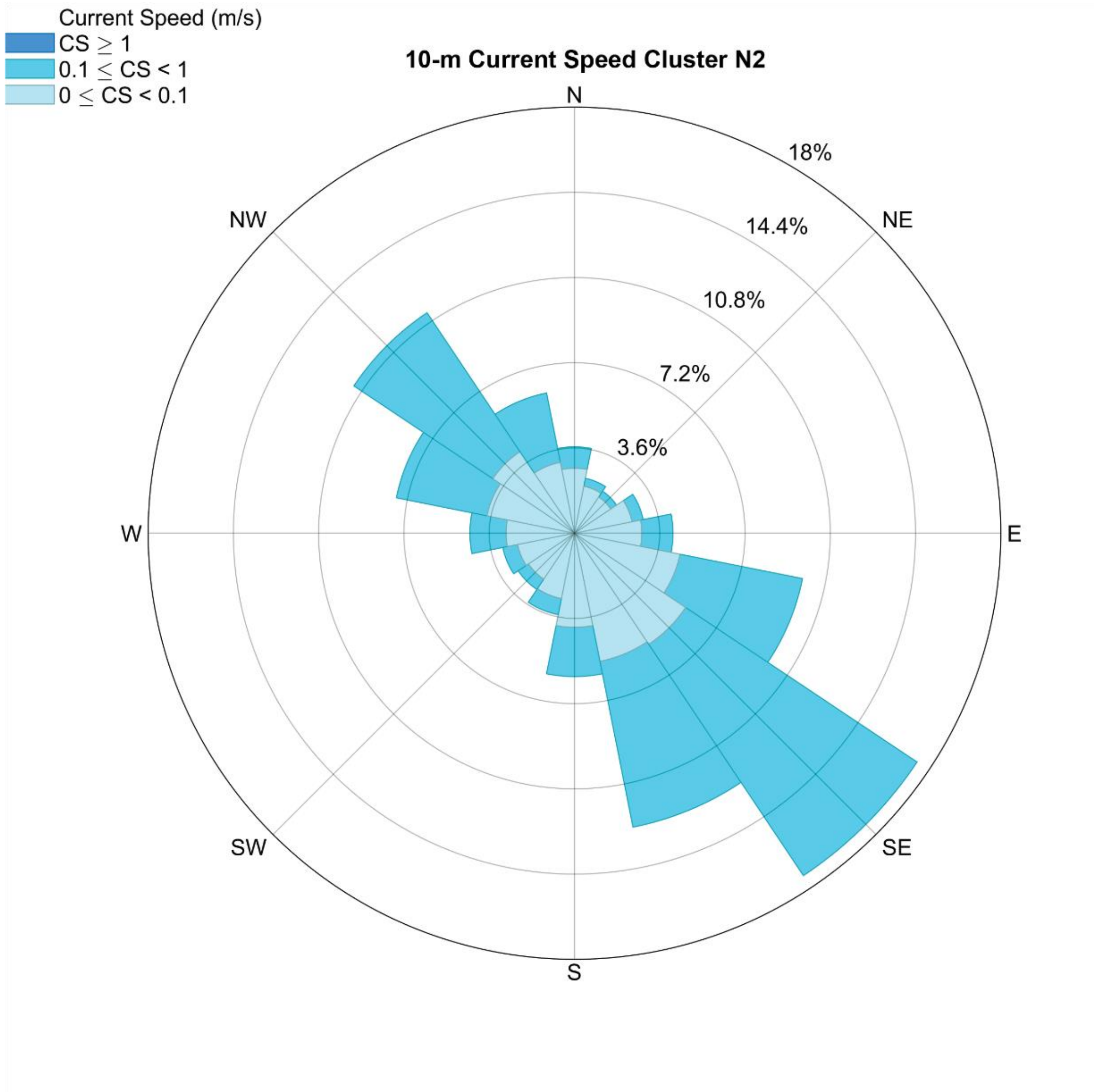


Figure 3.69. Ocean current magnitude and direction for cluster N2 at 10-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

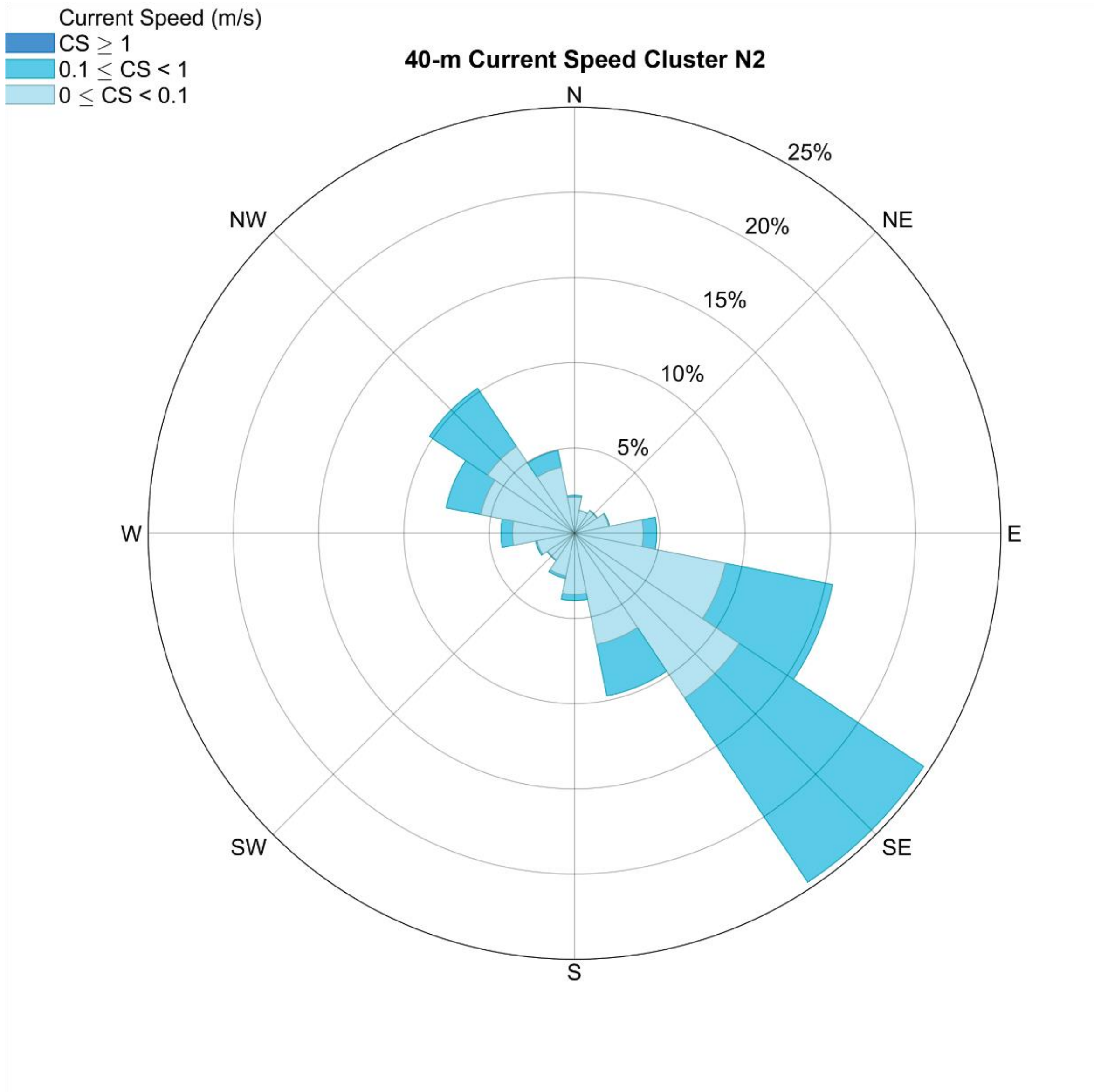


Figure 3.70. Ocean current magnitude and direction for cluster N2 at 40-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

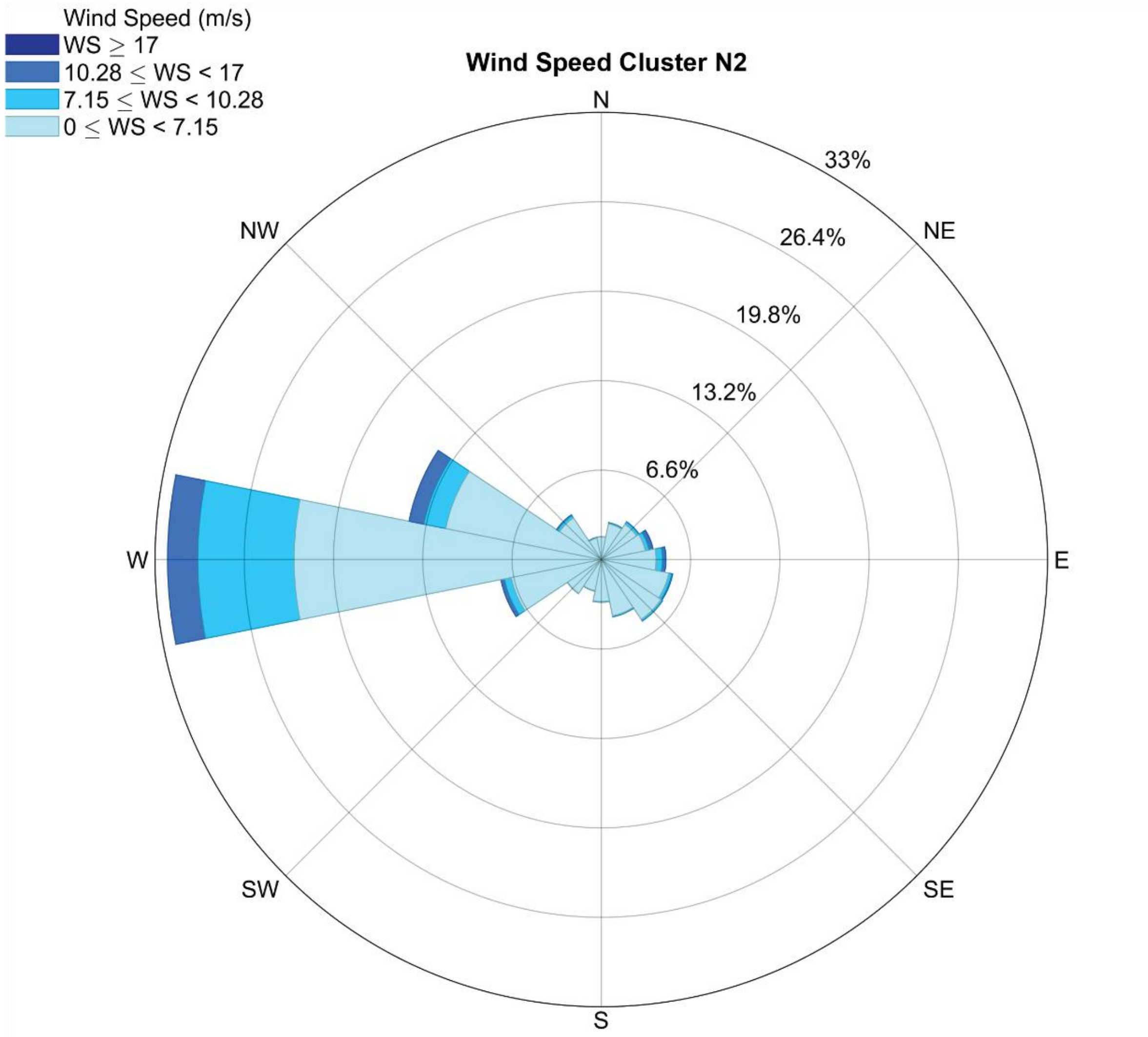


Figure 3.71. Wind velocity and direction at 10-m above sea level for cluster N2. The rose diagram provides percent occurrence for each wind speed (WS) category. Wind direction is displayed as the origin. Wind data are from the Coupled Ocean/Atmosphere Mesoscale Prediction System model (2016 - 2020).

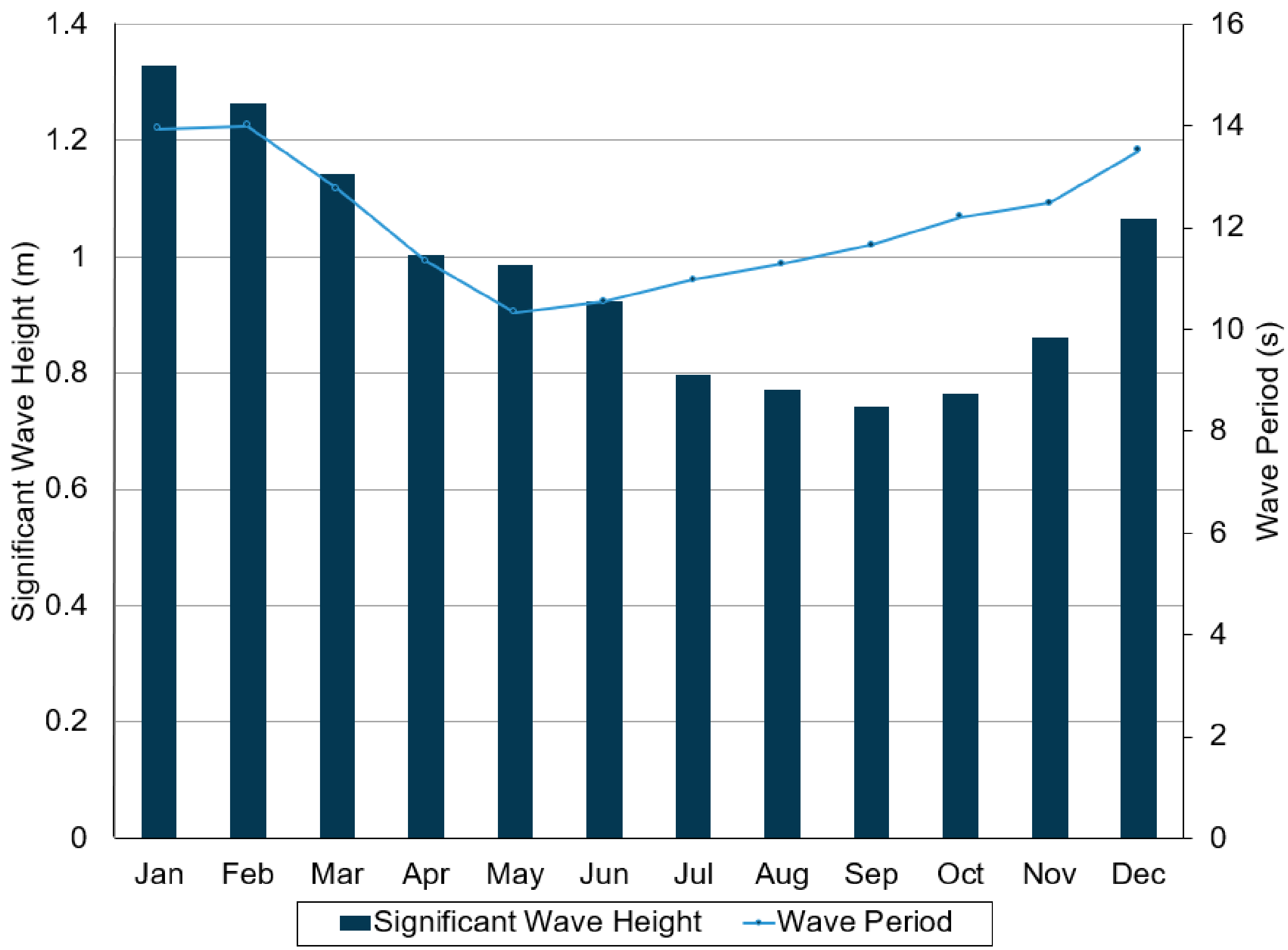


Figure 3.72. Wave height and period for cluster N2 from the Pacific Northwest National Laboratory Simulating WAves Nearshore wave model (1979 - 2010).

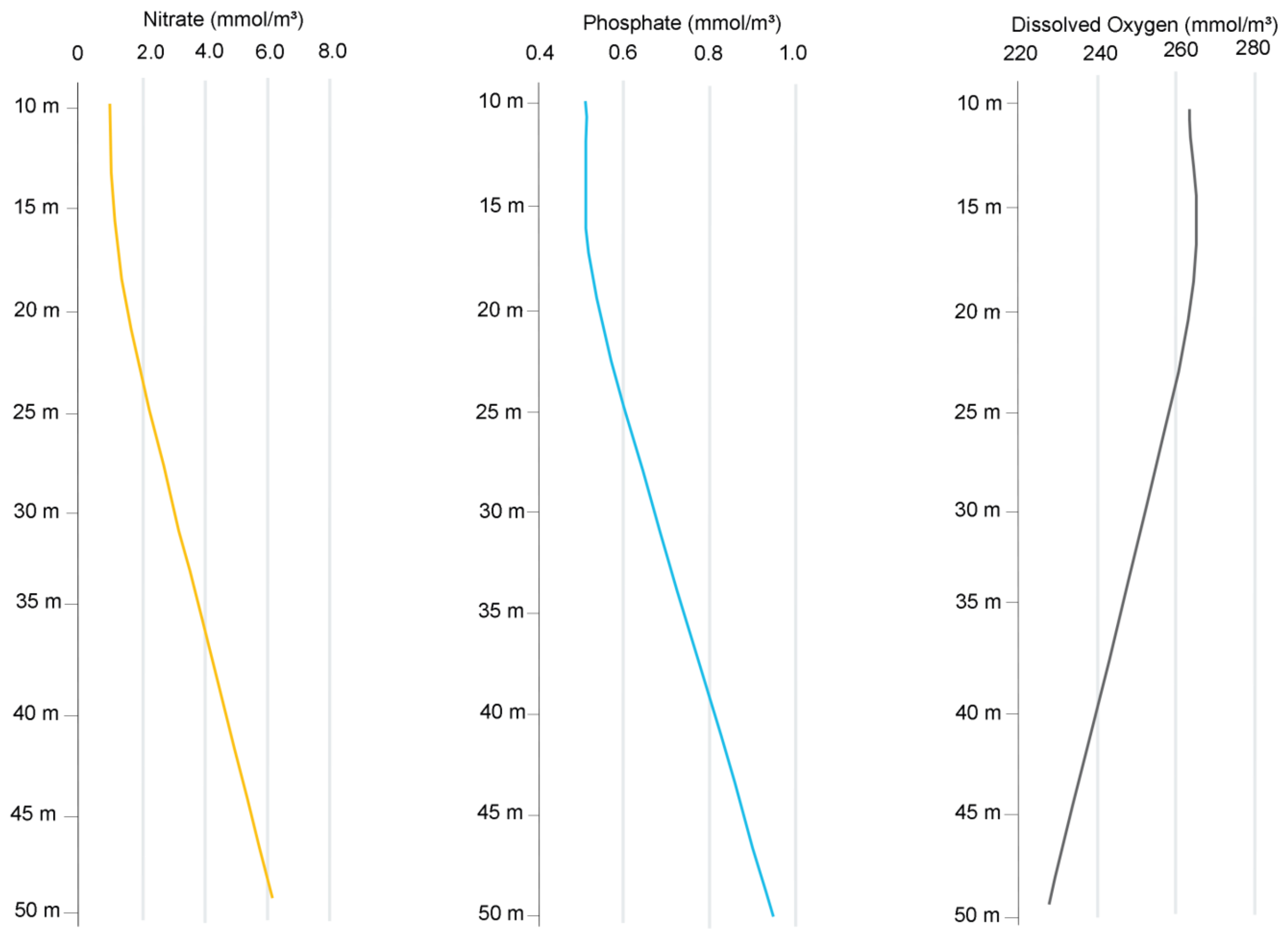


Figure 3.73. Cluster N2 concenration of nitrate, phosphate, and dissolved oxygen at depth (Kessouri et al. 2021).

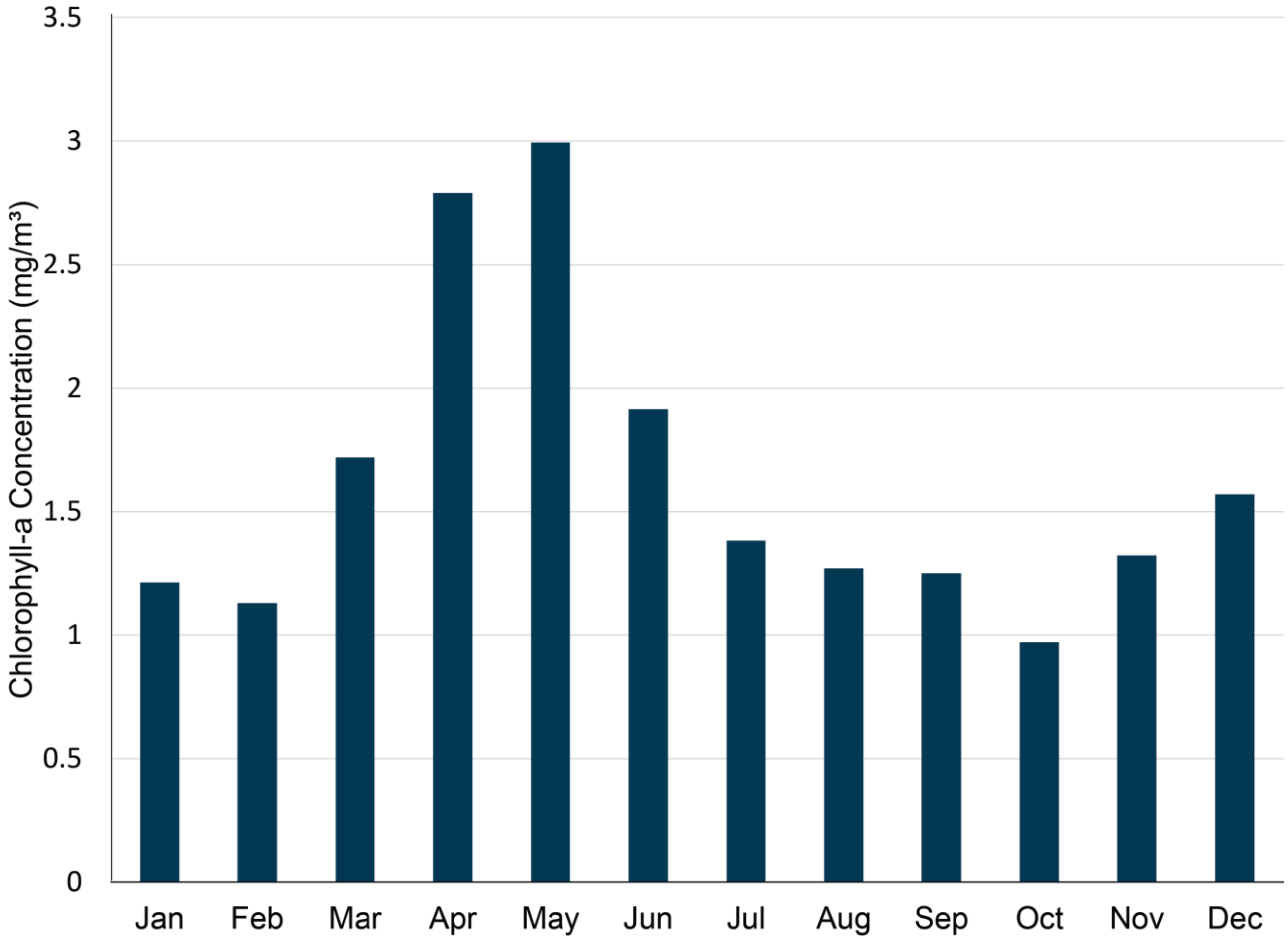


Figure 3.74. Cluster N2 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

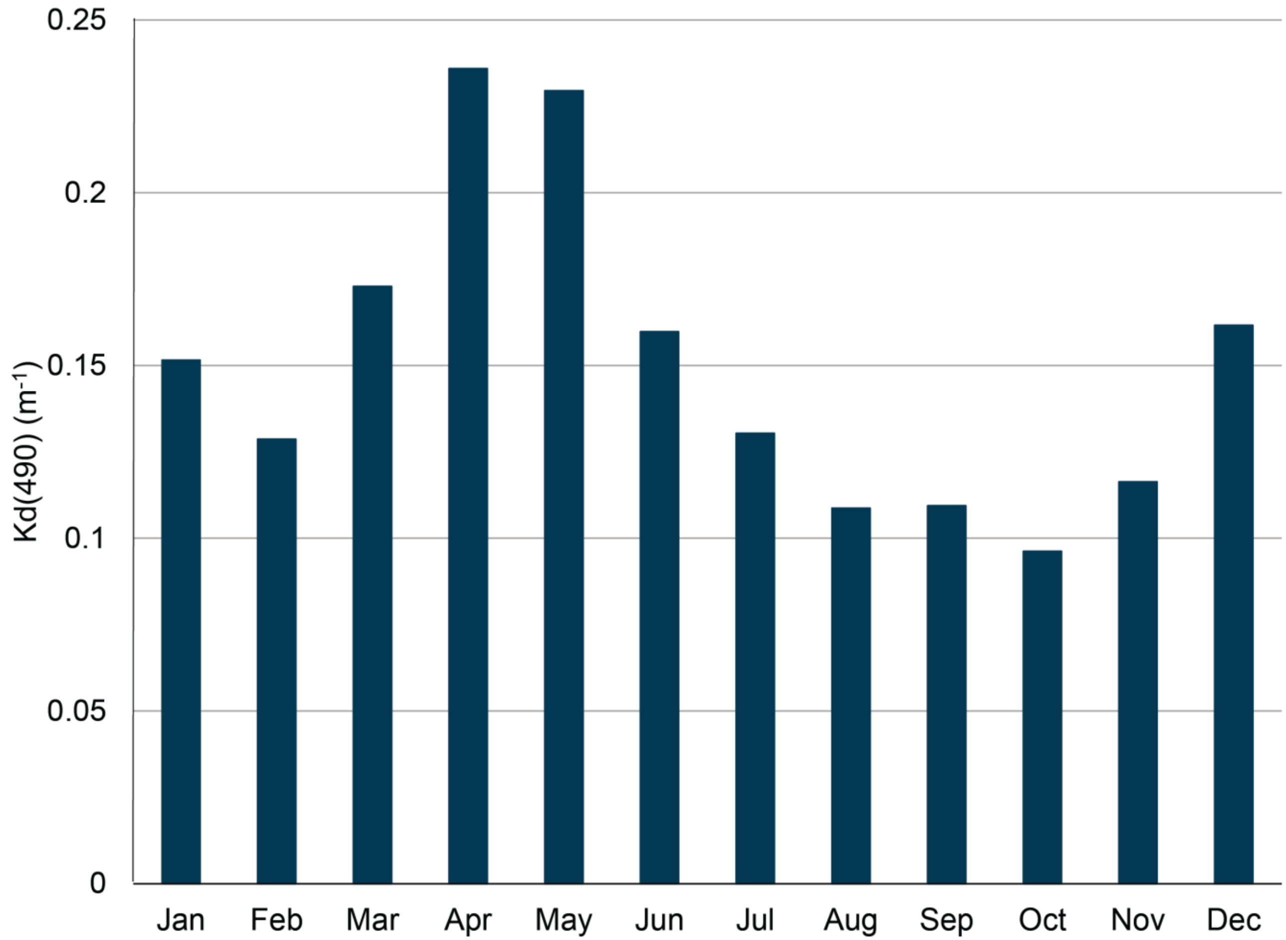


Figure 3.75. Cluster N2 monthly climatological mean (2010 - 2017) for light attenuation, Kd(490), at the sea surface produced by Visible Infrared Imaging Radiometer Suite 750-m data.

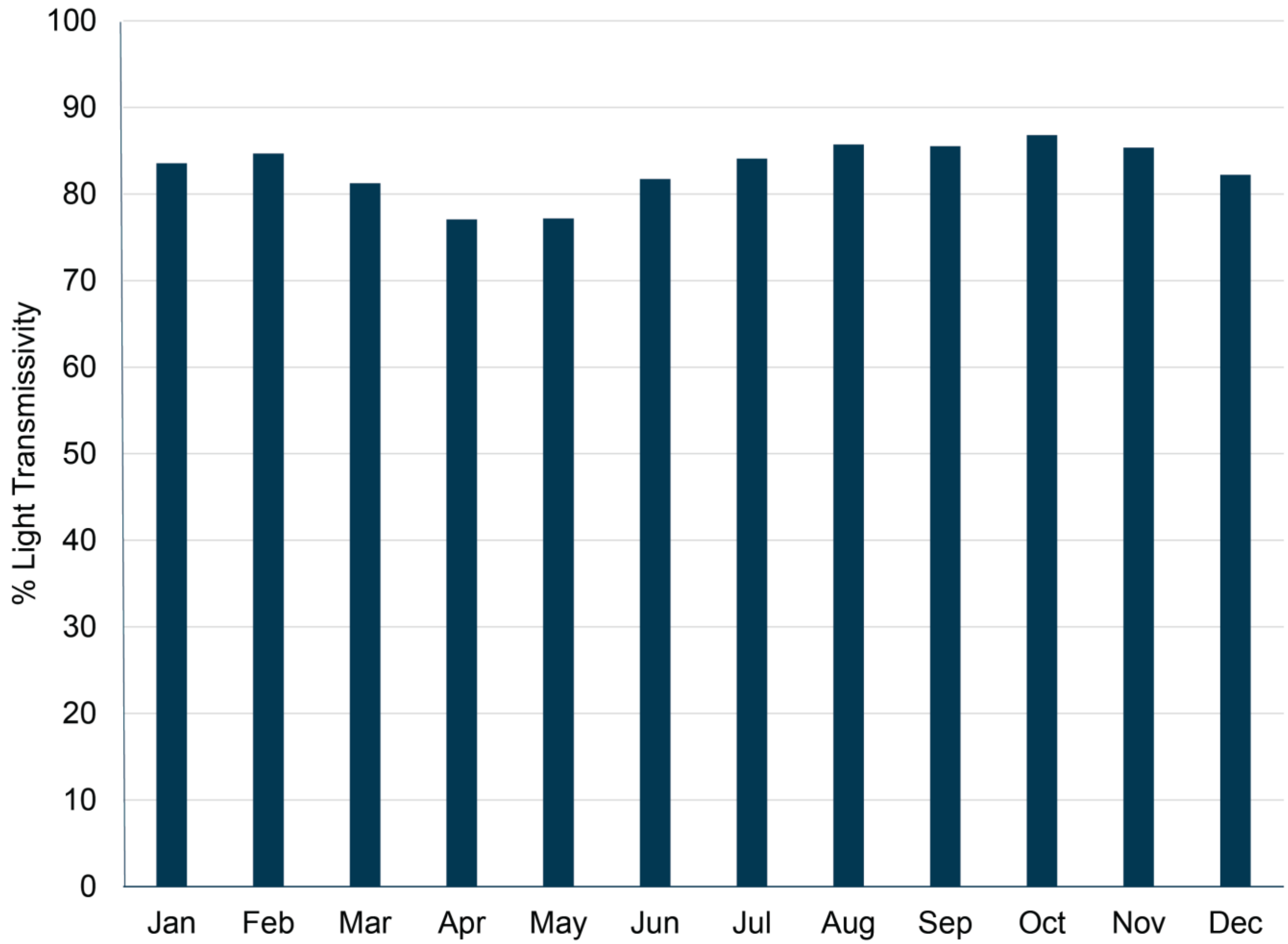


Figure 3.76. Cluster N2 monthly climatological mean (2010 - 2018) for percent light transmissivity at 1 m produced by Visible Infrared Imaging Radiometer Suite 750-m data.

AOA Option N2-A

AOA option N2-A is a 2,000-acre site within the Santa Barbara Channel, offshore of Rincon Point and Ventura County. The site is 23.8 km (12.9 nm) from Santa Barbara Harbor, 16.3 (8.8 nm) from Ventura Harbor, and 24.9 km (13.4 nm) from Port Hueneme (Table 3.11; Figure 3.77).

Depth and Substrate Type

The site ranges in depth from 41.9 m to 60.5 m with an average depth of 51.2 m (Figure 3.63). Option N2-A slopes gently, with an average slope of 0.7 degrees. The shallowest section of the site is found in the northeast corner, and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N2-A is composed of approximately 98.5% mud-like (coarse silt) substrate. As proximity increases to the bathymetric rise in the southwest corner, sediment changes to predominantly sand, which covers the remaining 1.5% of the site area. The mean sediment grain diameter is approximately 0.016 mm in N2-A, indicating medium to fine silt as the predominant substrate throughout the site. No grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

Site N2-A is outside any active or inactive BOEM oil and gas lease blocks, but oil and gas infrastructure is found outside the site within a 5-km radius. Inactive oil and gas wells can be found 1.7 km from the site, as can an oil and gas pipeline (2.1 km), and a CalCOFI sampling site (4.5 km) (Figure 3.64). Vessel transits are found within the site, with the highest from passenger vessels, followed by pleasure and sailing transits then other vessel transits (Table 3.12). VMS fishing data show that the highest number of transits occurred from the prawn trap or pot gear fishery, followed by Dungeness crab trap or pot gear, and California halibut trawl fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 665, with an average annual landing of 964,450 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, which removed these areas from the remainder of the analysis. Site N2-A is within a small portion of the MTR, which may place limits on the height of the operation and the use of drones at the site (Figure 3.65). The nature of military activities varies over space and time, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site is within the BIA for gray whale migration and a portion of the newly established Critical Habitat for humpback whale Central America and Mexico DPS. The site is also 2.3 km from hardbottom habitat (Figure 3.66) and lies within the Santa Barbara Basin Important Bird Area.

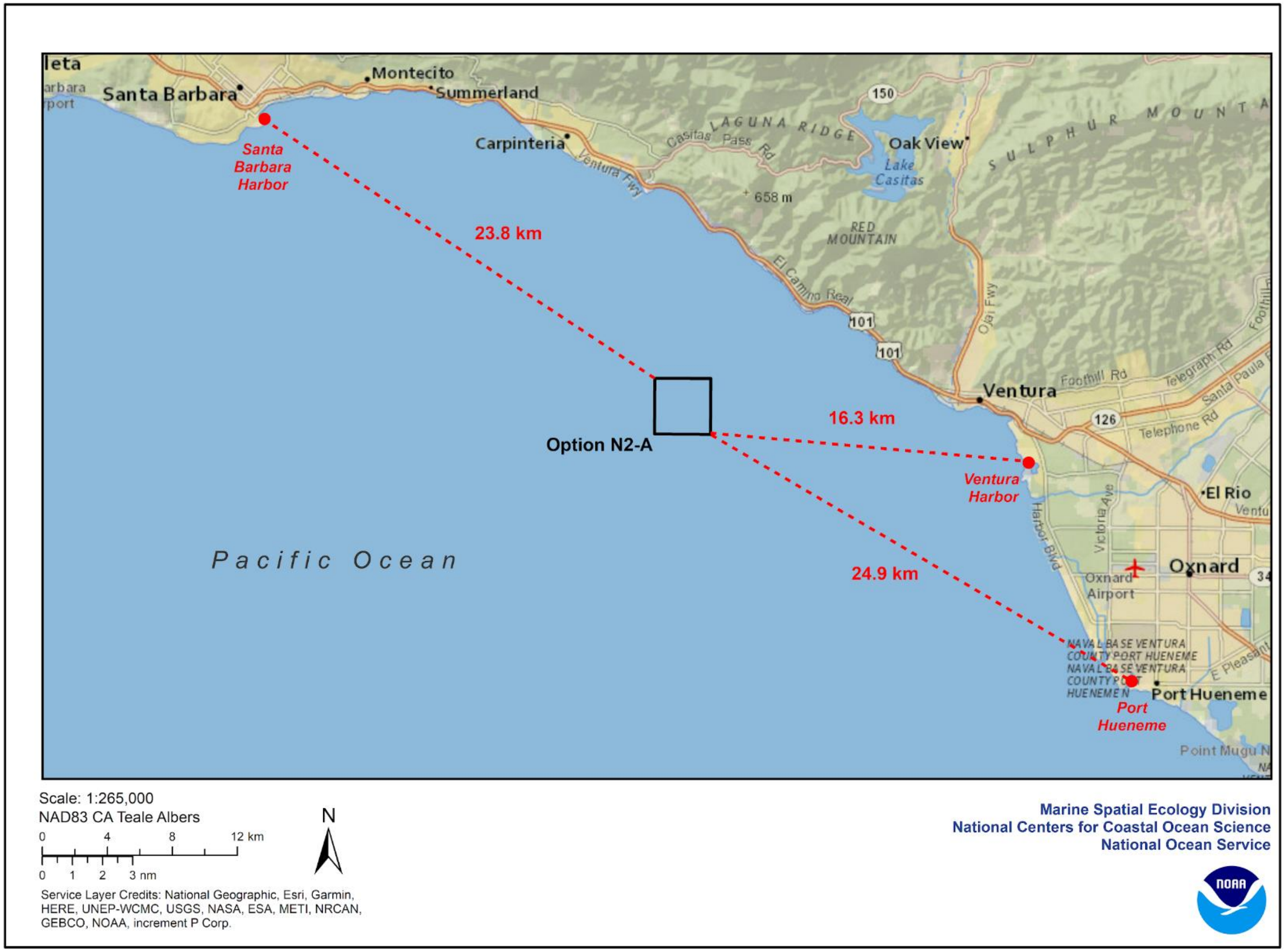


Figure 3.77. Option N2-A (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.12. Automatic Identification System vessel traffic transits by year for the N2-A option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N2-A	Cargo	0.50	0	0	0	4.00	2.50
N2-A	Fishing	6.50	13.50	4.75	13.00	8.50	5.25
N2-A	Military	0	0	0	0	0	0
N2-A	Other	34.25	20.75	30.50	31.00	28.75	24.50
N2-A	Passenger	92.75	57.25	134.75	86.00	197.00	86.75
N2-A	Pleasure and Sailing	24.75	22.75	31.00	50.75	52.00	38.75
N2-A	Tanker	0	0	0	0	0	0
N2-A	Tug and Tow	0.25	0.50	0.50	0.75	0	0.75

AOA Option N2-B

AOA option N2-B is a 2,000-acre site within the Santa Barbara Channel, offshore of Rincon Point and Ventura County. The site is 26.8 km (14.5 nm) from Santa Barbara Harbor, 14.8 km (8 nm) from Ventura Harbor, and 22.2 km (12 nm) from Port Hueneme (Table 3.11; Figure 3.78).

Depth and Substrate Type

The site ranges in depth from 38.9 to 56 m with an average depth of 47.3 m (Figure 3.63). Option N2-B slopes gently with an average slope of 0.7 degrees. The shallowest section of the site is found in the northeast corner and the deepest in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N2-B is composed of approximately 99% mud-like (coarse silt) substrate; patches of sand cover the remaining 1% of the site area. The mean sediment grain diameter is approximately 0.016 mm in N2-B, indicating medium to fine silt as the predominant substrate throughout the site. According to the data, no grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

N2-B is outside any active or inactive BOEM oil and gas lease blocks, but within a 5-km radius of an oil and gas pipeline (2.3 km) and inactive oil and gas wells (4 km), and 1.5 km from a CalCOFI sampling site (Figure 3.64). Vessel transits occur in the site with the highest from passenger vessels, followed by pleasure and sailing transits and other vessel transits (Table 3.13). VMS fishing data show that the highest number of transits occurred from the Dungeness crab trap or pot gear fishery, followed by prawn trap or pot gear and California gillnet fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 665, with an average annual landing of 964,450 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture 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. Site N2-B is within the MTR, which may place limits on the height of the operation and the use of drones at the site (Figure 3.65). The nature of military activities varies over space and time, making full compatibility assessments complex, and may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

This site is within the BIA for gray whale migration and a portion of the newly established Critical Habitat for humpback whale Central America and Mexico DPS. Site N2-B is 4.3 km from hardbottom habitat (Figure 3.66) and lies within the Santa Barbara Basin Important Bird Area.

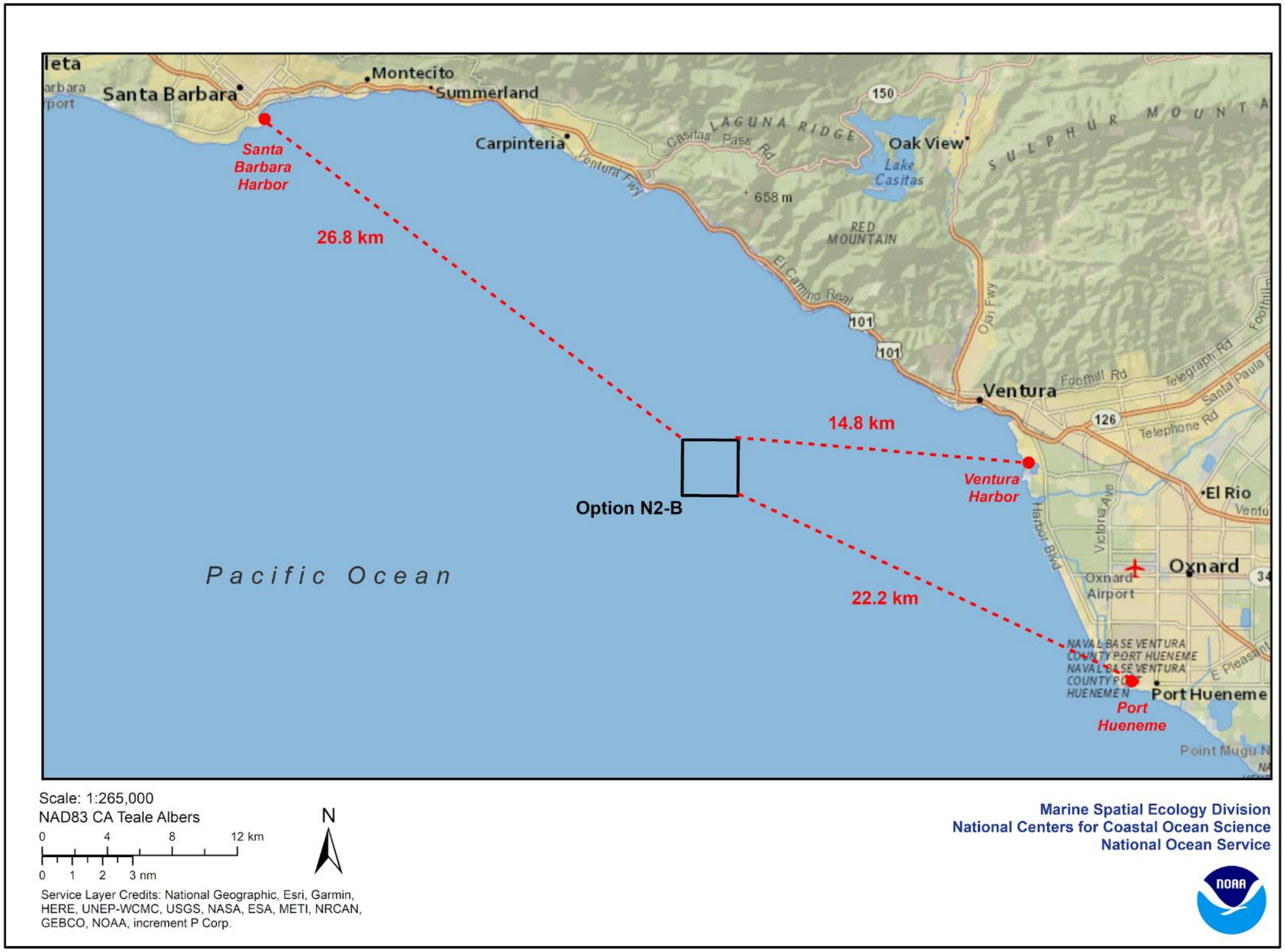


Figure 3.78. Option N2-B (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.13. Automatic Identification System vessel traffic transits by year for the N2-B option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N2-B	Cargo	1.50	0.75	0	0	4.00	2.25
N2-B	Fishing	4.50	8.75	2.25	1.25	3.50	0.50
N2-B	Military	0	0	0	0	0	0
N2-B	Other	17.75	15.00	17.50	17.00	23.50	14.50
N2-B	Passenger	121.50	82.00	156.00	81.25	234.75	84.25
N2-B	Pleasure and Sailing	16.75	26.00	24.00	41.00	48.00	34.25
N2-B	Tanker	0	0	0	0	0	0
N2-B	Tug and Tow	0.75	1.00	1.25	2.50	0	1.25

AOA Option N2-C

AOA option N2-C is a 2,000-acre site within the Santa Barbara Channel, offshore of the Ventura coast and Ventura County. The site is 29.2 km (15.8 nm) from Santa Barbara Harbor, 14.4 km (7.8 nm) from Ventura Harbor, and 20.5 km (11 nm) from Port Hueneme (Table 3.11; Figure 3.79).

Depth and Substrate Type

The site ranges in depth from 34.8 to 63.7 m with an average depth of 48.1 m (Figure 3.63). N2-C slopes gently with an average slope of 0.8 degrees. The shallowest section of the site is found in the northeast corner and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N2-C is composed of approximately 97.3% mud-like (coarse silt) substrate; sand covers 2.7% of the southeast corner, with less than 1% of gravel within the site area. The mean sediment grain diameter is approximately 0.016 mm in N2-C, indicating medium to fine silt as the predominant substrate throughout the site.

Industry Considerations

Site N2-C is within inactive BOEM oil and gas lease block 217 and active lease block 216. The site is 2.6 km from the producing oil and gas platform Gilda, it is also 3.3 km from platform Grace, which is currently shut-in and part of the first campaign of decommissioning in the region (Figure 3.64) (BSEE 2020). Oil and gas infrastructure are found outside the site within a 5-km radius, this includes wells (1.4 km), pipelines (1.8 km), submarine power cables (2.6 km), and the JOFLO corridor (2.2 km). Site N2-C is 1 km from a CalCOFI sampling site. Vessel transits occur within the site with the highest from passenger vessels, followed by pleasure and sailing transits, then other vessel transits (Table 3.14). VMS fishing data show that the highest number of transits occurred from the Dungeness crab trap or pot gear fishery, followed by prawn trap or pot gear, and California gillnet fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 665, with an average annual landing of 964,450 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture 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. Site N2-C is within the MTR, which may place limits on the height of the operation and the use of drones at the site (Figure 3.65). The nature of military activities varies over space and time, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

This site is within the BIA for gray whale migration and a portion of the newly established Critical Habitat for humpback whale Central America and Mexico DPS (Figure 3.66). The site also lies within the Santa Barbara Basin Important Bird Area.

Figure 3.79. Option N2-C (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.14. Automatic Identification System vessel traffic transits by year for the N2-C option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N2-C	Cargo	21.75	0.75	0	0	2.00	0.25
N2-C	Fishing	5.75	18.00	18.75	8.50	12.25	9.25
N2-C	Military	0	0.25	0	0	0	0
N2-C	Other	41.00	20.50	26.75	38.25	30.75	19.75
N2-C	Passenger	177.75	124.5	207.00	134.25	106.25	126.75
N2-C	Pleasure and Sailing	17.00	19.25	22.25	36.75	41.25	31.50
N2-C	Tanker	0	0	0	0	0	0
N2-C	Tug and Tow	1.00	0.50	1.75	3.25	0.50	1.50

AOA Option N2-D

AOA option N2-D is a 2,000-acre site within the Santa Barbara Channel, offshore of the Ventura coast and Ventura County. The site is 29.2 km (15.8 nm) from Santa Barbara Harbor, 11.7 km (6.3 nm) from Ventura Harbor, and 19.5 km (10.5 nm) from Port Hueneme (Table 3.11; Figure 3.80).

Depth and Substrate Type

The site ranges in depth from 25.5 m to 39 m with an average depth of 31.5 m (Figure 3.63). N2-D slopes gently with an average slope of 0.8 degrees. The shallowest section of the site is found in the northeast corner and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N2-D is composed of approximately 98.2% mud-like (coarse silt) substrate; sand covers 1.8% of the eastern site area. The mean sediment grain diameter is approximately 0.016 mm in N2-D, indicating medium to fine silt as the predominant substrate throughout the site. According to the data, no grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

N2-D is within 5 km of BOEM oil and gas lease blocks 215, 216, and 217, as well as other associated oil and gas infrastructure. Oil and gas wells are within 3.8 km, the JOFLO corridor is 3.6 km south of the site, and N2-D is 0.7 km from a CalCOFI sampling site; no other industry data layers are found within a 5-km radius of the site (Figure 3.64). Vessel transits are found within the site with the highest from passenger vessels, followed by pleasure and sailing, then other vessel transits (Table 3.15). VMS fishing data show that the highest number of transits occurred from Dungeness crab trap or pot gear, followed by prawn trap or pot gear, and the same number of transits from the California halibut trawl and California gillnet fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 665, with an average annual landing of 964,450 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture 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. Site N2-D is within the MTR, which may place limits on the height of the operation and the use of drones at the site (Figure 3.65). The nature of military activities varies over space and time, making full compatibility assessments complex, and may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

This site is within the BIA for gray whale migration and is 2.3 km from the newly established Critical Habitat for humpback whale Central America and Mexico DPS (Figure 3.66). The site also lies within the Santa Barbara Basin Important Bird Area.

Figure 3.80. Option N2-D (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.15. Automatic Identification System vessel traffic transits by year for the N2-D option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N2-D	Cargo	1.50	0	0	0	2.75	1.50
N2-D	Fishing	4.25	12.25	4.50	6.75	4.75	2.00
N2-D	Military	0	0	0	0	0	0
N2-D	Other	20.00	14.50	24.00	15.75	13.75	9.50
N2-D	Passenger	31.75	21.50	36.25	28.50	190.00	22.00
N2-D	Pleasure and Sailing	21.25	25.00	29.75	47.00	48.00	38.25
N2-D	Tanker	0	0	0	0	0	0
N2-D	Tug and Tow	0.25	1.00	0.75	0.75	0	0.75

AOA Option N2-E

AOA option N2-E is a 2,000-acre site within the Santa Barbara Channel, offshore of the Ventura coast and Ventura County. The site is 33.1 km (17.9 nm) from Santa Barbara Harbor, 8.6 km (4.6 nm) from Ventura Harbor, and 15.7 km (8.5 nm) from Port Hueneme (Table 3.11; Figure 3.81).

Depth and Substrate Type

The site ranges in depth from 23.1 m to 29.8 m with an average depth of 25.4 m (Figure 3.63). N2-E slopes gently with an average slope of 1.0 degree. The shallowest section of the site is found in the northeast corner and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of N2-E is composed of approximately 49.1% mud-like (coarse silt) substrate; sand covers 50.9% of the remainder. The mean sediment grain diameter is approximately 0.06 mm in N2-E, indicating coarse silt to very fine sand as the predominant substrate throughout the site. According to the data, no grain sizes of sediment occur in the site in the size range of gravel.

Industry Considerations

N2-E is within inactive BOEM oil and gas lease block 215 and within 4.6 km of the producing oil and gas platform Gilda and associated infrastructure (Figure 3.64). The site is 1.8 km from inactive oil and gas wells, 3.2 km from a pipeline and an underwater power cable, and 0.5 km from a JOFLO corridor. Site N2-E is 1.8 km and 3.9 km from CalCOFI sampling sites. Vessel transits are found within the site with the highest from passenger vessels, followed by pleasure and sailing, then other vessel transits (Table 3.16). VMS fishing data show that the highest number of transits occurred from Dungeness crab trap or pot gear, followed by California gillnet and prawn trap or pot gear fisheries (Figures 3.16 - 3.35). The site is within CDFW commercial landing block 665 with an average annual landing of 964,450 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture 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. Site N2-D is within the MTR, which may place limits on the height of the operation and the use of drones at the site (Figure 3.65). The nature of military activities varies over space and time, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

This site is within the BIA for gray whale migration and 3.5 km from the newly established Critical Habitat for humpback whale Central America and Mexico DPS. Site N2-E is 3.5 km from hardbottom habitat (Figure 3.66) and lies within the Santa Barbara Basin Important Bird Area.

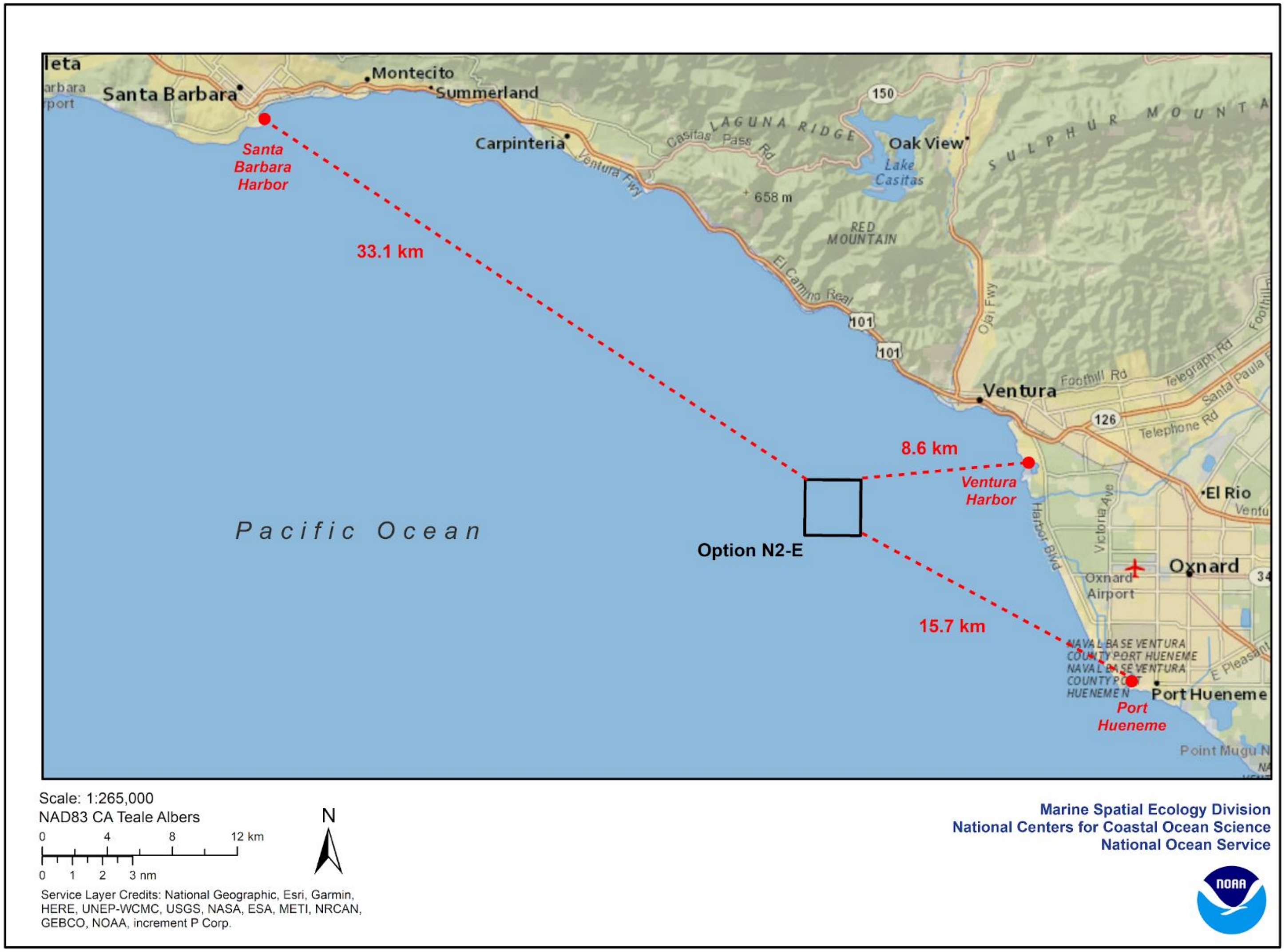


Figure 3.81. Option N2-E (black outlined box) and distance to the closest port from the closest corner point, includes Santa Barbara Port, Ventura Port, and Port Hueneme.

Table 3.16. Automatic Identification System vessel traffic transits by year for the N2-E option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
N2-E	Cargo	0	0	0	0	3.50	1.00
N2-E	Fishing	5.75	19.75	27.50	10.50	14.00	13.00
N2-E	Military	0	0	0	0	0	0
N2-E	Other	31.50	25.75	25.00	22.25	25.50	18.00
N2-E	Passenger	45.50	32.00	46.00	52.00	265.00	52.25
N2-E	Pleasure and Sailing	24.50	27.75	32.50	60.00	57.00	48.00
N2-E	Tanker	0	0	0	0	0	0
N2-E	Tug and Tow	0.50	0.50	1.50	0.75	0	0.50

Characteristics of AOA Cluster CN1

The following characteristics are similar among all AOA options within cluster CN1 including CN1-A and CN1-B. Descriptive data (Table 3.17), maps, and figures are provided for the general location of the cluster (Figure 3.82), bathymetry (Figure 3.83), interactions with industry (Figure 3.84), national security (Figure 3.85), interactions with natural resources (Figure 3.86), water temperature (Figure 3.87), current velocity and direction (Figures 3.88 - 3.90), wind velocity and direction (Figure 3.91), wave height and period (Figure 3.92), nutrient concentrations (Figure 3.93), chlorophyll-*a* concentration (Figure 3.94), light attenuation characteristics (Figure 3.95), and light transmissivity (Figure 3.96).

Water Temperature and Salinity

The mean water temperature at the surface between 2016 and 2020 was 17.2°C, with a minimum of 11.9°C and maximum of 23.3°C (Figure 3.87). The average temperature decreased to 16.4°C at 10-m depth and was the lowest at 40-m depth (13.1°C). Seasonally, temperature at the surface peaks in August and is lowest in April. Years with the highest surface water temperatures were 2016 and 2017. The surface salinity was consistent throughout the year and among sites, with an average of 33.6 psu.

Current Speed and Direction, Wind Speed and Direction, and Significant Wave Height

Current speed and direction vary by month and depth with a southeasterly direction on the surface. The annual average current velocity from the CA ROMS model from 2016 to 2020 at the surface was 0.11 m/s, with a minimum of 0 m/s and a and maximum of 0.48 m/s, respectively (Figure 3.88). Current speed decreased with depth, with average current speeds of 0.07 m/s at 10-m depth and 0.05 m/s at 40-m depth. The current speed did not exceed 1 m/s over the 5-year period. Wind velocity at the site averaged 4.5 m/s, with a minimum of 0 m/s and a maximum of 16.8 m/s. Wind direction was predominantly from the west-southwest (Figure 3.91). The average significant wave height from 1979 to 2010 was 0.91 m with a period of 13.8 seconds, with waves predominantly from the west (Figure 3.92).

Water Quality Considerations

Mean nutrient concentration for nitrate, phosphate, and dissolved oxygen at depth is an indicator of ocean health. Nitrate ranged from 1.03 mmol/m^3 at 10-m depth to 7.85 mmol/m^3 at 100-m depth (Figure 3.93). Phosphate ranged from 0.50 mmol/m^3 at 10-m depth to 1.47 mmol/m^3 at 100-m depth. Dissolved oxygen decreased from 265 mmol/m^3 at 10-m depth to 165 mmol/m^3 at 100-m depth.

Chlorophyll-*a* concentration (mg/m^3), an indicator of phytoplankton abundance, was highest in April (2.64 mg/m^3) and lowest in November (0.42 mg/m^3) (Figure 3.94). The diffuse light coefficient at 490 nm, Kd(490), is an indicator of water turbidity. Kd(490) was lowest for the month of November (Kd(490) = 0.08 m^{-1}) and was highest in April (Kd(490) = 0.19 m^{-1}) (Figure 3.95). Percent light transmissivity was calculated at 1-m depth, providing the percent of light that reaches that depth. Percent light transmissivity was highest in November at 88.1% and lowest in April at 79.5% (Figure 3.96).

Table 3.17. Characterization summary for southern California Aquaculture Opportunity Area options CN1-A and CN1-B.

Central North 1 (CN1)	CN1-A	CN1-B
General Characteristics		
Corner Coordinates (latitude, longitude) (decimal degrees)	33.963, -118.575	33.959, -118.559
	33.963, -118.597	33.960, -118.574
	33.981, -118.596	33.972, -118.574
	33.981, -118.575	33.972, -118.558
Size (acres)	1000	500
Marina del Rey (km to port, nm to port)	11.3 (6.1)	9.8 (5.3)
King Harbor (km to port, nm to port)	20.9 (11.3)	19.4 (10.5)
Depth (m) (minimum, maximum, mean), Average slope (°)	(58.9, 145.6, 98.9), 2.3	(55.4, 101.3, 66.6), 1.6
Industry, Navigation, and Transportation (within 5 km)		
Oil and Gas Platforms, Name and Status	No	No
Number of Boreholes	4 (1.9 km)	3 (2.4 km)
BOEM Oil and Gas Active Lease Block	No	No
Oil and Gas Pipelines	No	No
Submarine Cables	Yes (0.8 km)	Yes (0.8 km)
CalCOFI Sampling Site	No	No
CDFW Block Number and Average Catch 2010 - 2019 (pounds)	702	702
	915,018	915,018
National Security		
Overlap with MOAs (yes/no)	Yes	Yes
Overlap with MTR (yes/no)	No	No
Natural and Cultural Resources (within 5 km)		
Habitat - Hardbottom Substrate	Yes (0.3 km)	Yes (0.25 km)
Habitat - Deep-sea Coral Observations	Yes (2.4 km)	Yes (2.8 km)
HAPC - Rocky Reef	Yes (0.3 km)	Yes (0.25 km)
Important Bird Areas	No	No
Cetacean Biologically Important Areas	Gray Whale - Migration	Gray Whale - Migration
Critical Habitat - Humpback Whale	No	No

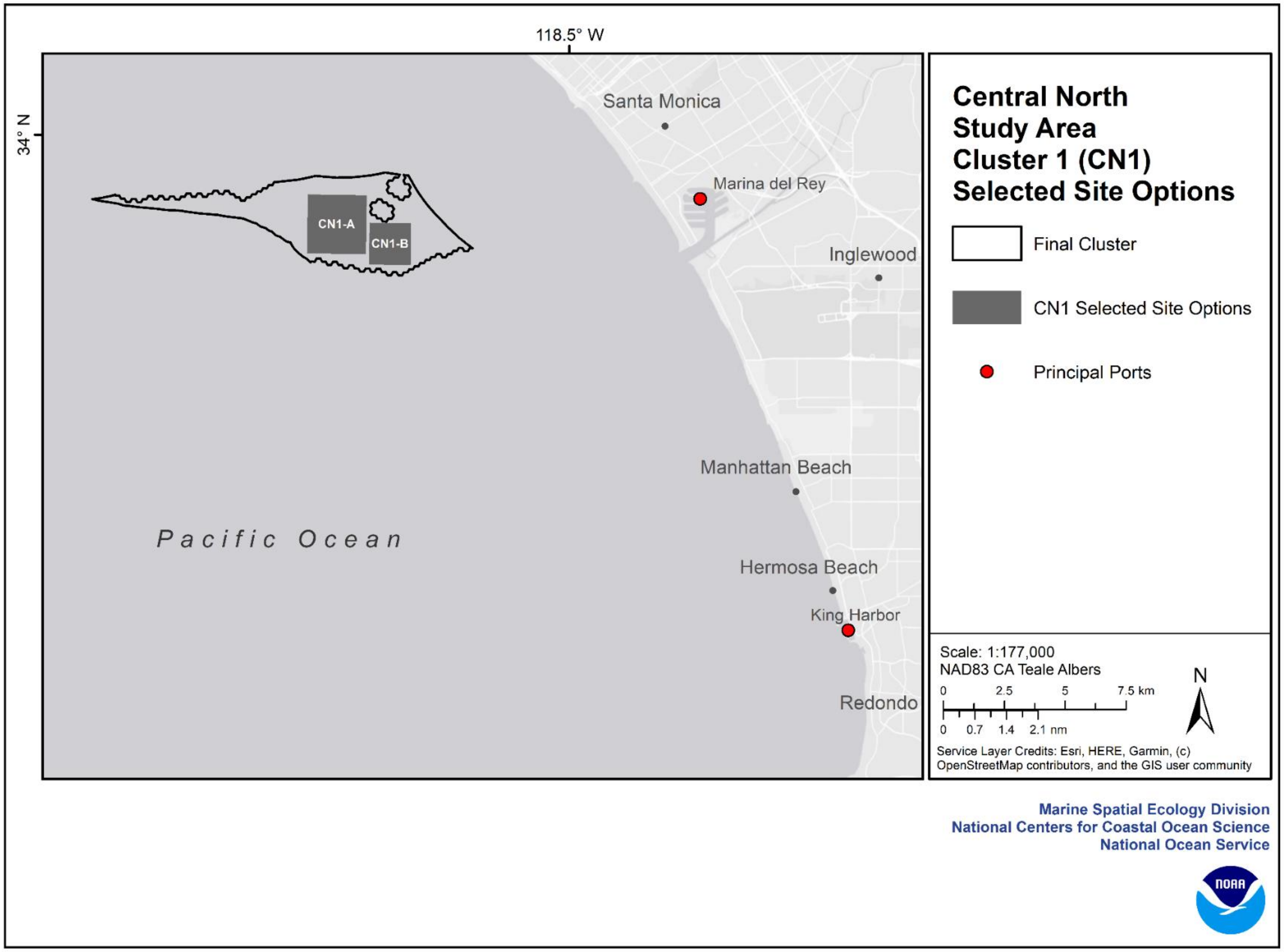


Figure 3.82. Central North study area with Aquaculture Opportunity Area options CN1-A and CN1-B.

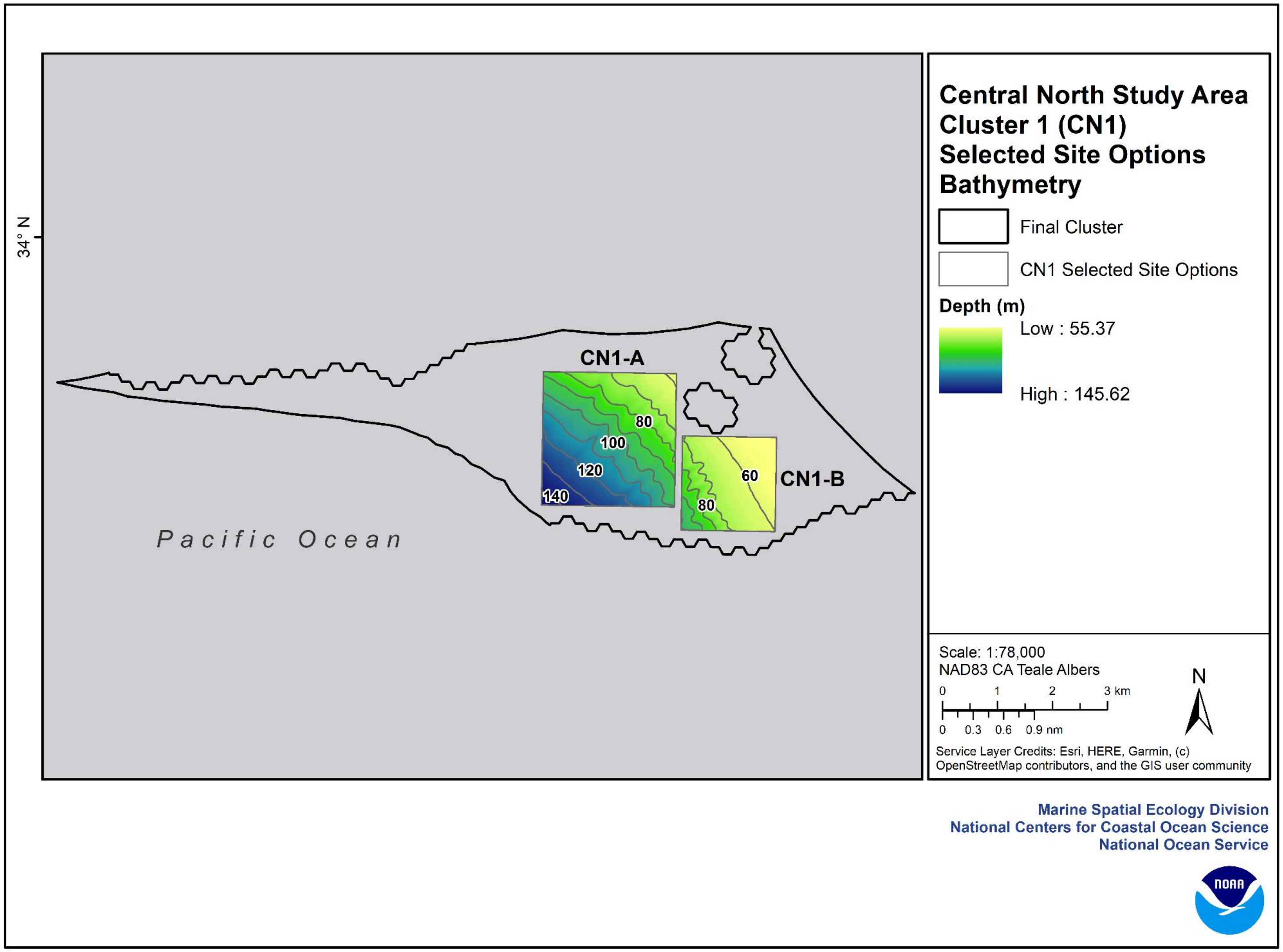


Figure 3.83. Bathymetry of CN1-A and CN1-B.

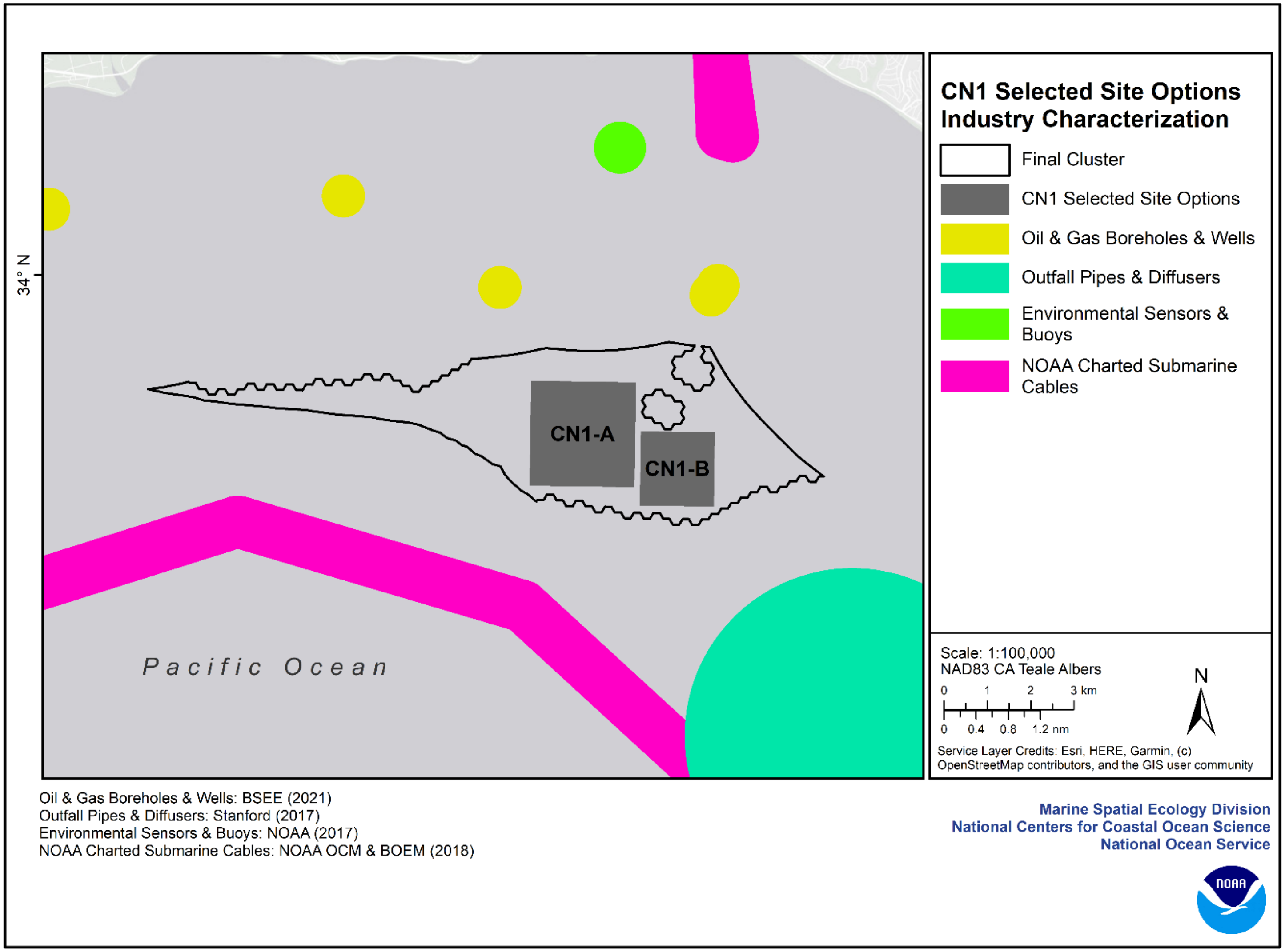


Figure 3.84. Industry interaction with Aquaculture Opportunity Area options CN1-A and CN1-B.

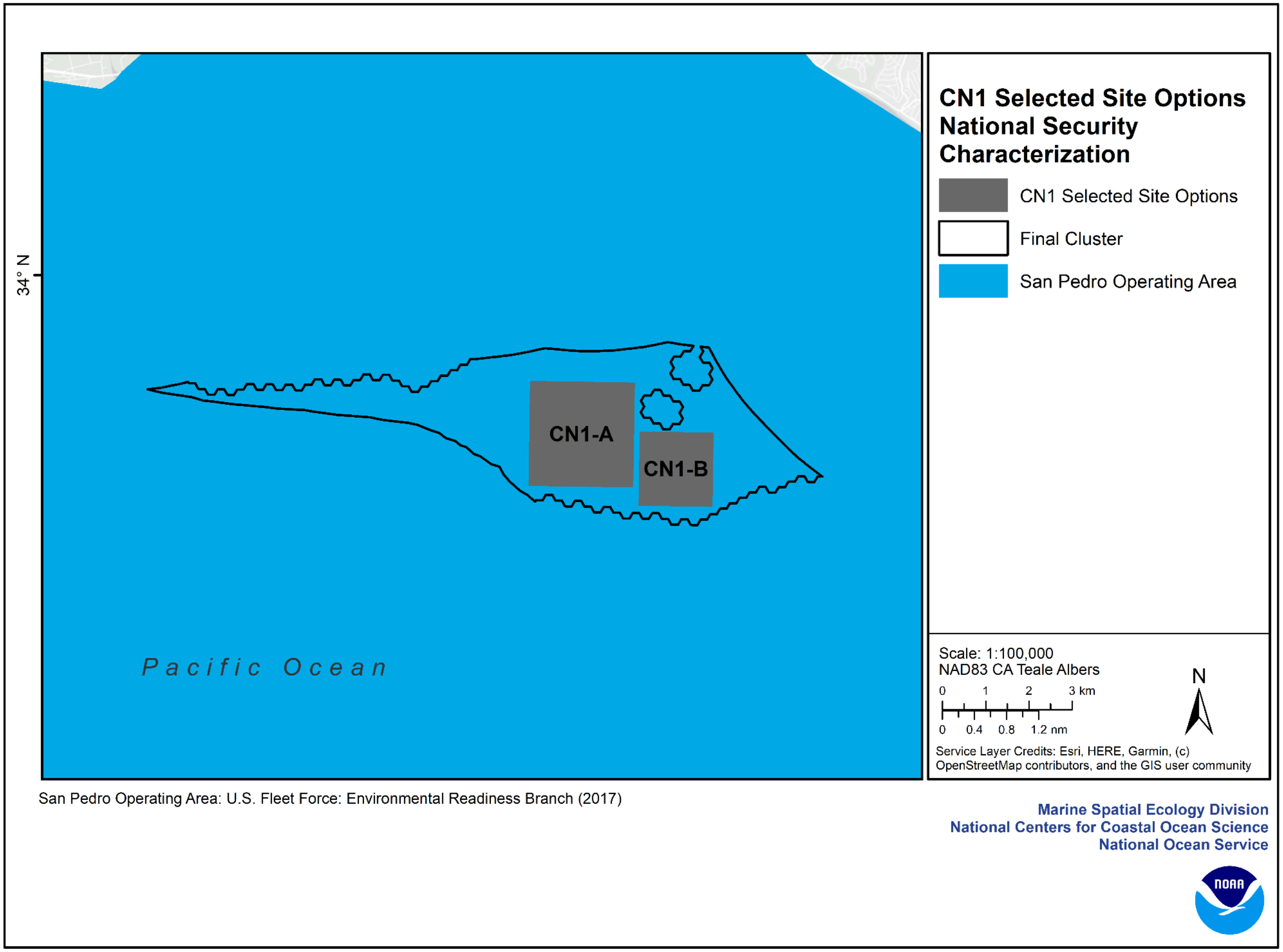
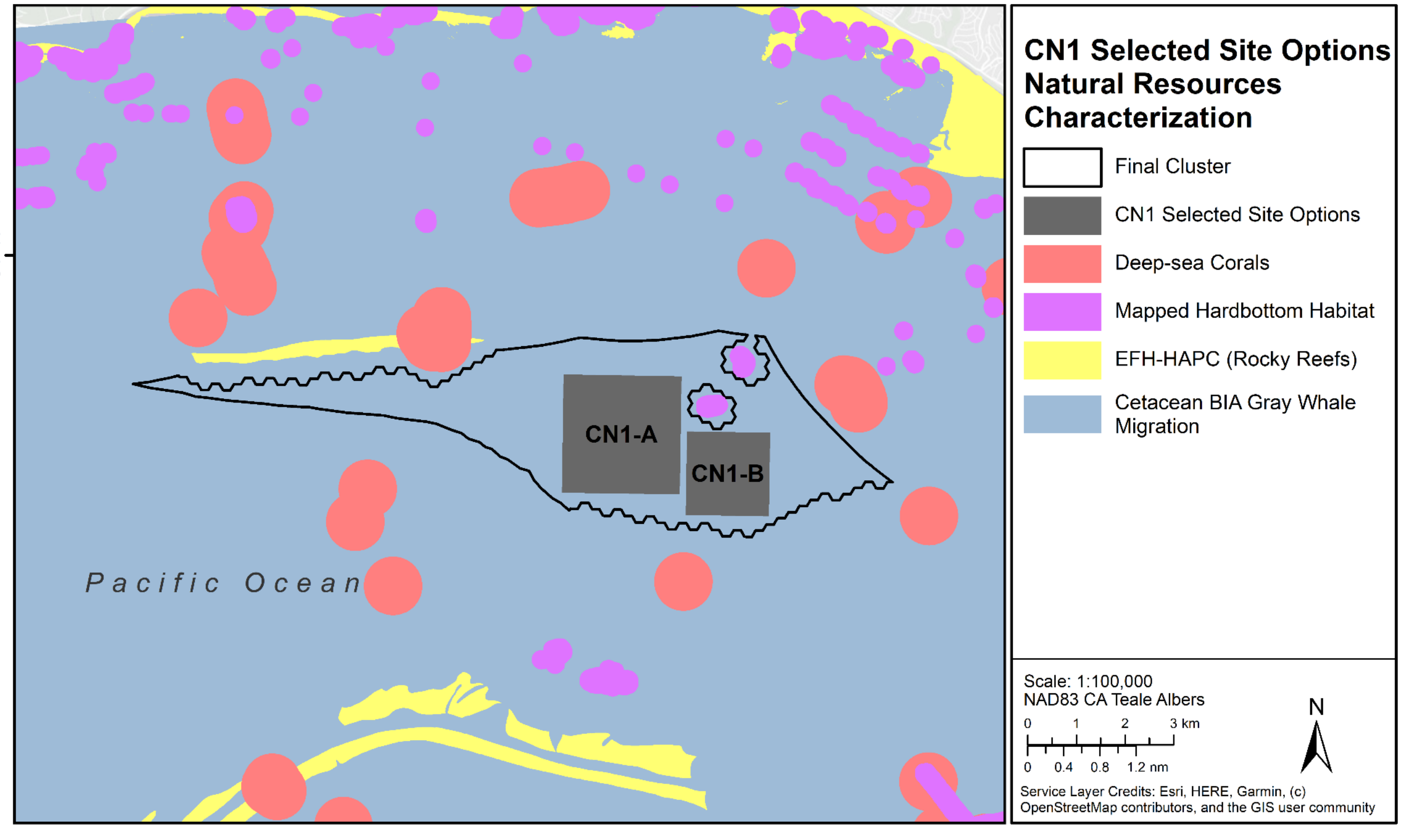


Figure 3.85. Military interaction with Aquaculture Opportunity Area options CN1-A and CN1-B.



Deep-sea Corals (1985 - present): NOAA Deep-sea Coral Research and Technology Program (2021)
Mapped Hardbottom: NOAA NMFS (2018)
EFH-HAPC (Rocky Reefs): NOAA NMFS (2020)
Cetacean Biologically Important Areas: NOAA NMFS (2019)
Gray whale North migration occurs January - July
Gray whale South migration occurs October - March

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

Figure 3.86. Natural resources surrounding Aquaculture Opportunity Area options CN1-A and CN1-B.

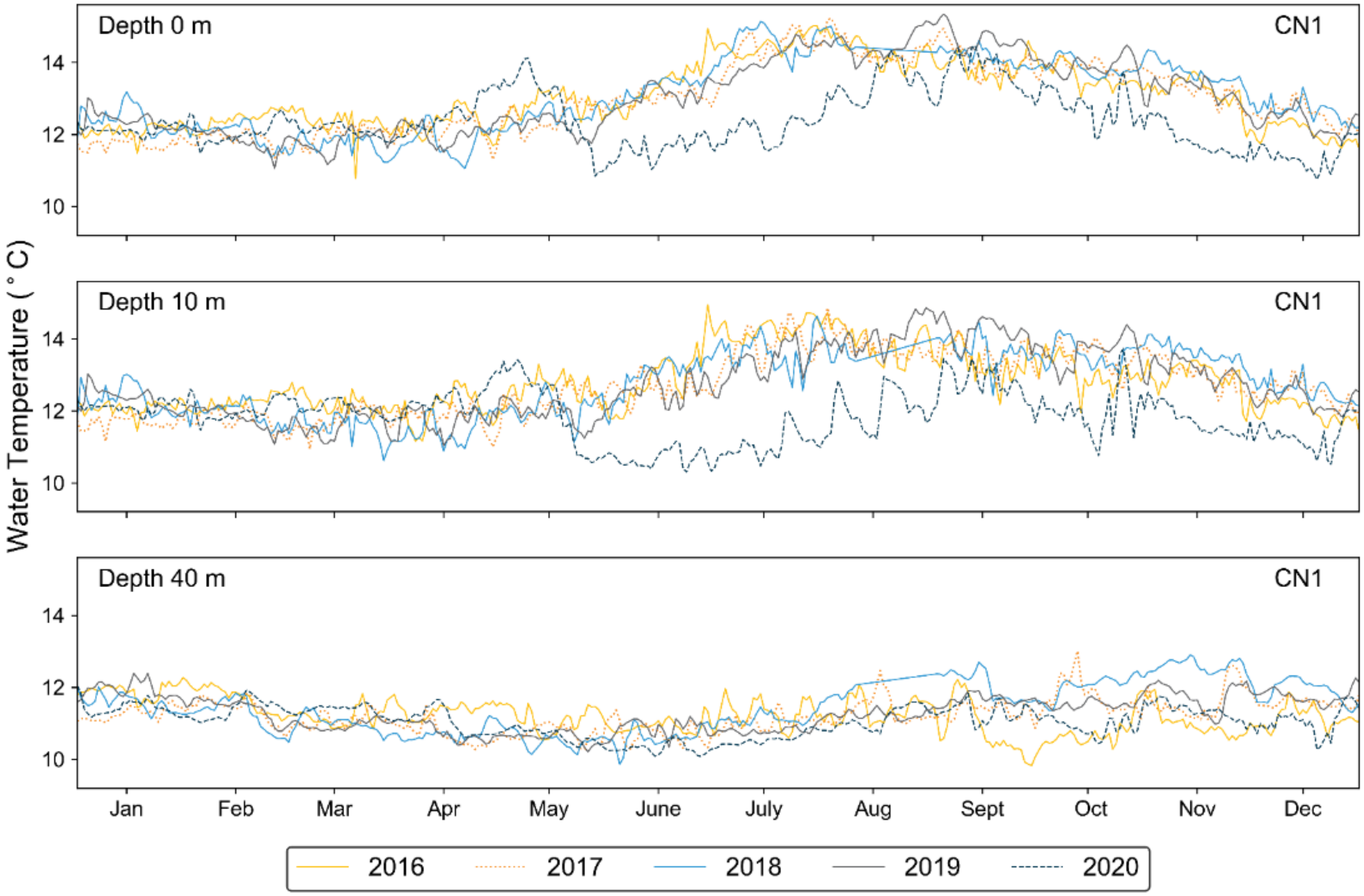


Figure 3.87. Water temperature at 0-m, 10-m, and 40-m depth for cluster CN1 from the California Regional Ocean Modeling system model (2016 - 2020).

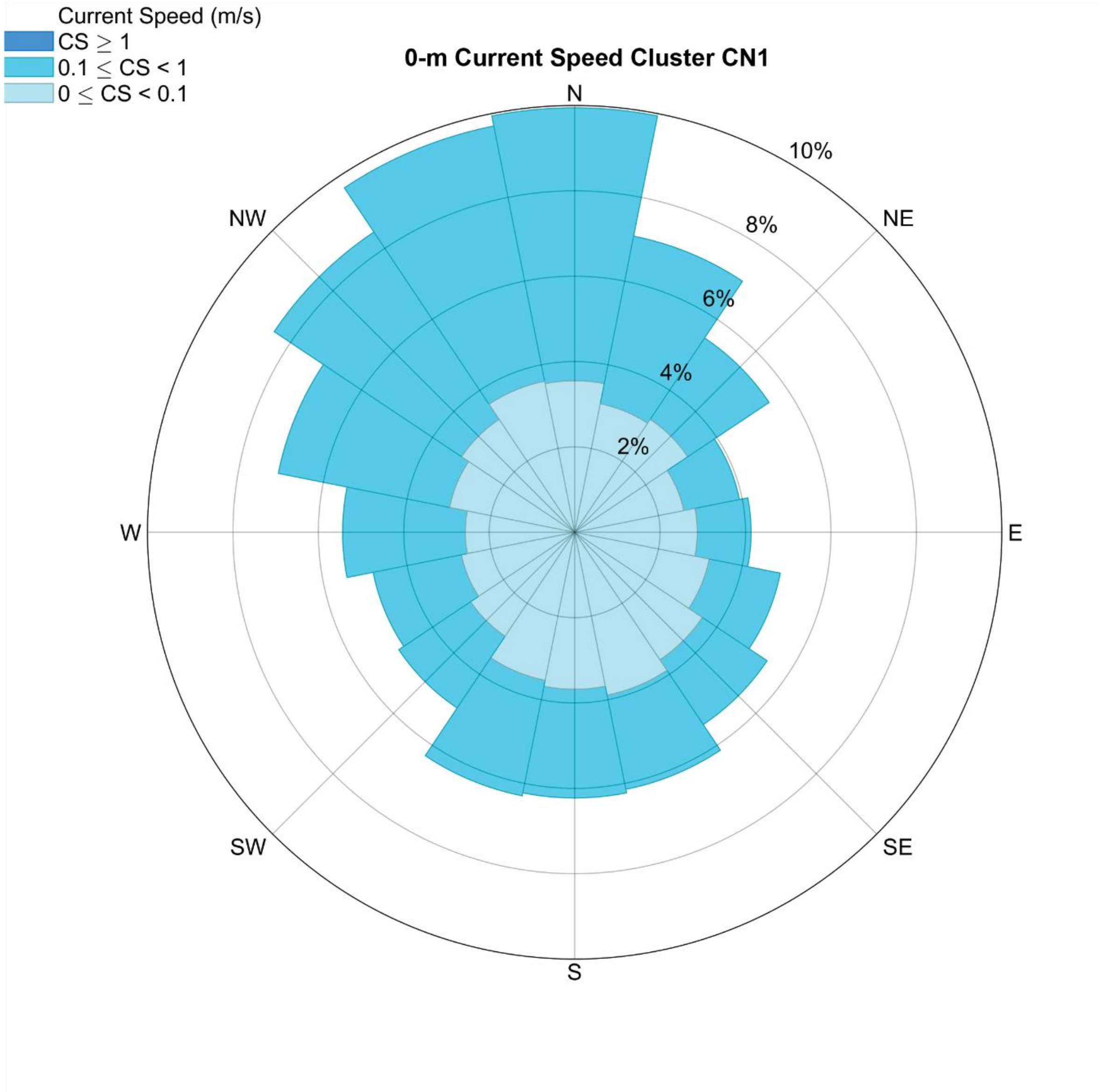


Figure 3.88. Ocean current magnitude and direction for cluster CN1 at the ocean surface. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

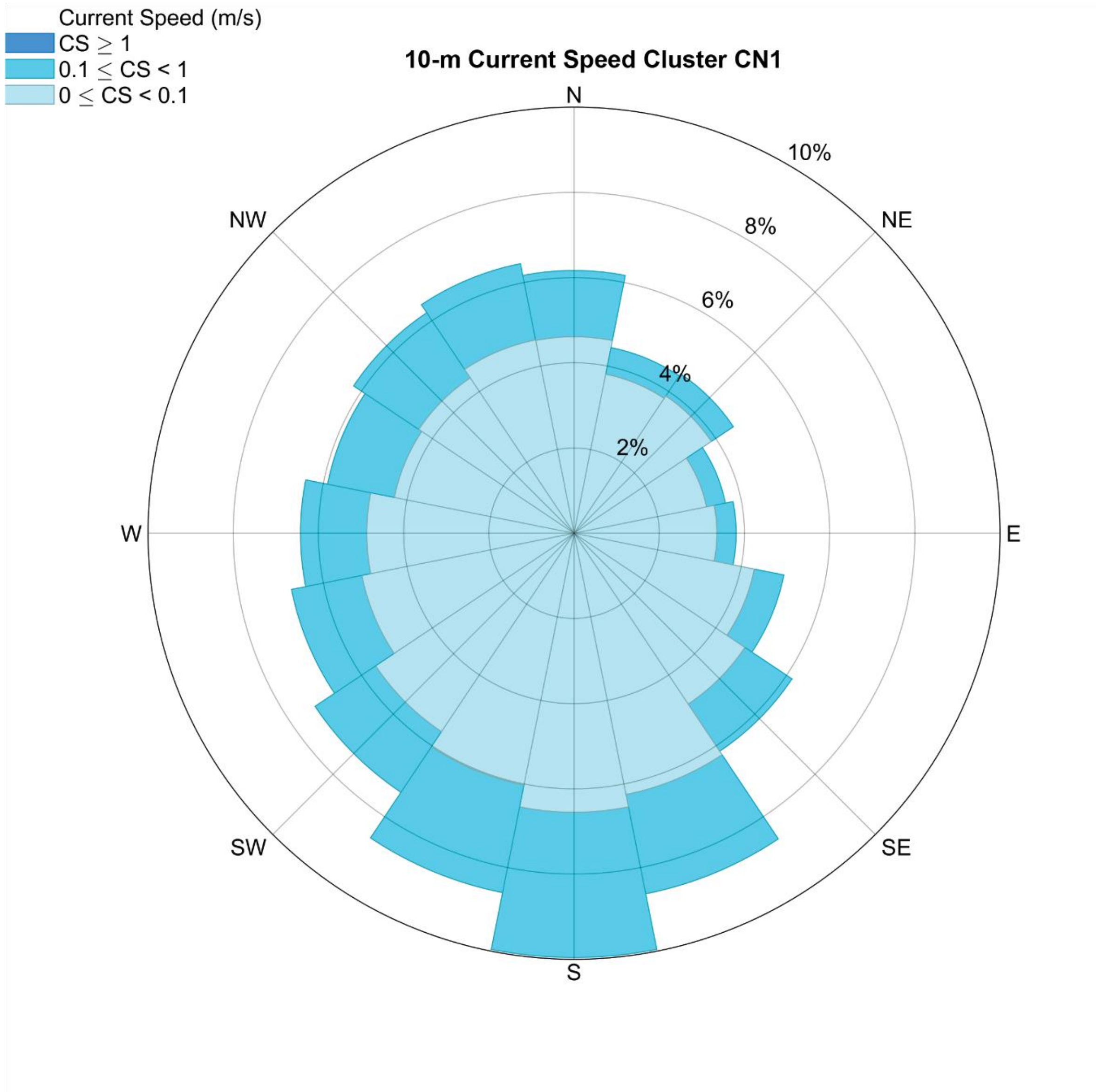


Figure 3.89. Ocean current magnitude and direction for cluster CN1 at 10-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

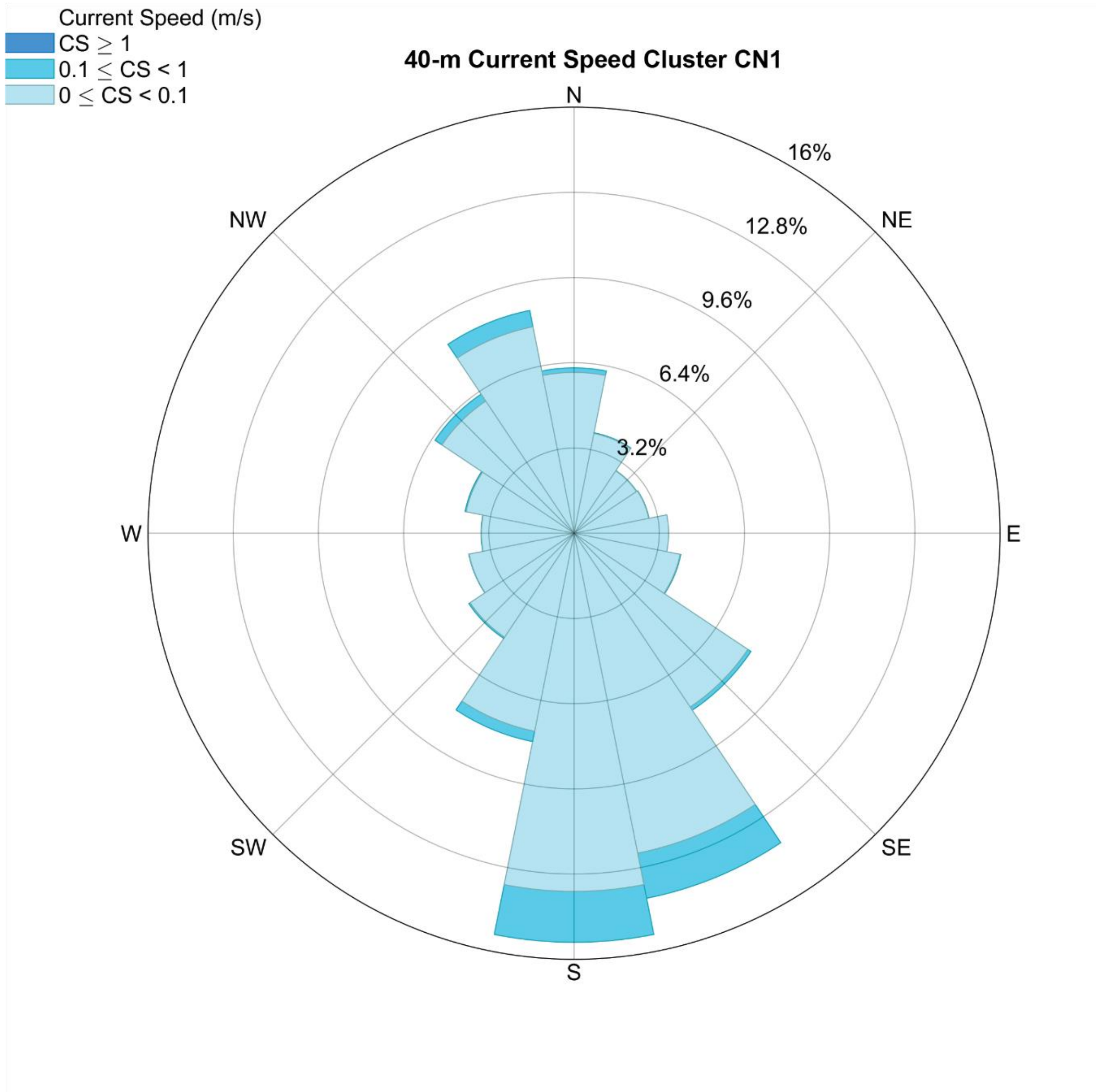


Figure 3.90. Ocean current magnitude and direction for cluster CN1 at 40-m depth. The rose diagram provides percent occurrence for each current speed (CS) category. Current flow is in the direction of the compass heading. Data are from the California Regional Ocean Modeling System (2016 - 2020).

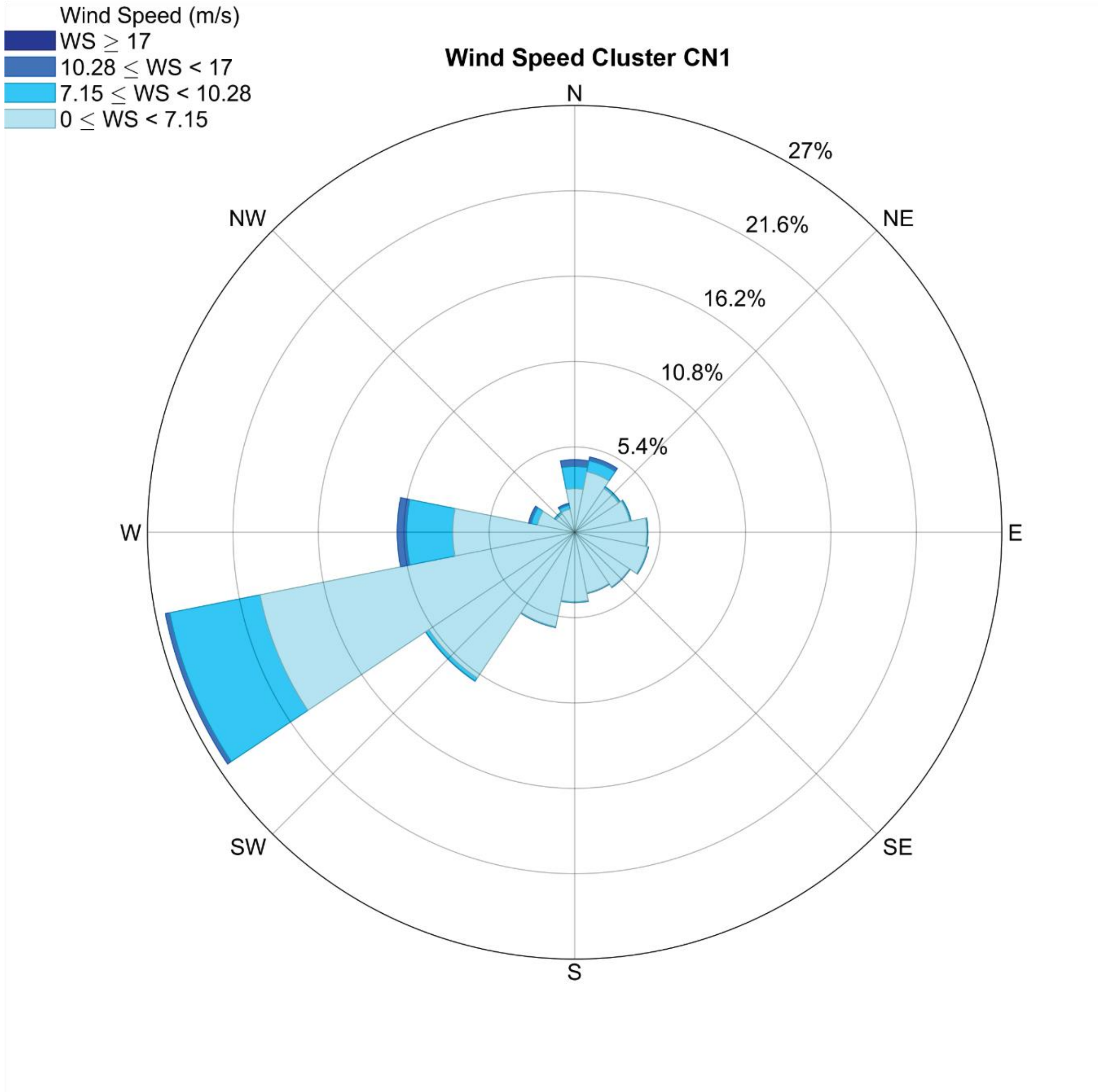


Figure 3.91. Wind velocity and direction at 10-m above sea level for cluster CN1. The rose diagram provides percent occurrence for each wind speed (WS) category. Wind direction is displayed as the origin. Wind data are from the Coupled Ocean/Atmosphere Mesoscale Prediction System model (2016 - 2020).

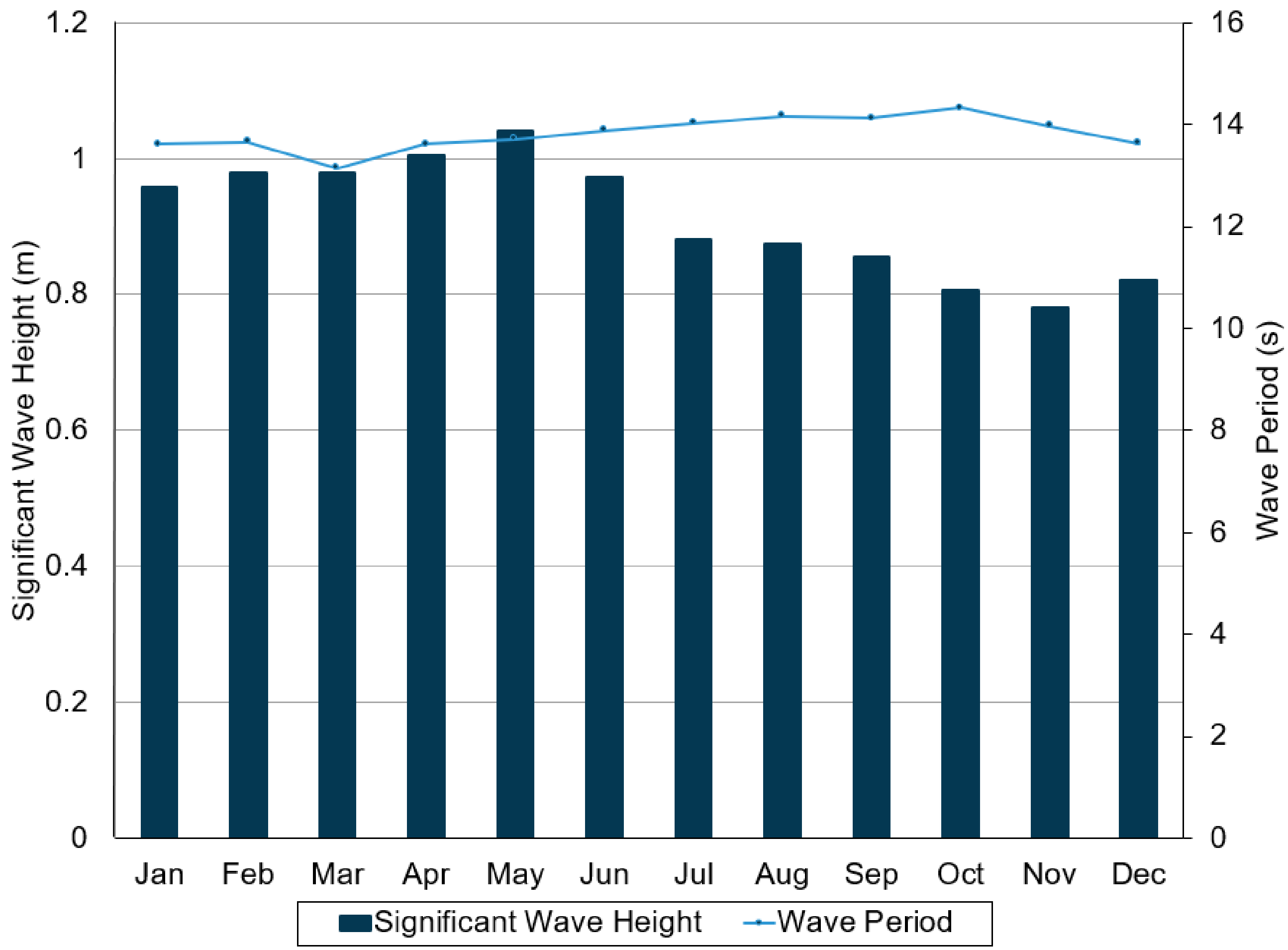


Figure 3.92. Wave height and period for cluster CN1 from the Pacific Northwest National Laboratory Simulating WAves Nearshore wave model (1979 - 2010).

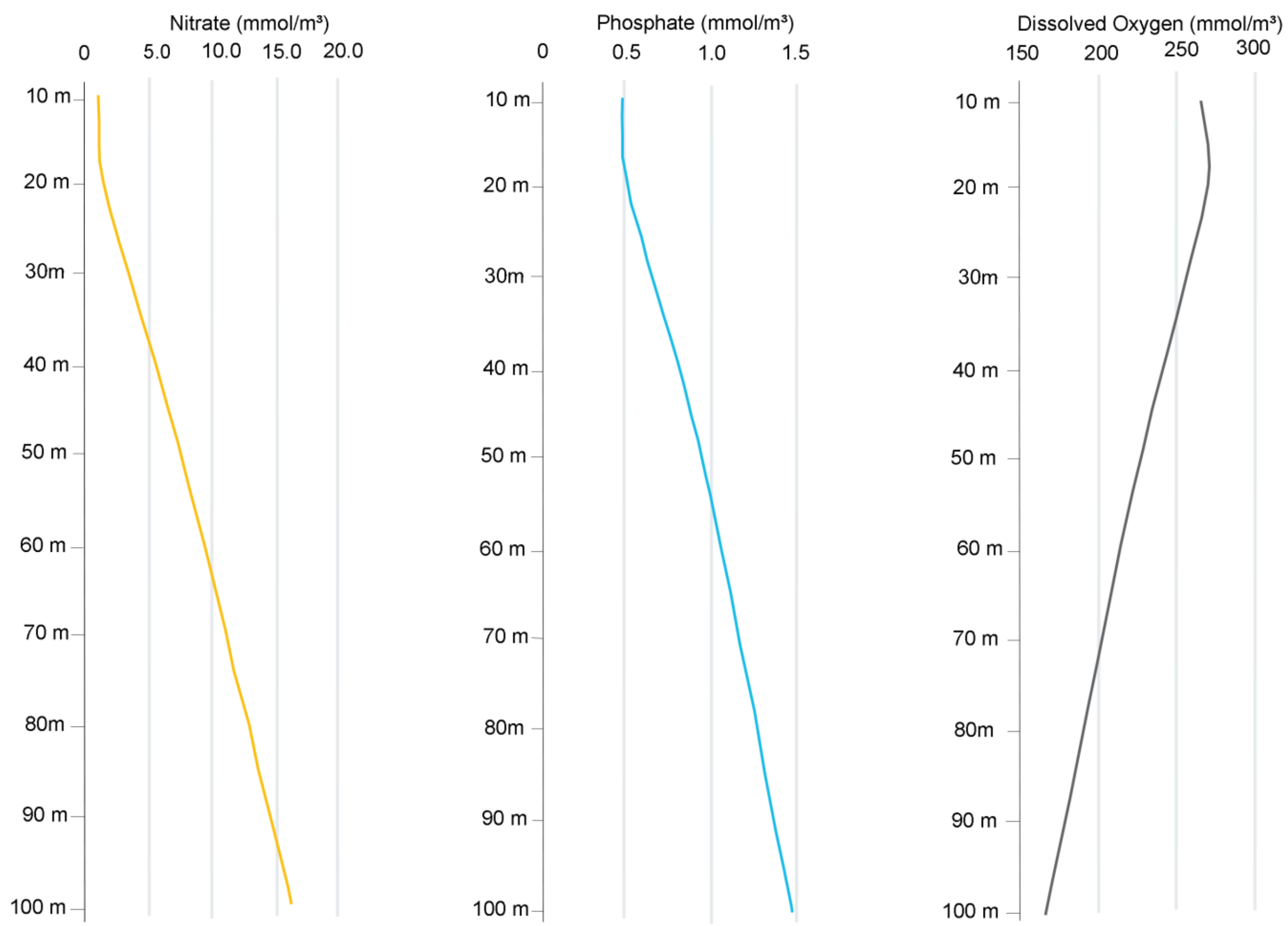


Figure 3.93. Cluster CN1 concentration of nitrate, phosphate, and dissolved oxygen at depth (Kessouri et al. 2021).

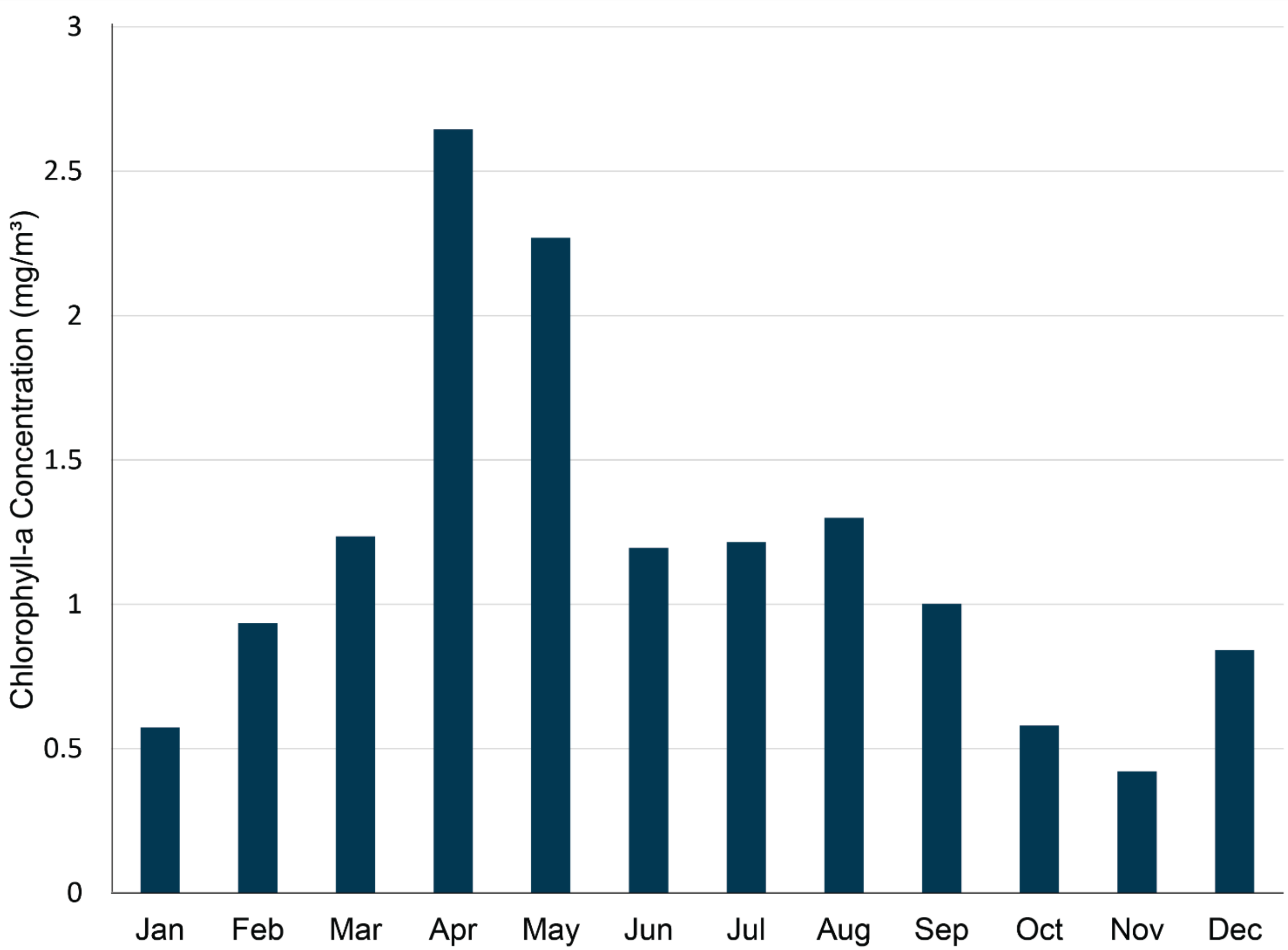


Figure 3.94. Cluster CN1 monthly climatological mean (2016 - 2020) concentration of chlorophyll-*a* (mg/m^3) at the surface from Visible Infrared Imaging Radiometer Suite Level 3 750-m data.

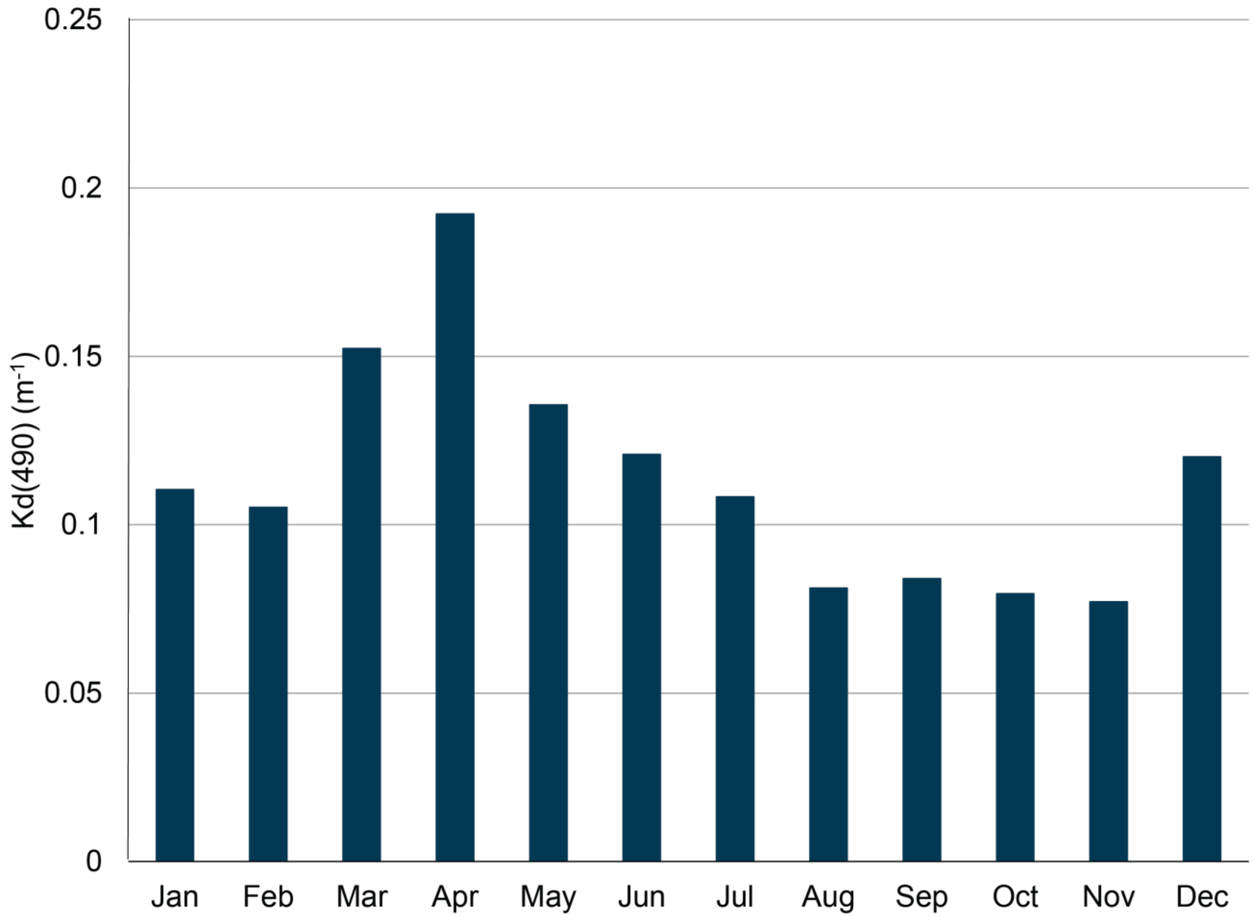


Figure 3.95. Cluster CN1 monthly climatological mean (2010 - 2018) for light attenuation, Kd(490) at the sea surface produced by Visible Infrared Imaging Radiometer Suite 750-m data.

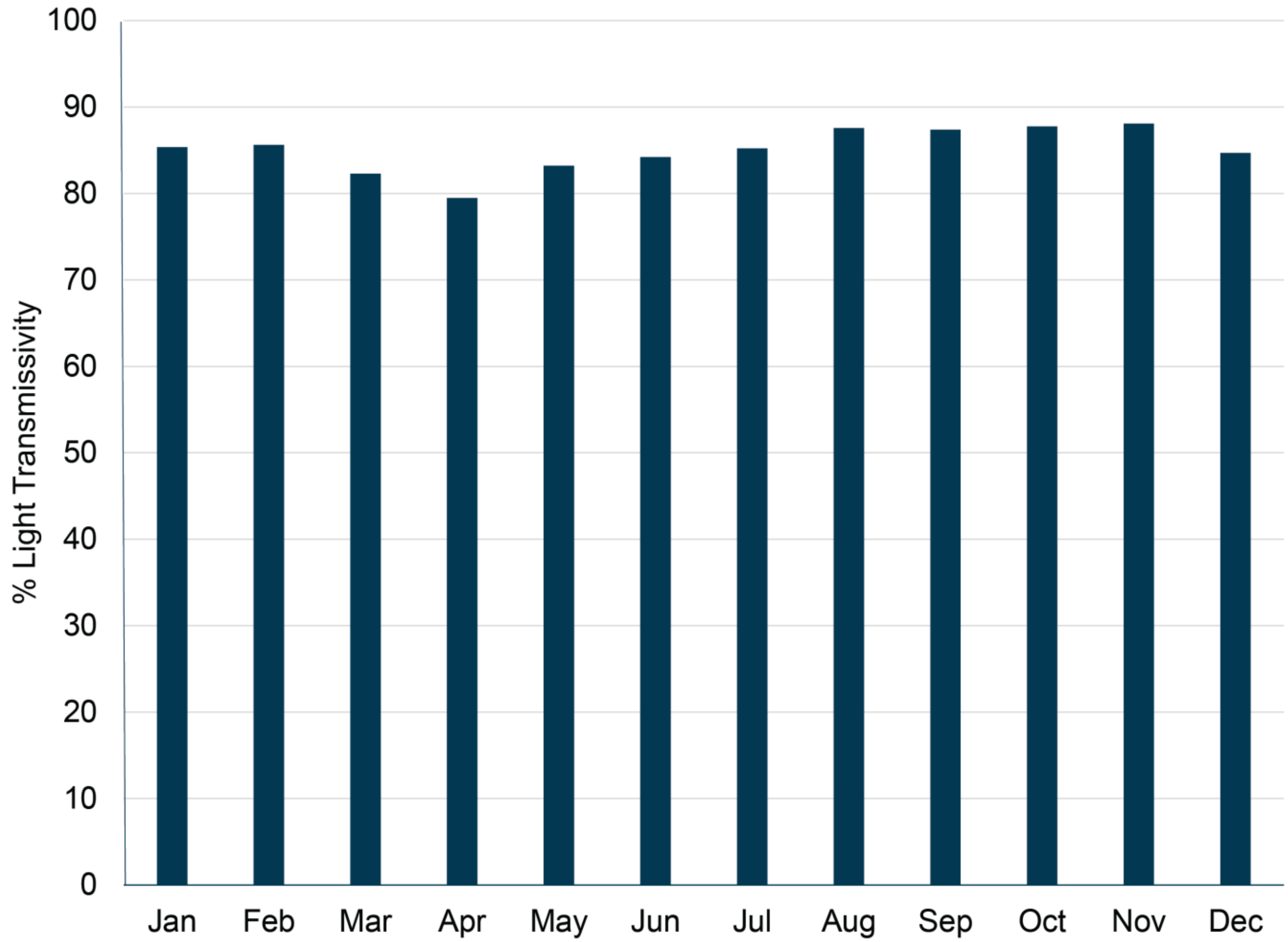


Figure 3.96. Cluster CN1 monthly climatological mean (2010 - 2018) for percent light transmissivity at 1 m produced by Visible Infrared Imaging Radiometer Suite 750-m data.

AOA Option CN1-A

AOA option CN1-A is a 1,000-acre site within Santa Monica Bay, offshore of the cities of Malibu and Santa Monica and Los Angeles County. The site is 11.4 km (6.1 nm) from Marina del Rey and 20.9 km (11.3 nm) from King Harbor (Table 3.17; Figure 3.97).

Depth and Substrate Type

The site ranges in depth from 58.9 m to 145.6 m with an average depth of 98.9 m (Figure 3.83). CN1-A has an average slope of 2.3 degrees. The shallowest section of the site is found in the northeast corner and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of CN1-A is composed of approximately 49.9% mud-like (coarse silt) substrate; sand covers 45.9% and gravel covers 4.2%. The mean sediment grain diameter is approximately 0.06 mm in CN1-A, indicating coarse silt to very fine sand as the predominant substrate throughout the site.

Industry Considerations

Site CN1-A is 0.8 km from a submarine cable, 1.9 km from an inactive oil and gas well, and 1.5 km from a 3-mi setback from a wastewater treatment outfall structure (Figure 3.84). National Data Buoy Center station 46268 is 4.5 km north of the site; this is a Waverider™ buoy that collects wave height, period, direction, and temperature data. Vessel transits are found within the site, with the highest from pleasure and sailing vessels, followed by other vessel and passenger transits (Table 3.18). The site is within CDFW commercial landing block 702, with an average annual landing of 915,038 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture were avoided (i.e., score of 0 with a setback) and moved to the constraints submodel, which removed these areas from the remainder of the analysis. Site CN1-A is within a military operating area (Figure 3.85). The nature of military activities varies over space and time, making full compatibility assessments complex; this may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site option is within the BIA for gray whale migration and within 0.3 km of both hardbottom habitat and HAPC for rocky reefs, and 2.4 km from deep-sea coral observations (Figure 3.86).

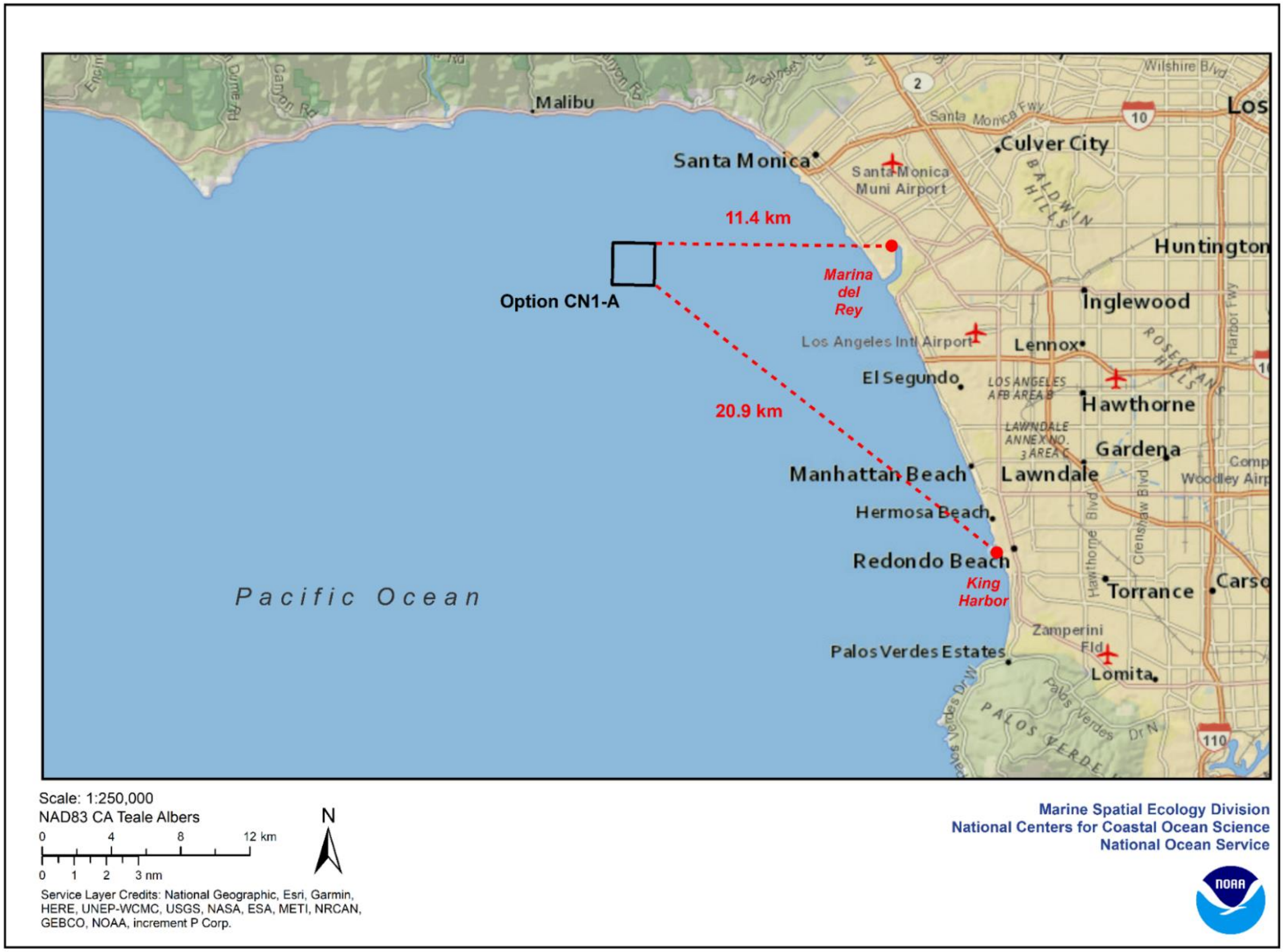


Figure 3.97. Option CN1-A (black outlined box) and distance to the closest port from the closest corner point; the area includes Marina del Rey and King Harbor.

Table 3.18. Automatic Identification System vessel traffic transits by year for the CN1-A option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
CN1-A	Cargo	0	0	0	0	0	0
CN1-A	Fishing	3.50	17.50	0.50	1.50	1	2.50
CN1-A	Military	0	0	0	0	0	0
CN1-A	Other	35.50	30.00	49.50	47.50	31.50	46.00
CN1-A	Passenger	0.50	0	45.00	34.50	30.00	19.50
CN1-A	Pleasure and Sailing	50.50	60.50	76.50	138.00	125.00	164.00
CN1-A	Tanker	0	0	0	0	0	0
CN1-A	Tug and Tow	4.00	3.50	0.50	13.00	1.50	3.00

AOA Option CN1-B

AOA option CN1-B is a 500-acre site within Santa Monica Bay, offshore of the cities of Malibu and Santa Monica and Los Angeles County. The site is 9.9 km (5.3 nm) from Marina del Rey and 19.4 km (10.5 nm) from King Harbor (Table 3.17; Figure 3.98).

Depth and Substrate Type

The site ranges in depth from 55.4 m to 101.3 m with an average depth of 66.6 m (Figure 3.83). Option CN1-B has an average slope of 1.6 degrees. The shallowest section of the site is found in the northeast corner and the deepest is found in the southwest corner. Based on predicted surficial sediment data (as percent sand/mud/gravel) for southern California, the sediment of CN1-B is composed of approximately 40.6% mud-like (coarse silt) substrate; sand covers 54.5% and gravel covers 5.8%. The mean sediment grain diameter is approximately 0.06 mm in CN1-B, indicating coarse silt to very fine sand as the predominant substrate throughout the site.

Industry Considerations

Site CN1-B is 0.8 km from a submarine cable, 2.4 km from an inactive oil and gas well, and 0.3 km from a 3-mile setback from a wastewater treatment outfall structure (Figure 3.84). Vessel transits are found within the site with the highest from pleasure and sailing vessels, followed by passenger and other vessel transits (Table 3.19). The site is within CDFW commercial landing block 702, with an average annual landing of 915,038 pounds from 2010 to 2019.

National Security Considerations

All national security layers with known direct constraints to aquaculture 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. Site CN1-B is within a military operating area (Figure 3.85). The nature of military activities varies over space and time, making full compatibility assessments complex, and may require a formal DOD clearinghouse process to make an informed decision regarding aquaculture compatibility.

Natural Resource Considerations

The site option is within the BIA for gray whale migration and within 0.25 km of both hardbottom habitat and HAPC for rocky reefs, and 2.8 km from deep-sea coral observations (Figure 3.86).

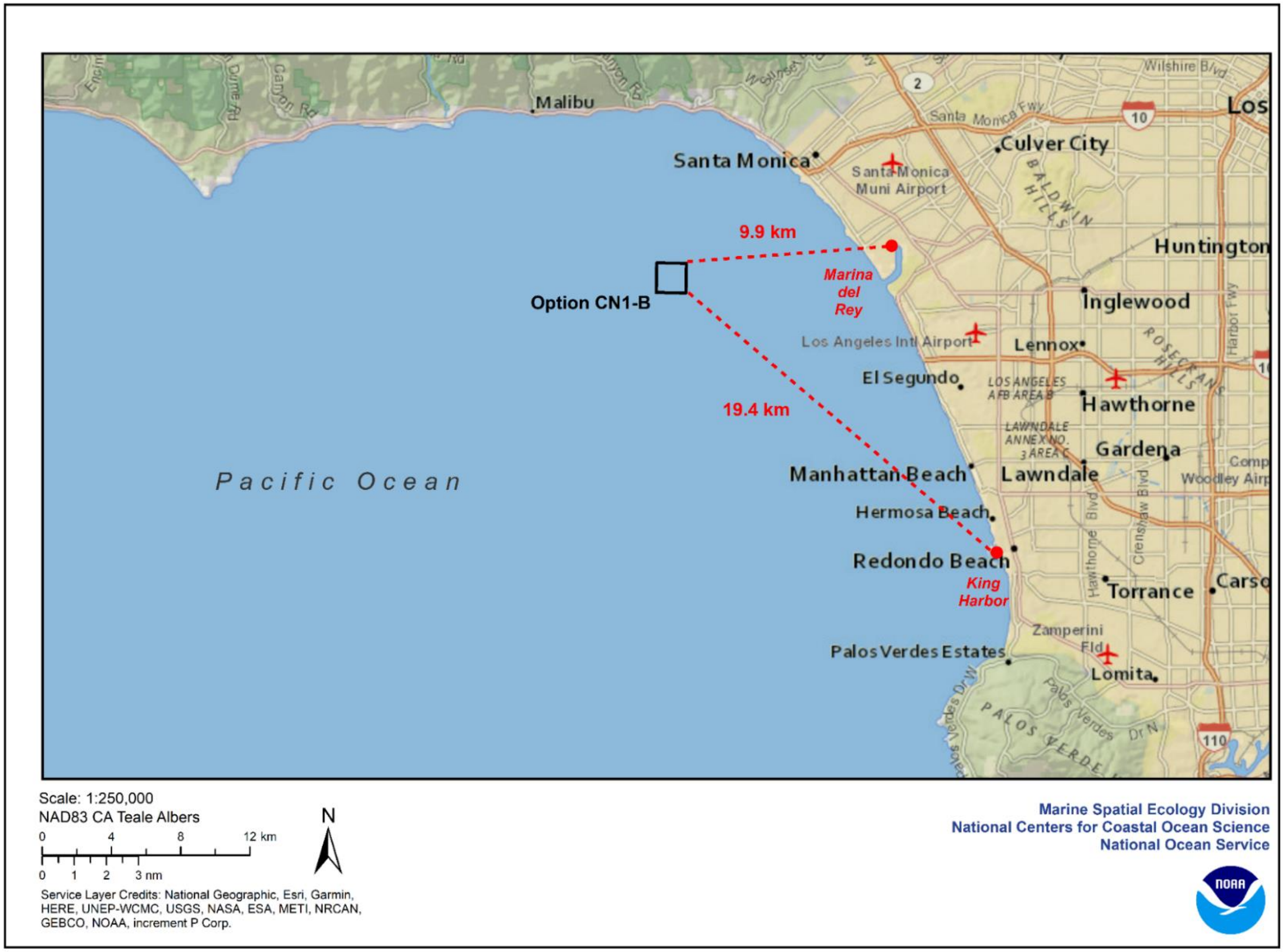


Figure 3.98. Option CN1-B (black outlined box) and distance to the closest port from the closest corner point; the area includes Marina del Rey and King Harbor.

Table 3.19. Automatic Identification System vessel traffic transits by year for the CN1-B option per 500 ac. Transits per 500 ac are presented to allow for a standardized comparison among all options.

Option	Vessel Type	2015	2016	2017	2018	2019	2020
CN1-B	Cargo	0	0	0	0	0	0
CN1-B	Fishing	6.00	22.00	0	3.00	5.00	6.00
CN1-B	Military	0	0	0	0	0	0
CN1-B	Other	54.00	38.00	77.00	60.00	38.00	56.00
CN1-B	Passenger	1.00	2.00	114.00	89.00	71.00	76.00
CN1-B	Pleasure and Sailing	92.00	103.00	112.00	206.00	195.00	226.00
CN1-B	Tanker	0	0	0	0	0	0
CN1-B	Tug and Tow	4.00	2.00	1.00	17.00	2.00	1.00

Similar Characteristics Across All AOA Options

Federal Statutes

Federal statutes cover a broad variety of legal restrictions and permitted activities within U.S. federal waters. A list of statutes is provided in the OceanReports analysis using the links provided in Appendix E; review of the list is recommended for each of the final ten AOA options. Please note that other federal statutes with complex or uncertain geographic boundaries may exist in the area.

Governance

Several federal agencies are responsible for ensuring that federal regulations are enforced within the areas of the AOA options. Table 3.20 provides a list of the federal agencies with corresponding regional or district information.

Table 3.20. List of primary federal agencies with organizational district information.

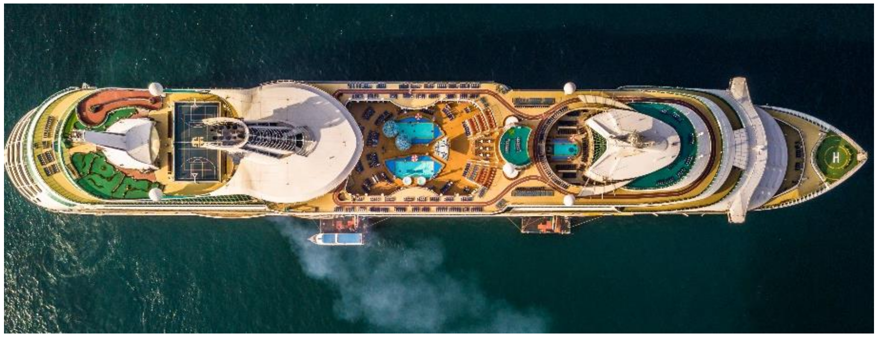
Federal Agency	District
USACE District	Los Angeles
USCG Sector	Los Angeles/Long Beach
NOAA NMFS	West Coast Region
USEPA Region	9
USFWS Region	8
BOEM OCS Region	Pacific
USGS Region	Southwest

Maritime Economy

The maritime economy of California supported a total of 586,028 jobs in 2018, with wages totaling $24.8 billion (NOAA OCM 2018). The leading economic sectors, comprising 88% of the maritime economy GDP for California, include tourism and recreation and marine transportation (NOAA OCM 2018). The majority of ocean jobs include the tourism and recreation and the marine transportation sectors, representing 75% and 19% respectively. The three clusters with AOA site options are offshore of the Santa Barbara, Ventura, and Los Angeles counties (Table 3.21).

Table 3.21. Maritime economy for counties adjacent to the Aquaculture Opportunity Area options (NOAA OCM 2018).

County	Employees	Wages ($ million)	GDP ($ billion)
Los Angeles	117,916	7,541	14.3
Santa Barbara	18,983	697	1.6
Ventura	17,367	499	1.2



Protected Resources

The following protected resources are known to occur within the Southern California Bight and will require further consideration when planning for aquaculture. Lists of species for both ESA-listed and MMPA stocks are provided in Table 2.4 and Table 2.5 with accompanying scores, which are included to provide context on the relative conservation status of the species. This list and the information below were provided by NMFS to inform early planning awareness related to aquaculture development activities in the coastal ocean of the Southern California Bight (Appendix B).

Large whales

Blue, fin, humpback, and gray whales are all found throughout the Southern California Bight depending on season and oceanographic conditions (Becker et al. 2020), including areas outside of BIAs. While the Eastern Pacific gray whale was removed from the list of threatened and endangered species in 1994, the Western North Pacific gray whale remains very low in numbers and is listed as endangered under the ESA. The fin whale is also an ESA-listed species that occurs in the Bight. Becker et al. (2020) provided distribution models which indicate that fin whales can occur within the general areas of the AOA options but are more frequently observed farther offshore.

Sea turtles

Four sea turtle species are known to inhabit the waters in the area of the AOA options, including green turtles, leatherback turtles, loggerhead turtles, and olive ridley turtles. Green turtles are mostly coastal-dwelling, occurring frequently in nearshore habitat; however, telemetry data document some movements in offshore areas. Leatherback turtles occur in the Bight mostly during transiting periods as they are more frequently observed in the Monterey Bay-Gulf of the Farallones region of the Central Coast. Leatherback sea turtles have also been observed using area-restricted search behavior, suggesting that they may also forage in the Southern California Bight (Benson et al. 2011). Loggerhead sea turtles are the most likely species to be found within or in proximity to the AOA options; however, their presence is sporadic and correlates with warm water periods.

Other protected species

Giant manta rays occur in the Southern California Bight. Their movement is driven by multiple factors including foraging on zooplankton, current and tidal patterns, seasonal upwelling, seawater temperature, and possibly reproduction. The scalloped hammerhead shark is another species that can frequent the Bight, albeit the Bight is considered to be the northernmost range of the species. Guadalupe fur seals also inhabit areas of the Bight; the occurrence of newborn pups and juveniles has been observed. Other pinnipeds including California sea lions and harbor seals are numerous and frequently observed in the region. Given the high occurrence of these species, it is unlikely that aquaculture activities can avoid interactions. However specific attention should be given to design, maintenance, and operation to both reduce attractants and create situations that could endanger the animals. All pinnipeds are protected under the MMPA and takes are illegal outside of exemptions or authorizations. Lastly, four species of dolphin including the common bottlenose, short-beaked and long-beaked common dolphin, and Risso's dolphin can also be found in the Bight. Dolphins have been documented to interact with aquaculture globally. Similar to pinnipeds, avoidance of areas with dolphins is unlikely; therefore, careful attention is required to minimize interactions with aquaculture during the operation of an aquaculture facility.

Essential Fish Habitat and Fishery Management Plans

Pursuant to the Magnuson-Stevens Act, each fishery management plan (FMP) must identify and describe Essential Fish Habitat (EFH) for the managed fishery. The statute defines EFH as "those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity." 16 U.S.C. § 1853(a)(7) and § 1802(10). NOAA regulations further define EFH by specifying that "necessary" means "the habitat required to support a sustainable fishery and the managed species contribution to a healthy ecosystem" (50 C.F.R. § 600.10). The Pacific Fisheries Management Council and NMFS manage fisheries within the U.S. West Coast EEZ for approximately 119 species of salmon, groundfish, coastal pelagic species, and highly migratory species. Table 3.22 provides several EFH areas that overlap with the AOA options.

Table 3.22. Essential Fish Habitat and Fisheries Management Plans that overlap with the Aquaculture Opportunity Area options.

Essential Fish Habitat	Fisheries Management Plan
Finfish and California Market Squid	Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)[29]
Krill - *Thysanoessa spinifera*	Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)
Krill - *Euphausia pacifica*	Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)
Other Krill Species	Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)
Coastal Pelagic Species	Coastal Pelagic Species (CPS) Fishery Management Plan (FMP)
Pacific Coast Groundfish	Groundfish Fishery Management Plan (FMP)[30]
HMS Albacore Tuna	Highly Migratory Species Fishery Management Plan (FMP)[31]
HMS Bigeye Tuna	Highly Migratory Species Fishery Management Plan (FMP)
HMS Blue Shark	Highly Migratory Species Fishery Management Plan (FMP)
HMS Common Thresher Shark	Highly Migratory Species Fishery Management Plan (FMP)
HMS Northern Bluefin Tuna	Highly Migratory Species Fishery Management Plan (FMP)
HMS Shortfin Mako Shark	Highly Migratory Species Fishery Management Plan (FMP)
HMS Yellowfin Tuna	Highly Migratory Species Fishery Management Plan (FMP)
HMS Dorado	Highly Migratory Species Fishery Management Plan (FMP)

[29] https://www.pcouncil.org/managed_fishery/coastal-pelagic-species/
[30] https://www.pcouncil.org/managed_fishery/groundfish/
[31] https://www.pcouncil.org/managed_fishery/highly-migratory-species/

Other Industry Considerations

Due to the area's proximity to other industries and natural resources, there is a potential for oil spills, natural oil seeps, and sewage and chemical spills to occur in the broader area. Although these events are considered rare, several notable events have occurred in the past 60 years.

Most notably, the Santa Barbara oil spill in 1969 released 100,000 barrels of crude oil into the Santa Barbara Channel and oiled beaches and wildlife in the area (NOAA 2021). In 1990, a spill occurred in Huntington Beach, releasing 13,000 barrels of oil, and in 1991 a pipeline in Santa Monica was damaged, releasing 21,000 gallons of a diesel-like mix used to flush the pipeline (NOAA 1991). In 2015, an onshore pipeline failure caused the release of more than 100,000 gallons of crude oil, which entered the ocean environment at Refugio Beach in Santa Barbara. The Refugio oil spill led to extended closures of commercial fishing and aquaculture sites in the vicinity. Recently, in October 2021, a pipeline off the coast of Huntington Beach released an estimated 125,000 gallons of crude oil. The spill also led to extended closures of commercial fishing and aquaculture in a 677-km^2 area (NOAA ORR 2021).

Historically, there have been releases of untreated wastewater and stormwater off the coast of California. Most recently, in July 2021, 17 million gallons of untreated wastewater was released into Santa Monica Bay through the 1-mile outfall and discharge pipe (LASAN 2021). Similar smaller releases have occurred off the coast of California either due to maintenance, overflow, blockages, or human error. Along with the release of wastewater, these same outfall and discharge pipes have released chemical compounds and heavy metals off the coast of California.

Dichloro-diphenyl-trichloroethane (DDT) and polychlorinated biphenyls (PCBs) were discharged off the coast of Los Angeles for several decades ending in the 1970s. Much of the DDT and PCBs are still found in sediments and can enter the food chain through fish and invertebrate species.

DISCUSSION

The Southern California Bight is geographically distinct, uniquely biodiverse, and consists of a temperate ocean climate with calm seas (Dailey et al. 1993). In addition, California is one of the most populated coastal states in the nation (U.S. Census Bureau 2018), containing the largest population center on the West Coast, namely, Los Angeles County (10 million people). With ready access to a dense human population, mild climate, and calm ocean conditions, southern California holds great promise and opportunity for coastal ocean aquaculture development. Realizing this opportunity, however, will require navigation through a complex ocean space that comprises high shipping traffic, diverse commercial fishing industries, sensitive habitat, protected species, and strategic national security assets. A critical element needed by coastal resource managers and stakeholders is the awareness and confidence to use geospatial analytical tools and science to inform regulation, protect the environment, and equitably resolve points of resistance to industry development. The spatial analysis presented herein provides supporting intelligence that will assist NOAA in the AOA development process. This Atlas was developed for the specific purpose of identifying locations that might be suitable for locating AOAs and includes limitations specific to that purpose. However, much of the spatial information provided herein will also be useful to the aquaculture industry and coastal managers for planning and siting of projects in the region.

This spatial analysis provides the most comprehensive marine spatial modeling in the Southern California Bight to date. These methods and models could significantly improve the next generation of marine spatial planning and contribute support far beyond aquaculture development by applying 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. With over 200 data layers included in this analysis, the maps, models, and descriptions provide unprecedented insights into the characteristics of the Bight and its ocean neighborhoods. While the overall suitability modeling used here is consistent with previous approaches utilized globally (Ehler and Douvere 2009), novel modeling approaches were developed for national security and NOAA trust resources (protected species). Further, new data products were developed and refined to provide increased resolution and geographic coverage. These modeling approaches and data products will serve useful for other marine planning efforts not only within the Bight, but also elsewhere in the U.S. EEZ.

Stakeholder input on relevant data and spatial modeling methodology was gathered through a Request for Information published in the Federal Register (85 FR 67519; October 23, 2020), public listening sessions, and one-on-one sessions with stakeholders. More than 200 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 development process in southern California will be when the Notice of Intent to prepare a Programmatic Environmental Impact Statement (PEIS) is published by NOAA.

This spatial modeling approach was specific to the planning goal of identifying discrete areas between 500 and 2,000 acres in the Southern California Bight that are potentially suitable for all types of aquaculture development including the cultivation of finfish, macroalgae, shellfish, or a combination of species. 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 opportunity, the parameters that were selected to conduct spatial modeling for AOAs (depth, distance to shore, and 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., mussel longline aquaculture) could identify different discrete areas that are more suitable than those proposed by this more general analysis.

The results of this analysis include detailed ocean neighborhood-level descriptions of the Southern California Bight AOA study areas, which are areas that met the industry and engineering requirements for depth and distance from shore. Spatial modeling was performed at 10-acre grid cell resolution, providing a high contrast of suitability. Modeling results identified eight AOA options in the North study area off of Santa Barbara, and two AOA options in the Central North study area off of Santa Monica. Major constraints in the Central South and South study areas, principally interactions with ports and military activities, posed constraints on AOA consideration. Offshore aquaculture development in areas south of Long Beach, will have to contend with these constraints, which may continue to affect siting and permitting efficiency.

The 10 AOA options identified were selected from 296 possibilities of the highest scoring ocean spaces (between 500 and 2,000 acres) within the two northern 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. 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.

North Study Area

Eight of the 10 highest ranking AOA options identified within the Southern California Bight are within the North study area, which is within the Santa Barbara Channel. The Santa Barbara Channel extends from Point Conception to Point Mugu in Ventura County. To the west of the channel, four of the Channel Islands, San Miguel, Santa Rosa, Santa Cruz, and Anacapa, are located 10 - 25 nm off the coast, providing habitat (rocky reefs and kelp forests) and protection from southerly storms. The Santa Barbara Channel is a transition zone where cold waters north of Point Conception mix with the warmer waters of southern California creating a biodiverse mixture of northern and southern marine life (CAMLPAI 2009). In addition, upwellings frequently occur off Point Conception, typically from March through September. These upwellings provide nutrient-rich waters that extend eastward through the channel. Giant kelp (*Macrocystis pyrifera*) is a dominating flora with dense canopies that provide habitat for diverse marine life. Hardbottom habitat, including rocky reefs and underwater pinnacles, are less common than soft-bottom habitat, with species composition varying along depth zones. Kelp forests are associated with the shallower rock bottoms, and deep-sea corals and sponges are more prevalent in the deep rocky habitat.

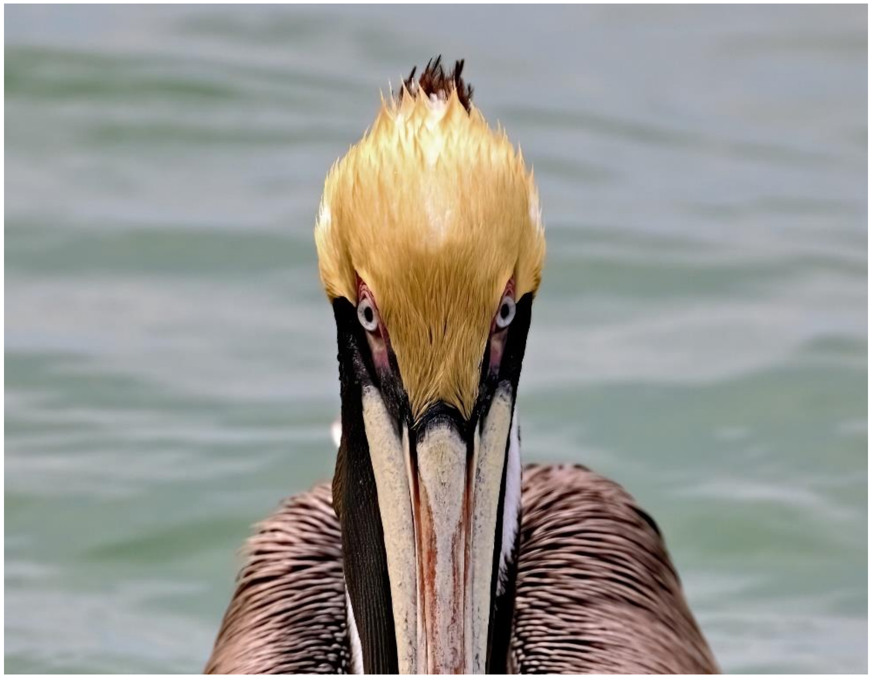
This region has a rich history in fishing dating back to the Chumash people as evidenced by the occurrence of large middens (Erlandson et al. 2005). Presently, the region supports vibrant fisheries for both finfish and shellfish with the highest landings, including the California spiny lobster, California market squid, sea urchin, and sablefish, through four primary ports and harbors: Santa Barbara Harbor, Ventura Harbor, Channel Islands Harbor, and Port Hueneme. The ports of Hueneme and Ventura primarily support the capture of larger, coastal pelagic species including market squid and tuna, whereas the harbors of Santa Barbara and Channel Islands serve smaller trap, dive, and trawl operations. Together, over 14 million pounds of seafood were landed on these docks in 2019 totaling nearly $25 million (CDFW 2020).

Aquaculture development within this region could complement wild-capture fisheries, working waterfronts, and regional seafood processing and distribution infrastructure. Of the eight AOA options identified in this region, six options are located within 10 nm of fishing docks, which could provide shore-based infrastructure for aquaculture. Five of the AOA options are closest to Ventura Harbor with the closest option (N2-E) located just 4.6 nm offshore, while the other options range from 6.3 to 14.9 nm offshore. The AOA options in this study area could also be accessed from the ports/harbors of Santa Barbara and Hueneme with distances ranging from 7.5 to 17.9 nm. The mean depth of all eight of the AOA options ranges from 25 to 95 m with the shallowest sites being N2-E (25.4 m), N2-D (31.5 m), and N2-C (48.1 m). Predominant currents are from the east-southeast with mean velocities ranging from 0.3 m/sec to upwards of 1.3 m/sec. The area consists of a mild wave climate with wave heights averaging 0.6 to around 1 m with 7- to 10-second wave periods predominantly from the west or west-southwest.

This study area largely avoids interactions with military operations, although there is a military training route (IR211 A B) that overlaps N2-D and N2-C completely, and partially overlaps N2-A, N2-B, and N2-E. This military training route provides support for the Point Mugu Sea Range. It is not anticipated that this interaction will cause significant conflict, as consultation with the DOD suggests that the AOA options may be compatible with military operations, but are subject to certain stipulations and final design review. The MTR is operated continuously day and night. Any structure, including vessels transiting to and from aquaculture facilities, may have height restrictions (likely not to exceed 100 ft) and appropriate lighting for structures under 100 ft may be necessary. Given that most aquaculture facilities do not exceed 50 ft vertically out of the water even during net cleaning periods, this potential military interaction may easily be mitigated through compliance with stipulations.

The potential interactions with protected species, including sea turtles, pinnipeds, and small and large cetaceans, will likely require considerable review and ESA Section 7 consultation with NMFS to ensure that aquaculture facilities pose minimal endangerment. All of the AOA options in this study area are located within a gray whale Biologically Important Area for migration. In addition, five of the eight AOA options overlap Critical Habitat for humpback whales, although the other three options will also require similar consideration for humpback whales. Any proposed projects within an AOA with the potential to adversely affect ESA-listed species, MMPA species of concern, and/or that have been designated Critical Habitat will require review and consultation within NMFS. Review of whale interactions will likely require consideration of entanglement risk, habitat displacement, and many other considerations (Price and Morris 2013; Price et al. 2017).

Habitat interactions including hardbottom substrate and corals were largely avoided using spatial modeling approaches. No hardbottom habitat areas are known within 3 km of any of the AOA options in the North study area; however, deep-sea coral observations have been made within 3 km of options N1-A and N1-B. Given the presence of corals in the area, it is likely that comprehensive habitat review and surveys will be required to characterize benthic habitat and ensure that impacts to habitat are minimized. Given that some types of aquaculture can discharge effluents, characterization of effluent biomass and fate is an important consideration for ensuring that aquaculture operations do not adversely impact nearby habitat (Price and Morris 2013).



Central North Study Area

Two of the top ten ranked AOA options are located within the Central North study area, which is within the South Coast region of the Southern California Bight, a region that is known historically as the “tuna capital of the world.” This region was home to one of the world’s largest fishing fleets of seine operators and to numerous tuna processing canneries (Felando and Medina 2012). By the early 1980s, most of the canneries had gone out of business or relocated to U.S. territories or other countries, due mainly to lower processing costs, fisheries management challenges, and the shifting of fishing operations to the western Pacific to avoid conflicts with dolphins and porpoises (California Sea Grant 2021). In spite of the decline in the tuna fishery, the fishing communities of the region persist due to the continued productivity of the ocean ecosystem, proximity to large urban communities, and an extensive and large port infrastructure that provides ready access and connection to both domestic and global markets (California Sea Grant 2021).

The Central North study area is located on the northern end of the south coast of the Southern California Bight in Santa Monica Bay. In contrast to waters further north, this area is in closer proximity to subtropical waters, which adds to its biodiversity and productivity. Highly migratory species such as yellowfin tuna and yellowtail jack are often found to migrate to the warmer offshore waters, whereas temperate species such as albacore, bluefin tuna, and swordfish occur during seasonal migrations (California Sea Grant 2021). Given the coastal geography and wind patterns, upwelling is more limited in the region; however, several submarine canyons provide nutrient-rich waters enhancing local production (CAMLPAI 2009). Located deep within Santa Monica Bay, these two AOA options exhibit a mild wave climate with heights ranging from 0.5 to 0.68 m with a period ranging from 8 to 10 seconds from the southwest. The mean depth of the two AOA options is 98.9 m for CN1-A and 66.6 m for CN1-B. Predominant currents are from the southeast and range from 0.2 to 0.45 m/sec. Wind speeds are also mild with ranges from 1.0 to 2.4 m/sec from the southwest.

The two Central North AOA options are two of the smaller options, with the largest being 1,000 acres. The nearest two harbors are Marina del Rey and Redondo Beach (King Harbor). AOA option CN1-B is the option nearest to shore, at 5.3 nm from Marina del Rey; CN1-A is approximately 6 nm away from the same harbor. Redondo Beach is 10.5 nm from CN1-B and 11.3 nm from CN1-A. These two harbors already support some commercial fishing landings, with Redondo Beach reporting over 264,000 pounds of seafood valued at nearly $700,000 in 2019, whereas Marina del

Rey reported over 230,000 pounds valued at nearly $442,000 in the same year (CDFW 2020). It is uncertain if either location could support the expansion of aquaculture-related shore-based infrastructure. Marina del Rey was once the largest man-made small craft harbor in the United States and today provides nearly 5,000 boat slips supporting the greater Los Angeles metro area. Similarly, Redondo Beach is primarily a harbor for pleasure and sailing vessels. Further consideration could be given to shore-based infrastructure farther south within the Port of Los Angeles complex. While access to this area is nearly 30 nm from these two AOA options, some types of aquaculture may accommodate this distance from port.

AOA options CN1-A and CN1-B overlap the San Pedro Channel Operating Area; however, it is not anticipated that this overlap is a major constraint for aquaculture development based on review by the DOD (Appendix D). There is also no oil and gas development in the general area, but there is an offshore marine terminal to off-load crude oil from ocean tankers within 6 nm of these options. These two AOA options are in proximity to hardbottom substrate and deep-sea corals, which will require further consideration during future planning or permitting efforts. Similar to the North study area, the Central North study area is located within a Biologically Important Area for gray whales and will require similar considerations.

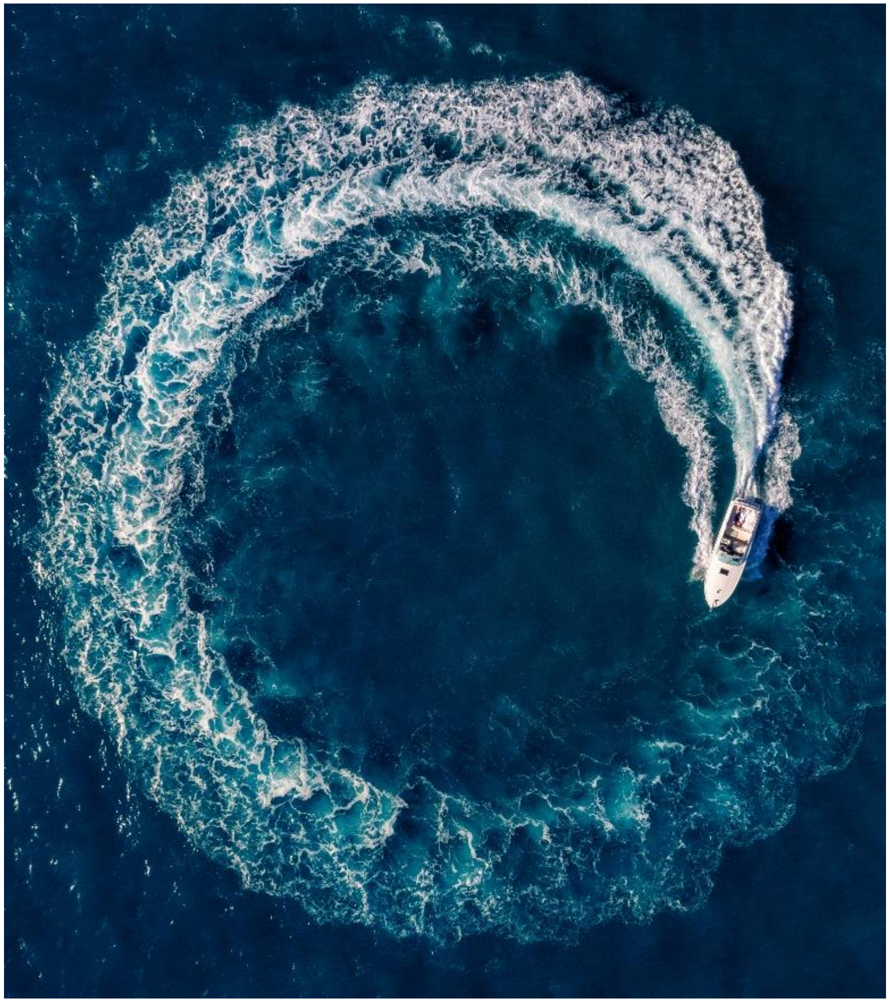
Of all the AOA options, the Central North AOA options have the lowest vessel traffic. Based on AIS data, the largest number of pleasure and sailing vessels transiting CN1-A is 90 per year. The nearby CN1-B option reported 35 pleasure and sailing vessels per year. Similarly, other vessels including fishing vessels transiting the sites were less than 40 vessels per year. Given the location closer to shore, no cargo, military, or other large vessels are reported. VMS reports are also significantly low (near zero) for all categories. As for the North study area, caution should be taken when considering commercial fishing, pleasure and sailing vessels, and other vessel traffic data from electronic reporting sources such as AIS and VMS given that these sources of data are typically under-reported.

While it is expected that the findings of this analysis will be relevant for some time, it is likely that specific and measurable changes will occur in the suitability of the study areas. Coastal ocean space is inherently temporally dynamic in nature, including both environmental and ocean use patterns. For example, growth of ports can drastically change the magnitude of shipping traffic, creating new ocean highways, anchorages, and associated buffer zones. The ecology of study areas can also vary in time as the distribution of habitat and marine life respond to human impacts and natural change as well as occasional stochastic influences. For these reasons, spatial analyses such as the one discussed here should be viewed as "living analyses," or decision support infrastructure, to be consulted for understanding opportunity in the context of space and time.

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 the 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 (HABs). 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.

The results of this analysis provide compelling evidence of the challenges of siting offshore aquaculture in the coastal ocean within a reasonable range of the waterfront in the Area of Interest. Further, this analysis demonstrates the inherent value of advanced regional-scale planning before permitting actions begin. Multiple prior permitting attempts for offshore aquaculture in the Southern California Bight have been unsuccessful, a result of the difficulty of navigating ocean use conflicts and complexities in the permitting process (D. Windham, NMFS West Coast Region Aquaculture Coordinator for California, pers. comm.). 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 the intelligence provided herein to industry, the public, and coastal managers in advance will unquestionably save resources and potentially shorten permitting timelines.

Visual impact is considered one of the main issues associated with 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, historically important scenic views, or when a project is in the vicinity of a cultural resource. Because of the proximity of AOA options along the coast of California, viewshed analysis coupled with visual simulations under different times of day and weather conditions could help stakeholders discern visual impacts to the coastal landscape. In previous planning studies conducted by NOAA NOS/NCCOS for southern California (San Diego), it was determined through modeling and photo-realistic simulations that offshore fish farms would have minimal impact on the seascape when farms are sited greater than 9 km (5 nm) from the shoreline (Morris et al. 2015). These simulations were used in regional workshops to support dialogue and exchange with coastal managers, industry participants, and stakeholders. Viewshed analysis applications within GIS have been developed and standardized to support offshore wind development. This technology could greatly benefit offshore aquaculture development when farming operations have a visual impact on the seascape.



The permitting and authorization requirements for aquaculture development within AOAs are the same as other projects 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 (ESA), Essential Fish Habitat (EFH) under the Magnuson-Stevens Act, Marine Mammal Protection Act (MMPA), 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 also 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 Southern California Bight and nationally. While this analysis did incorporate the best 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. 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 focused on addressing spatial data that are limited for specific fisheries or geographies (NOAA OCM 2014).

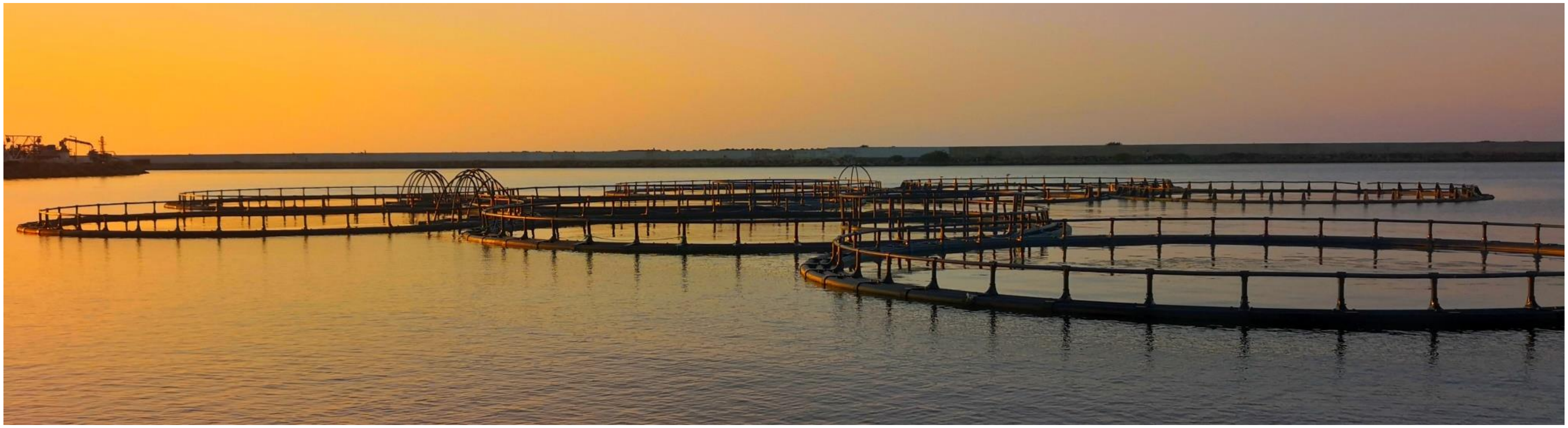
Improvement of marine traffic data could also benefit marine planning efforts. Marine traffic data used in this study were largely sourced from terrestrial AIS data sources, which have well-documented limitations including but not limited to noise due to erroneous transmissions, equipment compatibility 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 are not required to or do not transmit AIS data, making all AIS analyses 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 and sailing vessels). 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 acres) 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 low 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 that quantifies 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 future 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 find 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 Southern California Bight. 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, 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 utilize scenario planning approaches (Couture et al. 2021) to further explore the opportunity for aquaculture. 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 southern California 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. southern California waters.

National Security Datasets	Source	Source Link	MetaData Link
Camp Pendleton and San Diego Military Areas	U.S. Fleet Force: Environmental Readiness Branch	CUI	CUI
Danger and Restricted Zones	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 Installations	DOD	https://www.acq.osd.mil/eie/Downloads/DISDI/installations_ranges.zip	https://www.acq.osd.mil/dodsc/fast41_gisdatasets.html
Military Operating Area	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 Areas	U.S. Fleet Force: Environmental Readiness Branch	CUI	CUI
Military Training Routes	FAA	https://www.acq.osd.mil/dodsc/downloads/MTR_CYCLE_1909_FINAL.zip	https://www.acq.osd.mil/dodsc/fast41_gisDatasets.html
Point Mugu Sea Range	U.S. Fleet Force: Environmental Readiness Branch	CUI	CUI
San Pedro Channel Operating Area	U.S. Fleet Force: Environmental Readiness Branch	CUI	CUI
Special Use Airspace	Navy EIMS	https://www.acq.osd.mil/dodsc/downloads/SUA_PUBLIC.zip	https://sua.faa.gov/sua/siteFrame.app
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/
Unexploded Ordnance points	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	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

Table A-2. Natural and cultural resources data layers used for Aquaculture Opportunity Area planning in U.S. southern California waters.

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Marine Protected Area Inventory	NOAA NOS Marine Protected Areas Center and Anthropocene Institutes Protected Seas Team	https://protectedseas.net/mpa-download-Data/	https://protectedseas.net/mpa-attributes
National Oceanic and Atmospheric Administration Marine Protected Areas	NOAA	https://marineprotectedareas.noaa.gov/media/Data/NOAA_MPAI_2020_IUCN_gdb.zip	https://nmsmarineprotectedareas.blob.core.windows.net/marineprotectedareas-prod/media/Data/NOAA_MPAI_2020_IUCN_metaData.pdf
Marine Protected Area Watch Dataset	MPA Watch Collaborative	https://mpawatch.org/	https://mpawatch.org/
California Coastal National Monuments	BLM	https://erma.noaa.gov/admin/layer/33274	https://prod-erma-api.orr.noaa.gov/api/v1/Data_layer/33274/metaData_file/
National Marine Sanctuaries	NOAA NOS	https://sanctuaries.noaa.gov/library/imast_gis.html	https://sanctuaries.noaa.gov/library/imast_gis.html
Protected Areas	NOAA	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ProtectedAreas.zip	https://www.fisheries.noaa.gov/inport/item/54398
Abrahms Blue Whale	NOAA	https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/whalewatch2_explorer.html	https://onlinelibrary.wiley.com/doi/full/10.1111/ddi.12940
Predictive Models of Cetacean Densities in the California Current Ecosystem, 2016	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Baird's Beaked Whale	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Beaked Whale Guild Mesoplodon	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Blue Whale	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Bottlenose Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Dall's Porpoise	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Fin Whale	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Humpback Whale	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Long-beaked Common Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Northern Right Whale Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Pacific White-sided Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Risso's Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Short-beaked Common Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Sperm Whale	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Striped Dolphin	NOAA NMFS	https://cetsound.noaa.gov/packages/swfsc_CCE_SummerFall_Becker_et_al_2016.zip	https://inport.nmfs.noaa.gov/inport/item/55923
Computerized Database Analysis System Bird Surveys	CDFW	https://erma.noaa.gov/admin/folder/2050	https://prod-erma-api.orr.noaa.gov/api/v1/Data_layer_file/1433/download/
Ocean Biodiversity Information - Cetacean and Turtle Points (Various Species)	Duke University OBIS-SeaMap	https://seamap.env.duke.edu/	https://seamap.env.duke.edu/
Kelp Canopy (Persistence)	CDFW	https://catalog.Data.gov/Dataset/west-coast-canopy-forming-kelp-1989-2014	https://map.dfg.ca.gov/metaData/BIO_CA_KelpPersist.html
West Coast Canopy Forming Kelp	BOEM	www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Pacific-files/WestCoastCanopyFormingKelp.zip	www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Pacific-files/WestCoastCanopyFormingKelp.zip
Deep-sea Coral and Sponge Observations 1985 - Present (with 500-m buffer)	NOAA Deep-Sea Coral Research and Technology Program	https://www.ncei.noaa.gov/erddap/tabledap/deep_sea_corals.html	https://www.ncei.noaa.gov/maps/deep-sea-corals/mapSites.htm
AquaMaps Fur Seal	FishBase	https://www.aquamaps.org/	https://Data.unep-wcmc.org/pdfs/35/Kaschner-001-NorthernFurSeal2013.pdf?1418914314
Fish Biomass	SCCWRP	https://www.sccwrp.org/about/research-areas/regional-monitoring/southern-california-bight-regional-monitoring-program/bight-program-Data-portal/	https://www.sccwrp.org/about/research-areas/regional-monitoring/southern-california-bight-regional-monitoring-program/bight-program-Data-portal/

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Fish Ranges	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/BIOLOGICAL/Fish_Ranges/	https://wildlife.ca.gov/Data/CWHR
Areas of Special Biological Significance	SWRCB	https://gispublic.waterboards.ca.gov/arcgis/rest/services/Administrative/Areas_of_Special_Biological_Significance/MapServer	https://gispublic.waterboards.ca.gov/arcgis/rest/services/Administrative/Areas_of_Special_Biological_Significance/MapServer
Environmental Sensitivity Index	NOAA	https://response.restoration.noaa.gov/esi_download	https://response.restoration.noaa.gov/esi_basics
U.S. Geological Survey Habitat	CSMP	https://pubs.usgs.gov/ds/781/	https://pubs.usgs.gov/ds/781/
National Oceanic and Atmospheric Administration Essential Fish Habitat Layers	NOAA	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon
Essential Fish Habitat Salmon (Chinook, Coho, Pink, All)	NOAA NMFS	https://media.fisheries.noaa.gov/2020-04/noaa_wcr_salmonid_efh_2014.zip	https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=157fb010f86c72392755420317e1f5d8&mc=true&n=pt50.13.660&r=PART&ty=HTML#se50.13.660_1412

Essential Fish Habitat Groundfish (Arrowtooth Flounder, Aurora Rockfish, Bank Rockfish, Big Skate, Black-and-Yellow Rockfish, Blackgill Rockfish, Black Rockfish, Blue Rockfish, Bocaccio, Bronzespotted Rockfish, Brown Rockfish, Butter Sole, Cabezon, Calico Rockfish, California Scorpionfish, California Skate, Canary Rockfish, Chameleon Rockfish, Chilipepper Rockfish, China Rockfish, Copper Rockfish, Cowcod, Curlfin Sole, Darkblotched Rockfish, Dover Sole, Dusky Rockfish, Dwarf-Red Rockfish, English Sole, Finescale Codling, Flag Rockfish, Flathead Sole, Freckled Rockfish, Gopher Rockfish, Grass Rockfish, Greenblotched Rockfish, Greenspotted Rockfish, Greenstriped Rockfish, Halfbanded Rockfish, Harlequin Rockfish, Honeycomb Rockfish, Kelp Greenling, Kelp Rockfish, Leopard Shark, Lingcod, Longnose Skate, Longspine Thornyhead, Mexican Rockfish, Olive Rockfish, Pacific Cod, Pacific Ocean Perch, Pacific Rattail, Pacific Sanddab, Pacific Whiting, Petrale Sole, Pinkrose Rockfish, Pygmy Rockfish, Quillback Rockfish, Spotted Ratfish, Redbanded Rockfish, Redstripe Rockfish, Rex Sole, Rock Sole, Rosethorn Rockfish, Rosy Rockfish, Rougheye Rockfish, Sablefish, Sand Sole, Sharpchin Rockfish, Shortbelly Rockfish, Shortspine Thornyhead, Shortraker Rockfish, Silvergray Rockfish, Soupfin Shark, Speckled Rockfish, Spiny Dogfish, Splitnose Rockfish, Squarespot Rockfish,	NOAA NMFS	https://media.fisheries.noaa.gov/2021-02/EFH_HAPC_EFHCA_shapefiles_AM19-2006%2BAM28-2020.zip?null	https://www.pcouncil.org/documents/2016/08/pacific-coast-groundfish-fishery-management-plan.pdf/#page=116

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Starry Flounder, Starry Rockfish, Stripetail Rockfish, Swordspine Rockfish, Tiger Rockfish, Treefish, Widow Rockfish, Yelloweye Rockfish, Yellowmouth Rockfish, Yellowtail Rockfish, Vermilion Rockfish)			
Habitat Area of Particular Concern - Groundfish	NOAA NMFS	https://media.fisheries.noaa.gov/2021-02/EFH_HAPC_EFHCA_shapefiles_AM19-2006%2BAM28-2020.zip?null	https://www.fisheries.noaa.gov/west-coast/habitat-conservation/habitat-areas-particular-concern-west-coast#groundfish-hapcs
Deep-sea Ecosystem Conservation Area	NOAA NMFS	https://media.fisheries.noaa.gov/2020-04/groundfish_efh_deca_am28_2020.zip	https://www.ecfr.gov/cgi-bin/text-idx?SID=f4e7c2e03aa4236409fef8d66040910b&mc=true&node=se50.13.660_111&rgn=div8
Fish Essential Fish Habitat Layers	NOAA	https://www.habitat.noaa.gov/protection/efh/newInv/Data/west_coast/westcoast_efha.zip	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon
Habitat Essential Fish Habitat Layers	NOAA	https://www.habitat.noaa.gov/protection/efh/newInv/Data/west_coast/westcoast_hapc.zip	https://www.habitat.noaa.gov/protection/efh/newInv/Data/west_coast/westcoast_hapc.zip
Conservation Area Essential Fish Habitat Layers	NOAA	https://www.habitat.noaa.gov/protection/efh/newInv/Data/west_coast/westcoast_hapc.zip	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon
Coastal Regional Sediment Management Plan Identified Sensitive Areas	CA Parks	https://dbw.parks.ca.gov/?page_id=29602	https://www.researchgate.net/publication/268733451_Coastal_Regional_Sediment_Management_Planning_In_Southern_Monterey_Bay_California
Habitat California Eelgrass	CDFW	ftp://ftp.wildlife.ca.gov/R7_MR/HABITAT/HAB_CA_Eelgrass.zip	https://map.dfg.ca.gov/metaData/Eelgrass_161128.html
Habitat Kelp Administration Regions	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/MANAGEMENT/MAN_CA_KelpAdmin.zip	https://map.dfg.ca.gov/metaData/MAN_CA_KelpAdmin_140401.html

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
Coastal Critical Habitat Designation	NOAA	ftp://ftp.coast.noaa.gov/pub/MSP/CoastalCriticalHabitatDesignations.zip	https://www.fisheries.noaa.gov/inport/item/54209#:~:text=Critical%20habitat%20is%20defined%20as,areas%20outside%20the%20geographical%20area
Coastal Wetlands	USGS/USFWS	https://fwsprimary.wim.usgs.gov/wetlands/apps/wetlands-mapper/; https://www.fws.gov/wetlands/Data/Data-Download.html	https://www.fws.gov/wetlands/Data/metaData.html
Seagrasses in the United States	NOAA	ftp://ftp.coast.noaa.gov/pub/MSP/Seagrasses.zip	https://www.fisheries.noaa.gov/inport/item/56960/
Hardbottom Habitat	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/HABITAT/HAB_CA_PredictedSubstrate_WZ.zip	https://map.dfg.ca.gov/metaData/HAB_CA_PredictedSubstrate_WZ_10m_180710.html
National Oceanic and Atmospheric Administration Electronic Navigational Charts Artificial Reefs	NOAA ENC	ftp://ftp.coast.noaa.gov/pub/MSP/ArtificialReefs.zip	https://inport.nmfs.noaa.gov/inport/item/54191
Fish Havens	NOAA OCS	https://encdirect.noaa.gov/	https://www.fisheries.noaa.gov/inport/item/39976
National Oceanic and Atmospheric Administration National Marine Fisheries Service Cetacean Biologically Important Areas 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://www.fisheries.noaa.gov/inport/item/23643
Audubon Important Bird Areas	National Audubon Society	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalAudobonIBAs.zip	https://ca.audubon.org/important-bird-areas-9
National Marine Fisheries Service Essential Fish Habitat Areas of Particular Concern	NOAA NMFS	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon	https://www.habitat.noaa.gov/protection/efh/newInv/index.html
Deep-sea Coral Habitat Suitability (Soft Corals/Hard Corals) Models	NOAA NOS	ftp://ftp.coast.noaa.gov/pub/MSP/DeepSeaCoralHabitatSuitability.zip	https://inport.nmfs.noaa.gov/inport/item/48877

Natural and Cultural Resources Datasets	Source	Source Link	MetaData Link
California Coastal National Monuments	BLM	https://erma.noaa.gov/admin/layer/33274	https://erma.noaa.gov/admin/layer/33274
Economics: National Ocean Watch	NOAA NOS	https://coast.noaa.gov/digitalcoast/data/enow.html	https://www.fisheries.noaa.gov/inport/item/48033
Fishing Piers	CDFW	Direct from CDFW	Direct from CDFW
California Dive Sites	CDFW	Direct from CDFW	Direct from CDFW
California Boat Launch Sites	CDFW	Direct from CDFW	Direct from CDFW
Social Indicators of Fishing Communities	NOAA	https://www.st.nmfs.noaa.gov/Data-and-tools/social-indicators/	https://www.fisheries.noaa.gov/national/socioeconomics/social-indicators-fishing-communities-0

Table A-3. Industry, navigation, and transportation data layers used for Aquaculture Opportunity Area planning in U.S. southern California waters.

Industry, Navigation, and Transportation Datasets	Source	Source Link	MetaData Link
Principal Ports	USACE	ftp://ftp.coast.noaa.gov/pub/MSP/PrincipalPorts.zip	https://www.fisheries.noaa.gov/inport/item/56124
Deepwater Ports	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/DeepwaterPorts.zip	https://www.fisheries.noaa.gov/inport/item/54192
Pilot Boarding Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PilotBoarding.zip	https://www.fisheries.noaa.gov/inport/item/54393%20
Pilot Boarding Stations	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PilotBoarding.zip	https://www.fisheries.noaa.gov/inport/item/54394
Coastal Maintained Channels	USACE	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalMaintainedChannels.zip	https://www.fisheries.noaa.gov/inport/item/39972
Aids to Navigation	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/AidsToNavigation.zip	https://www.fisheries.noaa.gov/inport/item/56120
Anchorage Areas (Used/Disused)	NOAA OCM and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/AnchorageAreas.zip	https://www.fisheries.noaa.gov/inport/item/48849
Automated Wreck and Obstruction Information System Wrecks Polluting Remedial Underwater Legacy Environmental Threat	NOAA NOS	ftp://ftp.coast.noaa.gov/pub/MSP/WrecksAndObstructions.zip	https://www.fisheries.noaa.gov/inport/item/39961
Electronic Navigational Chart Wrecks	NOAA	https://wrecks.nauticalcharts.noaa.gov/downloads/ENC_Wrecks.zip	https://nauticalcharts.noaa.gov/Data/gis-Data-and-services.html
Electronic Navigational Chart Danger Wrecks	NOAA	https://www.nauticalcharts.noaa.gov/ENCOnline/enconline.html	https://nauticalcharts.noaa.gov/Data/gis-Data-and-services.html
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 Waters	USCG; DOT BTS	https://www.npms.phmsa.dot.gov/Data/CNW_V5_NAD83.zip	https://www.npms.phmsa.dot.gov/Data/metaData/CNW_V5_MetaData.pdf; https://www.nap.usace.army.mil/Portals/39/docs/regulatory/regs/33cfr329.pdf
U.S. Ferry Routes	National Atlas of the U.S.	https://geo.nyu.edu/catalog/stanford-gd729dg1947	https://geo.nyu.edu/catalog/stanford-gd729dg1947
Southern California Ferry Routes	Open Street Maps	http://overpass-turbo.eu/	https://wiki.openstreetmap.org/wiki/Tag:route%3Dferry
Automatic Identification System Vessel Traffic (2016, 2017, 2018, 2019) for Each Vessel Type (Cargo, Tanker, Passenger, Fishing, Tug and Tow, Pleasure and Sailing, Military, and Other)	NOAA OCM and BOEM (i.e., marinecadastre.gov) and USCG	https://marinecadastre.gov/ais/	https://inport.nmfs.noaa.gov/inport/item/53161
Marine Information for Safety and Law Enforcement	USCG	https://homeport.uscg.mil/Lists/Content/Attachments/211/MISLE%20DATA.zip	https://homeport.uscg.mil/Lists/Content/DispForm.aspx?ID=211&Source=/Lists/Content/DispForm.aspx?ID=211
California Lighthouses	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/CULTURAL/Lighthouses.zip	ftp://ftp.dfg.ca.gov/R7_MR/CULTURAL/Lighthouses.zip
Oil Seeps (Bureau of Ocean Energy Management)	USGS	https://pubs.usgs.gov/of/2009/1225/of2009-1225_shp.zip	https://pubs.usgs.gov/of/2009/1225/
Oil Spills (Raw Incidents)	NOAA	https://incidentnews.noaa.gov/raw/incidents.csv	https://incidentnews.noaa.gov/raw/index
Bureau of Ocean Energy Management Active Lease Blocks	BOEM	gis.boem.gov/arcgis/rest/services/BOEM_BSEE/POC_Layers/MapServer/7	gis.boem.gov/arcgis/rest/services/BOEM_BSEE/POC_Layers/MapServer/7

Industry, Navigation, and Transportation Datasets	Source	Source Link	MetaData Link
Active Renewable Energy Leases	BOEM	https://www.boem.gov/BOEM-Renewable-Energy-Shapefiles.zip https://www.boem.gov/BOEM-Renewable-Energy-GeoDatabase.zip	https://www.boem.gov/BOEM-Renewable-Energy-Shapefiles.zip https://www.boem.gov/BOEM-Renewable-Energy-GeoDatabase.zip
Marine Hydrokinetic Projects	BOEM	ftp://ftp.coast.noaa.gov/pub/MSP/PermittedMarineHydrokineticProjects.zip	https://www.fisheries.noaa.gov/inport/item/54966
Oil and Gas Platforms	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasPlatforms.zip	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasPlatforms.zip
Oil and Gas Wells	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasWells.zip	https://metaData.boem.gov/geospatial/OCSwells-POCSR-NAD83.xml
Oil and Gas Wells	California Department of Conservation	ftp://ftp.consrv.ca.gov/pub/oil/GIS/WellData/AllWells_gis.zip	https://www.conservation.ca.gov/calgem/maps/Pages/GISMapping2.aspx
Oil and Gas Resource Potential	BOEM	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/OilandGasResourcePotential.zip	http://metaData.boem.gov/geospatial/Oil%20and%20Gas%20Resource%20Plays.xml
Renewable Planning Areas	BOEM	https://www.boem.gov/BOEM-Renewable-Energy-GeoDatabase.zip	https://www.boem.gov/BOEM-Renewable-Energy-GeoDatabase.zip
Oil and Gas Planning Areas: Pacific Federal Waters	BOEM	https://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Pacific-files/PC_PLANAREA.aspx	https://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Pacific-files/PC_PLANAREA.aspx
State Lands Commission Active Lease	SLC	https://data-cslc.opendata.arcgis.com/datasets/29acc3254b5e414ba7aee2c3b6a93b0b_0/explore?location=21.872301%2C-76.298500%2C4.20	https://data-cslc.opendata.arcgis.com/datasets/CSLC::ca-state-lands-commission-leases/about
Commercial Fishing Marine Vessel Corridors	JOFLO	Digitized from maps	Digitized from maps
Cable Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SubmarineCableAreas.zip	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SubmarineCableAreas.zip

Industry, Navigation, and Transportation Datasets	Source	Source Link	MetaData Link
Pipeline Areas	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/PipelineArea.zip	https://inport.nmfs.noaa.gov/inport/item/54395
Pipelines	BSEE	https://www.Data.bsee.gov/Mapping/Files/ppl_arcs.zip; https://www.boem.gov/PC-pipe.zip	https://www.Data.bsee.gov/Mapping/Files/ppl_arcs.zip; https://www.boem.gov/PC-pipe.zip
Submarine Cables	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/SubmarineCables.zip	https://inport.nmfs.noaa.gov/inport/item/57238
Substations	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/Substations.zip	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/Substations.zip
Environmental Sensors and Buoys	NOAA	https://www.ndbc.noaa.gov/	https://www.ndbc.noaa.gov/

Table A-4. Fishing and aquaculture data layers used for Aquaculture Opportunity Area planning in U.S. southern California waters.

Fishing and Aquaculture Datasets	Source	Source Link	MetaData Link
Commercial Fishing Marine Vessel Corridors	JOFLO	Digitized from maps	Digitized from maps
California Department of Fish and Wildlife Aquaculture - 2020 Update	CDFW	Direct from CDFW	Direct from CDFW
Pacific Mariculture	NOAA	Available upon request and approval	Available upon request and approval
Avalon Site Alt A, B	NOAA	Available upon request and approval	Available upon request and approval
Ocean Rainforest Alt - State/ Fed	NOAA	Available upon request and approval	Available upon request and approval
Ventura Shellfish Enterprise - Fed	NOAA	Available upon request and approval	Available upon request and approval
Aquaculture	NOAA	ftp://ftp.coast.noaa.gov/pub/MSP/Aquaculture.zip	https://www.fisheries.noaa.gov/inport/item/53129/
Fishing Blocks	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/MANAGEMENT/Commercial_Fishingblocks.zip	https://map.dfg.ca.gov/metaData/MAN_CA_largeOffshoreblocks.html
Lobster Fishing Blocks	CDFW	Direct from CDFW	Direct from CDFW
Halibut Trawl Grounds	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/MANAGEMENT/MAN_SCSR_HalibutTrawlGrounds.zip	https://map.dfg.ca.gov/metaData/MAN_SCSR_HalibutTrawlGrounds_160830.html
Fish Houses/ Fish Processing	NOAA	CUI	CUI
Divelog	CDFW	Direct from CDFW	Direct from CDFW
Lobster Log	CDFW	Direct from CDFW	Direct from CDFW
Squid Landing Microblocks	CDFW	Direct from CDFW	Direct from CDFW
State Managed Trawl Vessel Monitoring Systems	CDFW	Direct from CDFW	Direct from CDFW
State Managed Trawl Vessel Monitoring Systems - Points	CDFW	Direct from CDFW	Direct from CDFW

Fishing and Aquaculture Datasets	Source	Source Link	MetaData Link
Pacific Coast Fisheries Geographic Information System Resource Database	USGS	https://www.usgs.gov/centers/werc/science/pacific-coast-fisheries-gis-resource-database?qt-science_center_objects=0#qt-science_center_objects	https://www.usgs.gov/centers/werc/science/pacific-coast-fisheries-gis-resource-Database?qt-science_center_objects=0#qt-science_center_objects
Drift Gill Net Fishing Areas	CDFW	Direct from CDFW	Direct from CDFW
Deep-set Buoy Gear Exempted Fishing Permit Fishing Areas	CDFW	Direct from CDFW	Direct from CDFW
Deep-set Linked Buoy Gear Exempted Fishing Permit Fishing Areas	CDFW	Direct from CDFW	Direct from CDFW
Harpoon Fishing Areas	CDFW	Direct from CDFW	Direct from CDFW
Highly Migratory Species Purse Seine Fishing Areas	CDFW	Direct from CDFW	Direct from CDFW
Observer Data - Catch Shares	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Observer Data - Limited Entry Fixed Gear Daily Trip Limit	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Observer Data - Nearshore	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Observer Data - Open Access California Halibut (Trawl)	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Observer Data - Open Access Fixed Gear	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Observer Data - Ridgeback Prawn (Trawl)	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program

Fishing and Aquaculture Datasets	Source	Source Link	MetaData Link
Observer Data - California Sea Cucumber (Trawl)	NOAA NMFS	Observer Data from NWFSC Fisheries Observation Science Program	Observer Data from NWFSC Fisheries Observation Science Program
Rockfish Conservation Areas	NOAA	https://media.fisheries.noaa.gov/2021-03/2021-22HarvestSpecifications-FinalDepthContourLats%26Longs_03162021.zip?null=	https://www.fisheries.noaa.gov/resource/data/depth-based-boundary-lines-west-coast
Groundfish Essential Fish Habitat Closed Areas	NOAA	https://media.fisheries.noaa.gov/2021-02/EFH_HAPC_EFHCA_shapefiles_AM19-2006%2BAM28-2020.zip?null	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon
Cowcod Conservation Areas	NOAA	https://wildlife.ca.gov/Conservation/Marine/Cowcod	https://wildlife.ca.gov/Conservation/Marine/Cowcod
Groundfish Recreational Conservation Areas	NOAA	https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=744a32745386a1b46a96323799bca186&rgn=div8&view=text&node=50:13.0.1.1.1.7.1.5&idno=50	https://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=744a32745386a1b46a96323799bca186&rgn=div8&view=text&node=50:13.0.1.1.1.7.1.5&idno=50
Ocean Salmon Essential Fish Habitat	NOAA NMFS	https://media.fisheries.noaa.gov/2020-04/noaa_wcr_salmonid_efh_2014.zip	https://www.fisheries.noaa.gov/resource/map/essential-fish-habitat-groundfish-and-salmon

Table A-5. Boundary data layers used for Aquaculture Opportunity Area planning in U.S. southern California waters.

Boundary Datasets	Source	Source Link	MetaData Link
U.S. Environmental Protection Agency Regional Boundaries	USEPA	https://www.epa.gov/frs/epa-regional-kml-download	https://www.epa.gov/ceam/metaData-epa-regional-boundaries
Convention on the International Regulations for Preventing Collisions at Sea 1972 Demarcation Line	NOAA and BOEM (i.e., marinecadastre.gov) and USCG	https://www.northeastoceanData.org/Data-download/?Data=Marine%20Transportation	https://inport.nmfs.noaa.gov/inport/item/56121
Federal Consistency Location Descriptions	NOAA NMFS	ftp://ftp.coast.noaa.gov/pub/MSP/GeographicLocationDescriptions.zip	https://inport.nmfs.noaa.gov/inport/item/51544
U.S. Coast Guard Districts	USCG	https://www.northeastoceanData.org/Data-download/?Data=Administrative%20Boundaries	https://services.northeastoceanData.org/arcgis1/rest/services/Administrative/MapServer/5
U.S. Army Corps of Engineers Districts	USACE	https://www.northeastoceanData.org/Data-download/?Data=Administrative%20Boundaries	https://www.arcgis.com/sharing/rest/content/items/70805e1a8fd74e42b0a9585088d6d151/info/metaData/metaData.xml?format=default&output=html
Federal/State Boundary (Submerged Lands Act)	NOAA	https://coast.noaa.gov/Data/Documents/OceanLawSearch/Summary%20of%20Law%20-%20Submerged%20Lands%20Act.pdf	https://Data.noaa.gov/waf/NOAA/NESDIS/ncei/
U.S. Exclusive Economic Zone	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/CoastalCounties.zip	https://inport.nmfs.noaa.gov/inport/item/54383
Coastal 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
Coastal 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
Coastal Counties	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

Boundary Datasets	Source	Source Link	MetaData Link
State Water Jurisdiction	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/MANAGEMENT/StateWaterJurisdiction.zip	ftp://ftp.dfg.ca.gov/R7_MR/MANAGEMENT/StateWaterJurisdiction.zip
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
California Coast North American Datum 1983 (NAD 83)	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/BASE/Coastn83.zip	ftp://ftp.dfg.ca.gov/R7_MR/BASE/Coastn83.zip
Marine Ecoregions of the World	TNC	https://www.arcgis.com/sharing/rest/content/items/903c3ae05b264c00a3b5e58a4561b7e6/Data	https://geospatial.tnc.org/Datasets/903c3ae05b264c00a3b5e58a4561b7e6

Table A-6. Socio-economic data layers used for Aquaculture Opportunity Area planning in U.S. southern California waters.

Socio-Economic Datasets	Source	Source Link	MetaData Link
National Oceanic and Atmospheric Administration Economics: National Ocean Watch Marine Economic Gross Domestic Product by state	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ENOW2015.zip	https://inport.nmfs.noaa.gov/inport/item/54382
National Oceanic and Atmospheric Administration Economics: National Ocean Watch Marine Ocean Economy Percent by State	NOAA and BOEM (i.e., marinecadastre.gov)	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/ENOW2015.zip	https://inport.nmfs.noaa.gov/inport/item/54381
National Oceanic and Atmospheric Administration Economics: National Ocean Watch Ocean Economy State Statistics	NOAA and BOEM (i.e., marinecadastre.gov)	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. southern California waters.

Public Health Indicators[32]	Source	Source Link	MetaData Link
Bight Regional Survey - Sediment Toxicity and Marine Debris	SCCWRP	https://www.sccwrp.org/about/research-areas/Data-portal/	https://www.sccwrp.org/about/research-areas/Data-portal/
Harmful Algal Blooms - Cellular and Particulate	NOAA	http://thredds.cencoos.org/thredds/catalog.html?Dataset=HAB_CELLULAR_DOMOIC_ACID_NOWCAST	http://thredds.cencoos.org/thredds/catalog.html?Dataset=HAB_CELLULAR_DOMOIC_ACID_NOWCAST
California Harmful Algae Risk Mapping - CoastWatch	NOAA	https://coastwatch.pfeg.noaa.gov/erddap/griddap/charmForecast0day.graph	https://coastwatch.pfeg.noaa.gov/erddap/info/charmForecast0day/index.html
Outfall Structures: Southern California	Stanford University	https://stacks.stanford.edu/file/druid:qc126xt5171/Data.zip	https://earthworks.stanford.edu/catalog/stanford-qc126xt5171
Ocean Disposal Sites	USEPA	ftp://ftp.coast.noaa.gov/pub/MSP/OceanDisposalSites.zip	https://www.fisheries.noaa.gov/inport/item/54193
Wastewater Treatment Outfall Structures	USEPA	https://edg.epa.gov/Data/PUBLIC/OEI/OIC/FRS_Wastewater.zip	https://ofmext.epa.gov/FLA/www3/national_frs.kmz
Integrated Compliance Information System - National Pollutant Discharge Elimination System Discharge Points	USEPA	https://echo.epa.gov/files/echodownloads/npdes_outfalls_layer.zip	https://echo.epa.gov/tools/Data-downloads/icis-npdes-discharge-points-download-summary
Dichloro-diphenyl-trichloroethane (DDT) Southern California Coastal Water Research Project	SCCWRP	https://www.sccwrp.org/about/research-areas/data-portal/	https://www.sccwrp.org/about/research-areas/data-portal/
Oil Spills (Raw Incident)	NOAA	https://incidentnews.noaa.gov/raw/incidents.csv	https://incidentnews.noaa.gov/raw/index

[32] These datasets and any information contained with provided sources in this table have not been evaluated by the Food and Drug Administration (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. southern California waters.

Physical, Chemical, Biological Datasets	Source	Source Link	MetaData Link
Santa Barbara Bathymetry	NOAA	https://maps.ngdc.noaa.gov/viewers/bathymetry/	https://Data.noaa.gov/metaview/page?xml=NOAA/NESDIS/NGDC/MGG/DEM/iso/xml/603.xml&view=getDataView&header=none
Santa Monica Bathymetry	NOAA	https://maps.ngdc.noaa.gov/viewers/bathymetry/	https://Data.noaa.gov/metaview/page?xml=NOAA/NESDIS/NGDC/MGG/DEM/iso/xml/726.xml&view=getDataView&header=none
Orange County Bathymetry	NOAA	https://maps.ngdc.noaa.gov/viewers/bathymetry/	https://maps.ngdc.noaa.gov/viewers/bathymetry/
San Diego Bathymetry	NOAA	https://maps.ngdc.noaa.gov/viewers/bathymetry/	https://maps.ngdc.noaa.gov/viewers/bathymetry/
Coastal National Elevation Database Bathymetry	NOAA	https://coast.noaa.gov/htdata/raster2/elevation/CA_Southern_CoNED_DEM_2016_8658/	https://www.fisheries.noaa.gov/inport/item/55359
Point Loma Monitoring Sites Conductivity, Temperature, Depth Casts	Point Loma	https://Data.sandiego.gov/Datasets/monitoring-ocean-water-quality/	https://seshat.Datasd.org/pud/omp/water_quality_dictionary_Datasd.csv
California Regional Ocean Modeling System Model - Salinity	SCOOS - UCLA	https://erddap.sccoos.org/erddap/files/roms_ncst/	https://erddap.sccoos.org/erddap/info/roms_ncst/index.html
Chlorophyll *a* Concentration (National Aeronautics and Space Administration)	NASA OceanColor L3 SMI Product	https://oceanData.sci.gsfc.nasa.gov/MODIS-Aqua/Binned/Monthly/	https://inport.nmfs.noaa.gov/inport/item/54369
Kd(490)	NOAA	ftp://ftp.star.nesdis.noaa.gov/pub/socd1/mecb/coastwatch/viirs/science/L3/global/kd/monthly/WW00/	https://inport.nmfs.noaa.gov/inport/item/54385
Nutrients at Depth (Silicate, Phosphate, Nitrate)	BioOracle	http://bio-oracle.org/downloads-to-email.php	http://bio-oracle.org/downloads-to-email.php
Dissolved Oxygen	BioOracle	http://bio-oracle.org/downloads-to-email.php	http://bio-oracle.org/downloads-to-email.php
Iron Concentration	BioOracle	http://bio-oracle.org/downloads-to-email.php	http://bio-oracle.org/downloads-to-email.php
Salinity (Hybrid Coordinate Ocean Model 1/12°)	NOAA	https://www.hycom.org/Dataserver/gofs-3pt0/reanalysis	https://www.hycom.org/hycom/documentation

Physical, Chemical, Biological Datasets	Source	Source Link	MetaData Link
Simulating WAves Nearshore Model Significant Wave Height, Period, Direction (H_s, T_p and D_p)	PNNL	https://polar.ncep.noaa.gov/waves/hindcasts/nopp-phase2/	Zhaoqing Yang, PNNL. Steven DeWitt, DOE water power technology office program manager, TJ (Thomas Heibel), PNNL water power program manager, Levi Kilcher of NREL, our multi-lab project lead, Vince Neary of SNL PI, partner on wave modeling for the East Coast, GoM and Caribbean Sea.
Aragonite Saturation State	NOAA NCEI	ftp://ftp.coast.noaa.gov/pub/MSP/ORT/SurfaceAragonite.zip	https://inport.nmfs.noaa.gov/inport/item/54405
Sediment Thickness	NOAA NCEI	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018GC008115 ; http://earthdynamics.org/Data/	http://www.earthdynamics.org/page5.html
Beach Nourishment	ASBPA and Western Carolina University	https://gim2.aptim.com/ASBPANationwideRenourishment/; http://beachnourishment.wcu.edu/	https://gim2.aptim.com/ASBPANationwideRenourishment/; http://beachnourishment.wcu.edu/
Predicted Sediment Characteristics	NOAA	Direct from NOAA	https://coastalscience.noaa.gov/project/predictive-benthic-habitat-suitability-modeling-of-deep-sea-biota-on-the-us-pacific-outer-continental-shelf/
Bathymetry Contours 10 m	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/BATHYMETRY/10m_bathy_to_600m.zip	ftp://ftp.dfg.ca.gov/R7_MR/BATHYMETRY/10m_bathy_to_600m.zip
Bathymetry Contours 5 m	CDFW	ftp://ftp.dfg.ca.gov/R7_MR/BATHYMETRY/contours_5m.zip	ftp://ftp.dfg.ca.gov/R7_MR/BATHYMETRY/contours_5m.zip
High Frequency Radar (surface currents)	SCOOS	https://sccoos.org/high-frequency-radar/	https://sccoos.org/high-frequency-radar/
California Regional Ocean Modeling System Model - Water Temperature	SCOOS - UCLA	https://thredds.cencoos.org/thredds/ncss/CENCOOS_CA_ROMS_DAS.nc/Dataset.html	http://thredds.cencoos.org/thredds/catalog.html
California Regional Ocean Modeling System Model - Current Speed and Direction	SCOOS - UCLA	https://thredds.cencoos.org/thredds/ncss/CENCOOS_CA_ROMS_DAS.nc/Dataset.html	http://thredds.cencoos.org/thredds/catalog.html

Physical, Chemical, Biological Datasets	Source	Source Link	MetaData Link
Bight 2003, 2008, 2013, 2018 Regional Surveys	SCCWRP	https://www.sccwrp.org/about/research-areas/Data-portal/	https://www.sccwrp.org/about/research-areas/Data-portal/
Sea Surface Temperature (National Aeronautics and Space Administration) OceanColor - Remotely Sensed	NASA OceanColor L3 SMI Product	https://podaac.jpl.nasa.gov/SeaSurfaceTemperature; https://oceanData.sci.gsfc.nasa.gov/MODIS-Aqua/Binned/Monthly/	https://podaac.jpl.nasa.gov/AQUA
% Light Transmissivity Kd(PAR)	NOAA	ftp://ftp.star.nesdis.noaa.gov/pub/socd1/mecb/coastwatch/viirs/science/L3/global/kd/monthly/WW00/	https://inport.nmfs.noaa.gov/inport/item/54386
Seafloor Character	USGS	https://pubs.usgs.gov/ds/781/OffshoreSantaBarbara/metaData/SeafloorCharacter_OffshoreSantaBarbara_metaData.html	https://pubs.usgs.gov/ds/781/
California Cooperative Oceanic Fisheries Investigations Database (CTD 1992 - present) (Hydrographic 1949 - present) (ADCP 2000 - 2018)	CalCOFI	ttps://www.calcofi.org/ccData.html	ttps://www.calcofi.org/ccData.html
Bathymetry (General Bathymetric Chart of the Oceans)	NOAA	https://www.gebco.net/Data_and_products/historical_Data_sets/	https://inport.nmfs.noaa.gov/inport/item/54365
Current Speed and Direction (Hybrid Coordinate Ocean Model 1/12°)	NOAA	https://www.hycom.org/Dataserver/gofs-3pt0/reanalysis	https://www.hycom.org/hycom/documentation
Temperature (Hybrid Coordinate Ocean Model 1/12°)	NOAA	https://www.hycom.org/Dataserver/gofs-3pt0/reanalysis	https://www.hycom.org/hycom/documentation
Sea Surface Height	NASA JPL	https://podaac-www.jpl.nasa.gov/Dataset/SEA_SURFACE_HEIGHT_ALT_GRIDS_L4_2SATS_5DAY_6THDEG_V_JPL1609?ids=Measurement:ProcessingLevel&values=Sea%20Surface%20Topography:*4*	https://podaac-www.jpl.nasa.gov/Dataset/SEA_SURFACE_HEIGHT_ALT_GRIDS_L4_2SATS_5DAY_6THDEG_V_JPL1609?ids=Measurement:ProcessingLevel&values=Sea%20Surface%20Topography:*4*
Fog	USGS	https://www.usgs.gov/centers/wgsc/science/pacific-coastal-fog-project?qt-science_center_objects=0#qt-science_center_objects	http://climate.calcommons.org/Datasets/summertime-fog

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)

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NOAA Fisheries, Office of Aquaculture (OAQ)

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

Penny Ruvelas
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NOAA Fisheries, West Coast Region (WCR)

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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.

2

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

[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.

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.

[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

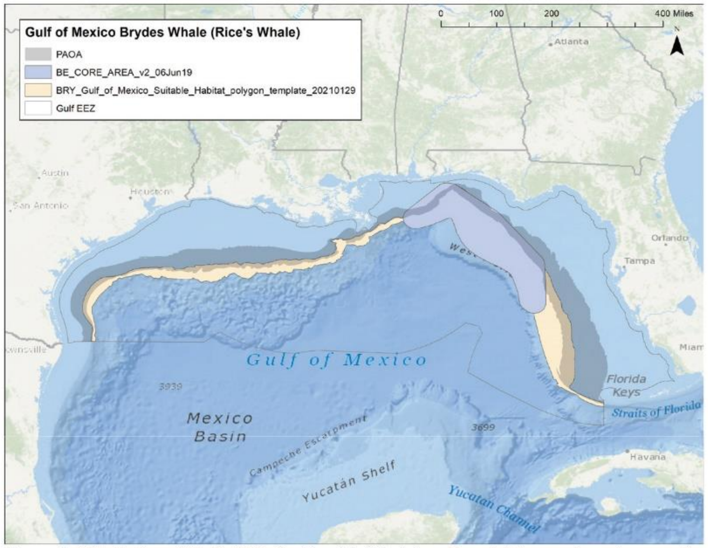

Figure 1. Distribution of Gulf of Mexico Bryde's Whale based on sightings and passive acoustic monitoring. PAOA: proposed aquaculture opportunity atlas study areas.

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]

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[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

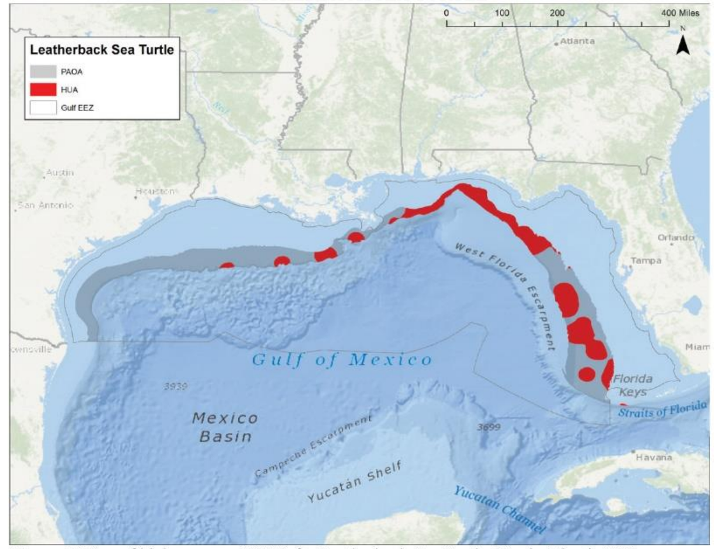


Figure 2. Map of high use area (HUA) for Leatherback Sea Turtle, North Atlantic DPS.

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

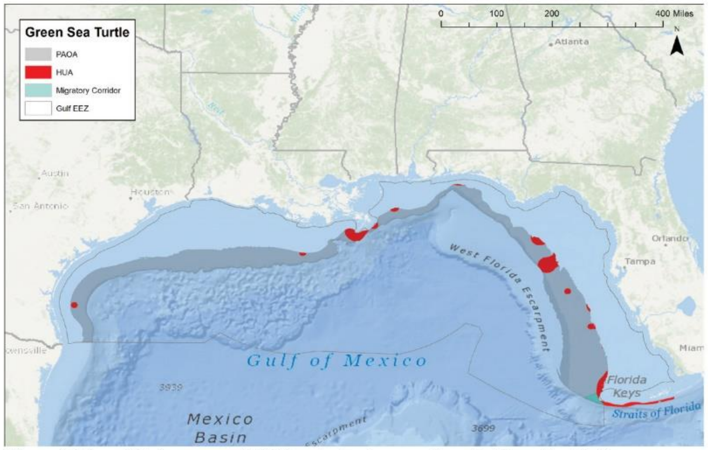


Figure 6. Map of high use areas (HUA) and migratory corridors for Green Sea Turtle.

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

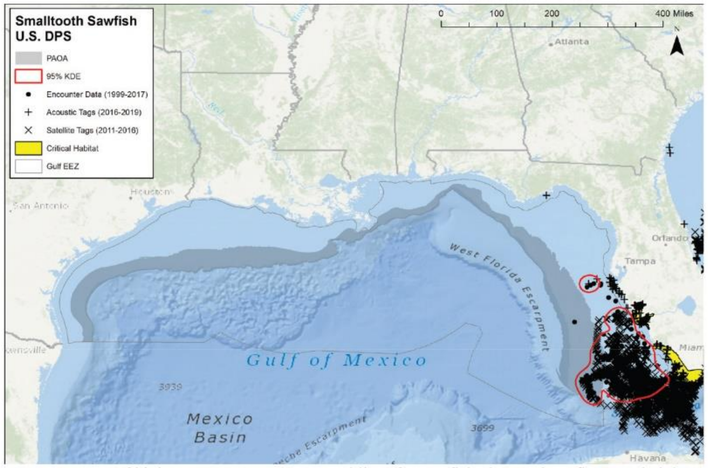


Figure 7. Map of high use areas (95% KDE; red line) for sawfish observations fit to pooled data from Sawfish Encounter Database (1999-2017), sawfish acoustic tag detections (2016-2019), and sawfish positioning estimates from satellite tags (2011-2016).

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

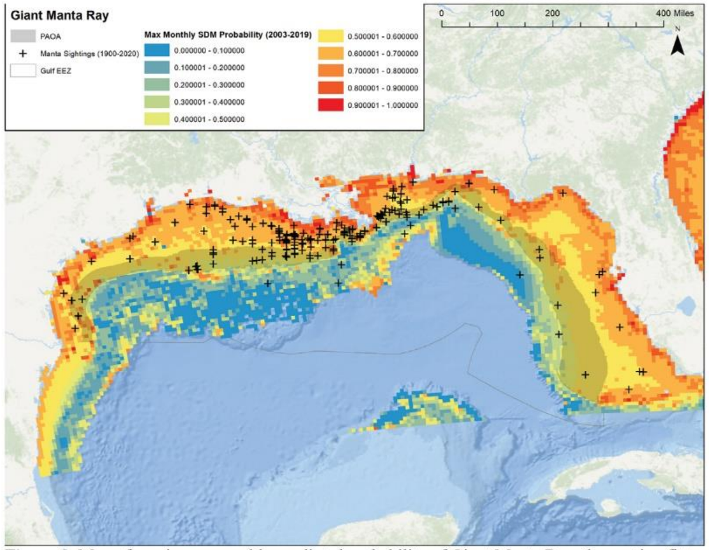


Figure 8. Map of maximum monthly predicted probability of Giant Manta Ray observation fit to environmental data from January 2003 to December 2019, overlaid with Giant Manta Ray sightings from 1900-2020.

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.

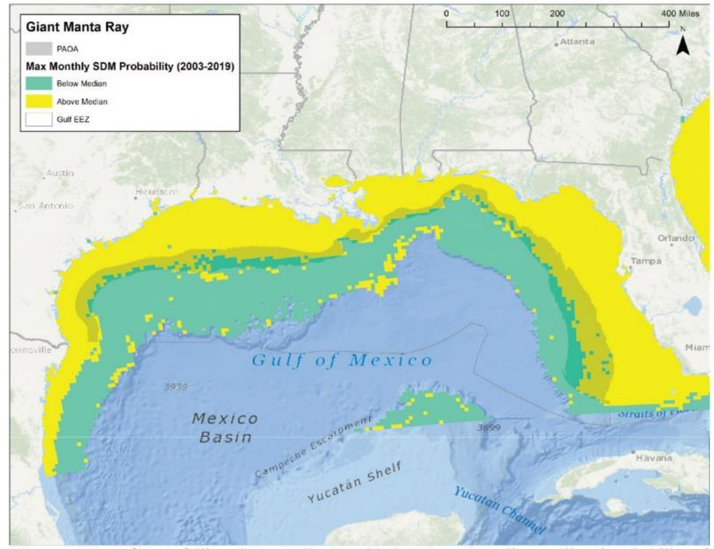


Figure 9. Map of areas falling above (yellow) and below (green) median predicted probability of occurrence values from maximum monthly predicted probabilities fit to environmental data from January 2004 to December 2019.

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**).

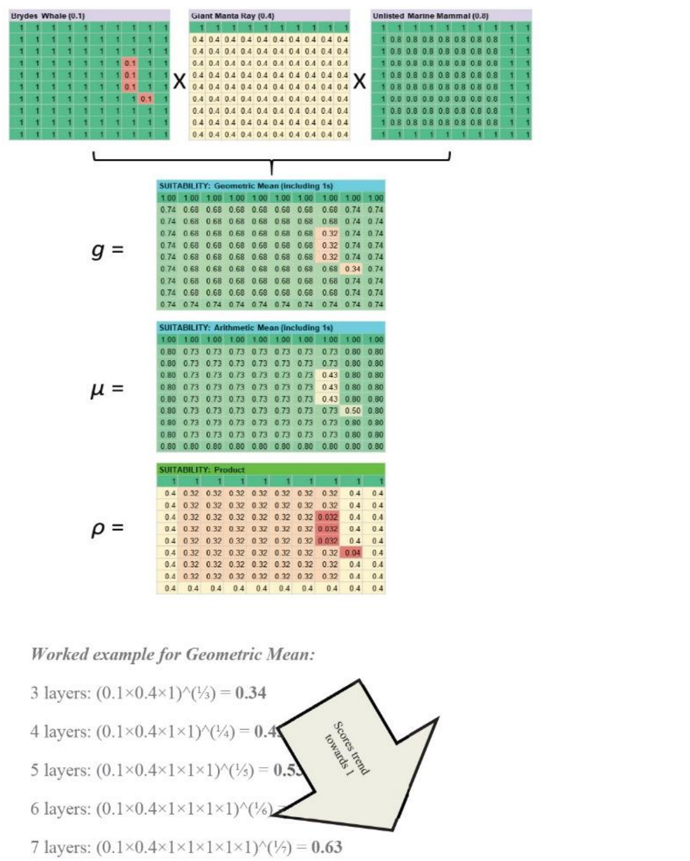


Figure 10. Comparison of geometric mean (g), arithmetic mean (μ), and product (ρ) approaches for hypothetical distributions of protected species with different scores based on status and trend.

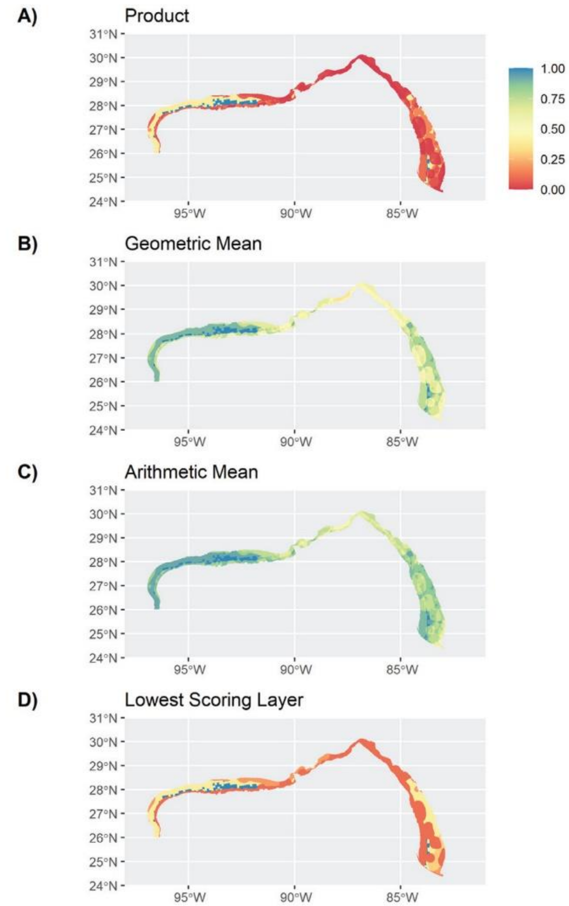


Figure 11. Comparison of SERO-PRD overall vulnerability scores using four different approaches. Warmer colors denote areas of greatest vulnerability.

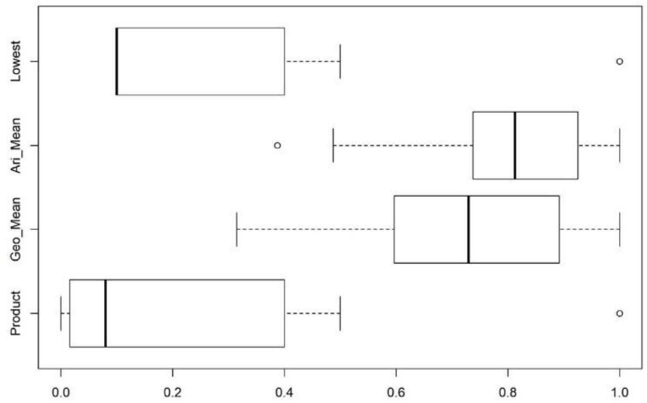
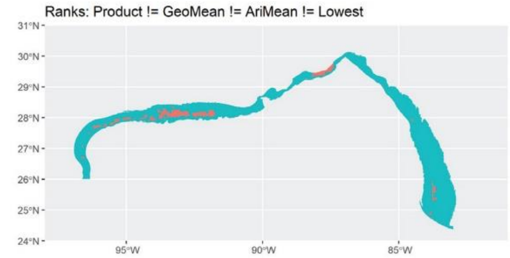


Figure 12. Comparison of vulnerability scores for protected species across the entire Gulf of Mexico study area under Product, Geometric mean, Arithmetic mean, and Lowest scoring layer methods. Lower scores denote greater vulnerability.

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)

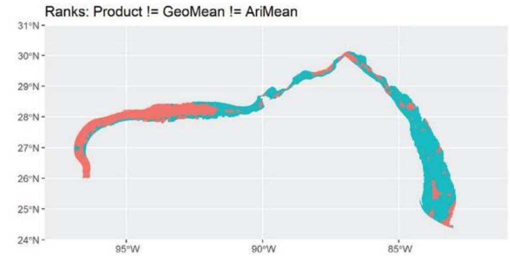


Figure 13. Comparison of protected species ranked scores by cell between methods, with blue denoting areas where approaches had inconsistencies in ranking.

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.

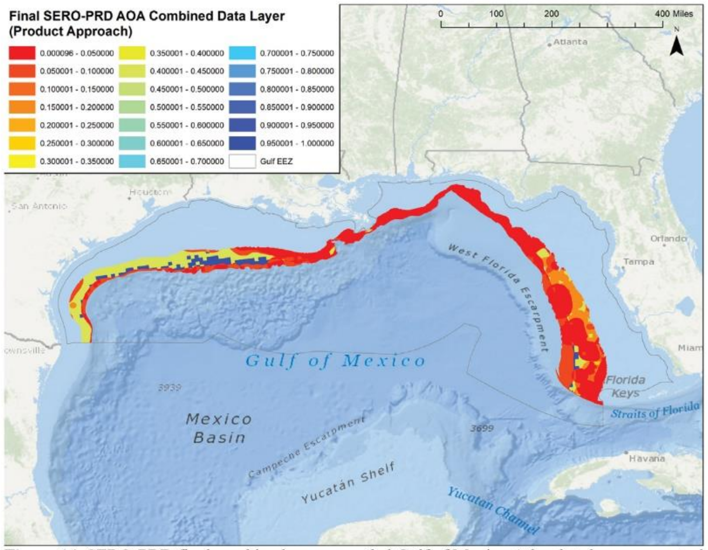


Figure 14. SERO-PRD final combined recommended Gulf of Mexico Atlas data layer, generated by combining layers for Gulf of Mexico Bryde's Whale, five Sea Turtles, Smalltooth Sawfish, and Giant Manta Ray using the Product method. Note that warmer colored areas are of relatively higher concern with regards to species status, population size, and trajectory.

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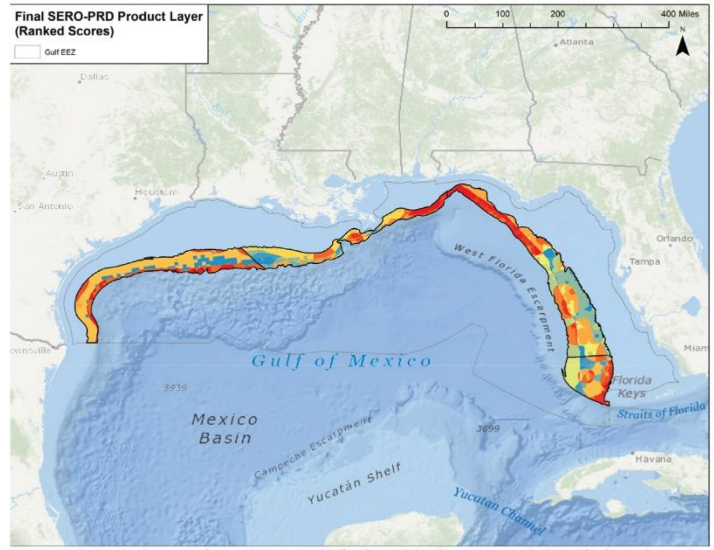

Figure 15. Ranked scores from SERO-PRD final combined recommended Gulf of Mexico Atlas data layer for each of the four Atlas sub-regions, generated using the Product method. Note that warmer colored areas are of relatively higher concern with regards to species status, population size, and trajectory.

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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

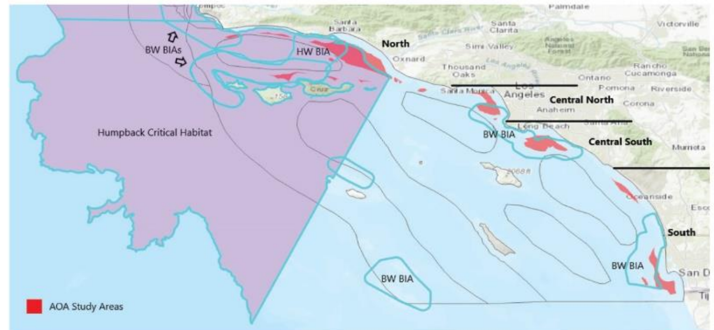

Figure 16. Cetacean Biologically Important Areas and Humpback critical habitat (blue outlines) and Aquaculture Opportunity Area study areas in red.

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.

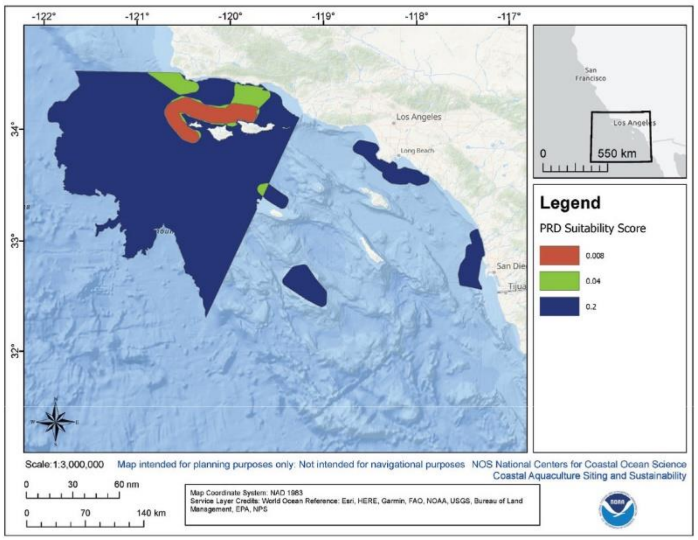

Figure 17. WCR-PRD-recommended southern California Atlas data layer, generated by combining layers for humpback whales, blue whales, and humpback critical habitat using the Product method. The legend provides the results of the protected species scoring and highlights areas that are of relatively higher 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.

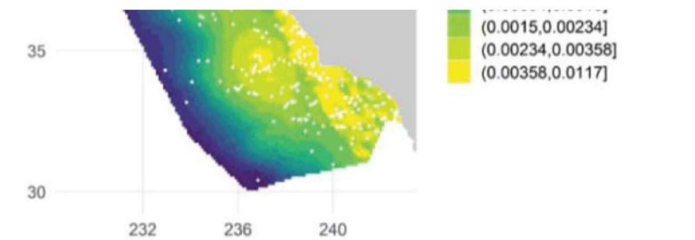

Figure 18. Screen capture excerpt of blue whale density predictions, taken from Becker et al (2020, Figure 2-k). Densities are reported as means in animals/km^2.

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.

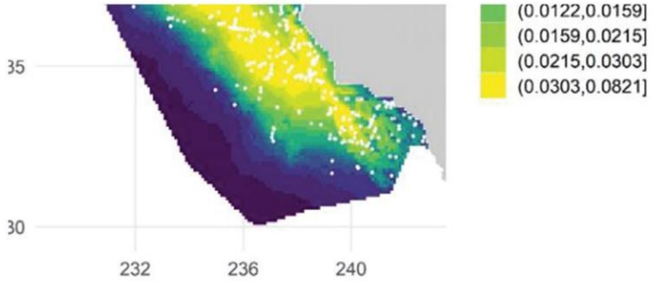

Figure 19. Screen capture excerpt of fin whale density predictions, taken from Becker et al (2020, Figure 2-l). Densities are reported as means in animals/km^2.

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).

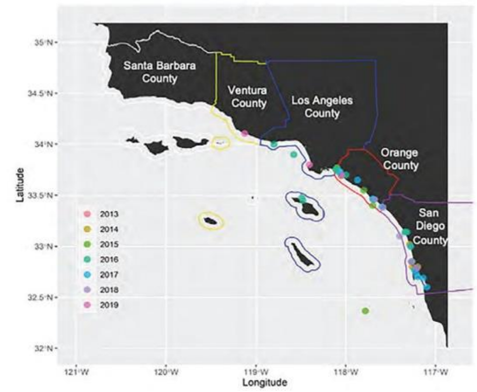

Figure 20. Location of public-reported green turtle sightings in the southern California Bight. From Hanna et al. (2021)[52].

[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.

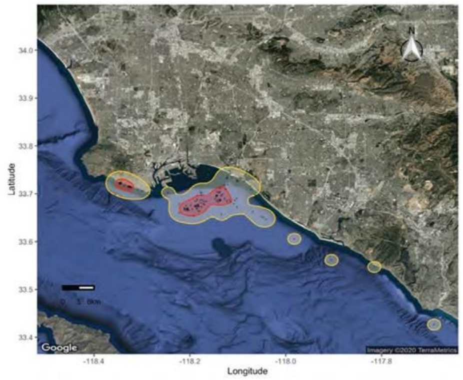

Figure 21. Map of kernel home range estimates for two green turtles included as part of the inshore Seal Beach NWR tracking project that departed the Refuge and moved into Anaheim Bay. Data from Hanna et al. (2020) interim report to Navy[53].

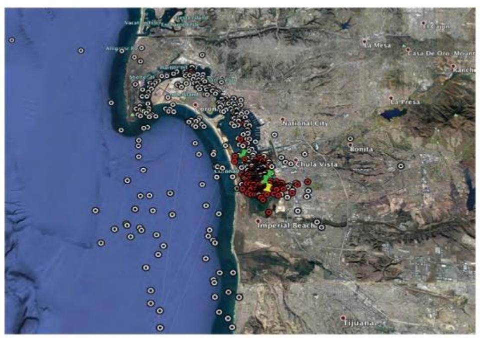

Figure 22 Satellite-tracked locations (circles) and putative track lines (gray lines) of 4

[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.

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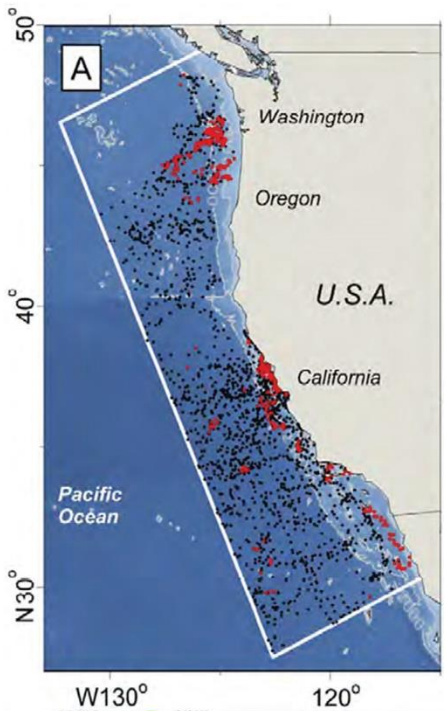


Figure 25. Leatherback telemetry locations with Area Restricted Search behavior (red dots) and transit behavior (black dots) along the U.S. West Coast. Modified from Figure 5 in Benson et al. (2011)[55].

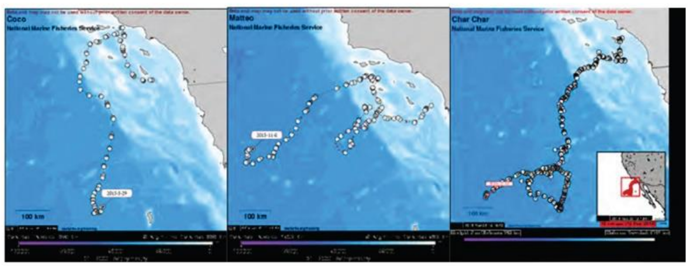
[55] Benson,S.R., T. Eguchi, D.G. Foley, K.A. Forney, H. Bailey, C. Hitipeuw, B.P. Samber, R.F. Tapilatu, V. Rei, P. Ramohia, and J. Pita. 2011. Large-scale movements and high-use areas of western Pacific leatherback turtles, Dermochelys coriacea. Ecosphere. 2(7):1-27.

46

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.

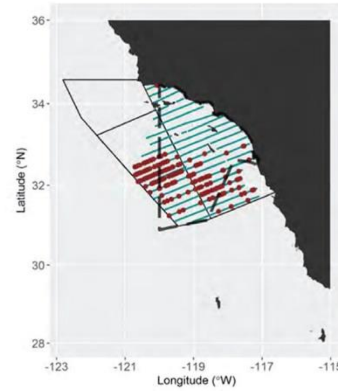
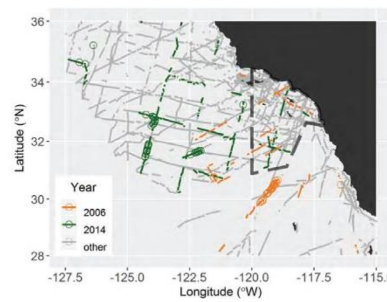


Figure 27. Loggerhead locations determined via NOAA aerial surveys in fall 2015. Blue lines indicate surveyed tracklines. Modified from Eguchi et al. (2018)[62].



[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.

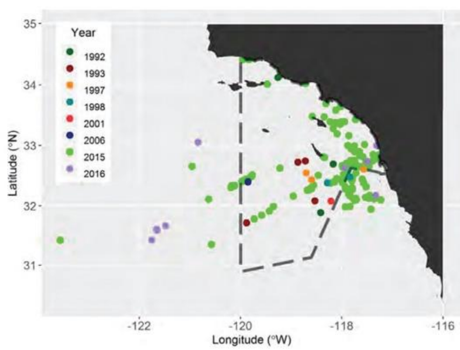


Figure 29. Location and timing of sea turtle sightings (mostly loggerheads) reported by the public to the NOAA sightings hotline. The year 2015 (green) was the time of a large influx of loggerheads into the bight, and most of these data points likely represent loggerheads. Data from Eguchi et al. (2018) Front. Mar. Sci.

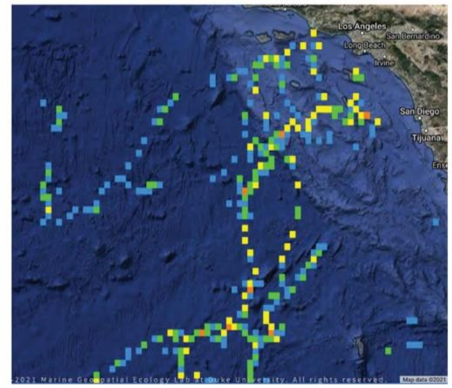


Figure 30. Summary of loggerhead locations reported in the OBIS Seamap database (https://seamap.env.duke.edu/species/173830).

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]

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.

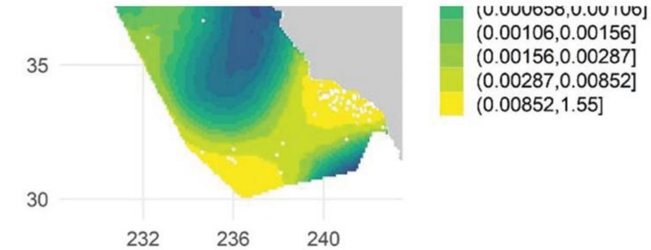


Figure 33. Screen capture excerpt of common bottlenose dolphin density predictions, taken from Becker et al (2020, Figure 2-g). Densities are reported as means in animals/km^2.

SUPPLEMENTAL FILES

Link to SERO-PRD Aquaculture Data Layers and Custom R Script

https://drive.google.com/drive/folders/1Z7rEIc2vrT-Qk-4qGFvI_FY8B8C2LQeI?usp=sharing

Appendix C

Appendix C: Scoring rationale for data layers used in the spatial analyses for the Southern California Bight Aquaculture Opportunity Area analyses. Information is included 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 North (N), Central North (CN), Central South (CS), or South (S) 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. Data were collected and reviewed by Department of Defense Military Aviation and Installation Assurance Siting Clearinghouse 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 Datasets	N	CN	CS	S	Score	Rationale for Score
Camp Pendleton and San Diego Military Areas	-	-	-	x	0.5	The South study area is located off the San Diego County coast and is within or in close proximity to several mission critical DOD areas, including the Naval Base Point Loma in San Diego and Camp Pendleton. Data layers for this area were combined for ease of analysis. Guidance on compatibility of aquaculture operations in the AOA options with DOD activities was provided through a formal DOD Clearinghouse consultation (Appendix D). The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

National Security Datasets	N	CN	CS	S	Score	Rationale for Score
Military Training Routes	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 VFR (visual flight rules) flight are more difficult to track without increased vigilance in areas containing such operations.[33] To ensure the greatest practical level of safety for all flight operations, the MTR program was conceived. Due to activities presently conducted within the MTRs, as well as having multiple training events occurring on a regular basis, these areas were assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
Point Mugu Sea Range (PMSR)	x	-	-	-	0.5	PMSR provides modern instrumented airspace, sea space, testing and training areas and facilities, and range infrastructure to support Research, Development, Acquisition, Test and Evaluation training requirements as well as used for air- and in-water training.[34] The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.
San Pedro Channel Operating Area	x	x	x	-	0.5	Areas where military training is conducted (i.e., parade ground, obstacle course, bivouac area). The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination. The area falls within a Navy vessel traffic corridor between range complexes.[35]
Special Use Airspace (W412 and W289E) (SUA)	x	-	-	-	0.5	This SUA overlaps the North study 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.
Unexploded Ordnance Formerly Used Defense Sites (UXO FUDS)	x	-	x	x	0.5	UXO FUDs were formally active DOD training areas that now contain contamination or weapons that did not explode when they were deployed and still pose a risk of detonation.[36] The area was assigned a score of 0.5 as the details of the current and future training portfolio need further examination.

[33] https://www.faa.gov/air_traffic/publications/atpubs/aip_html/part2_enr_section_5.2.html
[34] https://pmsr-eis.com/portals/pmsr-eis/files/EIS/Draft_EIS/Point_Mugu_Sea_Range_Draft_EIS_OEIS_April_2020.pdf
[35] https://www.hstteis.com/portals/hstteis/files/hstteis_p3/deis/HSTT_DEIS_Volume_4_October_2017.pdf
[36] https://www.usace.army.mil/missions/environmental/formerly-used-defense-sites/

National Security Datasets	N	CN	CS	S	Score	Rationale for Score
Camp Pendleton and San Diego Military Exclusion Areas	-	-	-	x	0	The South study area is located off the San Diego County coast and is within or in close proximity to several mission critical DOD areas, including the Naval Base Point Loma in San Diego and Camp Pendleton. Data layers for this area were combined for ease of analysis. Guidance on compatibility of aquaculture operations in the AOA options with DOD activities was provided through a formal DOD Clearinghouse consultation (Appendix D). Due to the known nature of activities, these areas were assigned a score of 0 for complete avoidance.

Table C-2. Natural and cultural resources submodel datasets used in suitability modeling. Data were collected and reviewed in coordination with multiple agencies, including the National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, Bureau of Ocean Energy Management, and other state agencies such as the California Department of Fish and Wildlife. 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	N	CN	CS	S	Score	Rationale for Score
Bureau of Ocean Energy Management (BOEM) Preserve	x	-	-	-	0.5	As a result of the Santa Barbara oil spill, the largest to occur in California waters, the Santa Barbara Channel Ecological Preserve and Buffer Zone was established March 21, 1969 by Public Land Order 4587.[37] The area was assigned a score of 0.5.
Cetacean Biologically Important Area (BIA) - Blue Whale Feeding Area	x	x	x	x	0.2	This layer was used within the protected resources consideration combined species layer for AOA suitability model. This Biologically Important Area (BIA) represents an area where blue whales selectively feed from June through October. These areas may be found consistently in space and time or may be associated with ephemeral features that are less predictable but can be delineated and are generally located within a larger identifiable area.[38] A score of 0.2 was assigned based on species listing as endangered under the ESA and also has stable or unknown population trends.
Cetacean Biologically Important Area (BIA) - Humpback Whale Feeding Area	x	-	-	-	0.2	This layer was used within the protected resources consideration combined species layer for AOA suitability model. This BIA represents an area where humpback whales selectively feed from March through September. These areas may be found consistently in space and time or may be associated with ephemeral features that are less predictable. They can be delineated and are generally located within a larger identifiable area. A score of 0.2 was assigned based on species listing as endangered under the ESA and also has stable or unknown population trends.

[37] https://metadata.boem.gov/geospatial/pc_eco.xml
[38] https://cetsound.noaa.gov/important

Natural and Cultural Resources Datasets	N	CN	CS	S	Score	Rationale for Score
Critical Habitat - Humpback Whale	x	-	-	-	0.2	This layer was used within the protected resources consideration combined species layer for AOA suitability model. In April 2021, there was a new Critical Habitat established for the endangered Central America Distinct Population Segment (DPS) of threatened humpback whales. Specific areas designated as Critical Habitat for the Central America DPS of humpback whales contain approximately 166,422.4 km² of marine habitat in the North Pacific Ocean within the portions of the California Current Ecosystem off the coasts of Washington, Oregon, and California.[39] A score of 0.2 was assigned based on species listing as endangered under the ESA and also has stable or unknown population trends.
Deep-sea Coral and Sponge Observations (1985 to present) with 500-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.[40] Observations are point data, so a 500-m setback was applied to each point, and both were assigned a score of 0 for complete avoidance given the sensitivity level of this habitat to bottom disturbance.
Hardbottom Habitat - with 500-ft 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). Due to the importance of this habitat, areas were assigned a score of 0 for complete avoidance.[41]
National Marine Sanctuaries (NMS)	x	-	-	-	0	In southern California, the Channel Islands NMS protects 1,470 mi² of ocean waters around the Northern Channel Islands: Anacapa, Santa Cruz, Santa Rosa, San Miguel, and Santa Barbara Islands.[42] This NMS provides protection for endangered species, sensitive habitat, historic shipwrecks, and cultural resources. The NMS has policies and rules that limit new activities or development that are not consistent with management plans. The area was scored 0.

[39] https://www.fisheries.noaa.gov/action/final-rule-designate-critical-habitat-central-america-mexico-and-western-north-pacific
[40] https://spo.nmfs.noaa.gov/sites/default/files/TMOHC7.pdf
[41] https://www.pcouncil.org/managed_fishery/habitat/
[42] https://channelislands.noaa.gov/

Natural and Cultural Resources Datasets	N	CN	CS	S	Score	Rationale for Score
Essential Fish Habitat Area of Particular Concern (HAPC - Rocky Reef)	x	x	x	-	0	The rocky reef HAPC includes those waters, substrates, and other biogenic features associated with hard substrates (i.e., bedrock, boulders, cobble, gravel, etc.).[43] Due to the ecological importance of this habitat, rocky reefs were assigned a score of 0 for complete avoidance.
National Oceanic and Atmospheric Administration (NOAA) Fish Havens - with 500-ft setback	-	-	x	x	0	Fish havens are artificial reefs deliberately constructed or placed on the seabed to emulate some functions of a natural reef.[44] A 500-ft setback was applied to each polygon, and both were assigned a score of 0 for complete avoidance.

[43] https://www.fisheries.noaa.gov/west-coast/habitat-conservation/habitat-areas-particular-concern-west-coast
[44] 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 the National Oceanic and Atmospheric Administration, U.S. Coast Guard, U.S. Army Corps of Engineers, Environmental Protection Agency, Bureau of Ocean Energy Management, Bureau of Safety and Environmental Enforcement, and other state agencies. “Cont.” denotes continuous data (0 - 1).

Industry, Navigation, and Transportation Datasets	N	CN	CS	S	Score	Rationale for Score
Bureau of Ocean Energy Management (BOEM) Active Lease Blocks	x	-	x	-	0.5	Active leases are those BOEM OCS Lease Blocks which are currently leased out to private entities for oil and/or gas mining rights.[45] 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 0.5.
Automatic Identification System 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.
Automatic Identification System 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.
Automatic Identification System Vessel Traffic 2019 - Military	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.
Automatic Identification System 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.
Automatic Identification System 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.
Automatic Identification System 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.
Automatic Identification System 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.
Automatic Identification System 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.

[45] https://metadata.boem.gov/geospatial/GOM_Active_OG_Leases.xml

Industry, Navigation, and Transportation Datasets	N	CN	CS	S	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, getting from one place to another, or staying out of danger.[46] Aids range from lighthouses to minor lights, day beacons, range lights and sound signals, and lighted or unlighted buoys.[47] 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	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.[48] Due to the nature of activities, and the possibility of change in use, these areas were assigned a score of 0 for complete avoidance.
Automated Wreck and Obstruction Information System (AWOIS) Wrecks Polluting, Remediation of Underwater Legacy Environmental Threats (RULET) Wrecks, Electronic Navigational Chart (ENC) Wrecks and Obstructions, ENC 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.
Boreholes, Test Wells, and Wells with 500-m setback	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.

[46] https://www.navcen.uscg.gov/pdf/navRules/US_ATON_Guide.pdf
[47] 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
[48] https://marinecadastre.gov/news/load.php?url=posts/anchorage-areas.html

Industry, Navigation, and Transportation Datasets	N	CN	CS	S	Score	Rationale for Score
California Cooperative Oceanic Fisheries Investigations (CalCOFI) Sampling Sites with 500-m setback	x	x	-	-	0	CalCOFI studies the marine environment off the coast of California, manages living resources, and monitors the indicators of *El Nino* and climate change. Quarterly cruises are conducted where hydrographic and biological data are collected.[49] Due to the long-term sampling schedule, these sites and a 500-m setback were assigned a score of 0.
Environmental Sensors and Buoys with 500-m setback	-	-	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.[50] These buoys and environmental sensors, along with a 500-m setback, and were both assigned a score of 0 for complete avoidance.
Joint Oil Fisheries Liaison Office (JOFLO) Corridors	x	-	-	-	0	JOFLO has established transportation corridors directly from offshore platforms to the onshore ports, harbors, and piers from which crew and supplies are conveyed. The purpose of the corridors is to provide a safe access route for oil and gas industry vessels in designated corridors as they approach and leave moorings, terminals, crew, supply, and harbor facilities, which reduces the potential for interference with commercial fishing vessels.[51] These corridors were assigned a score of 0.
U.S. Environmental Protection Agency (USEPA) Ocean Disposal Sites	x	-	x	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.[52] These areas were assigned a score of 0 for complete avoidance.
Oil and Gas Pipelines with 500-m setback	x	-	x	-	0	Submerged structures transporting oil and gas from offshore platforms or terminals to inshore facilities.[53] 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.

[49] https://calcofi.org/about-calcofi.html
[50] https://www.ndbc.noaa.gov/
[51] https://www.slc.ca.gov/wp-content/uploads/2014/07/3.17_Traffic.pdf
[52] https://www.epa.gov/ocean-dumping/ocean-disposal-sites
[53] https://metadata.boem.gov/geospatial/OCSpipelines-GOMR-NAD27.xml

Industry, Navigation, and Transportation Datasets	N	CN	CS	S	Score	Rationale for Score
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.[54] 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.
Outfall Pipes and Diffusers with 3-mi setback	-	x	x	x	0	Outfall pipes and diffusers in southern California coastal waters are structures where wastewater effluent is discharged from shore-based facilities and transferred to offshore waters. The most notable outfall pipes and diffusers are the Hyperion (average discharge rate of over 300 million gallons per day) and Point Loma outfalls. These facilities, and a 3-mi setback determined by the California Department of Public Health (CDPH), were scored 0 for complete avoidance.
Pilot Boarding Areas	-	x	-	-	0	Pilot Boarding Areas are specific areas depicted on National Oceanic and Atmospheric Administration (NOAA) navigational charts where pilots rendezvous with ships.[55] These areas were assigned a score of 0 for complete avoidance.
Pilot Boarding Stations with 500-m setback	-	-	x	-	0	Pilot Boarding Stations are specific point locations depicted on NOAA navigational charts where pilots rendezvous with ships.[56] These areas and a 500-m setback were assigned a score of 0 for avoidance.
Shipping Fairways with 500-m setback	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.

[54] https://metadata.boem.gov/geospatial/OCSplatforms-GOMR-NAD27.xml
[55] https://data.noaa.gov/dataset/dataset/pilot-boarding-areas4
[56] https://www.fisheries.noaa.gov/inport/item/54473

Industry, Navigation, and Transportation Datasets	N	CN	CS	S	Score	Rationale for Score
Southern California Ferry Routes	x	-	x	-	0	There are several ferry routes that run from mainland California to the Channel Islands. The Catalina ferry departs from San Pedro, Long Beach, and Balboa, runs to Catalina Island, and is part of the U.S. ferry routes. These navigational corridors are incompatible with aquaculture due to transportation and were assigned a score of 0 for complete avoidance.
Submarine Cables with 500-m setback	x	x	x	x	0	Comprehensive submarine cable data were obtained from the U.S. Naval Seafloor Cable Protection Office.[57] 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.

[57] NOAA's Marine Chart Division

Table C-4. Fuzzy logic Z-shaped membership function rescaling for Automatic Identification System data. Rescaling of Automatic Identification System 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
North	Cargo	0 - 60.9	0	61.9
North	Fishing	0 - 9.2	0	10.2
North	Other	0 - 833.7	0	834.7
North	Passenger	0 - 2602.9	0	2603.9
North	Pleasure and Sailing	0 - 40.8	0	41.8
North	Tanker	0 - 3.6	0	4.6
North	Tug and Tow	0 - 13.7	0	14.7
Central North	Cargo	0 - 2	0	3.0
Central North	Fishing	0 - 7.5	0	8.5
Central North	Other	0 - 29.4	0	30.4
Central North	Passenger	0 - 104.5	0	105.5
Central North	Pleasure and Sailing	0 - 68.8	0	69.8
Central North	Tanker	0 - 63.9	0	64.9
Central North	Tug and Tow	0 - 21	0	22.0
Central South	Cargo	0 - 195.8	0	196.8
Central South	Fishing	0 - 27.9	0	28.9
Central South	Military	0 - 2	0	3.0
Central South	Other	0 - 223.2	0	224.2
Central South	Passenger	0 - 1524.9	0	1525.9
Central South	Pleasure and Sailing	0 - 67.3	0	68.3
Central South	Tanker	0 - 106	0	107.0
Central South	Tug and Tow	0 - 88.8	0	89.8
South	Cargo	0 - 61.8	0	62.8
South	Fishing	0 - 8.8	0	9.8
South	Military	0 - 18.3	0	19.3

Study Area	Data Set	Range	Ceiling	Foot
South	Other	0 - 100	0	101
South	Passenger	0 - 159.5	0	160.5
South	Pleasure and Sailing	0 - 68.8	0	69.8
South	Tanker	0 - 18.7	0	19.7
South	Tug and Tow	0 - 12.6	0	13.6

Table C-5. Fishing and aquaculture submodel datasets used in suitability modeling. Data were collected from multiple sources, including the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and the California Department of Fish and Wildlife. "Cont." denotes continuous data (0 - 1).

Fishing and Aquaculture Datasets	N	CN	CS	S	Score	Rationale for Score
Ocean Rainforest Aquaculture with 500-m setback	x	-	-	-	0.5	The potential Ocean Rainforest farm site is a macroalgae aquaculture facility located off the coast of Santa Barbara. Permitting is underway for this site; therefore, it was assigned a score of 0.5.
Pacific Ocean AquaFarms (POA) San Diego Aquaculture with 500-m setback	-	-	x	x	0.5	The potential POA farm site is a commercial-scale finfish aquaculture facility off the coast of San Diego. Permitting is underway for this site; therefore, it was assigned a score of 0.5.
California Recreational Fisheries Surveys 2010 - 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.
Commercial Passenger Fishing Vessels 2010 - 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.
Divelog 1998 - 2016	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.
Lobster Log 2016 - 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.
Squid Landing Microblocks 2000 - 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.
VMS 210 Limited Entry Fixed Gear, Not Including Shore-based IFQ 2010 - 2017	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.

Fishing and Aquaculture Datasets	N	CN	CS	S	Score	Rationale for Score
VMS 233 Open Access Longline Gear for Groundfish 2010 - 2017	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.
VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	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.
VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	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.
VMS 240 Non-groundfish Trawl Gear for Ridgeback Prawn 2010 - 2017	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.
VMS 241 Non-groundfish Trawl for Pink Shrimp 2010 - 2017	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.
VMS 242 Non-groundfish Trawl for California Halibut 2010 - 2017	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.
VMS 243 Non-groundfish Trawl for California Sea Cucumber 2010 - 2017	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.
VMS 260 Open Access Prawn Trap or Pot Gear 2010 - 2017	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.
VMS 261 Open Access Dungeness Crab Trap or Pot Gear 2010 - 2017	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.

Fishing and Aquaculture Datasets	N	CN	CS	S	Score	Rationale for Score
VMS 264 Open Access California Halibut Line Gear 2010 - 2017	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.
VMS 265 Open Access Sheephead Trap or Pot Gear 2010 - 2017	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.
VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	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.
VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	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.
VMS 269 A Gear That Is Not Listed Above 2010 - 2017	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.
VMS 310 Haul Out Exemption 2010 - 2017	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.
VMS 330 Emergency Exemption 2010 - 2017	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.
VMS 340 Long-term Departure Exemption 2010 - 2017	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.
Pacific Mariculture Aquaculture with 500-m setback	-	-	x	-	0	Pacific Mariculture is a mussel longline farm located southeast of Long Beach, approximately 9.65 km from the coast in federal waters. Due to permits in place this area and a 500-m setback were assigned a score of 0 for complete avoidance of aquaculture operations.

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
North	California Recreational Fisheries Surveys (CRFS) Fishing 2010 - 2019	0 - 105	0	106
North	Commercial Passenger Fishing Vessels (CPFV) Fishing 2010 - 2019	0 - 65	0	66
North	Divelog 1998 - 2016	0 - 26	0	27
North	Lobster Log 2016 - 2019	0 - 32	0	33
North	Squid Landing Microblocks 2000 - 2019	0 - 614.4	0	615.4
North	VMS 210 Limited Entry Fixed Gear Not Including Shore-based IFQ 2010 - 2017	0 - 9	0	10
North	VMS 233 Open Access Longline Gear for Groundfish 2010 - 2017	0 - 22	0	23
North	VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	0 - 49	0	50
North	VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	0 - 78	0	79
North	VMS 240 Non-groundfish Trawl Gear for Ridgeback Prawn 2010 - 2017	0 - 369	0	370
North	VMS 241 Non-groundfish Trawl Gear for Pink Shrimp 2010 - 2017	0 - 120	0	121
North	VMS 242 Non-groundfish Trawl Gear for California Halibut 2010 - 2017	0 - 282	0	283
North	VMS 243 Non-groundfish Trawl Gear for California Sea Cucumber 2010 - 2017	0 - 405	0	406
North	VMS 260 Open Access Prawn Trap or Pot Gear 2010 - 2017	0 - 156	0	157
North	VMS 261 Open Access Dungeness Crab Trap or Pot Gear 2010 - 2017	0 - 143	0	144
North	VMS 264 Open Access California Halibut Line Gear 2010 - 2017	0 - 88	0	89
North	VMS 265 Open Access Sheephead Trap or Pot Gear 2010 - 2017	0 - 3	0	4
North	VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	0 - 4	0	5
North	VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	0 - 167	0	168
North	VMS 269 A Gear That Is Not Listed Above 2010 - 2017	0 - 56	0	57
North	VMS 310 Haul Out Exemption 2010 - 2017	0 - 1	0	2
North	VMS 330 Emergency Exemption 2010 - 2017	0 - 77	0	78
North	VMS 340 Long-term Departure Exemption 2010 - 2017	0 - 30	0	31
Central North	California Recreational Fisheries Surveys (CRFS) Fishing 2010 - 2019	0 - 98.5	0	99.5
Central North	Commercial Passenger Fishing Vessels (CPFV) Fishing 2010 - 2019	0 - 44	0	45

Study Area	Data Set	Range	Ceiling	Foot
Central North	Divelog 1998 - 2016	0 - 6	0	7
Central North	Lobster Log 2016 - 2019	0 - 9	0	10
Central North	Squid Landing Microblocks 2000 - 2019	0 - 11.8	0	12.8
Central North	VMS 210 Limited Entry Fixed Gear, Not Including Shore-based IFQ 2010 - 2017	0 - 6	0	7
Central North	VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	0 - 1	0	2
Central North	VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	0 - 70	0	71
Central North	VMS 241 Non-groundfish Trawl for Pink Shrimp 2010 - 2017	0 - 153	0	154
Central North	VMS 243 Non-groundfish Trawl for California Sea Cucumber 2010 - 2017	0 - 1	0	2
Central North	VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	0 - 2	0	3
Central North	VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	0 - 56	0	57
Central North	VMS 269 A Gear That Is Not Listed Above 2010 - 2017	0 - 4	0	5
Central North	VMS 330 Emergency Exemption 2010 - 2017	0 - 36	0	37
Central North	VMS 340 Long-term Departure Exemption 2010 - 2017	0 - 8	0	9
Central South	California Recreational Fisheries Surveys (CRFS) Fishing 2010 - 2019	0 - 156	0	157
Central South	Commercial Passenger Fishing Vessels (CPFV) Fishing 2010 - 2019	0 - 34	0	35
Central South	Divelog 1998 - 2016	0 - 10	0	11
Central South	Lobster Log 2016 - 2019	0 - 8	0	9
Central South	Squid Landing Microblocks 2000 - 2019	0 - 508.9	0	509.9
Central South	VMS 210 Limited Entry Fixed Gear Not Including Shore-based IFQ 2010 - 2017	0 - 70	0	71
Central South	VMS 233 Open Access Longline Gear for Groundfish 2010 - 2017	0 - 62	0	63
Central South	VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	0 - 50	0	51
Central South	VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	0 - 114	0	115
Central South	VMS 240 Non-groundfish Trawl Gear for Ridgeback Prawn 2010 - 2017	0 - 103	0	104
Central South	VMS 241 Non-groundfish Trawl Gear for Pink Shrimp 2010 - 2017	0 - 131	0	132
Central South	VMS 242 Non-groundfish Trawl Gear for California Halibut 2010 - 2017	0 - 1	0	2
Central South	VMS 243 Non-groundfish Trawl Gear for California Sea Cucumber 2010 - 2017	0 - 45	0	46
Central South	VMS 260 Open Access Prawn Trap or Pot Gear 2010 - 2017	0 - 1	0	2
Central South	VMS 261 Open Access Dungeness Crab Trap or Pot Gear 2010 - 2017	0 - 1	0	2
Central South	VMS 264 Open Access California Halibut Line Gear 2010 - 2017	0 - 169	0	170

Study Area	Data Set	Range	Ceiling	Foot
Central South	VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	0 - 2	0	3
Central South	VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	0 - 252	0	253
Central South	VMS 269 A Gear That Is Not Listed Above 2010 - 2017	0 - 109	0	110
Central South	VMS 330 Emergency Exemption 2010 - 2017	0 - 75	0	76
Central South	VMS 340 Long-term Departure Exemption 2010 - 2017	0 - 10	0	11
South	California Recreational Fisheries Surveys (CRFS) Fishing 2010 - 2019	0 - 47.2	0	48.2
South	Commercial Passenger Fishing Vessels (CPFV) Fishing 2010 - 2019	0 - 23	0	24
South	Divelog 1998 - 2016	0 - 3	0	4
South	Lobster Log 2016 - 2019	0 - 28	0	29
South	Squid Landing Microblocks 2000 - 2019	0 - 71.2	0	72.2
South	VMS 210 Limited Entry Fixed Gear Not Including Shore-based IFQ 2010 - 2017	0 - 4	0	5
South	VMS 233 Open Access Longline Gear for Groundfish 2010 - 2017	0 - 6	0	7
South	VMS 234 Open Access Groundfish Trap or Pot Gear 2010 - 2017	0 - 23	0	24
South	VMS 235 Open Access Line Gear for Groundfish 2010 - 2017	0 - 71	0	72
South	VMS 240 Non-groundfish Trawl Gear for Ridgeback Prawn 2010 - 2017	0 - 29	0	30
South	VMS 241 Non-groundfish Trawl Gear for Pink Shrimp 2010 - 2017	0 - 145	0	146
South	VMS 242 Non-groundfish Trawl Gear for California Halibut 2010 - 2017	0 - 28	0	29
South	VMS 243 Non-groundfish Trawl Gear for California Sea Cucumber 2010 - 2017	0 - 27	0	28
South	VMS 261 Open Access Dungeness Crab Trap or Pot Gear 2010 - 2017	0 - 33	0	34
South	VMS 264 Open Access California Halibut Line Gear 2010 - 2017	0 - 13	0	14
South	VMS 265 Open Access Sheephead Trap or Pot Gear 2010 - 2017	0 - 8	0	9
South	VMS 266 Open Access Highly Migratory Species Line Gear 2010 - 2017	0 - 17	0	18
South	VMS 268 Open Access California Gillnet Complex Gear 2010 - 2017	0 - 56	0	57
South	VMS 269 A Gear That Is Not Listed Above 2010 - 2017	0 - 15	0	16
South	VMS 310 Haul Out Exemption 2010 - 2017	0 - 14	0	15
South	VMS 330 Emergency Exemption 2010 - 2017	0 - 27	0	28
South	VMS 340 Long-term Departure Exemption 2010 - 2017	0 - 1	0	2

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

October 1, 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 off the coast of Southern California. The following is a list of points of contact that were identified through this process that request participation in future working groups:

- John Demers | john.a.demers@navy.mil
- Steve Chung | steve.u.chung@navy.mil
- Robert Nowak | robert.w.nowak@navy.mil
- John Gamelin | john.j.gamelin@usmc.mil
- Walt Schobel | walter.schobel@us.af.mil
- Monique Flores | monique.flores@us.af.mil
- Michelle Perry | michelle.perry.2@us.af.mil
- Kurt Schmidtman | kurt.schmidtman.1.ctr@us.af.mil
- MSgt. Dane Polston | dane.polston@spaceforce.mil

The U.S. Navy provided assessments of individual aquaculture opportunity area subsections, identifying areas 102b (3.9 sq. NM), 107a (30.5 sq. NM), and 107b (19.9 sq. NM) as compatible with their missions. 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-10 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

October 22, 2021

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) a review of the NOAA Aquaculture Opportunity Areas located off the coast of Southern California.

The proposed Aquaculture Opportunity Areas (AOAs) N-1A, N-1B, N1-C, CN-1A and CN-1B were reviewed by DoD and deemed compatible with DoD operations, subject to final design review. Our review found that aquaculture development in AOAs N-2A, N-2B, N-2C, N-2D and N-2E may be compatible with military testing and training conducted by the Department of the Navy.

Essential mission activity occurs in Military Training Route (MTR) IR-211 and proximate to DoD testing and training range of W-289 for AOAs N-2A, N-2B, N-2C, N-2D and N-2E. MTR IR-211 is operated continuously (day/night), and any structure exceeding a height of 100 feet may pose an impact to the military mission.

Due to the hazardous nature of this activity, there are safety concerns and military readiness aspects that will require further review by DoD when project details are available. We request that any permit for aquaculture in these areas include a stipulation for DoD review and concurrence. Please contact Mr. Steve Chung (steve.u.chung@navy.mil), DoD Pacific Coast Compatibility lead, to discuss further.

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-10 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
Executive Director
Military Aviation and Installation
Assurance Siting Clearinghouse

Appendix E

Appendix E. OceanReports analyses supporting characterization of Aquaculture Opportunity Area options for southern California.

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, National Oceanic and Atmospheric Administration, and 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 energy, shipping and transportation, aquaculture, fisheries, and seabed mining to navigate conflicting uses, analyze environmental considerations, and assess economic opportunity. In Table E-1, we provide links for custom analysis for the top ten AOA options for the Southern California Bight. Readers can navigate and further explore each AOA option using the links provided. We also provide two customized reports for the North study area including a combined cluster analysis for N1 and N2 (due to the close proximity of these clusters) and an analysis for the CN1 cluster in the Central North study area.

Table E-1. Study area, Aquaculture Opportunity Area option, and link for custom OceanReports analysis for each Aquaculture Opportunity Area option.

Study Area	AOA Option	OceanReports Link
North	N1-A	https://bit.ly/3AoJ2Sv
North	N1-B	https://bit.ly/3dCggUJ
North	N1-C	https://bit.ly/3Ak9rRb
North	N2-A	https://bit.ly/3hx6BQa
North	N2-B	https://bit.ly/2Tu8uoW
North	N2-C	https://bit.ly/3jBAem8
North	N2-D	https://bit.ly/3dC3ZQ4
North	N2-E	https://bit.ly/3yhQkFD
Central North	CN1-A	https://bit.ly/3dDqgwP
Central North	CN1-B	https://bit.ly/2V6LNYx

Appendix F

Appendix F. List of top Aquaculture Opportunity Area options identified for the North and Central North study areas with submodel and final scores.

Table F-1. All Aquaculture Opportunity Area options (n = 38) for the N1 cluster (North study area). Aquaculture Opportunity Area options included in the top 10 highest ranked options are indicated with light grey shading.

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
1	32	-119.566, 34.237 -119.597, 34.237 -119.597, 34.263 -119.566, 34.263	0.9096	0.9707	0.9255	0.9349	https://bit.ly/3c4ZxYG
2	37	-119.56, 34.242 -119.591, 34.242 -119.591, 34.268 -119.56, 34.268	0.9401	0.9893	0.8776	0.9345	https://bit.ly/3ChVCCQ
3	34	-119.563, 34.24 -119.594, 34.24 -119.594, 34.266 -119.563, 34.266	0.9255	0.9814	0.8958	0.9336	https://bit.ly/3na8TJ3
4	35	-119.56, 34.24 -119.591, 34.24 -119.591, 34.266 -119.56, 34.266	0.9056	0.9830	0.9045	0.9303	https://bit.ly/3c7hR3B
5	38	-119.556, 34.242 -119.587, 34.242 -119.587, 34.268 -119.556, 34.268	0.9195	0.9917	0.8802	0.9294	https://bit.ly/3Ddzv1B
6	29	-119.566, 34.235 -119.597, 34.235	0.8743	0.9627	0.9537	0.9294	https://bit.ly/3n9F5fK

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.597, 34.261 -119.566, 34.261					
7	33	-119.563, 34.237 -119.594, 34.237 -119.594, 34.263 -119.563, 34.263	0.8905	0.9731	0.9224	0.9281	https://bit.ly/3CbwI7R
8	36	-119.556, 34.24 -119.587, 34.24 -119.587, 34.266 -119.556, 34.266	0.8853	0.9859	0.9129	0.9270	https://bit.ly/3wIg6DB
9	30	-119.572, 34.23 -119.603, 34.23 -119.603, 34.255 -119.572, 34.255	0.8384	0.9235	0.9264	0.8952	https://bit.ly/3Ca7TJk
10	31	-119.569, 34.23 -119.6, 34.23 -119.6, 34.255 -119.569, 34.255	0.8210	0.9392	0.9285	0.8946	https://bit.ly/3Ca8rPo
11	28	-119.572, 34.227 -119.603, 34.227 -119.603, 34.253 -119.572, 34.253	0.8022	0.9072	0.9181	0.8742	https://bit.ly/2YG5Hvv
12	15	-119.523, 34.237 -119.55, 34.237 -119.55, 34.259 -119.523, 34.259	0.5268	0.9890	0.9768	0.7984	https://bit.ly/3wEhNlc
13	16	-119.52, 34.237 -119.547, 34.237 -119.547, 34.259 -119.52, 34.259	0.5053	0.9902	0.9794	0.7884	https://bit.ly/3c8gaTy

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
14	27	-119.51, 34.243 -119.536, 34.243 -119.536, 34.266 -119.51, 34.266	0.4950	0.9921	0.9742	0.7821	https://bit.ly/3wGIlga
15	22	-119.515, 34.239 -119.542, 34.239 -119.542, 34.261 -119.515, 34.261	0.4882	0.9958	0.9799	0.7810	https://bit.ly/3C5IW1v
16	17	-119.518, 34.237 -119.545, 34.237 -119.545, 34.259 -119.518, 34.259	0.4836	0.9914	0.9815	0.7778	https://bit.ly/3wCDWR2
17	23	-119.512, 34.239 -119.539, 34.239 -119.539, 34.261 -119.512, 34.261	0.4658	0.9963	0.9818	0.7695	https://bit.ly/3CdNCTb
18	18	-119.515, 34.237 -119.542, 34.237 -119.542, 34.259 -119.515, 34.259	0.4616	0.9935	0.9803	0.7660	https://bit.ly/3wHVYRH
19	26	-119.51, 34.241 -119.537, 34.241 -119.537, 34.263 -119.51, 34.263	0.4692	0.9949	0.9564	0.7643	https://bit.ly/3DaPihG
20	24	-119.51, 34.239 -119.537, 34.239 -119.537, 34.261 -119.51, 34.261	0.4431	0.9959	0.9842	0.7573	https://bit.ly/3CaJ1kH
21	19	-119.512, 34.237 -119.539, 34.237	0.4394	0.9946	0.9786	0.7534	https://bit.ly/3oruADU

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.539, 34.259 -119.512, 34.259					
22	25	-119.507, 34.239 -119.534, 34.239 -119.534, 34.261 -119.507, 34.261	0.4202	0.9926	0.9861	0.7437	https://bit.ly/3n8UJbe
23	20	-119.51, 34.237 -119.537, 34.237 -119.537, 34.259 -119.51, 34.259	0.4169	0.9948	0.9807	0.7409	https://bit.ly/3C4trqI
24	21	-119.507, 34.237 -119.534, 34.237 -119.534, 34.259 -119.507, 34.259	0.3942	0.9944	0.9825	0.7276	https://bit.ly/3DchXCY
25	14	-119.489, 34.199 -119.515, 34.199 -119.515, 34.221 -119.489, 34.221	0.5380	0.7714	0.8359	0.7027	https://bit.ly/3n7KgwC
26	10	-119.497, 34.224 -119.513, 34.224 -119.513, 34.236 -119.497, 34.236	0.4542	0.7530	0.9429	0.6858	https://bit.ly/3wNSwW0
27	8	-119.496, 34.222 -119.511, 34.222 -119.511, 34.235 -119.496, 34.235	0.4726	0.6860	0.9878	0.6842	https://bit.ly/3c2HUZM
28	7	-119.497, 34.222 -119.513, 34.222 -119.513, 34.235 -119.497, 34.235	0.4527	0.7150	0.9801	0.6820	https://bit.ly/2YG7IYB

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
29	11	-119.524, 34.277 -119.546, 34.277 -119.546, 34.295 -119.524, 34.295	0.9027	0.2689	0.3387	0.4348	https://bit.ly/3C9l51a
30	12	-119.524, 34.278 -119.545, 34.278 -119.545, 34.297 -119.524, 34.297	0.9220	0.2226	0.2849	0.3882	https://bit.ly/3c9je1Q
31	9	-119.533, 34.224 -119.548, 34.224 -119.548, 34.237 -119.533, 34.237	0.2304	0.1922	0.8144	0.3304	https://bit.ly/3cb6FCQ
32	6	-119.533, 34.222 -119.548, 34.222 -119.548, 34.235 -119.533, 34.235	0.2139	0.1169	0.8125	0.2729	https://bit.ly/3Dc2vqt
33	4	-119.536, 34.208 -119.551, 34.208 -119.551, 34.221 -119.536, 34.221	0.0513	0.2109	0.4626	0.1711	https://bit.ly/3wNT524
34	5	-119.536, 34.21 -119.551, 34.21 -119.551, 34.223 -119.536, 34.223	0.0683	0.0927	0.5554	0.1521	https://bit.ly/2YGzfsV
35	3	-119.536, 34.207 -119.551, 34.207 -119.551, 34.22 -119.536, 34.22	0.0343	0.2449	0.3871	0.1481	https://bit.ly/3C8m8y7
36	2	-119.536, 34.206 -119.551, 34.206	0.0172	0.3669	0.2977	0.1235	https://bit.ly/3c5PLph

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.551, 34.219					
		-119.536, 34.219					
37	13	-119.526, 34.284	1.0000	0.0146	0.0685	0.1000	https://bit.ly/3ccDz65
		-119.548, 34.284					
		-119.548, 34.302					
		-119.526, 34.302					
38	1	-119.536, 34.205	0.0001	0.4389	0.2074	0.0234	https://bit.ly/3c7uSdu
		-119.551, 34.205					
		-119.551, 34.217					
		-119.536, 34.217					

Table F-2. Top 50 Aquaculture Opportunity Area options (n = 246) for the N2 cluster (North study area). Aquaculture Opportunity Area options included in the top 10 highest ranked options are indicated with light grey shading.

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
1	127	-119.393, 34.237 -119.424, 34.237 -119.424, 34.262 -119.393, 34.262	0.8861	0.632	0.6898	0.7283	https://bit.ly/3wEKEG2
2	126	-119.396, 34.237 -119.427, 34.237 -119.427, 34.262 -119.396, 34.262	0.8763	0.6604	0.6612	0.726	https://bit.ly/3wKepoX
3	128	-119.39, 34.237 -119.421, 34.237 -119.421, 34.262 -119.39, 34.262	0.8944	0.5927	0.7185	0.7249	https://bit.ly/3n9xtKb
4	125	-119.399, 34.237 -119.43, 34.237 -119.43, 34.262 -119.399, 34.262	0.8725	0.6855	0.6325	0.7232	https://bit.ly/2YH1I1D
5	72	-119.368, 34.221 -119.399, 34.221 -119.399, 34.247 -119.368, 34.247	0.7138	0.5735	0.9184	0.7217	https://bit.ly/3wHIC89
6	124	-119.402, 34.237 -119.433, 34.237 -119.433, 34.262 -119.402, 34.262	0.8481	0.7	0.6038	0.7104	https://bit.ly/3wDKPBD
7	123	-119.405, 34.237 -119.436, 34.237	0.8554	0.7196	0.5752	0.7074	https://bit.ly/3n7wEBI

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.436, 34.262 -119.405, 34.262					
8	64	-119.368, 34.218 -119.399, 34.218 -119.399, 34.244 -119.368, 34.244	0.6579	0.5777	0.9169	0.7037	https://bit.ly/3C6b8kR
9	122	-119.408, 34.237 -119.439, 34.237 -119.439, 34.262 -119.408, 34.262	0.8453	0.7321	0.5465	0.6967	https://bit.ly/3naWPY9
10	144	-119.399, 34.239 -119.43, 34.239 -119.43, 34.265 -119.399, 34.265	0.8599	0.6194	0.6325	0.6958	https://bit.ly/3ohLDIo
11	121	-119.411, 34.237 -119.442, 34.237 -119.442, 34.262 -119.411, 34.262	0.8405	0.748	0.5178	0.6879	https://bit.ly/3CbLz1K
12	110	-119.418, 34.234 -119.449, 34.234 -119.448, 34.26 -119.417, 34.26	0.8939	0.7897	0.4605	0.6876	https://bit.ly/3wHPAda
13	99	-119.421, 34.229 -119.452, 34.229 -119.452, 34.255 -119.421, 34.255	0.9212	0.8096	0.4318	0.6855	https://bit.ly/3DaGS9S
14	98	-119.421, 34.232 -119.452, 34.232 -119.452, 34.257	0.93	0.7996	0.4318	0.6848	https://bit.ly/3onoLrh

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.421, 34.257					
15	145	-119.396, 34.239 -119.427, 34.239 -119.427, 34.265 -119.396, 34.265	0.8732	0.5504	0.6612	0.6824	https://bit.ly/3Df8eeY
16	120	-119.414, 34.237 -119.445, 34.237 -119.445, 34.262 -119.414, 34.262	0.8425	0.7688	0.4892	0.6817	https://bit.ly/3CbvHwj
17	142	-119.405, 34.239 -119.436, 34.239 -119.436, 34.265 -119.405, 34.265	0.8486	0.6476	0.5752	0.6812	https://bit.ly/30ncGdm
18	143	-119.402, 34.239 -119.433, 34.239 -119.433, 34.265 -119.402, 34.265	0.8587	0.6094	0.6038	0.6811	https://bit.ly/3n7BIpF
19	109	-119.421, 34.234 -119.452, 34.234 -119.452, 34.26 -119.421, 34.26	0.9118	0.8008	0.4318	0.6806	https://bit.ly/3n8noNr
20	101	-119.421, 34.226 -119.452, 34.226 -119.452, 34.252 -119.421, 34.252	0.9085	0.7947	0.4318	0.6781	https://bit.ly/3c70Y9d
21	141	-119.408, 34.239 -119.439, 34.239 -119.439, 34.265 -119.408, 34.265	0.8443	0.6697	0.5465	0.6761	https://bit.ly/3n8g4l0

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
22	140	-119.411, 34.239 -119.442, 34.239 -119.442, 34.265 -119.411, 34.265	0.8331	0.7104	0.5178	0.6742	https://bit.ly/3qywntG
23	65	-119.365, 34.218 -119.396, 34.218 -119.396, 34.244 -119.365, 34.244	0.6281	0.5149	0.9455	0.6737	https://bit.ly/3c7ZjjC
24	78	-119.421, 34.224 -119.452, 34.224 -119.452, 34.25 -119.421, 34.25	0.891	0.7945	0.4318	0.6736	https://bit.ly/3C4YsuE
25	119	-119.417, 34.237 -119.449, 34.237 -119.449, 34.262 -119.417, 34.262	0.86	0.7692	0.4605	0.6728	https://bit.ly/2YEXxDu
26	139	-119.414, 34.239 -119.445, 34.239 -119.445, 34.265 -119.414, 34.265	0.8307	0.7478	0.4892	0.6723	https://bit.ly/3wEC4r0
27	54	-119.368, 34.216 -119.399, 34.216 -119.399, 34.242 -119.368, 34.242	0.6018	0.5515	0.9145	0.672	https://bit.ly/3DaKRDm
28	108	-119.424, 34.234 -119.455, 34.234 -119.455, 34.26 -119.424, 34.26	0.9062	0.8246	0.4032	0.6704	https://bit.ly/3Cc5Zbh
29	95	-119.424, 34.232	0.9059	0.8225	0.4032	0.6697	https://bit.ly/3n7EV8H

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.455, 34.232 -119.455, 34.257 -119.424, 34.257					
30	97	-119.424, 34.229 -119.455, 34.229 -119.455, 34.255 -119.424, 34.255	0.8836	0.835	0.4032	0.6675	https://bit.ly/3DiJXoE
31	71	-119.421, 34.221 -119.452, 34.221 -119.452, 34.247 -119.421, 34.247	0.8736	0.7778	0.4314	0.6643	https://bit.ly/3nbeSgO
32	163	-119.399, 34.242 -119.43, 34.242 -119.43, 34.268 -119.399, 34.268	0.8568	0.5393	0.6325	0.6636	https://bit.ly/3CdxL77
33	100	-119.424, 34.226 -119.455, 34.226 -119.455, 34.252 -119.424, 34.252	0.8741	0.8254	0.4032	0.6626	https://bit.ly/3ChGzJm
34	117	-119.424, 34.237 -119.455, 34.237 -119.455, 34.263 -119.424, 34.263	0.9024	0.7994	0.4032	0.6625	https://bit.ly/3DgA36M
35	118	-119.421, 34.237 -119.452, 34.237 -119.452, 34.263 -119.421, 34.263	0.8651	0.7782	0.4318	0.6625	https://bit.ly/3c3gjYq
36	63	-119.421, 34.219 -119.452, 34.219	0.8624	0.7782	0.4303	0.661	https://bit.ly/3C5z87X

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.452, 34.245 -119.421, 34.245					
37	161	-119.405, 34.242 -119.436, 34.242 -119.436, 34.268 -119.405, 34.268	0.8502	0.5883	0.5752	0.6602	https://bit.ly/3DaAhfO
38	77	-119.424, 34.224 -119.455, 34.224 -119.455, 34.25 -119.424, 34.25	0.8592	0.822	0.4031	0.6579	https://bit.ly/2YLCwas
39	162	-119.402, 34.242 -119.433, 34.242 -119.433, 34.268 -119.402, 34.268	0.8493	0.5545	0.6038	0.6576	https://bit.ly/3wILQbK
40	138	-119.417, 34.239 -119.448, 34.239 -119.448, 34.265 -119.417, 34.265	0.8176	0.7527	0.4605	0.6569	https://bit.ly/3ongeEG
41	158	-119.414, 34.242 -119.445, 34.242 -119.445, 34.268 -119.414, 34.268	0.8244	0.7003	0.4892	0.6561	https://bit.ly/3wGvUq6
42	107	-119.427, 34.234 -119.458, 34.234 -119.458, 34.26 -119.427, 34.26	0.8827	0.8481	0.3745	0.6545	https://bit.ly/3CaOM1P
43	146	-119.393, 34.239 -119.424, 34.239 -119.424, 34.265	0.889	0.452	0.6898	0.652	https://bit.ly/3CaW4CA

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-119.393, 34.265					
44	137	-119.421, 34.239	0.831	0.7671	0.4318	0.6505	https://bit.ly/3wG3uN6
		-119.452, 34.239					
		-119.452, 34.265					
		-119.421, 34.265					
45	70	-119.424, 34.221	0.851	0.8008	0.4027	0.6499	https://bit.ly/3wIRWZG
		-119.455, 34.221					
		-119.455, 34.247					
		-119.424, 34.247					
46	53	-119.421, 34.216	0.8556	0.7436	0.4287	0.6486	https://bit.ly/30idXlC
		-119.452, 34.216					
		-119.452, 34.242					
		-119.421, 34.242					
47	116	-119.427, 34.237	0.8833	0.8233	0.3745	0.6482	https://bit.ly/3wE065r
		-119.458, 34.237					
		-119.458, 34.263					
		-119.427, 34.263					
48	157	-119.417, 34.242	0.814	0.7265	0.4605	0.6482	https://bit.ly/3Ccflnp
		-119.448, 34.242					
		-119.448, 34.268					
		-119.417, 34.268					
49	62	-119.424, 34.219	0.847	0.7989	0.4017	0.6478	https://bit.ly/3DaUB0o
		-119.455, 34.219					
		-119.455, 34.245					
		-119.424, 34.245					
50	160	-119.408, 34.242	0.8299	0.598	0.5465	0.6473	https://bit.ly/3n7Pc4M
		-119.439, 34.242					
		-119.439, 34.268					

Table F-3. All Aquaculture Opportunity Area options (n = 12) for the CN1 cluster (Central North study area). Aquaculture Opportunity Area options included in the top 10 highest ranked options are indicated with light grey shading.

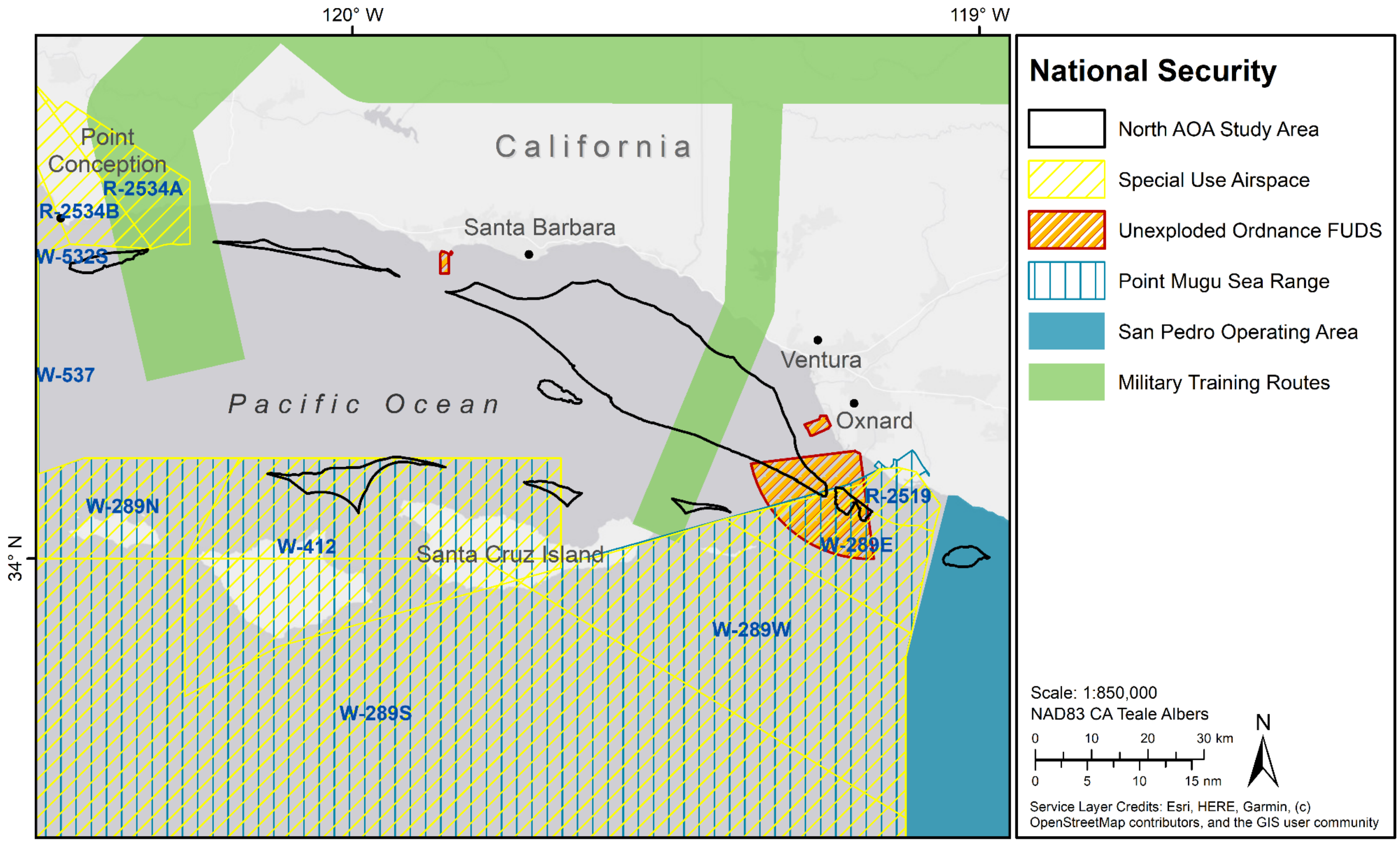
Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
1	2	-118.575, 33.964 -118.597, 33.964 -118.597, 33.982 -118.575, 33.982	0.2555	0.9919	0.9592	0.6241	https://bit.ly/3wG995K
2	9	-118.575, 33.967 -118.597, 33.967 -118.597, 33.985 -118.575, 33.985	0.2555	0.966	0.8246	0.5883	https://bit.ly/3wGowLr
3	5	-118.575, 33.965 -118.597, 33.965 -118.597, 33.983 -118.575, 33.983	0.2555	0.9402	0.8246	0.583	https://bit.ly/3DbsIoV
4	1	-118.577, 33.964 -118.599, 33.964 -118.599, 33.982 -118.577, 33.982	0.1705	0.9953	0.8246	0.5191	https://bit.ly/30jZBkF
5	4	-118.577, 33.965 -118.599, 33.965 -118.599, 33.983 -118.577, 33.983	0.1705	0.9841	0.5657	0.4562	https://bit.ly/3Dd2mmE
6	8	-118.577, 33.967 -118.599, 33.967 -118.599, 33.985 -118.577, 33.985	0.1705	0.9606	0.5657	0.4525	https://bit.ly/3CbODen
7	3	-118.579, 33.965 -118.601, 33.965 -118.601, 33.983	0.0855	0.95	0.5657	0.3581	https://bit.ly/3Ddy9nx

Rank	ID	Coordinates	Logistics Submodel	Vessel Traffic Submodel	Commercial Fishing Submodel	Final Score	OceanReports
		-118.579, 33.983					
8	7	-118.579, 33.967 -118.601, 33.967 -118.601, 33.985 -118.579, 33.985	0.0855	0.9468	0.5657	0.3577	https://bit.ly/3nbgyHb
9	10	-118.558, 33.96 -118.574, 33.96 -118.574, 33.973 -118.558, 33.973	0.8804	0.0354	1	0.3148	https://bit.ly/3c5309N
10	11	-118.557, 33.96 -118.572, 33.96 -118.572, 33.973 -118.557, 33.973	0.9402	0.0083	1	0.1982	https://bit.ly/3wEQKGC
11	12	-118.555, 33.96 -118.571, 33.96 -118.571, 33.973 -118.555, 33.973	1	0.0009	1	0.0951	https://bit.ly/3n9Ewm8
12	6	-118.581, 33.967 -118.603, 33.967 -118.603, 33.985 -118.581, 33.985	0.0004	0.9944	0.4989	0.0594	https://bit.ly/3wKqnz8

Appendix G

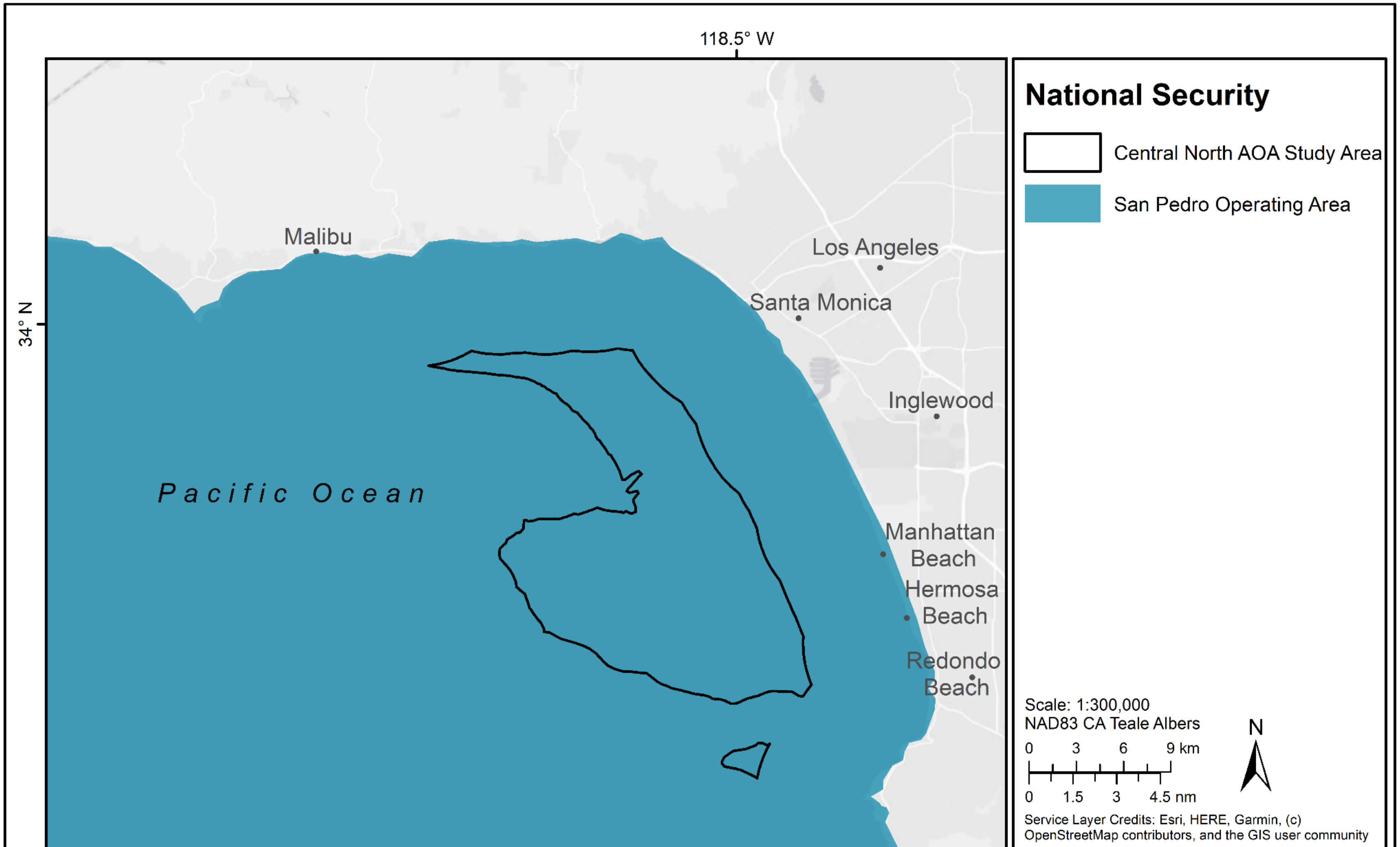
Appendix G: Large format maps to aid with viewing and interpretation.

National Security



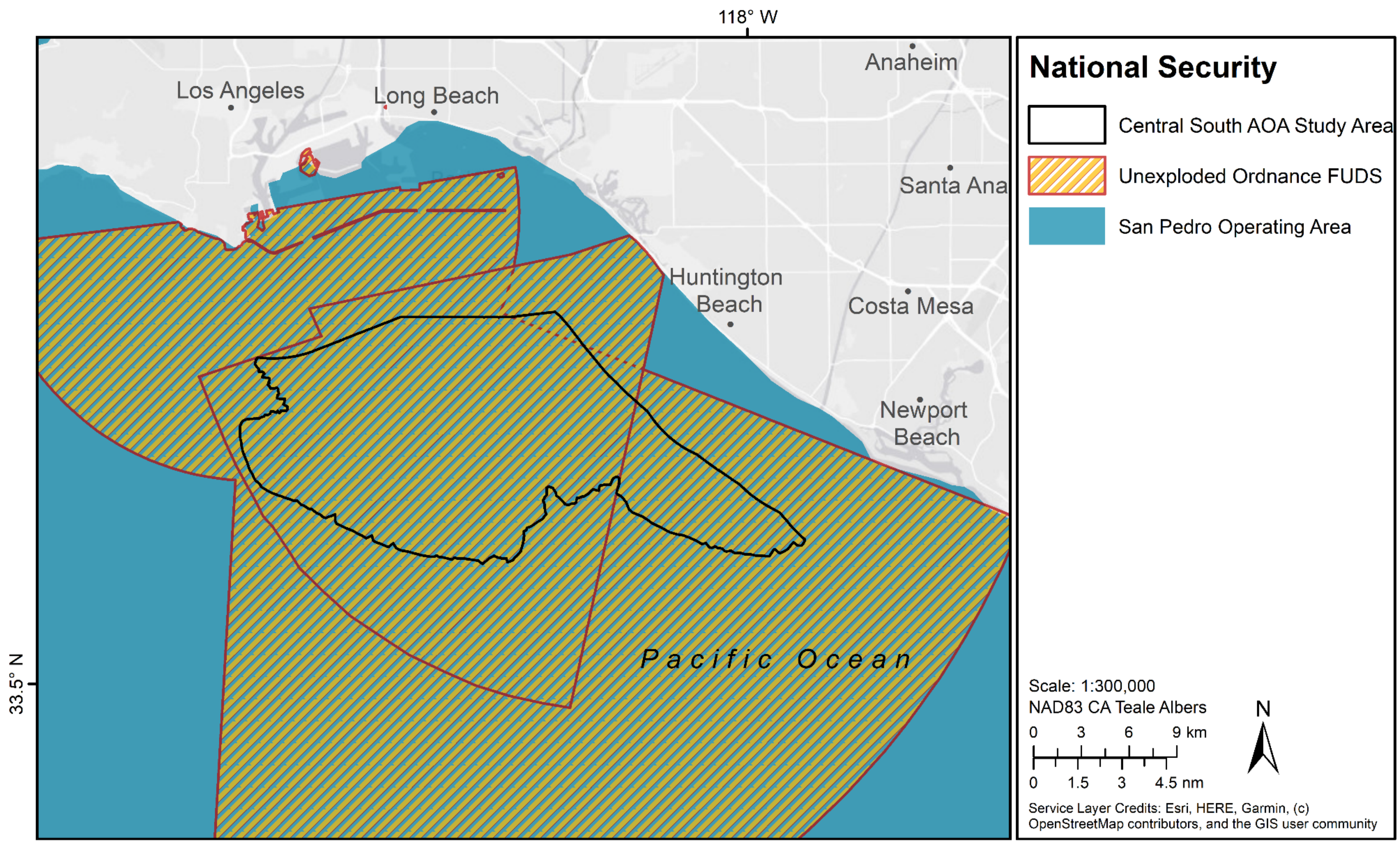
Special Use Airspace: Military Aviation and Installation Assurance Siting Clearinghouse (2019)
Unexploded Ordnance FUDS: NOAA OCM & BOEM (2018)
Point Mugu Sea Range: U.S. Fleet Force Environmental Readiness Branch (2017)
San Pedro Operating Area: U.S. Fleet Force Environmental Readiness Branch (2017)
Military Training Routes: FAA (2019)

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



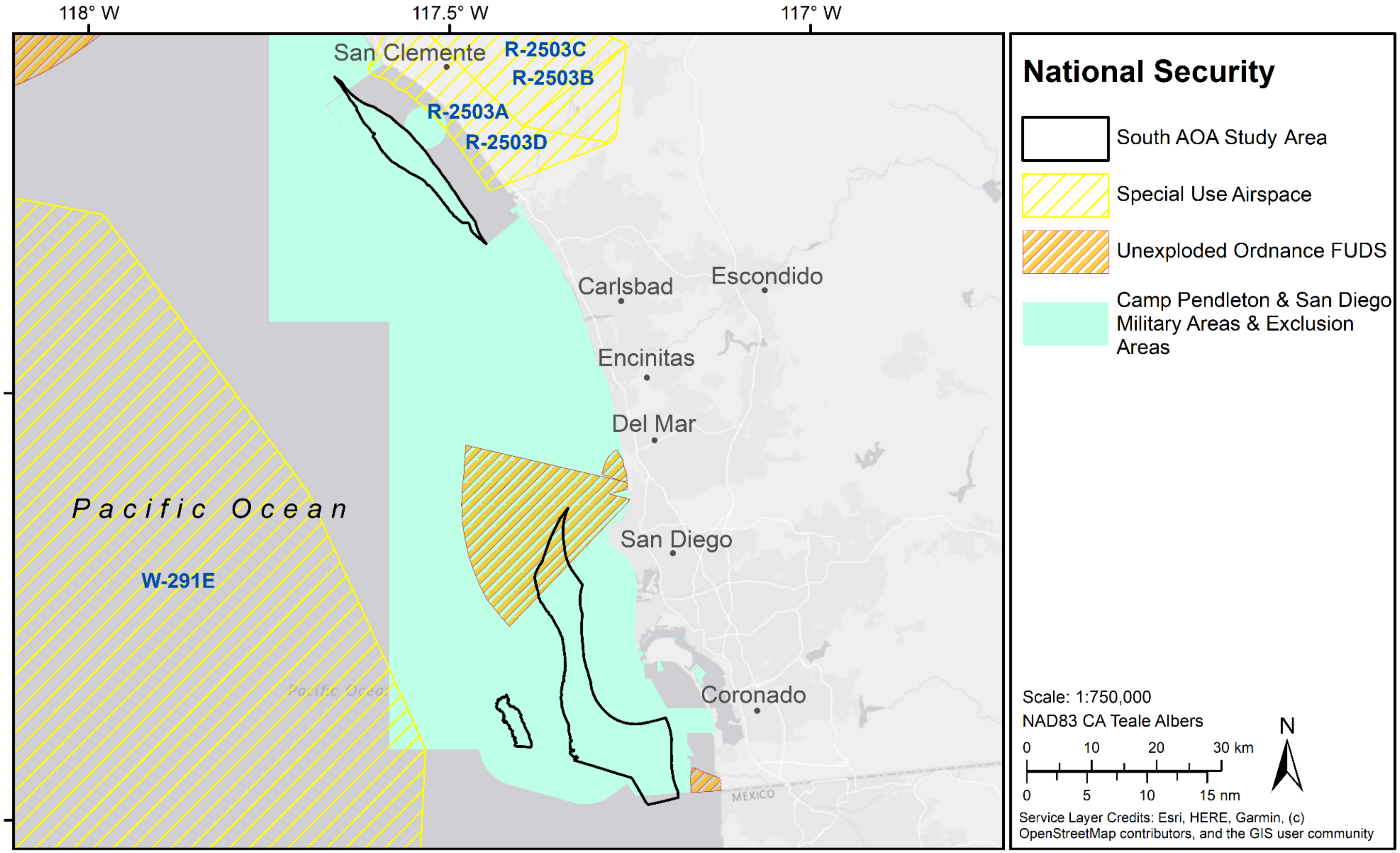
San Pedro Operating Area: U.S. Fleet Force: Environmental Readiness Branch (2017)

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



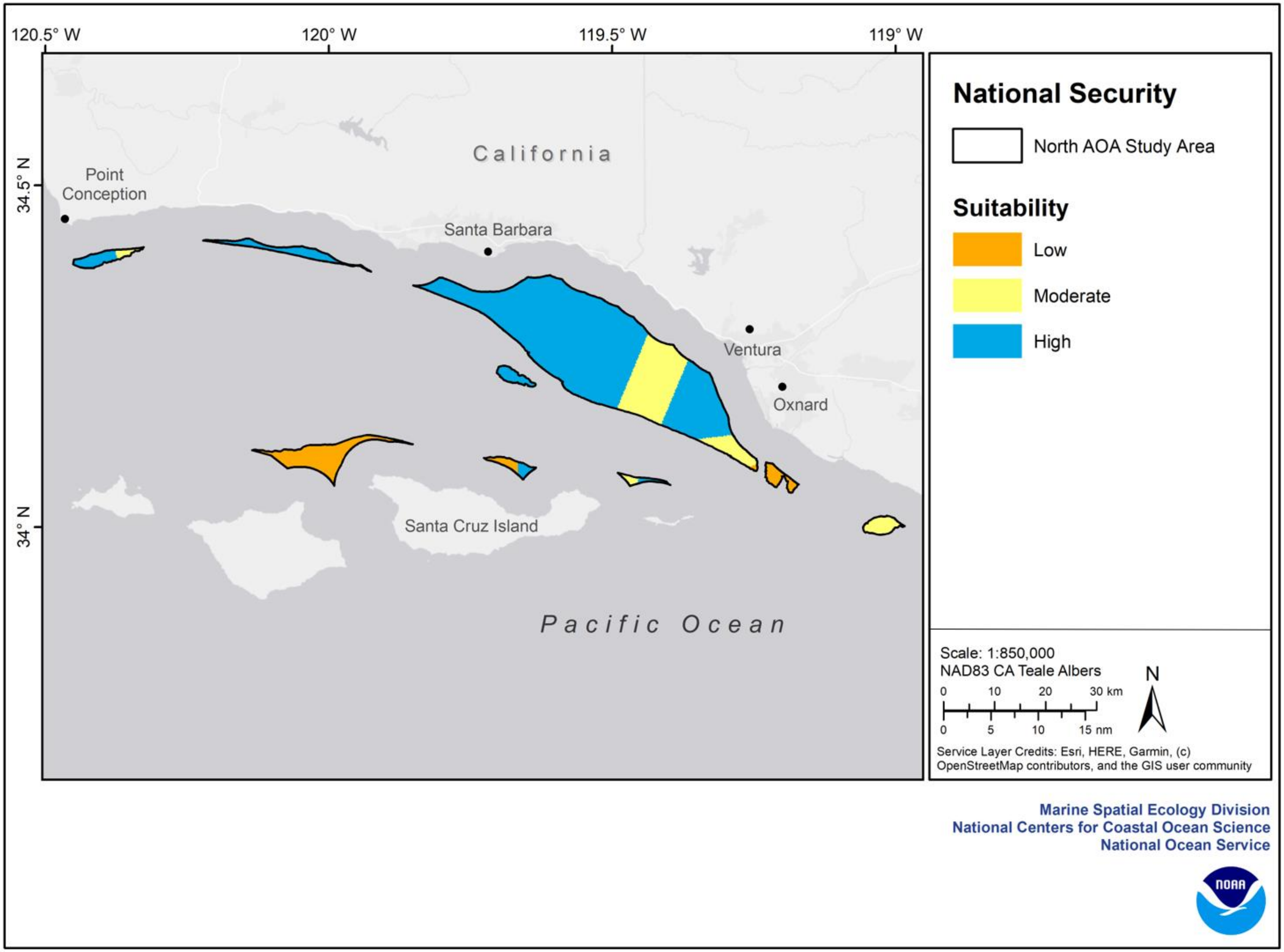
Unexploded Ordnance FUDS: NOAA OCM & BOEM (2018)
San Pedro Operating Area: U.S. Fleet Force: Environmental Readiness Branch (2017)

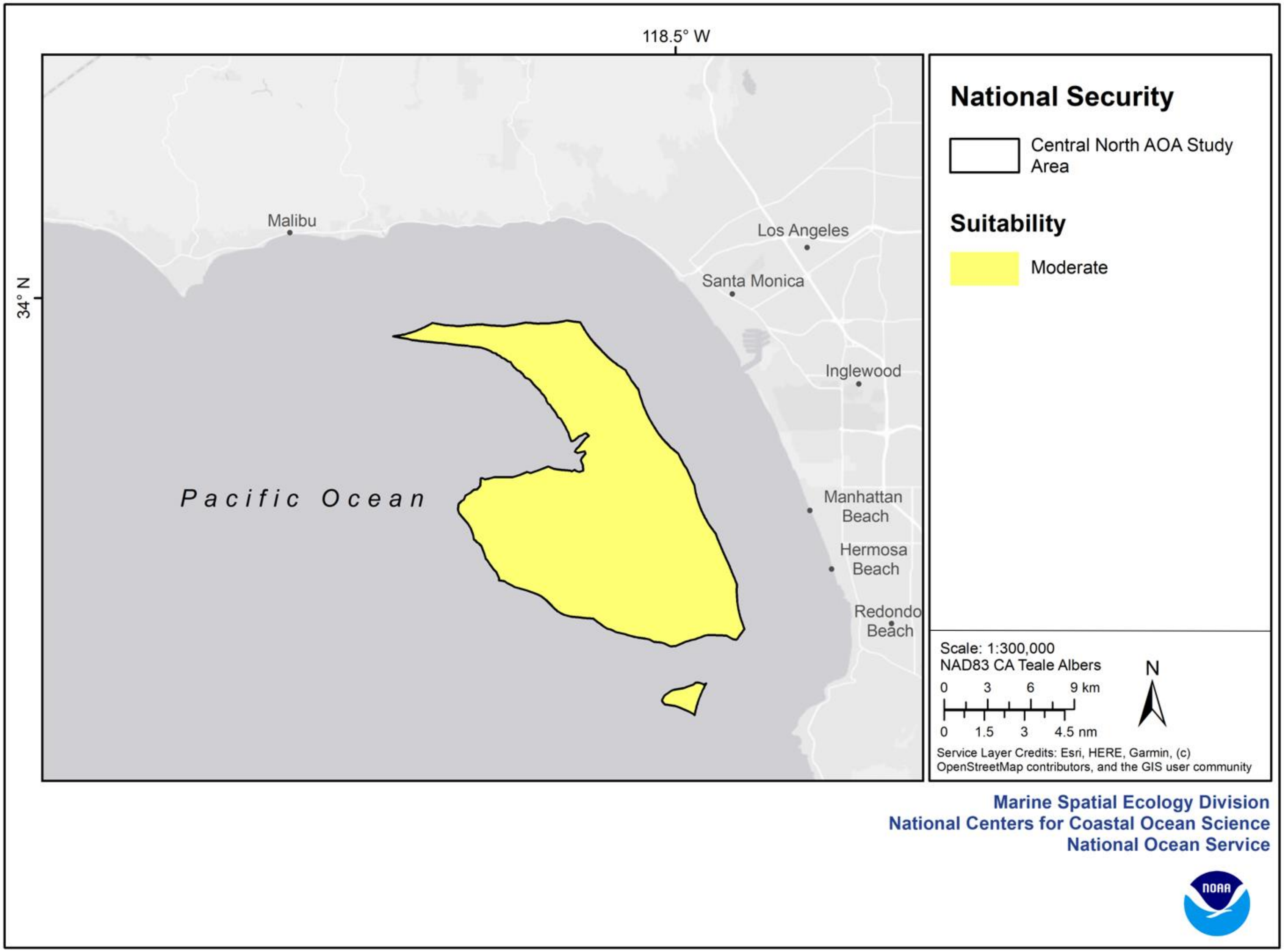
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

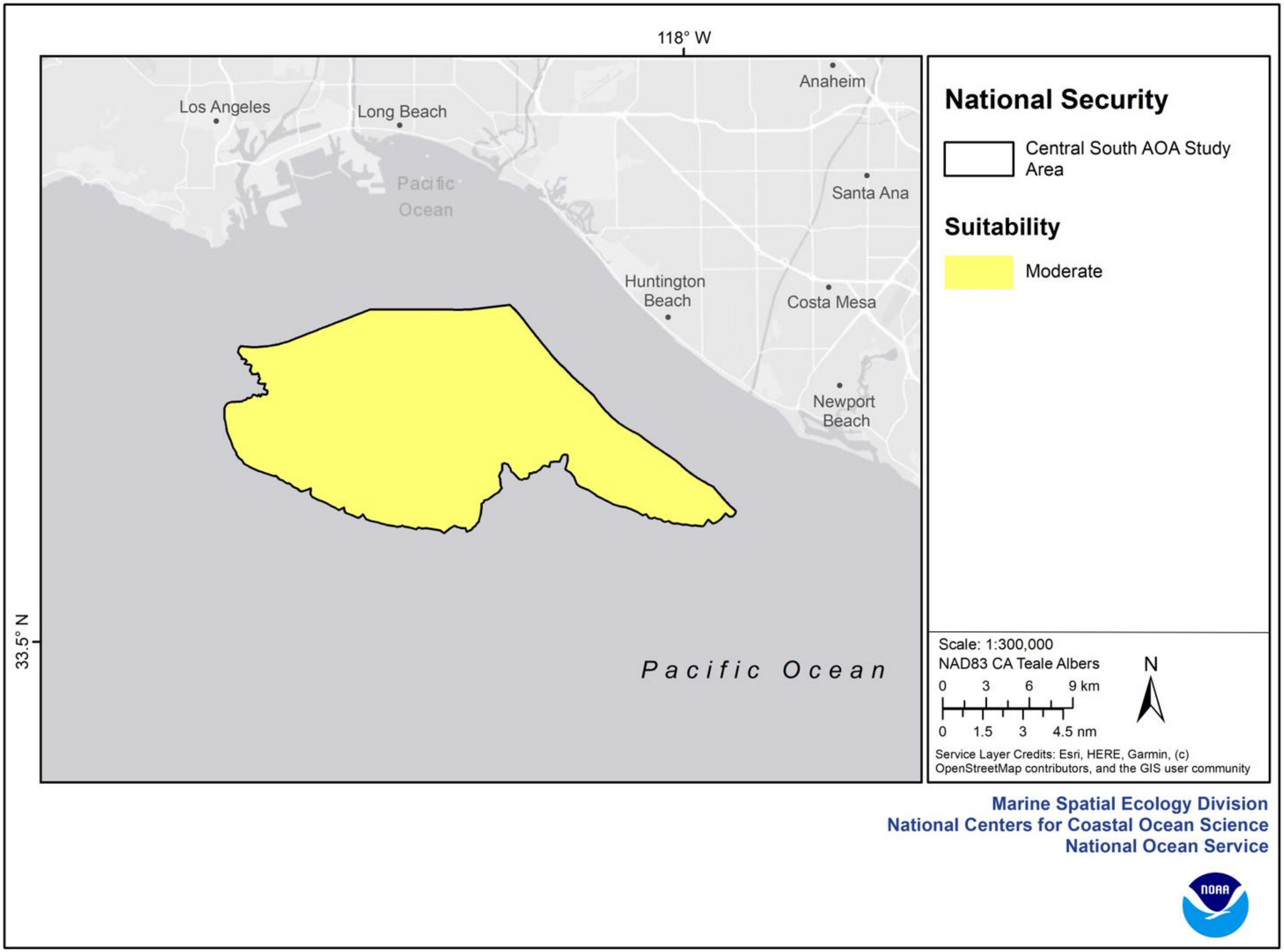


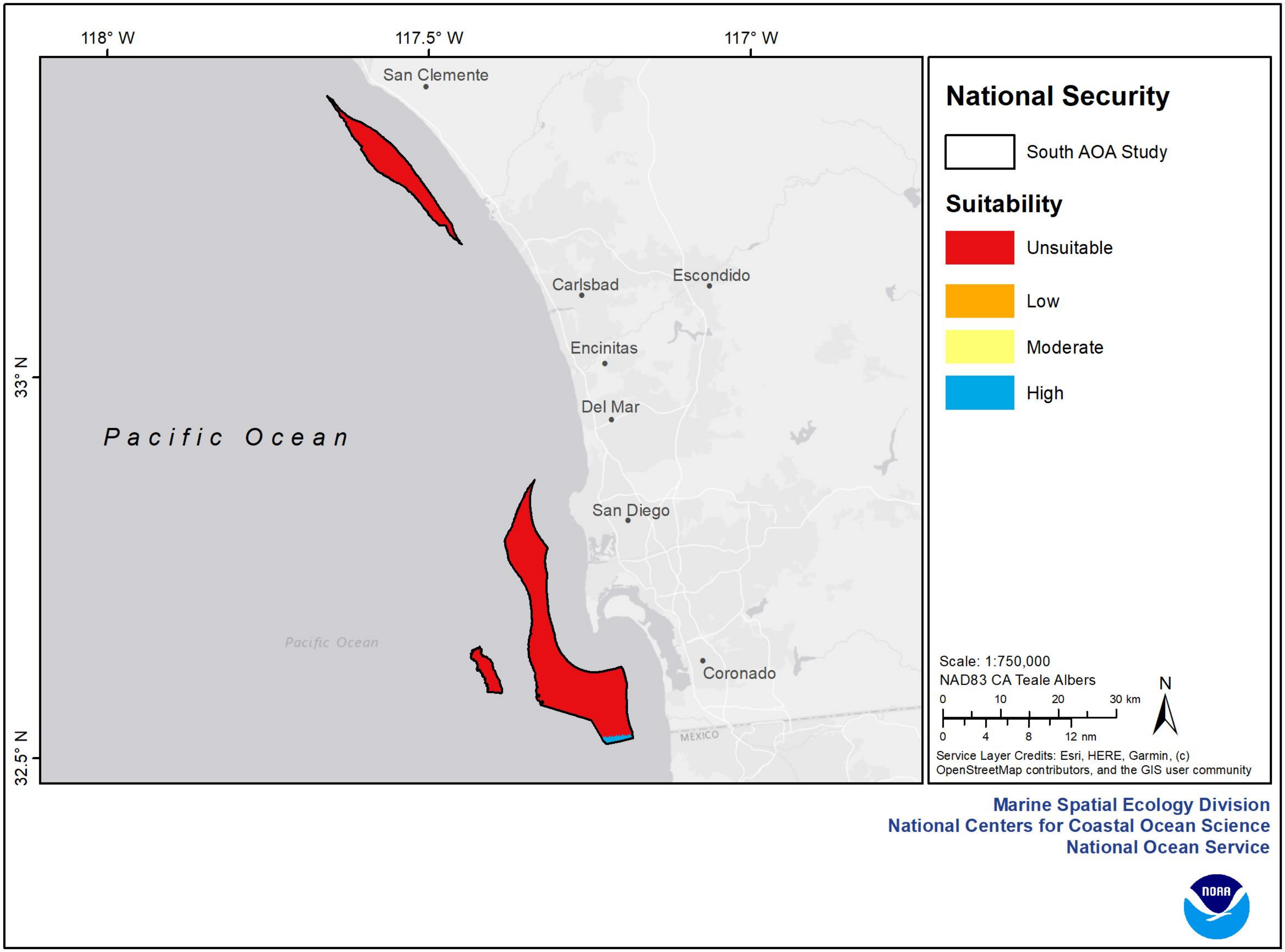
Special Use Airspace: Navy Environmental Information Management System (2017)
Unexploded Ordnance FUDS: NOAA OCM & BOEM (2018)
Camp Pendleton & San Diego Military Areas: U.S. Fleet Force: Environmental Readiness Branch (2016)

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


120.5° W
120° W
119.5° W
119° W
34.5° N
34° N
Point Conception
California
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
National Security
North AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 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

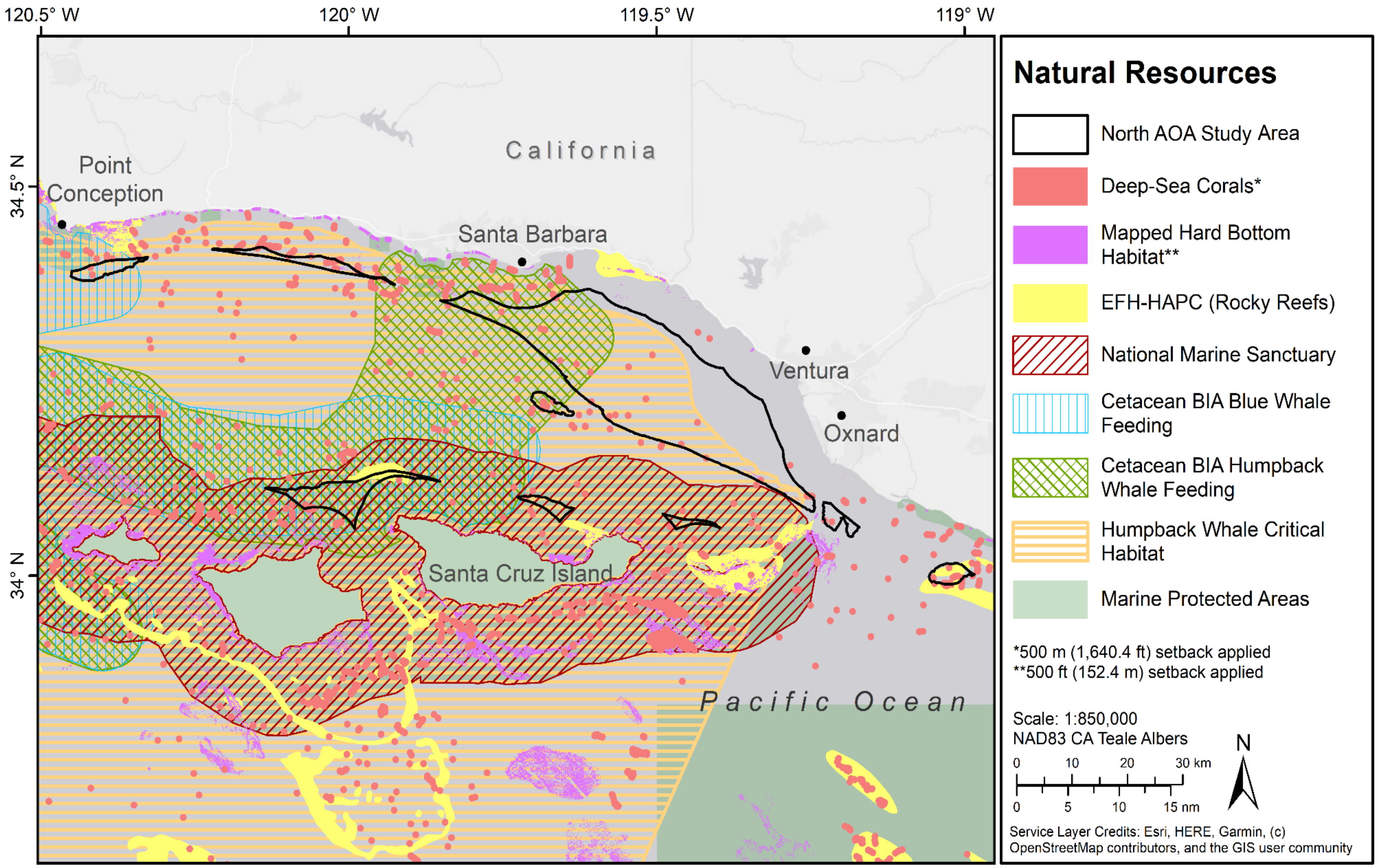

118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
National Security
Central North AOA Study Area
Suitability
Moderate
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA


118° W
33.5° N
Los Angeles
Long Beach
Anaheim
Santa Ana
Pacific Ocean
Huntington Beach
Costa Mesa
Newport Beach
Pacific Ocean
National Security
Central South AOA Study Area
Suitability
Moderate
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 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



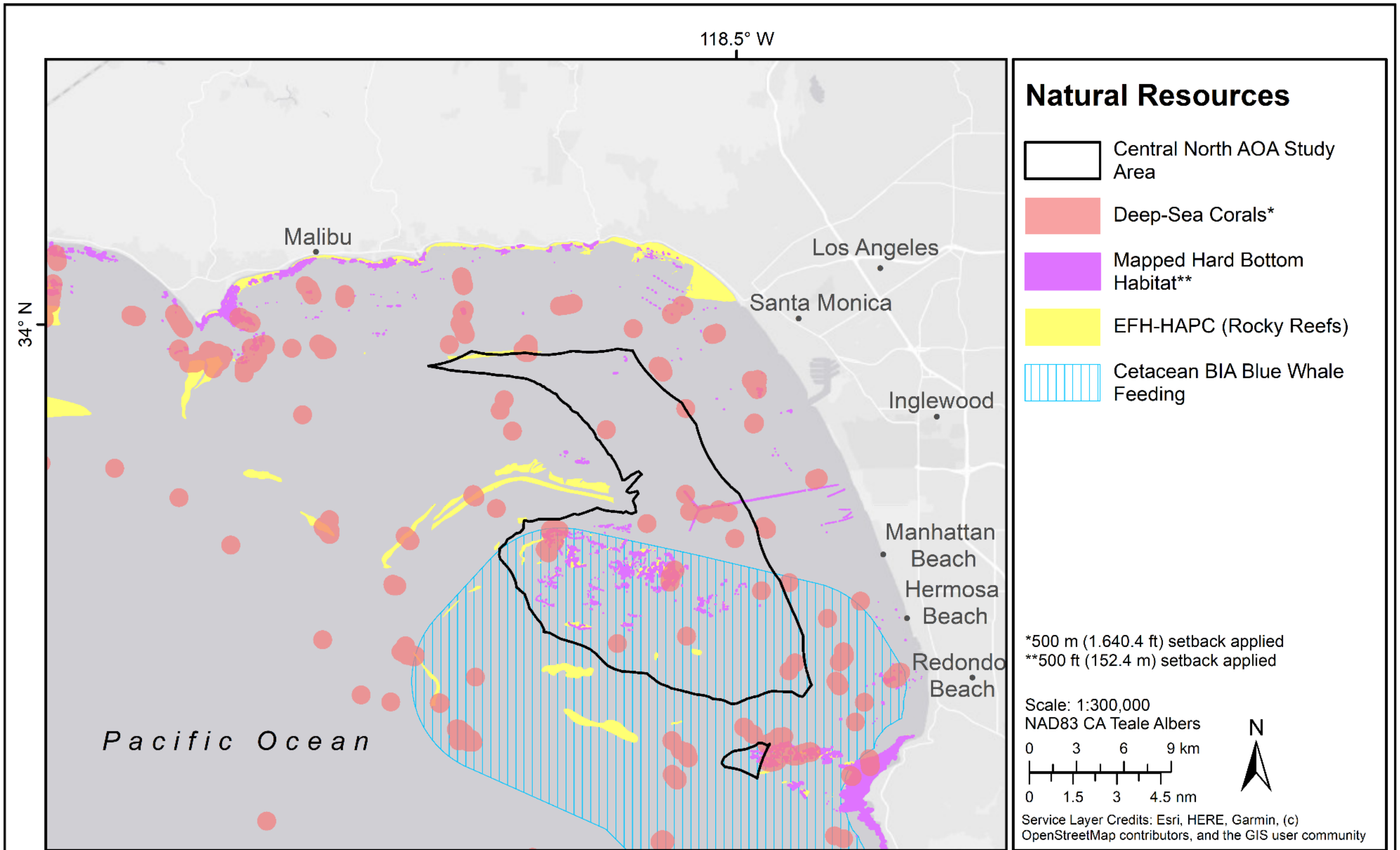
118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
National Security
South AOA Study
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 nm
N
Service Layer Credits: 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

Natural and Cultural Resources



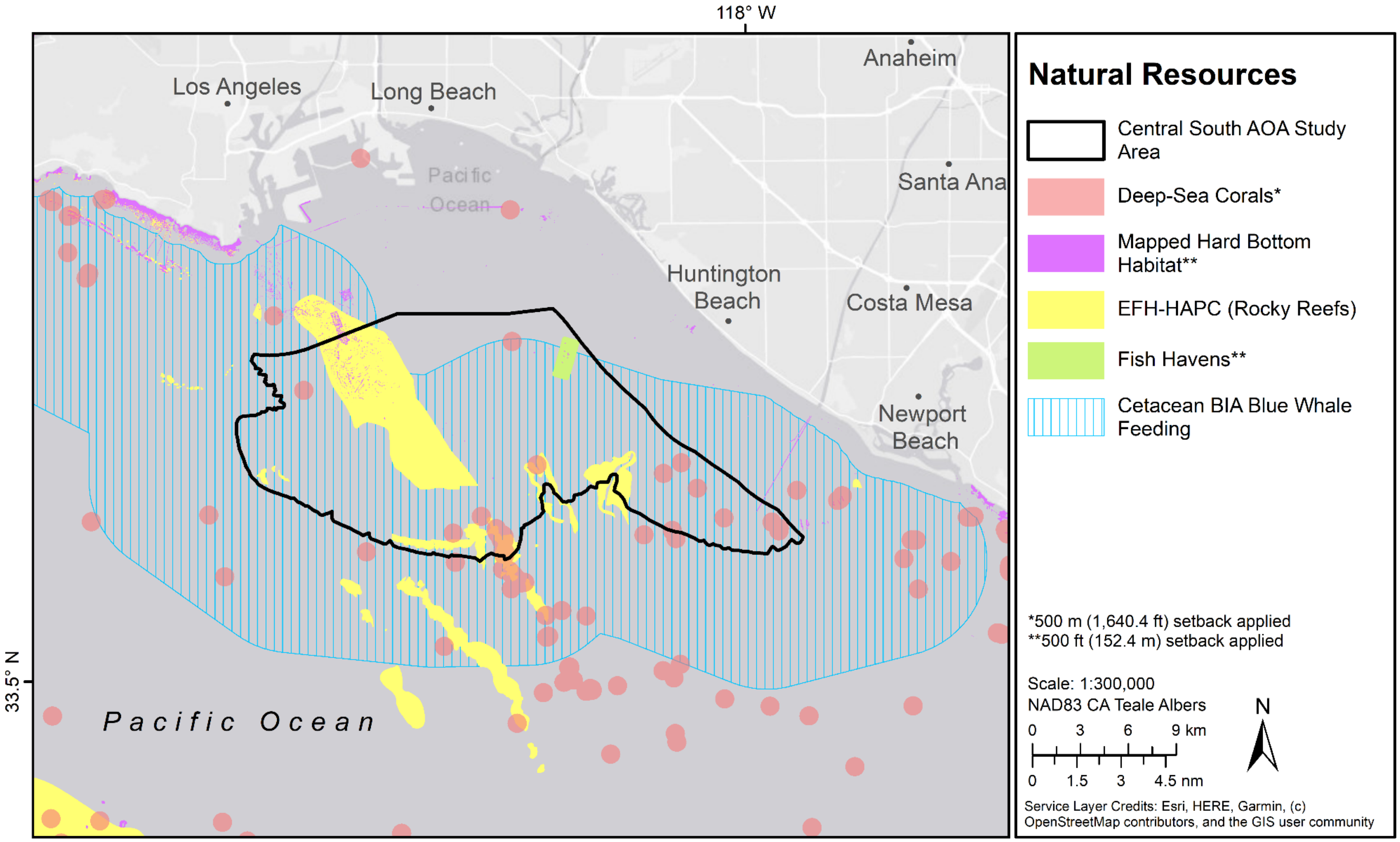
Deep-Sea Corals (1985 - present): NOAA Deep-Sea Coral Research and Technology Program (2021)
Mapped Hard Bottom Habitat: NOAA NMFS (2020)
Essential Fish Habitat (EFH) - Habitat Areas of Particular Concern (HAPC) (Rocky Reefs): NOAA NMFS (2018)
National Marine Sanctuary: NOAA (2018)
Marine Protected Areas: NOAA (2018)
Cetacean Biologically Important Areas: NOAA NMFS (2019)
Humpback whale feeding occurs March - September
Blue whale feeding occurs June - October

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



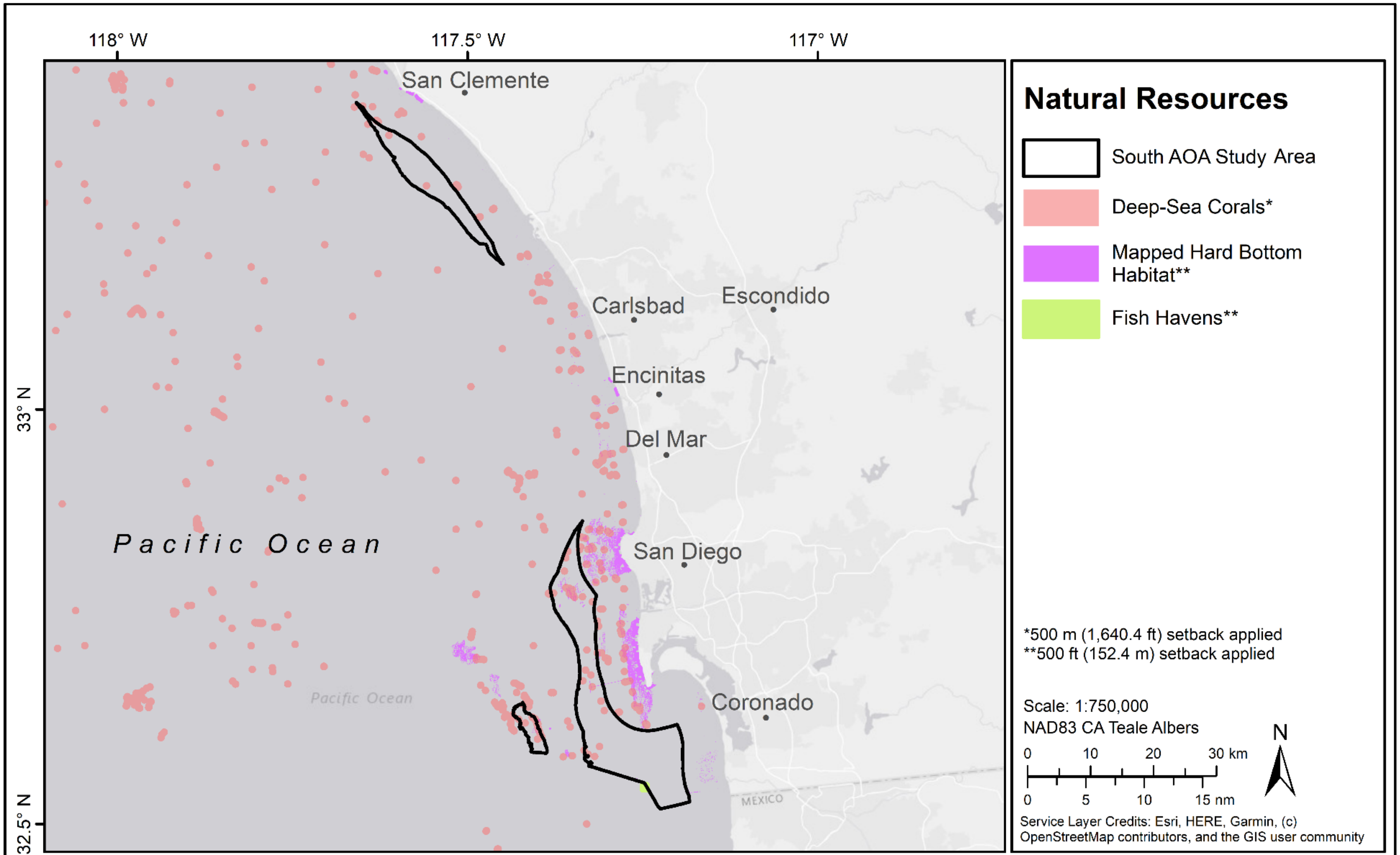
Deep-Sea Corals (1985 - present): NOAA Deep-Sea Coral Research and Technology Program (2021)
Mapped Hard Bottom Habitat: NOAA NMFS (2018)
EFH-HAPC (Rocky Reefs): NOAA NMFS (2020)
Cetacean Biologically Important Areas: NOAA NMFS (2019)
Blue whale feeding occurs June - October

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



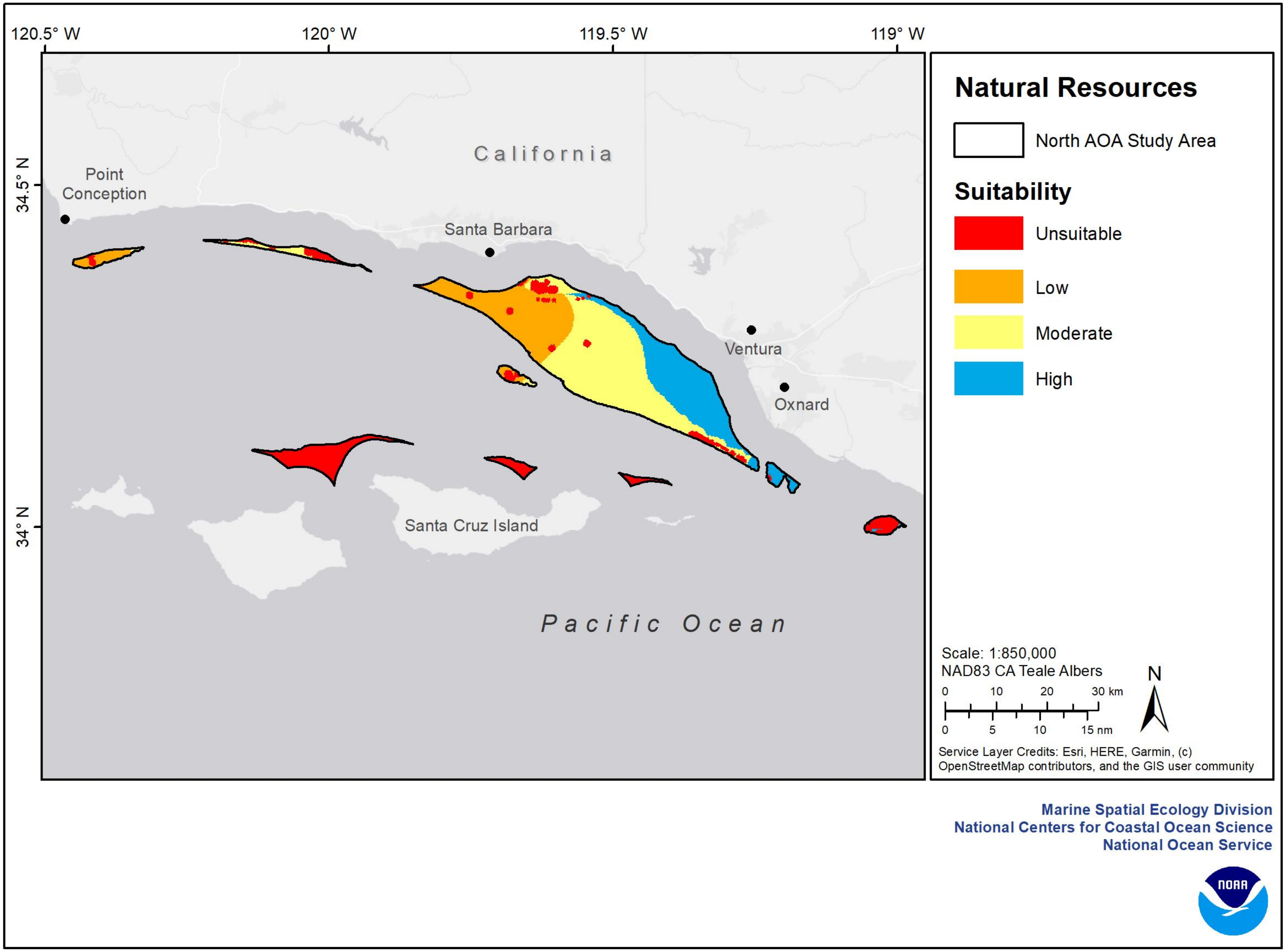
Deep-Sea Corals (1985 - present): NOAA Deep-Sea Coral Research and Technology Program (2021)
Mapped Hard Bottom Habitat: NOAA NMFS (2018)
Essential Fish Habitat (EFH) - Habitat Areas of Particular Concern (HAPC) (Rocky Reefs): NOAA NMFS (2020)
Fish Havens: NOAA ENC (2020)
Cetacean Biologically Important Areas: NOAA NMFS (2019)
Blue whale feeding occurs June - October

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

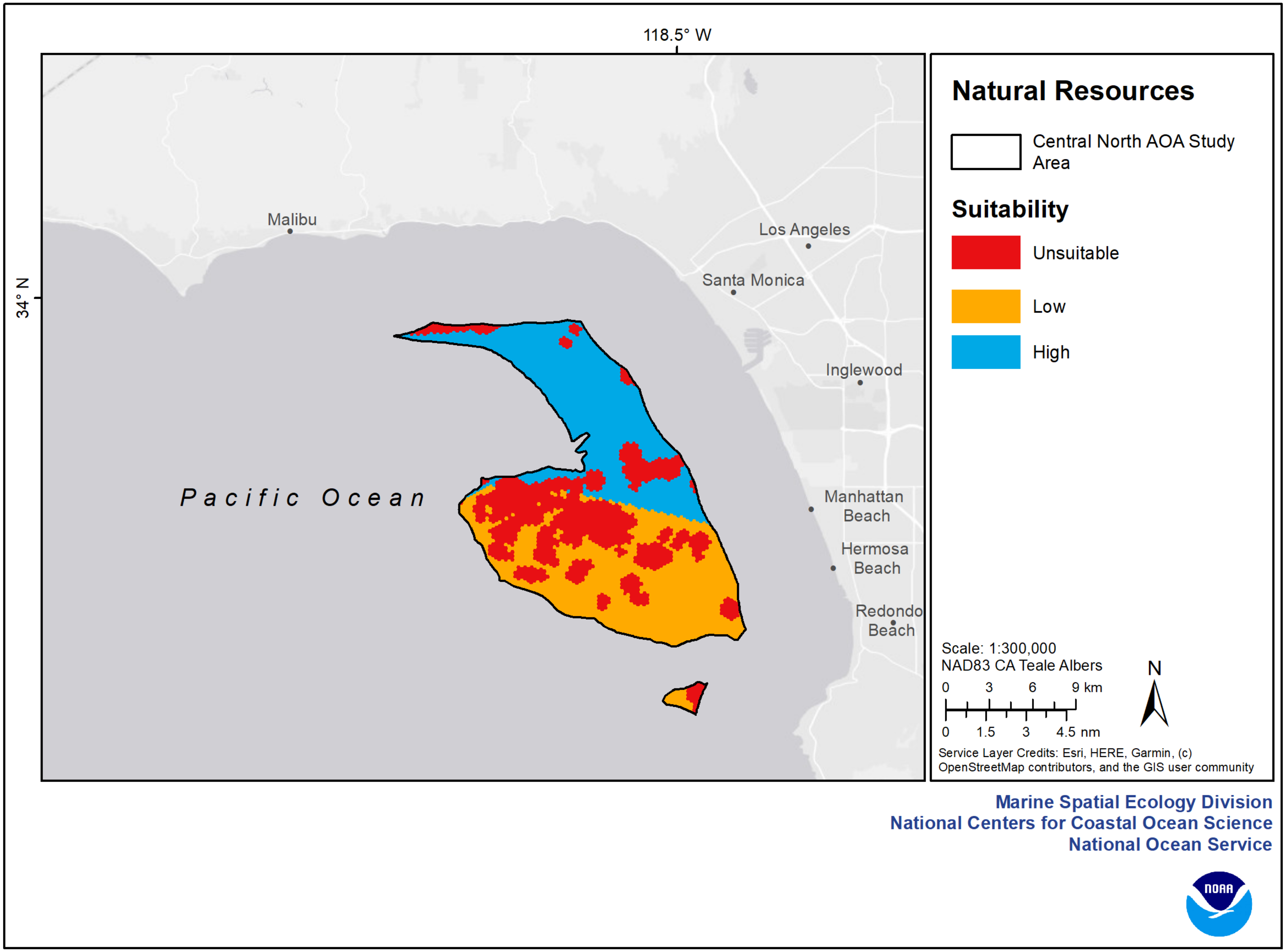


Deep-Sea Corals (1985 - present): NOAA Deep-Sea Coral Research and Technology Program (2021)
Mapped Hard Bottom Habitat: NOAA NMFS (2018)
Fish Havens: NOAA ENC (2020)

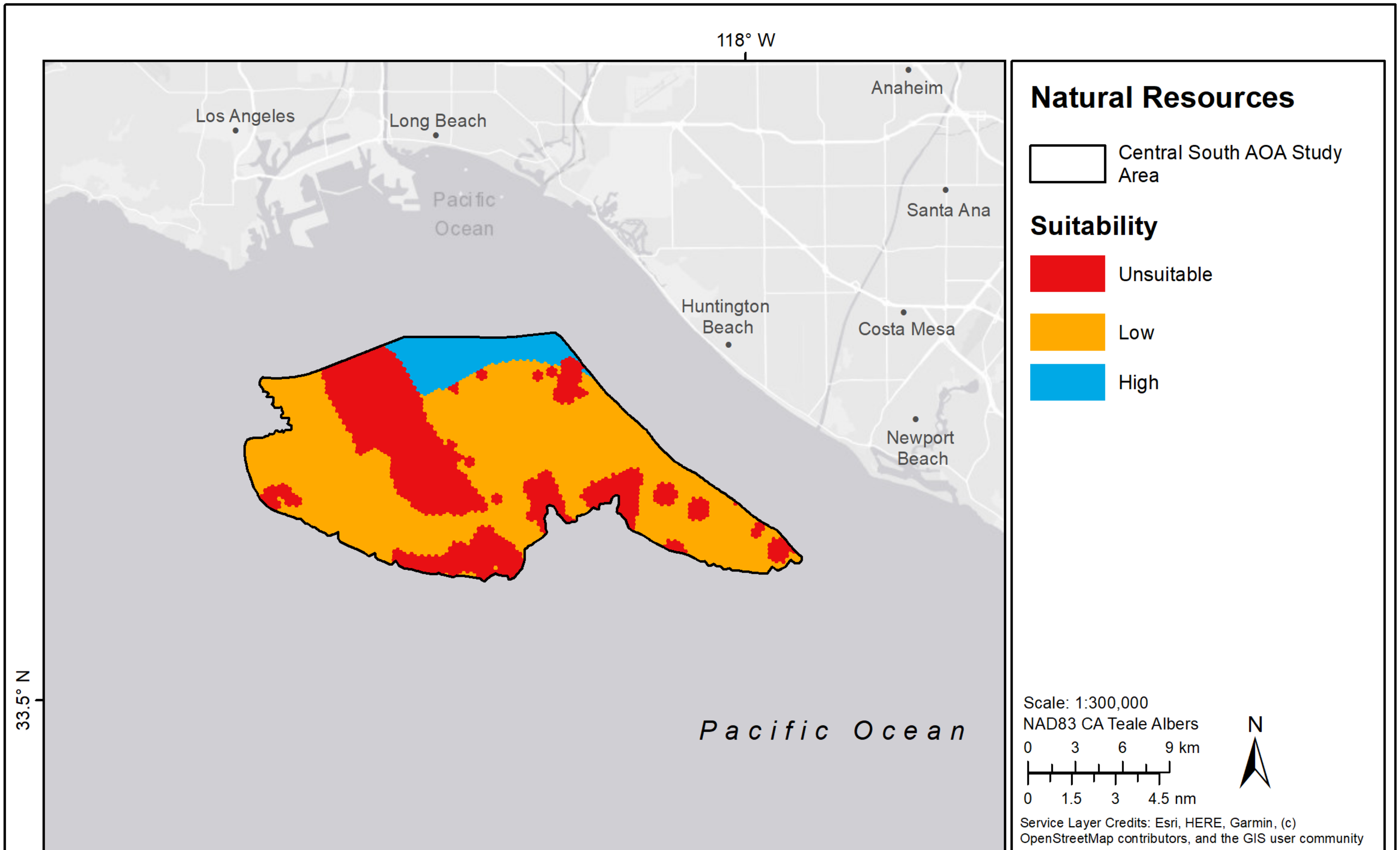
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



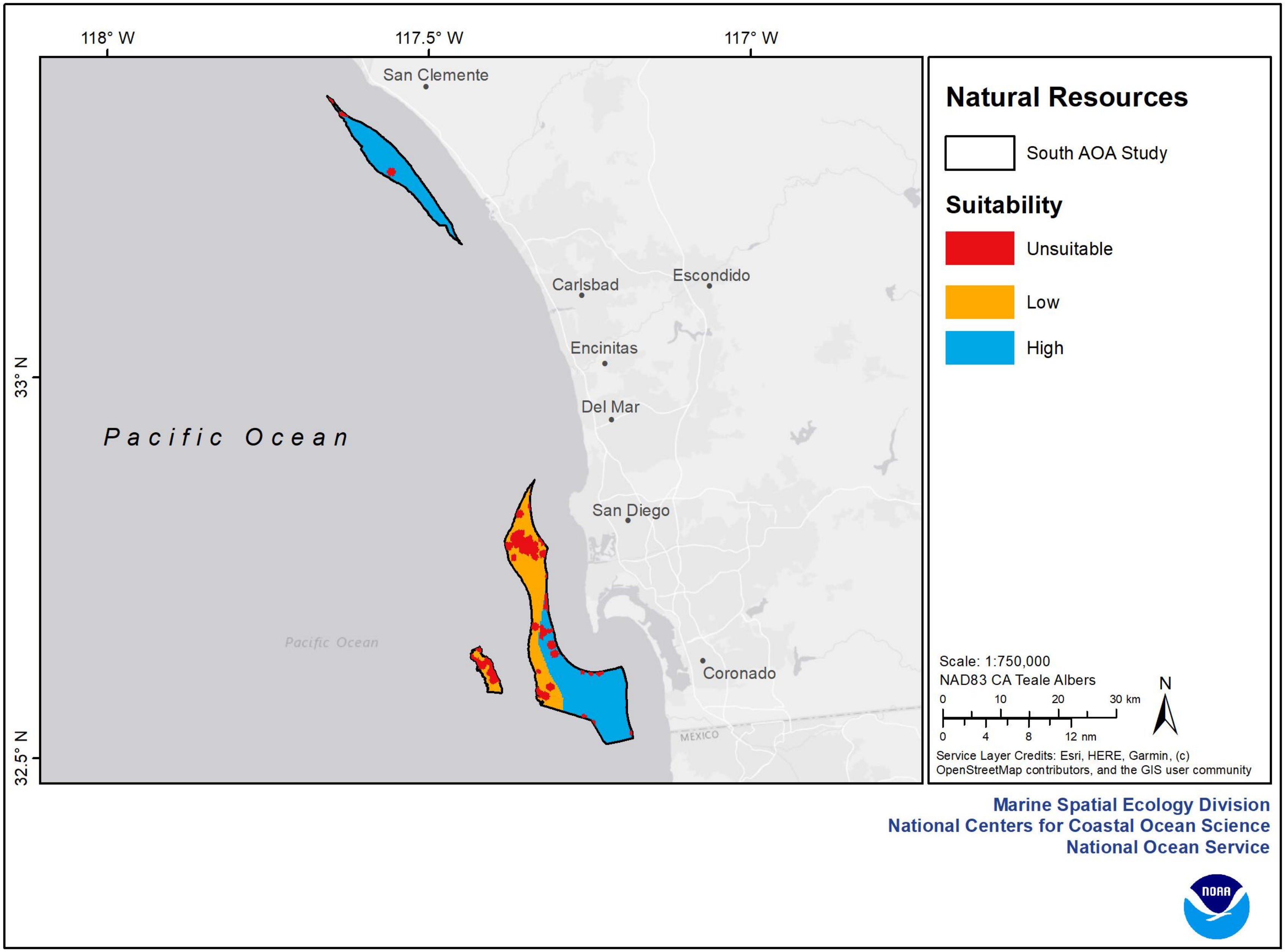
120.5° W
120° W
119.5° W
119° W
34.5° N
34° N
California
Point Conception
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
Natural Resources
North AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 nm
N
Service Layer Credits: 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

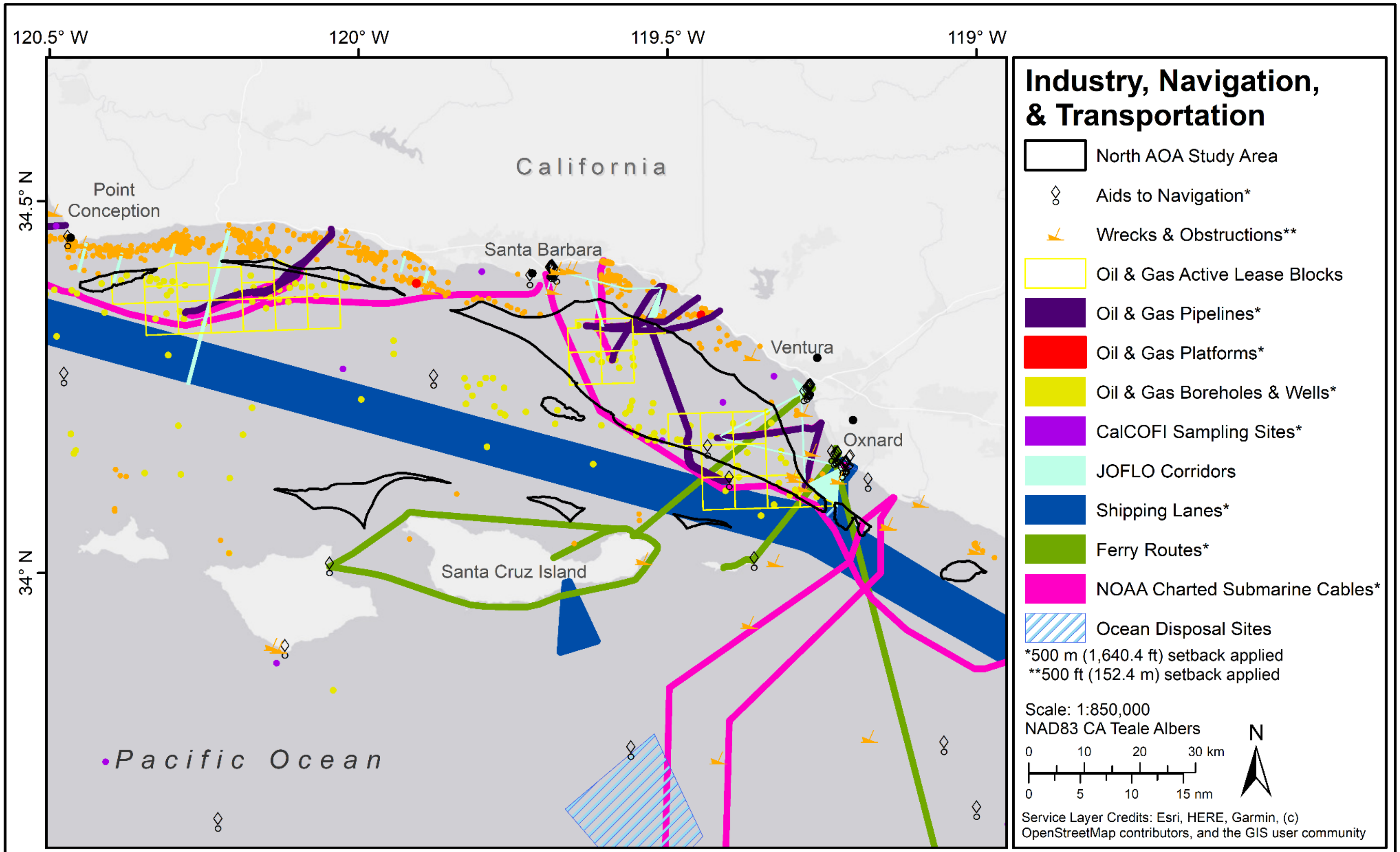


Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
Natural Resources
South AOA Study
Suitability
Unsuitable
Low
High
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 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

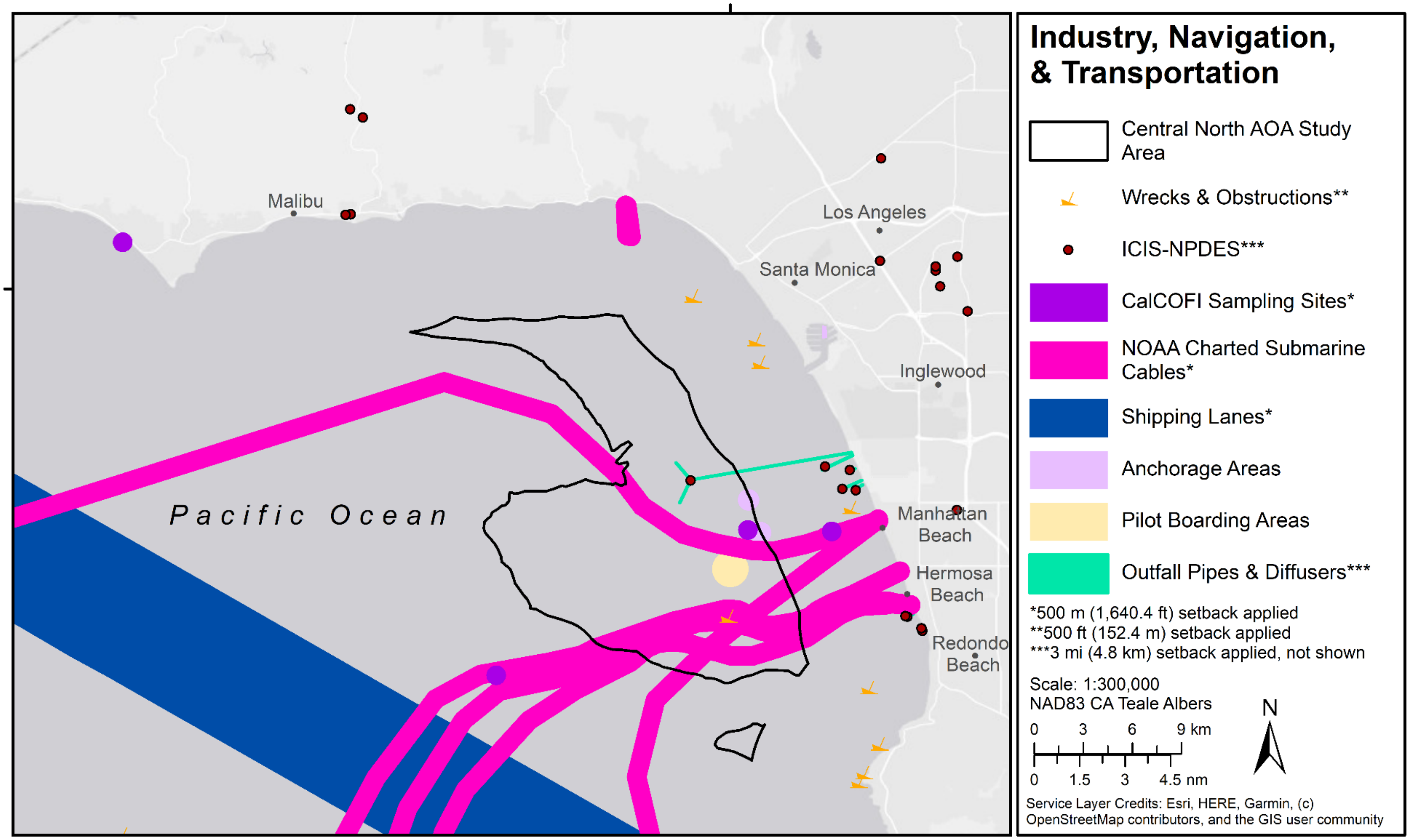
Industry, Navigation, and Transportation



Aids to Navigation: NOAA OCM & BOEM (2019)
Wrecks & Obstructions: NOAA OCM & BOEM (2018)
Shipping Lanes: NOAA OCM & BOEM (2018)
Ferry Routes: Open Street Maps (2020)
Oil & Gas Active Lease Blocks: BOEM (2021)
Oil & Gas Boreholes & Wells: BSEE (2021)
Oil & Gas Platforms: BSEE (2021)
Oil & Gas Pipelines: BSEE (2021)
CalCOFI Sampling Sites: California Cooperative Oceanic Fisheries Investigations & California Department of Fish & Wildlife (2020)

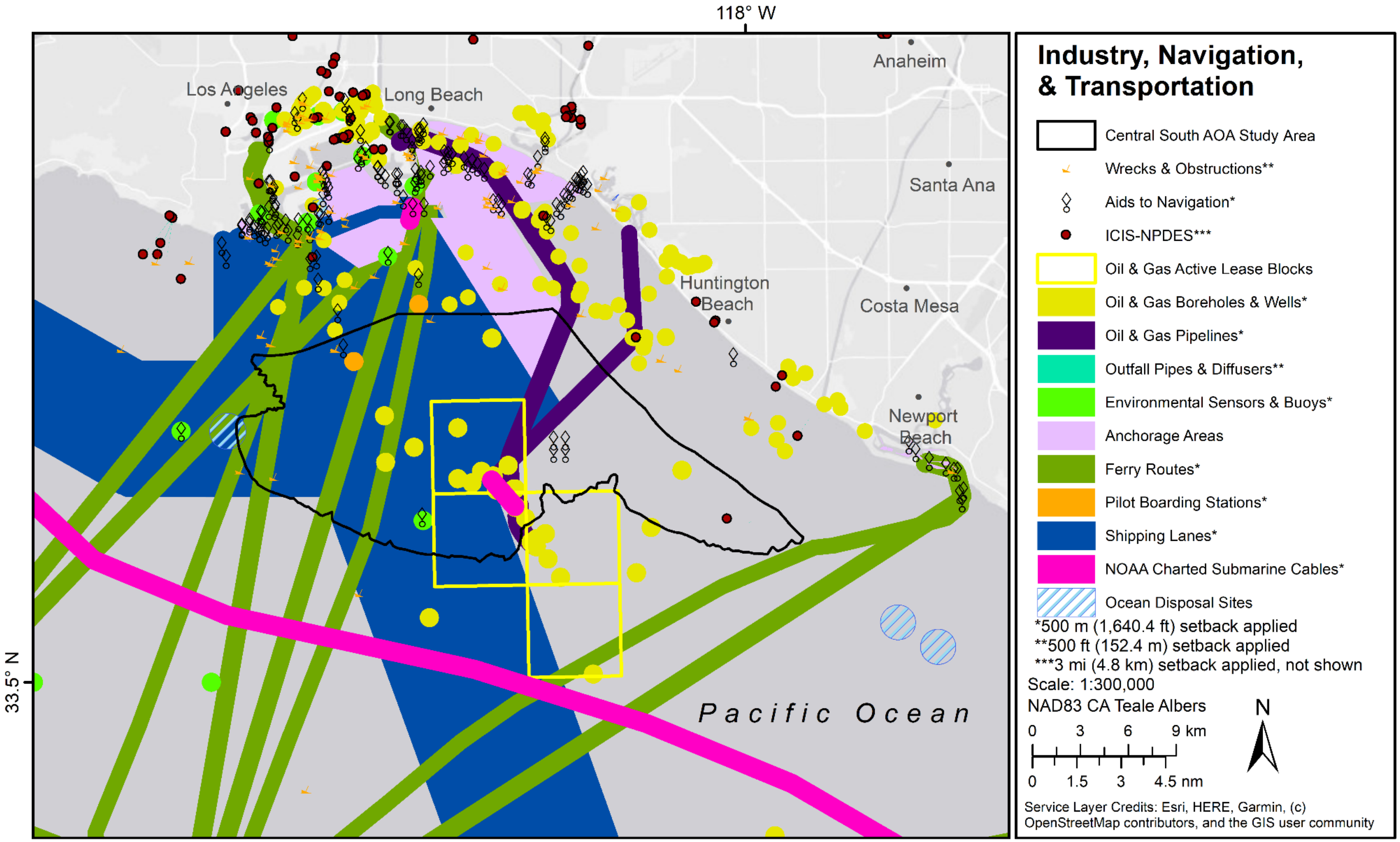
NOAA Charted Submarine Cables: NOAA OCM & BOEM (2018)
EPA Ocean Disposal Sites: NOAA OCM & BOEM (2018)
JOFLO Corridors: Joint Oil Fisheries Liaison Office (2020)

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



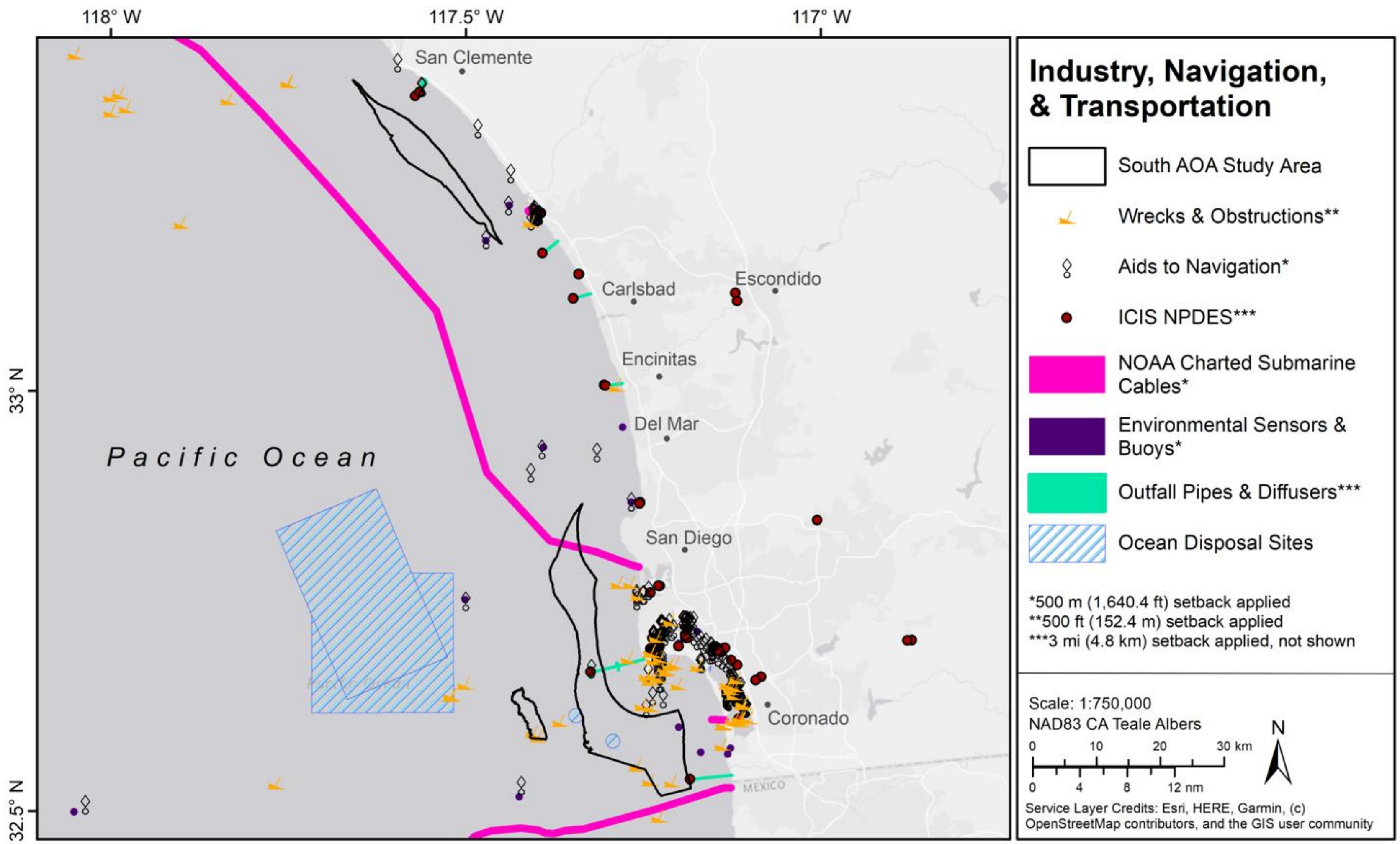
Wrecks & Obstructions: NOAA OCM & BOEM (2018)
Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES): EPA (2019)
NOAA Charted Submarine Cables: NOAA OCM & BOEM (2018)
Shipping Lanes: NOAA OCM & BOEM (2018)
Anchorage Areas: NOAA OCM & BOEM (2018)
Pilot Boarding Areas: NOAA OCM & BOEM (2018)
Outfall Pipes and Diffusers: Stanford (2017)
CalCOFI Sampling Sites: California Cooperative Oceanic Fisheries Investigations & California Department of Fish & Wildlife (2020)

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



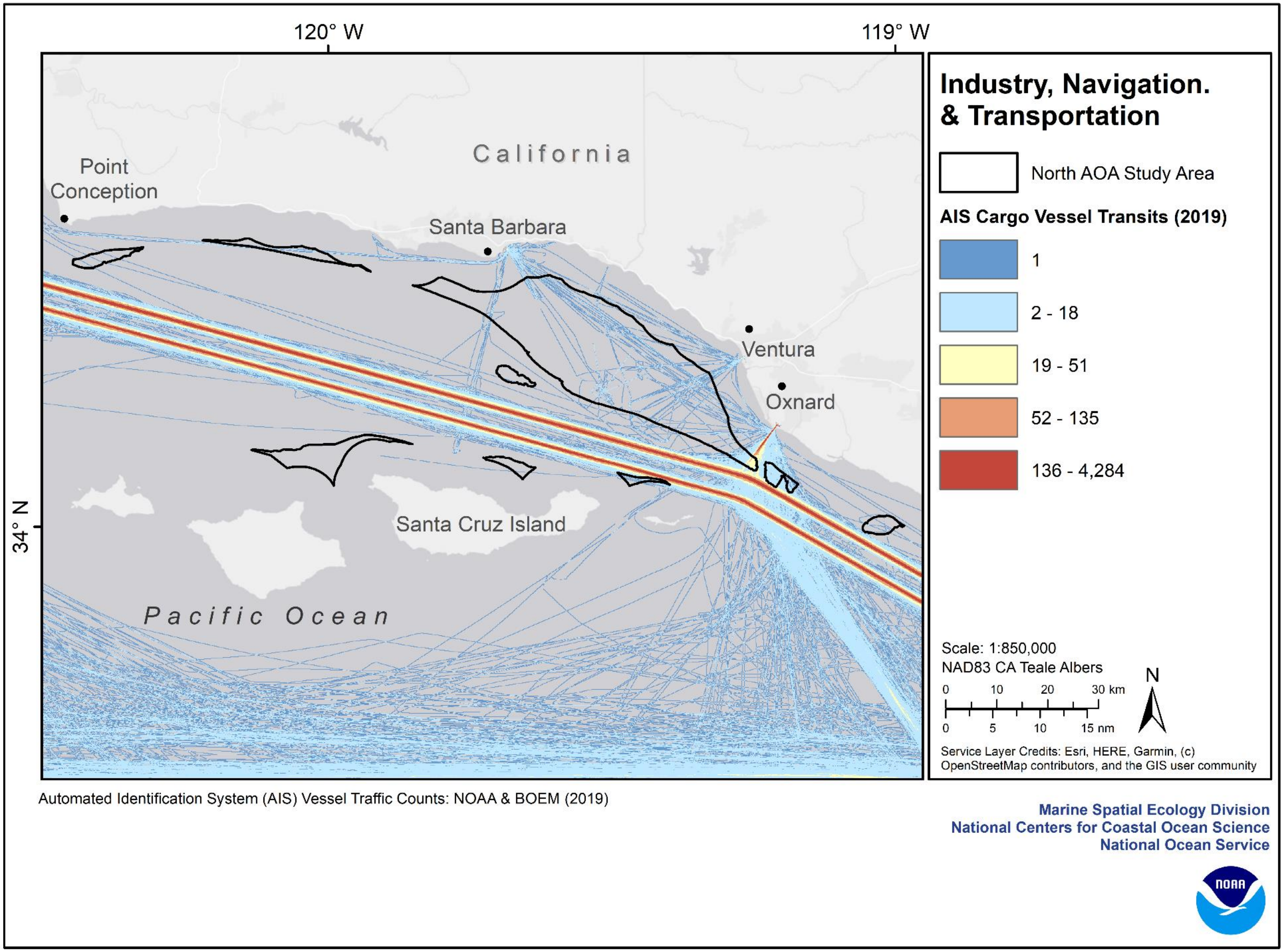
Wrecks & Obstructions: NOAA OCM & BOEM (2018)
Aids to Navigation: NOAA OCM & BOEM (2019)
Shipping Lanes: NOAA OCM & BOEM (2018)
Anchorage Areas: NOAA OCM & BOEM (2018)
Pilot Boarding Stations: NOAA OCM & BOEM (2018)
CA Ferry Routes: Open Street Maps (2020)
U.S. Ferry Routes: National Atlas of the U.S. (2020)

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

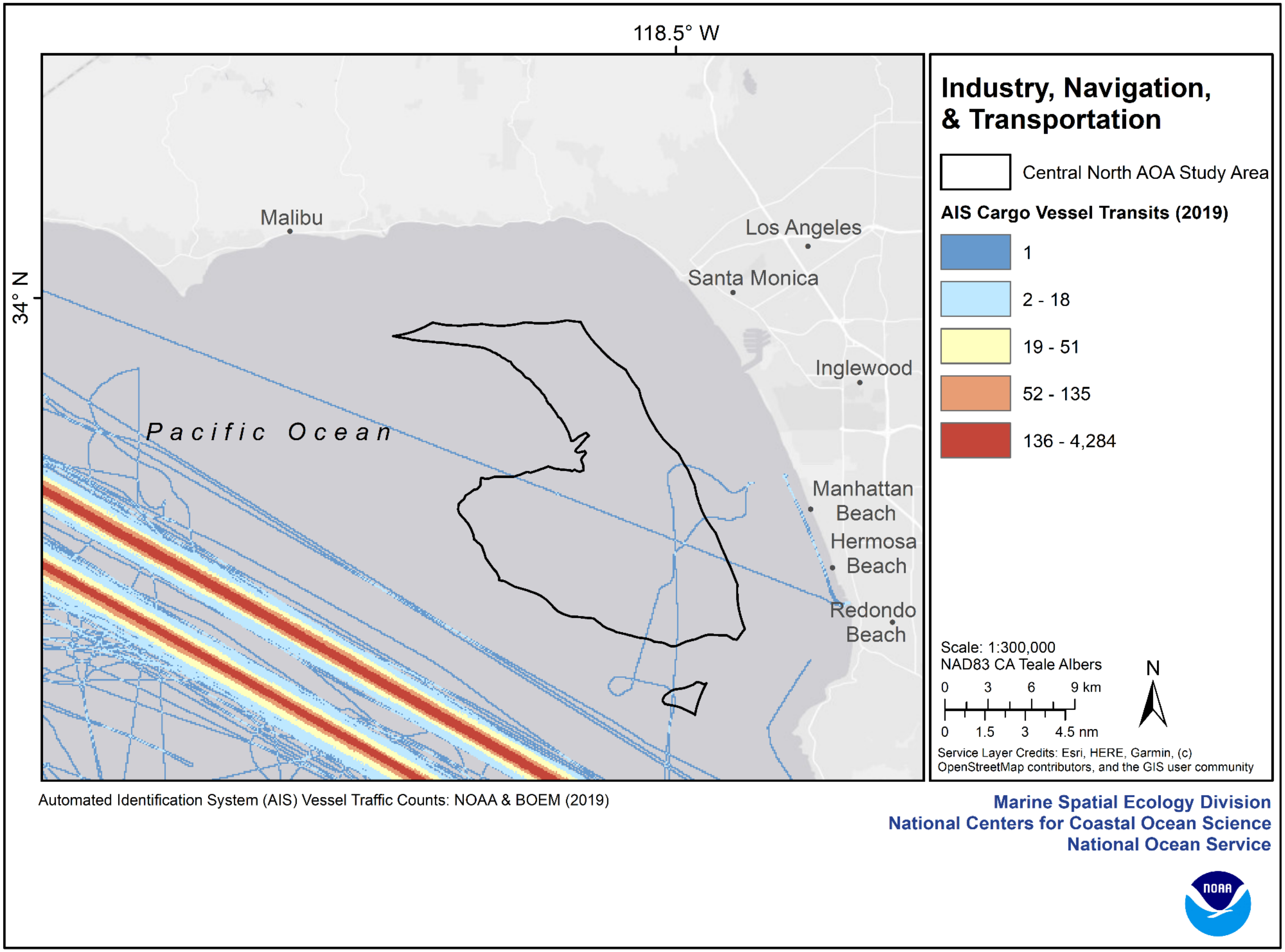


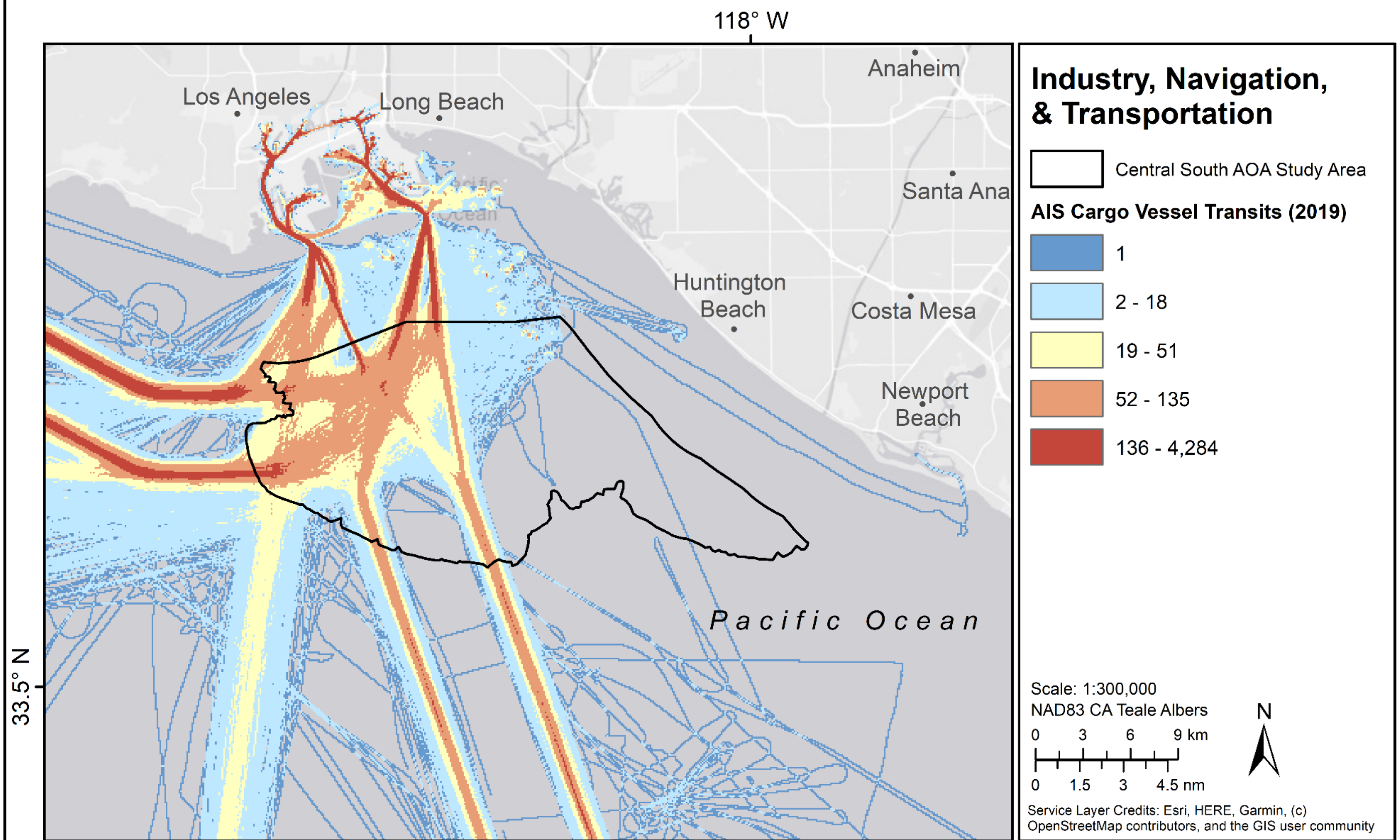
Wrecks & Obstructions: NOAA OCM & BOEM (2018)
Aids to Navigation: NOAA OCM & BOEM (2019)
Integrated Compliance Information System National Pollutant Discharge Elimination System (ICIS-NPDES): EPA (2019)
NOAA Charted Submarine Cables: NOAA OCM & BOEM (2018)
Environmental Sensors & Buoys: (2017)
Outfall Pipes and Diffusers: Stanford (2017)
EPA Ocean Disposal Sites: NOAA OCM & BOEM (2018)

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



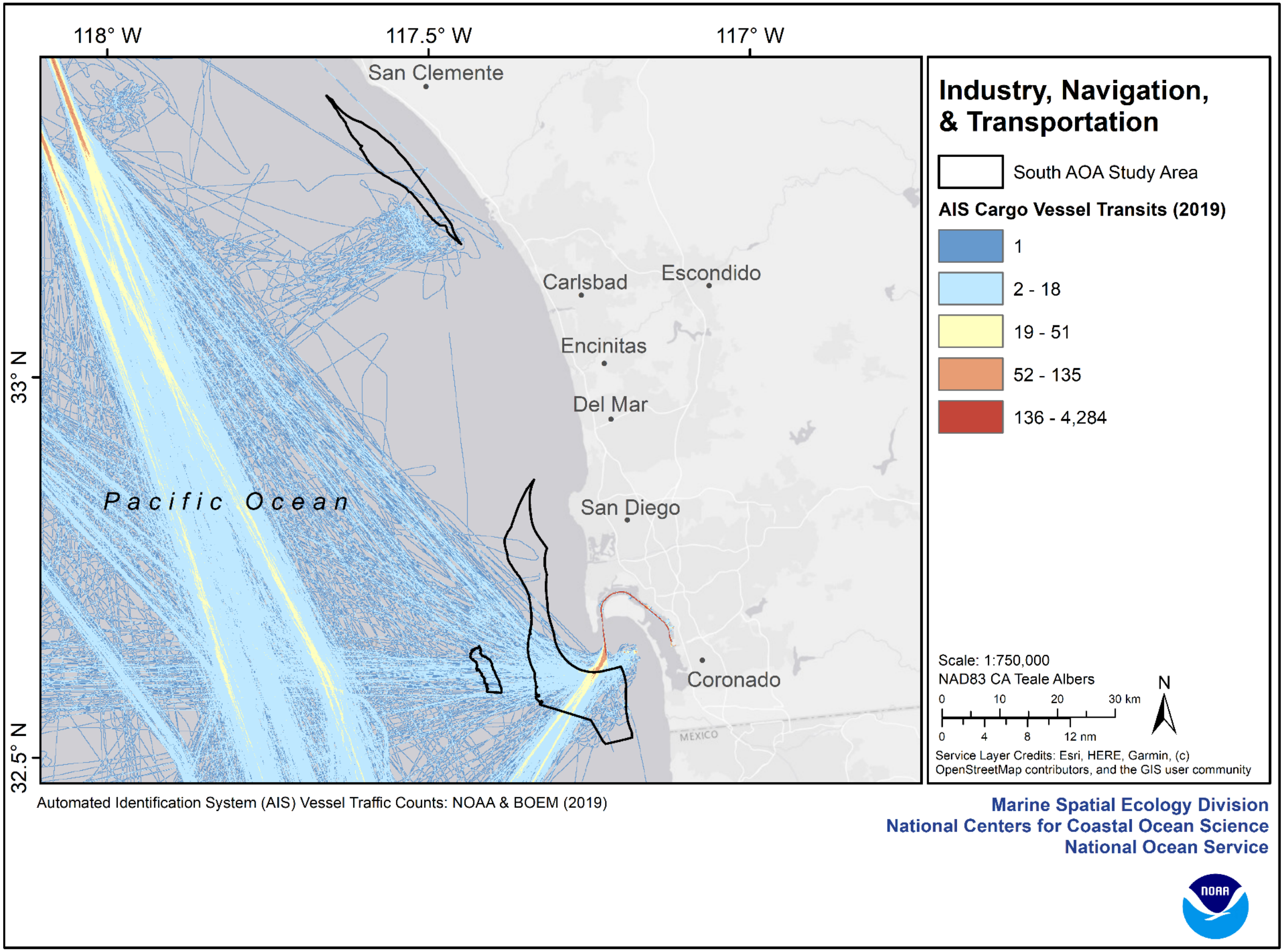
120° W
119° W
34° N
California
Point
Conception
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
Industry, Navigation.
& Transportation
North AOA Study Area
AIS Cargo Vessel Transits (2019)
1
2 - 18
19 - 51
52 - 135
136 - 4,284
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c)
OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
Industry, Navigation, & Transportation
Central North AOA Study Area
AIS Cargo Vessel Transits (2019)
1
2 - 18
19 - 51
52 - 135
136 - 4,284
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA

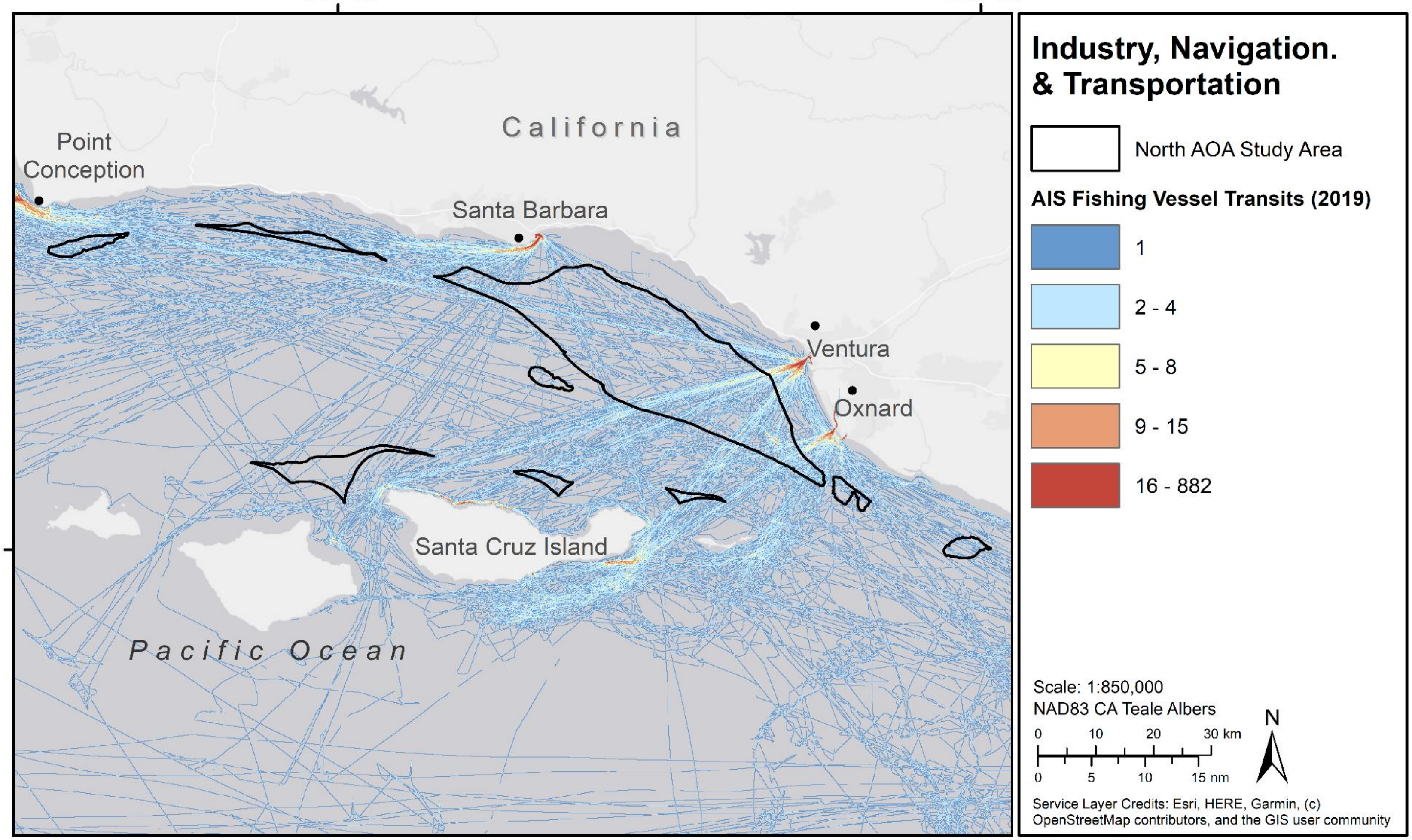


Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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

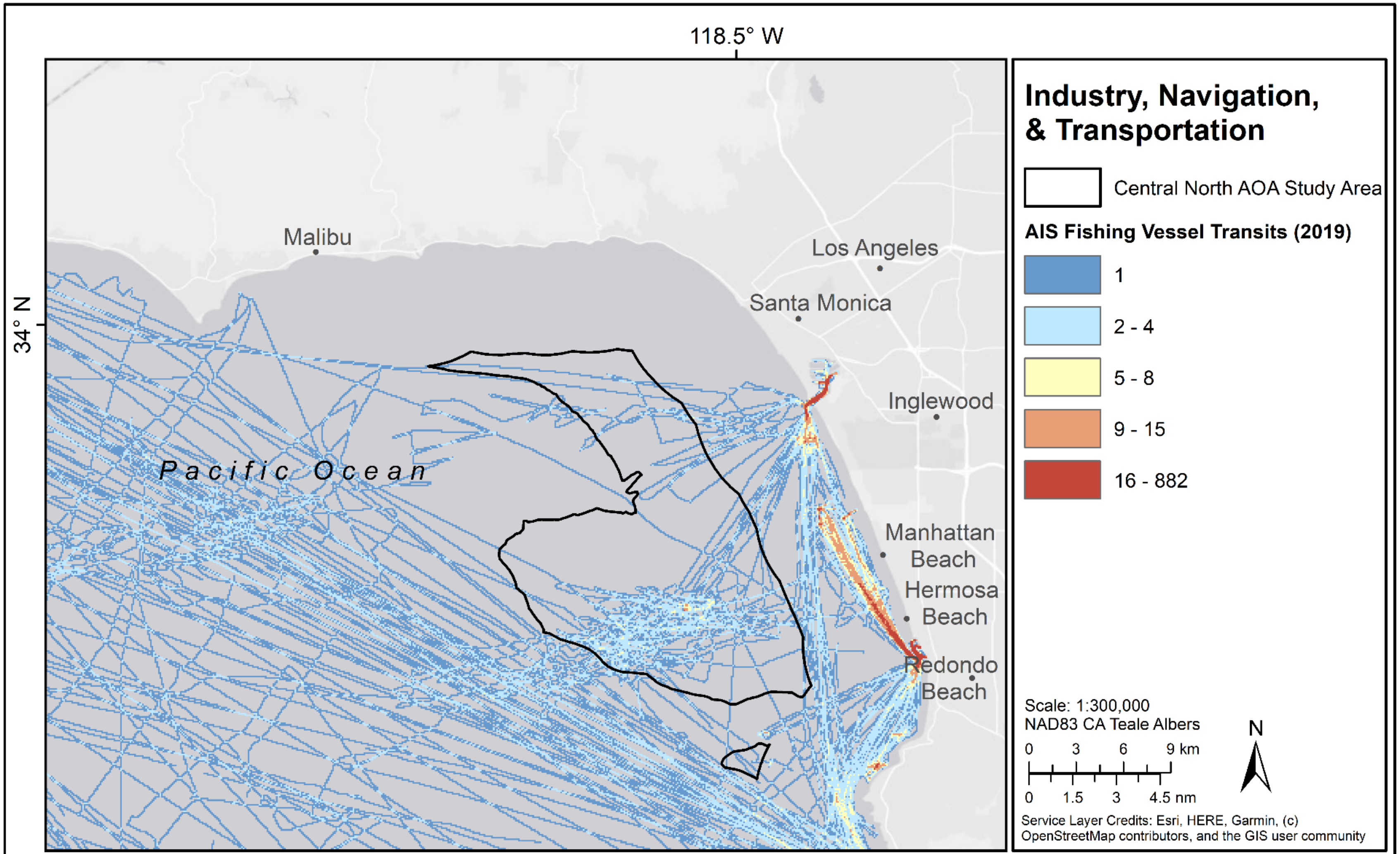


118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Coronado
MEXICO
Industry, Navigation, & Transportation
South AOA Study Area
AIS Cargo Vessel Transits (2019)
1
2 - 18
19 - 51
52 - 135
136 - 4,284
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA



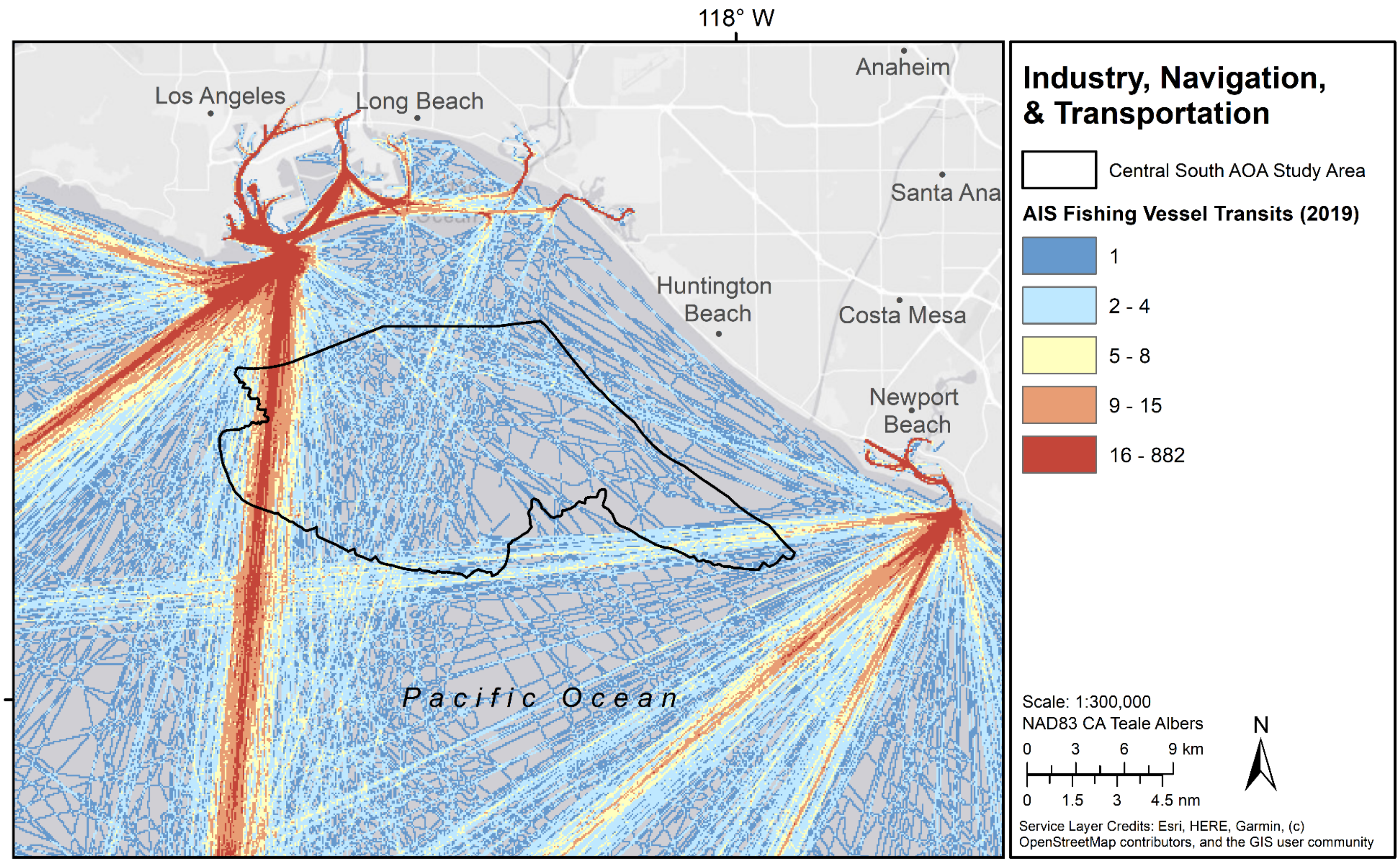
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



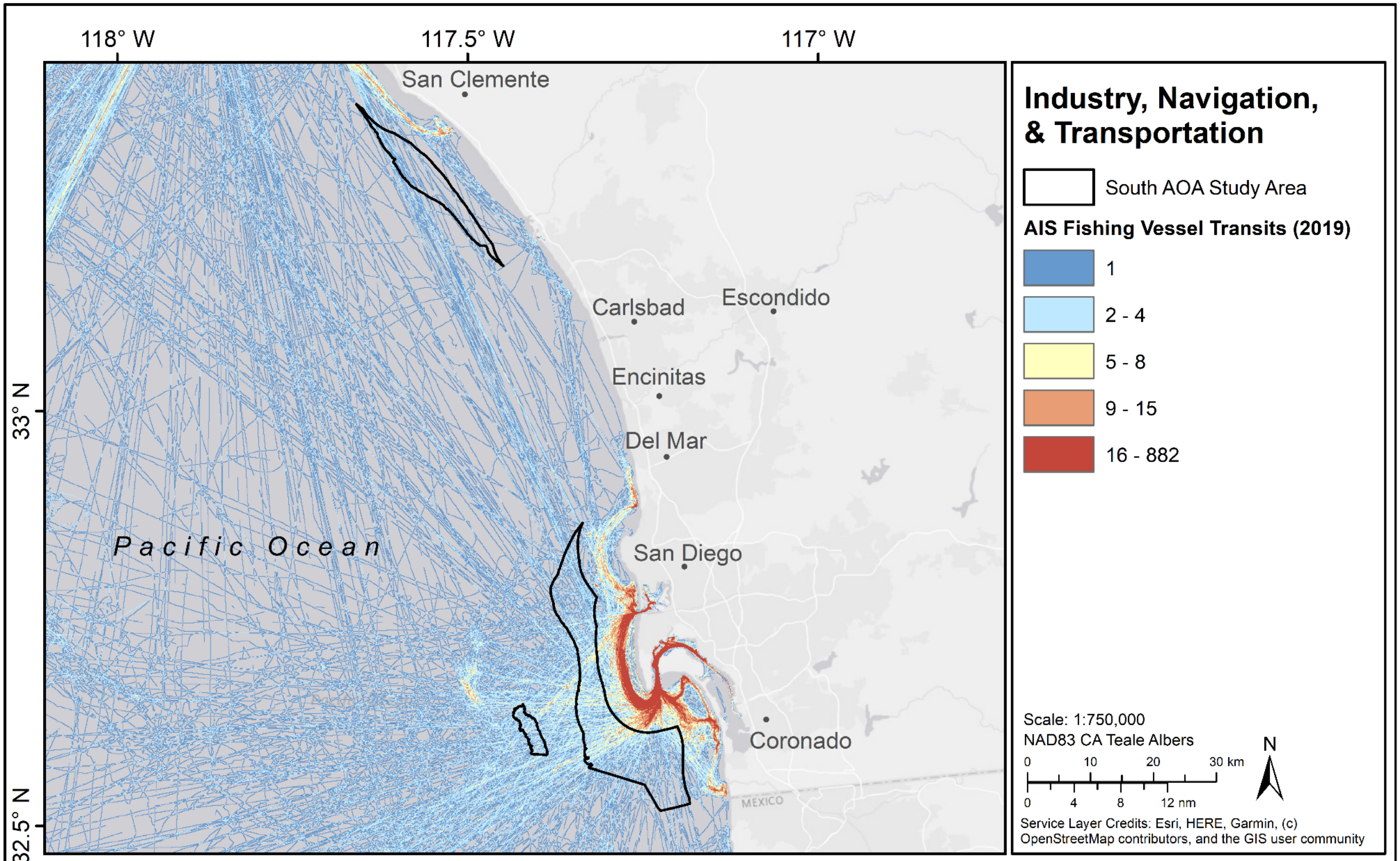
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



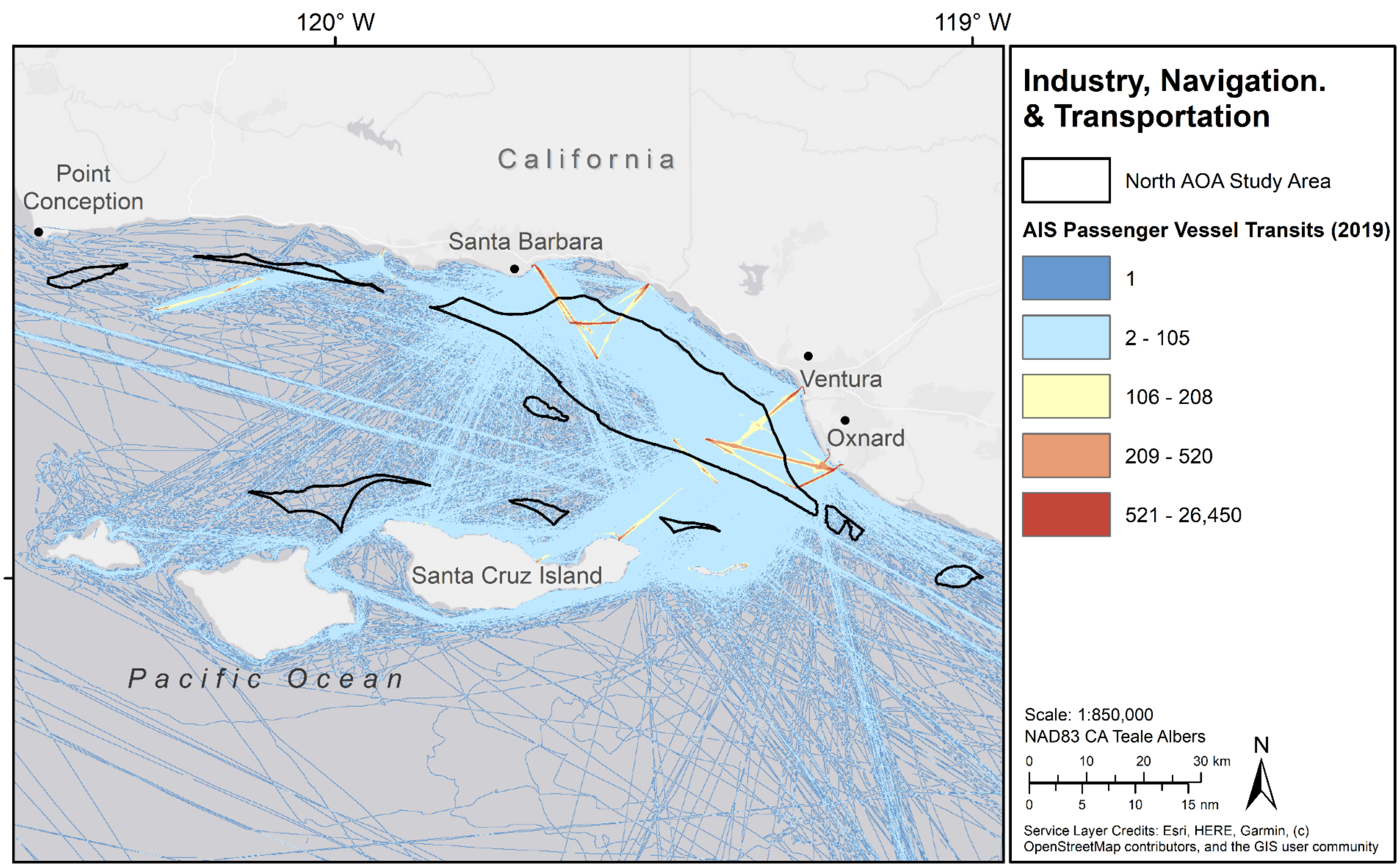
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



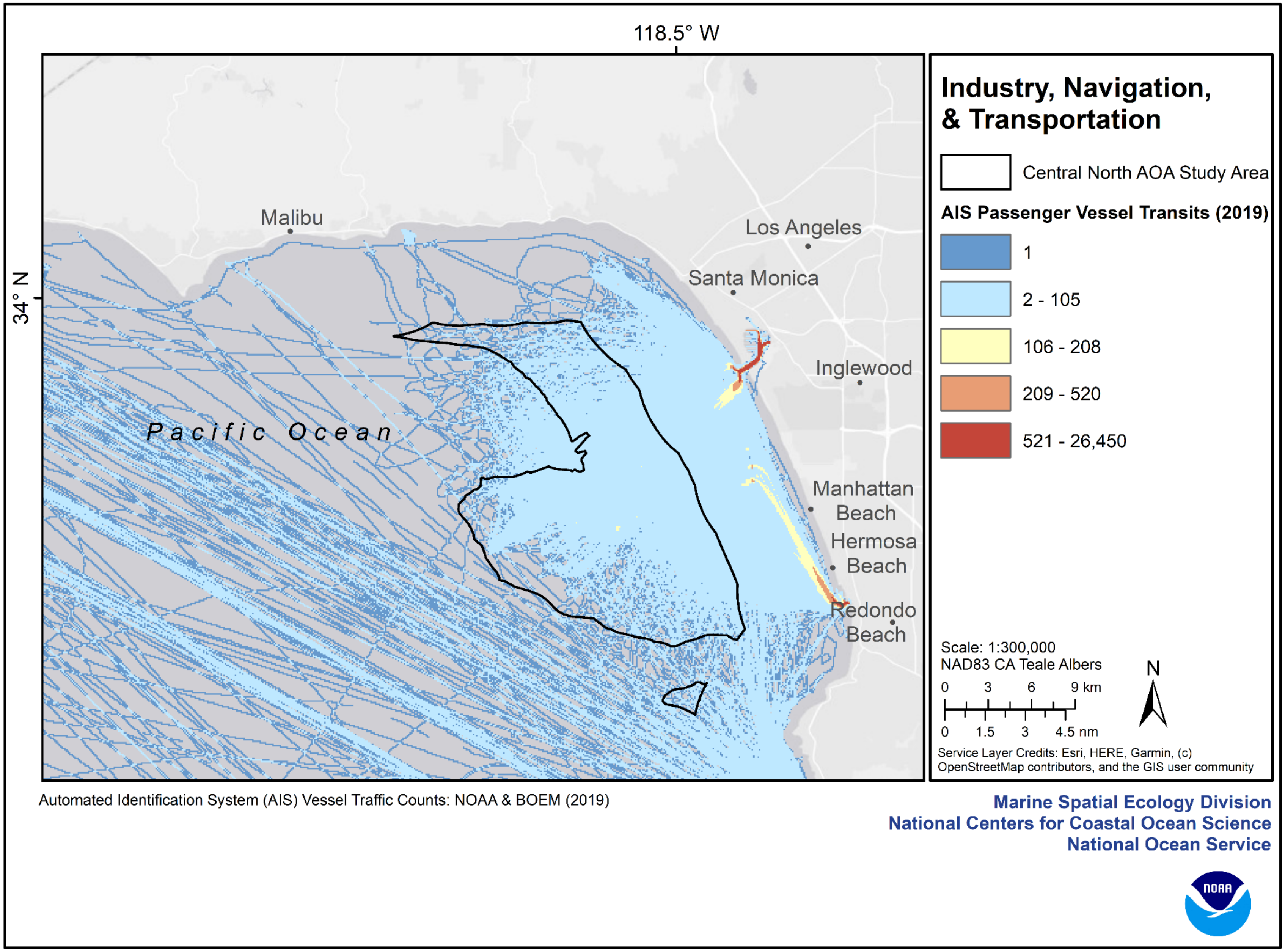
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

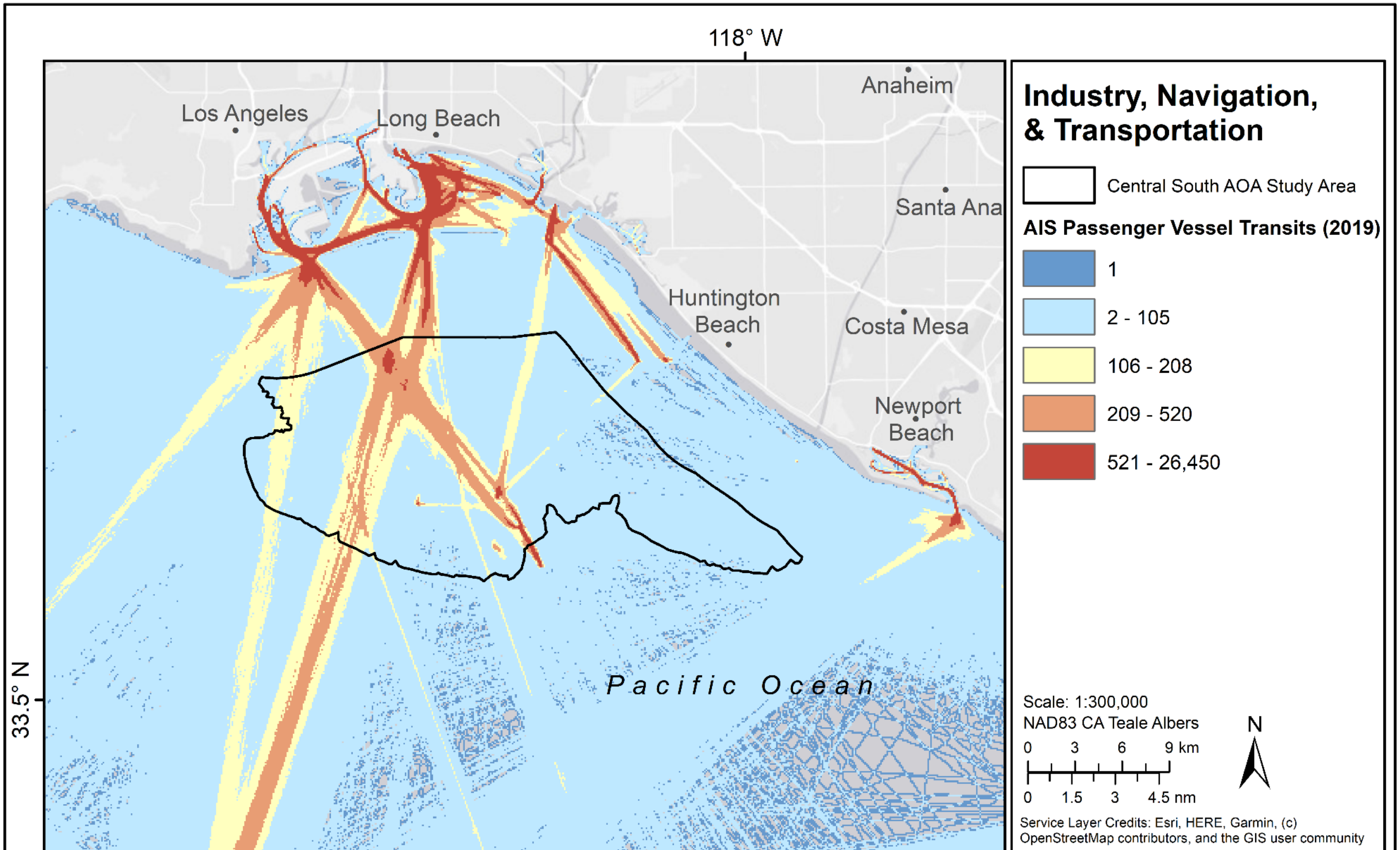
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

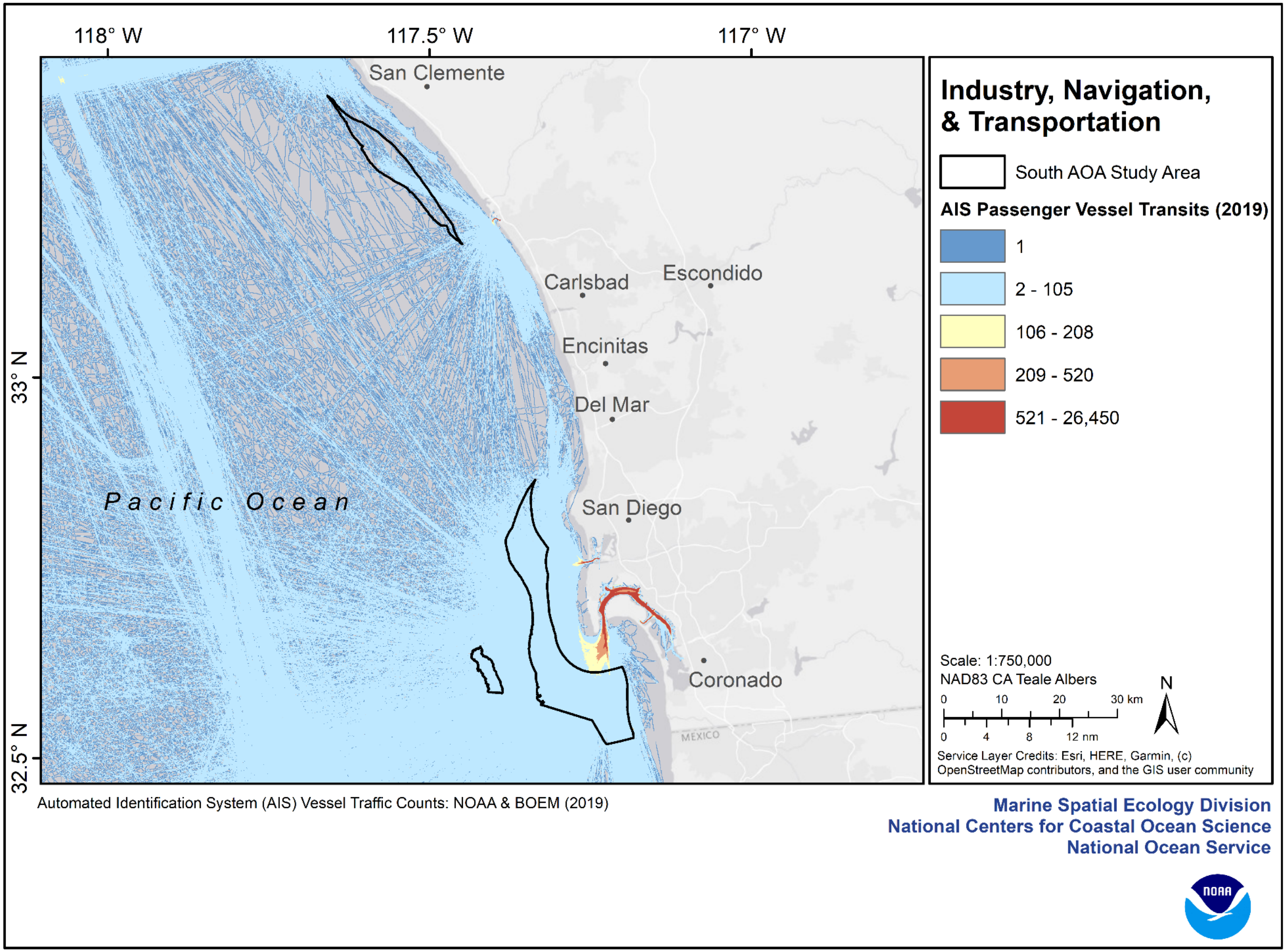
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


118.5° W
34° N
Industry, Navigation, & Transportation
Central North AOA Study Area
AIS Passenger Vessel Transits (2019)
1
2 - 105
106 - 208
209 - 520
521 - 26,450
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

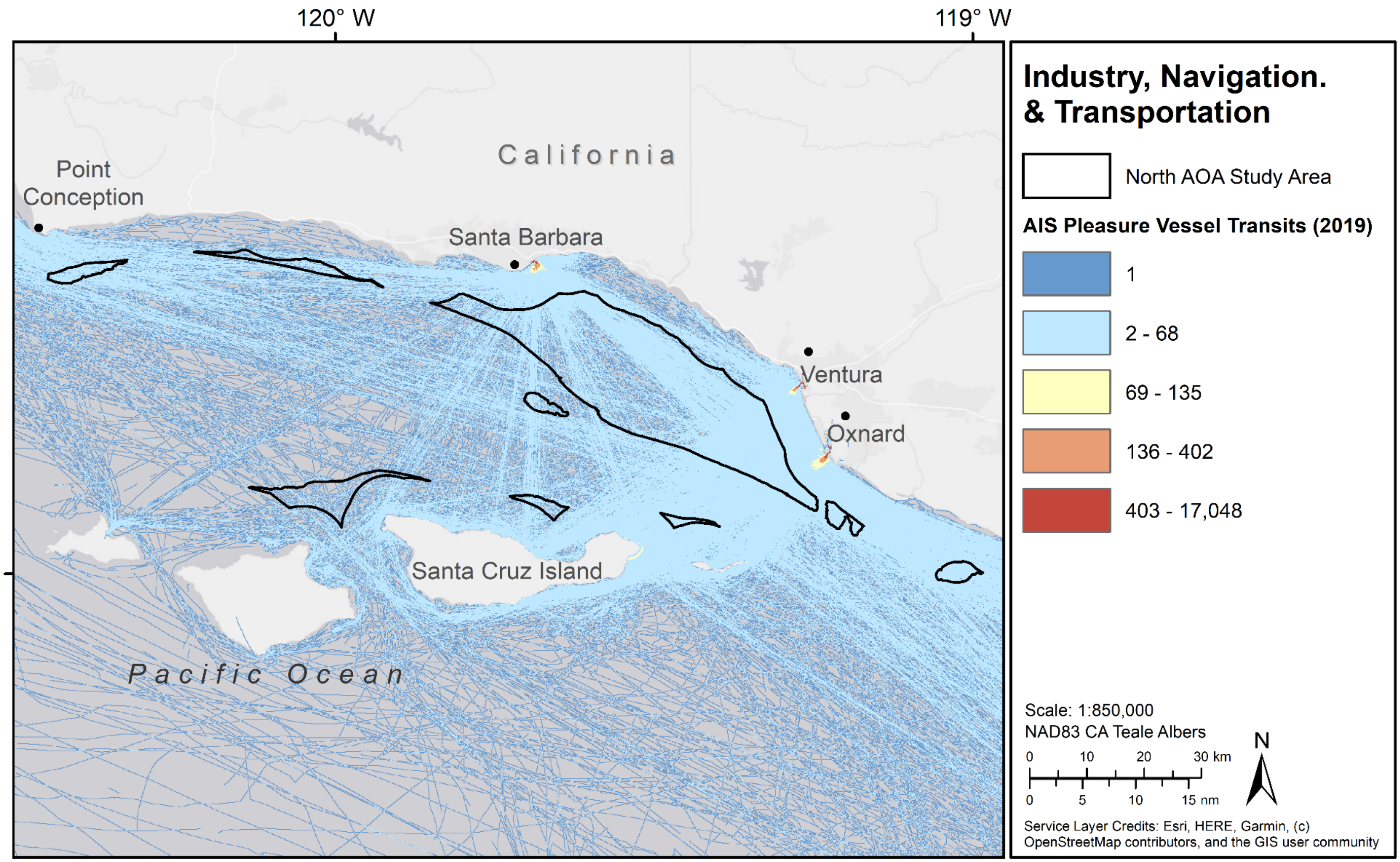


Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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

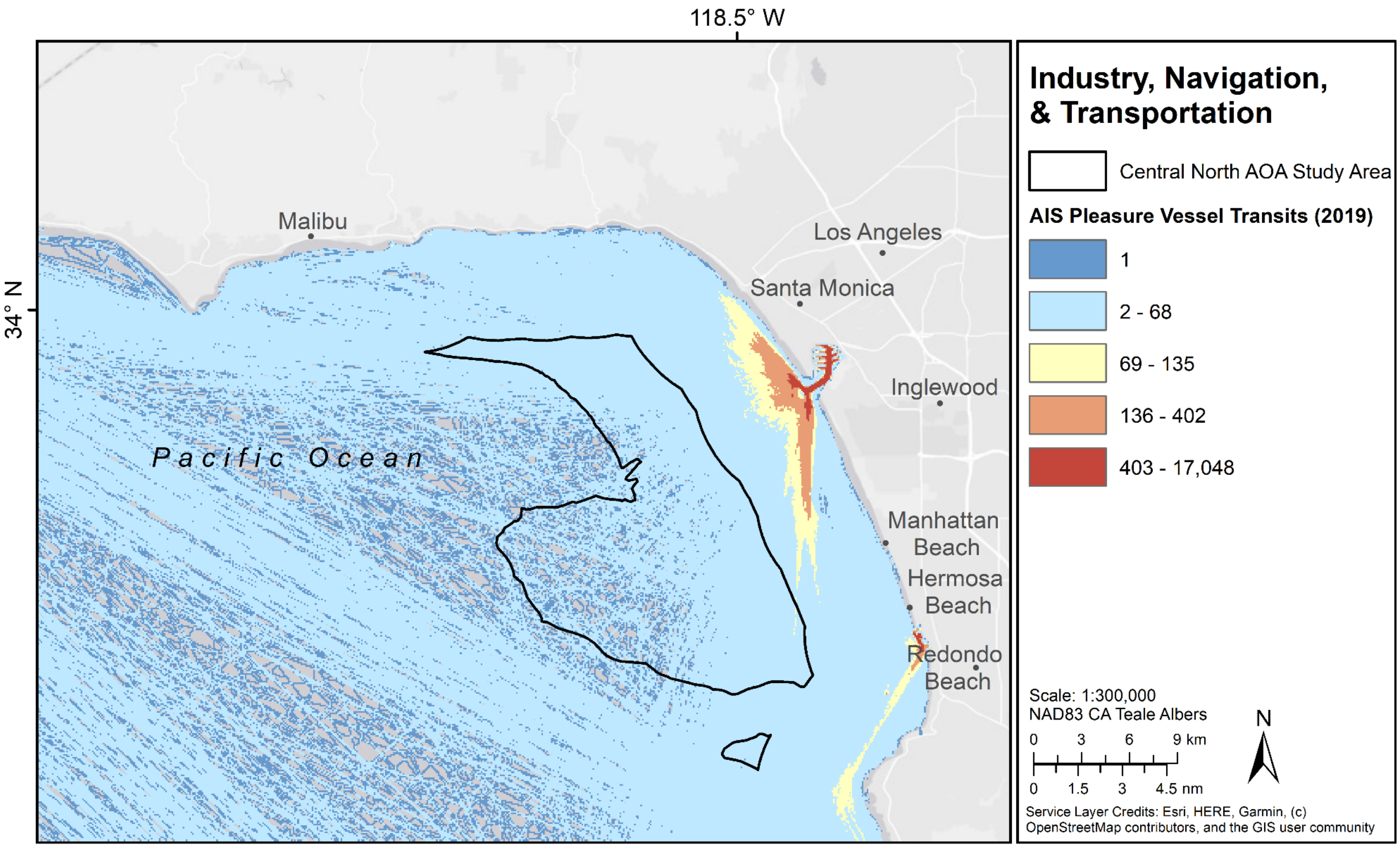


118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
San Diego
Coronado
MEXICO
Pacific Ocean
Industry, Navigation, & Transportation
South AOA Study Area
AIS Passenger Vessel Transits (2019)
1
2 - 105
106 - 208
209 - 520
521 - 26,450
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



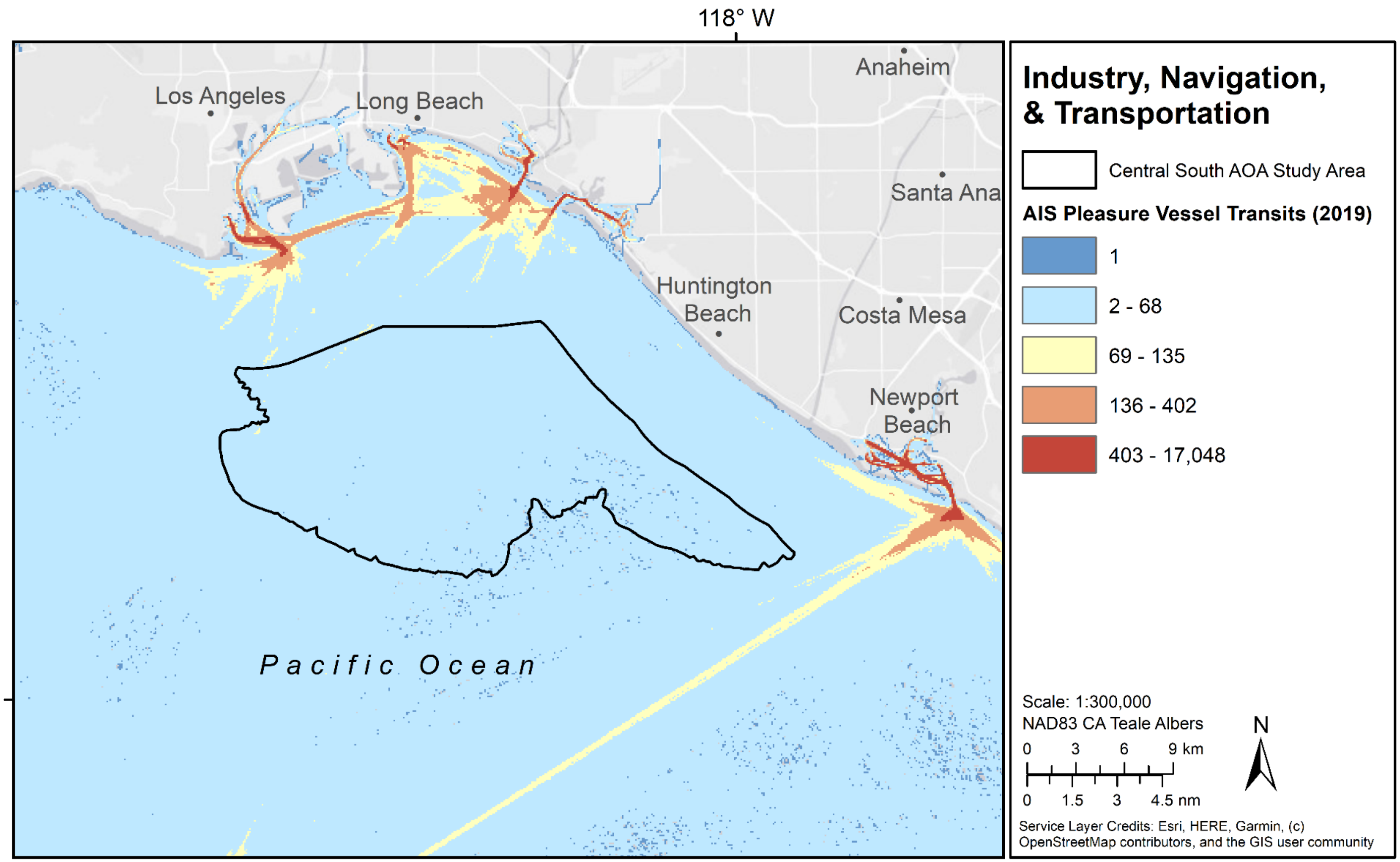
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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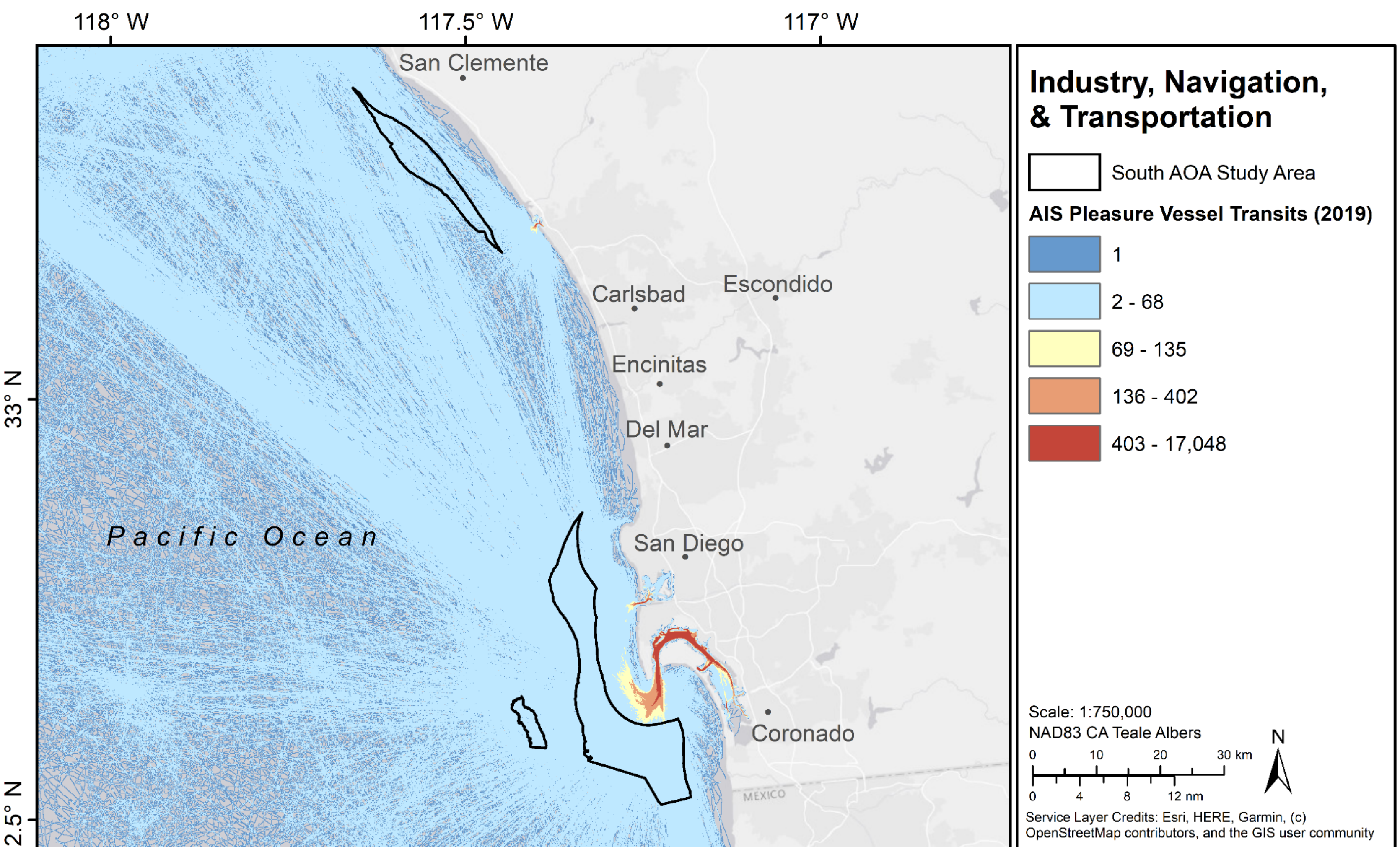

Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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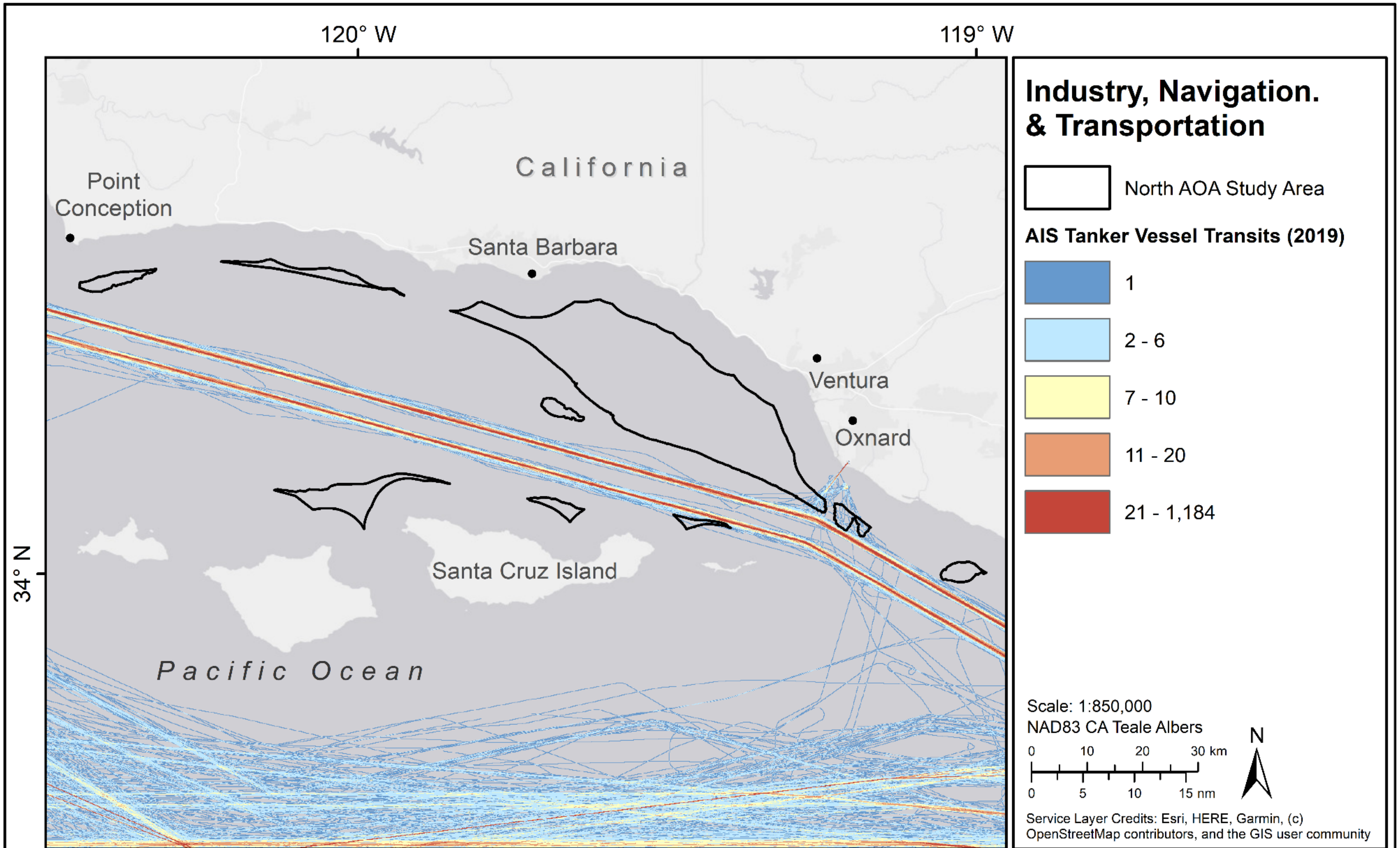

Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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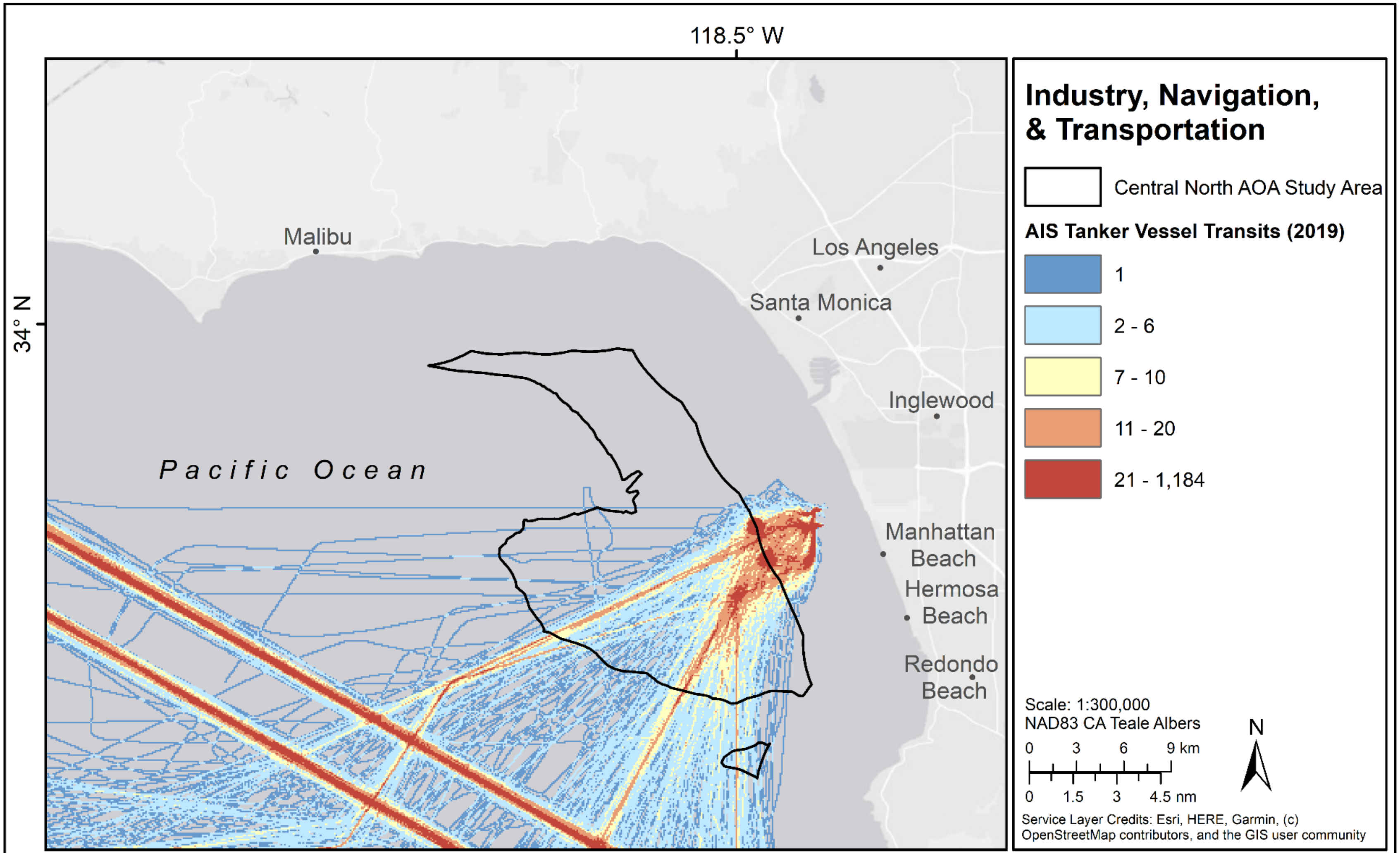

Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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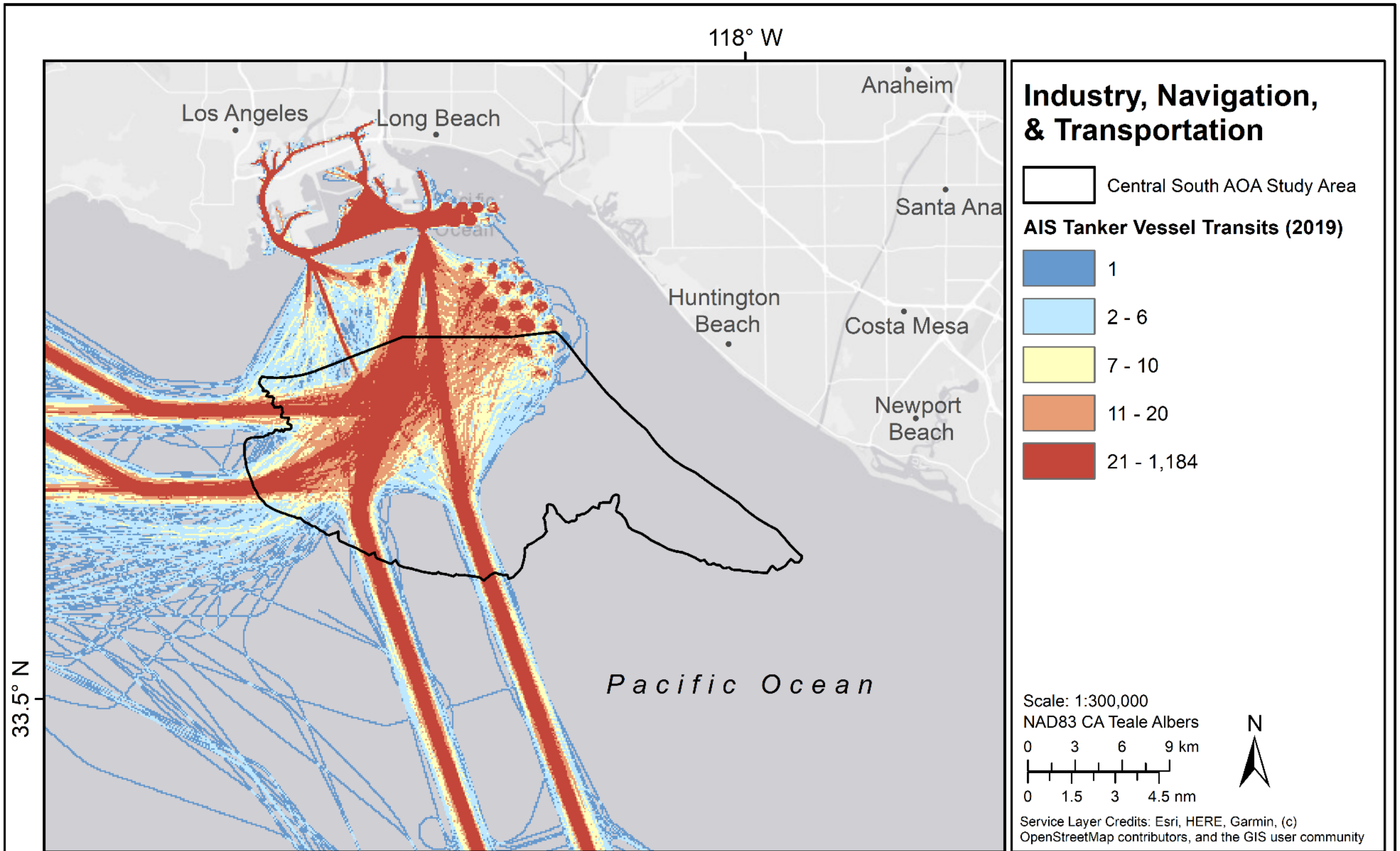
National Ocean Service



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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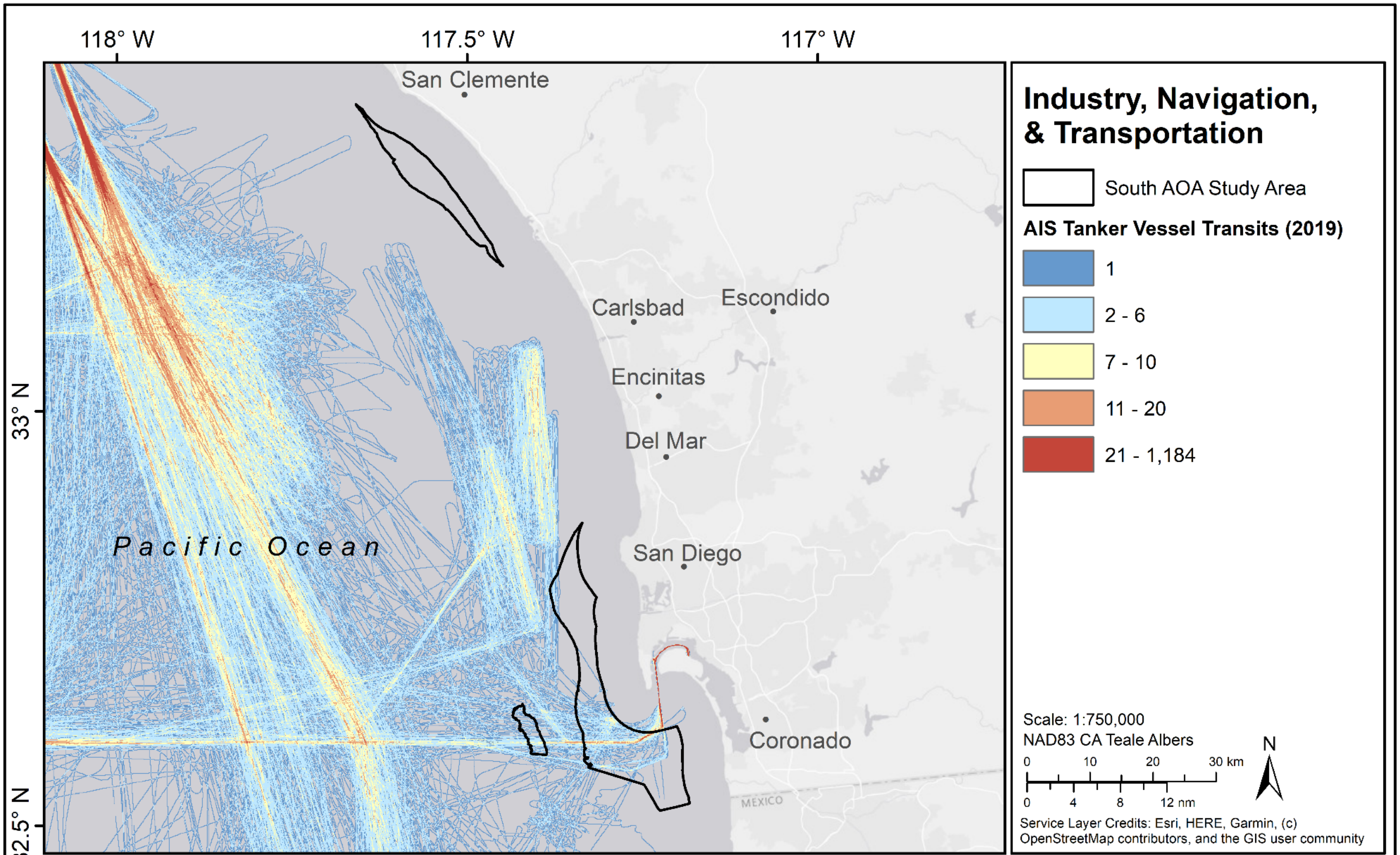

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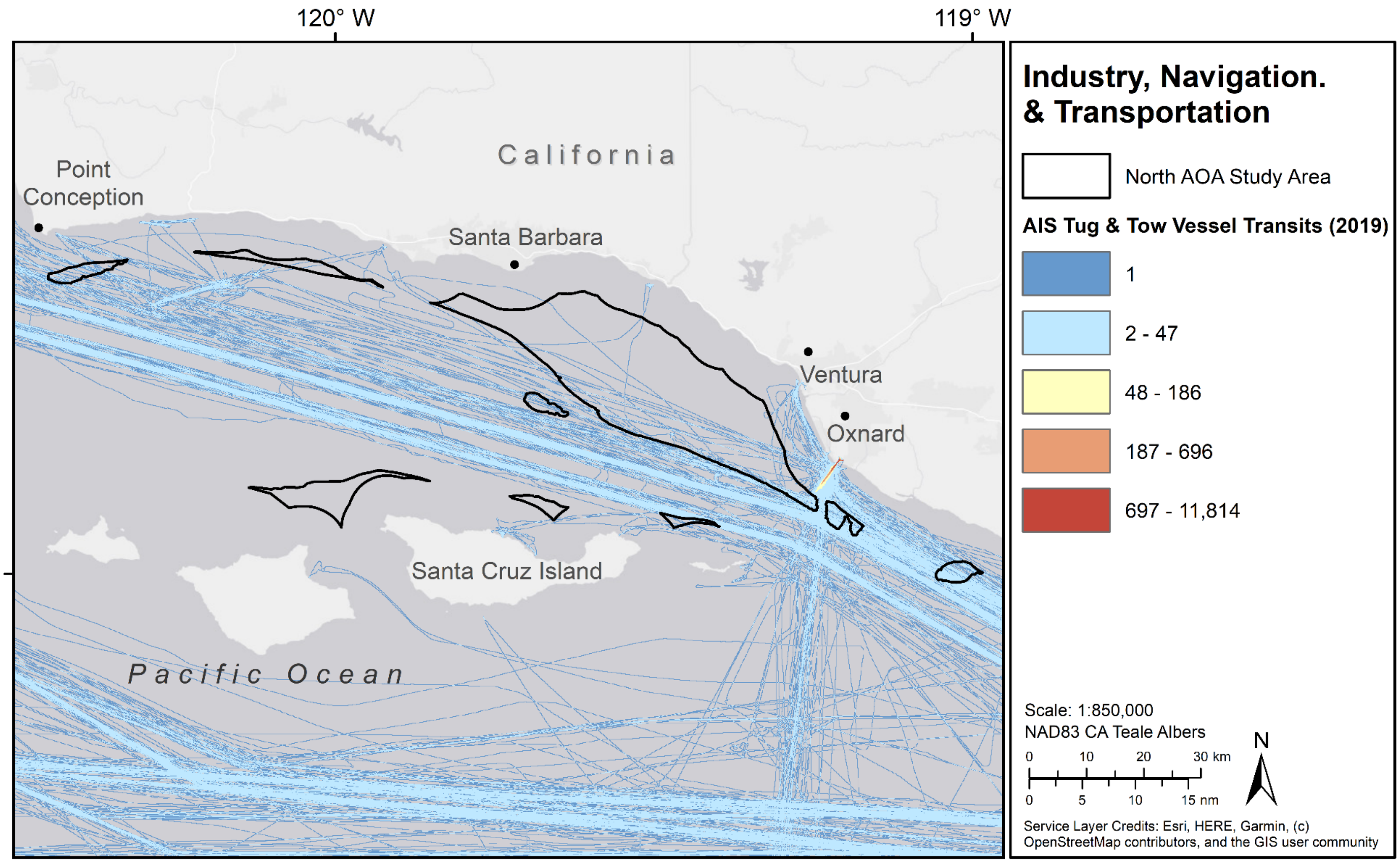
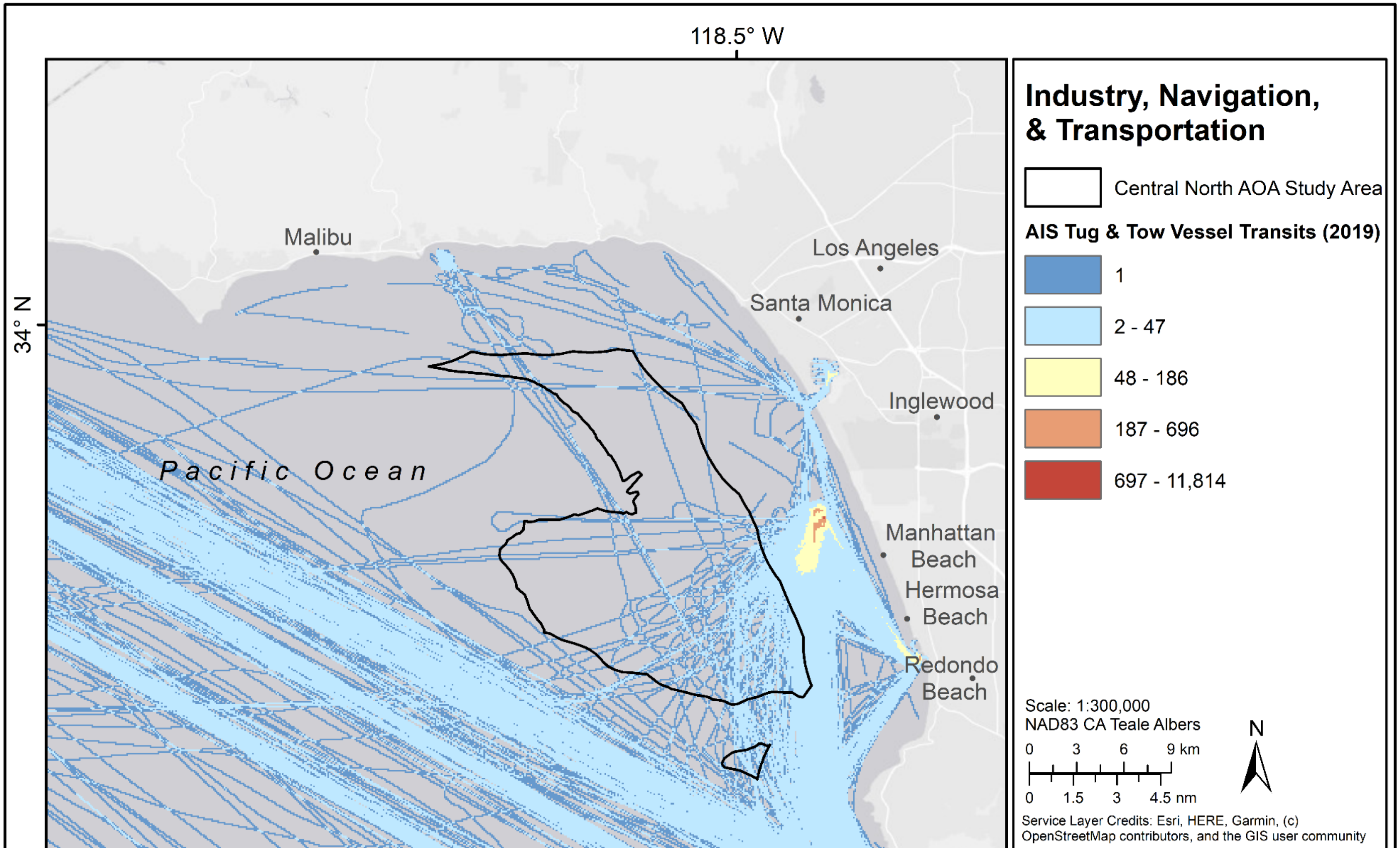
National Ocean Service



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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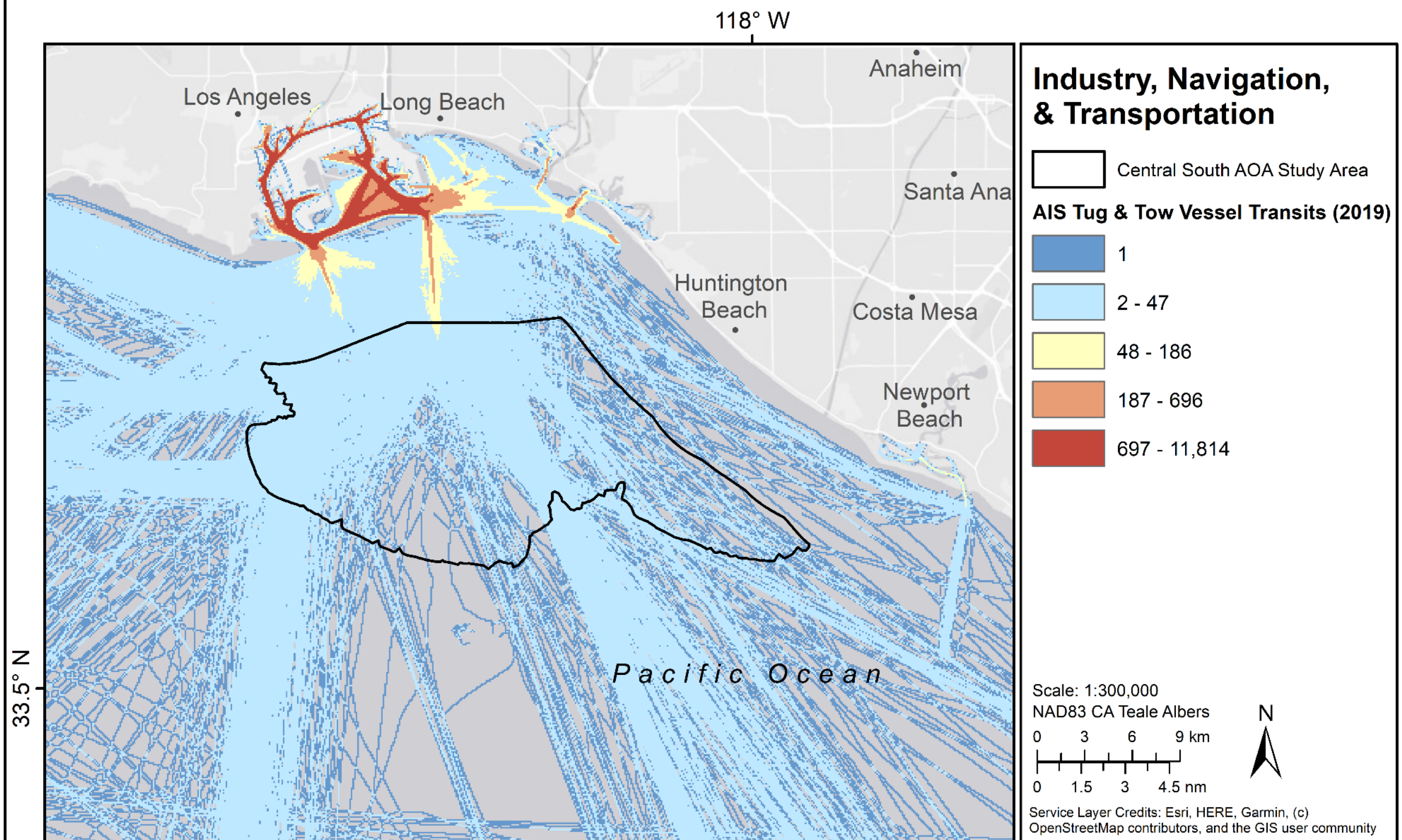
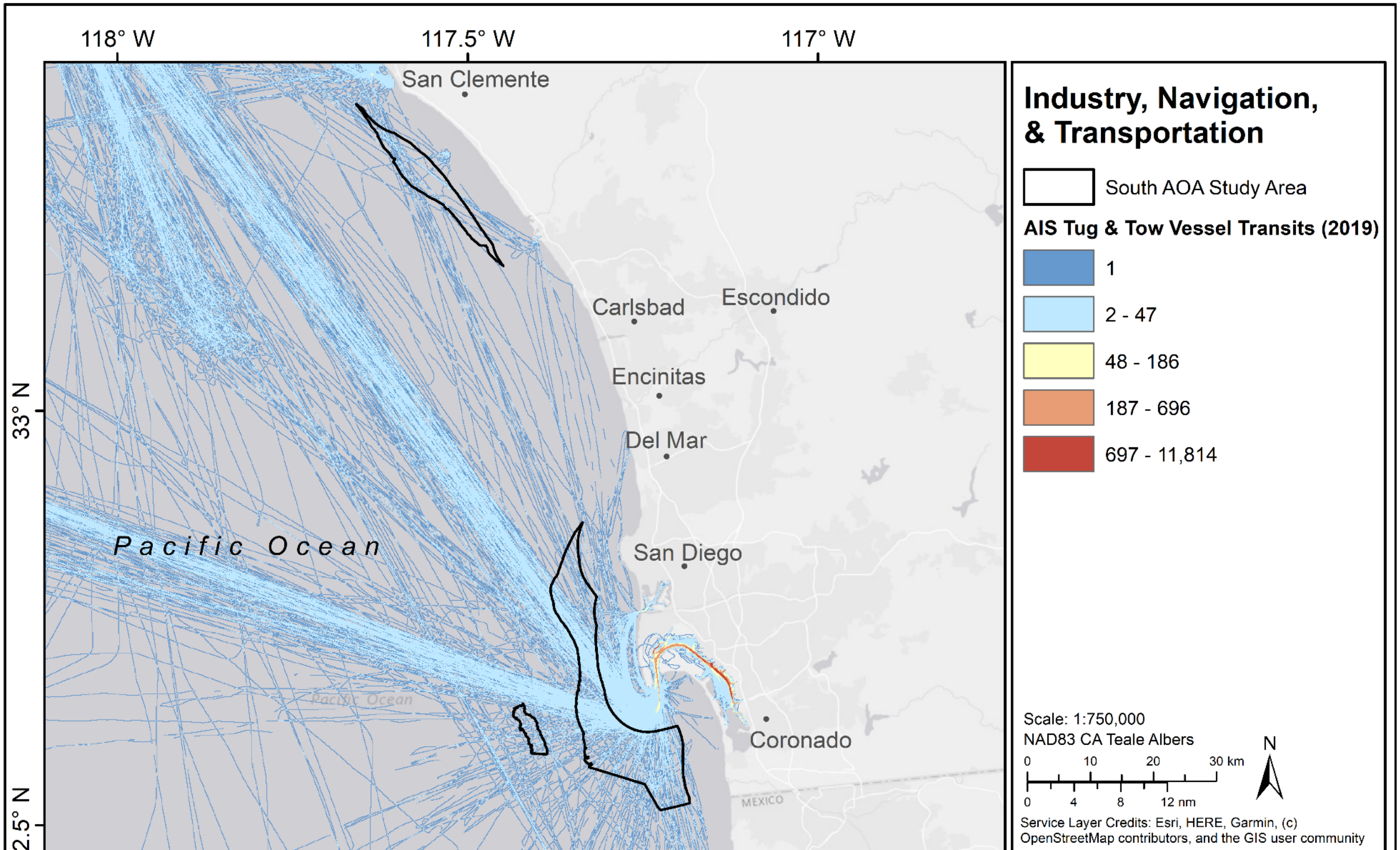
National Centers for Coastal Ocean Science
National Ocean Service



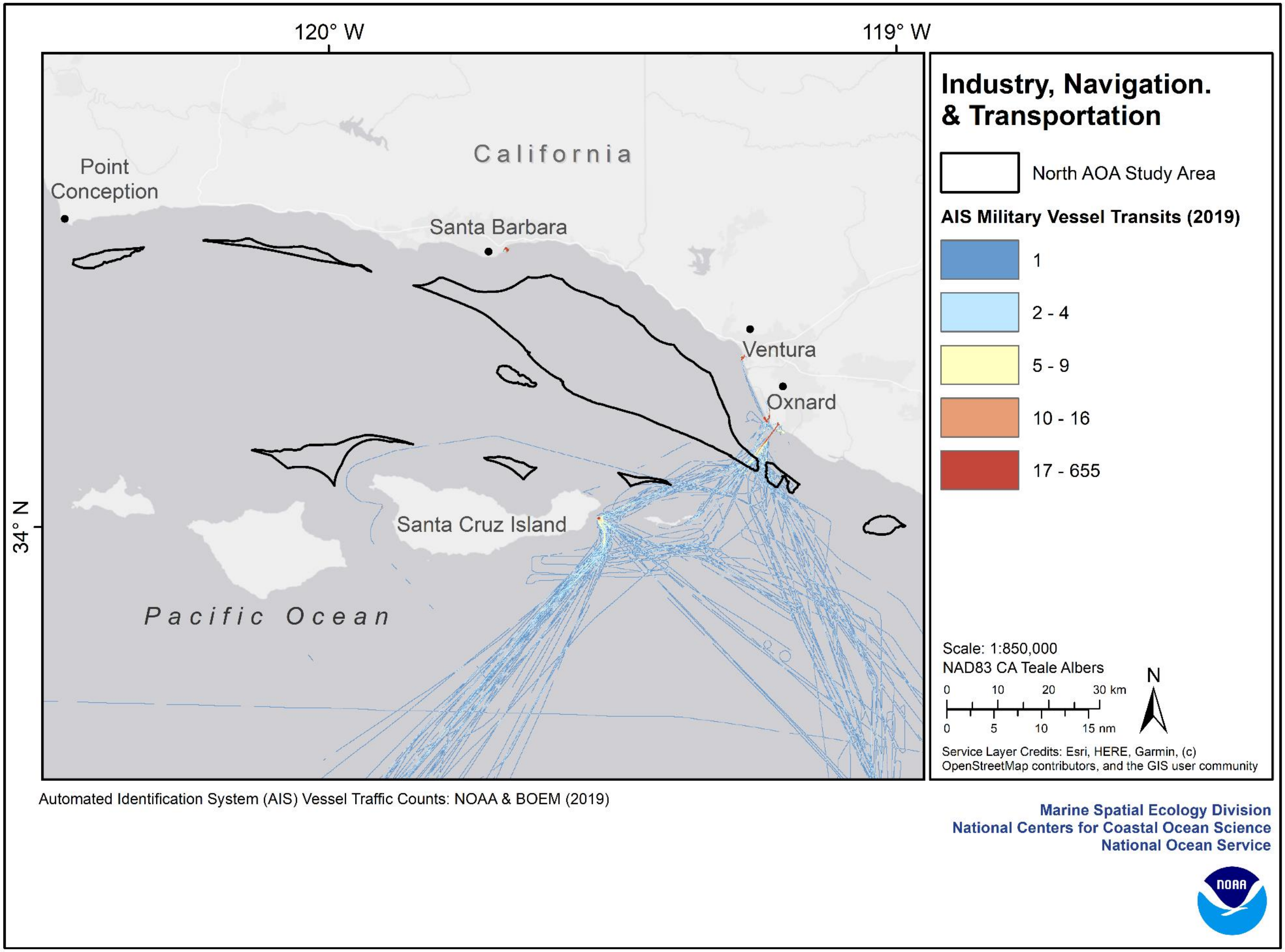
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

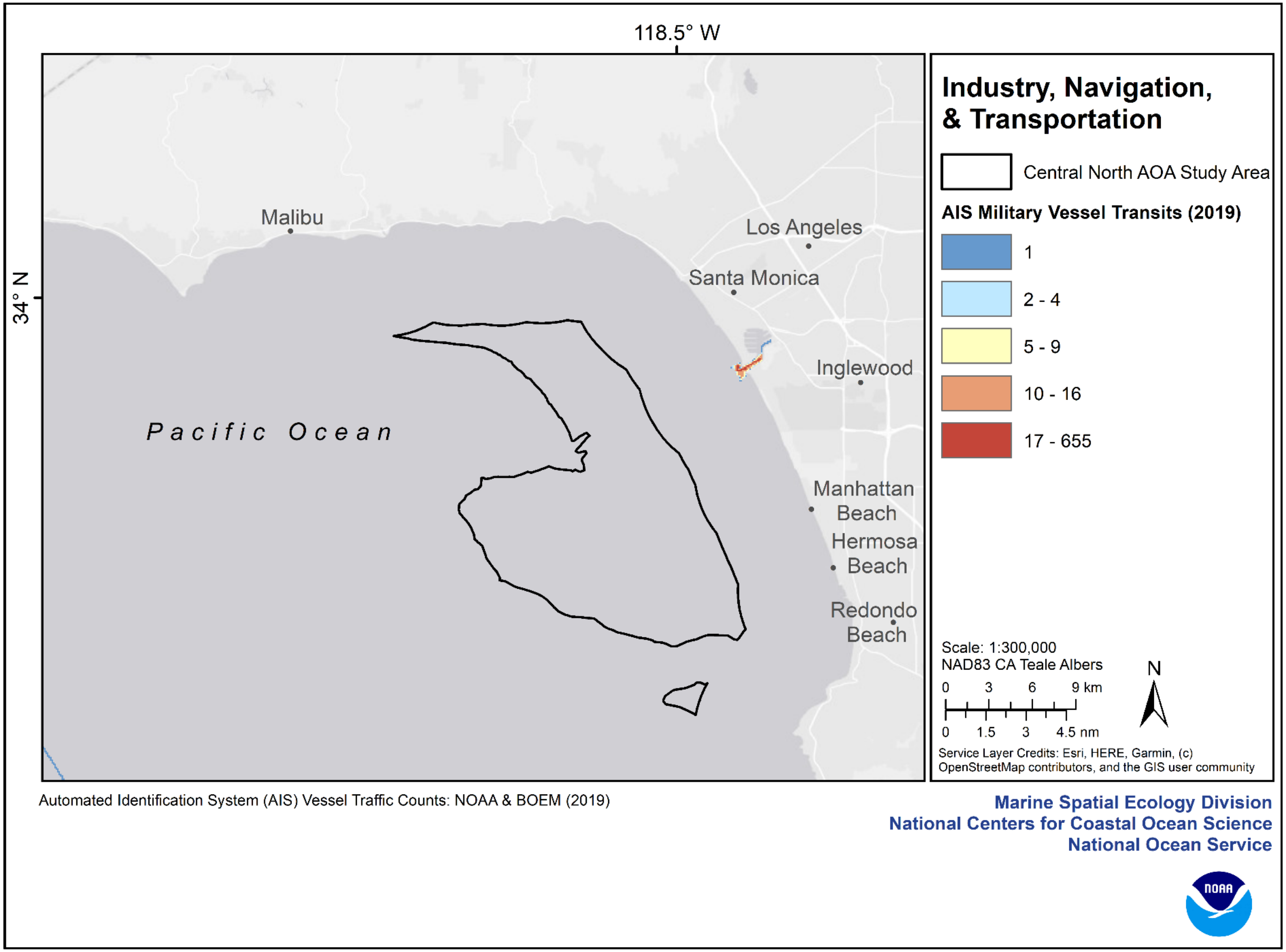
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



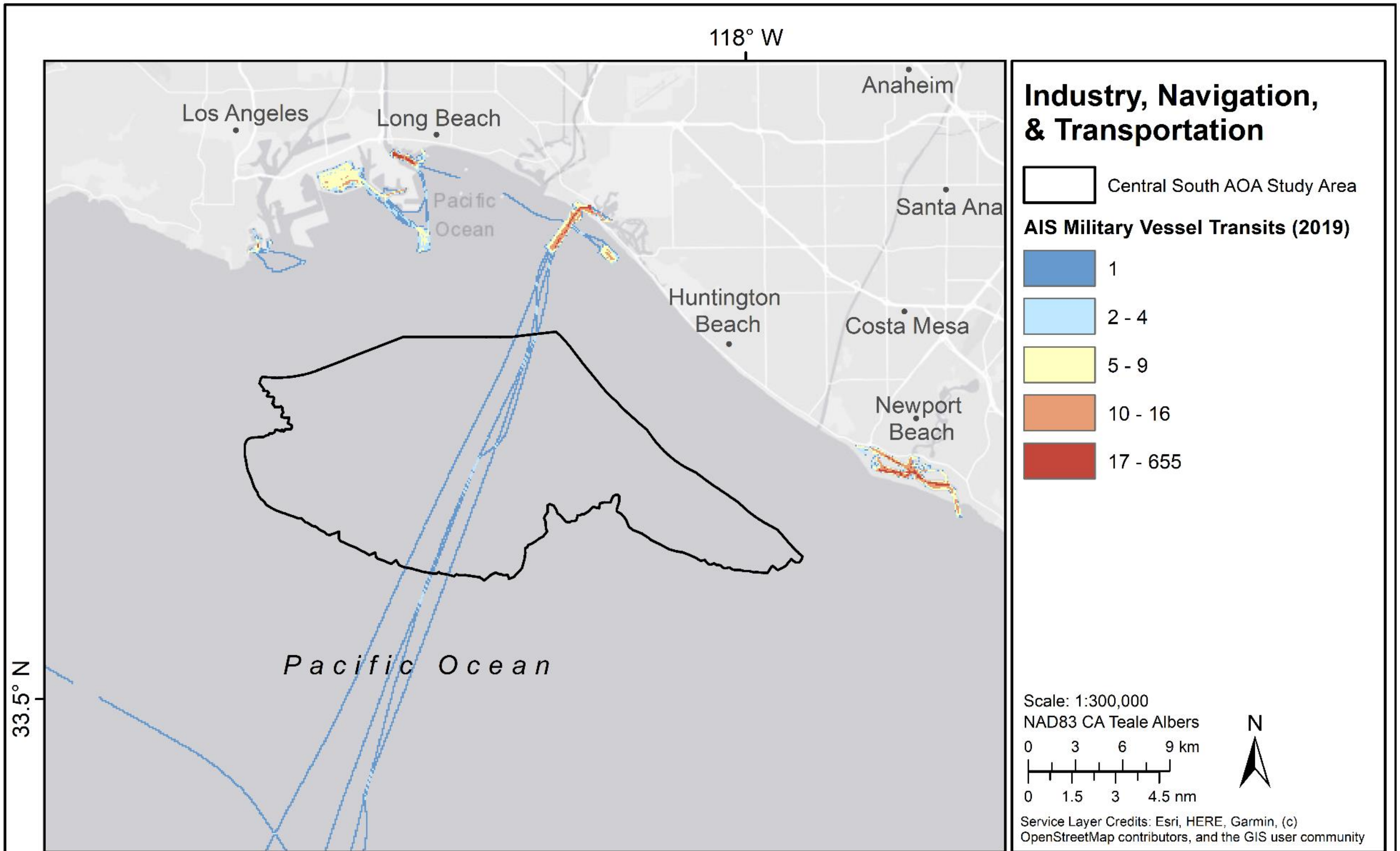
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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


120° W
119° W
34° N
Point Conception
California
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
Industry, Navigation. & Transportation
North AOA Study Area
AIS Military Vessel Transits (2019)
1
2 - 4
5 - 9
10 - 16
17 - 655
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

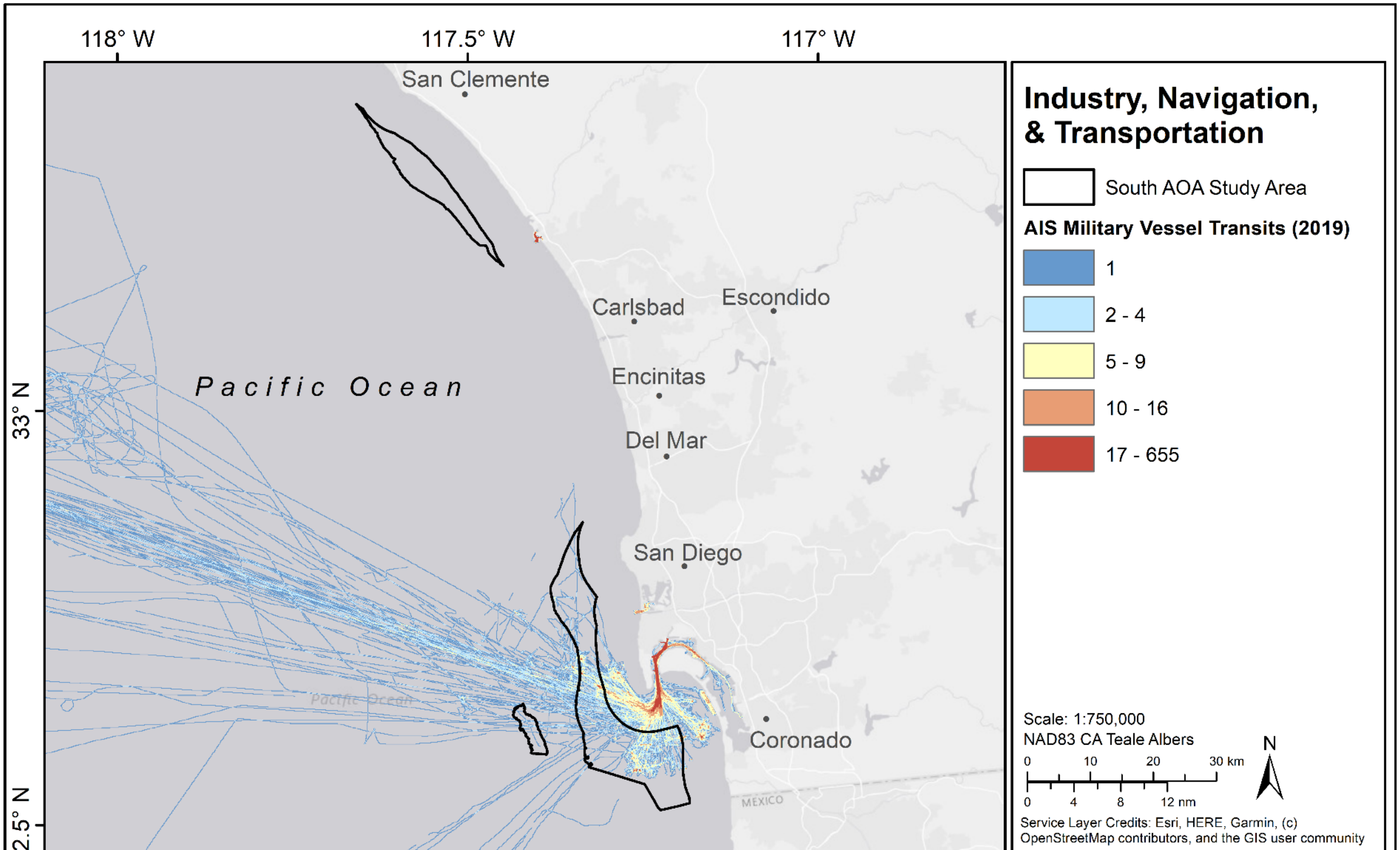


118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
Industry, Navigation, & Transportation
Central North AOA Study Area
AIS Military Vessel Transits (2019)
1
2 - 4
5 - 9
10 - 16
17 - 655
Scale: 1:300,000
NAD83 CA Teale Albers
N
0 3 6 9 km
0 1.5 3 4.5 nm
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



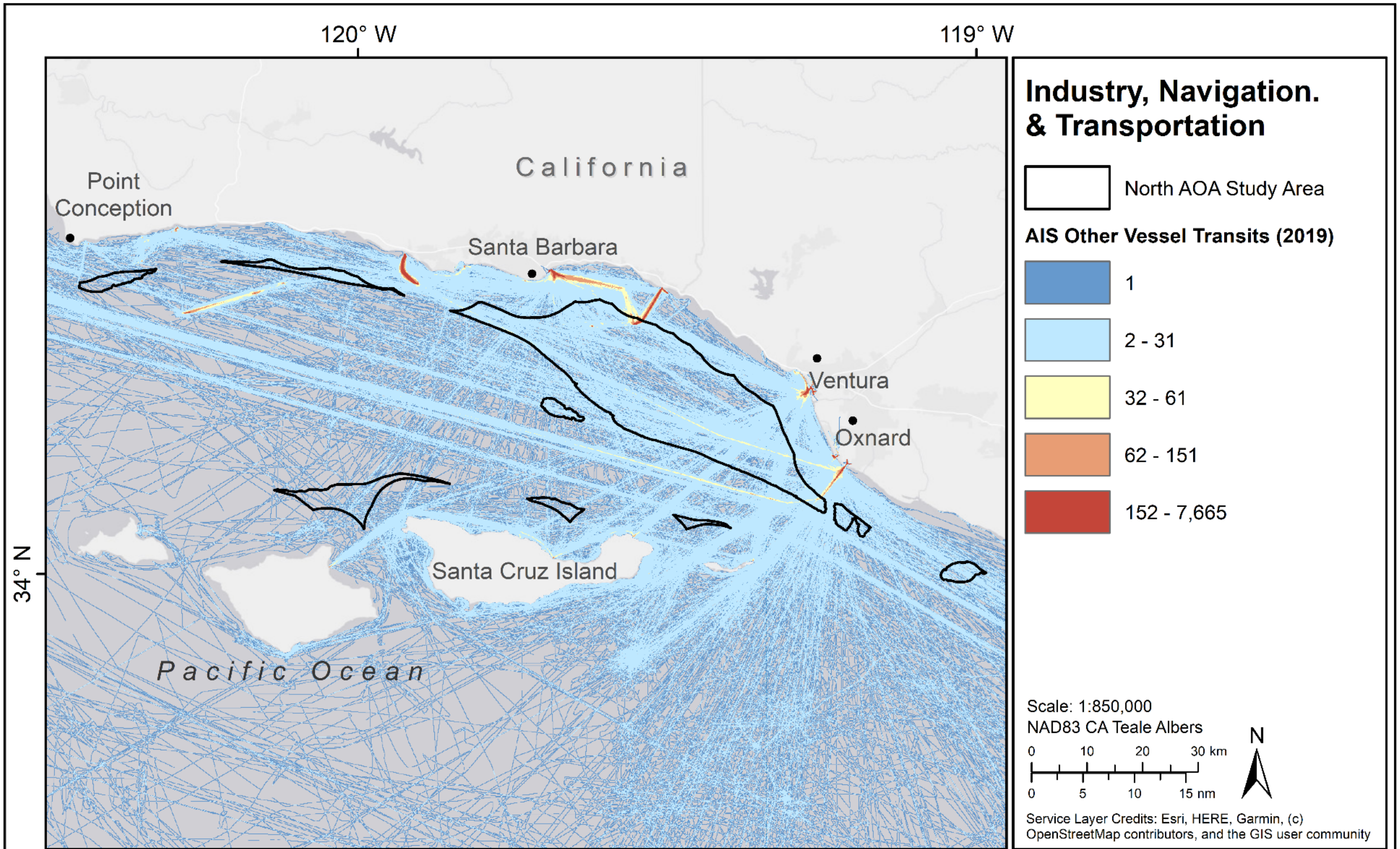
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



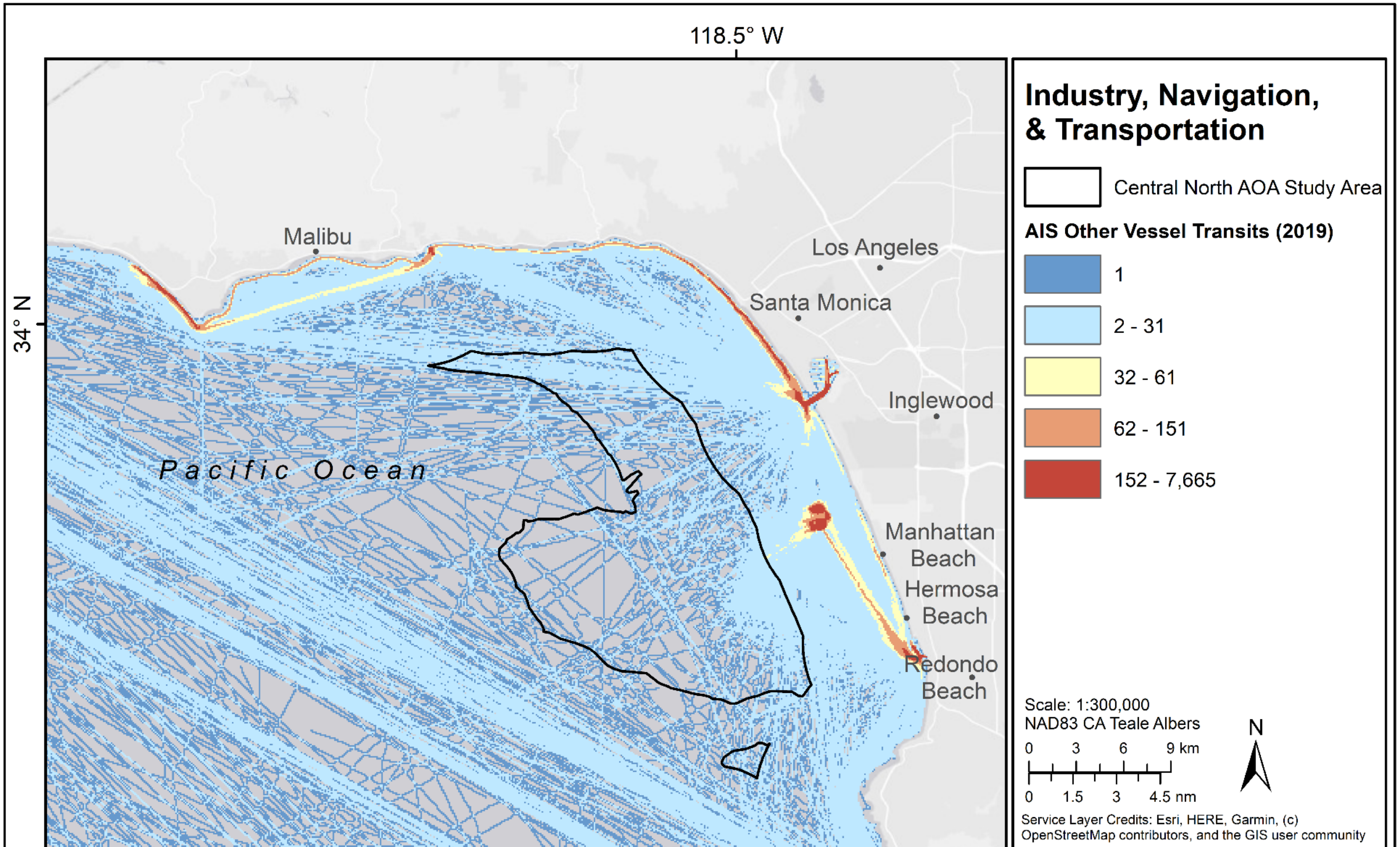
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



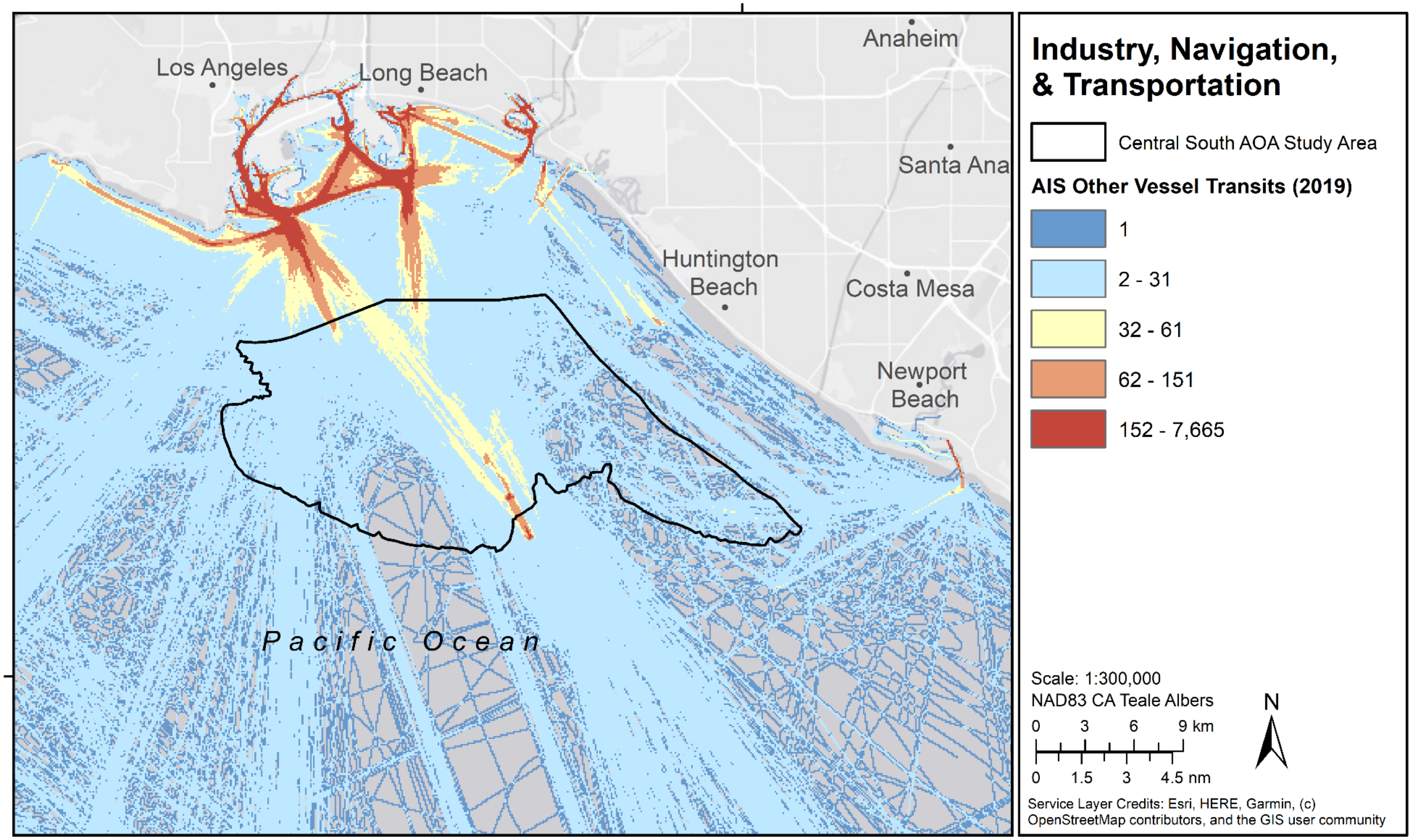
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



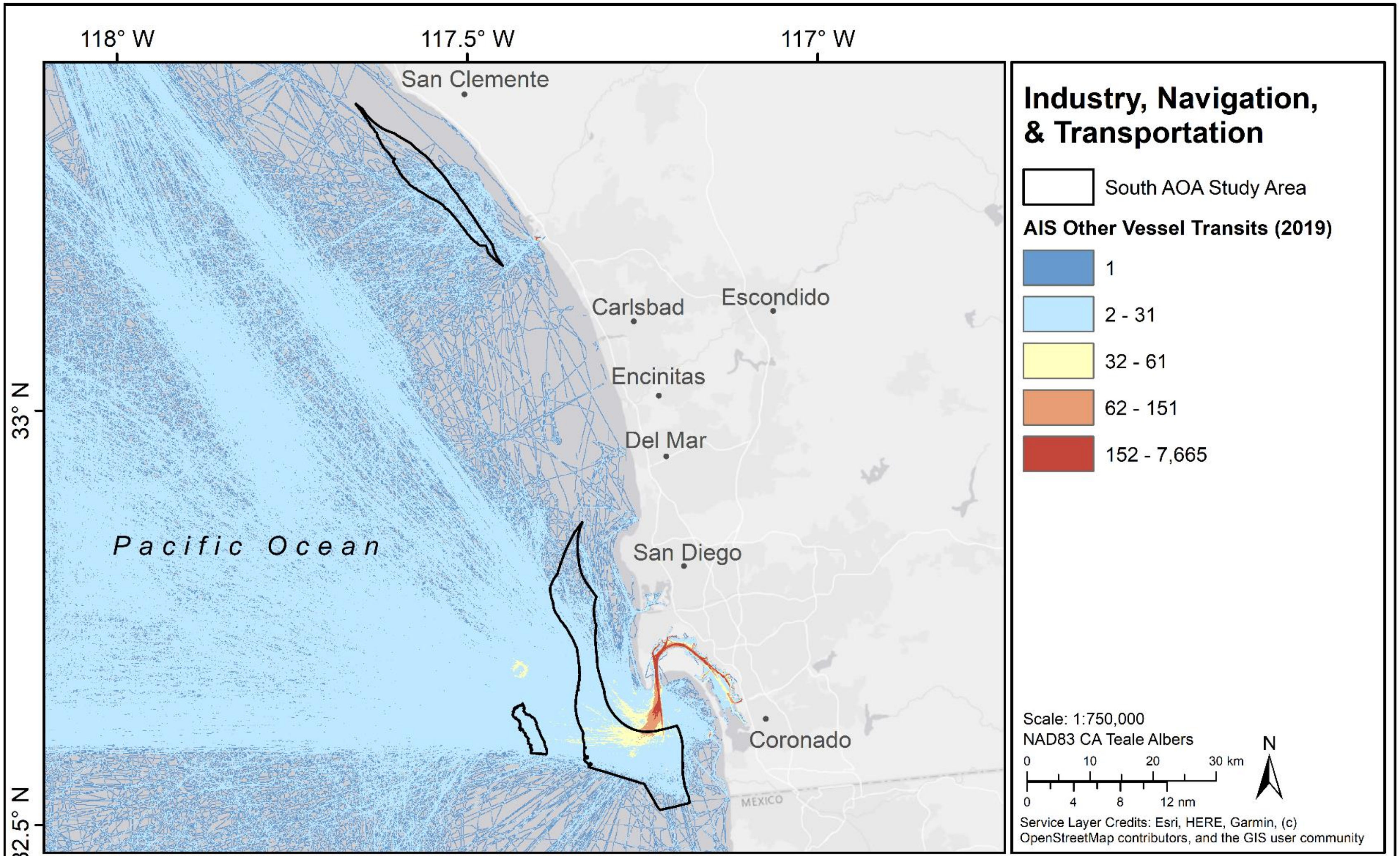
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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



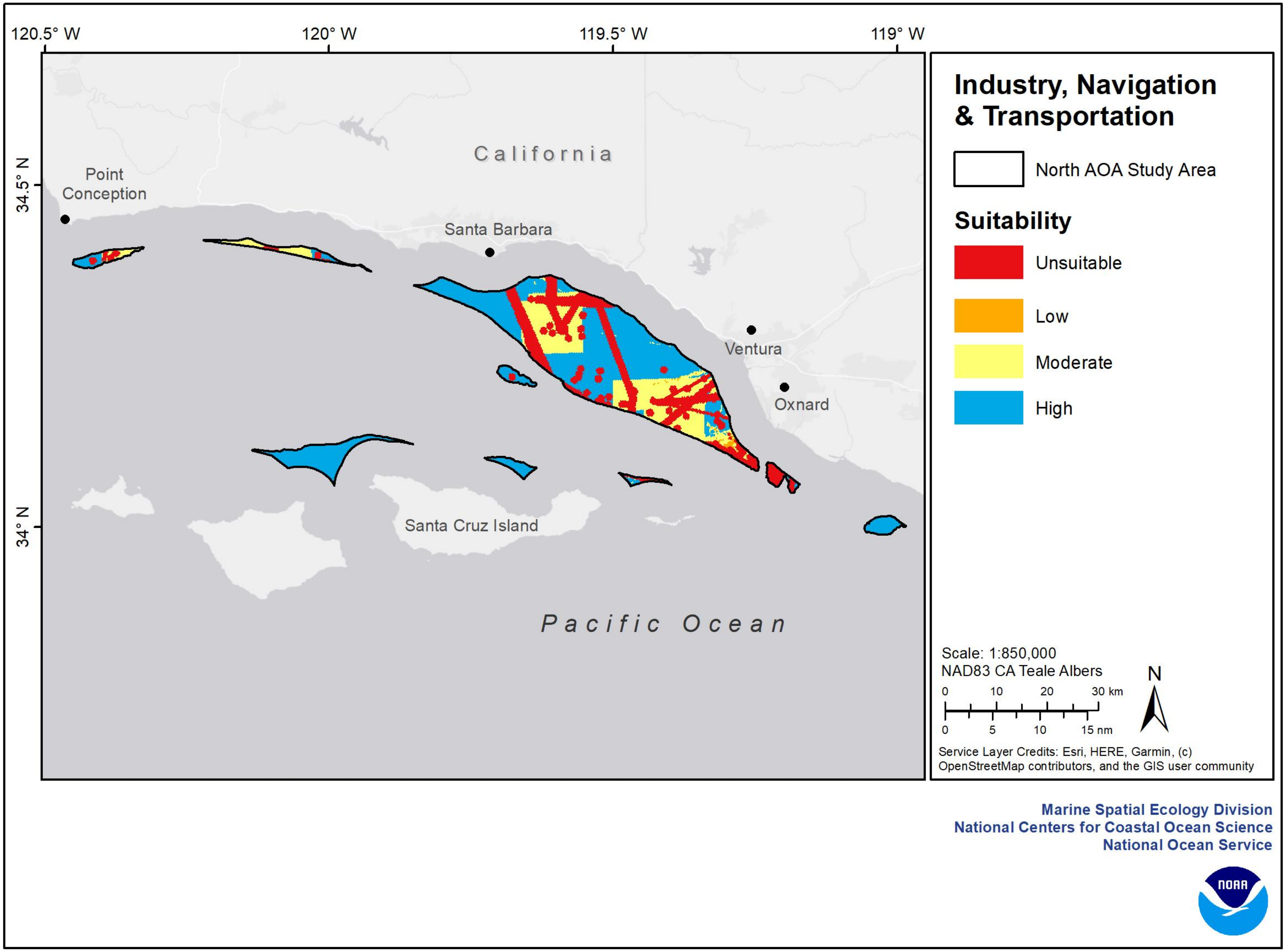
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

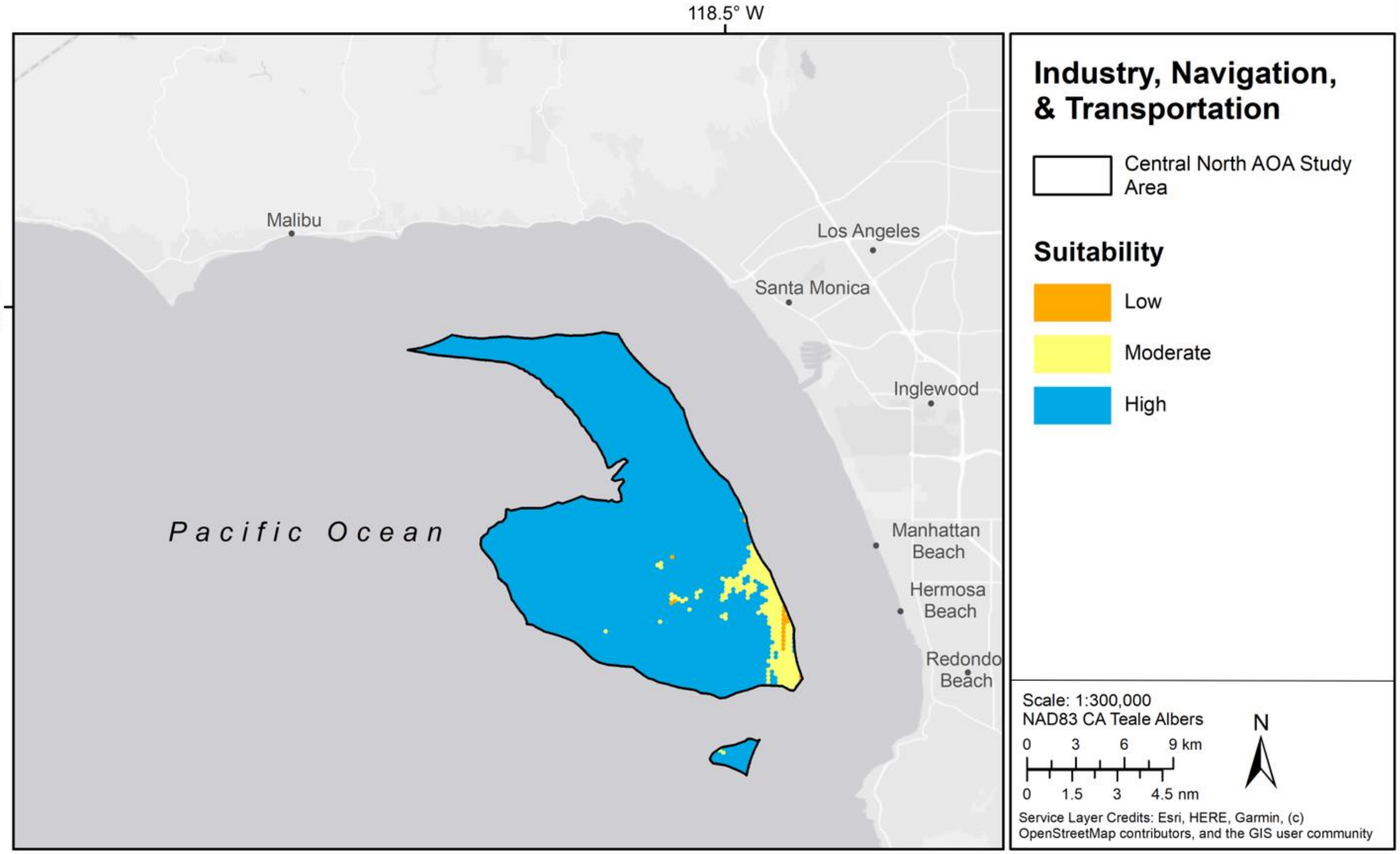
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



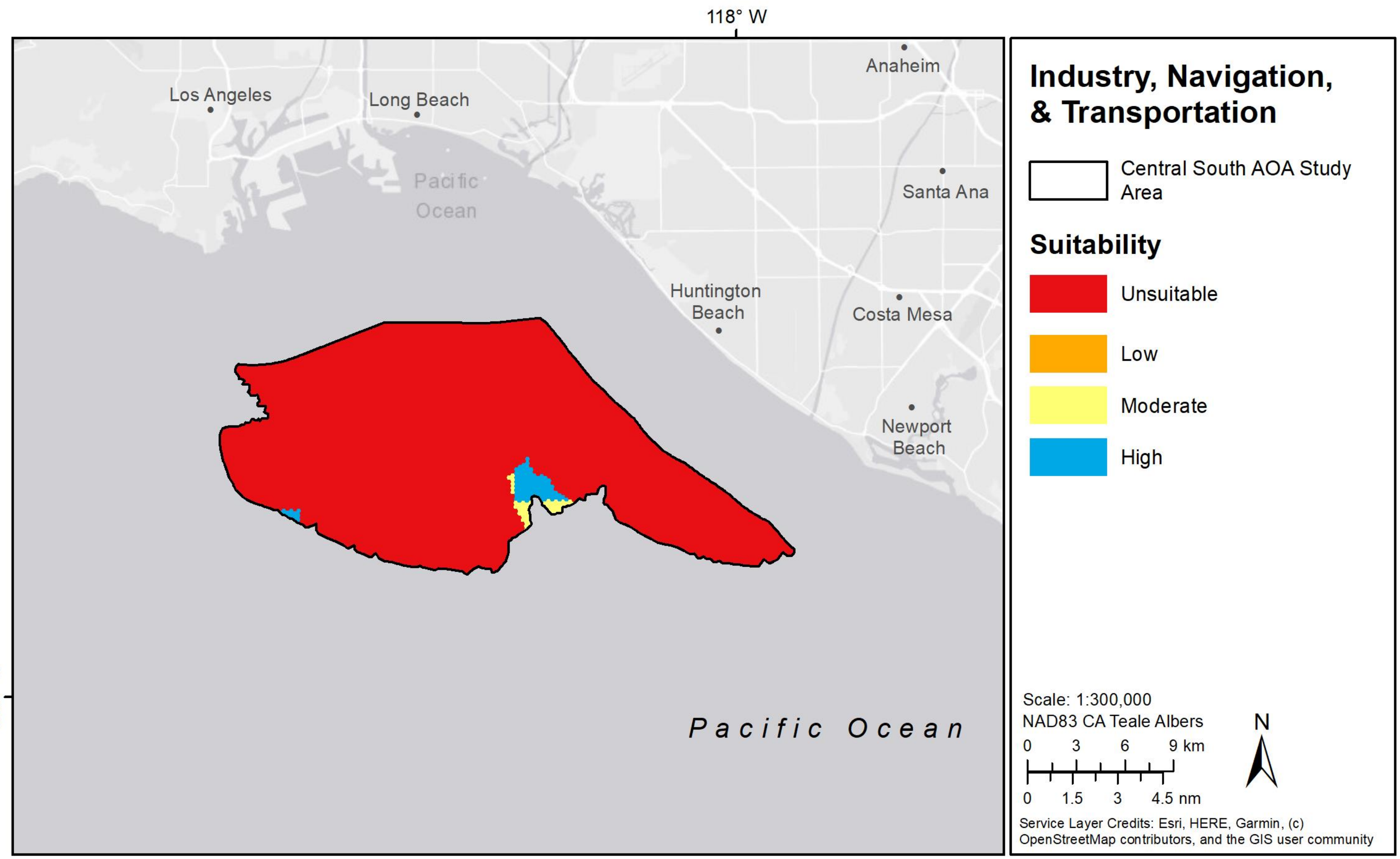
Automated Identification System (AIS) Vessel Traffic Counts: NOAA & BOEM (2019)

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

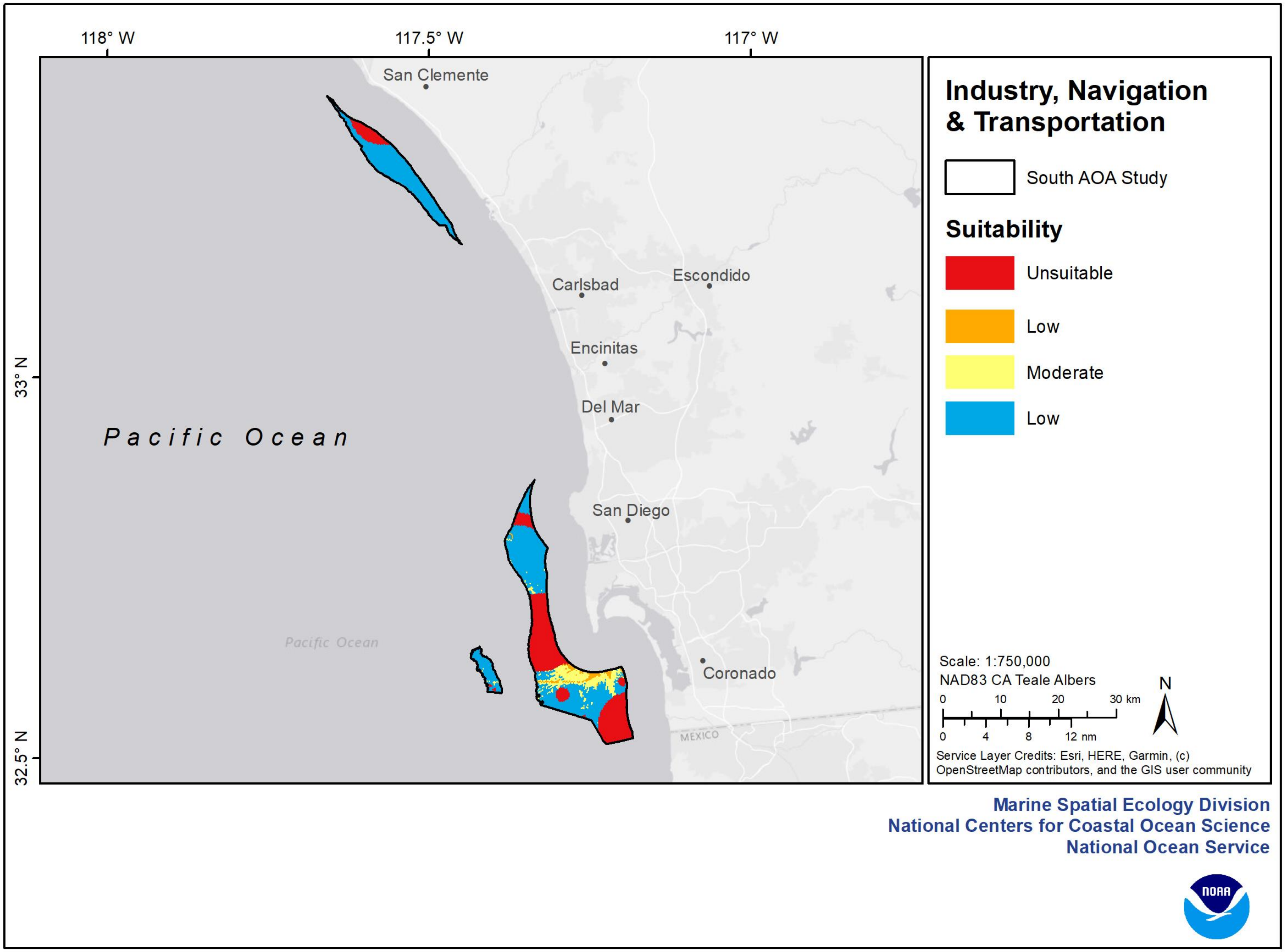

120.5° W
120° W
119.5° W
119° W
34.5° N
34° N
Point Conception
California
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
Industry, Navigation & Transportation
North AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 nm
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

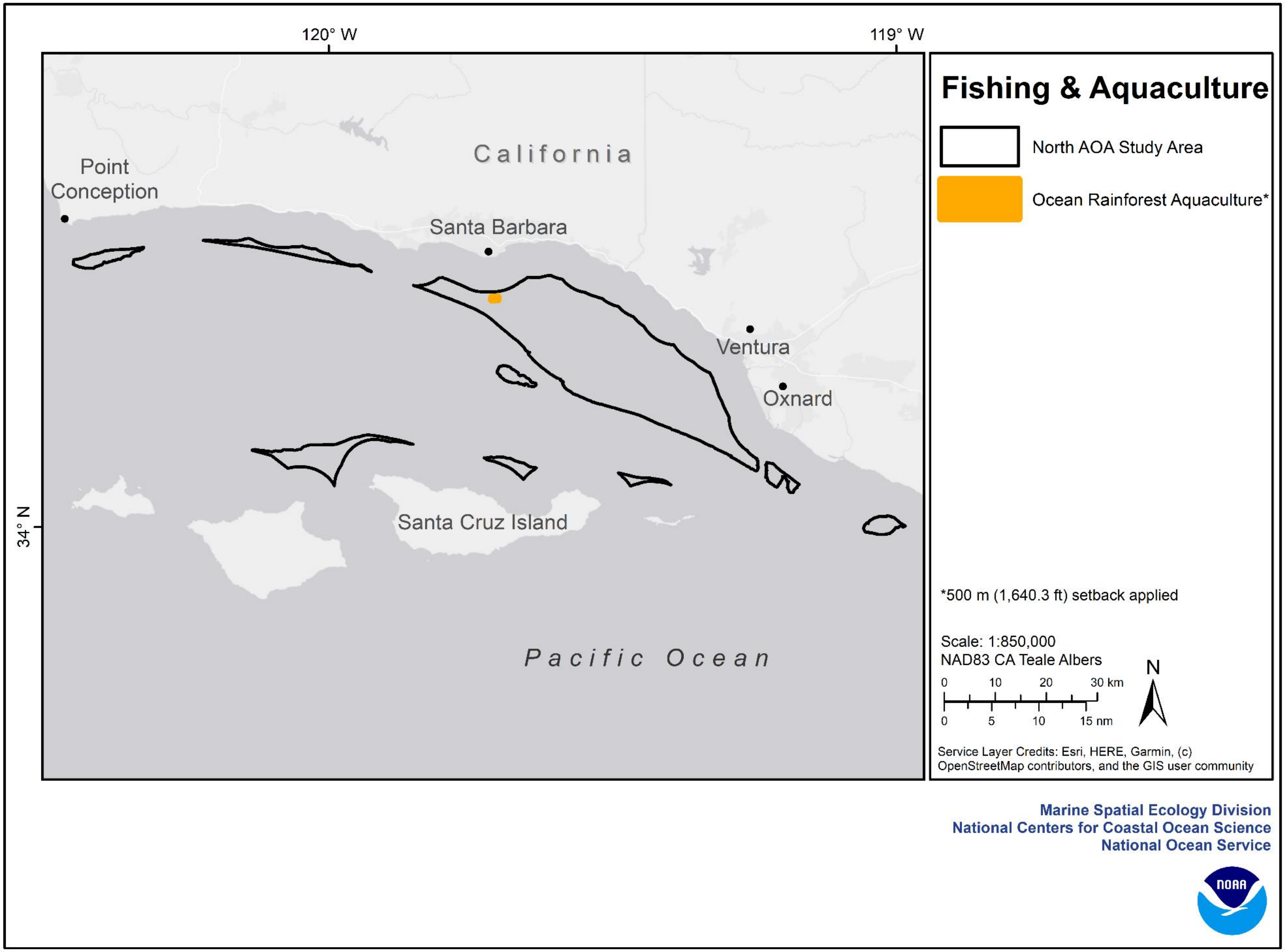


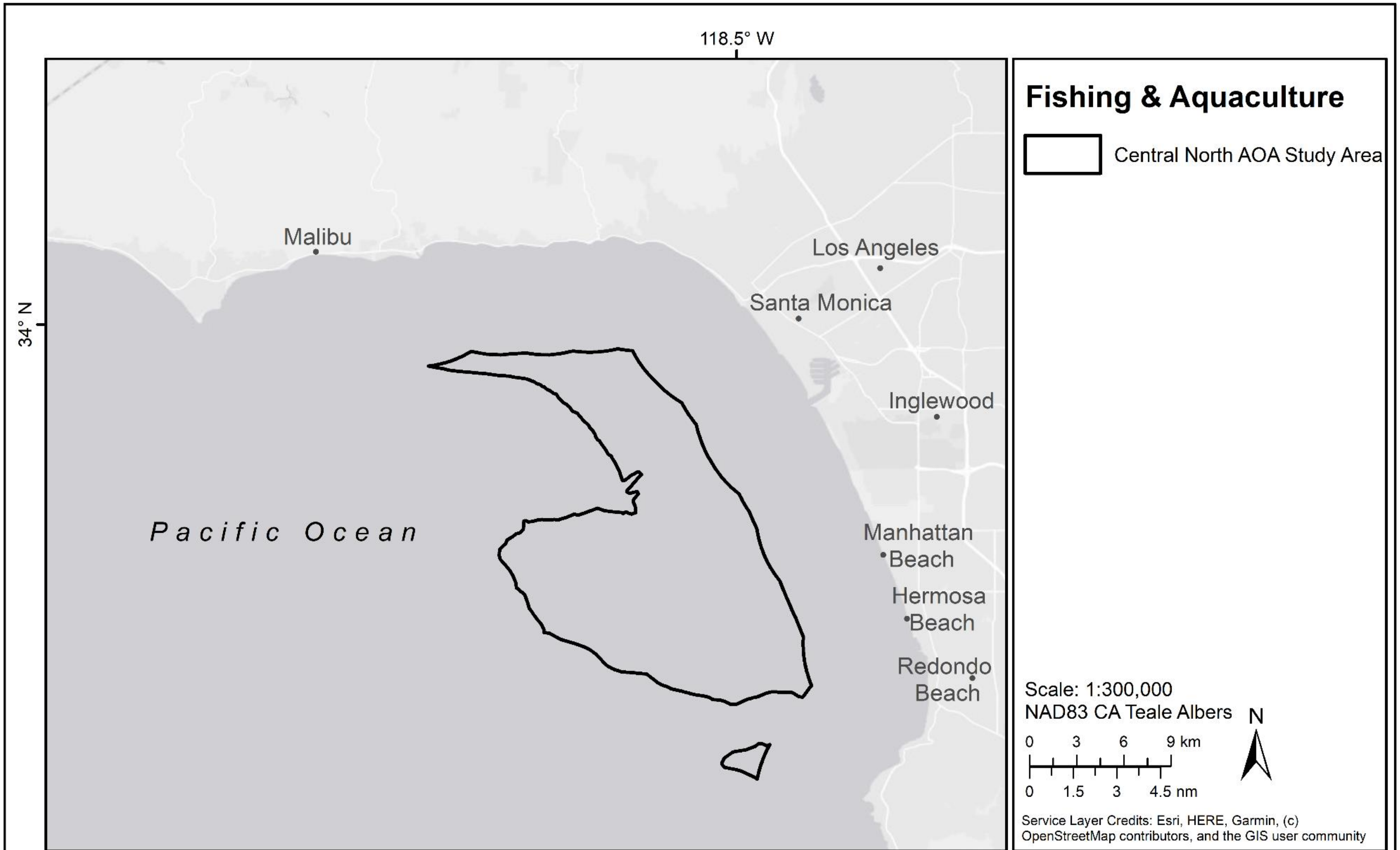
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



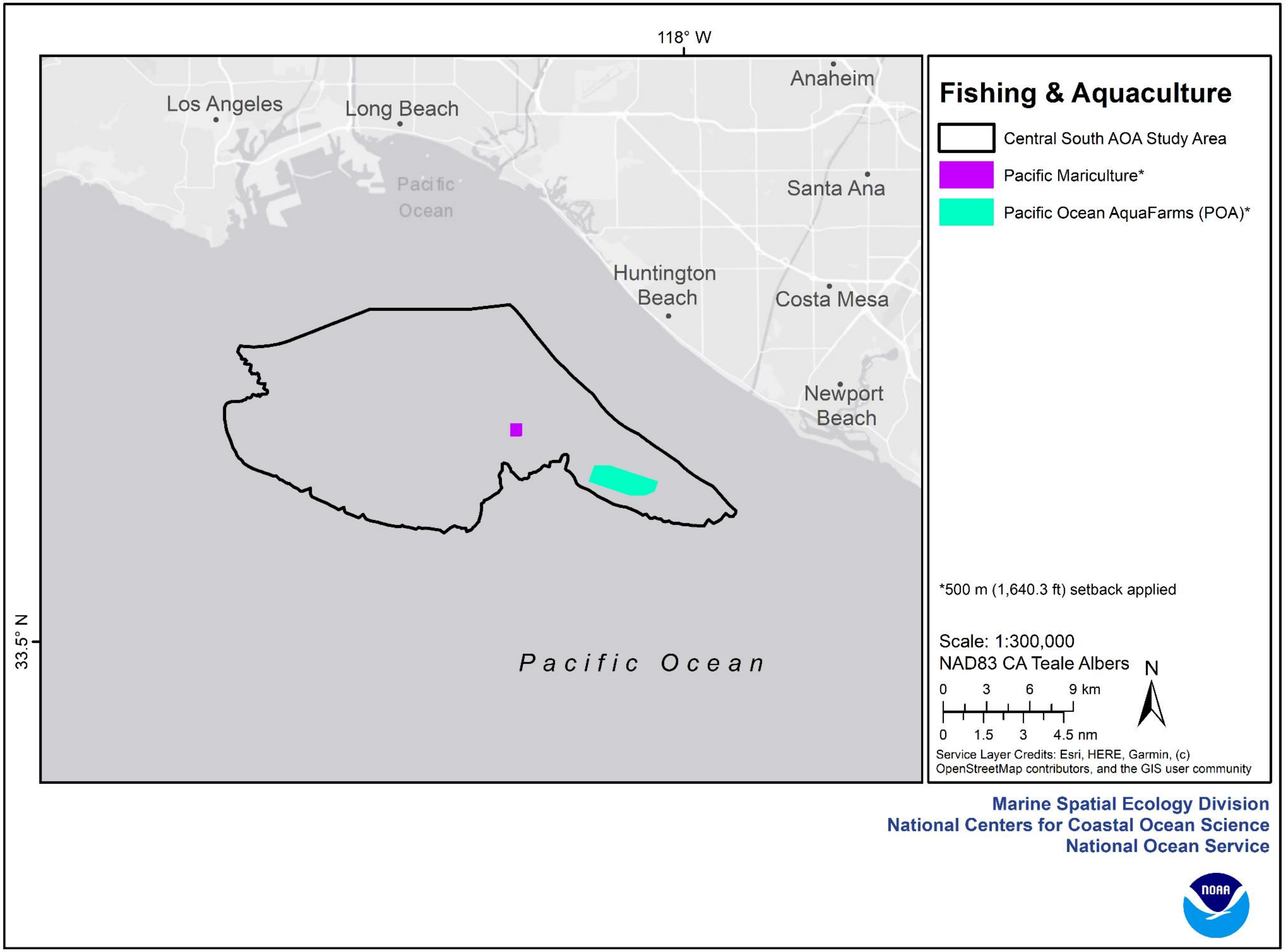
118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
Industry, Navigation & Transportation
South AOA Study
Suitability
Unsuitable
Low
Moderate
Low
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 nm
N
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

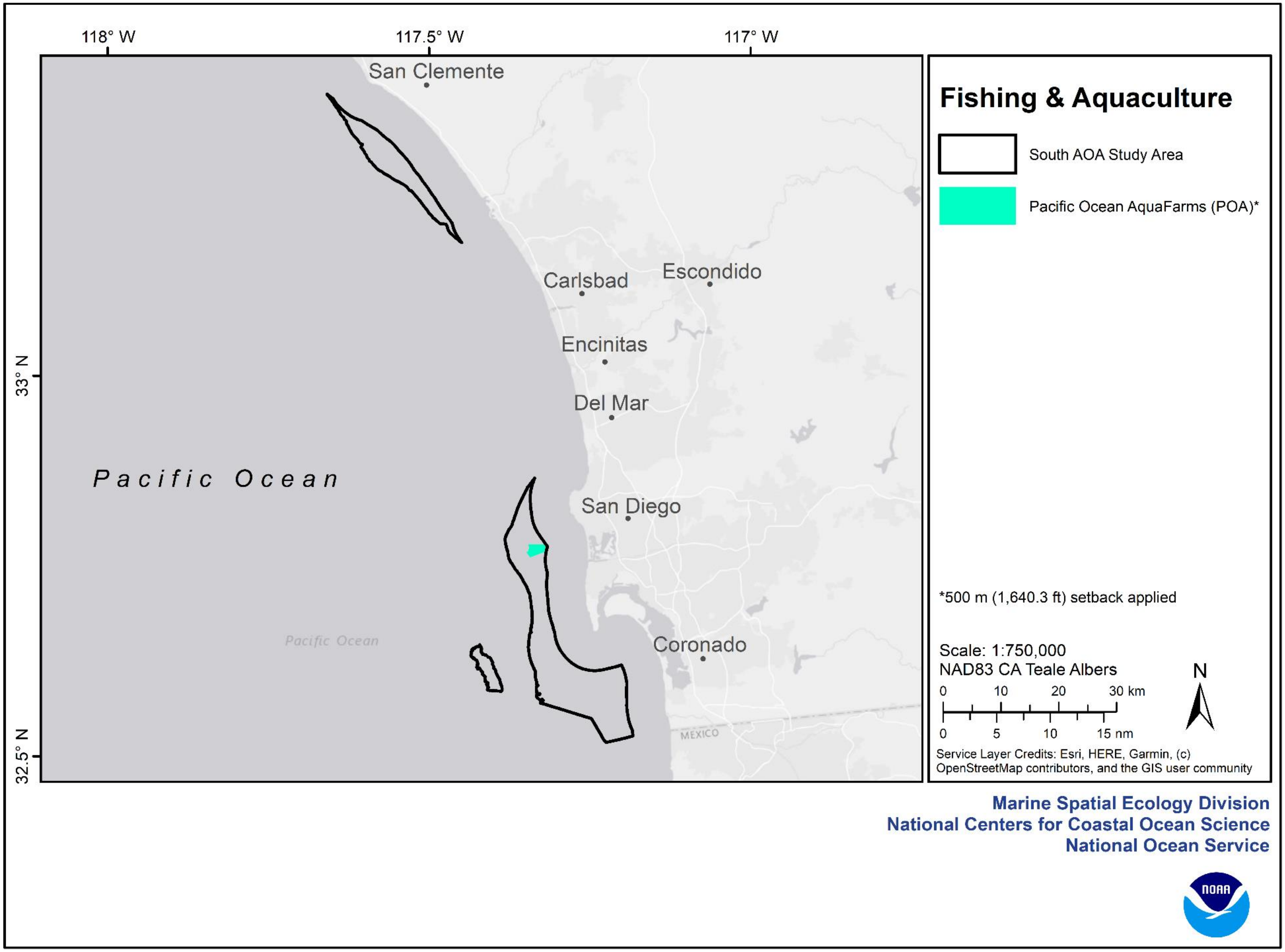
Fishing and Aquaculture





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


118° W
33.5° N
Los Angeles
Long Beach
Anaheim
Pacific Ocean
Santa Ana
Huntington Beach
Costa Mesa
Newport Beach
Pacific Ocean
Fishing & Aquaculture
Central South AOA Study Area
Pacific Mariculture*
Pacific Ocean AquaFarms (POA)*
*500 m (1,640.3 ft) setback applied
Scale: 1:300,000
NAD83 CA Teale Albers
N
0 3 6 9 km
0 1.5 3 4.5 nm
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


118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
Fishing & Aquaculture
South AOA Study Area
Pacific Ocean AquaFarms (POA)*
*500 m (1,640.3 ft) setback applied
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
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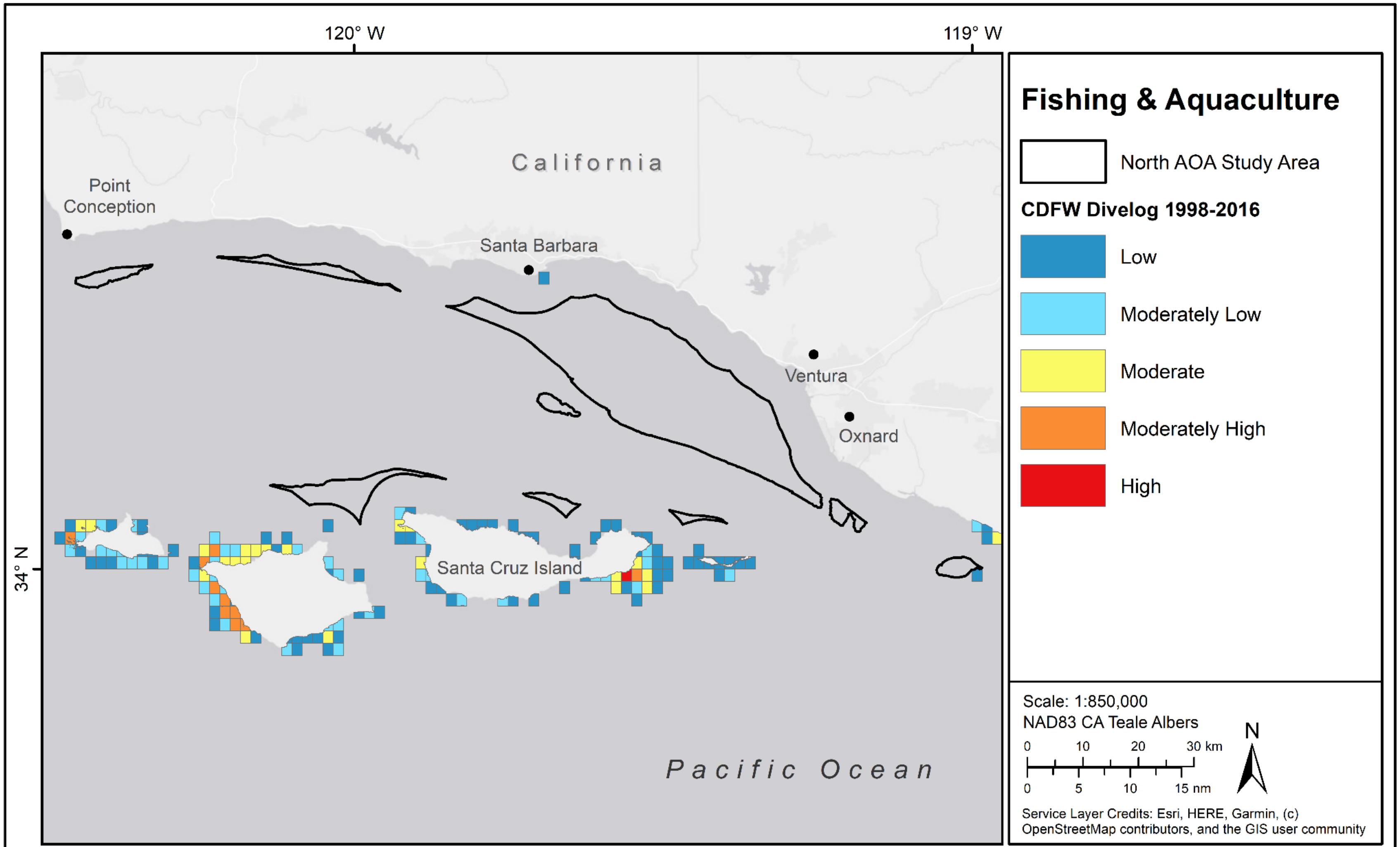
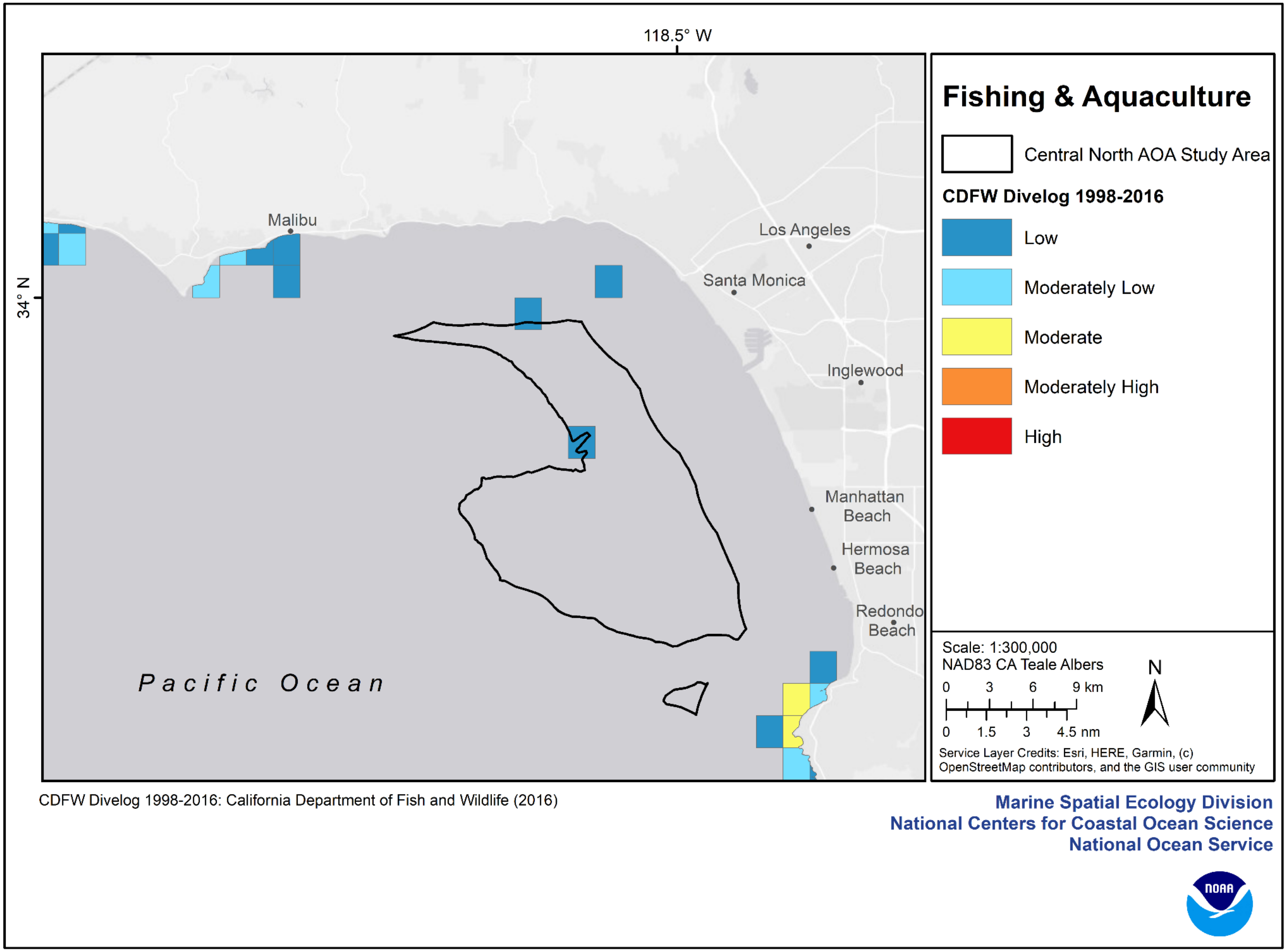
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



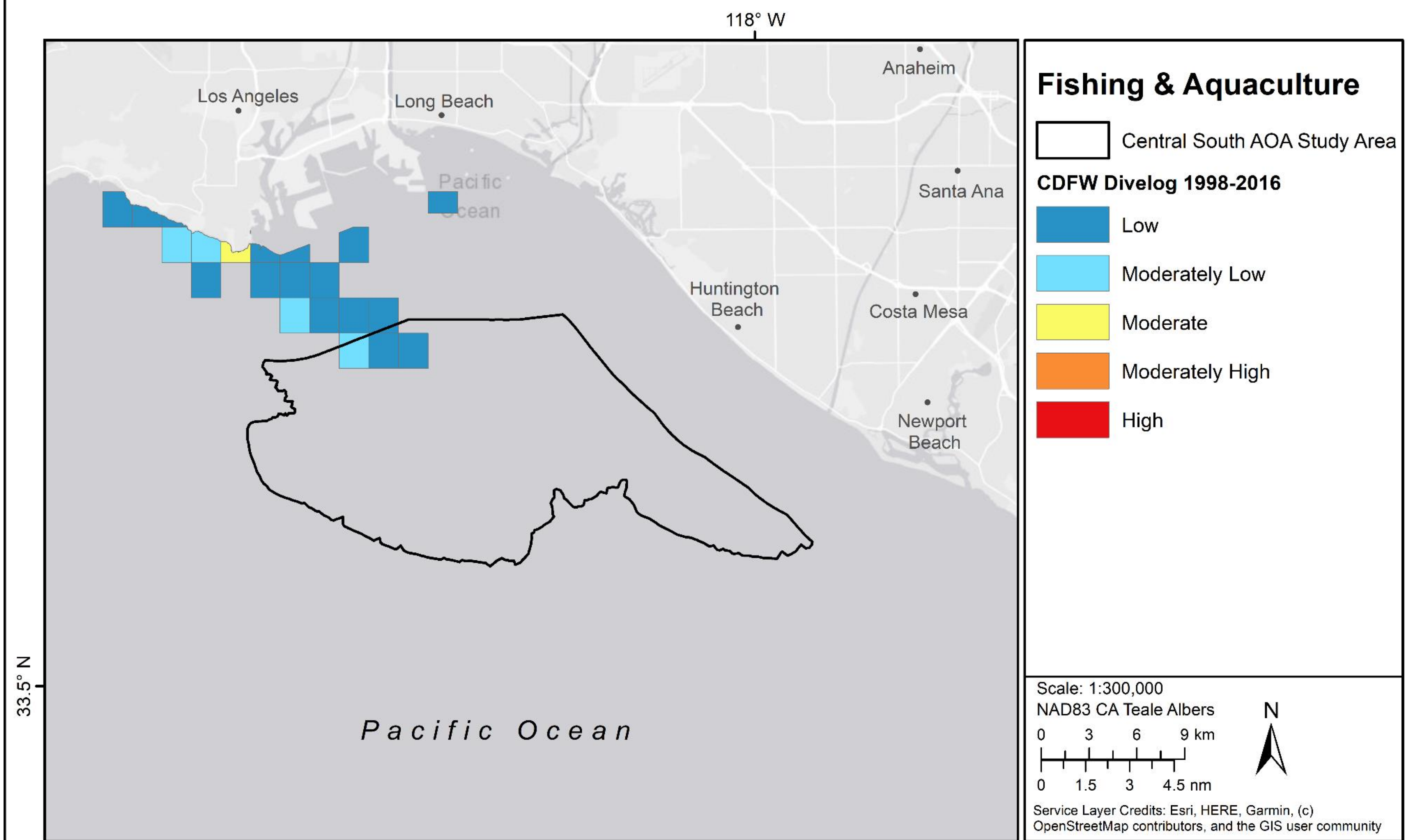
CDFW Divelog 1998-2016: California Department of Fish and Wildlife (2016)

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



CDFW Divelog 1998-2016: California Department of Fish and Wildlife (2016)

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



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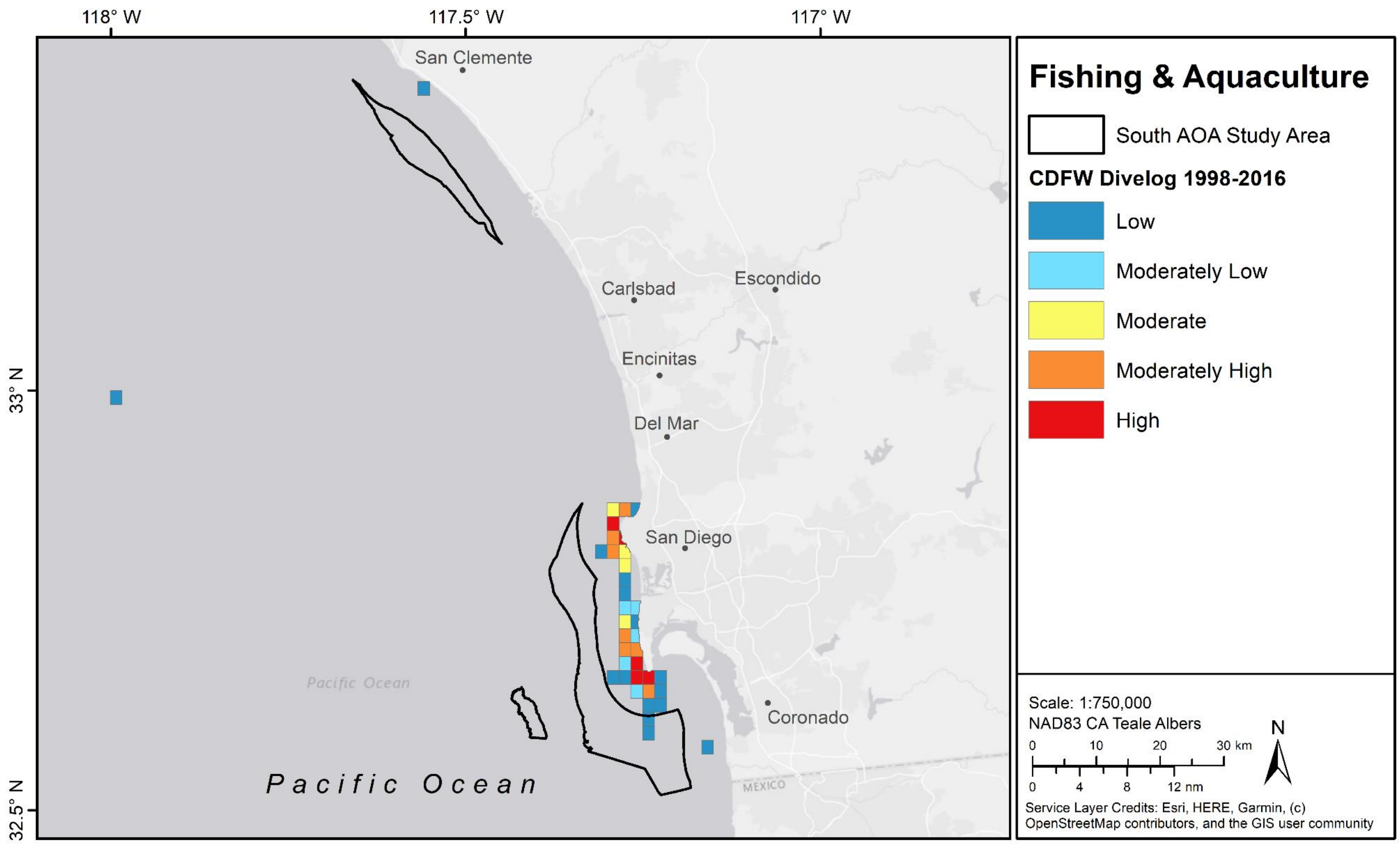

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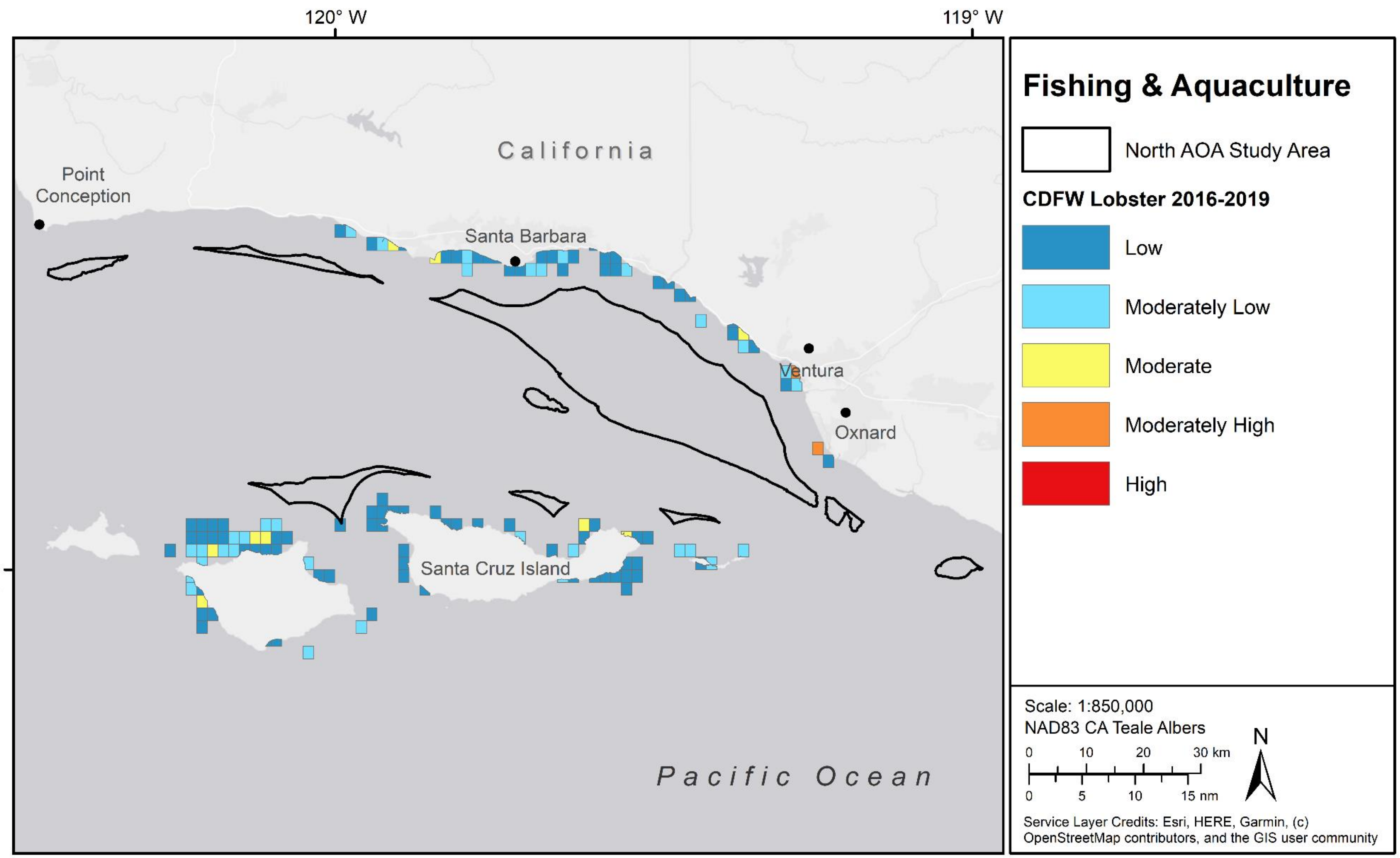
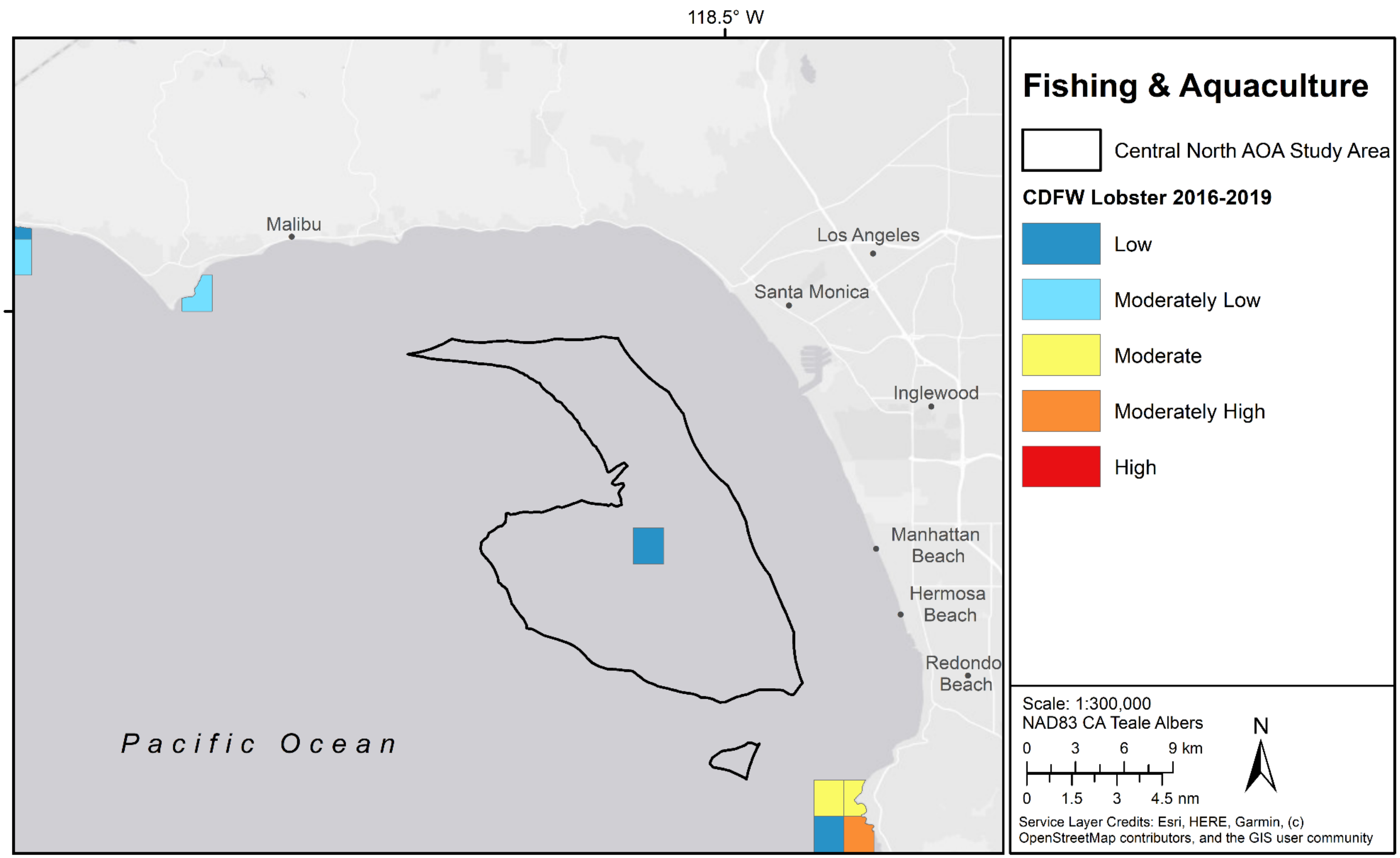


CDFW Lobster 2016-2019: California Department of Fish and Wildlife (2019)

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



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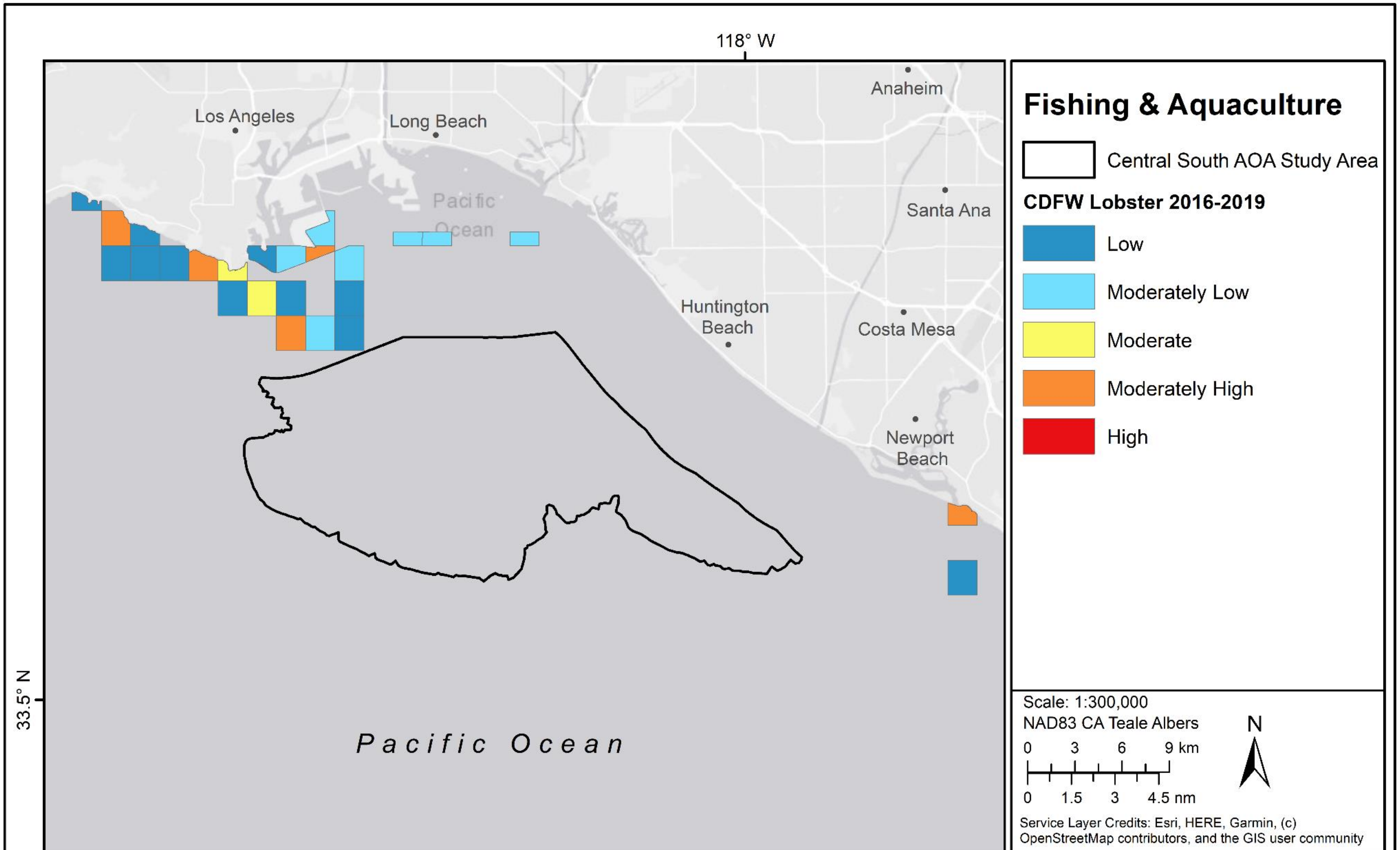

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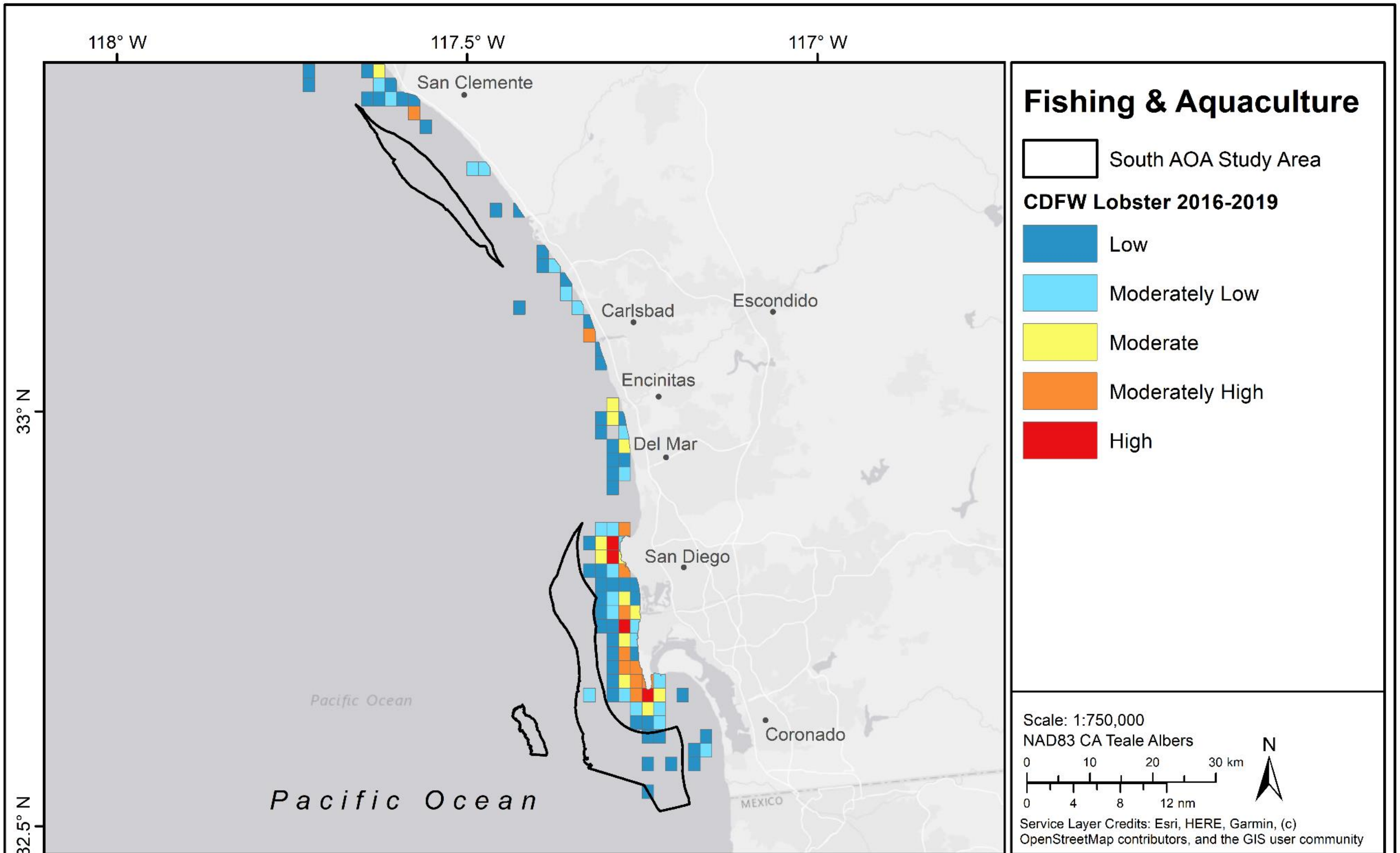

CDFW Lobster 2016-2019: California Department of Fish and Wildlife (2019)

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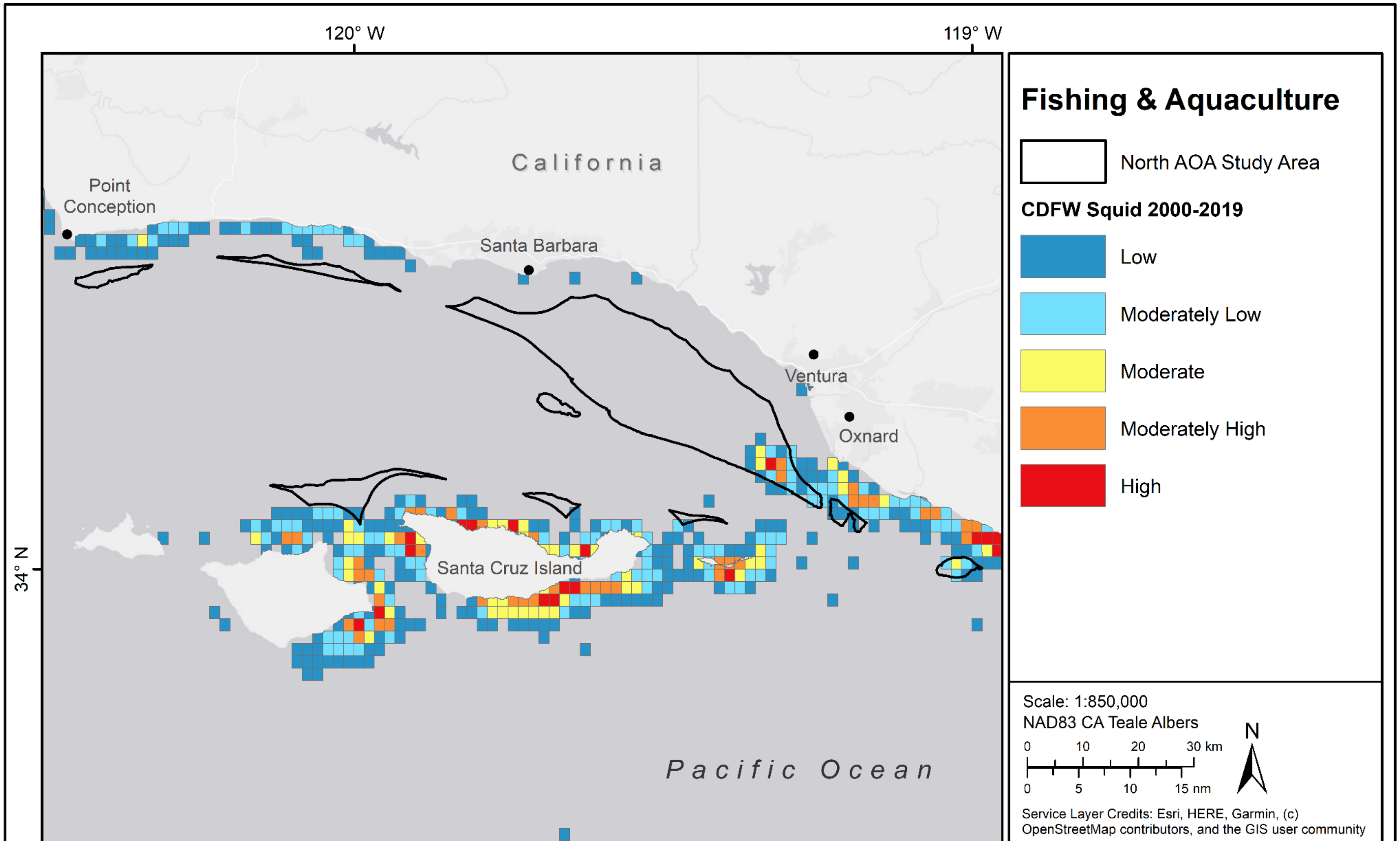
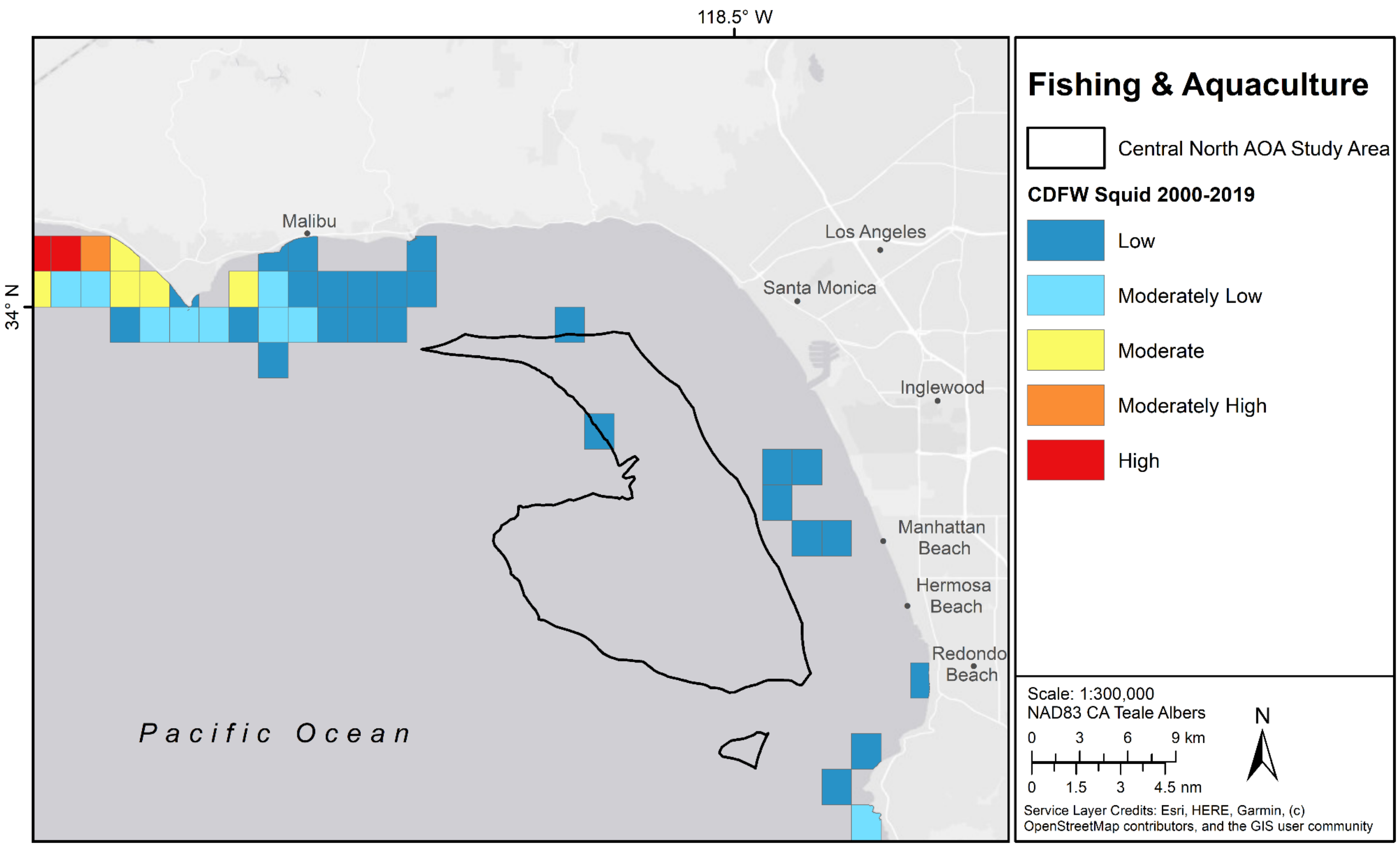
National Ocean Service



CDFW Squid 2000-2019: California Department of Fish and Wildlife (2019)

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



CDFW Squid 2000-2019: California Department of Fish and Wildlife (2019)

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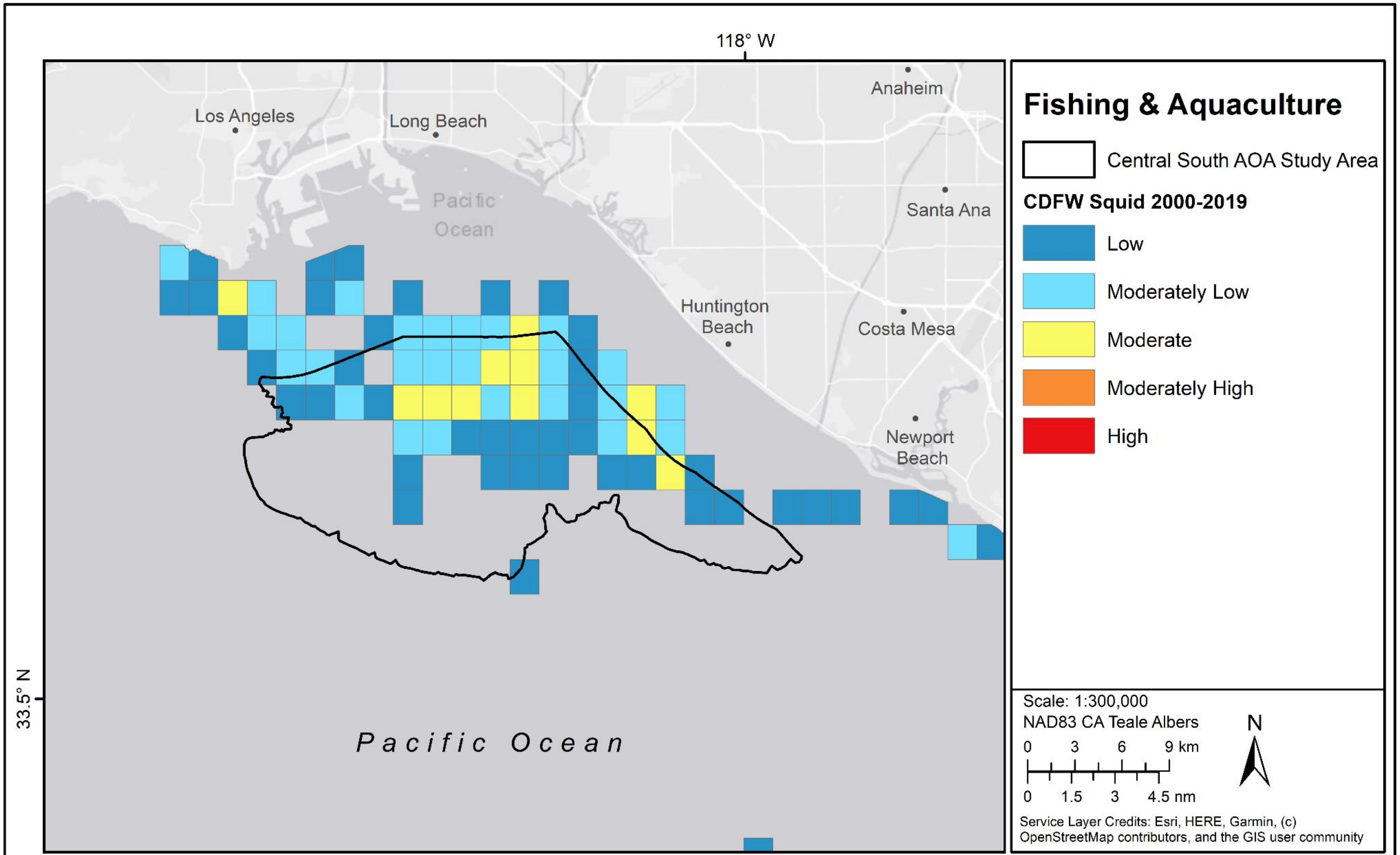

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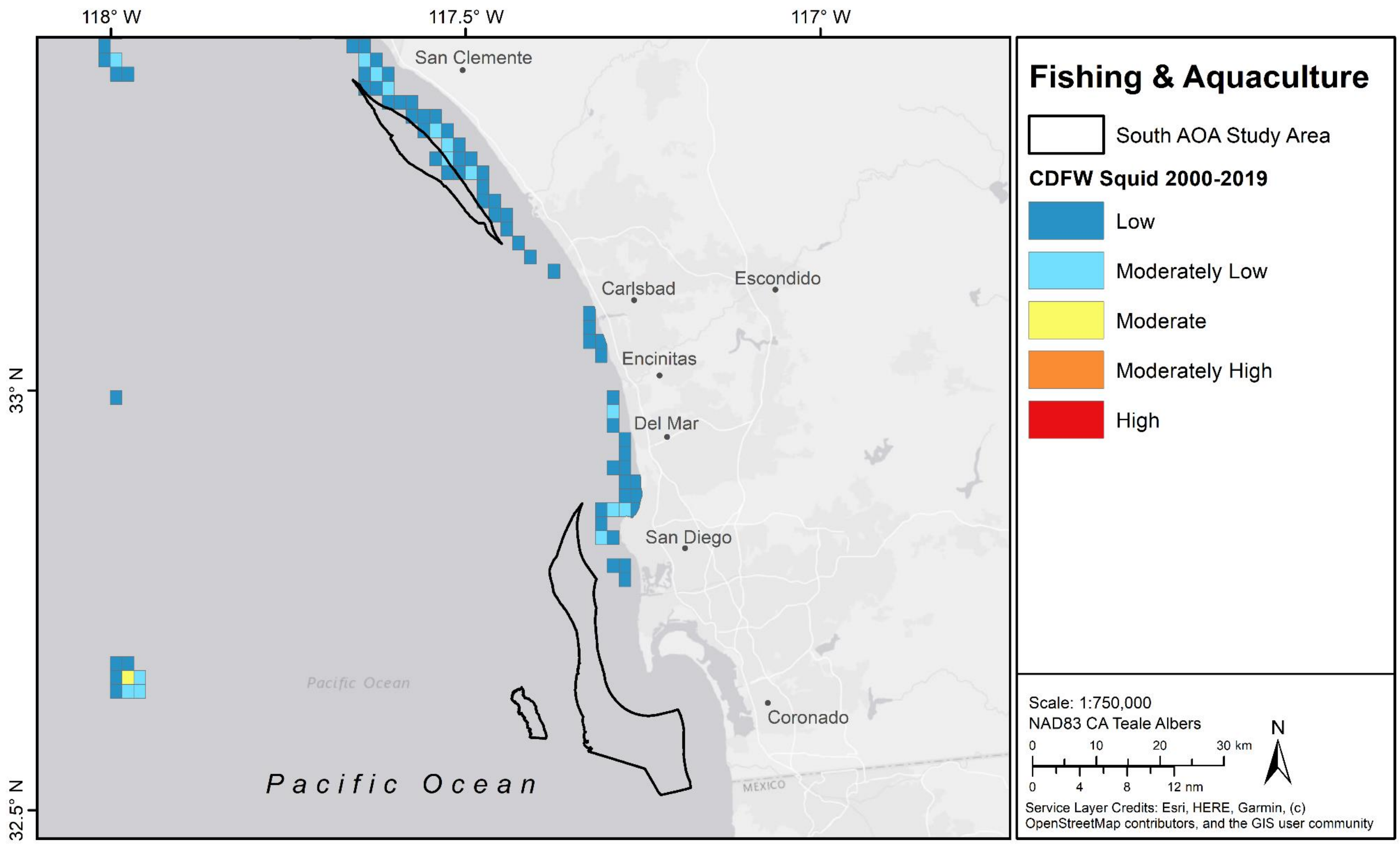

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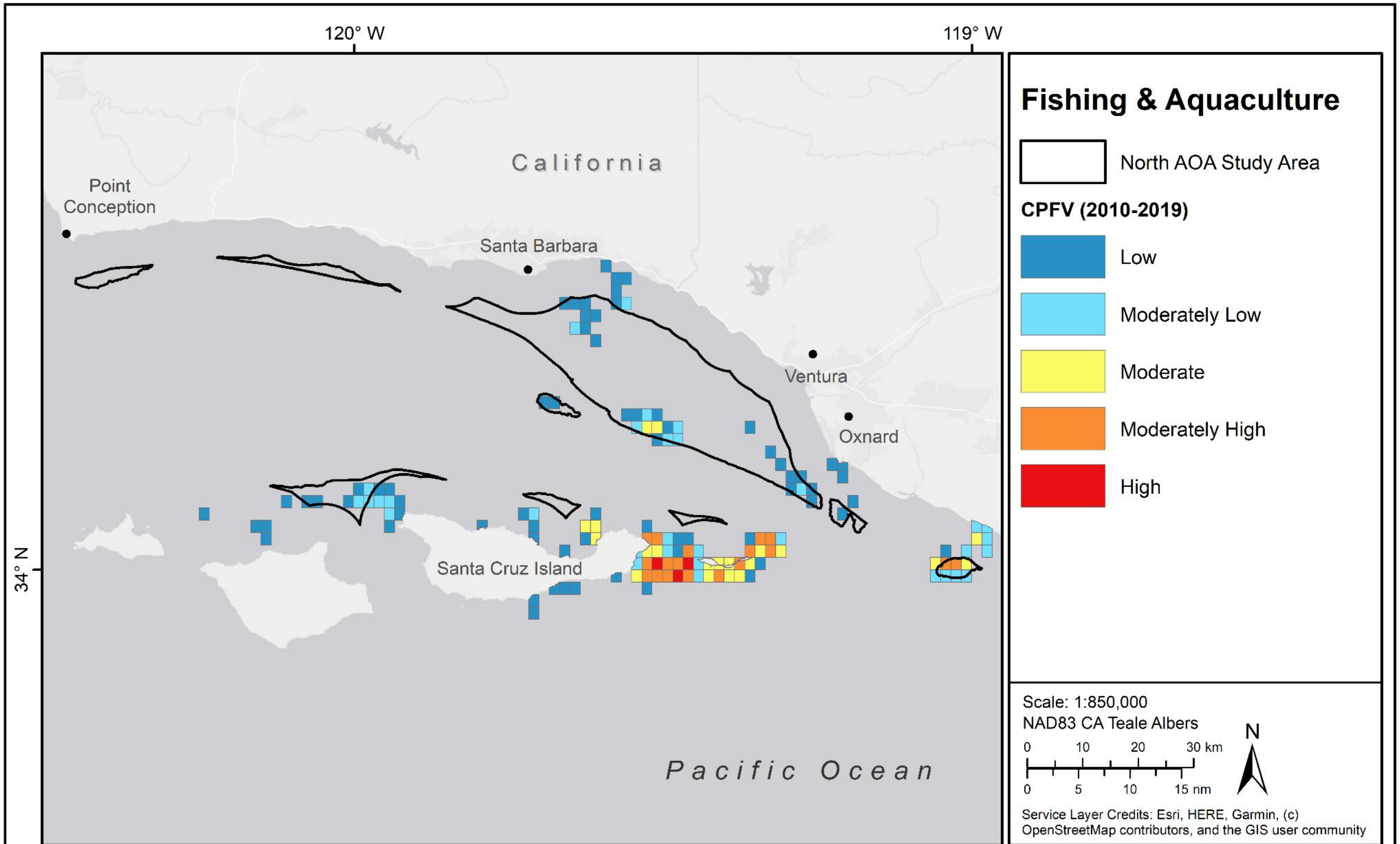
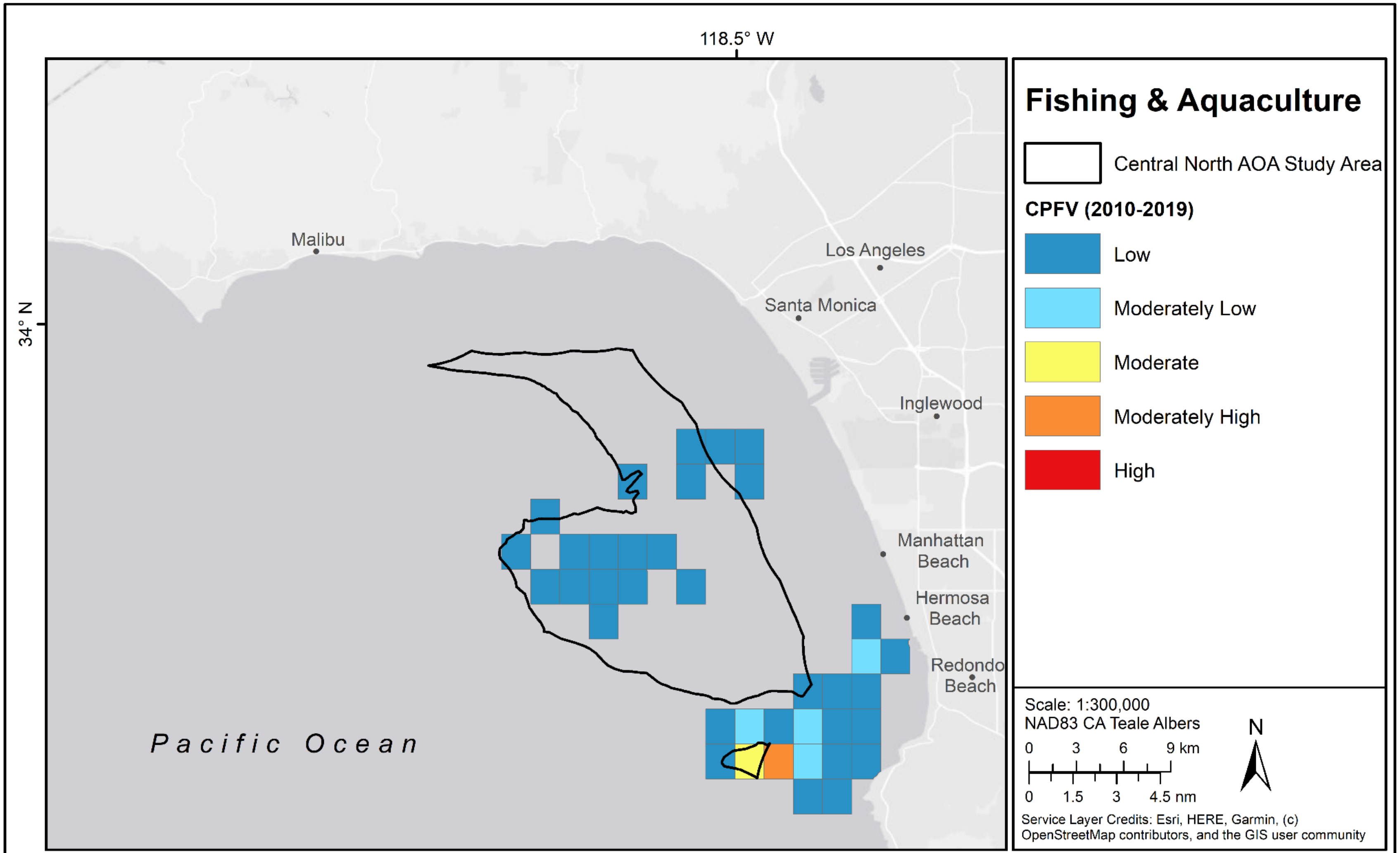


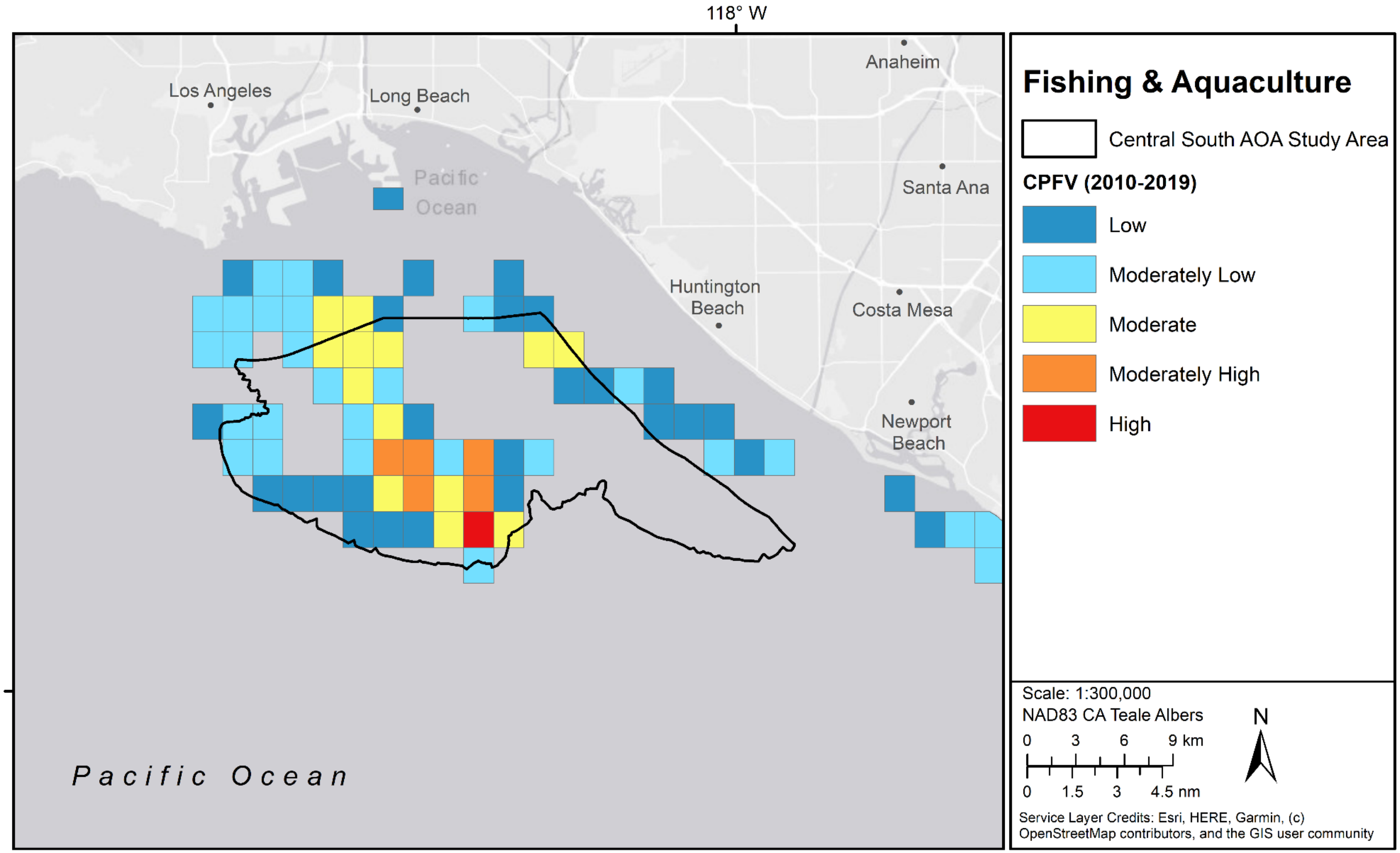
Commercial Passenger Fishing Vessel Fishing 2010-2019: California Department of Fish and Wildlife (2019)

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



Commercial Passenger Fishing Vessel Fishing 2010-2019: California Department of Fish and Wildlife (2019)

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



Commercial Passenger Fishing Vessel Fishing 2010-2019: California Department of Fish and Wildlife (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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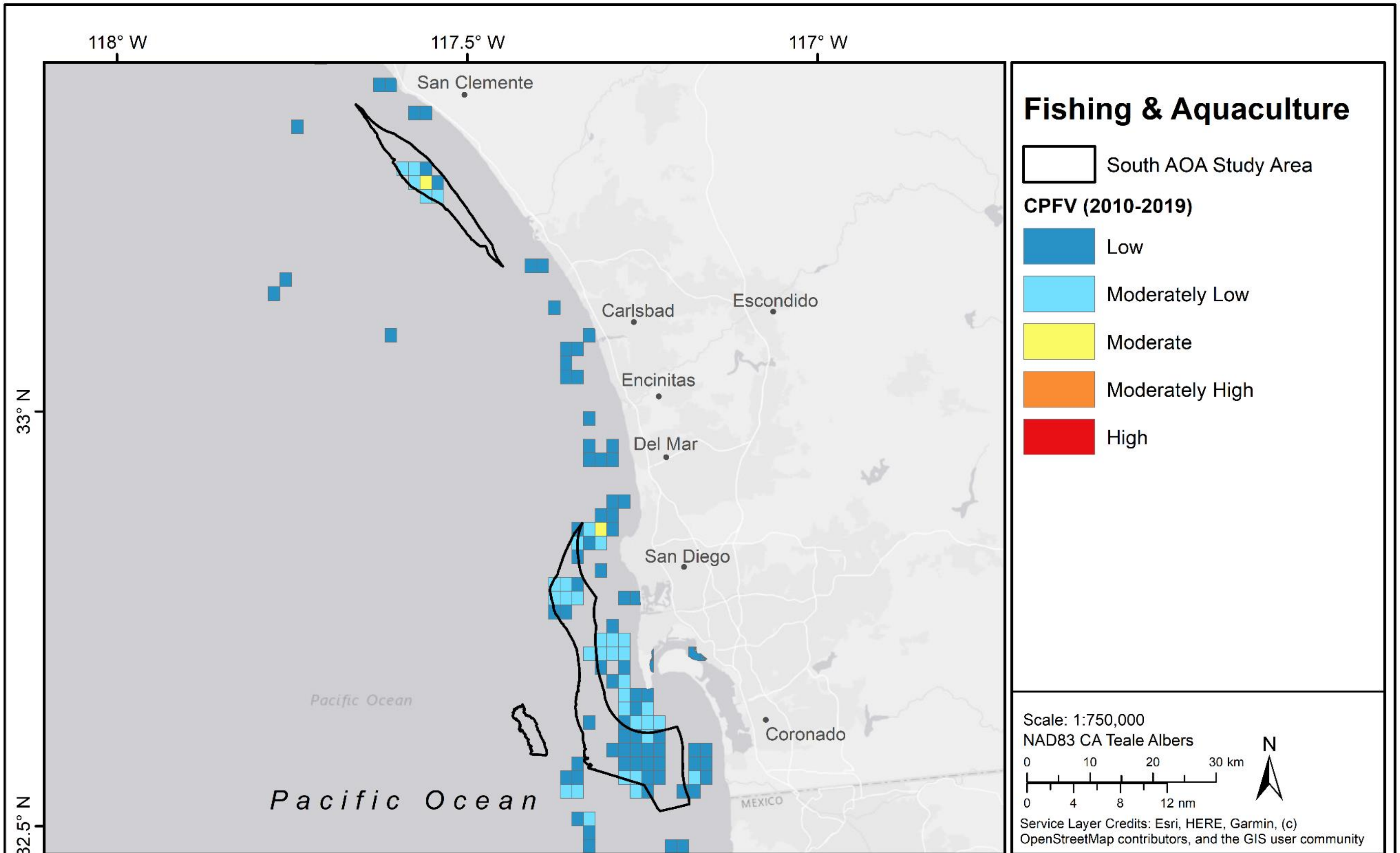

Commercial Passenger Fishing Vessel Fishing 2010-2019: California Department of Fish and Wildlife (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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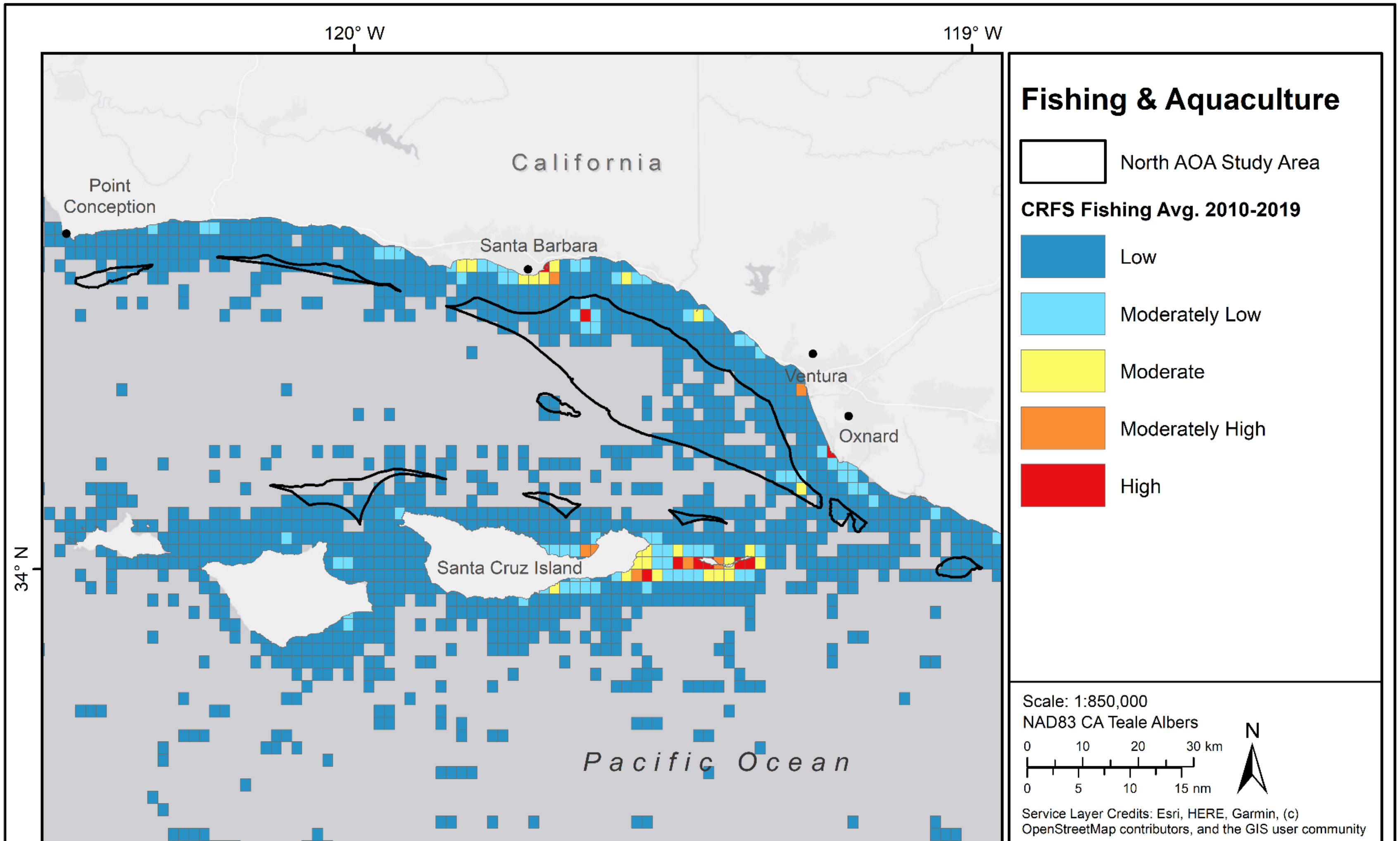
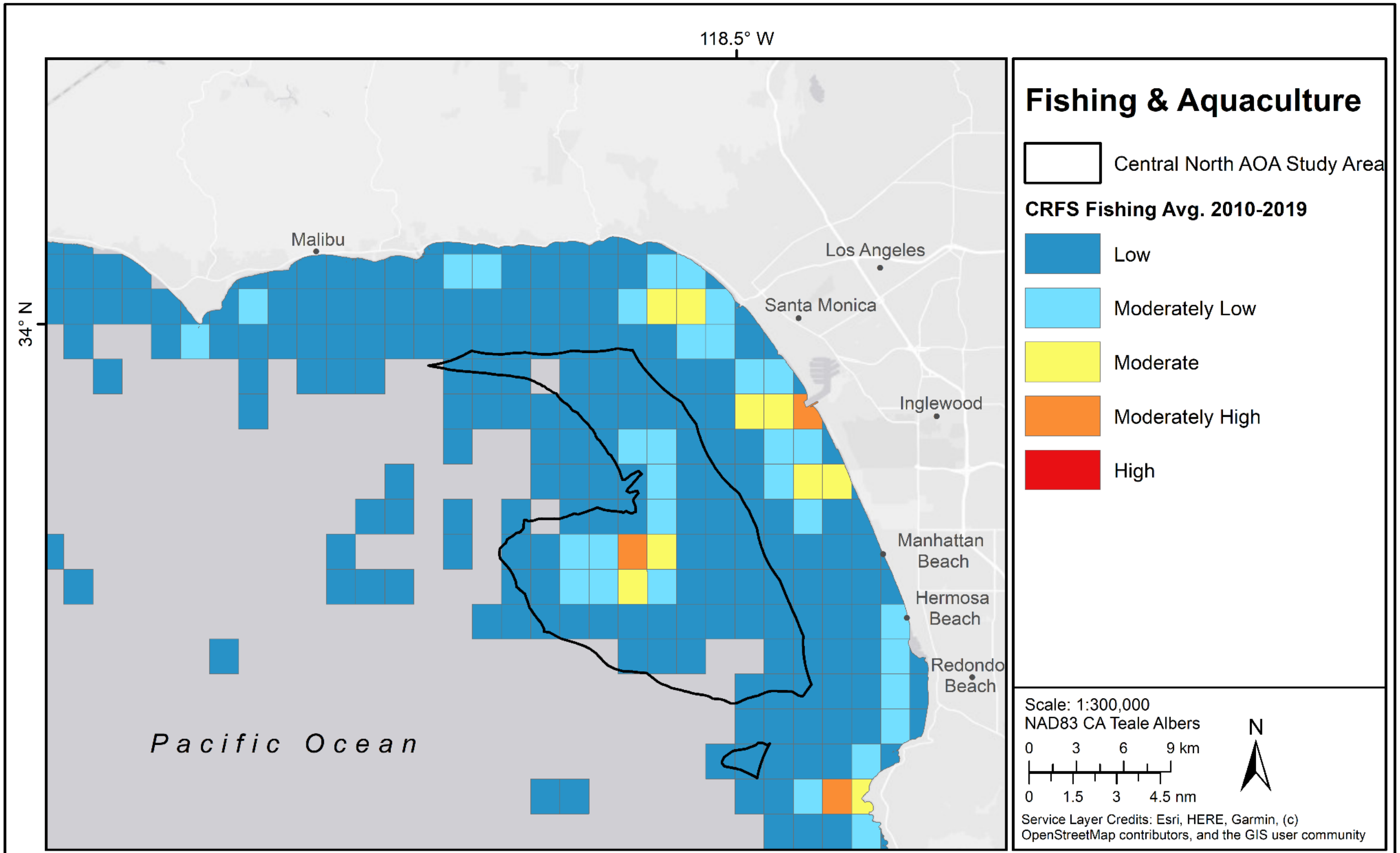


California Recreational Fisheries Survey 2010-2019: California Department of Fish and Wildlife (2019)

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



California Recreational Fisheries Survey 2010-2019: California Department of Fish and Wildlife (2019)

Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
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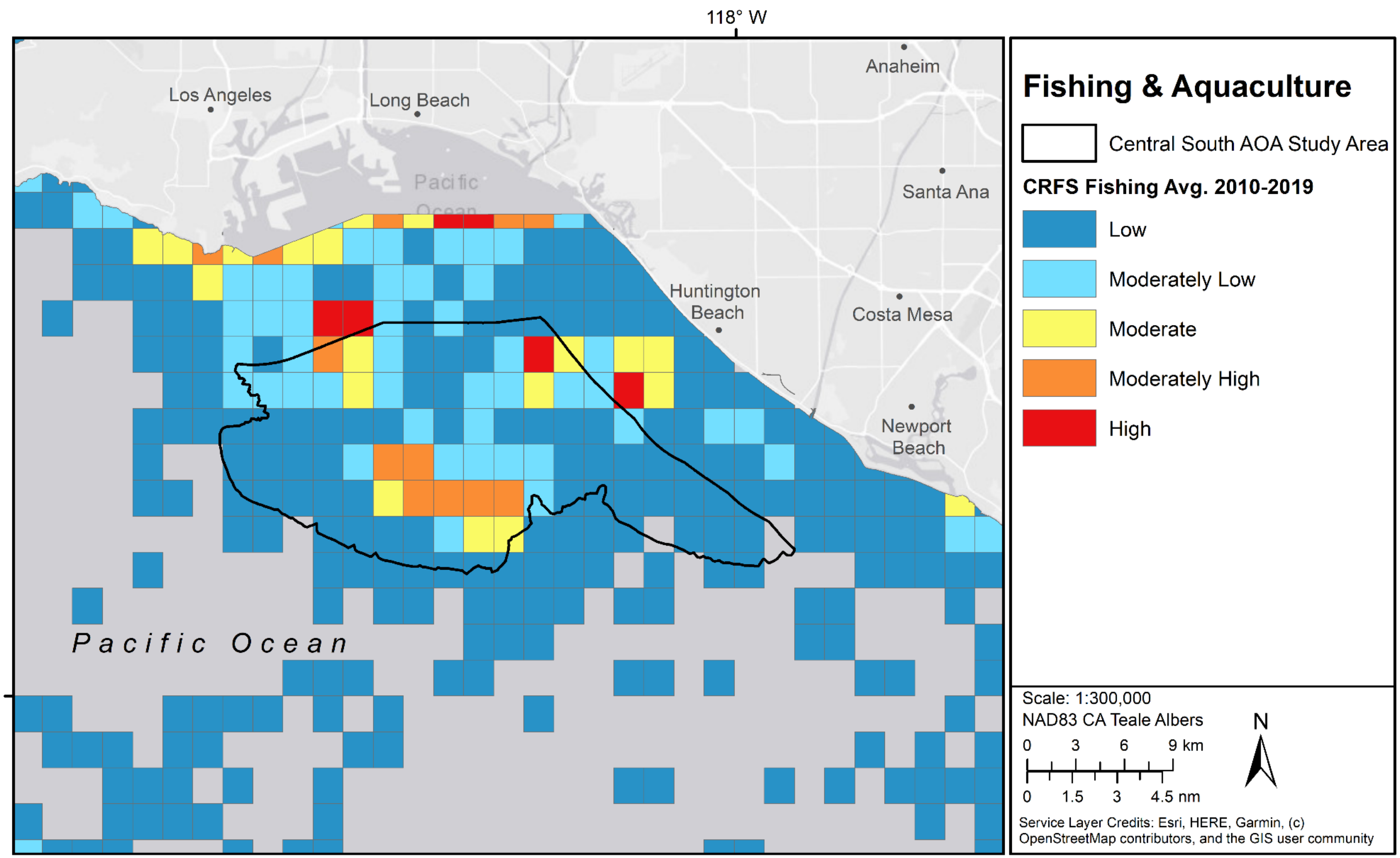

California Recreational Fisheries Survey 2010-2019: California Department of Fish and Wildlife (2019)

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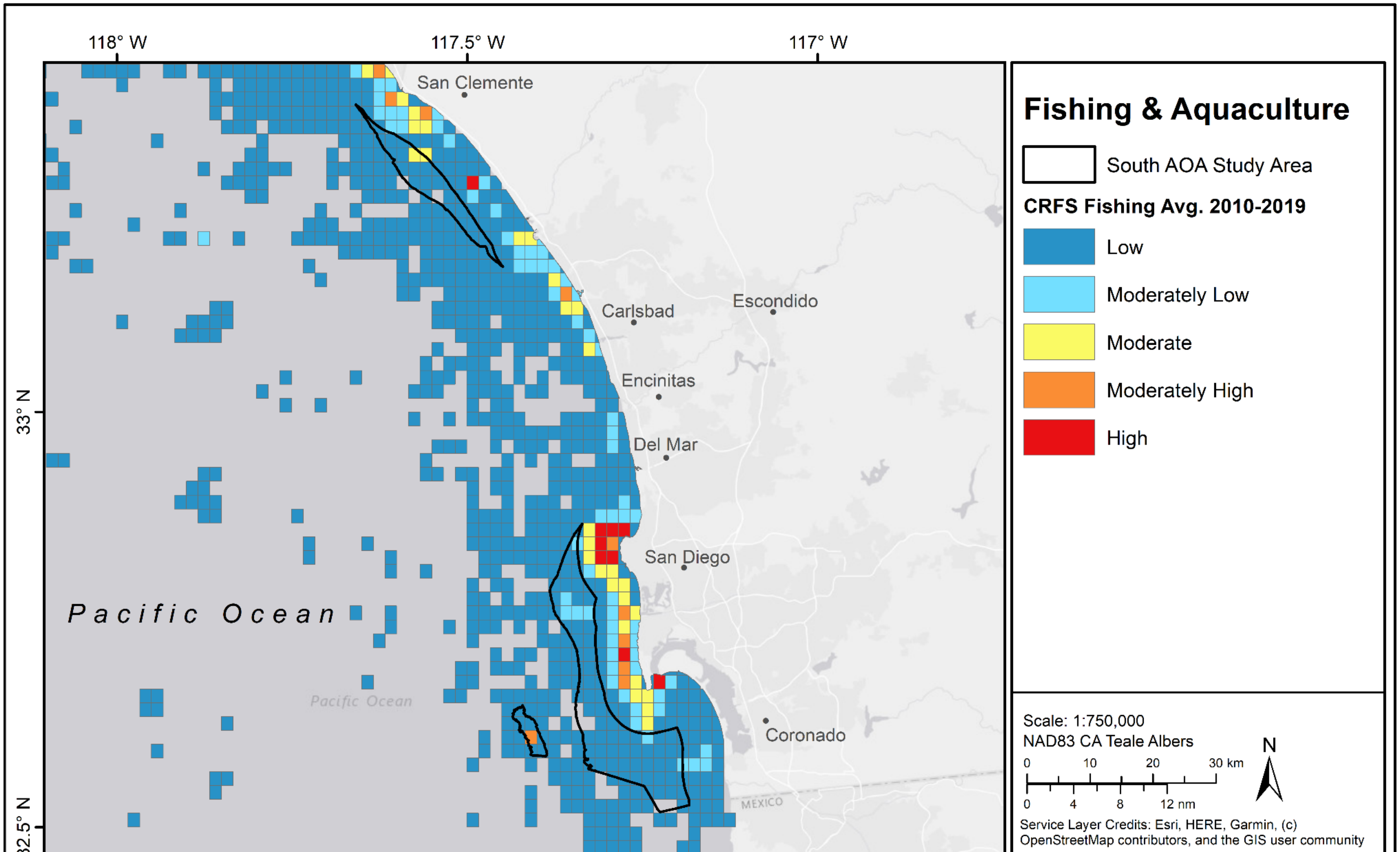
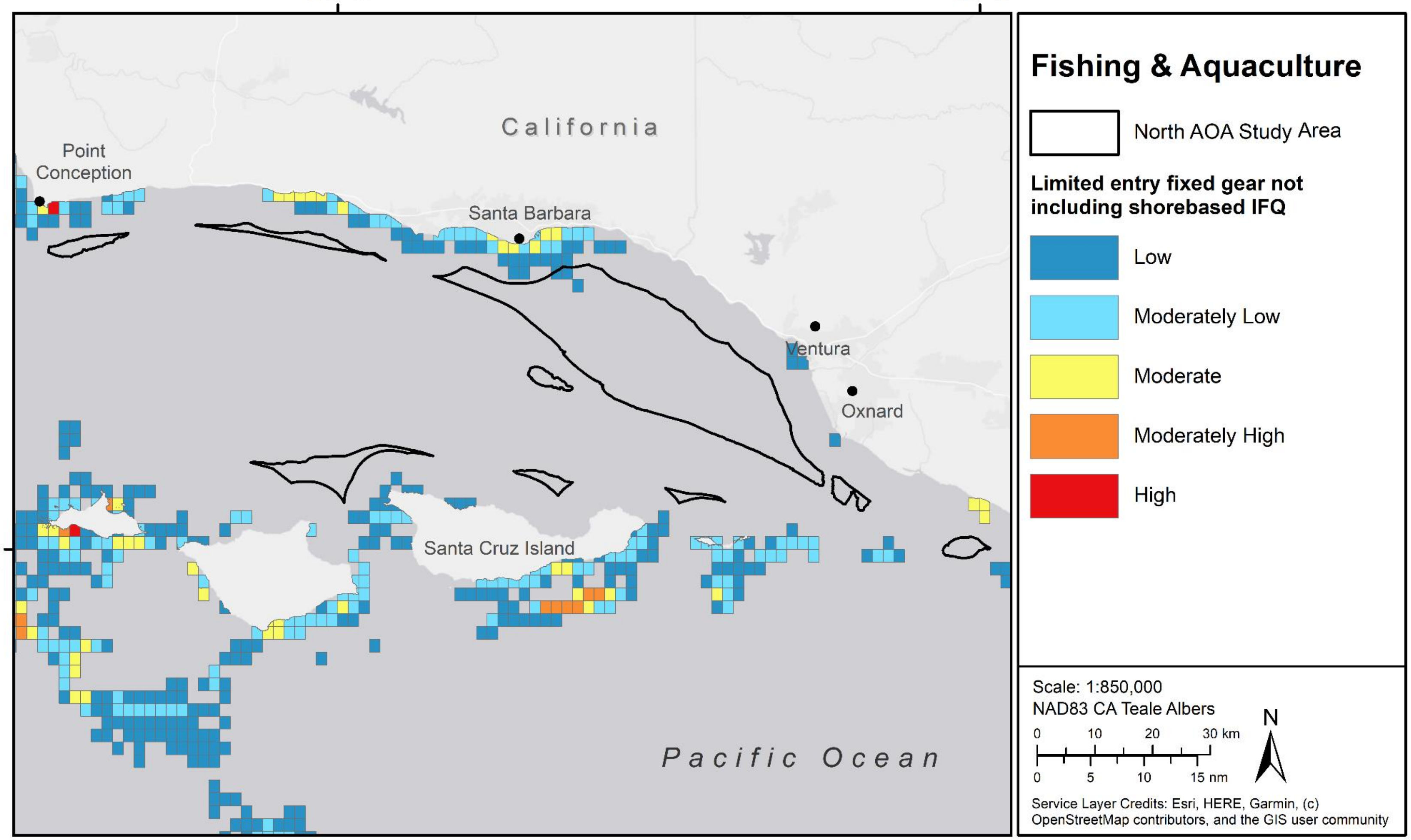
National Centers for Coastal Ocean Science
National Ocean Service



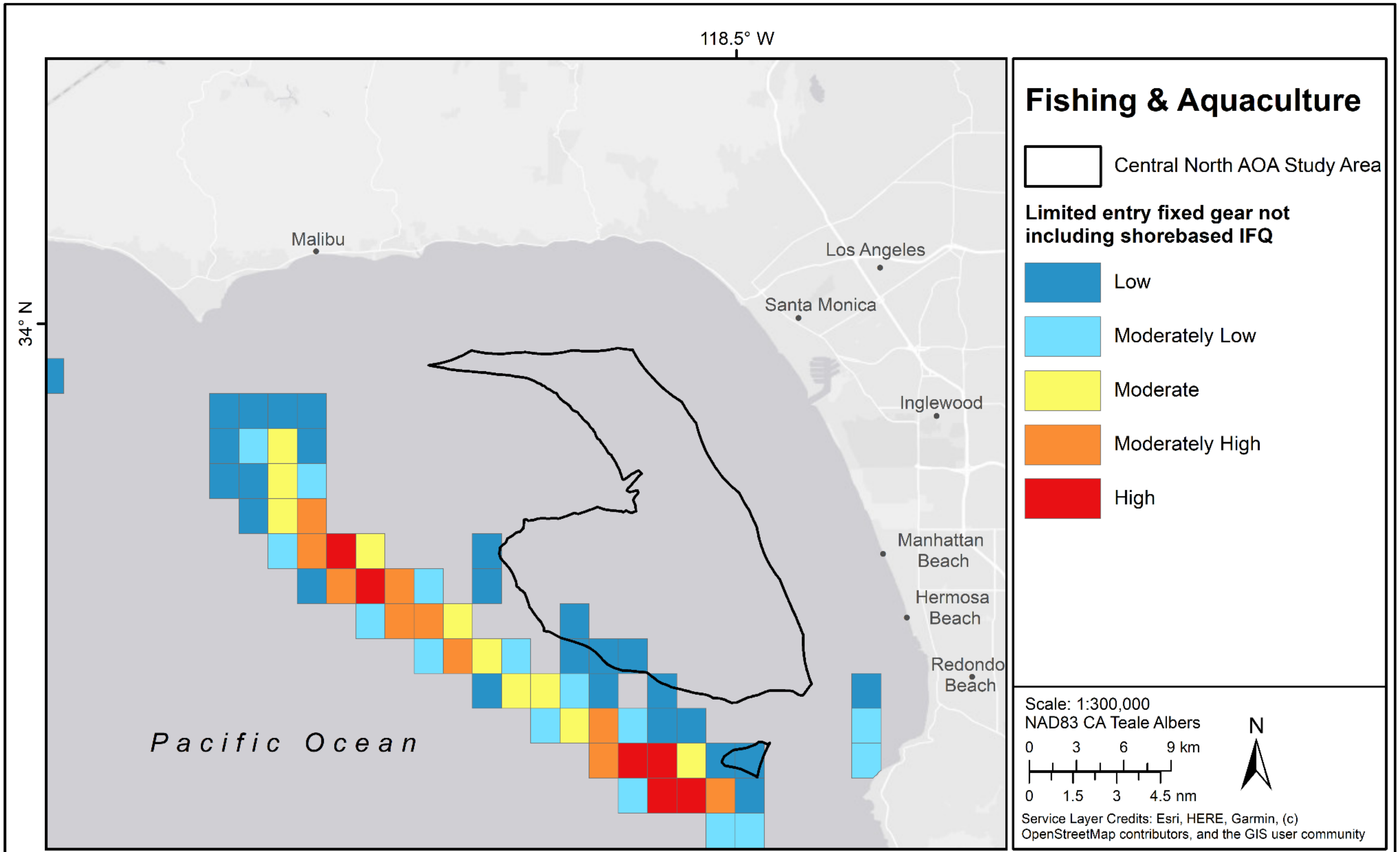
California Recreational Fisheries Survey 2010-2019: California Department of Fish and Wildlife (2019)

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



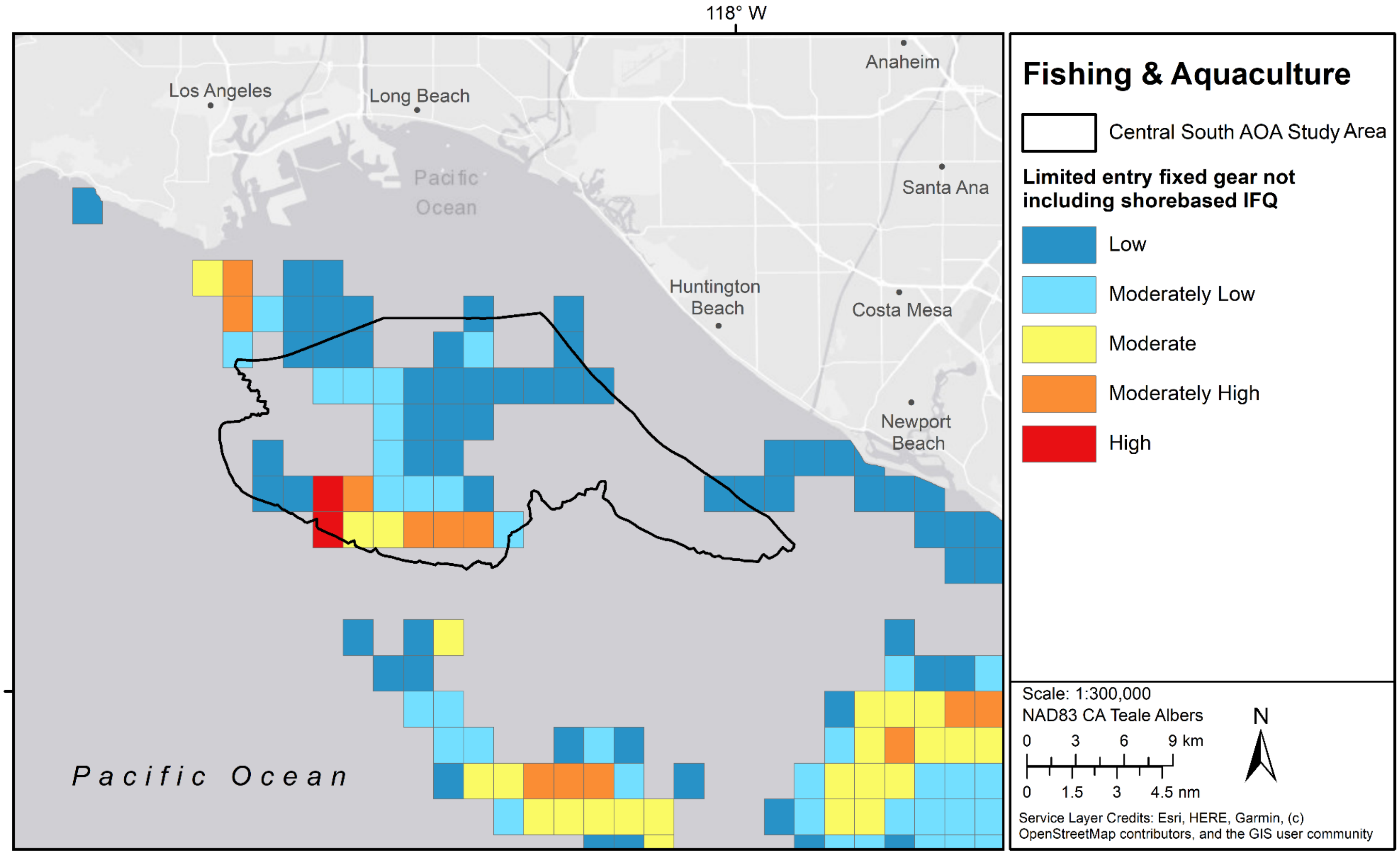
VMS 210 Limited entry fixed gear not including shorebased IFQ: NOAA - OLE (2017)

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



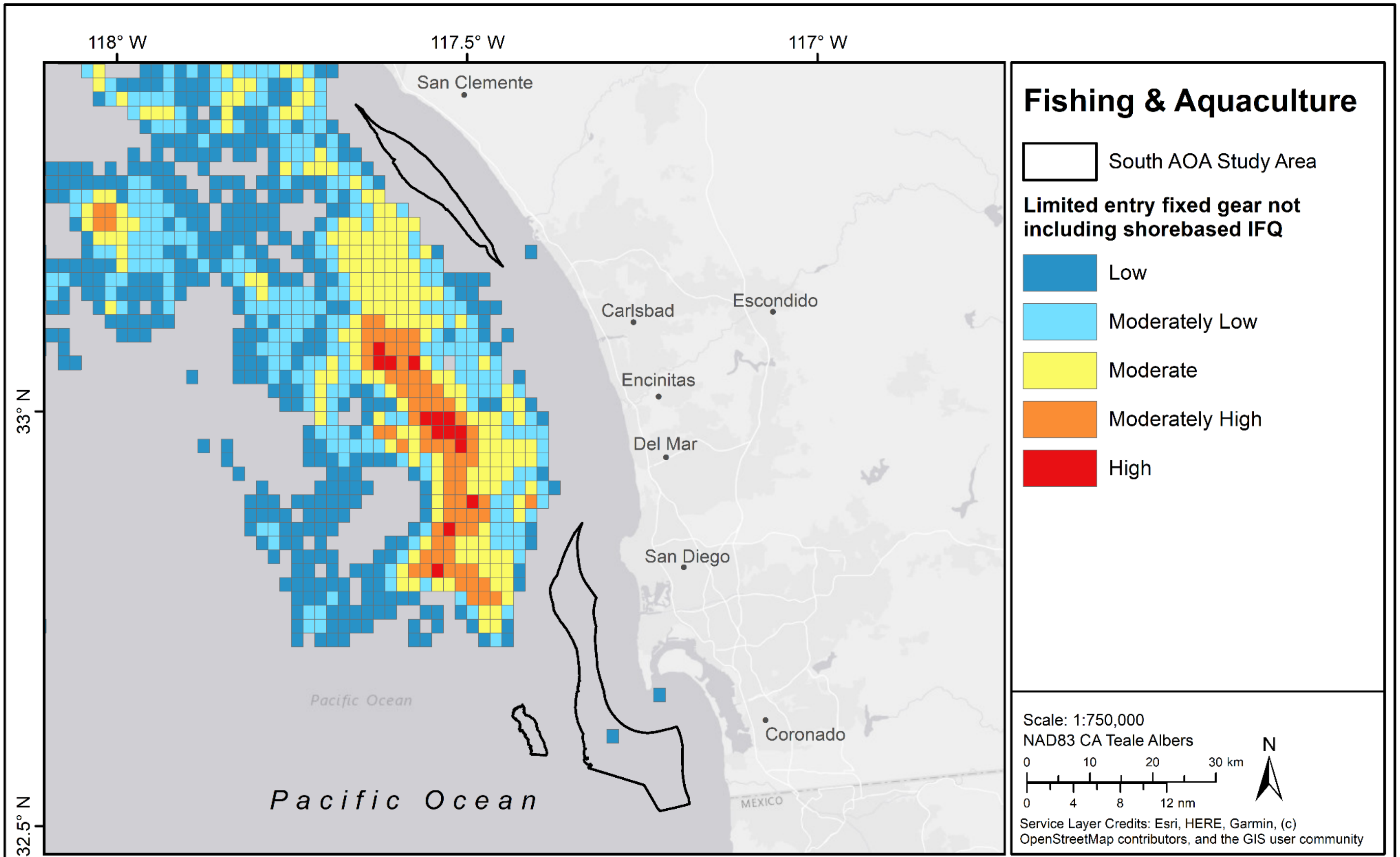
VMS 210 Limited entry fixed gear not including shorebased IFQ 2010-2017: NOAA - OLE (2017)

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



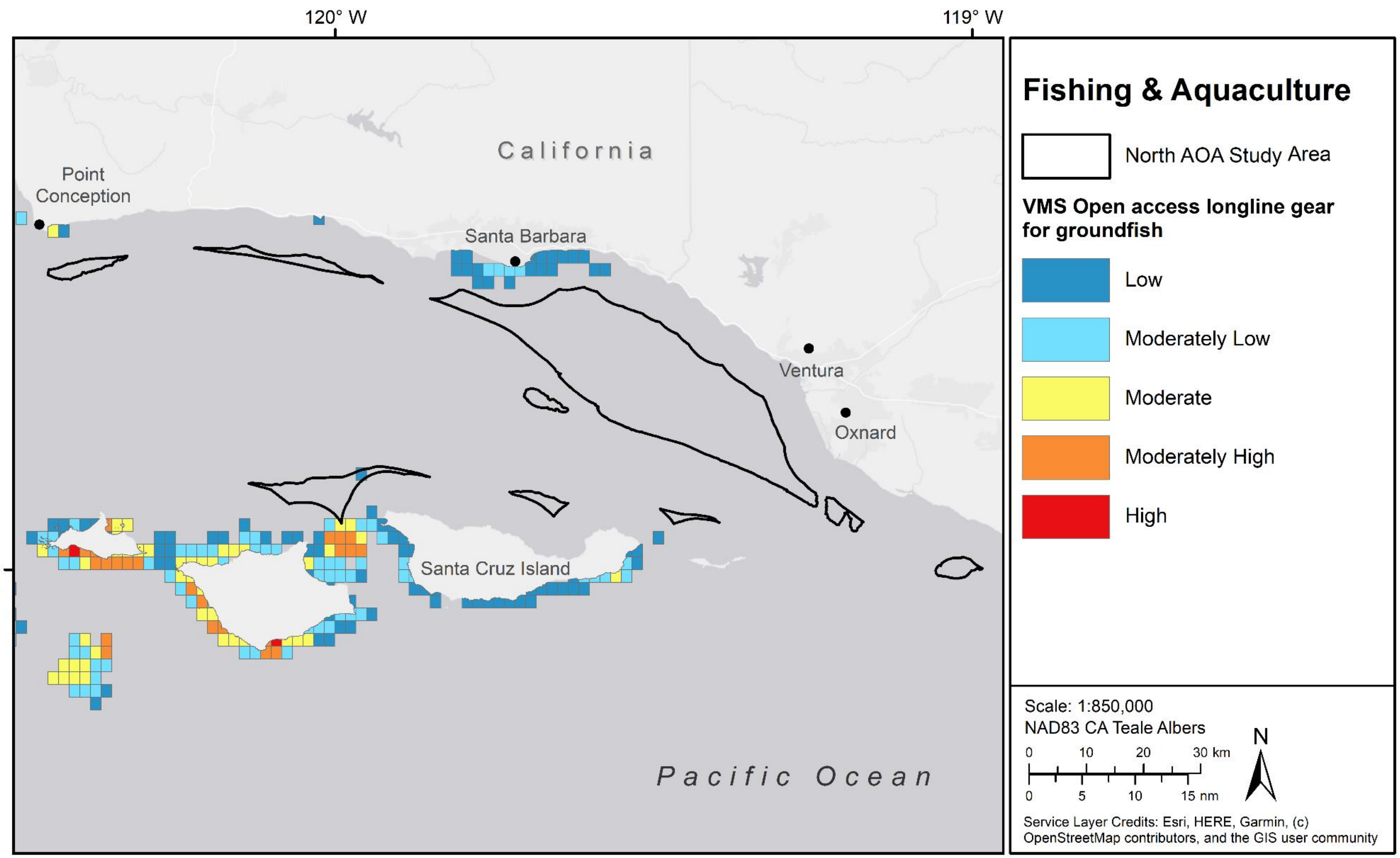
VMS 210 Limited entry fixed gear not including shorebased IFQ 2010-2017: NOAA - OLE (2017)

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



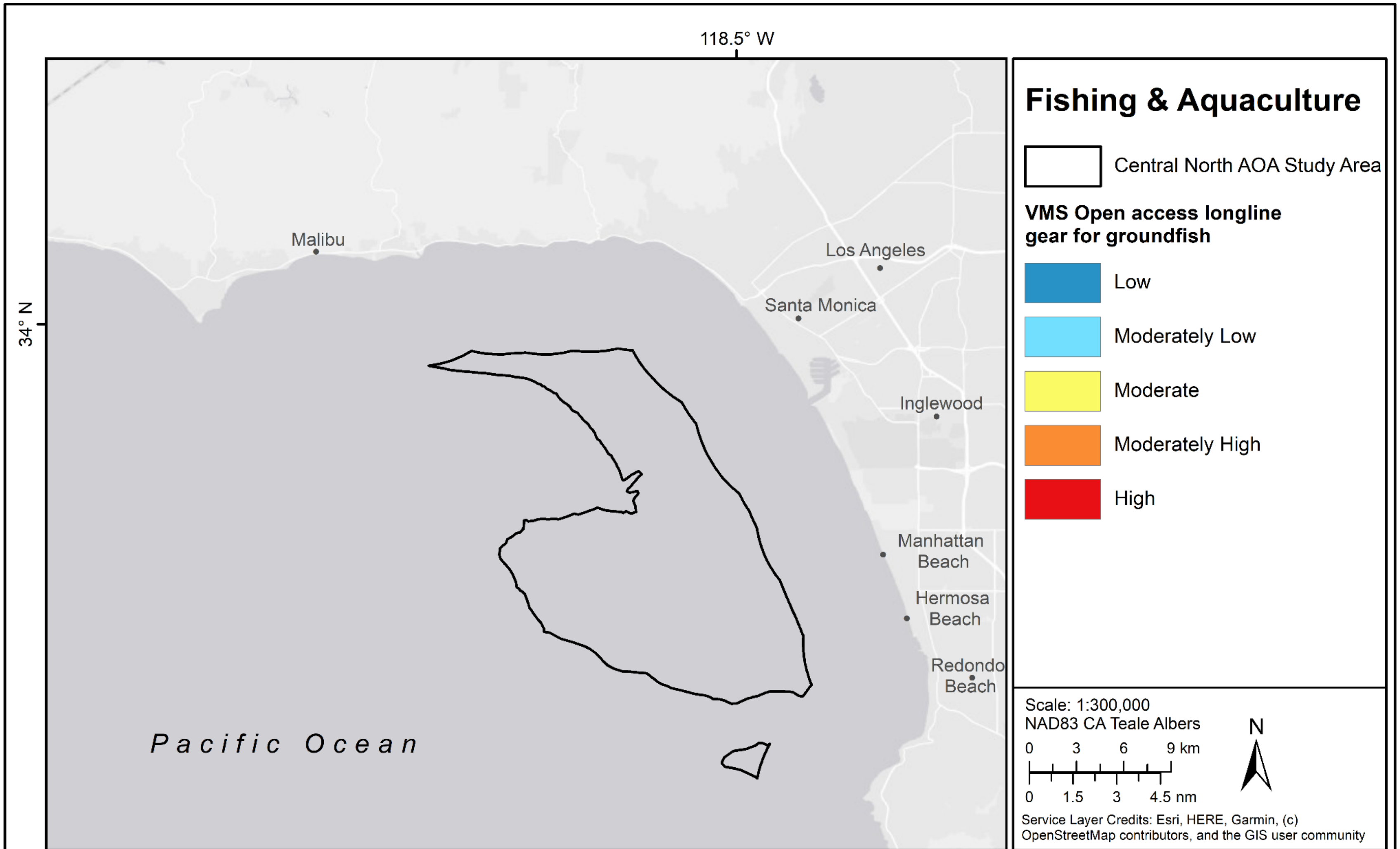
VMS 210 Limited entry fixed gear not including shorebased IFQ 2010-2017: NOAA - OLE (2017)

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



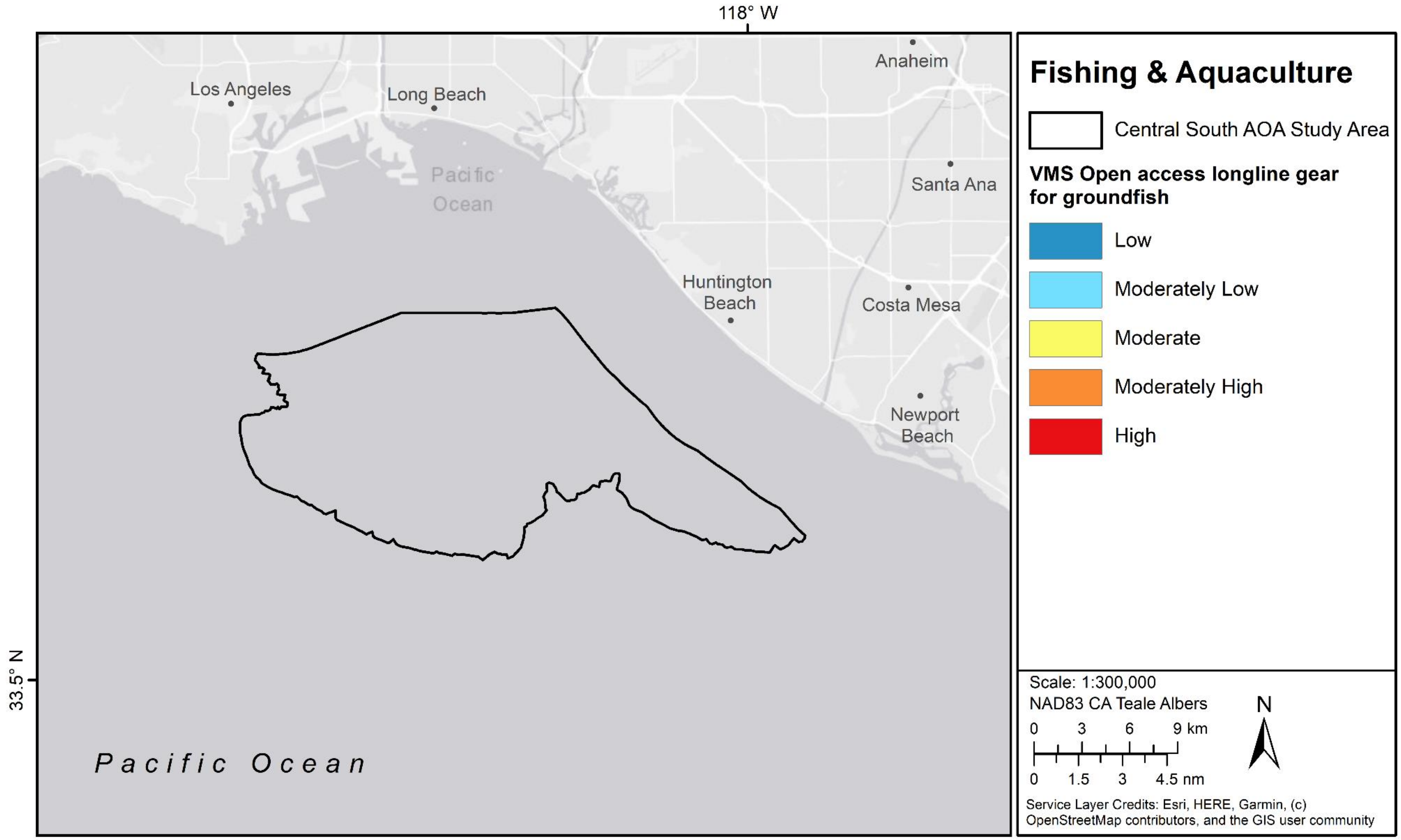
VMS 233 Open access longline gear for groundfish: NOAA - OLE (2017)

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



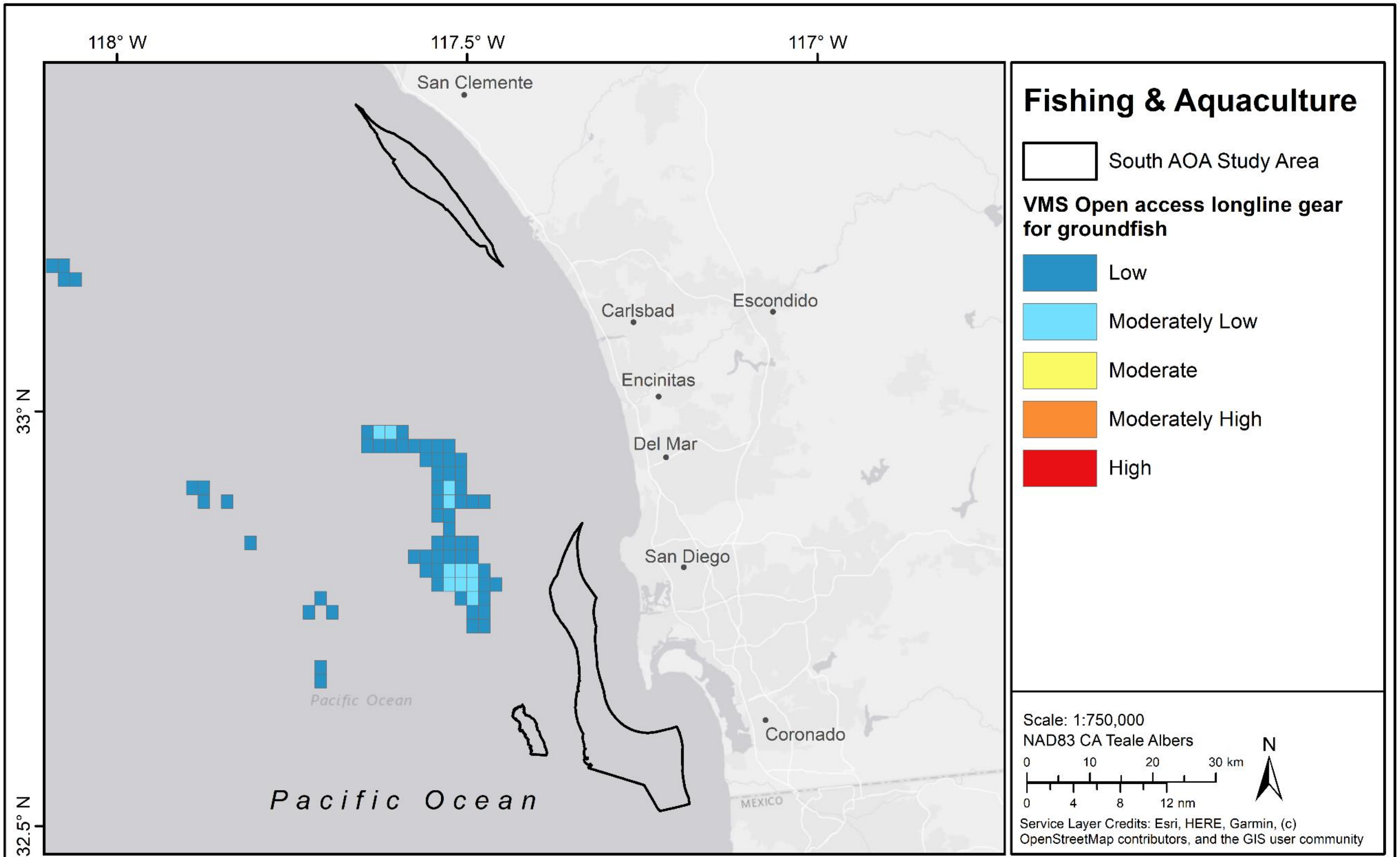
VMS 233 Open access longline gear for groundfish 2010-2017: NOAA - OLE (2017)

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



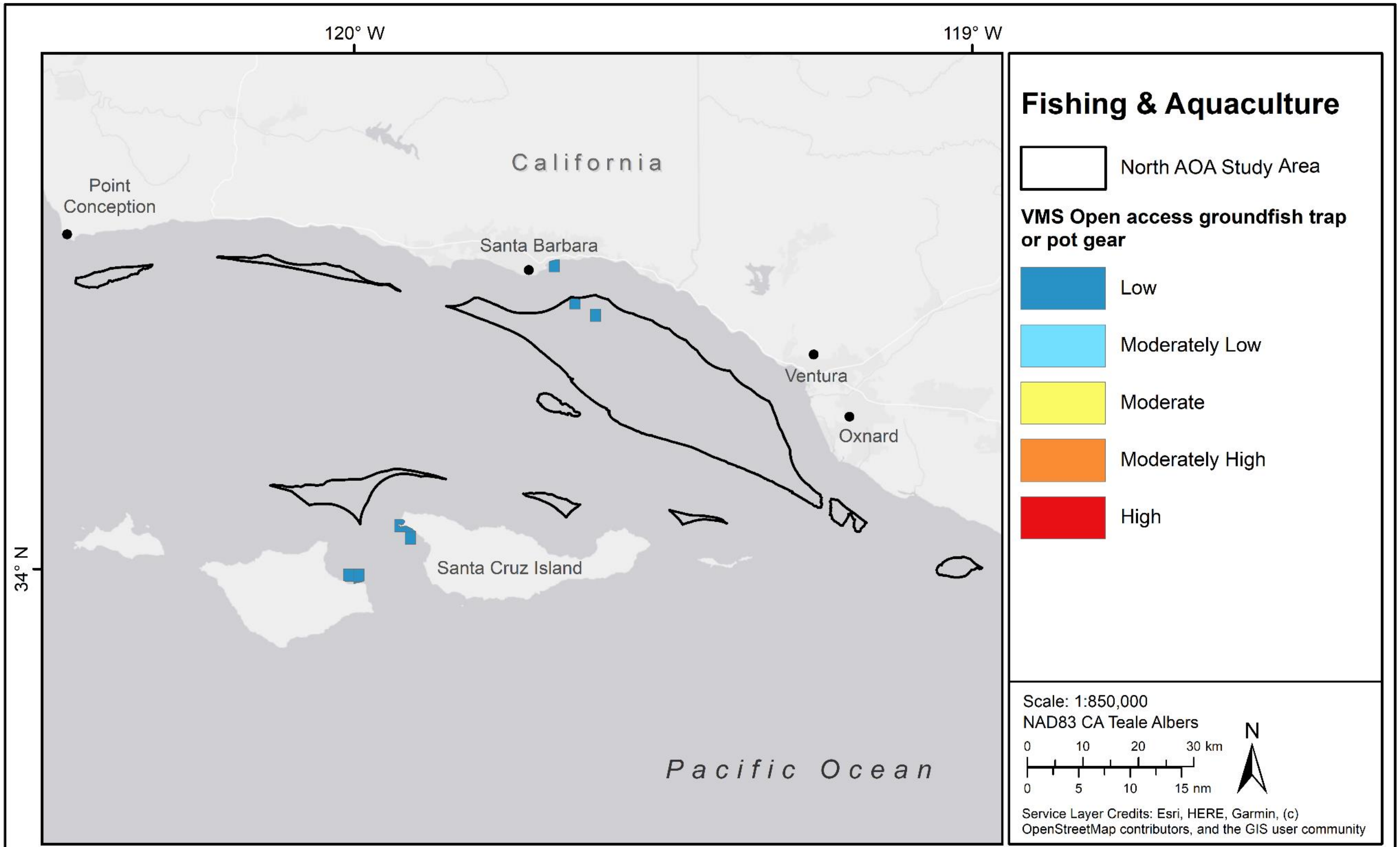
VMS 233 Open access longline gear for groundfish 2010-2017: NOAA - OLE (2017)

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



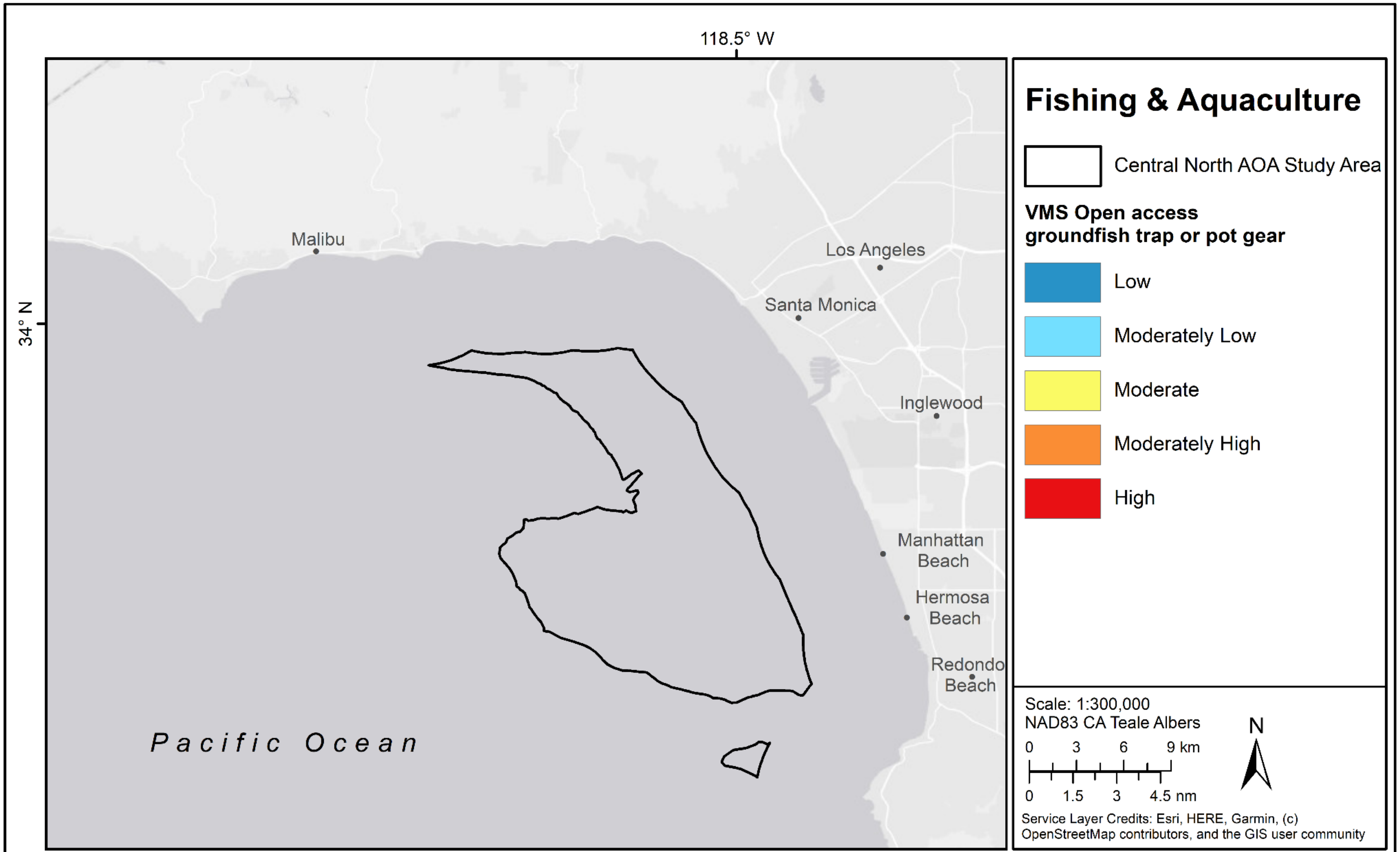
VMS 233 Open access longline gear for groundfish 2010-2017: NOAA - OLE (2017)

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



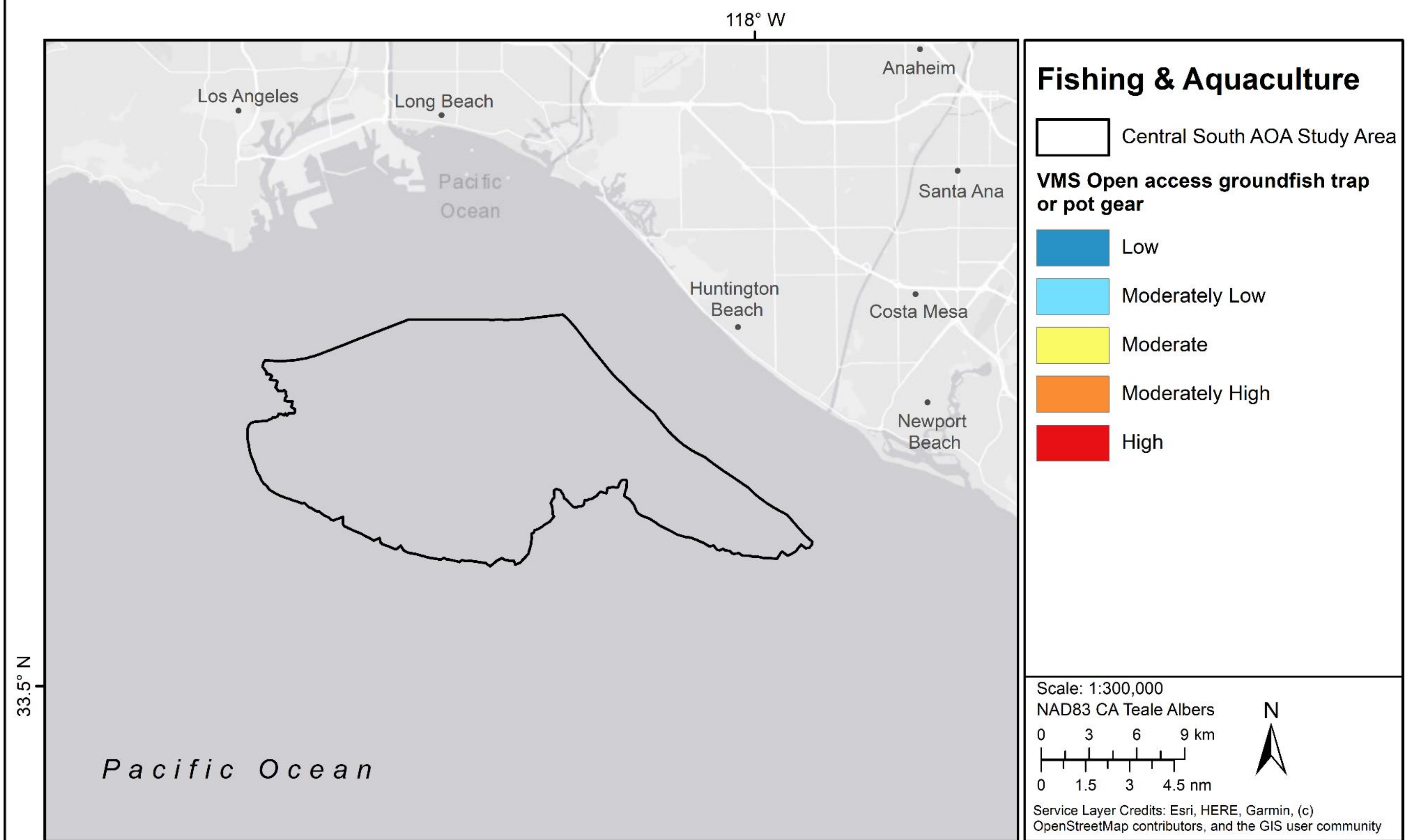
VMS 234 Open access groundfish trap or pot gear: NOAA - OLE (2017)

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



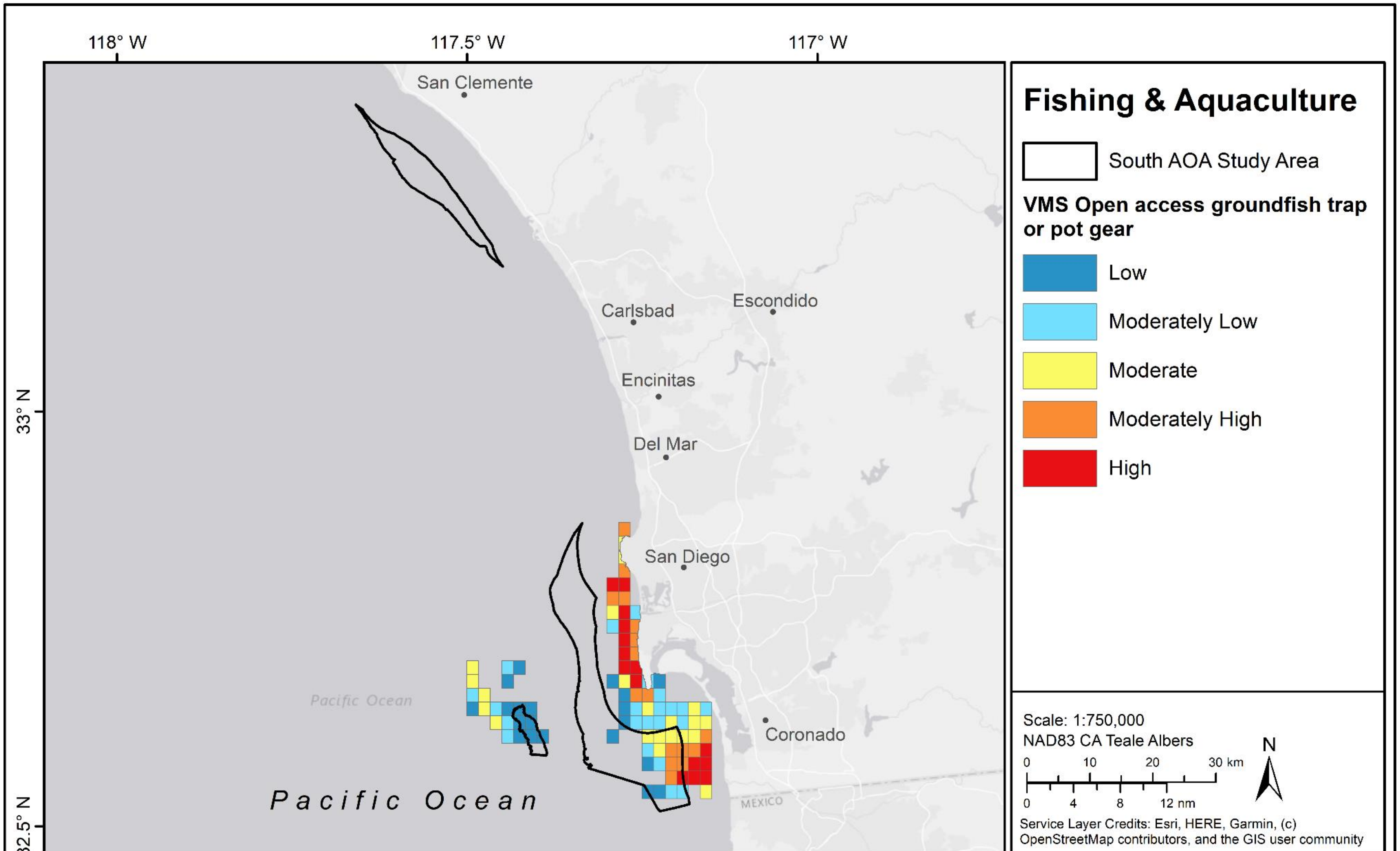
VMS 234 Open access groundfish trap or pot gear 2010-2017: NOAA - OLE (2017)

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



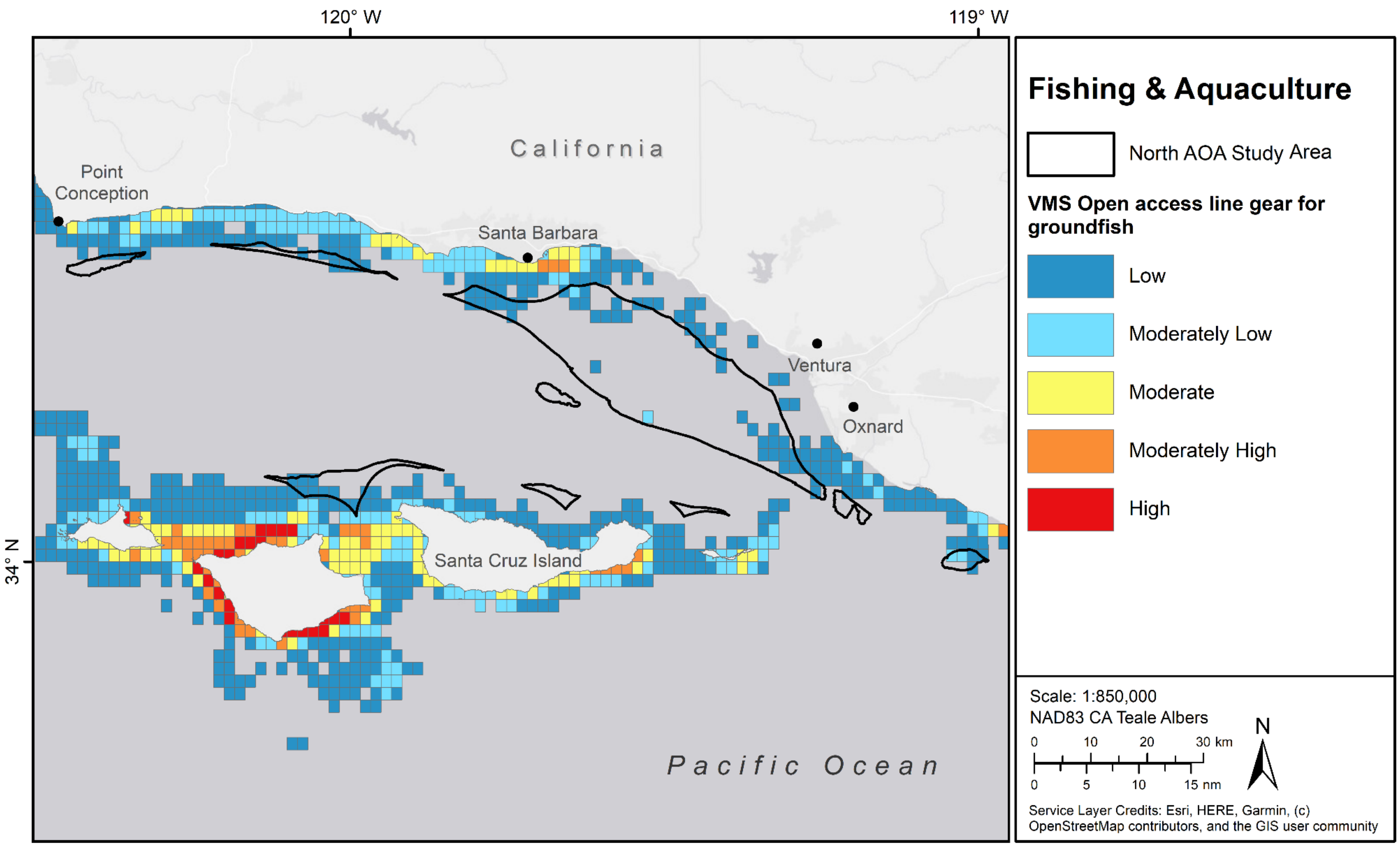
VMS 234 Open access groundfish trap or pot gear 2010-2017: NOAA - OLE (2017)

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



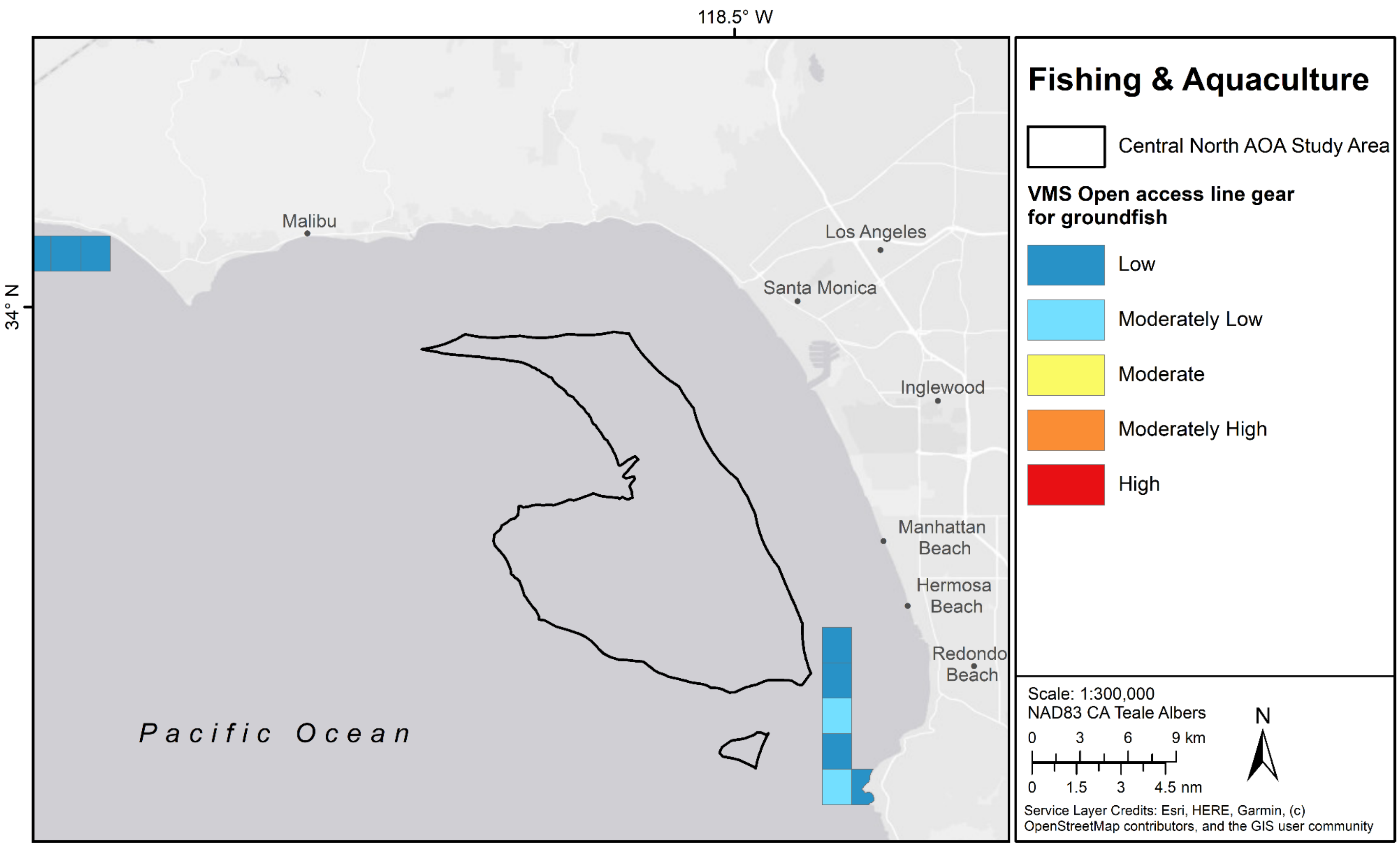
VMS 234 Open access groundfish trap or pot gear 2010-2017: NOAA - OLE (2017)

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



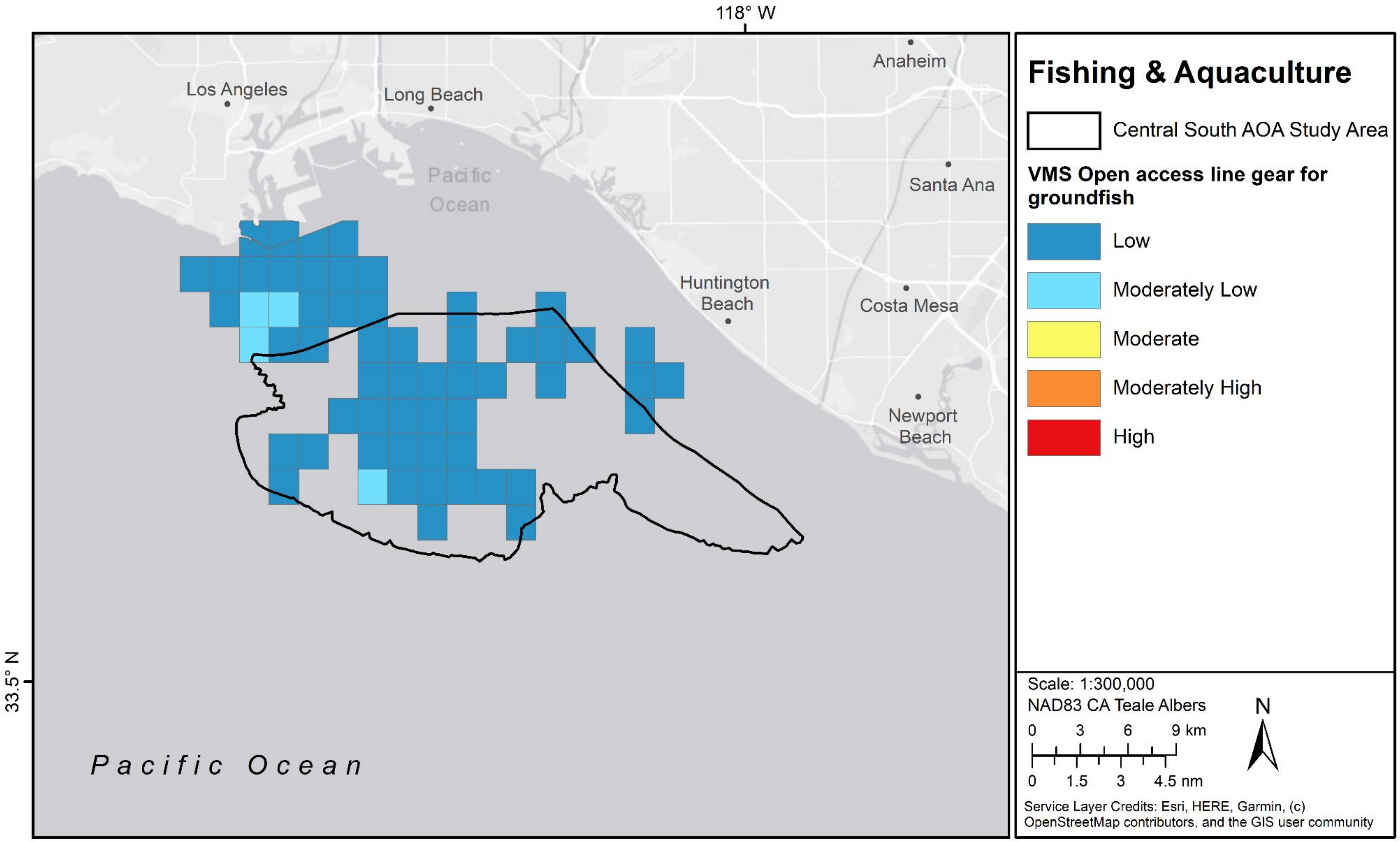
VMS 235 Open access line gear for groundfish: NOAA - OLE (2017)

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



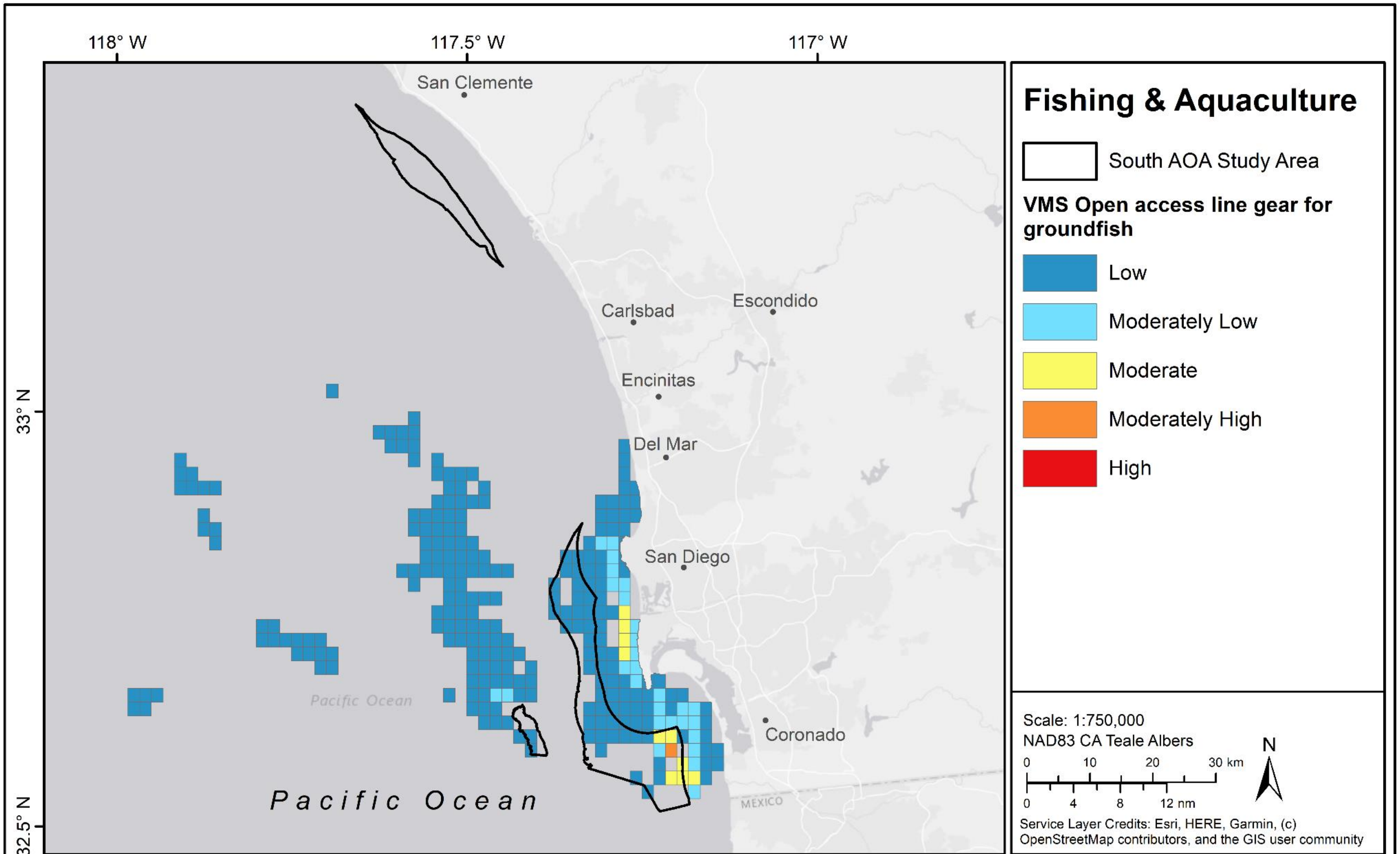
VMS 235 Open access line gear for groundfish 2010-2017: NOAA - OLE (2017)

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



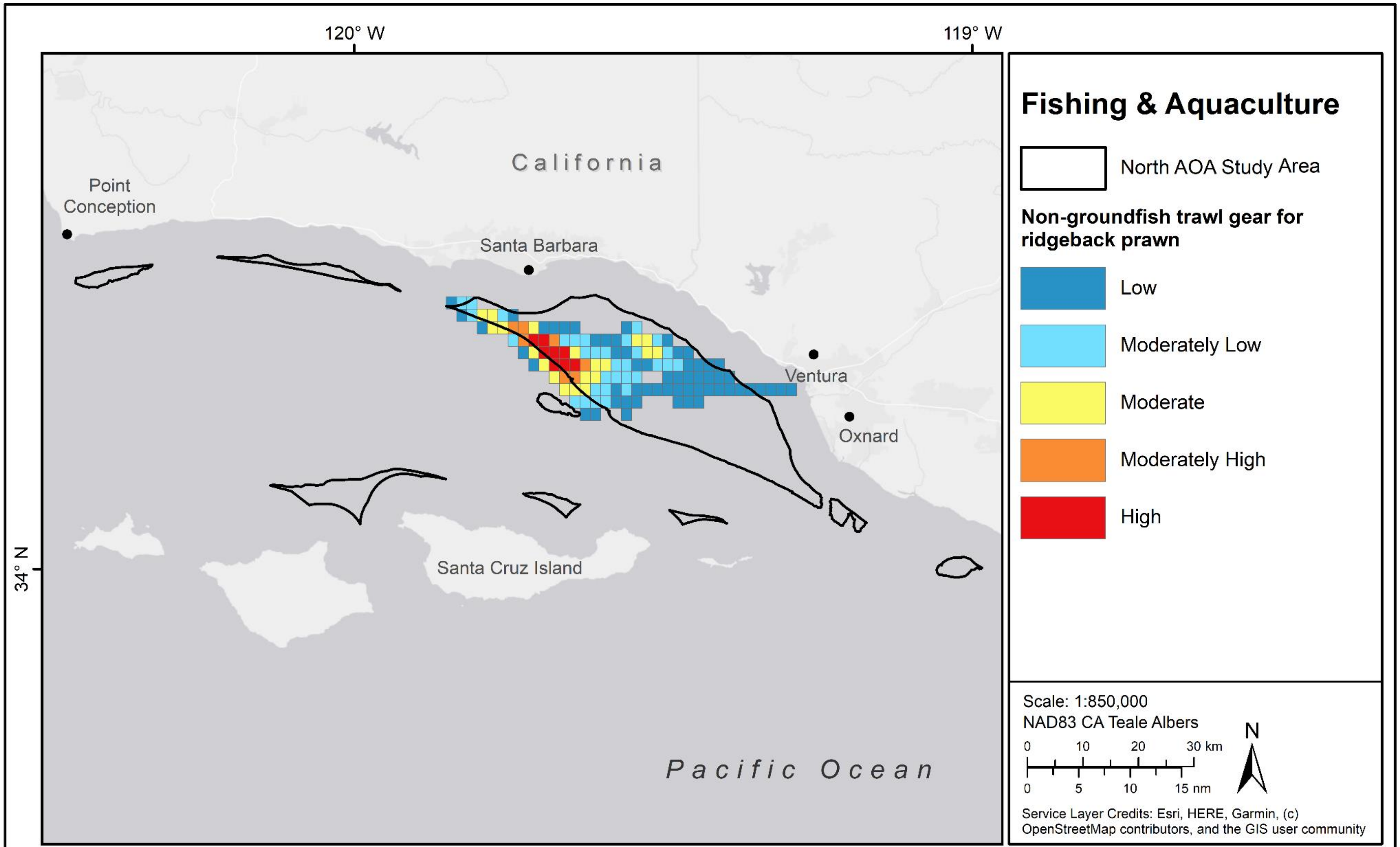
VMS 235 Open access line gear for groundfish 2010-2017: NOAA - OLE (2017)

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



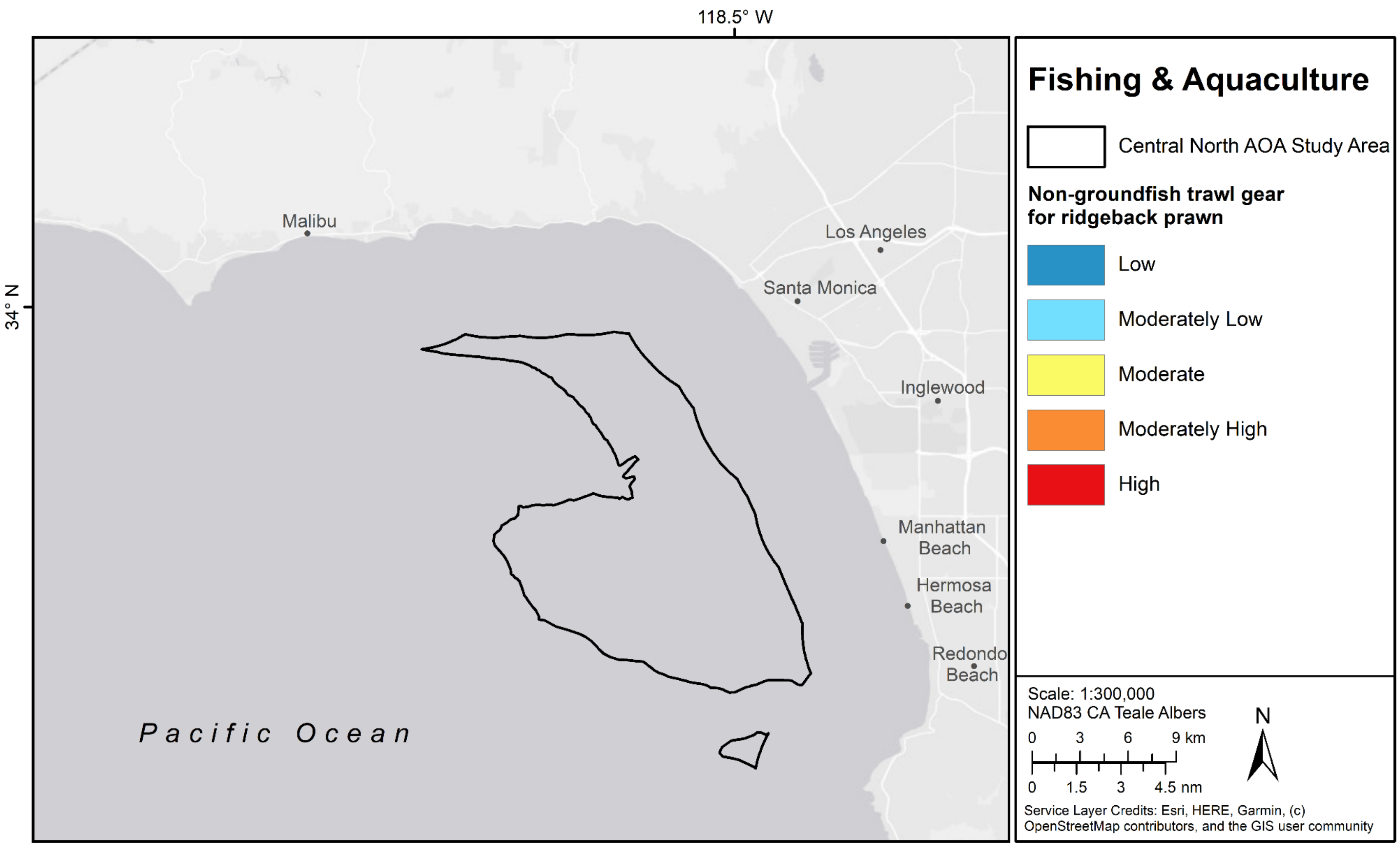
VMS 235 Open access line gear for groundfish 2010-2017: NOAA - OLE (2017)

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



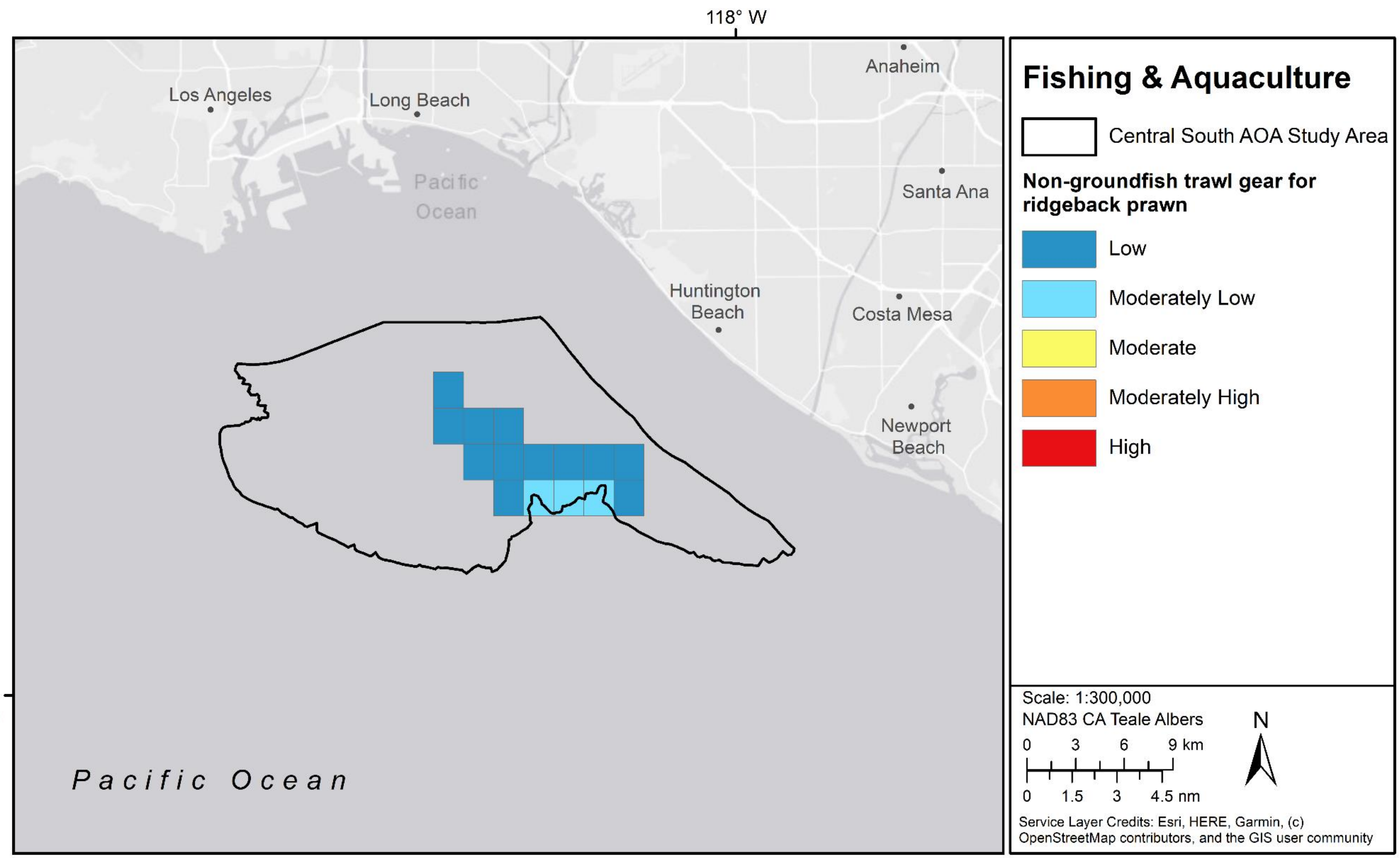
VMS 240 Non-groundfish trawl gear for ridgeback prawn: NOAA - OLE (2017)

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



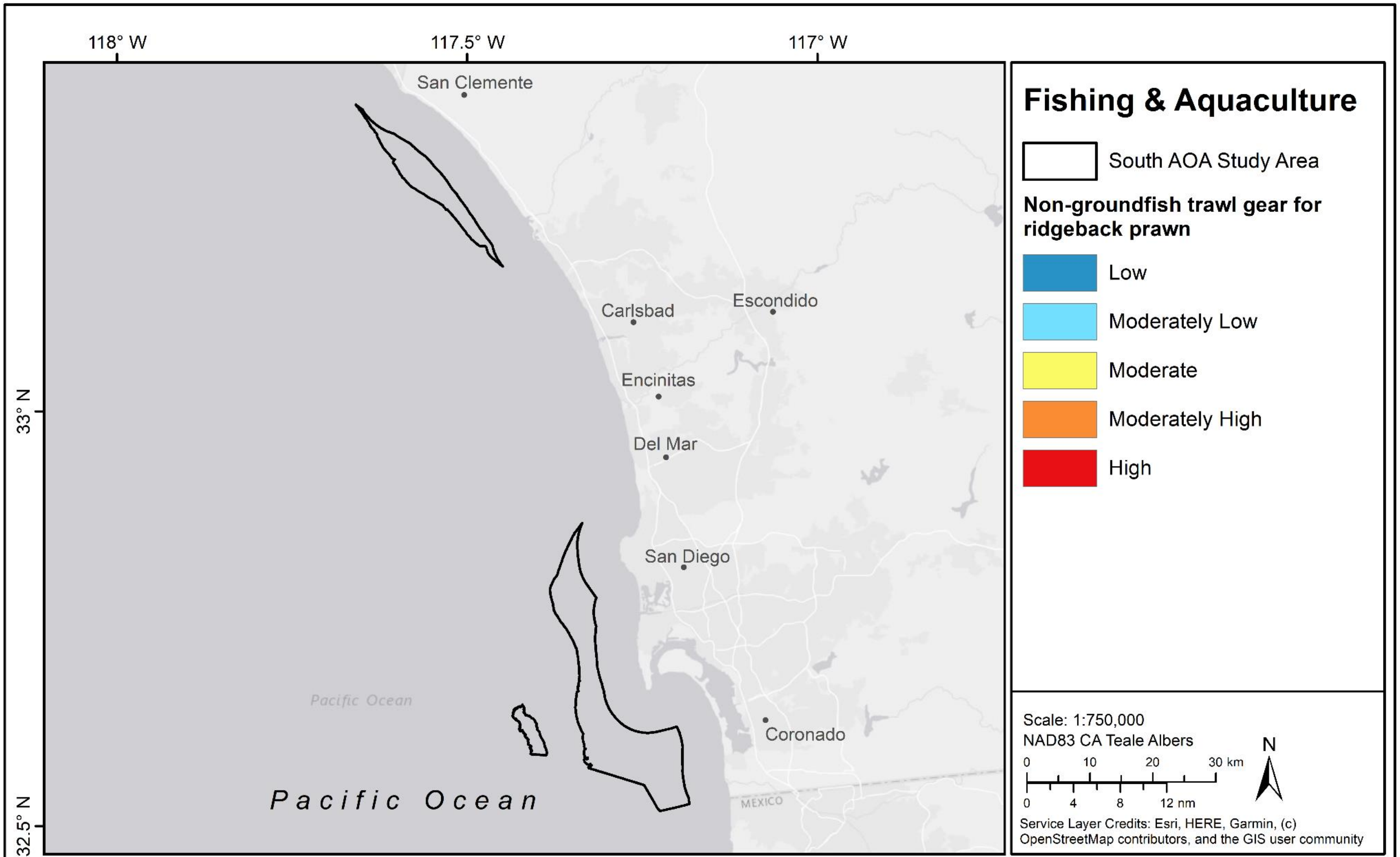
VMS 240 Non-groundfish trawl gear for ridgeback prawn 2010-2017: NOAA - OLE (2017)

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



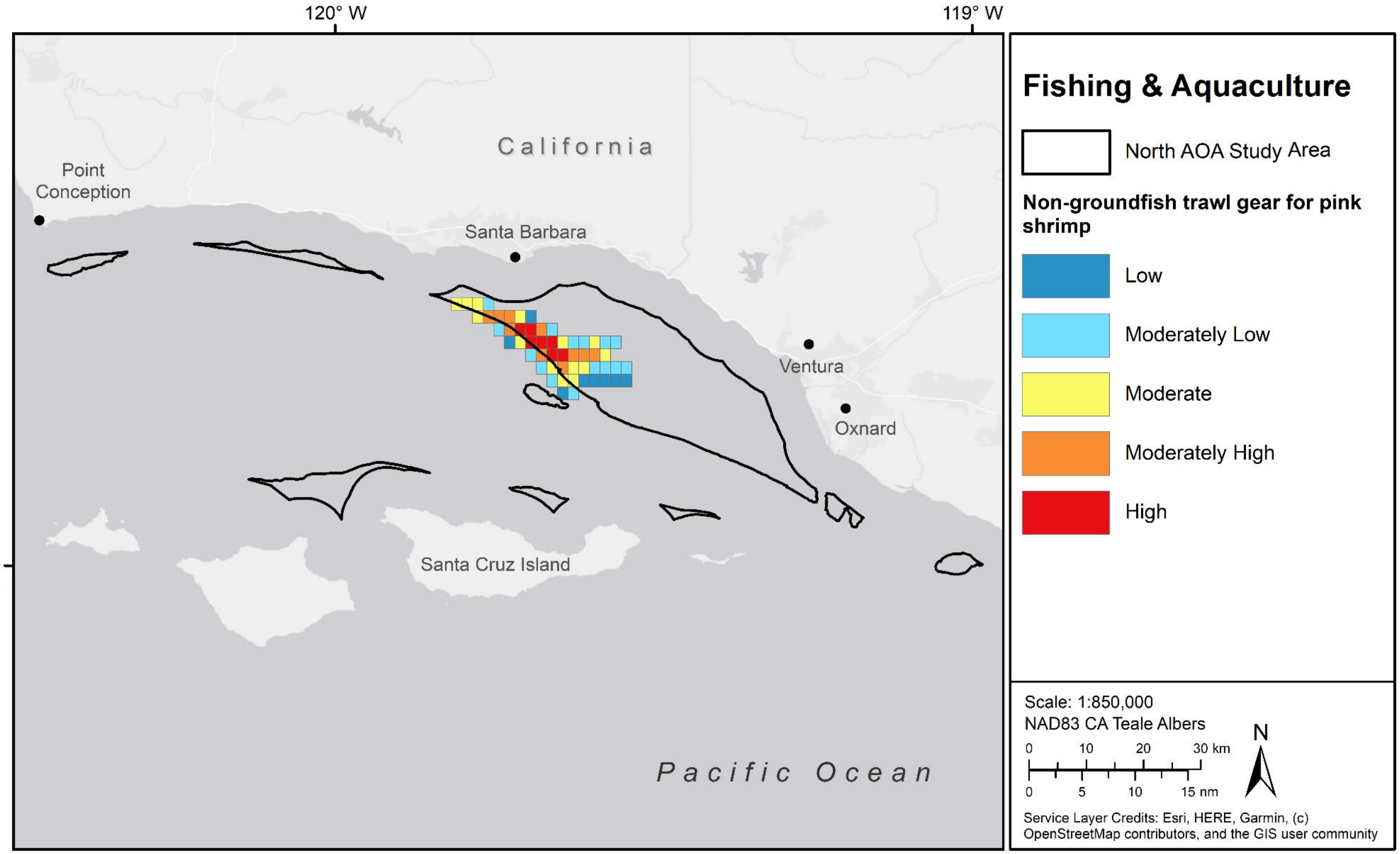
VMS 240 Non-groundfish trawl gear for ridgeback prawn 2010-2017: NOAA - OLE (2017)

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



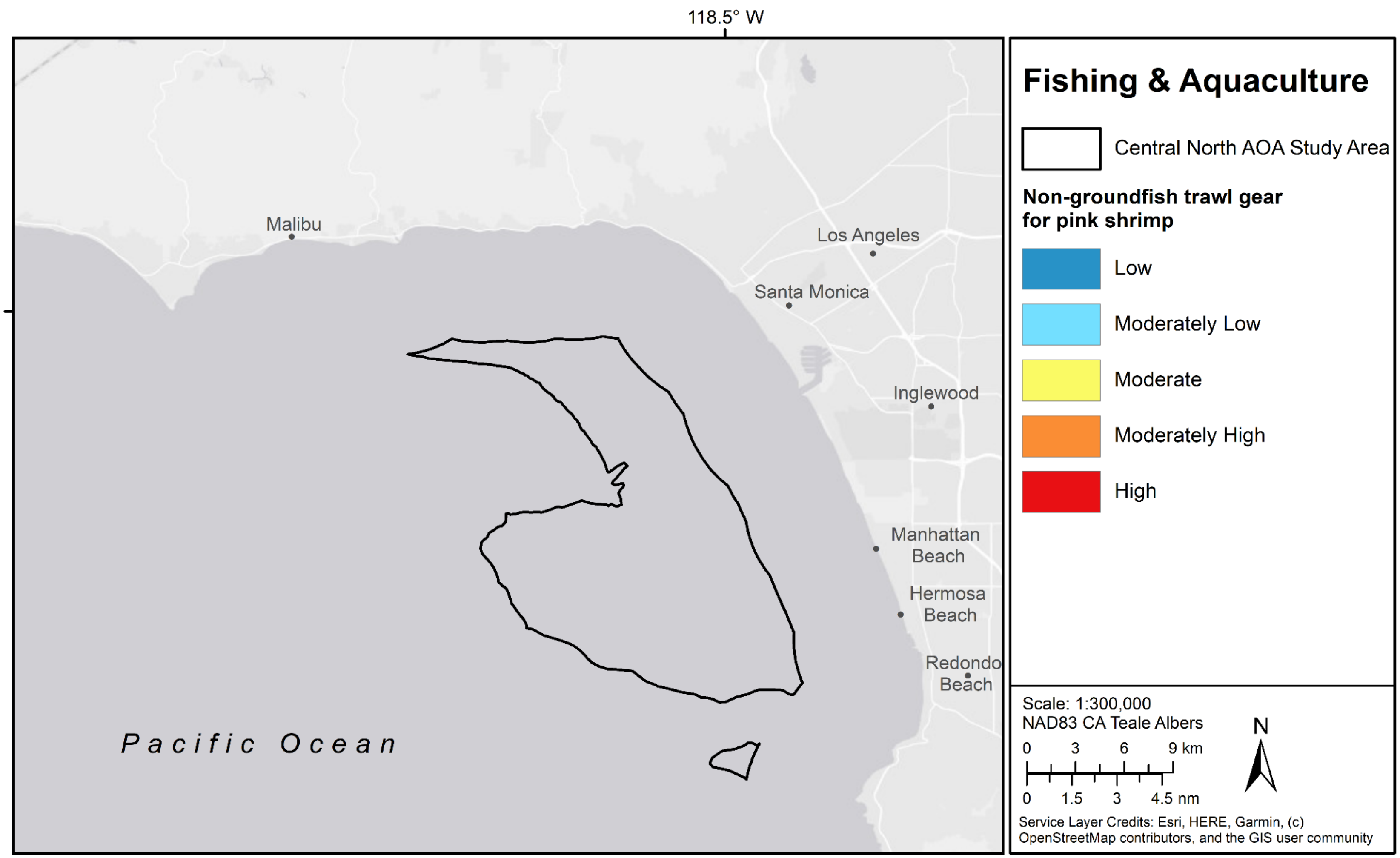
VMS 240 Non-groundfish trawl gear for ridgeback prawn 2010-2017: NOAA - OLE (2017)

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



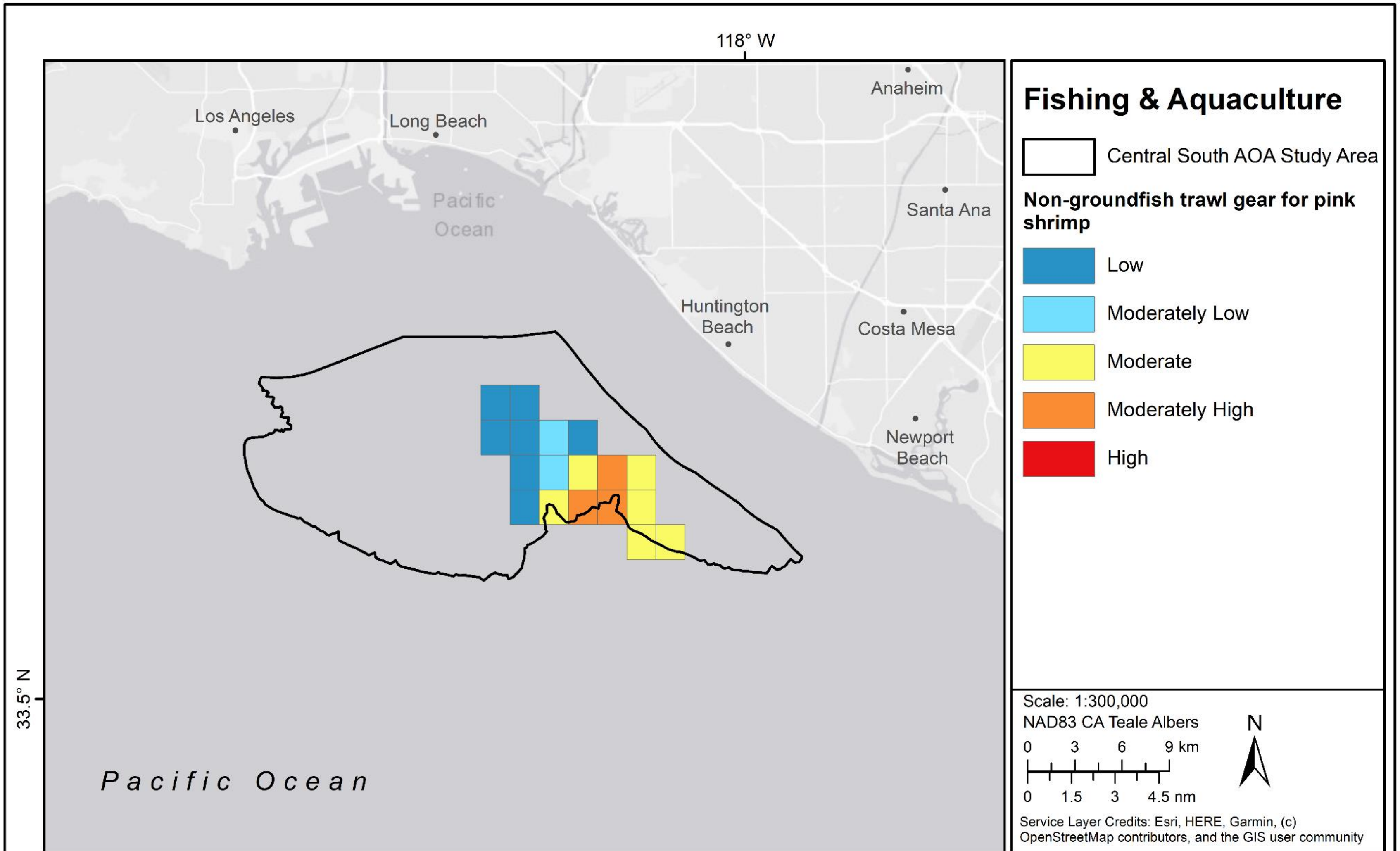
VMS 241 Non-groundfish trawl gear for pink shrimp: NOAA - OLE (2017)

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



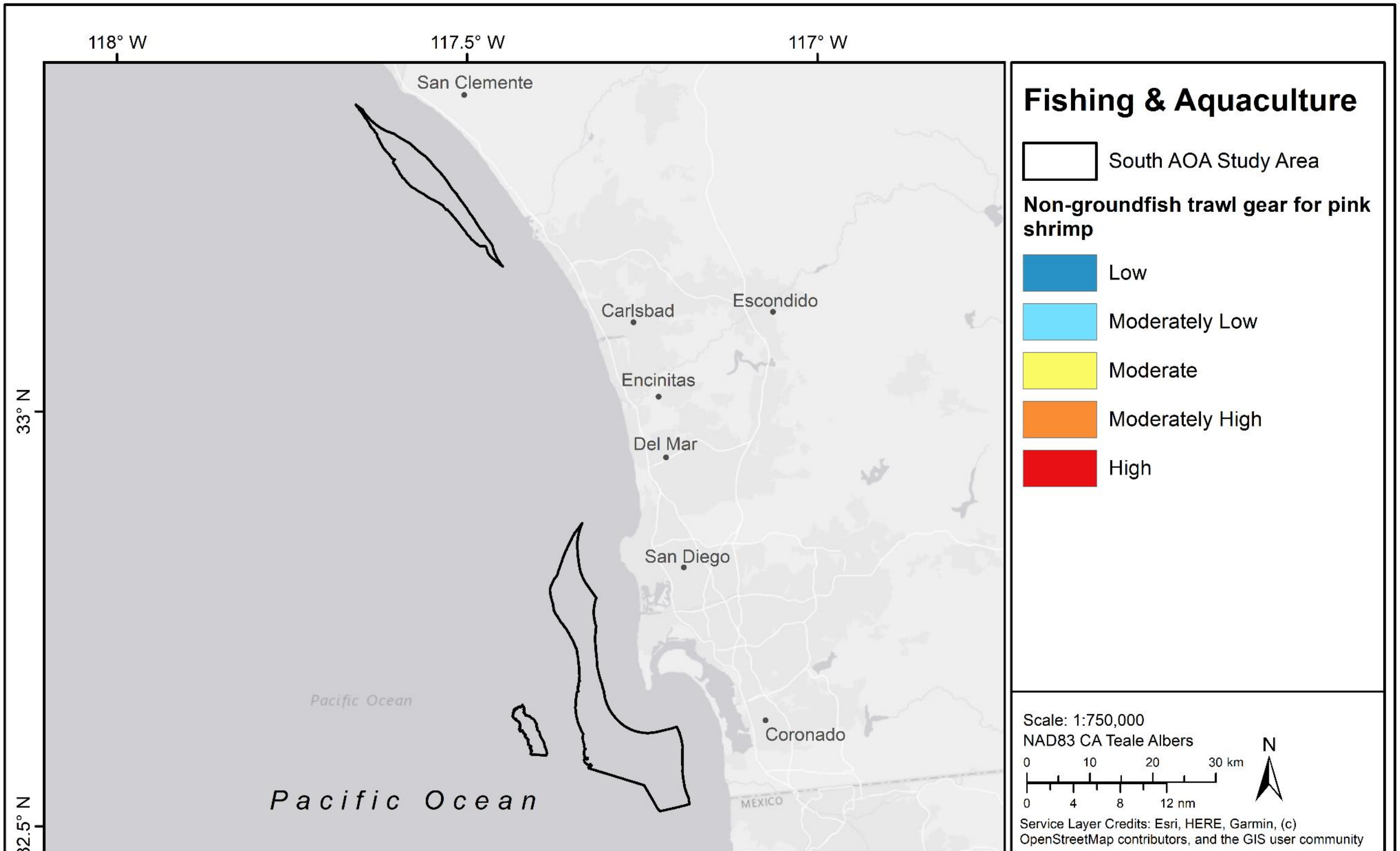
VMS 241 Non-groundfish trawl gear for pink shrimp 2010-2017: NOAA - OLE (2017)

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



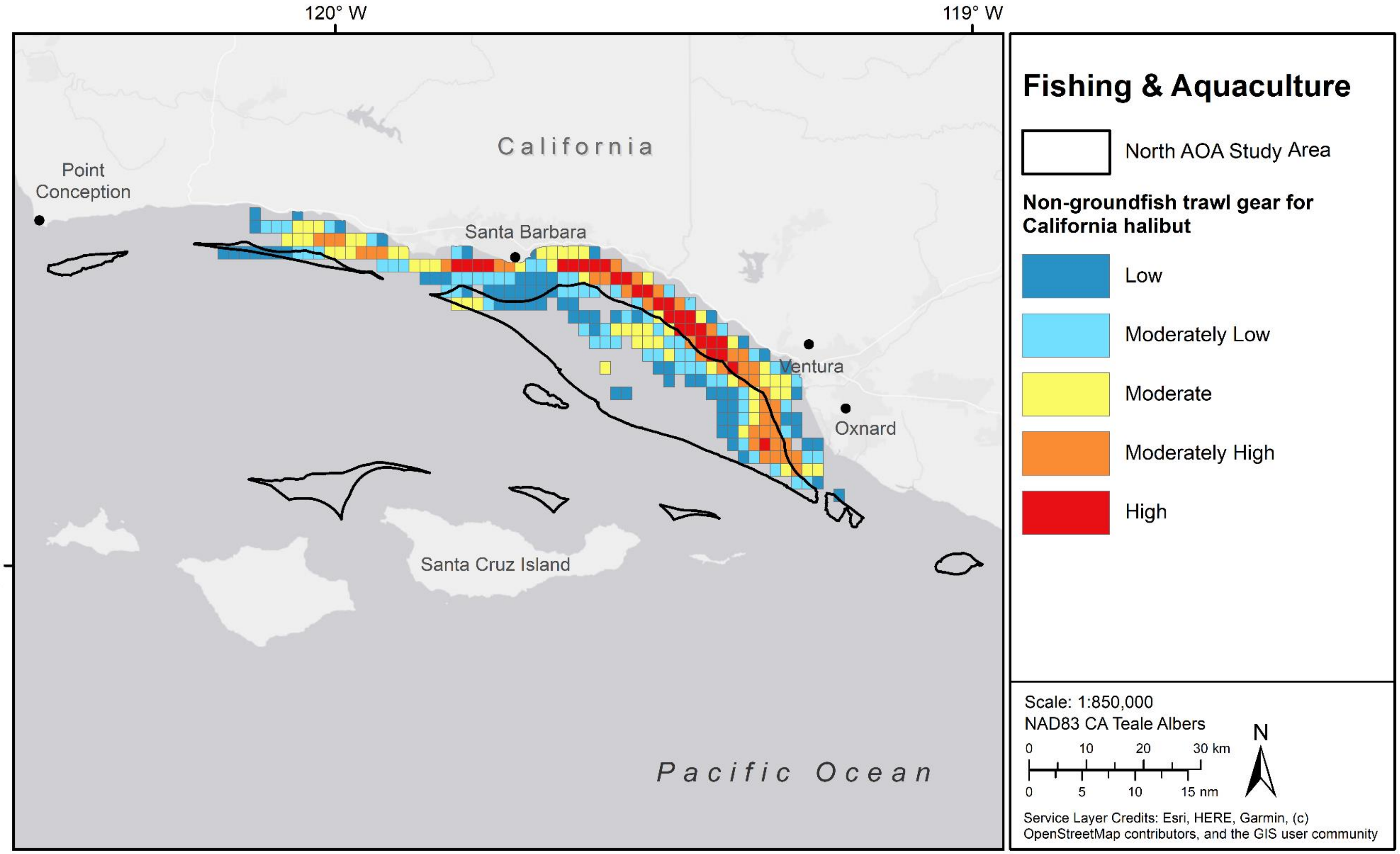
VMS 241 Non-groundfish trawl gear for pink shrimp 2010-2017: NOAA - OLE (2017)

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



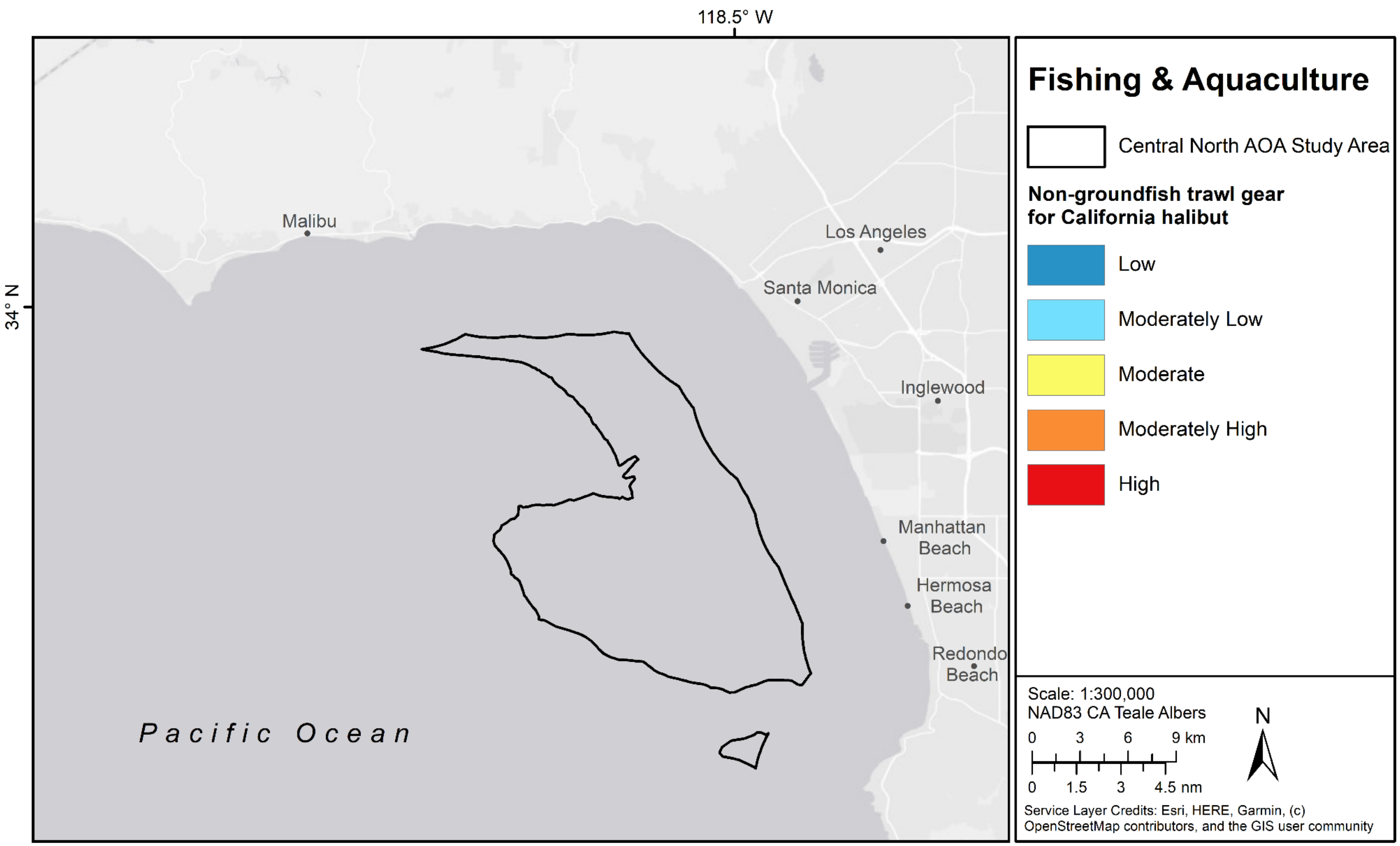
VMS 241 Non-groundfish trawl gear for pink shrimp 2010-2017: NOAA - OLE (2017)

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



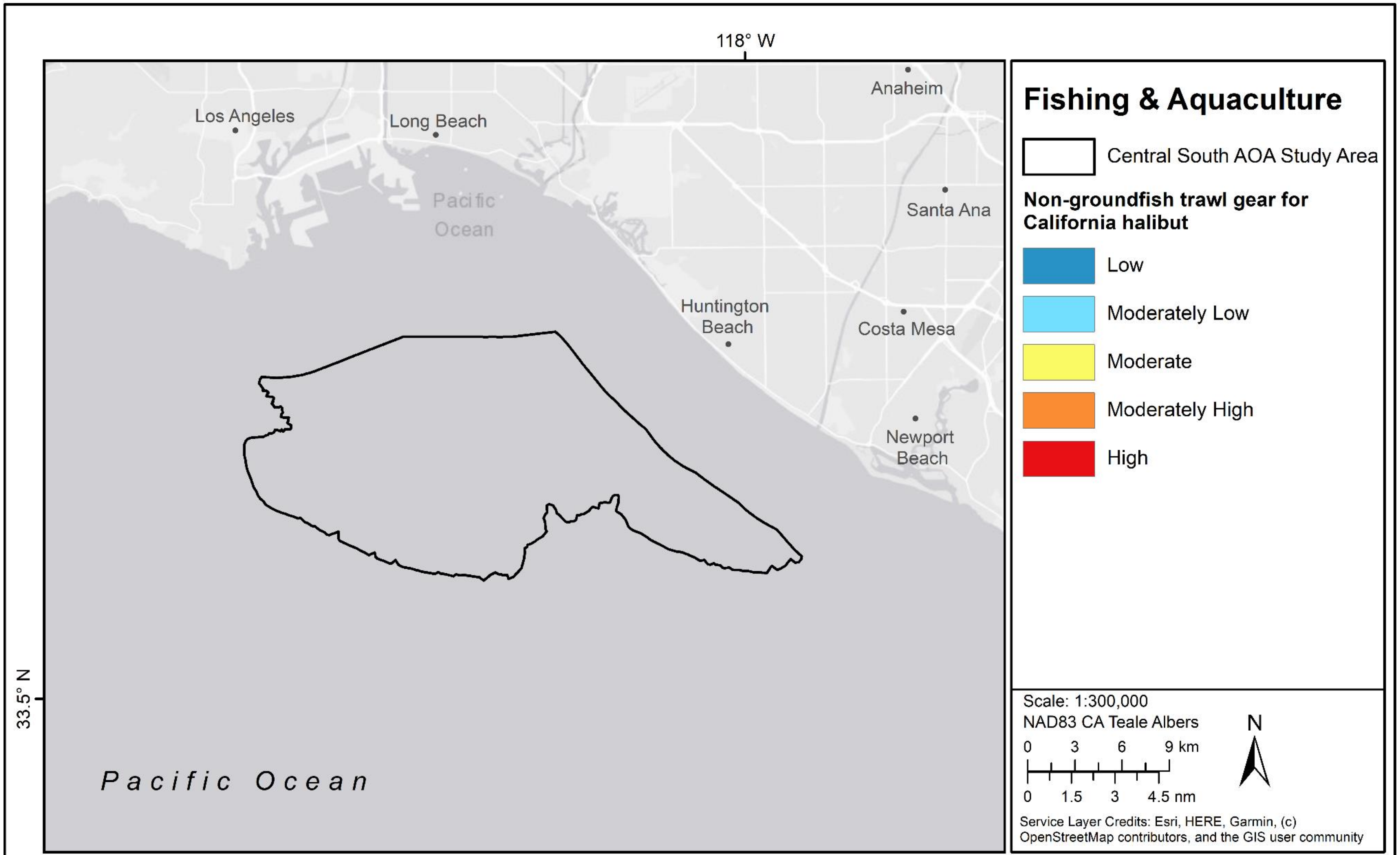
VMS 242 Non-groundfish trawl gear for California halibut: NOAA - OLE (2017)

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



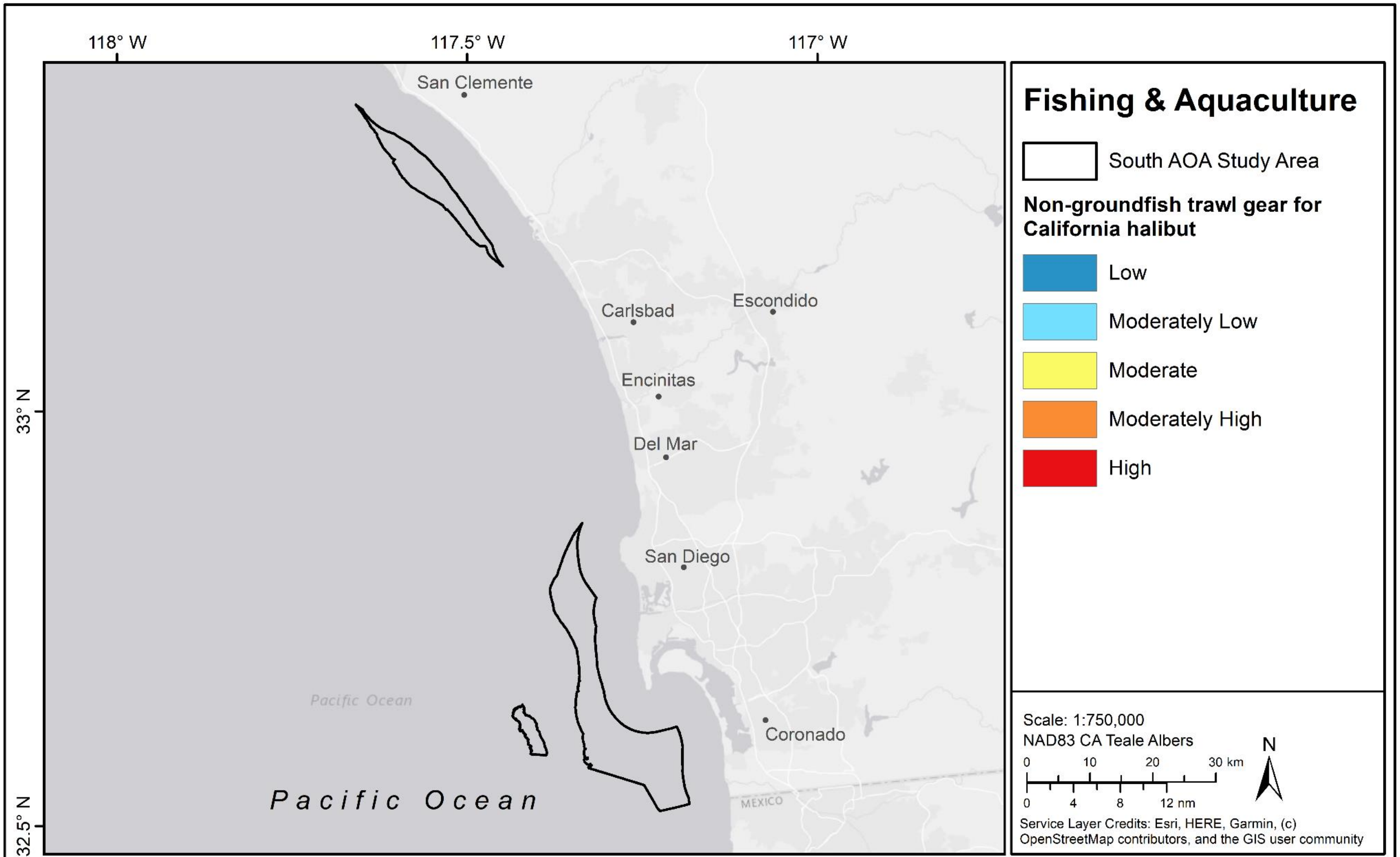
VMS 242 Non-groundfish trawl gear for California halibut 2010-2017: NOAA - OLE (2017)

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



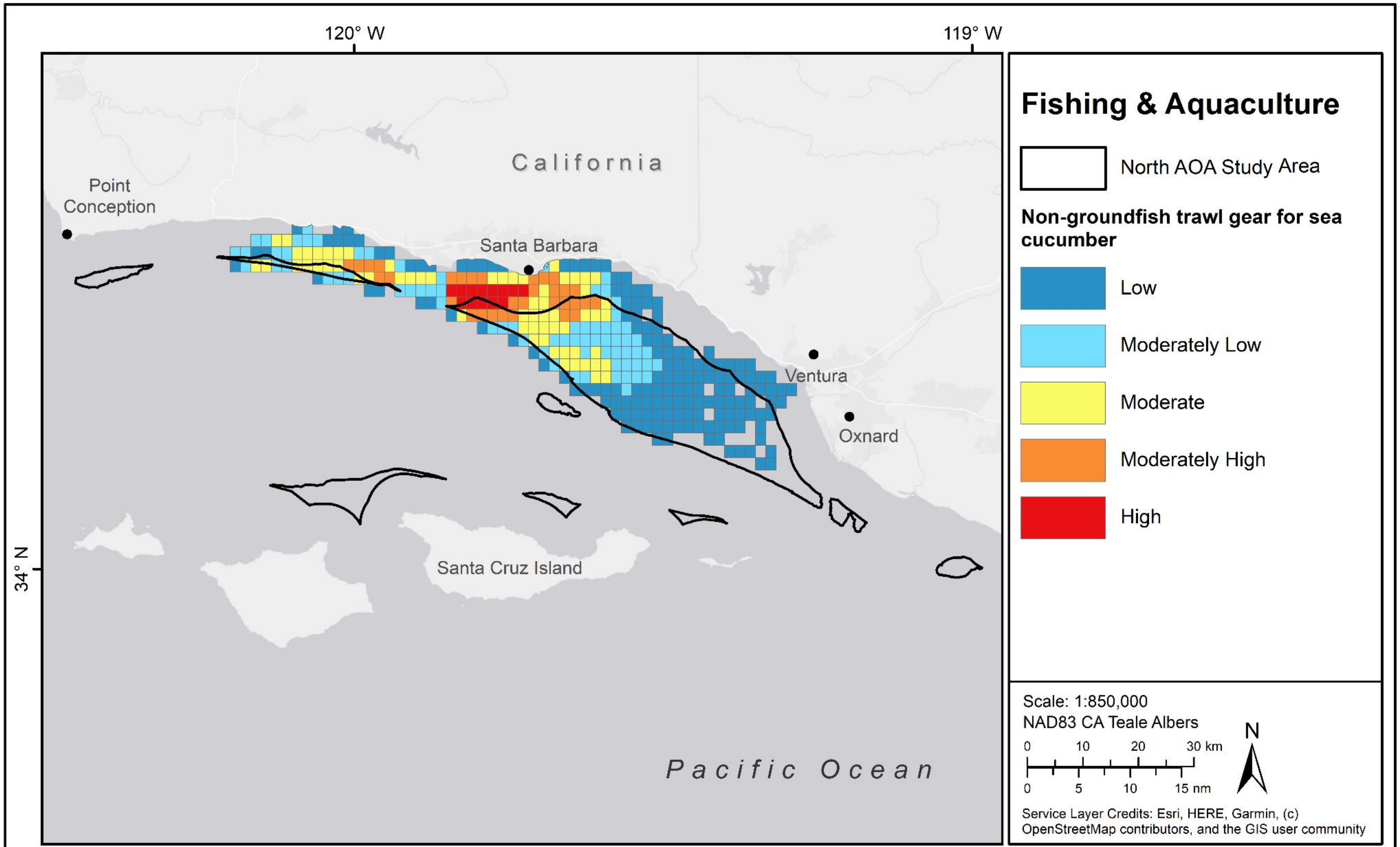
VMS 242 Non-groundfish trawl gear for California halibut 2010-2017: NOAA - OLE (2017)

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



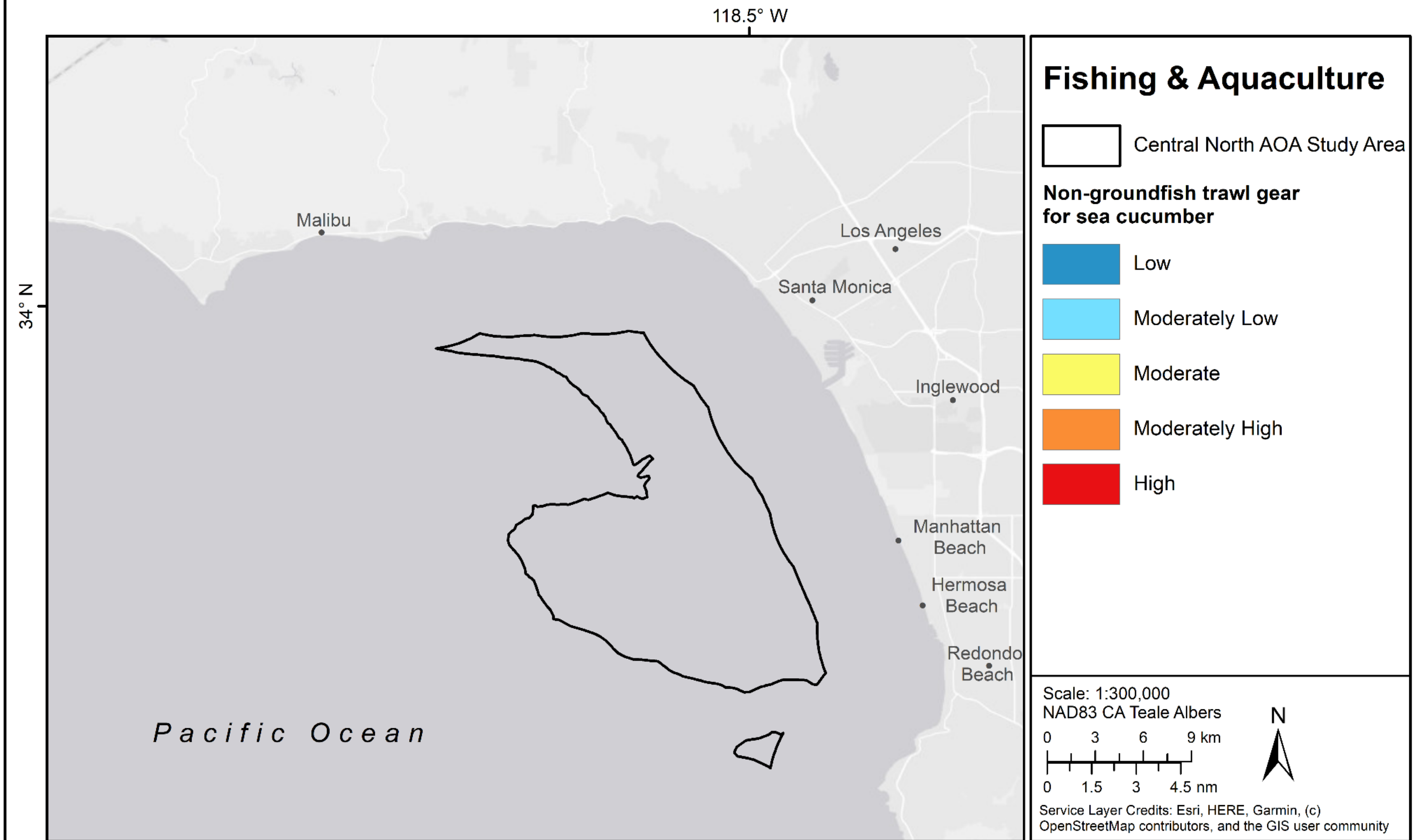
VMS 242 Non-groundfish trawl gear for California halibut 2010-2017: NOAA - OLE (2017)

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



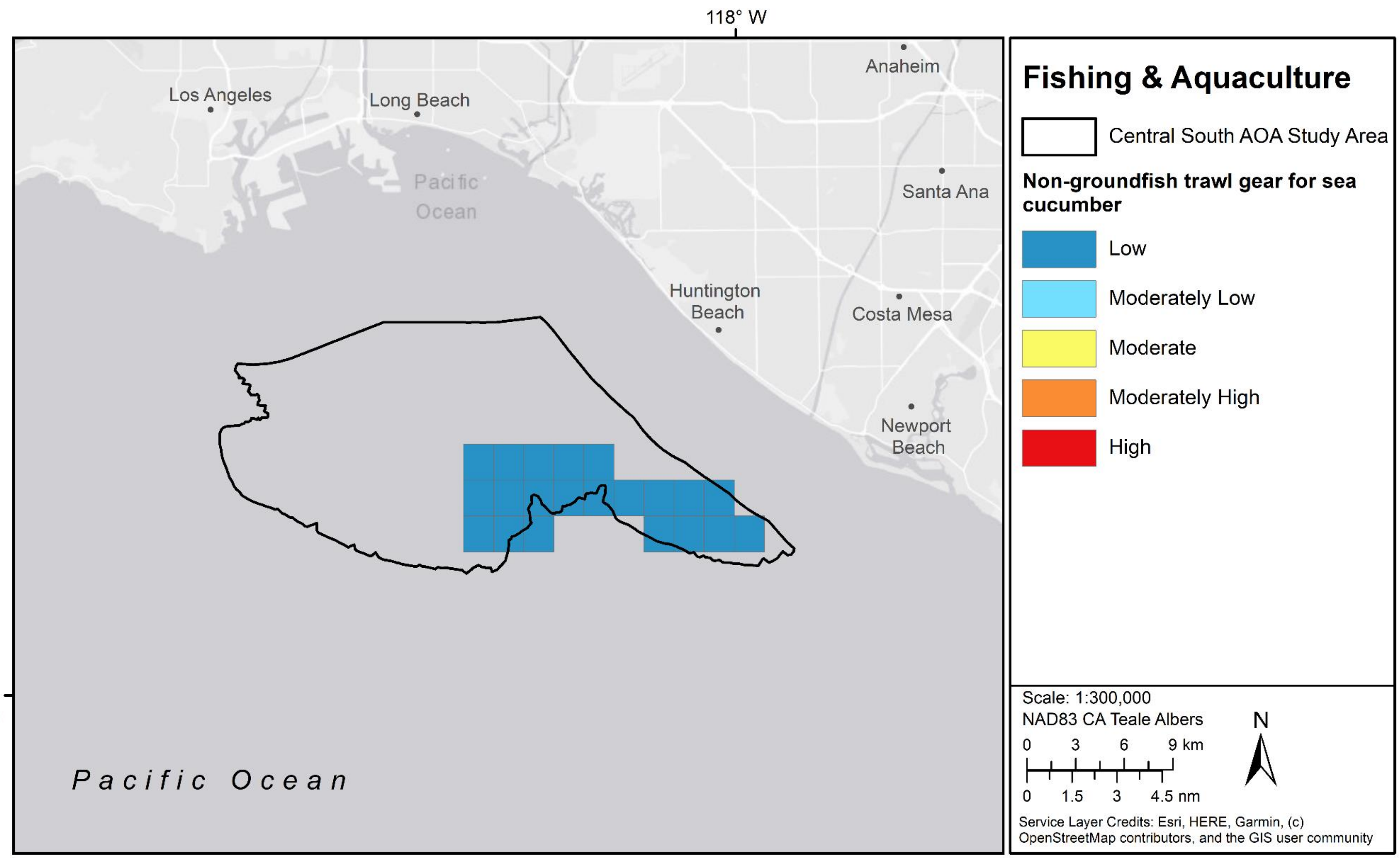
VMS 243 Non-groundfish trawl gear for sea cucumber: NOAA - OLE (2017)

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



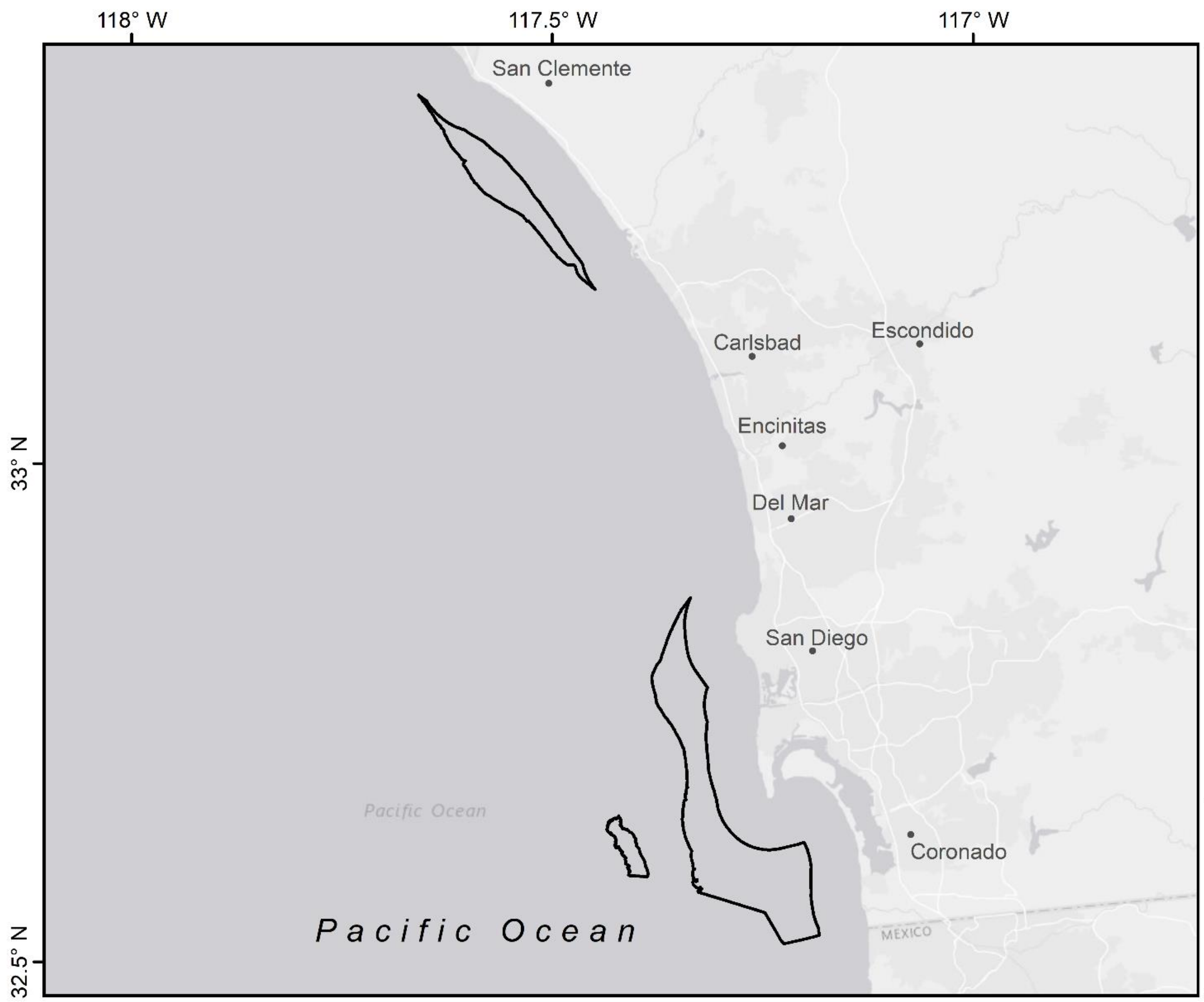
VMS 243 Non-groundfish trawl gear for sea cucumber 2010-2017: NOAA - OLE (2017)

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



VMS 243 Non-groundfish trawl gear for sea cucumber 2010-2017: NOAA - OLE (2017)

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



Fishing & Aquaculture

South AOA Study Area

Non-groundfish trawl gear for sea cucumber

- Low
- Moderately Low
- Moderate
- Moderately High
- High

Scale: 1:750,000
NAD83 CA Teale Albers

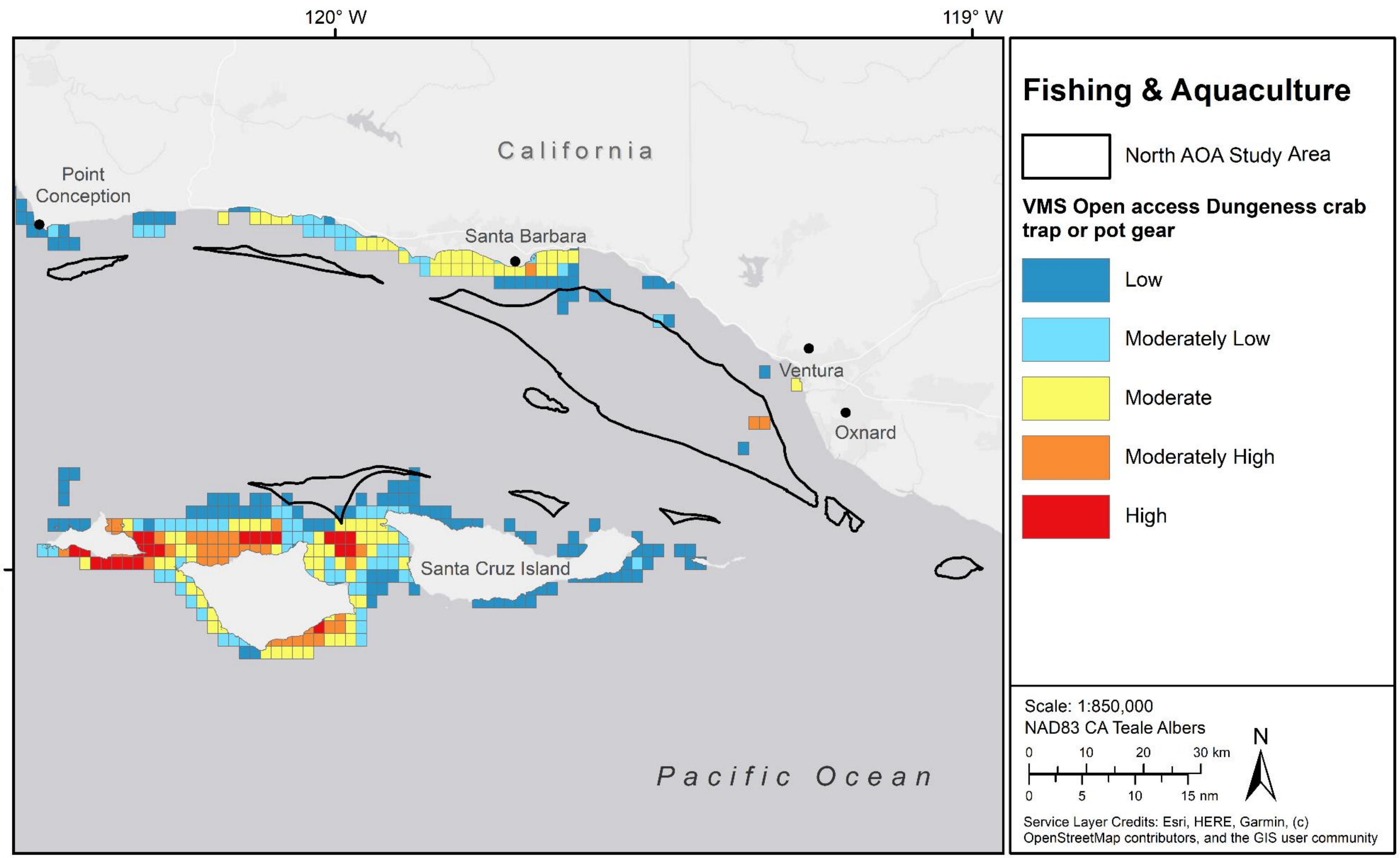
0 10 20 30 km
0 4 8 12 nm

N

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

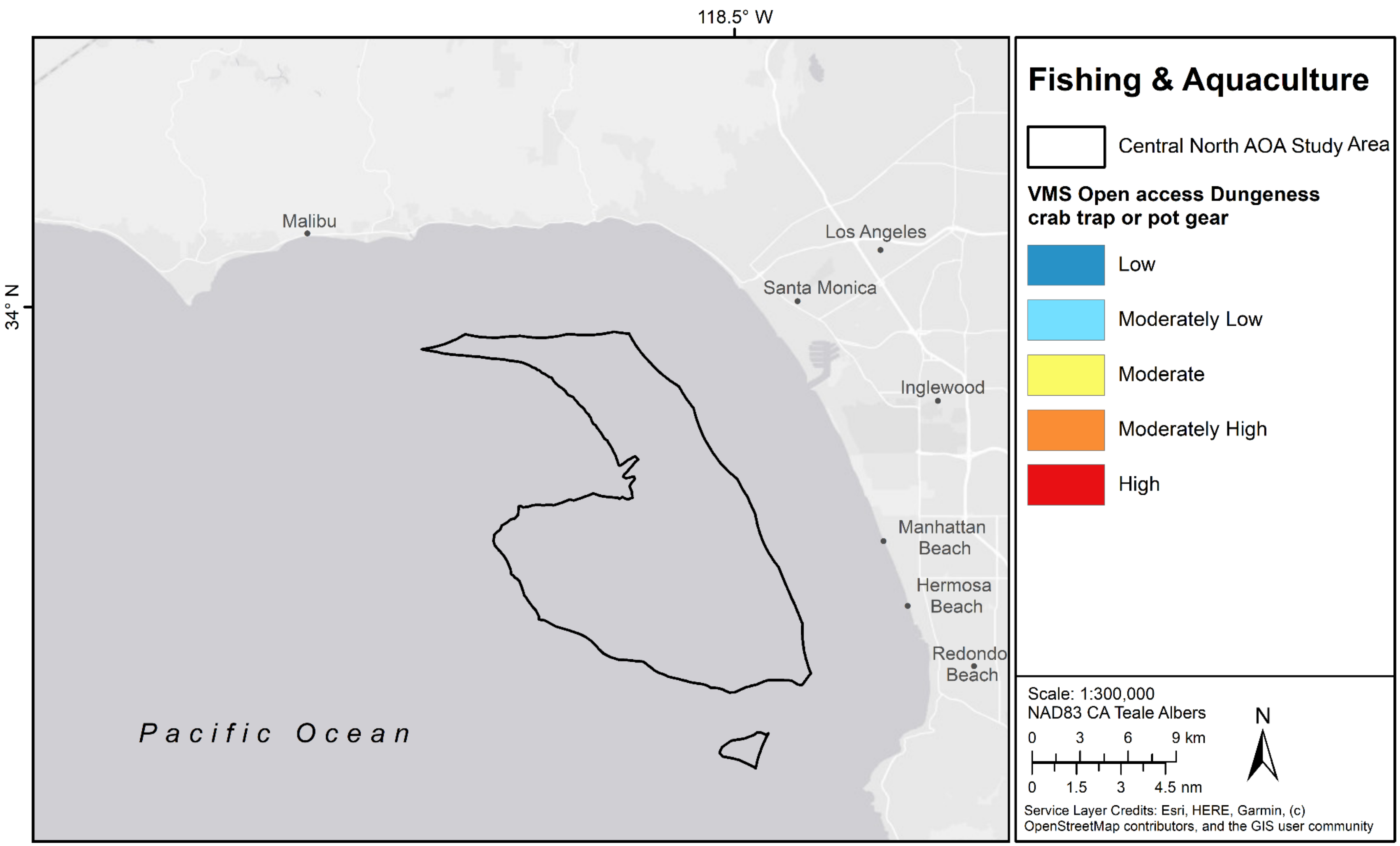
VMS 243 Non-groundfish trawl gear for sea cucumber 2010-2017: NOAA - OLE (2017)

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



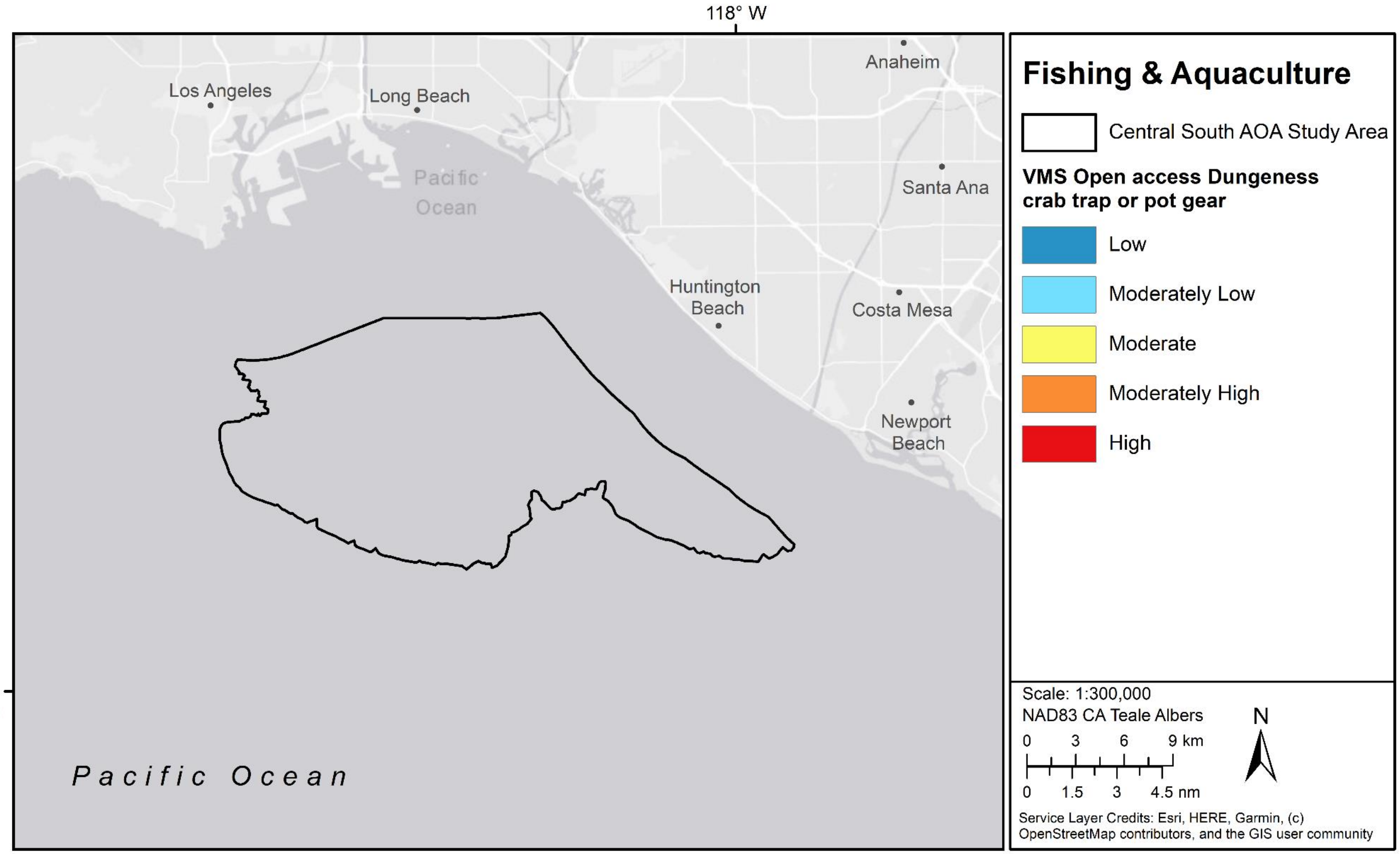
VMS 261 Open access Dungeness crab trap or pot gear: NOAA - OLE (2017)

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



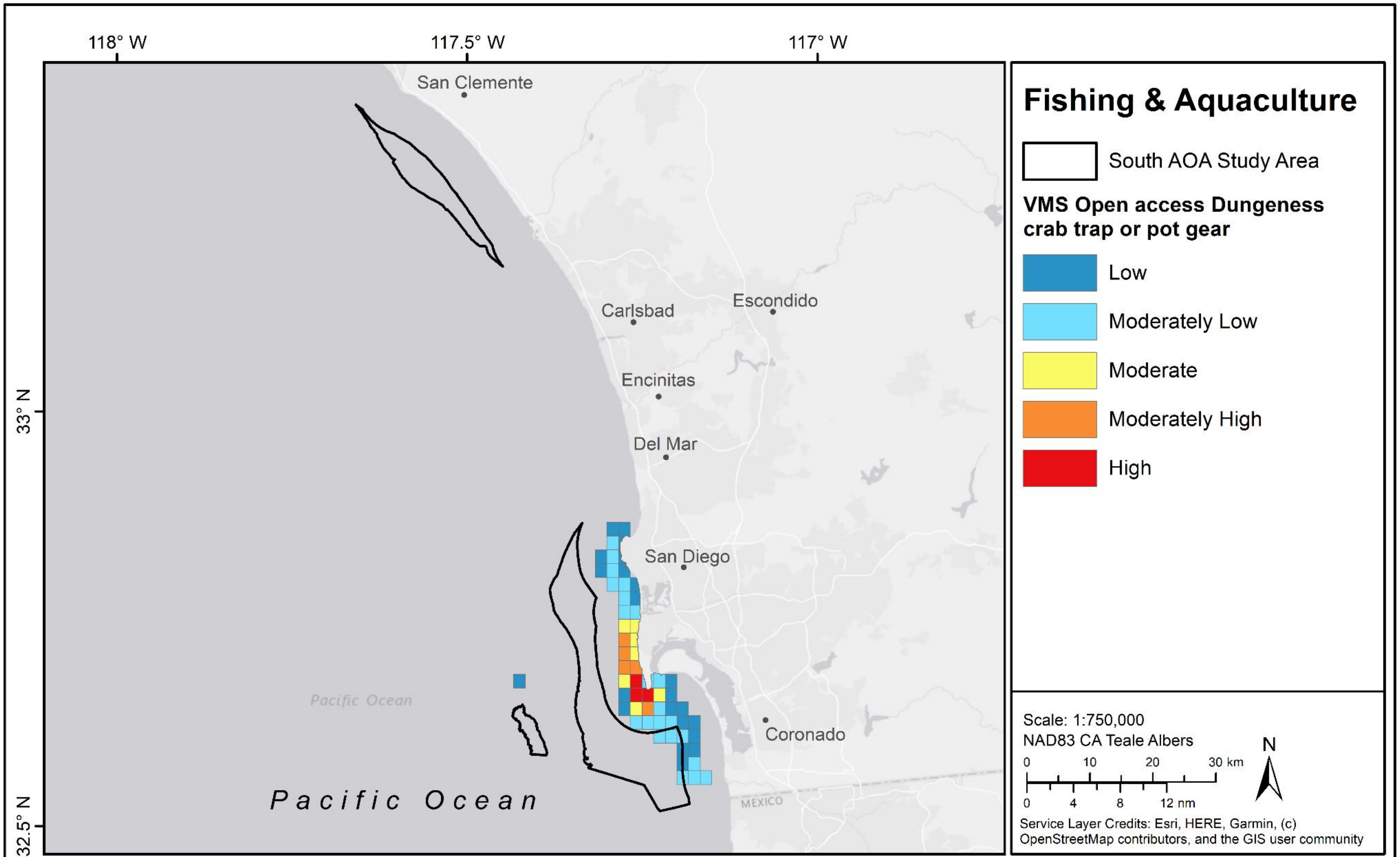
VMS 261 Open access Dungeness crab trap or pot gear 2010-2017: NOAA - OLE (2017)

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



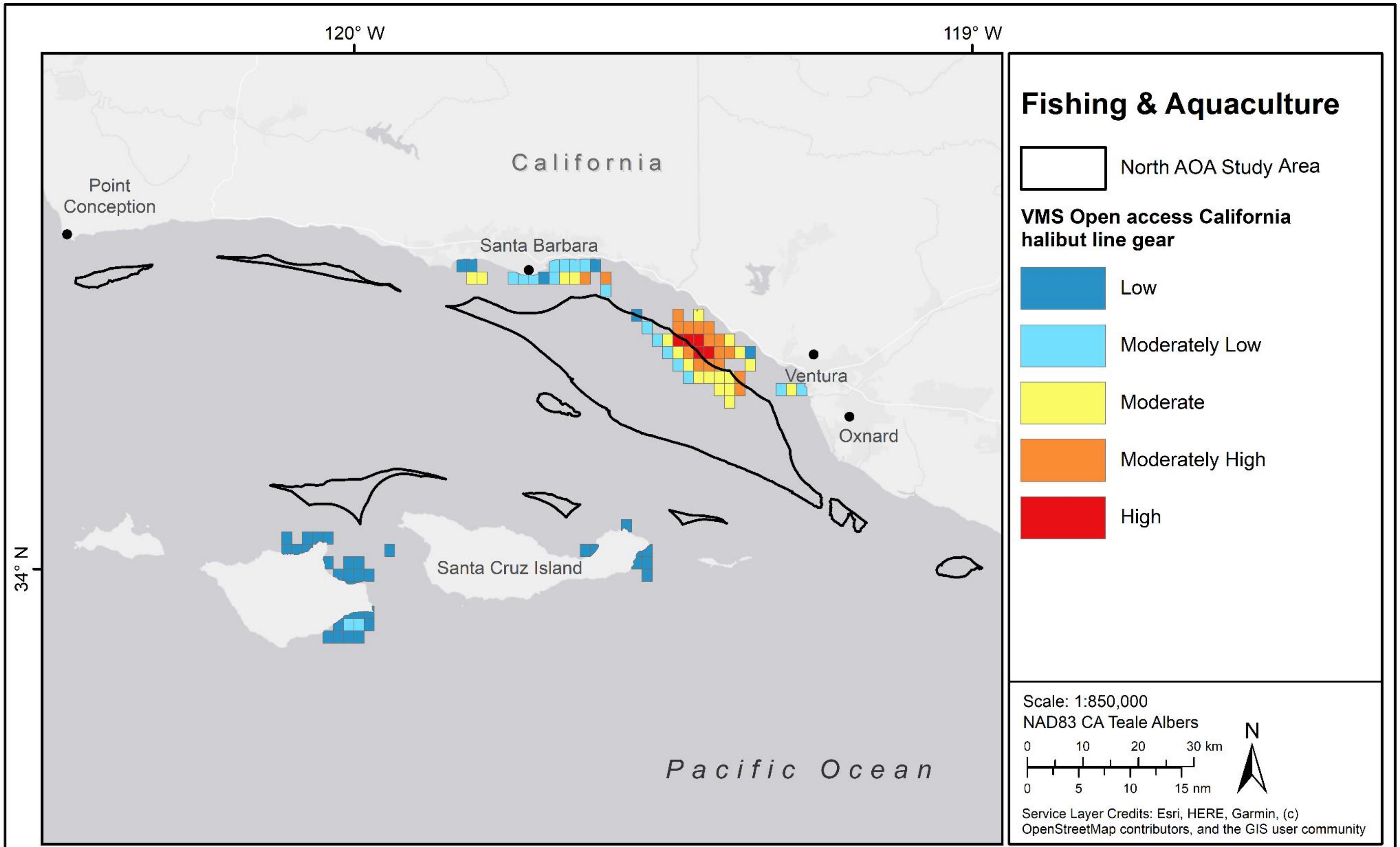
VMS 261 Open access Dungeness crab trap or pot gear 2010-2017: NOAA - OLE (2017)

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



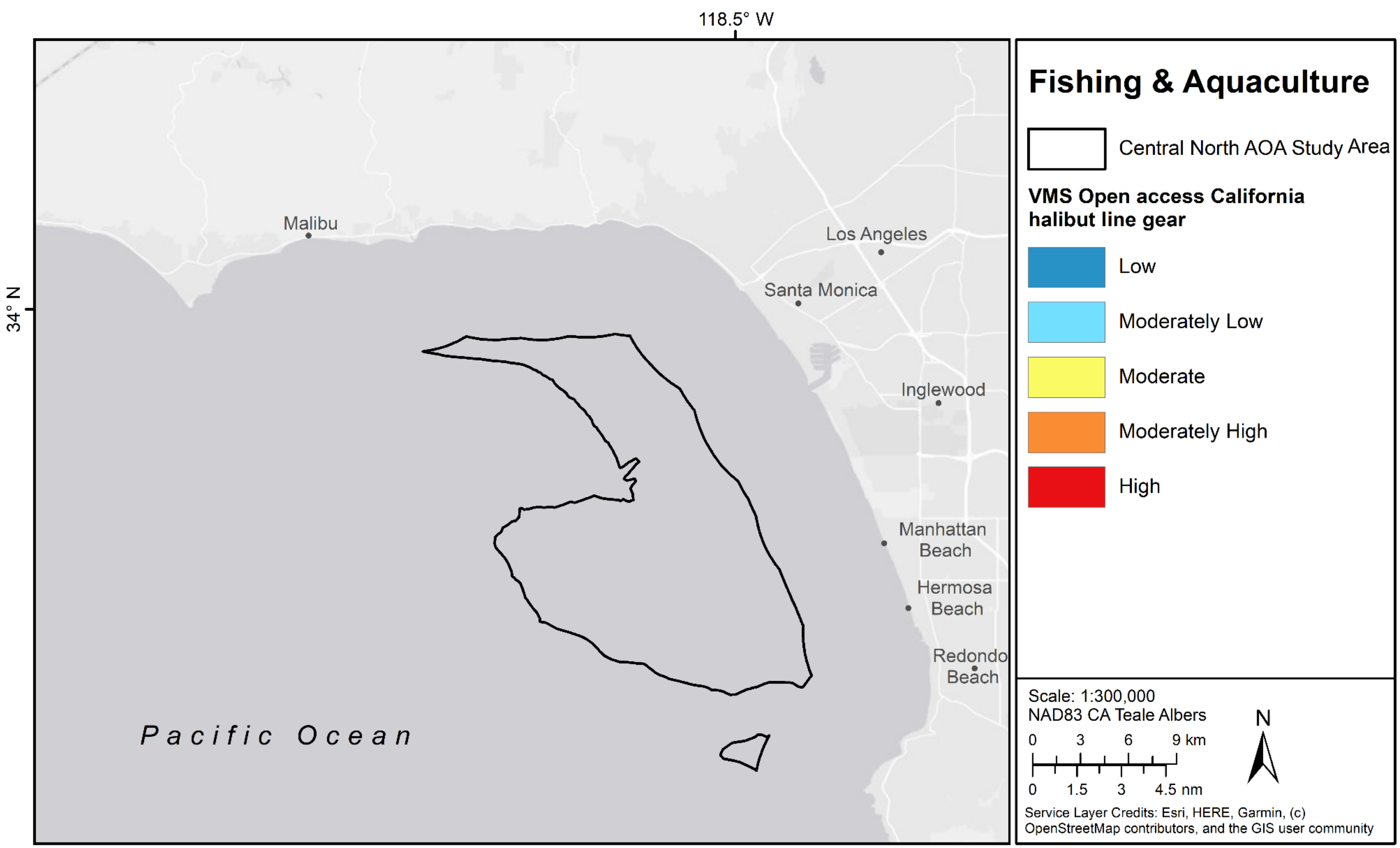
VMS 261 Open access Dungeness crab trap or pot gear 2010-2017: NOAA - OLE (2017)

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



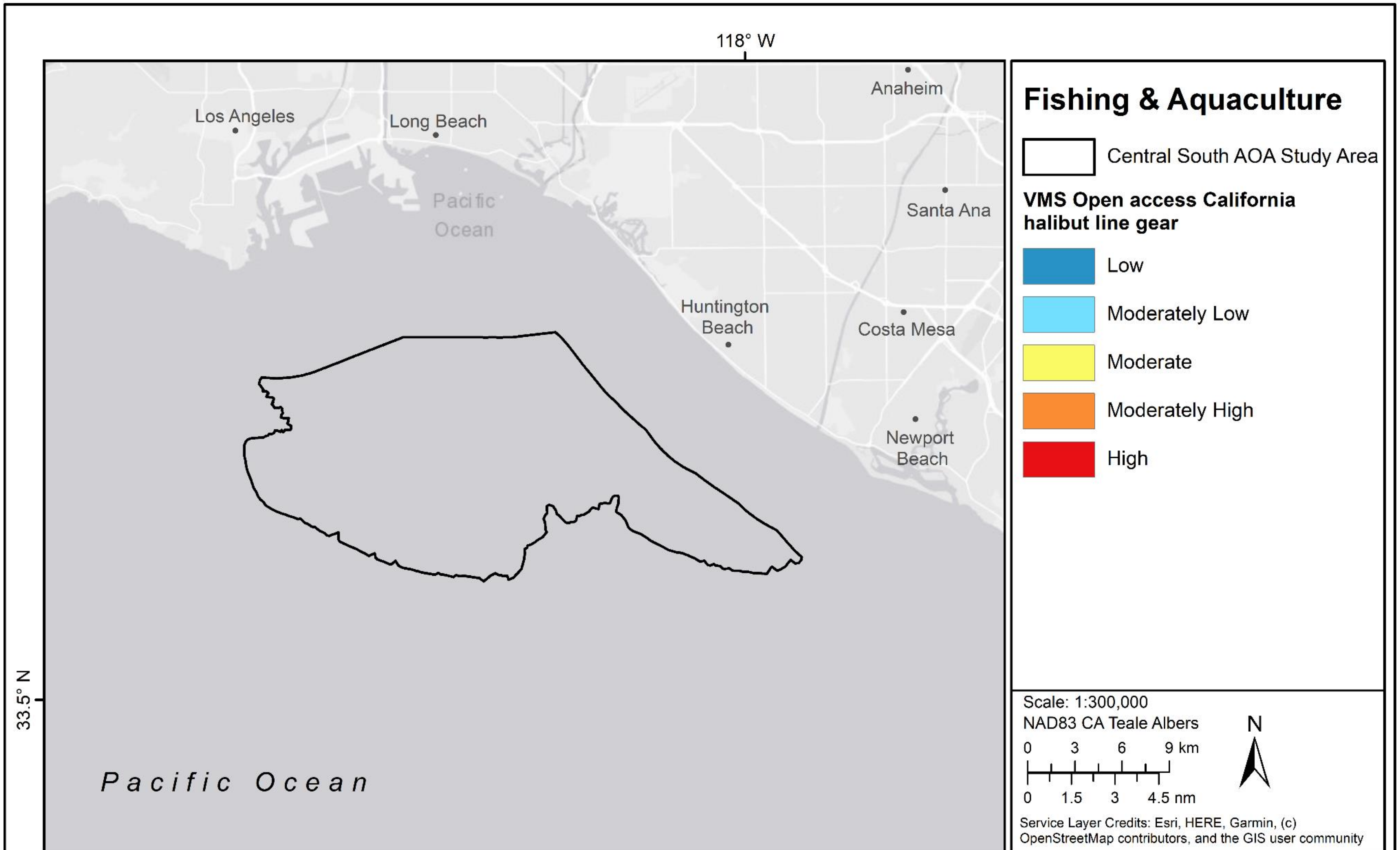
VMS 264 Open access California halibut line gear: NOAA - OLE (2017)

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



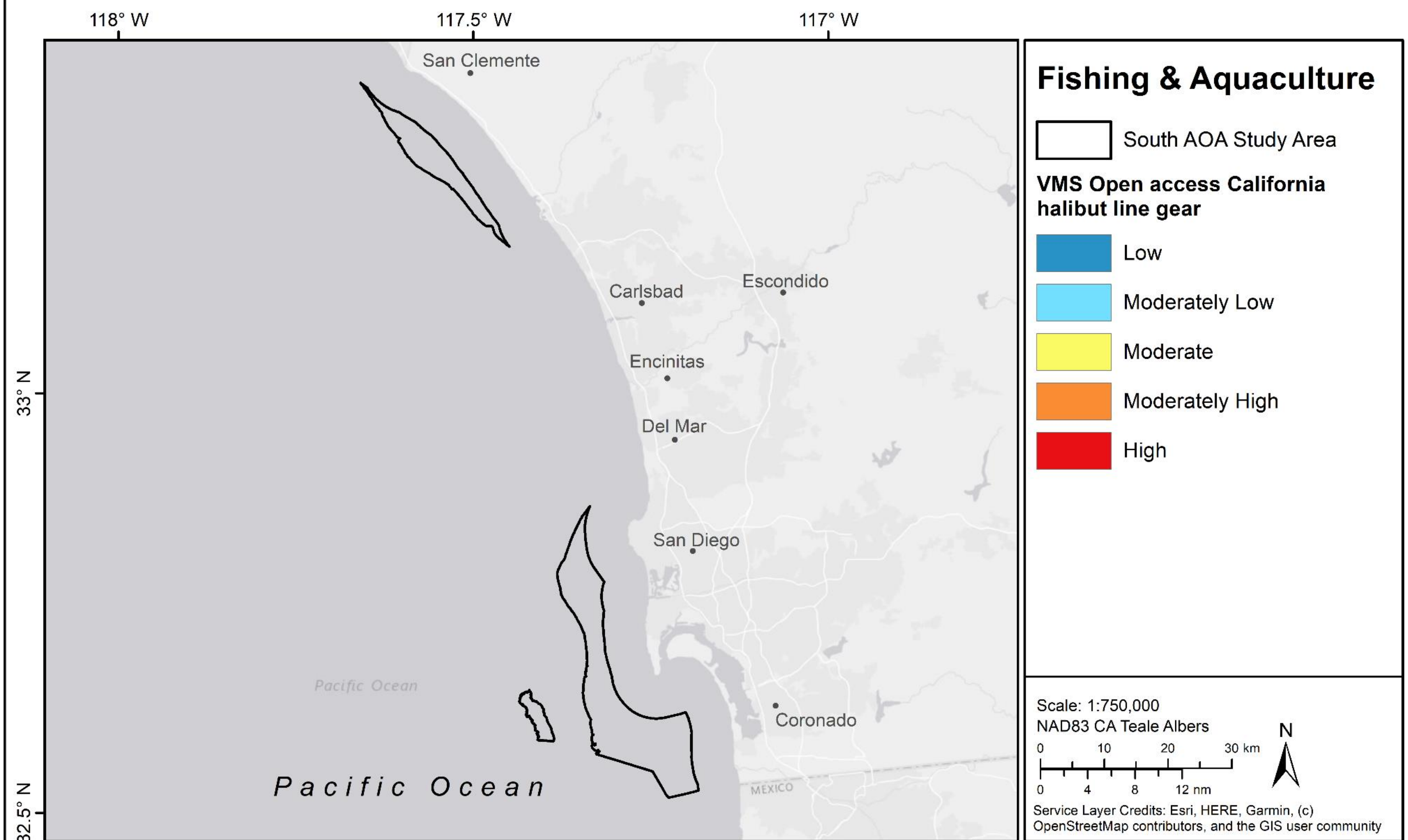
VMS 264 Open access California halibut line gear 2010-2017: NOAA - OLE (2017)

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



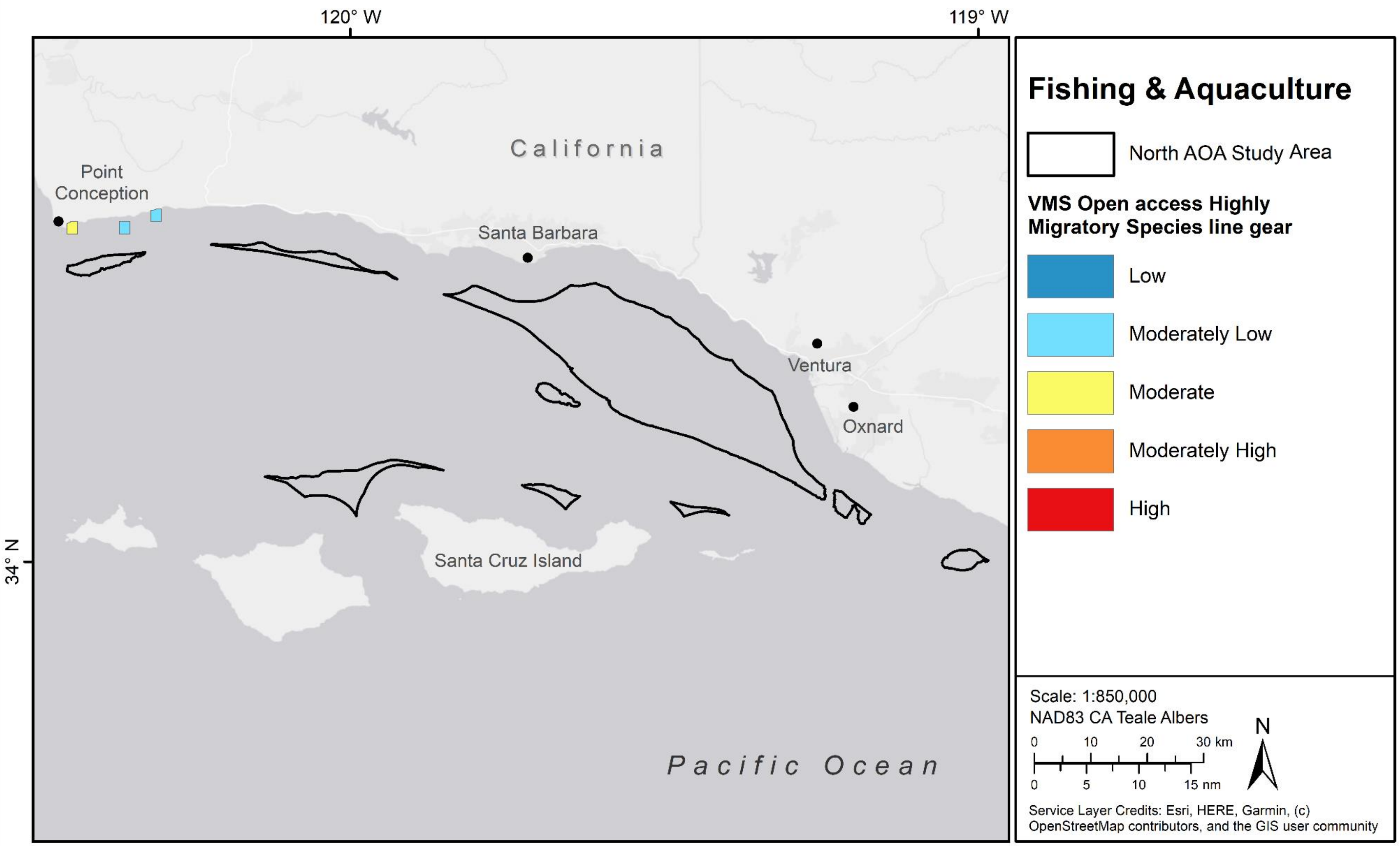
VMS 264 Open access California halibut line gear 2010-2017: NOAA - OLE (2017)

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



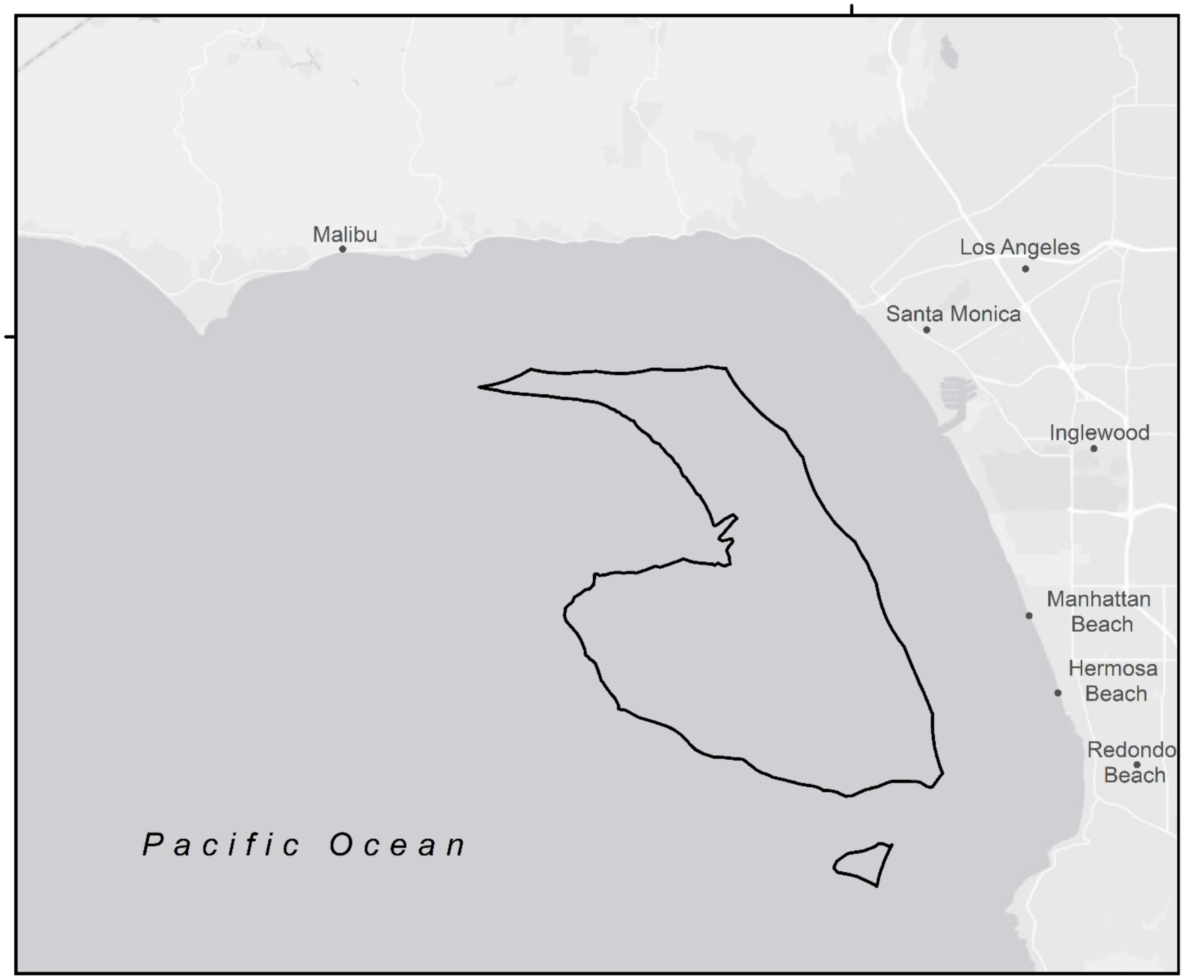
VMS 264 Open access California halibut line gear 2010-2017: NOAA - OLE (2017)

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



VMS 266 Open access Highly Migratory Species line gear: NOAA - OLE (2017)

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



Fishing & Aquaculture

Central North AOA Study Area

VMS Open access Highly Migratory Species line gear

- Low
- Moderately Low
- Moderate
- Moderately High
- High

Scale: 1:300,000
NAD83 CA Teale Albers

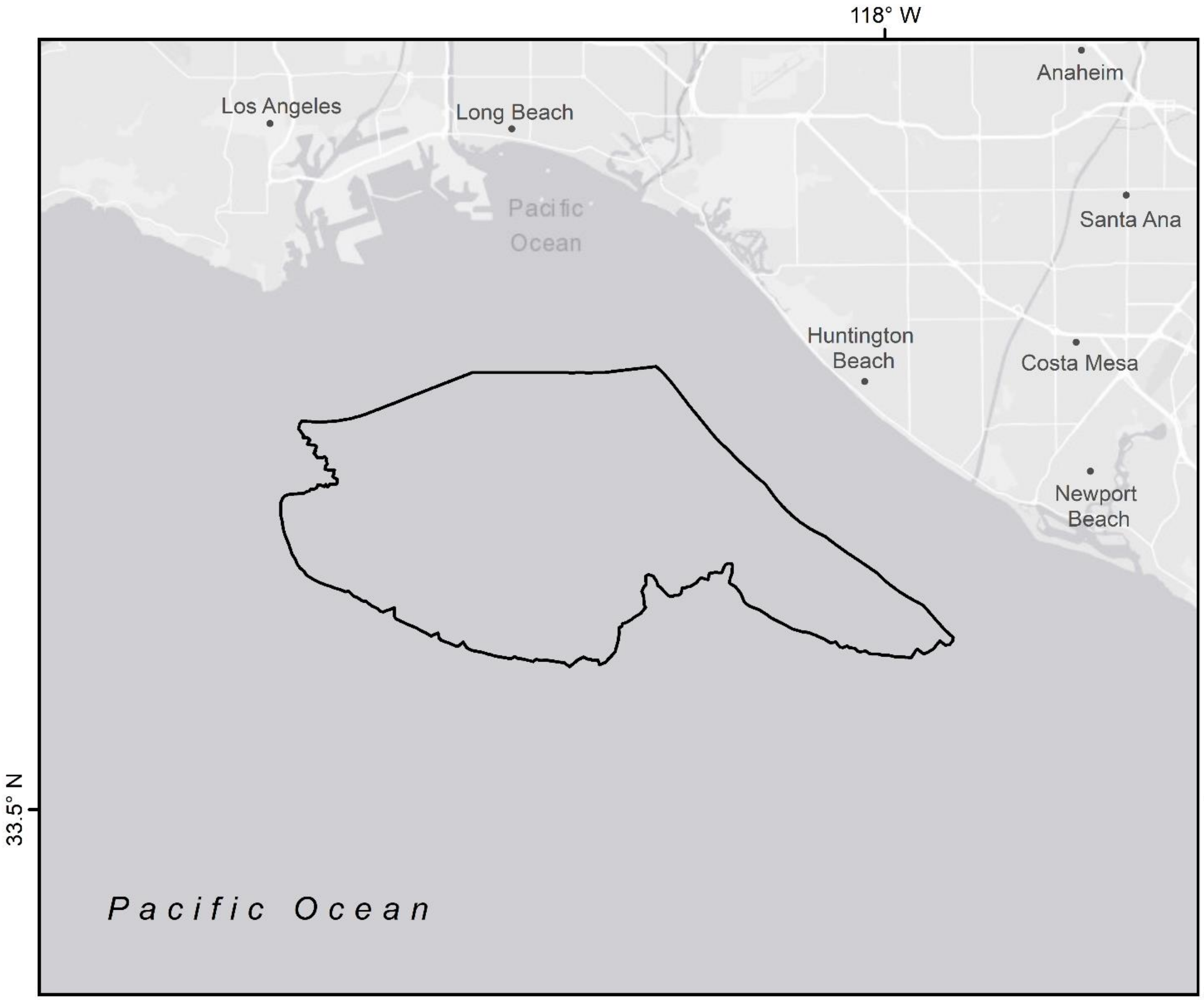
0 3 6 9 km
0 1.5 3 4.5 nm

N

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

VMS 266 Open access Highly Migratory Species line gear 2010-2017: NOAA - OLE (2017)

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



Fishing & Aquaculture

Central South AOA Study Area

VMS Open access Highly Migratory Species line gear

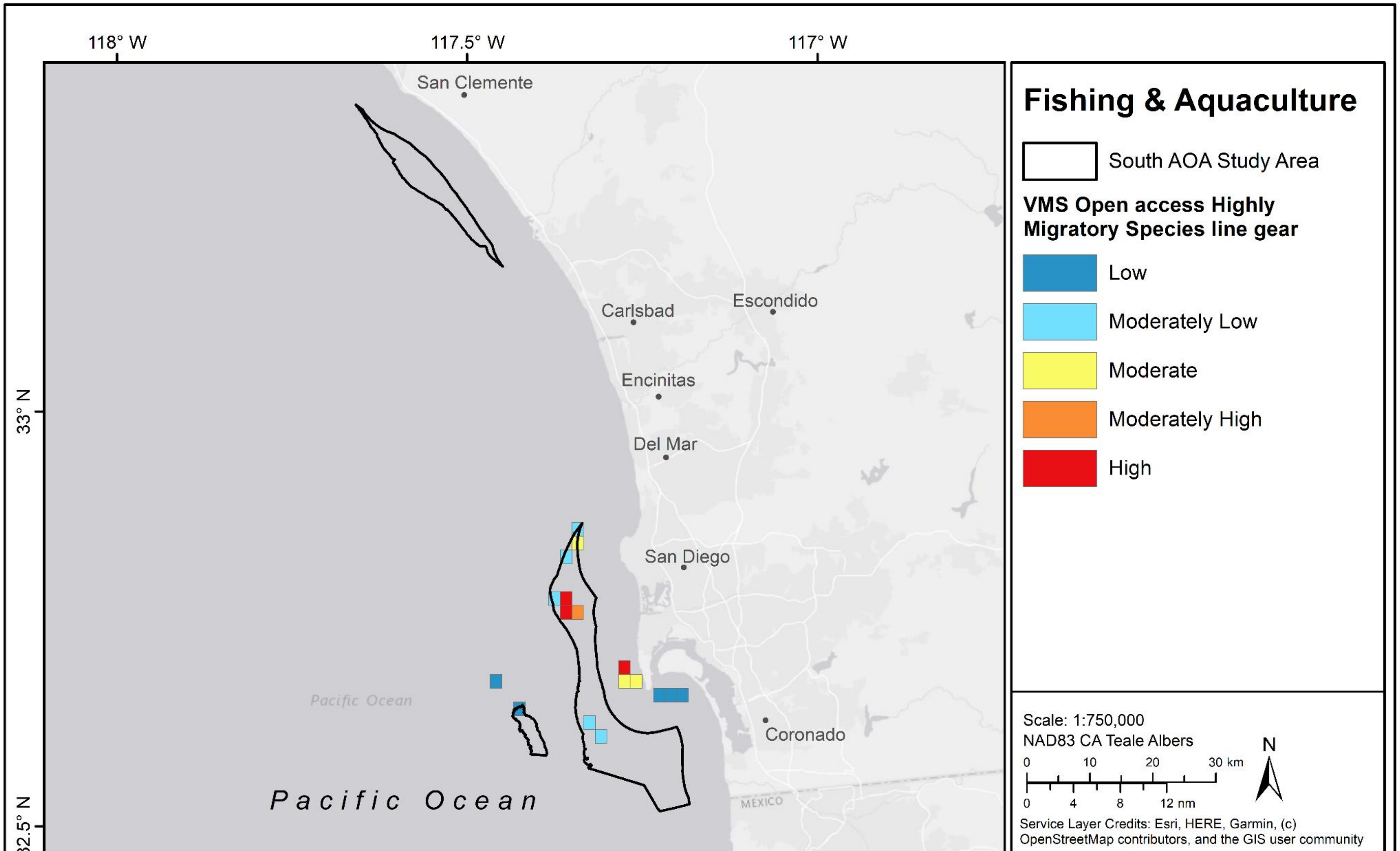
- Low
- Moderately Low
- Moderate
- Moderately High
- High

Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

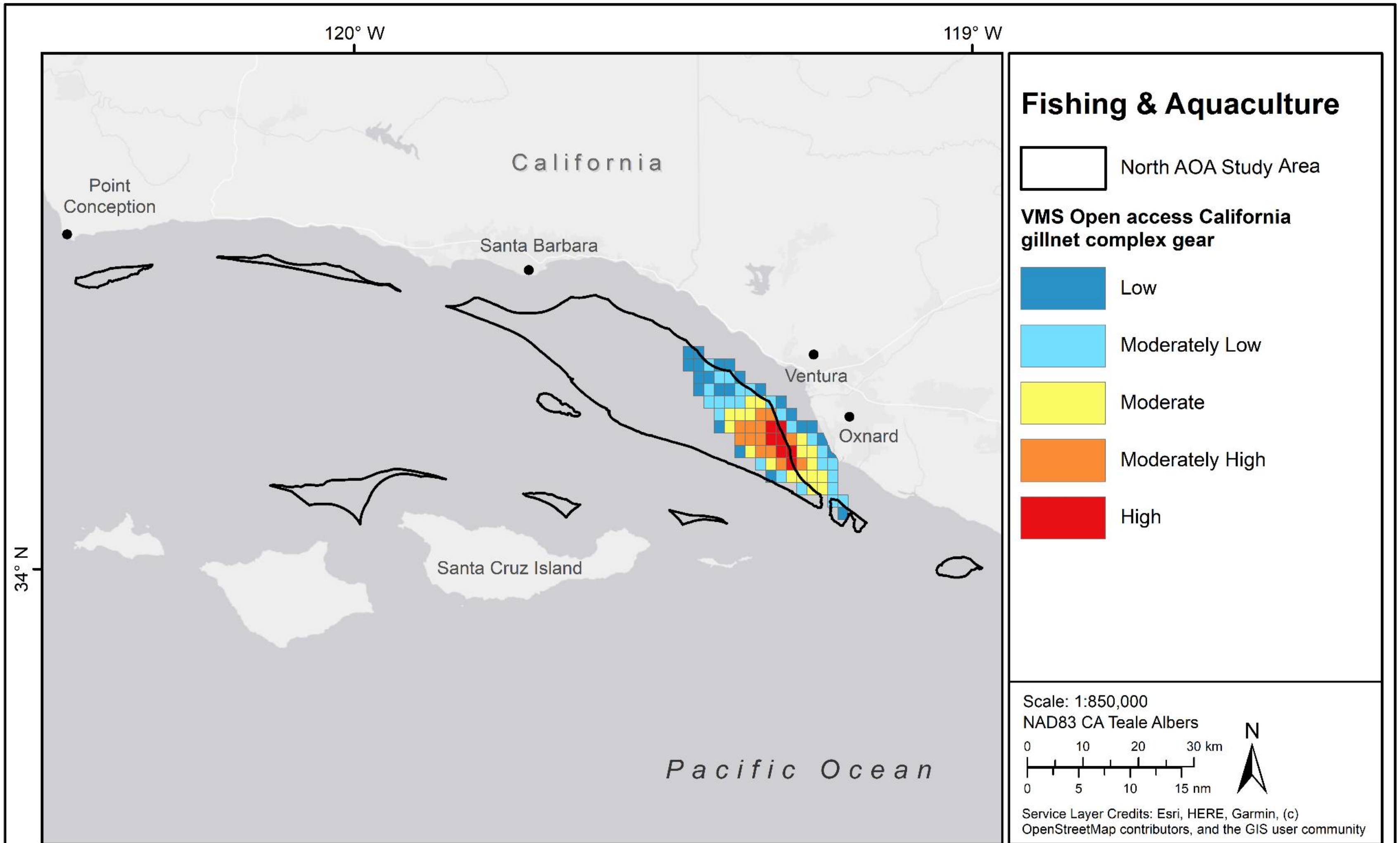
VMS 266 Open access Highly Migratory Species line gear 2010-2017: NOAA - OLE (2017)

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



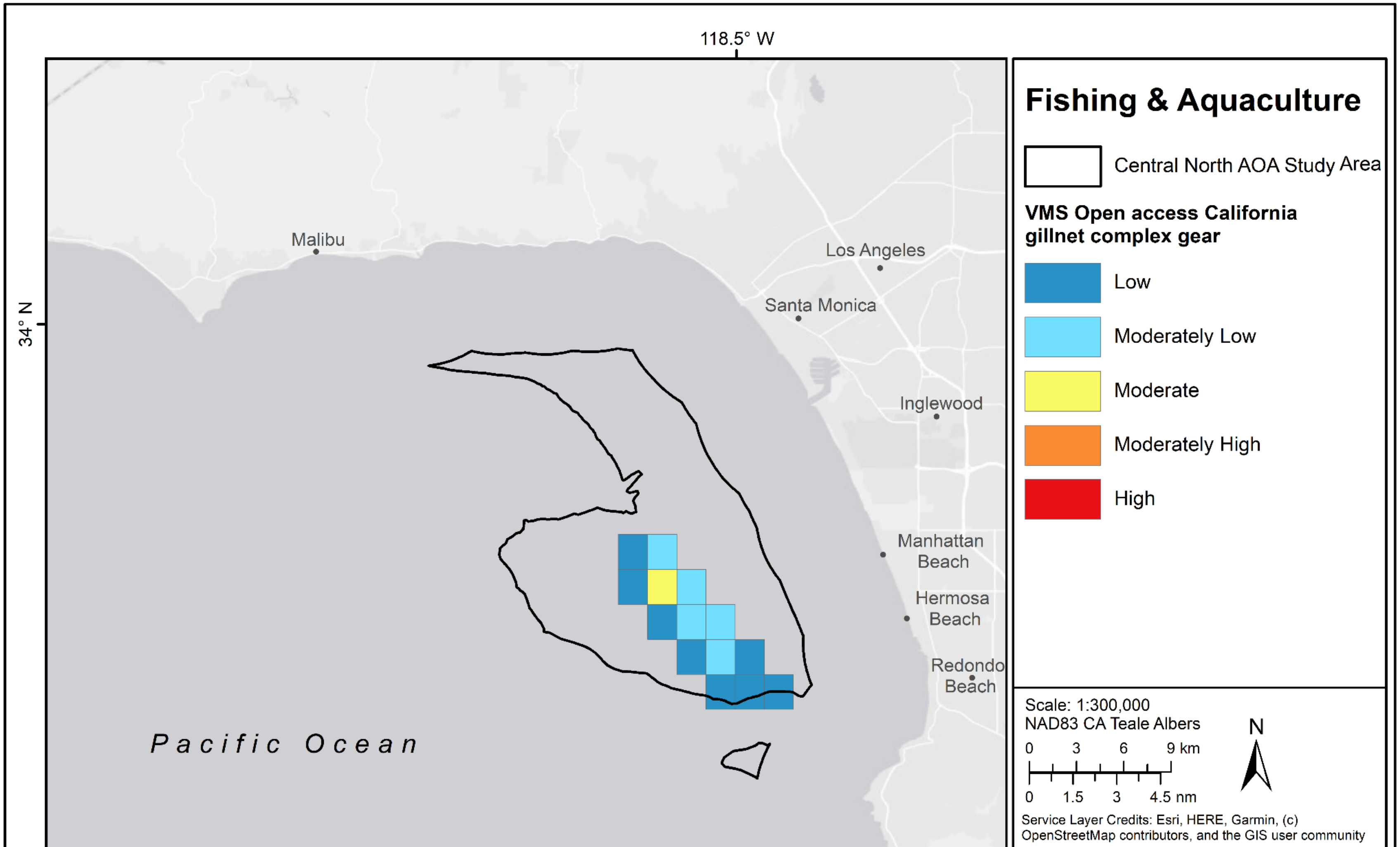
VMS 266 Open access Highly Migratory Species line gear 2010-2017: NOAA - OLE (2017)

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



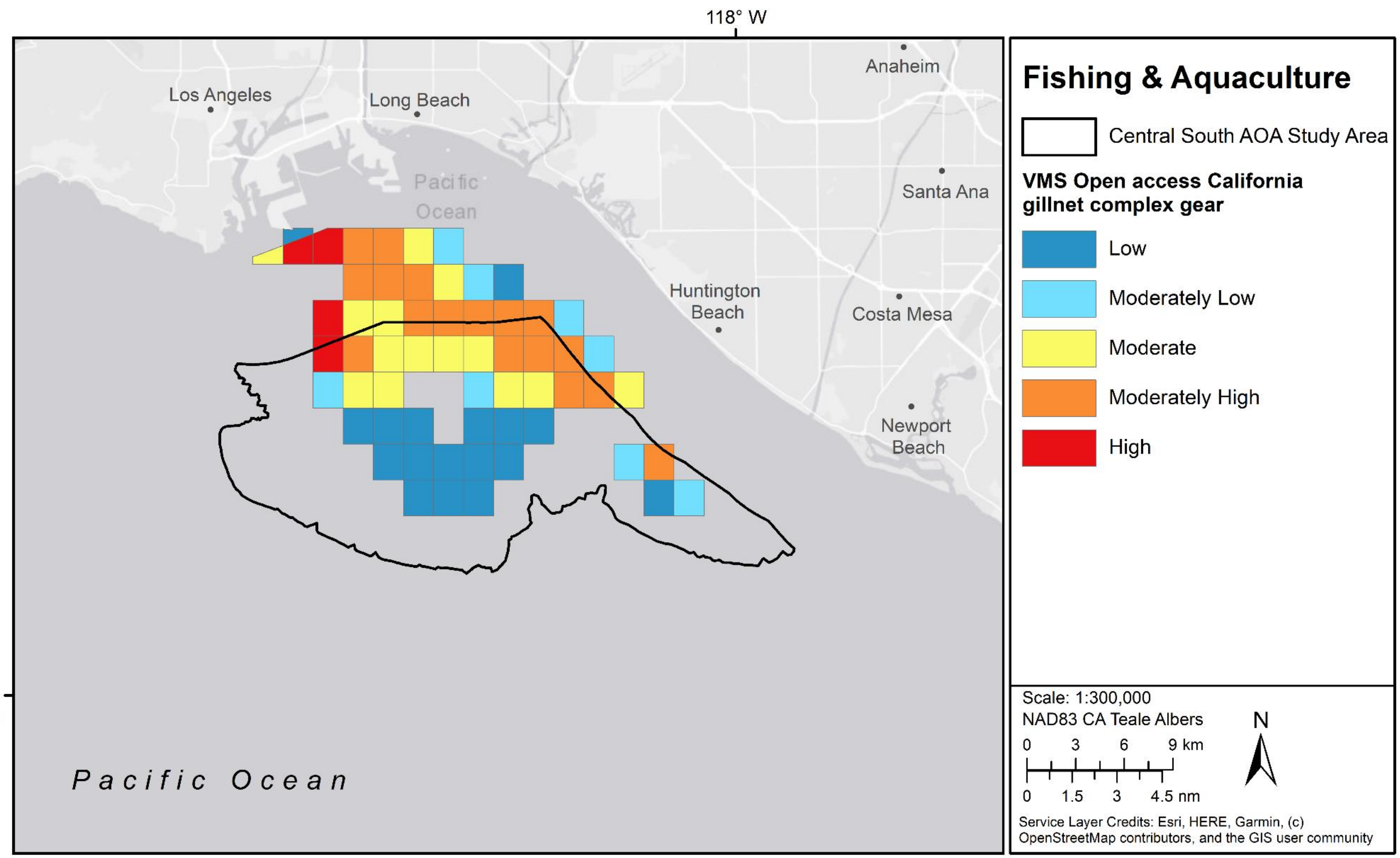
VMS 268 Open access California gillnet complex gear: NOAA - OLE (2017)

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



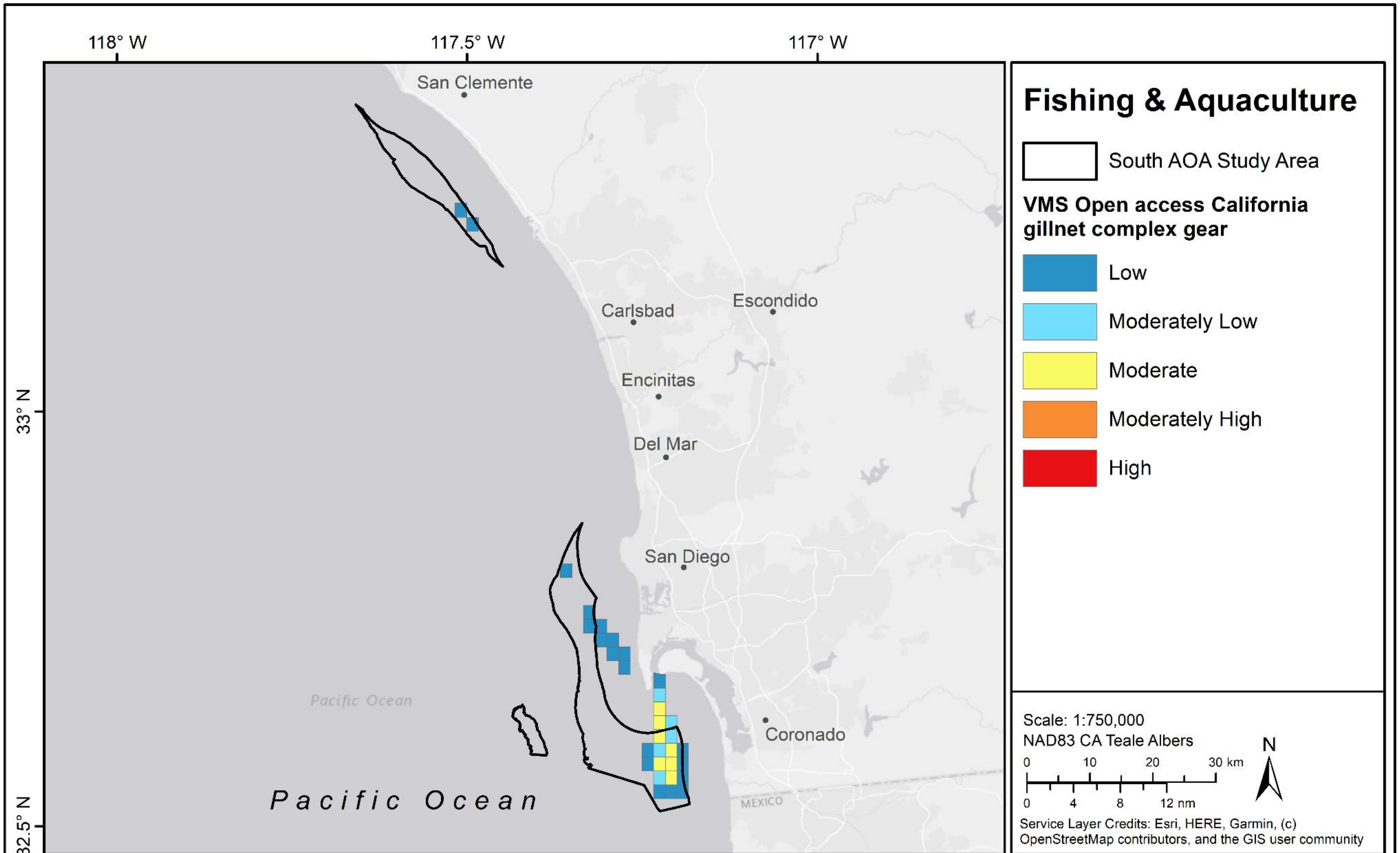
VMS 268 Open access California gillnet complex gear 2010-2017: NOAA - OLE (2017)

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



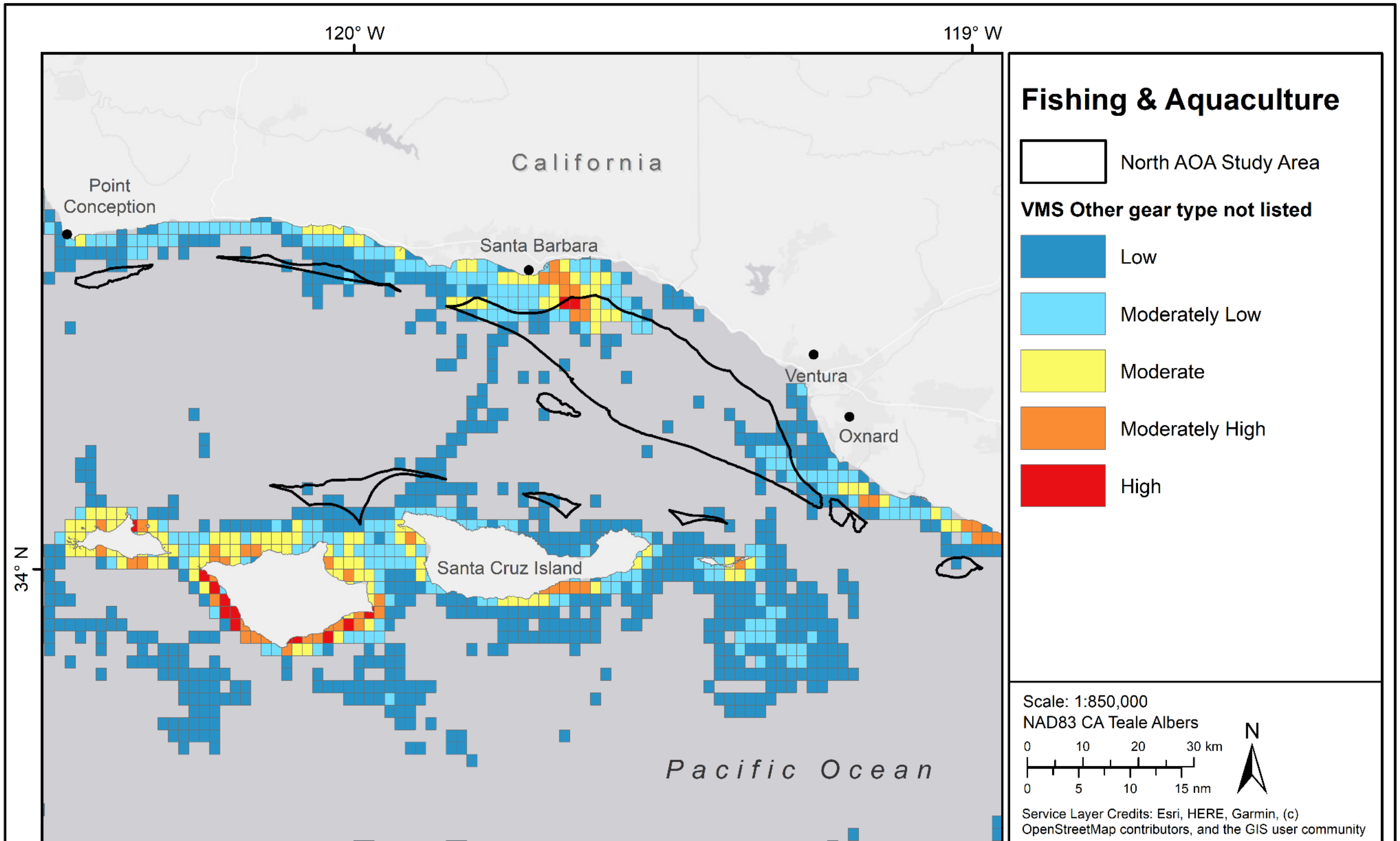
VMS 268 Open access California gillnet complex gear 2010-2017: NOAA - OLE (2017)

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



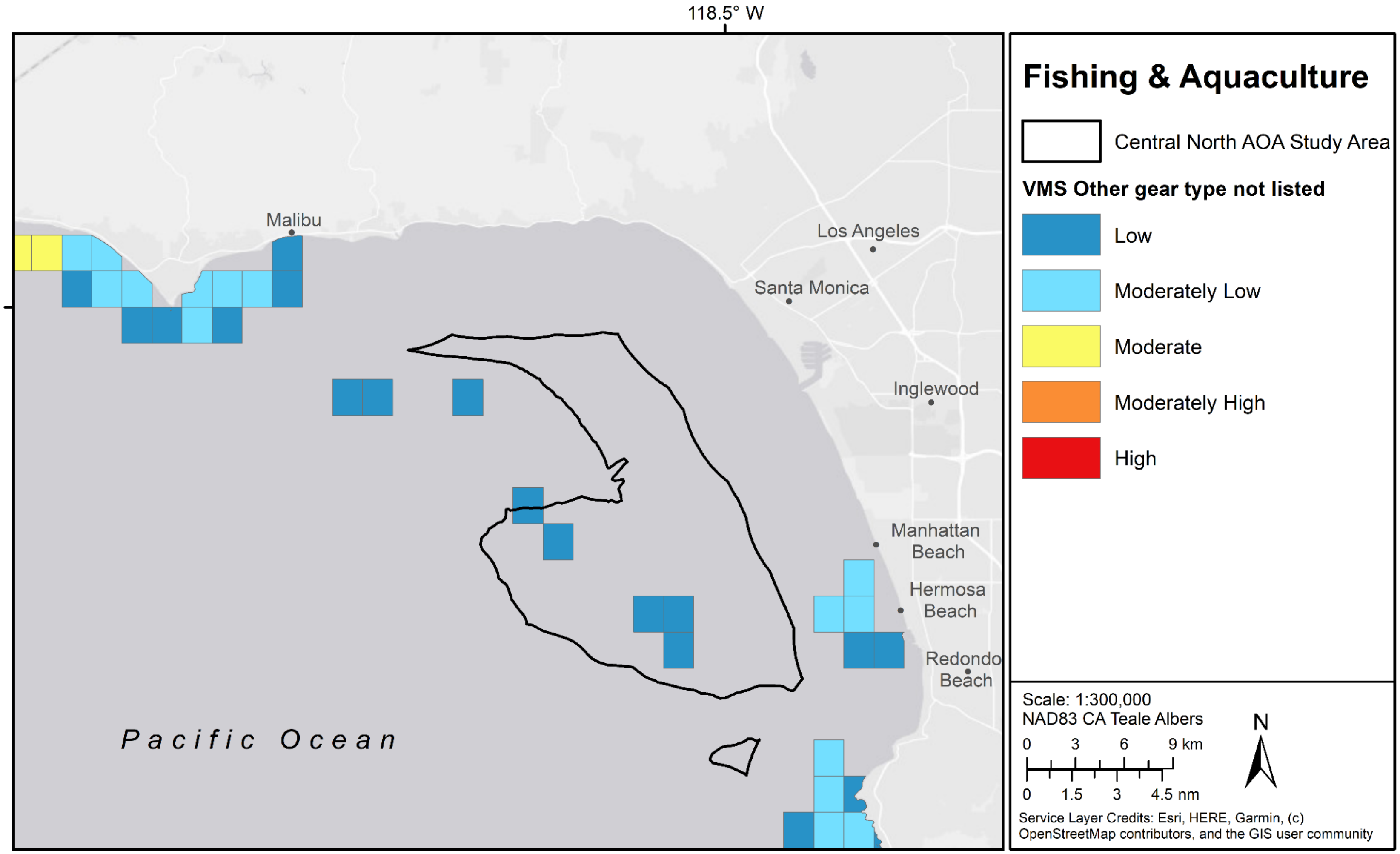
VMS 268 Open access California gillnet complex gear 2010-2017: NOAA - OLE (2017)

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



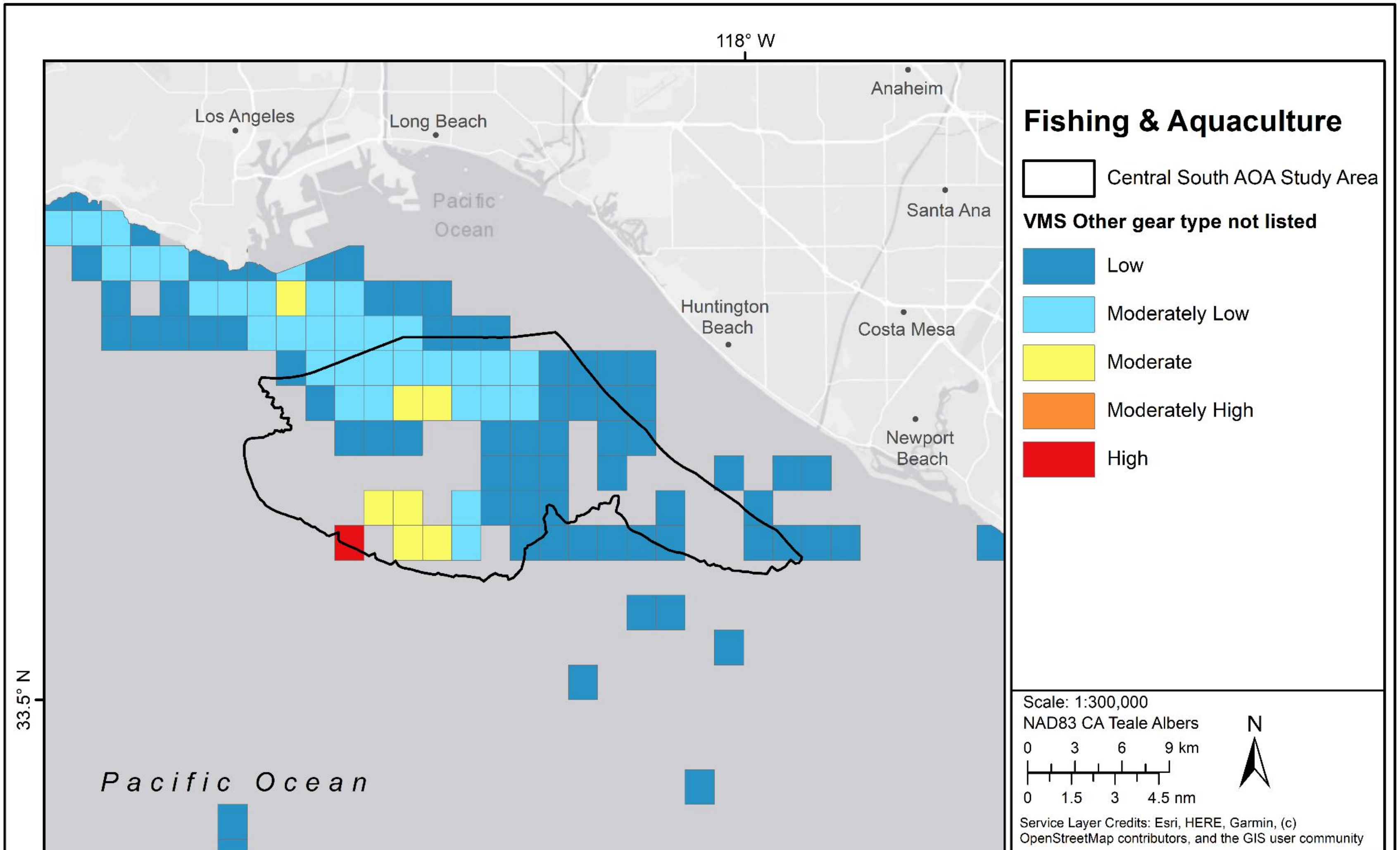
VMS 269 Other gear type not listed: NOAA - OLE (2017)

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



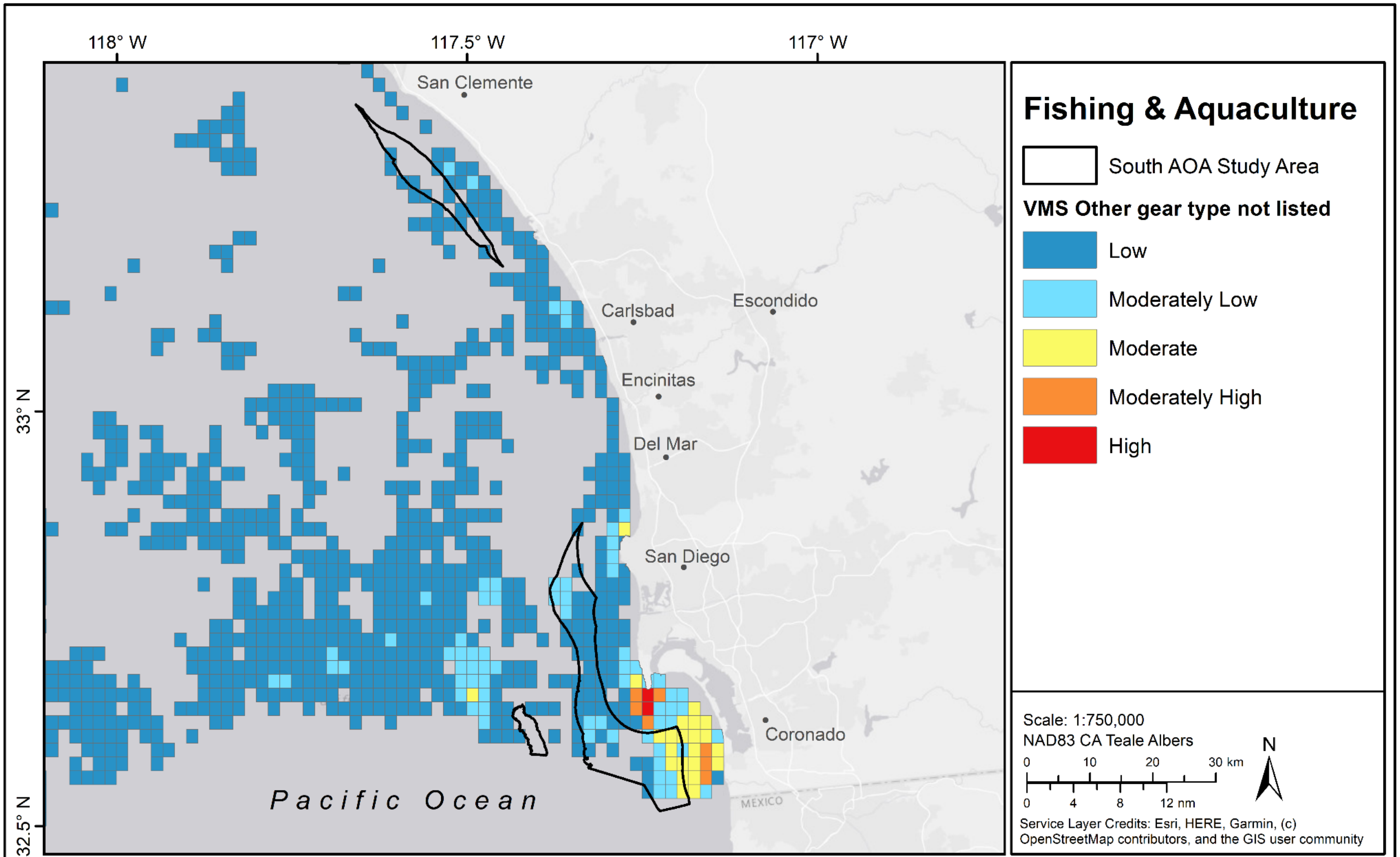
VMS 269 Other gear type not listed 2010-2017: NOAA - OLE (2017)

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



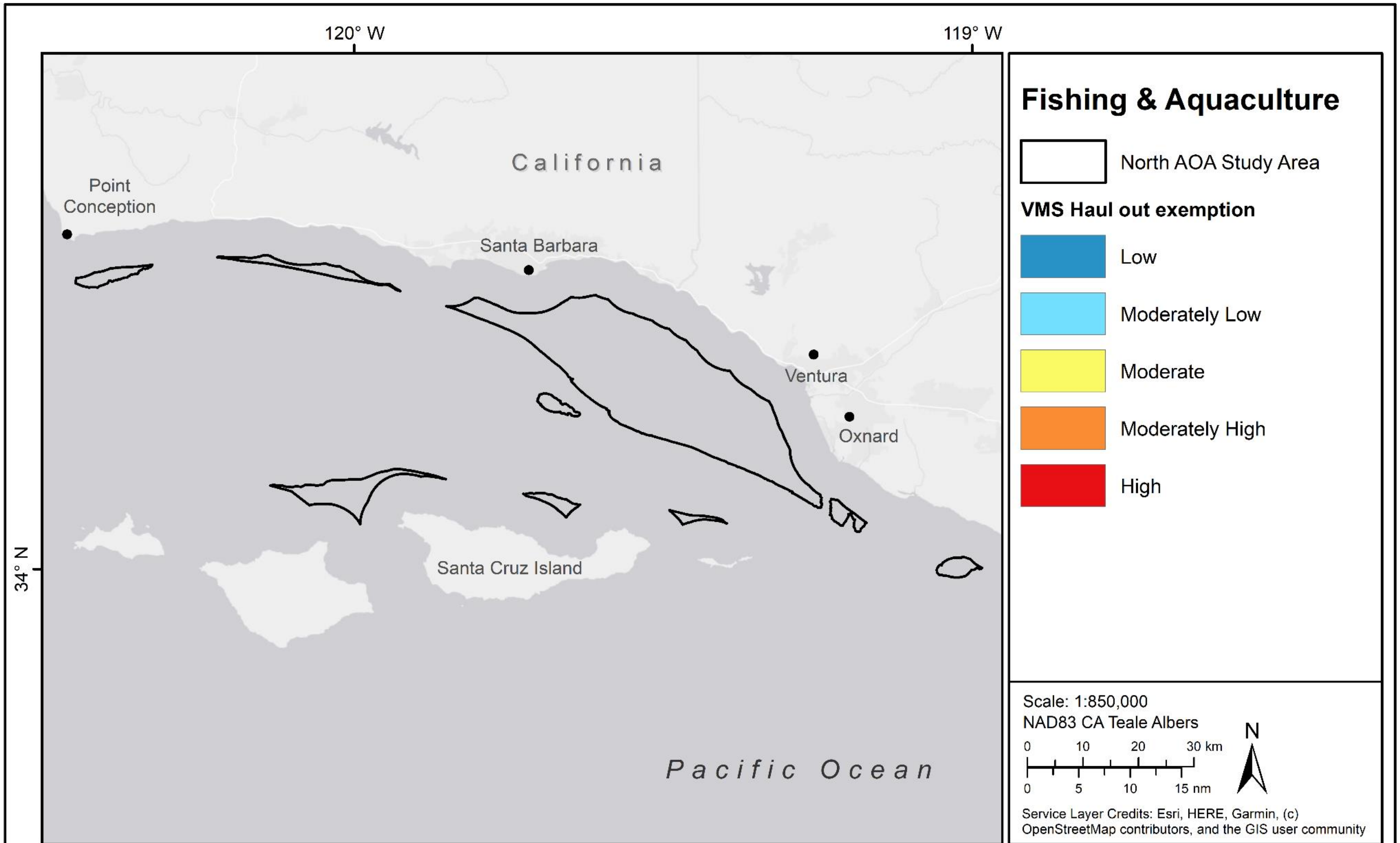
VMS 269 Other gear type not listed 2010-2017: NOAA - OLE (2017)

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



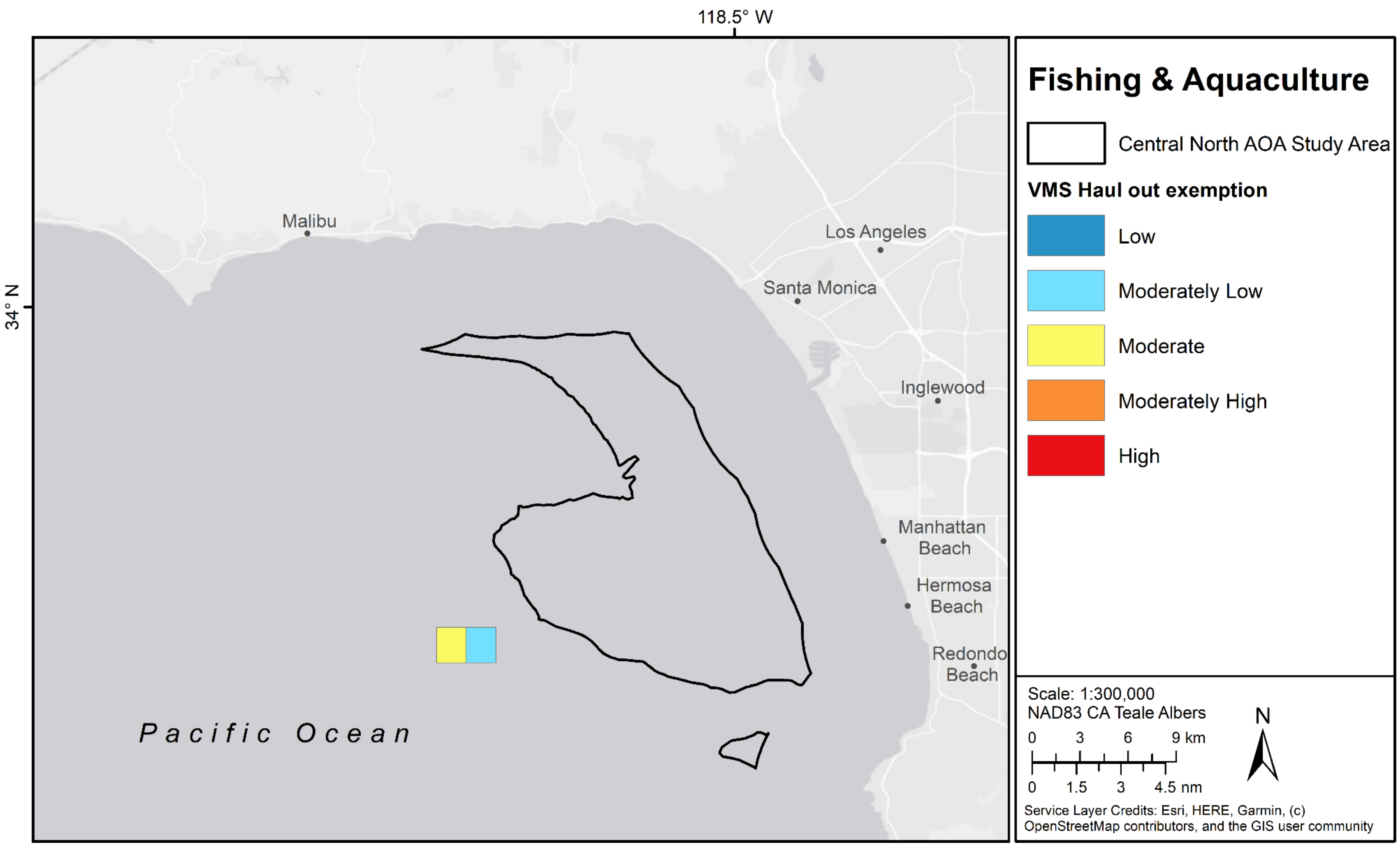
VMS 269 Other gear type not listed 2010-2017: NOAA - OLE (2017)

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



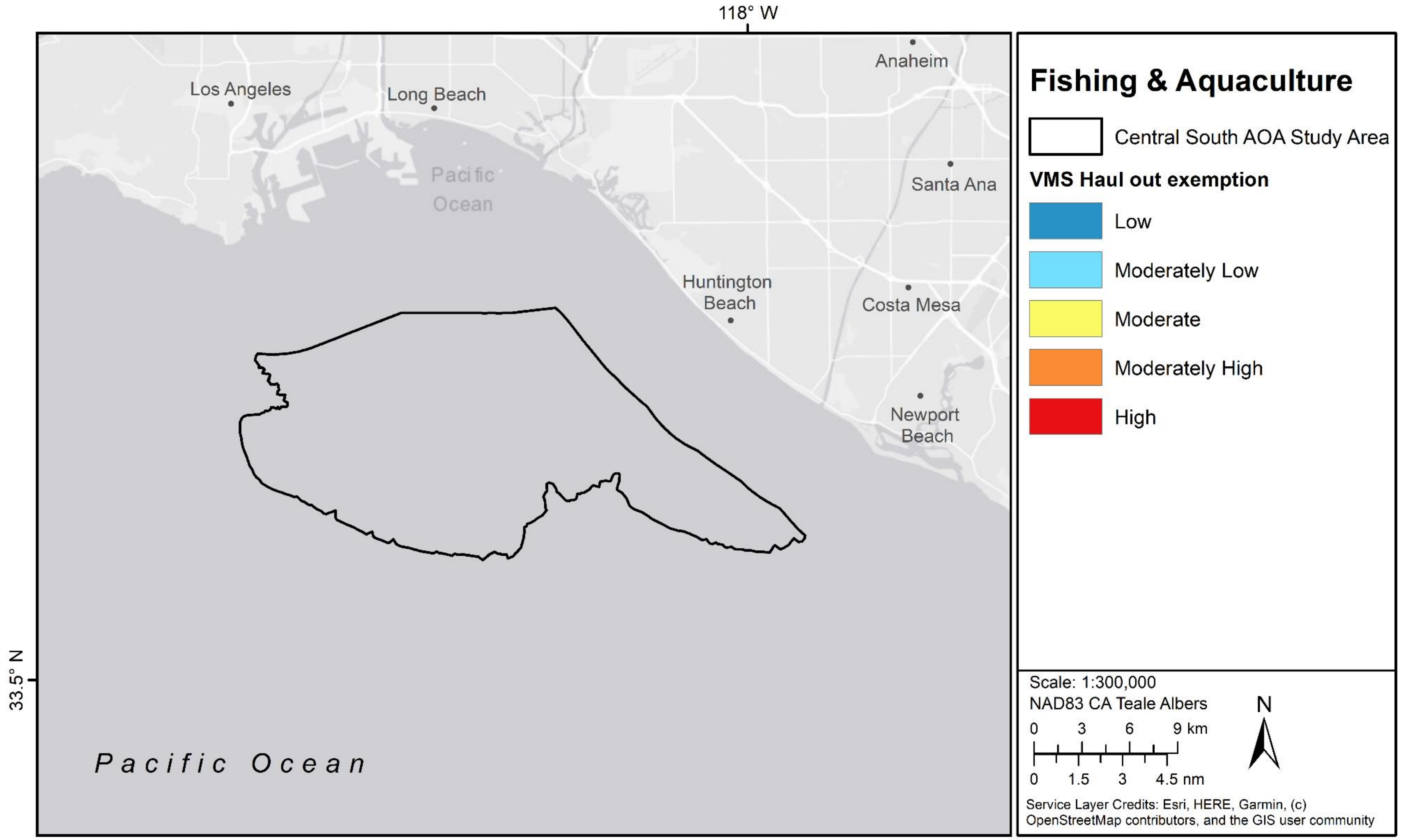
VMS 310 Haul out exemption: NOAA - OLE (2017)

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



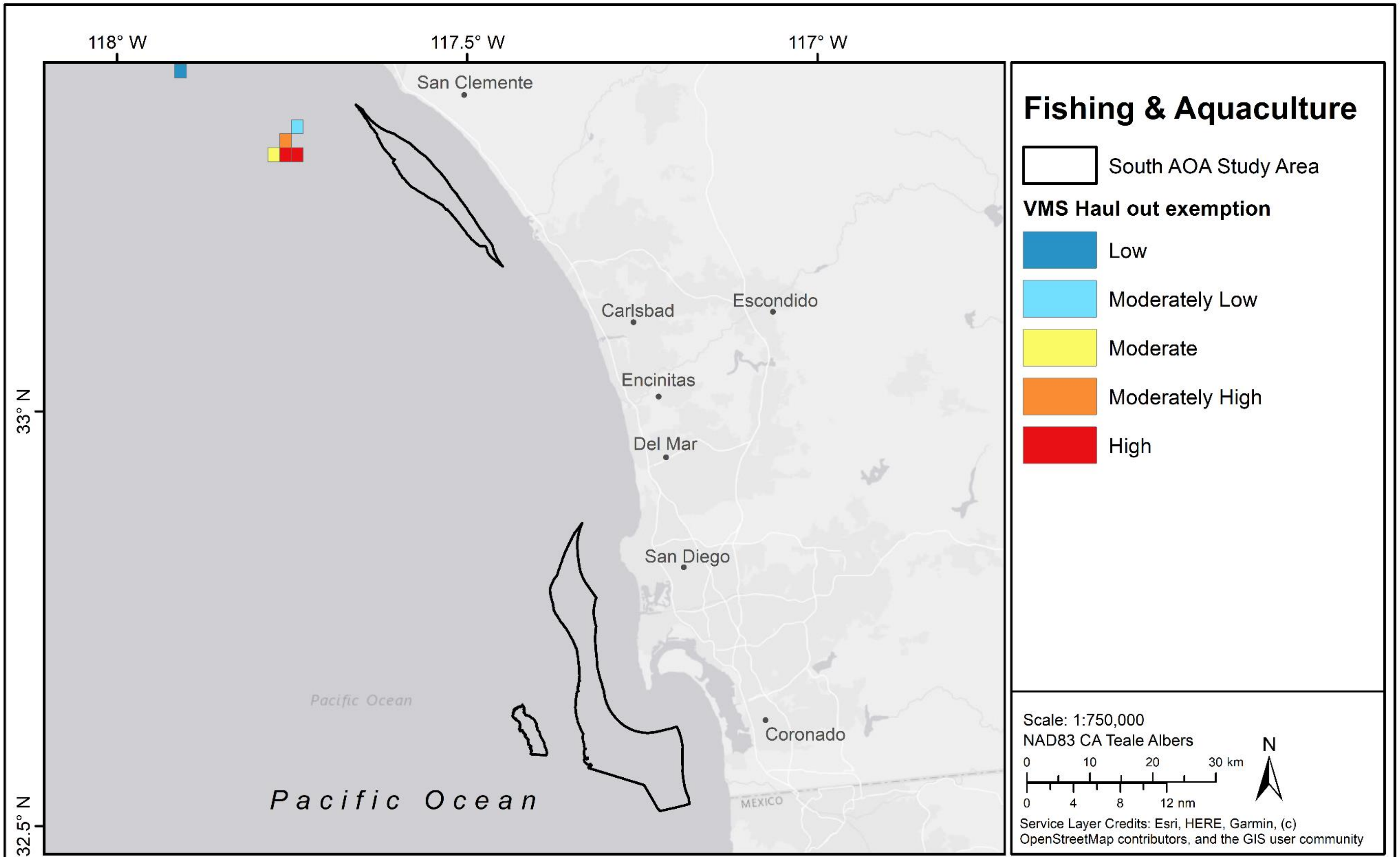
VMS 310 Haul out exemption 2010-2017: NOAA - OLE (2017)

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



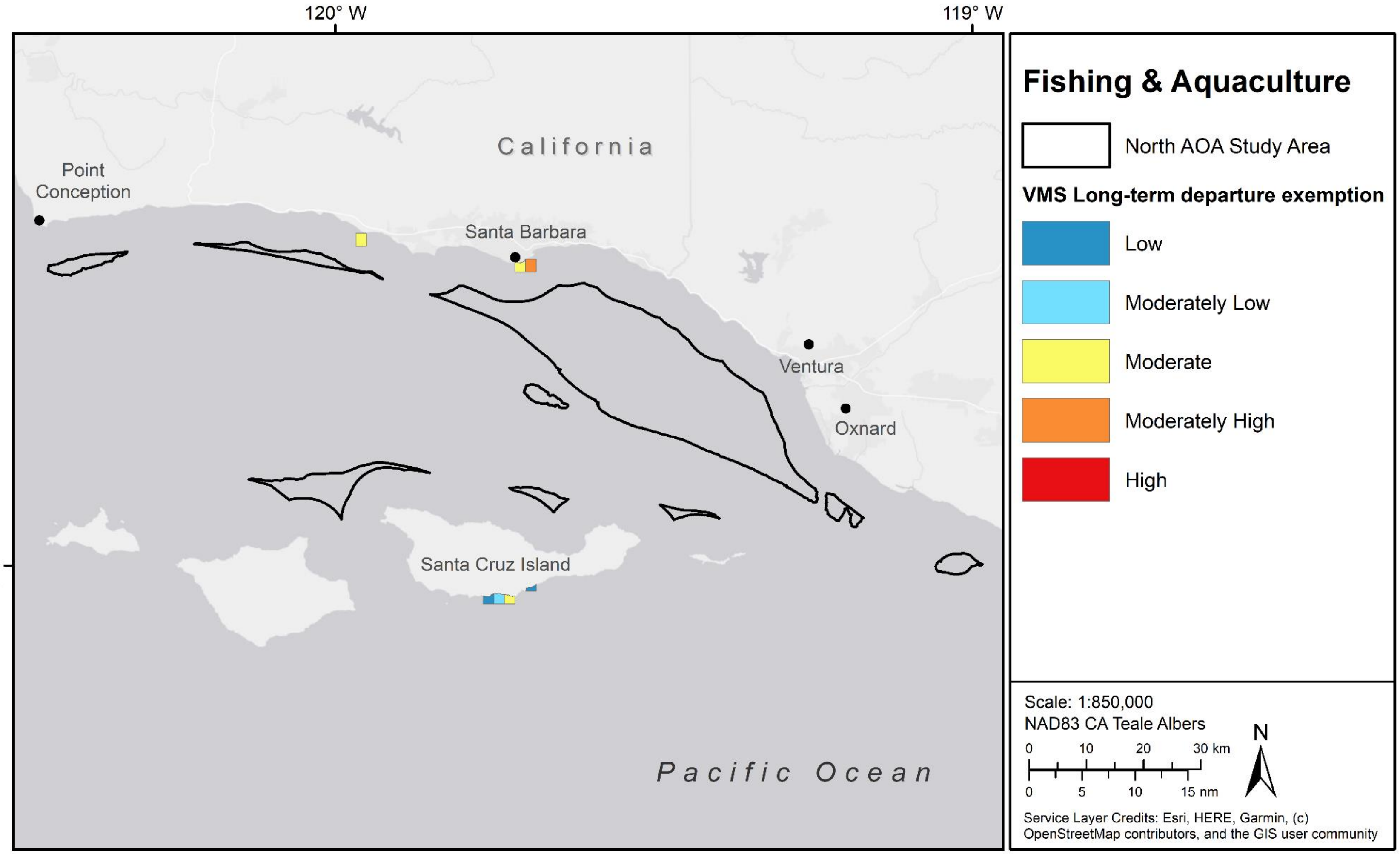
VMS 310 Haul out exemption 2010-2017: NOAA - OLE (2017)

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



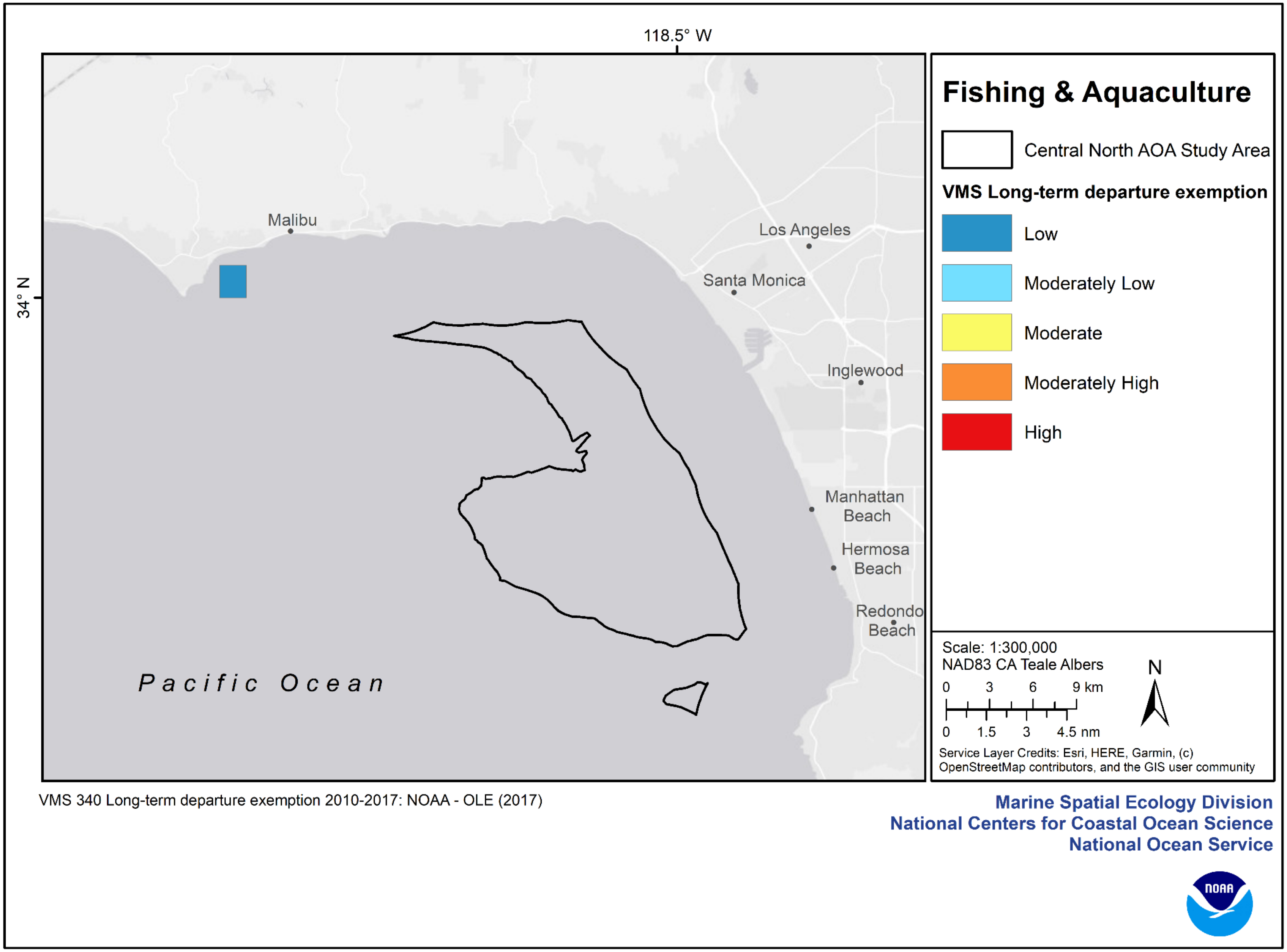
VMS 310 Haul out exemption 2010-2017: NOAA - OLE (2017)

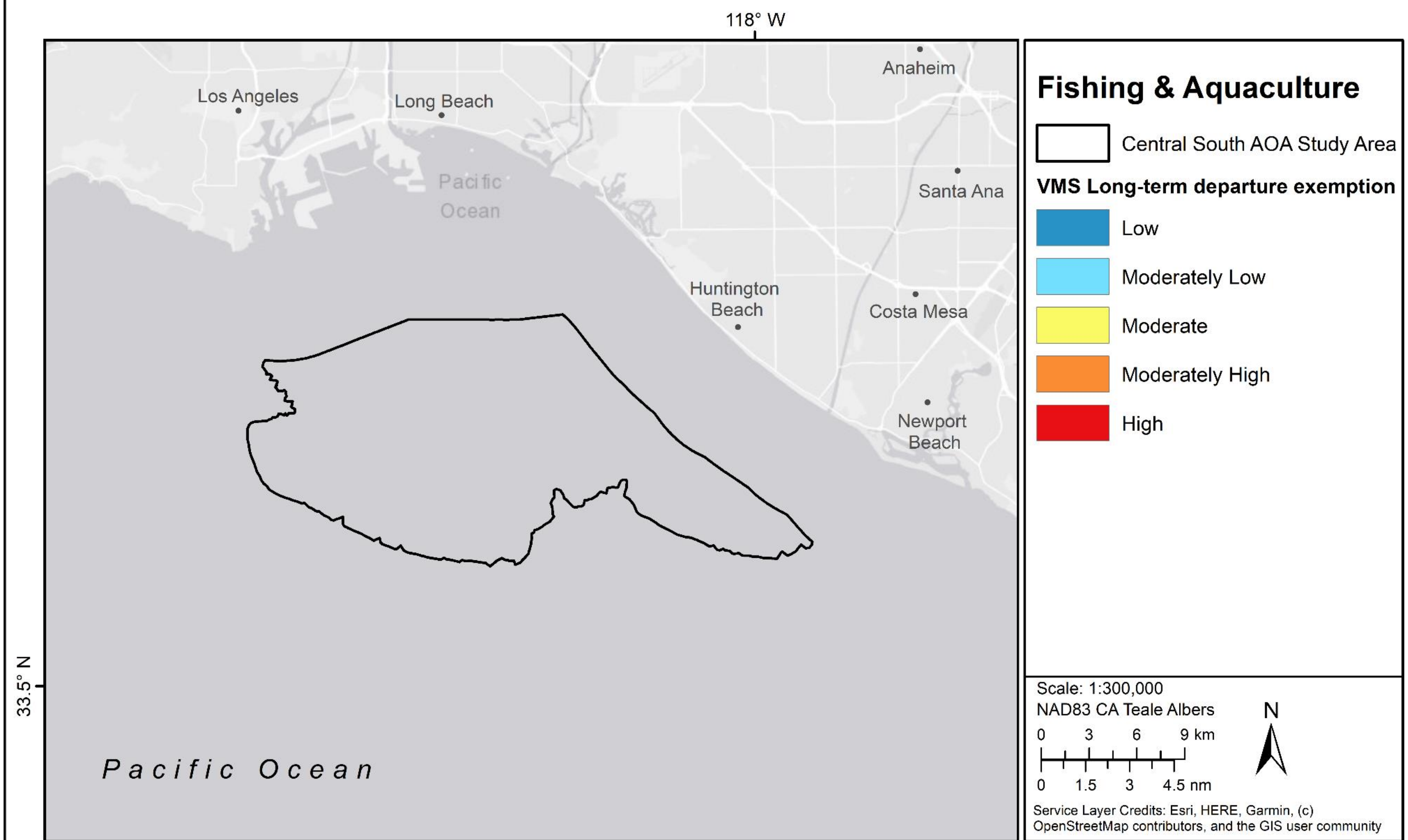
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



VMS 340 Long-term departure exemption: NOAA - OLE (2017)

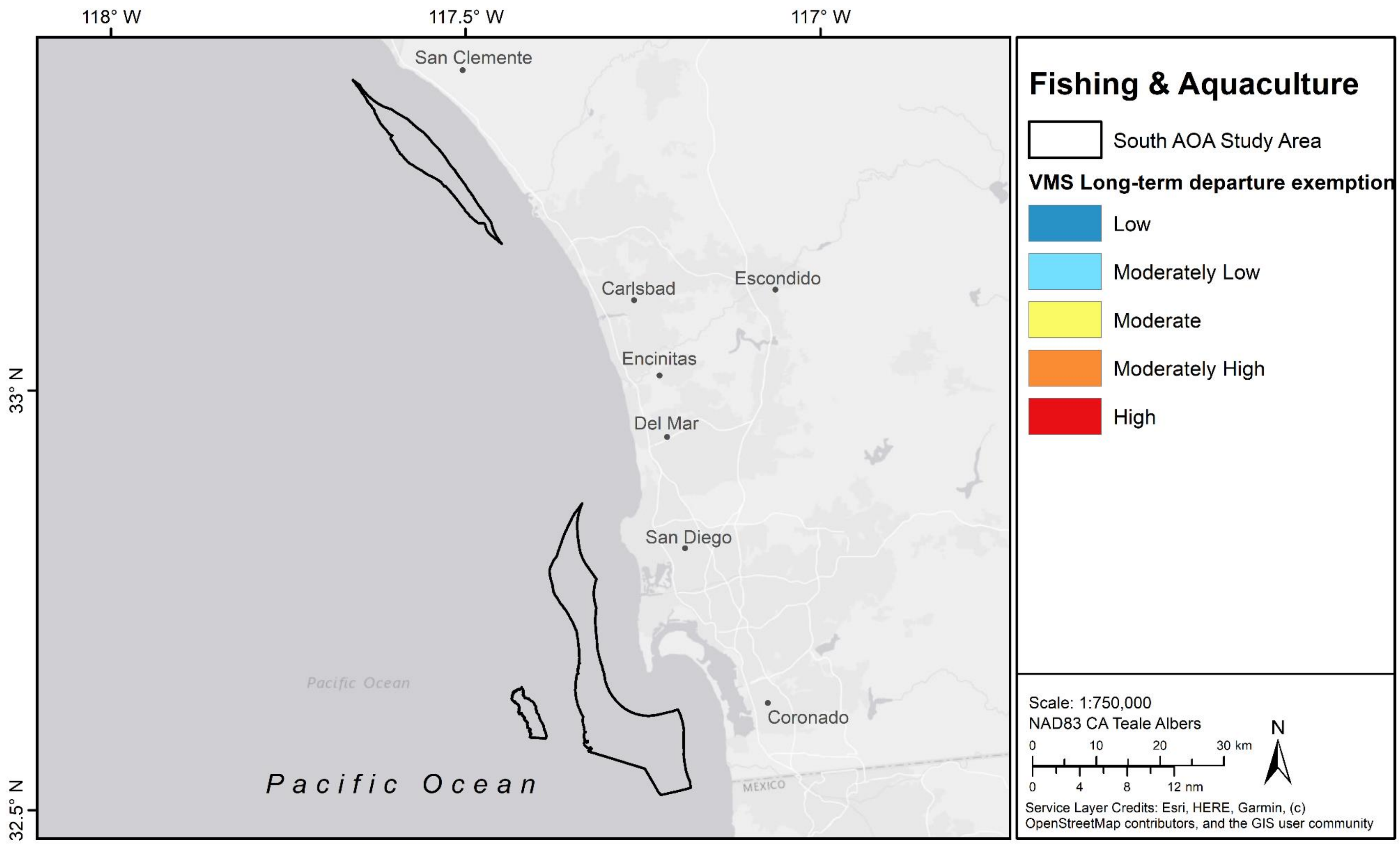
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service


118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Manhattan Beach
Hermosa Beach
Redondo Beach
Pacific Ocean
Fishing & Aquaculture
Central North AOA Study Area
VMS Long-term departure exemption
Low
Moderately Low
Moderate
Moderately High
High
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
VMS 340 Long-term departure exemption 2010-2017: NOAA - OLE (2017)
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service



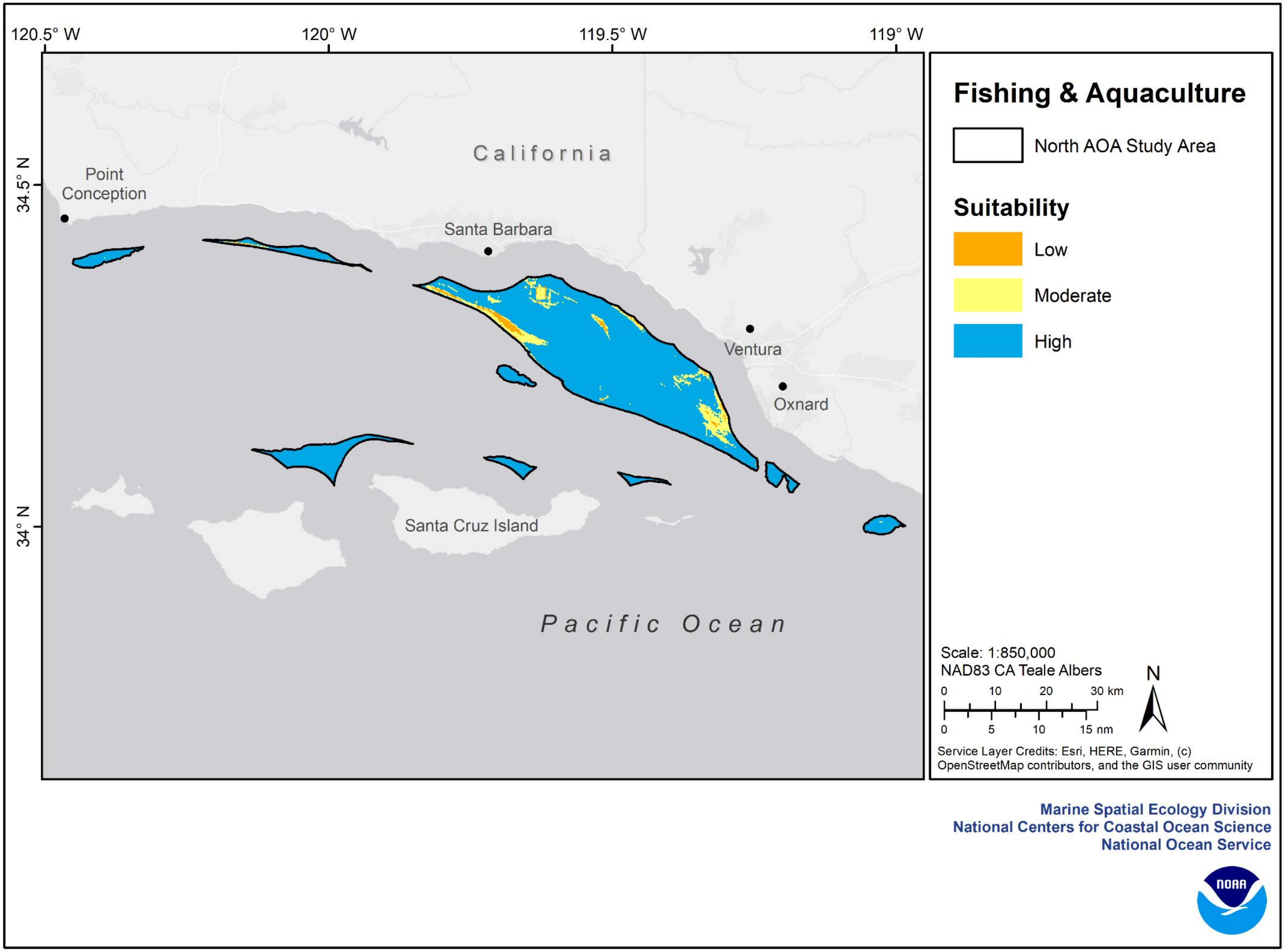
VMS 340 Long-term departure exemption 2010-2017: NOAA - OLE (2017)

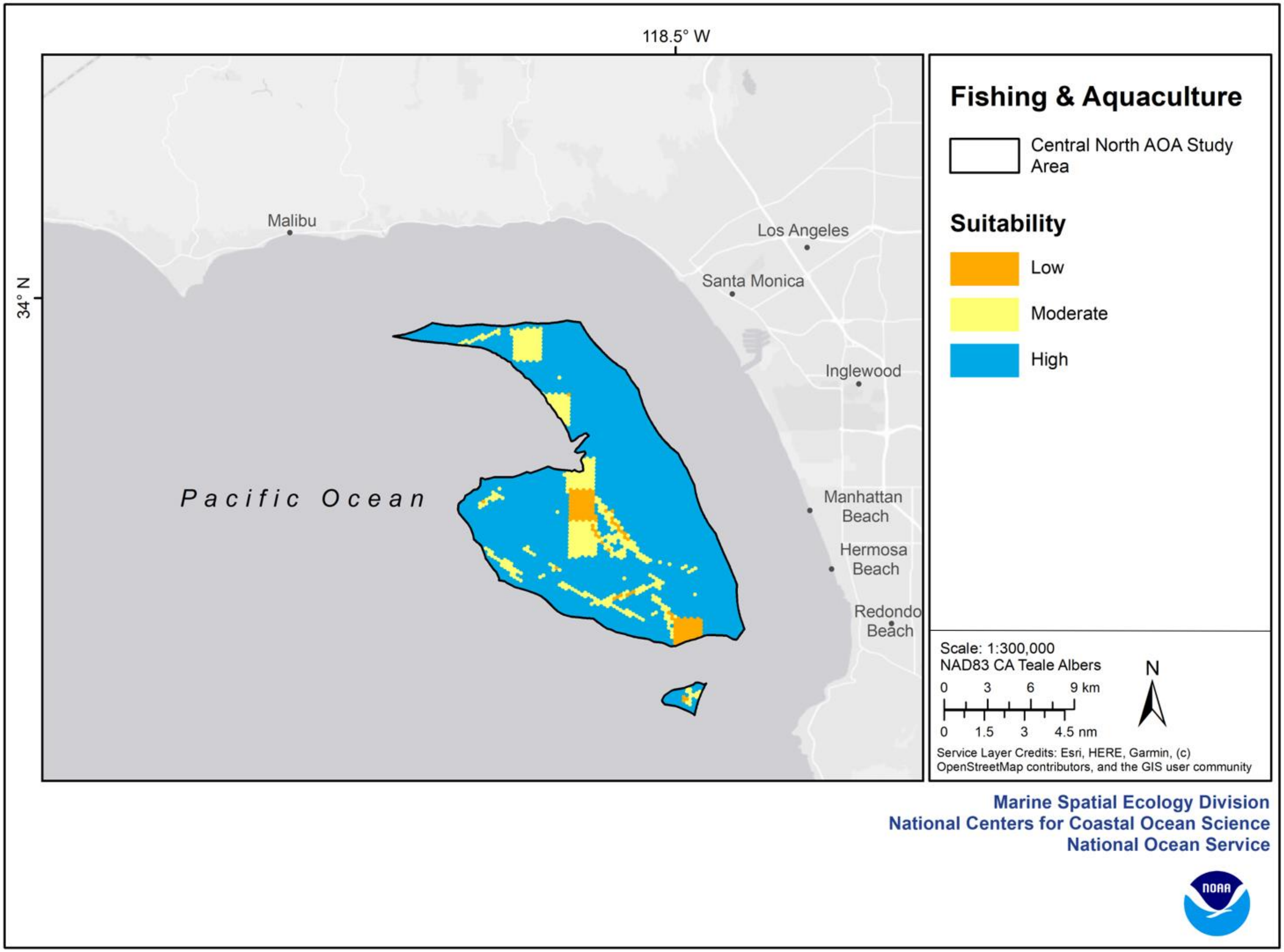
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

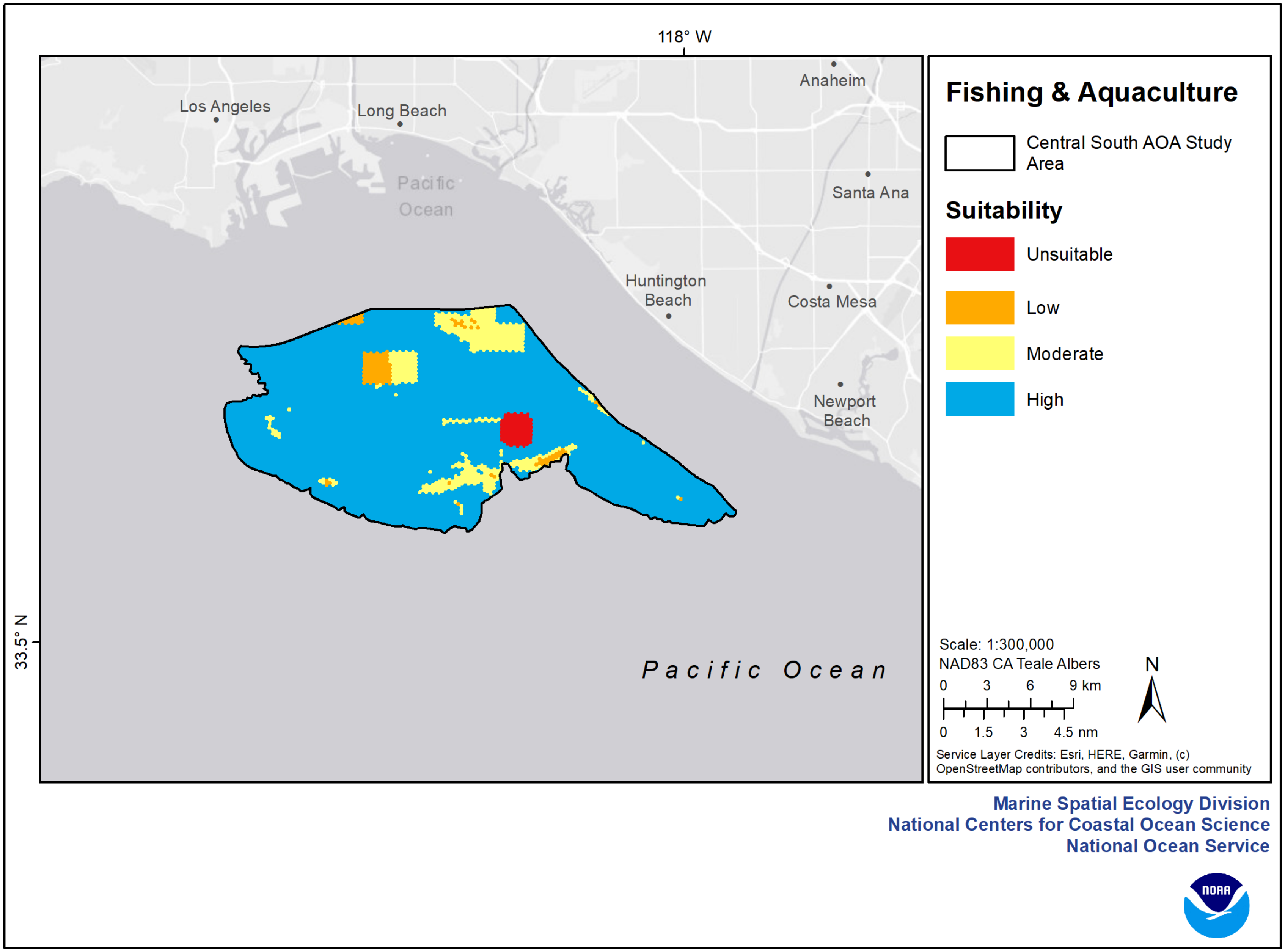


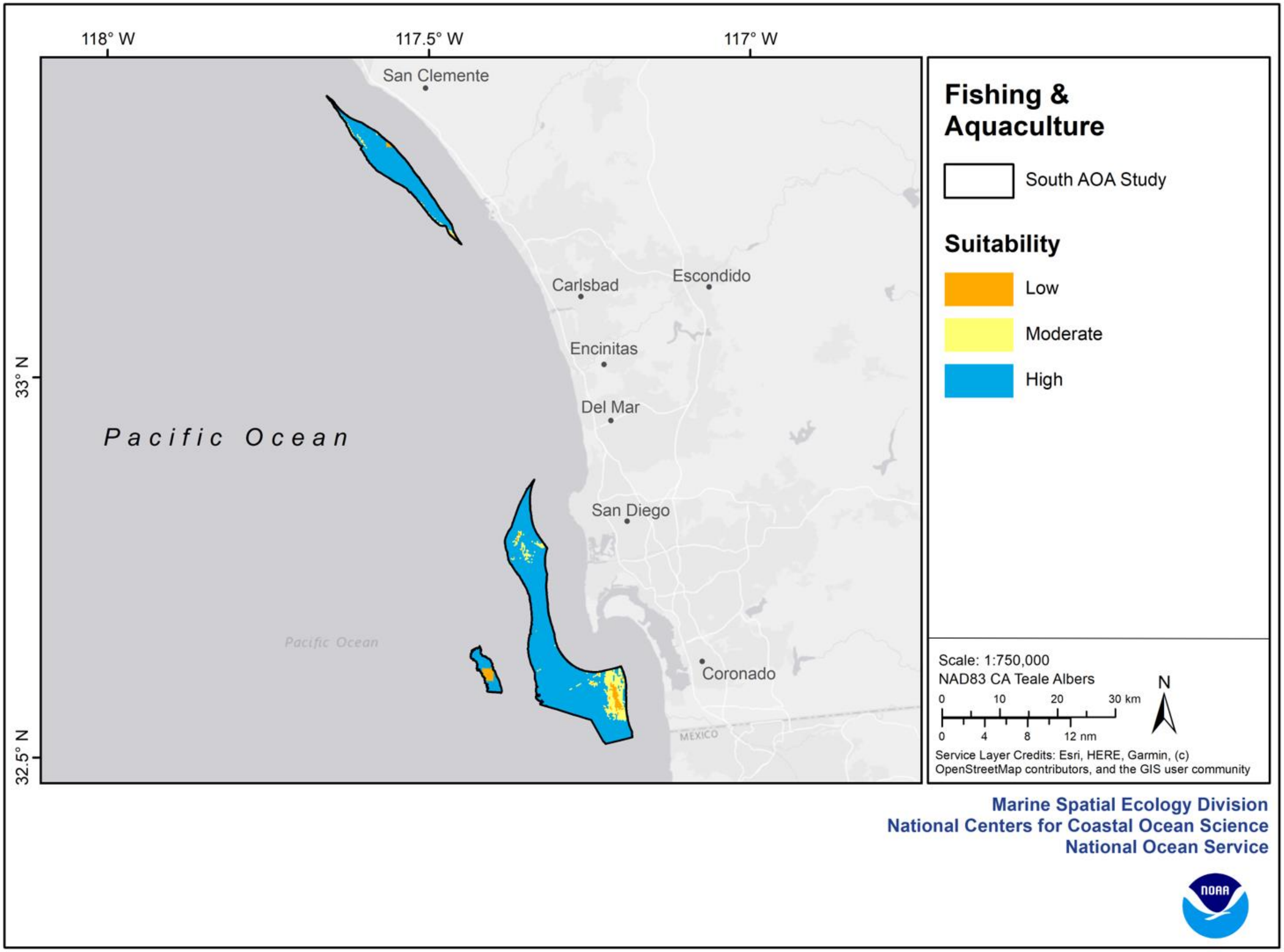
VMS 340 Long-term departure exemption 2010-2017: NOAA - OLE (2017)

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

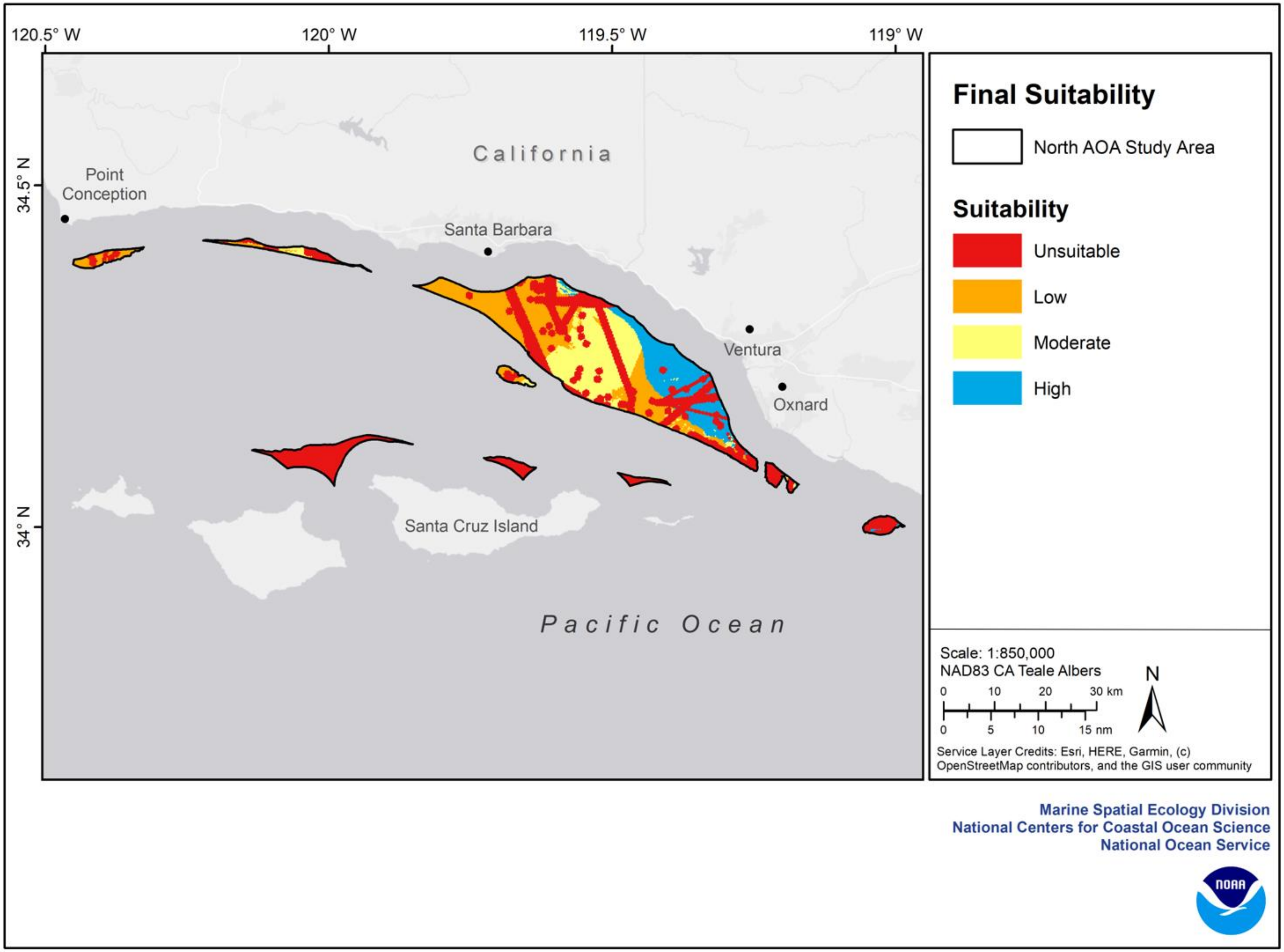

120.5° W
120° W
119.5° W
119° W
34.5° N
34° N
California
Point Conception
Santa Barbara
Ventura
Oxnard
Santa Cruz Island
Pacific Ocean
Fishing & Aquaculture
North AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:850,000
NAD83 CA Teale Albers
0 10 20 30 km
0 5 10 15 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service
NOAA

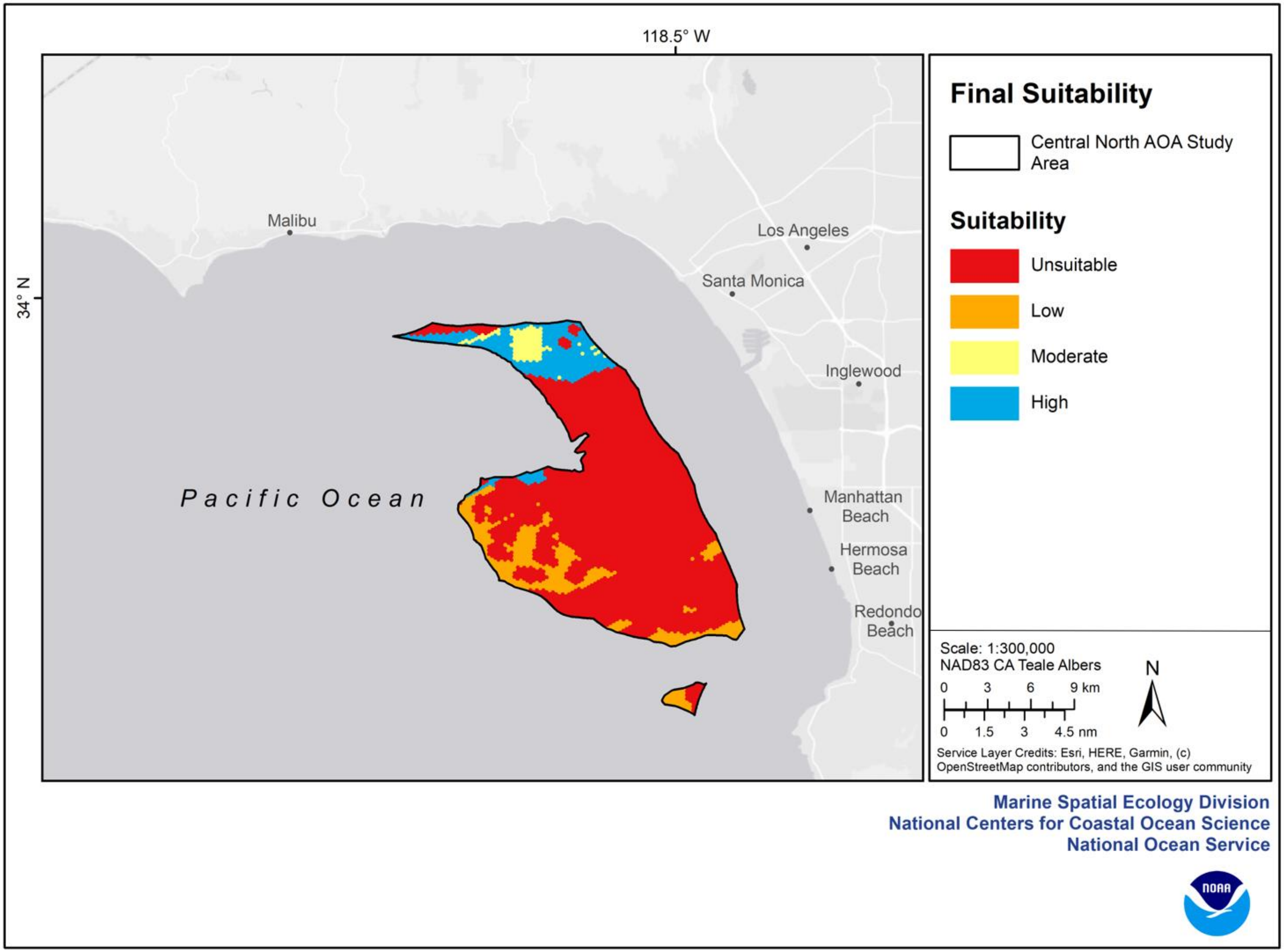

118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
Fishing & Aquaculture
Central North AOA Study Area
Suitability
Low
Moderate
High
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Marine Spatial Ecology Division
National Centers for Coastal Ocean Science
National Ocean Service

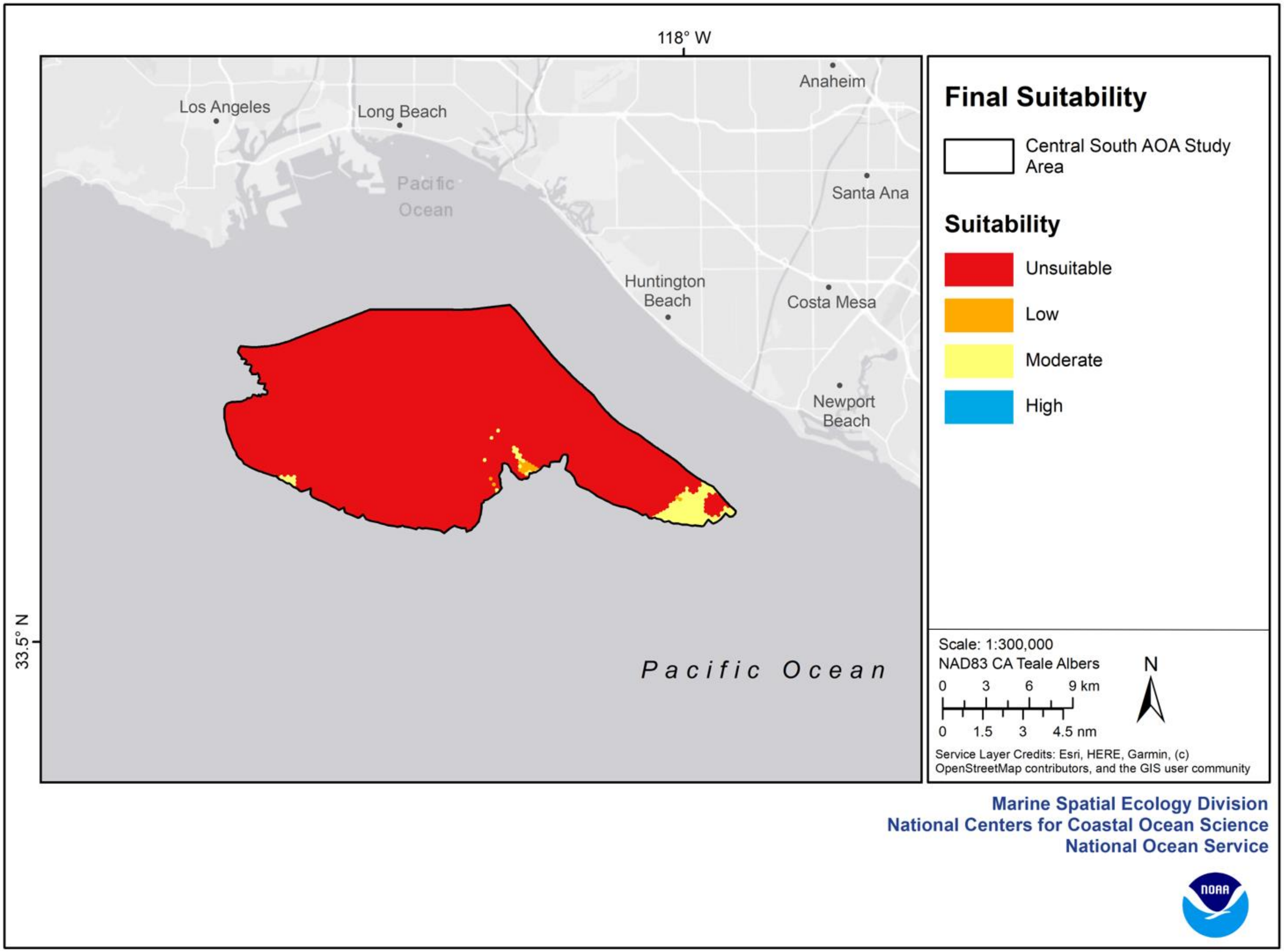

118° W
33.5° N
Los Angeles
Long Beach
Anaheim
Pacific
Ocean
Santa Ana
Huntington
Beach
Costa Mesa
Newport
Beach
Pacific Ocean
Fishing & Aquaculture
Central South AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 nm
N
Service Layer Credits: 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


118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
Fishing & Aquaculture
South AOA Study
Suitability
Low
Moderate
High
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 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

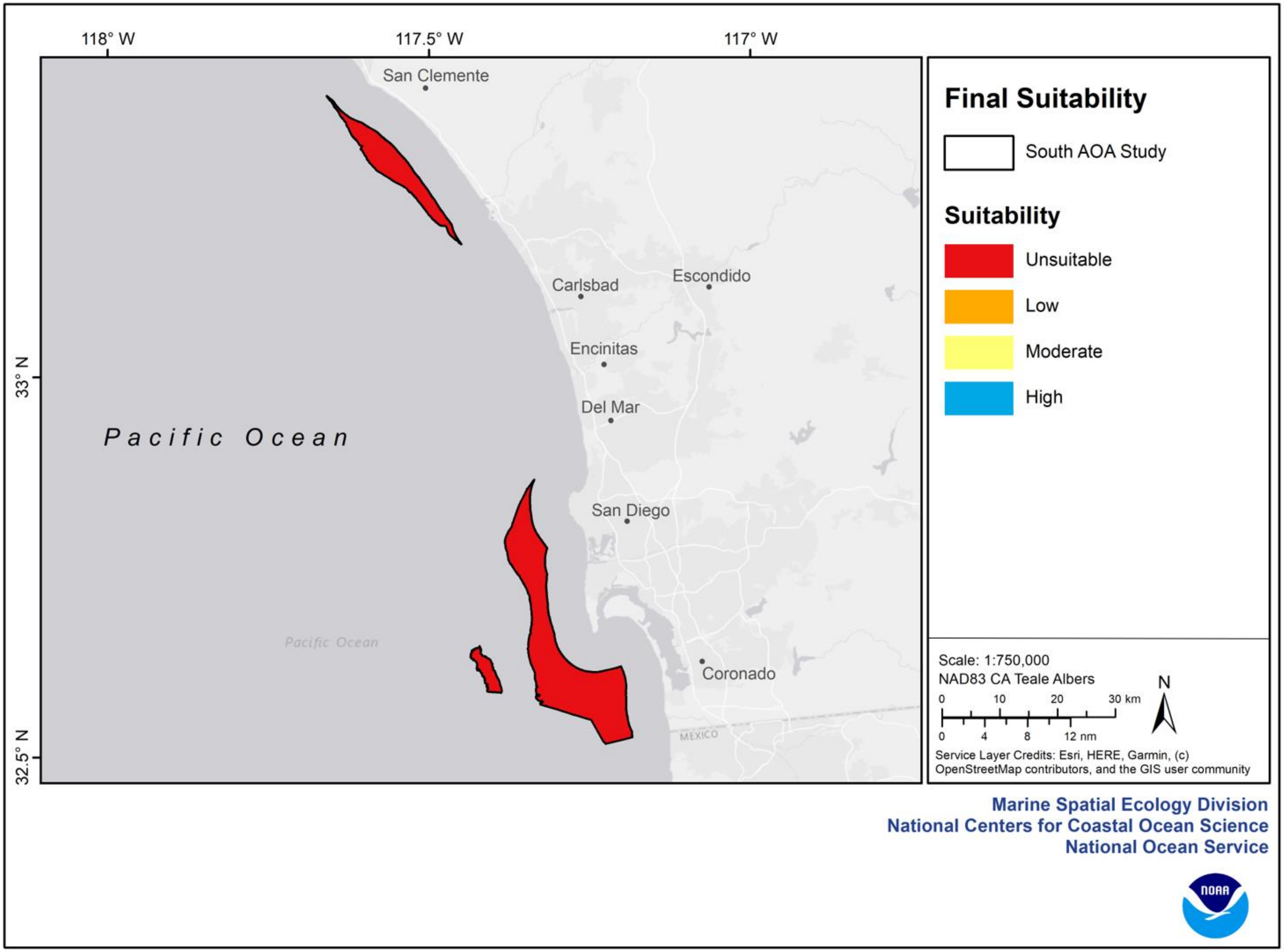
Suitability Modeling Results




118.5° W
34° N
Malibu
Los Angeles
Santa Monica
Inglewood
Pacific Ocean
Manhattan Beach
Hermosa Beach
Redondo Beach
Final Suitability
Central North AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 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



118° W
33.5° N
Los Angeles
Long Beach
Anaheim
Pacific
Ocean
Santa Ana
Huntington
Beach
Costa Mesa
Newport
Beach
Pacific Ocean
Final Suitability
Central South AOA Study Area
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:300,000
NAD83 CA Teale Albers
0 3 6 9 km
0 1.5 3 4.5 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


118° W
117.5° W
117° W
33° N
32.5° N
San Clemente
Carlsbad
Escondido
Encinitas
Del Mar
Pacific Ocean
San Diego
Pacific Ocean
Coronado
MEXICO
Final Suitability
South AOA Study
Suitability
Unsuitable
Low
Moderate
High
Scale: 1:750,000
NAD83 CA Teale Albers
0 10 20 30 km
0 4 8 12 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

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