Spatial Analysis to evaluate options for siting Ventura Shellfish Enterprise in California State Waters, Santa Barbara Channel, California, USA

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September 2020

BACKGROUND

Planning and siting for marine aquaculture operations require thorough synthesis and spatial analyses of critical environmental and ocean space use conflicts (Kapetsky et al. 2013). Implementing spatial planning strategies into the process allows compatibility to be assessed and works towards environmental and economically sustainable aquaculture operations. This integral process allows for efficient collaboration and data sharing with regional agencies, improving the accuracy and inclusion of essential considerations during the planning process.

Ventura Shellfish Enterprise (hereafter 'VSE') is a multi-party initiative led by the Ventura Port District in California seeking to permit twenty 100-acre (40.5 ha) plots for the production of mussels (*Mytilus galloprovincialis)*. This technical report covers the NOAA Coastal Aquaculture Siting and Sustainability (CASS) program's siting analysis for the proposed mussel farm in California state waters (0 – 3 nm/ 0 – 5.6 km from shore); a separate 2018 report focuses on a similar analysis for federal waters. The intended users of this information include the permitting interagency workgroup (e.g., the US Army Corps of Engineers, California Coastal Commission, and other state and federal agencies, etc.) as well as VSE.

Farming parameters were provided by VSE to account for system operational requirements in this analysis. VSE provided the estimated maximum operating distance from Ventura harbor, desired operational depth, the general farm footprint, water temperature for cultivated species, and current velocity range thresholds (Table 1). This information was used to identify the initial Areas of Interest (AOI) and identify site alternatives suitable for mussel aquaculture operations.

The **Coastal Aquaculture Siting and Sustainability (CASS)** program works to provide science-based decision support tools to local, state, and federal coastal managers supporting sustainable aquaculture development. The CASS program is located within the Marine Spatial Ecology Division of the National Centers for Coastal Ocean Science, National Ocean Service, NOAA.

To learn more about CASS and how we are growing sustainable marine aquaculture practices visit https://coastalscience.noaa.gov/research/marine-spatial-ecology/aquaculture/ or contact Dr. James Morris at James.Morris@noaa.gov.

Table 1. Ventura Shellfish Enterprise farming requirements.

Requirement	
Preferred port	Ventura Harbor, California
Federal/State waters	State Waters (0 – 3 nm from CA shore)
Selected culture species	Mussels (*Mytilus galloprovincialis*)
Farm Footprint Size	20 x 100 acres (2,000 acres)
Maximum distance from port	≤ 9 nm
Gear depth requirements	≥ 25 and ≤ 37 m
Seawater temperature	5 – 30 ºC, optimal 20 ºC
Current Velocity	0.025 – 0.1 m^{-s}
Significant wave height	Depth range selected due to wave climate

Spatial data are utilized to represent critical potential environmental and ocean space use conflicts that potentially constrain, or conditionally constrain, the siting of aquaculture in California state waters. Following the workflow in Figure 1, a suitability analysis was performed evaluating numerous spatial data types for a location and provides a relative comparison of how suitable the areas are for marine aquaculture of mussels. Additionally, protected species, habitat descriptions, various fishing activities, management areas, and oceanographic and biophysical characteristics are described and utilized in the aquaculture site suitability model. This report provides information to the regulatory working groups involved in aquaculture permitting and VSE.

NOAA NCCOS has technically reviewed this report. Information within this report is intended for site characterization and does not equate to work needed concerning biological consultations, section 7 review, or other necessary consultations that may occur in the pre-permitting or permitting process with the state and/or federal agencies. NOAA NCCOS makes no warranties to the accuracy or completeness of the data presented here, and NOAA will not be responsible for any adverse result based upon users' reliance on the application or the data presented. This report provides a "first look" screening effort focused on information available in the geographic area of interest. Users are advised to exercise due diligence and independently confirm the accuracy and correctness of the data provided. Approval does not signify that the contents necessarily reflect the views and policies of NOAA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

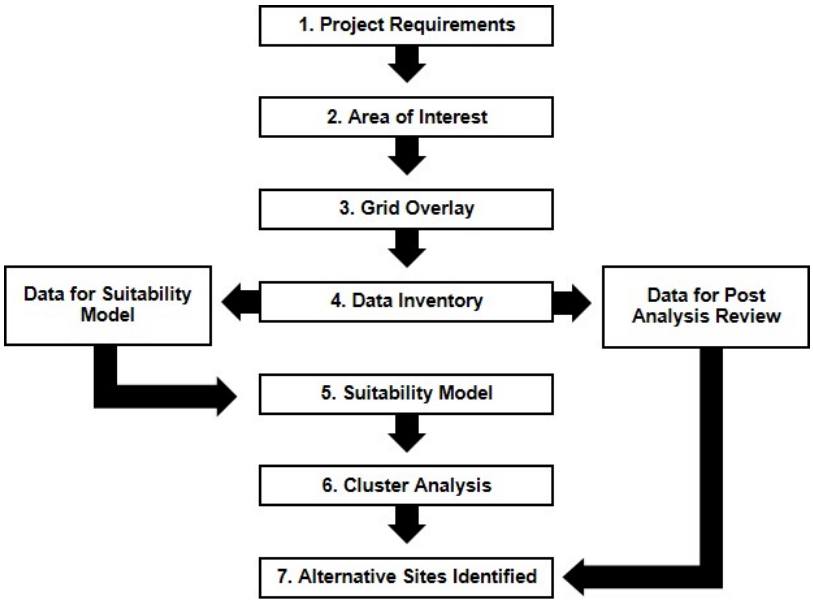

Figure 1. Spatial analysis workflow.

METHODS

Area of Interest

The Area of Interest (AOI) was delineated in state waters using the farm operational constraints provided by VSE (Table 1). To delineate the AOI, first, the state waters within 9-nm from the chosen port, Ventura harbor, were delineated. The distance to port is based on needed proximity to the port (i.e., economic and logistical needs) where land-based assets exist, workers transport to and from the farm, where gear is shipped in and transported to the farm site, stationing and repair of equipment occur, and where the harvested product will be landed. Next, the depth requirement of 25 m (i.e., the shallowest depth) to 37 m (i.e., the deepest depth that is logistically and economically feasible) further refined the area creating the AOI (Figure 2). The resulting final AOI within state waters has an area of 20.9 km² (5,179 acres). Within the AOI a grid of one-hectare (2.4 acres) hexagonal polygons was placed to receive values from the siting analysis (Figure 3).

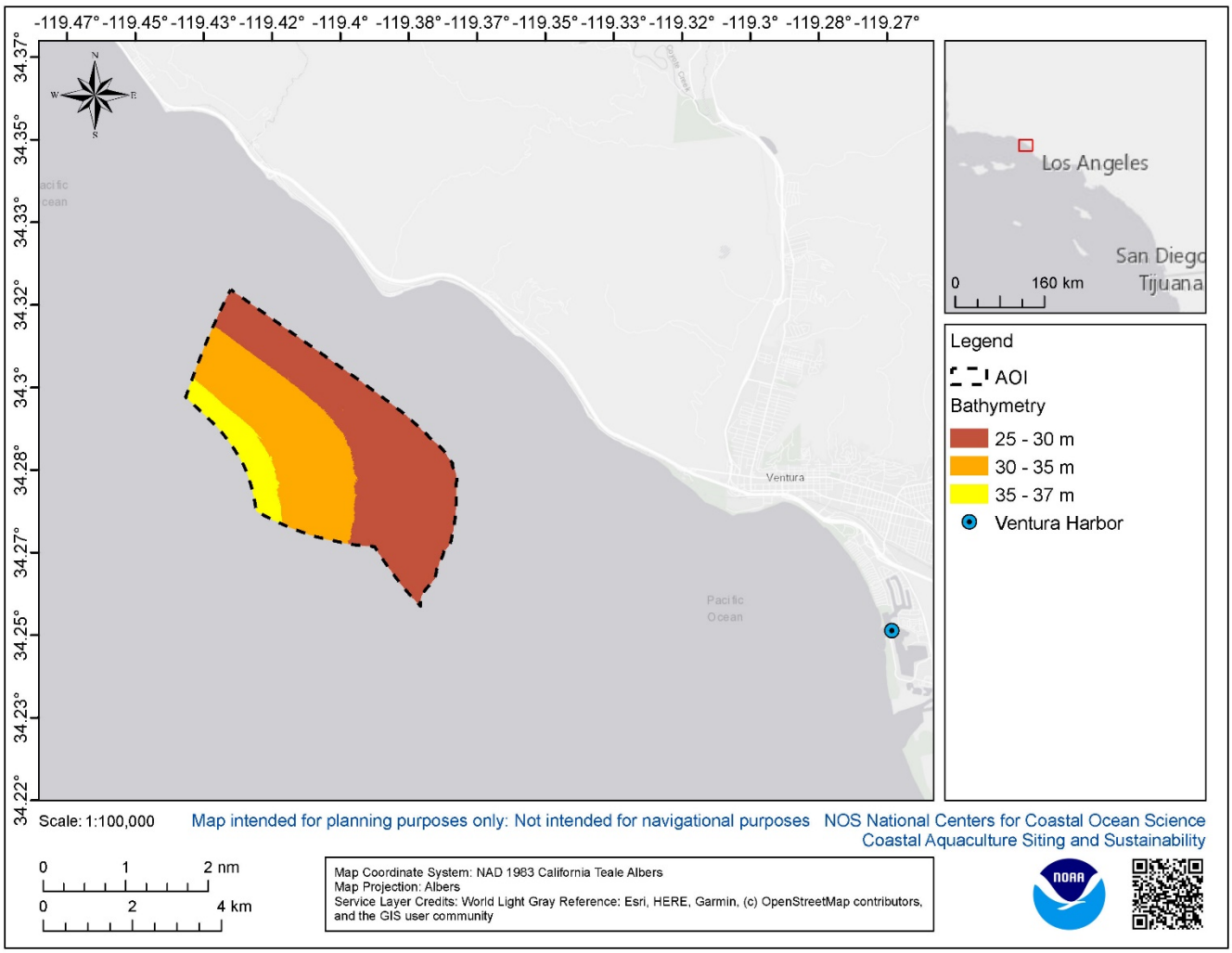

Figure 2. Bathymetric data for the area of interest (AOI), which was delineated using the distance from port and depth parameters.

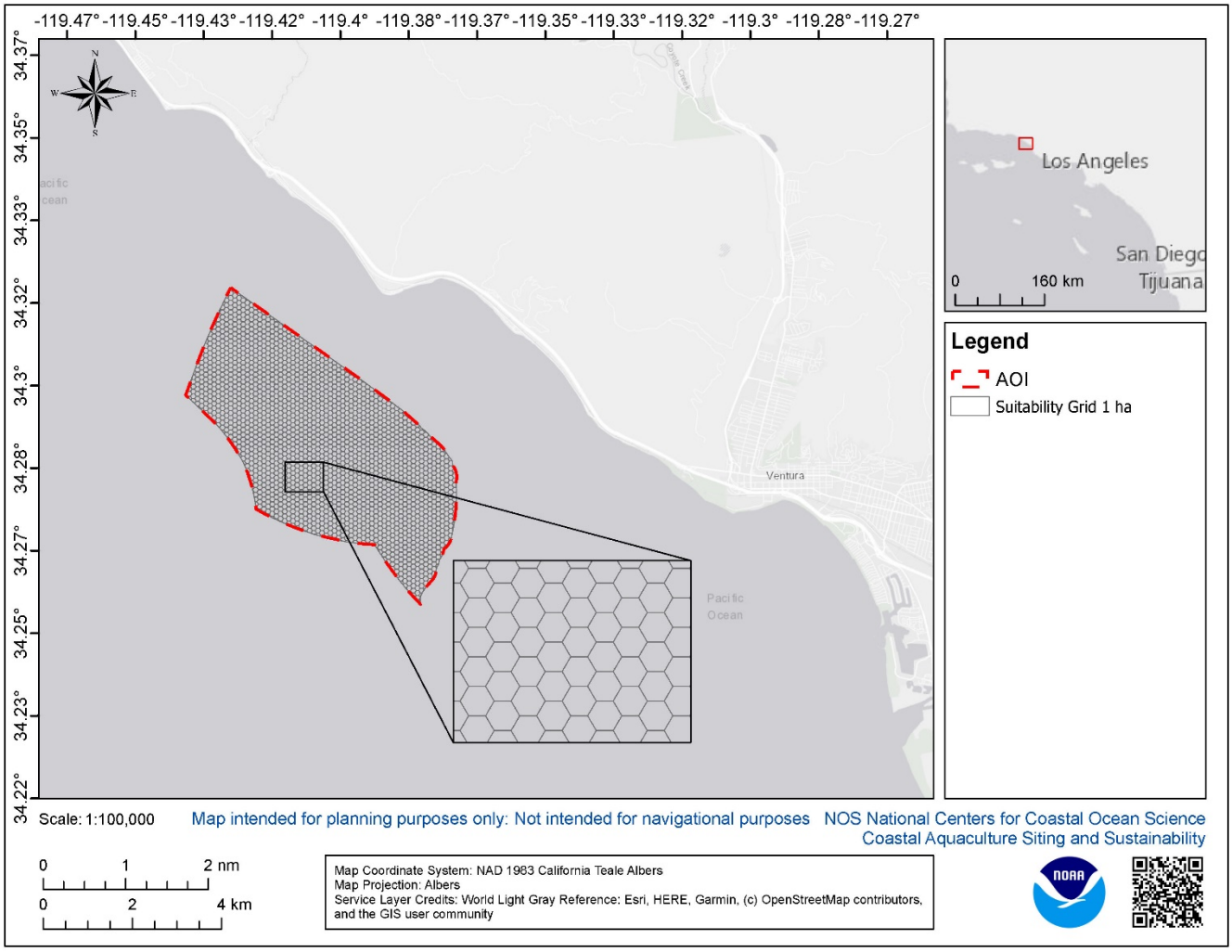

Figure 3. Final AOI with a one-hectare hexagonal grid and zoom inset illustrating how values are attributed to each grid cell.

Data Inventory

We reviewed 264 data layers for Southern California from the following categories: governance, infrastructure, living resources, non-living resources, and ocean uses. Data were sourced from a broad suite of authoritative sources including federal and state agencies (e.g., NOAA National Marine Fisheries Service, US Department of Defense, Bureau of Ocean Energy Management, US Geological Survey, California Department of Fish and Wildlife, California State Lands Commission, California Geologic Energy Management Division). The data layers were examined in the proximity of the AOI and a total of 11 layers were used for this analysis (i.e., 5 discrete and 6 continuous layers), 27 additional layers were used in the ocean neighborhood characterization (Table 2). Data were quality assured and the most authoritative, up-to-date sources were used when possible. For this analysis, data were projected in NAD 1983 California Teale Albers.

Data Processing

Many datasets required some form of processing to be utilized in the siting analysis. Below are the methods used to generate, process, and format the following datasets:

Bathymetry and Slope

NOAA's National Geophysical Data Center (NGDC)[1] and U.S. Geological Survey (USGS)[2] were combined to create a uniform bathymetric surface for the analysis. The coarsest resolution, 10 m cell size, was used to combine both surveys into a single surface (Figure 2). The slope is often integrated into predictive models for rugosity (roughness of seafloor) and hard-bottom habitat (Dunn and Halpin, 2009). The slope was calculated in degrees across the final bathymetry raster surface (Figure 4). The mean bathymetry and slope value was calculated for each grid cell and were the values used in the site suitability analysis.

Vessel Traffic

Automatic Identification System (AIS) vessel traffic data from the most recent year available (2019) was downloaded and processed for the AOI.[3] The cleaned and processed data in text files were made into spatial point data, and track lines were created for several vessel categories (cargo, tanker, tug and tow, fishing, passenger, pleasure/sailing, and other).[4] The track lines were rasterized at a 100 m cell resolution with each cell containing a count for vessel transits over the year. The total vessel transits for 2019 was used for the site suitability analysis.

Commercial Fishing

Vessel Monitoring System (VMS) commercial trawl fishery data provided by the California Department of Fish and Wildlife (CDFW) for 2010 to 2016 were examined for the AOI. VMS data consist of logbook-derived trawl fishery track lines that were rasterized at a 100 m cell size representing total trawl density. Squid commercial fishery landing by micro-block (1 nm or ~2 km) data was provided by CDFW for 2012 to 2017, an average landing in short tons per year was calculated and examined for the AOI. Halibut trawl grounds in California State waters were also provided by CDFW, including current closure areas. Additional commercial fishing data were examined but due to the coarse resolution >10 nm they were not used but maps were created (Appendix A, Figure A1-2), the commercial fishing data listed above were used for the site suitability analysis.

Recreational Fishing

Commercial Passenger Fishing Vessel (CPFV) data provided by CDFW comprised of GPS points from 2010 to 2019 that were aggregated to the micro-block (1 nm) resolution. A count of unique vessels per block per day was performed and the total of these counts was summarized by year to represent the average number of vessels per year per micro-block. CDFW California Recreational Fisheries Survey (CRFS) private vessel data comprised of dockside surveys recorded at the micro-block (1 nm or ~2 km) and block (10 nm or 18.5 km) resolution. The surveys represent a subsection of the total recreational fishing effort, the surveys are conducted at public docks and by phone to licensed anglers.[5] All micro-block data were extracted and a count per month for each micro-block was performed. The total of the counts was summarized by year to represent the average number of vessels per year per micro-block. Both CPFV and CRFS data were used for the site suitability analysis.

Oceanographic Conditions

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[1] https://maps.ngdc.noaa.gov/viewers/bathymetry/
[2] https://www.usgs.gov/centers/pcmsc/science/california-seafloor-mapping-program
[3] https://marinecadastre.gov/ais/
[4] https://coast.noaa.gov/data/marinecadastre/ais/VesselTypeCodes2018.pdf
[5] https://wildlife.ca.gov/Conservation/Marine/CRFS

Oceanographic data was analyzed from NOAA National Data Buoy Center's buoy station 46053 located 19 nm (~35 km) offshore from the AOI[6]. The values from 2013 – 2018 for daily maximum significant wave height and mean daily temperature were compared to needed project requirements (Table 1). Maximum current velocity data were analyzed from the Hybrid Coordinate Ocean Model (HYCOM) + Navy Coupled Ocean Data Assimilation (NCODA) Global Re-analysis Model via OceanReports tool. Oceanographic data was not used for the suitability analysis as the wave height and temperature are from a point source and the current velocity data is of a coarse resolution, this data was used for site characterization.

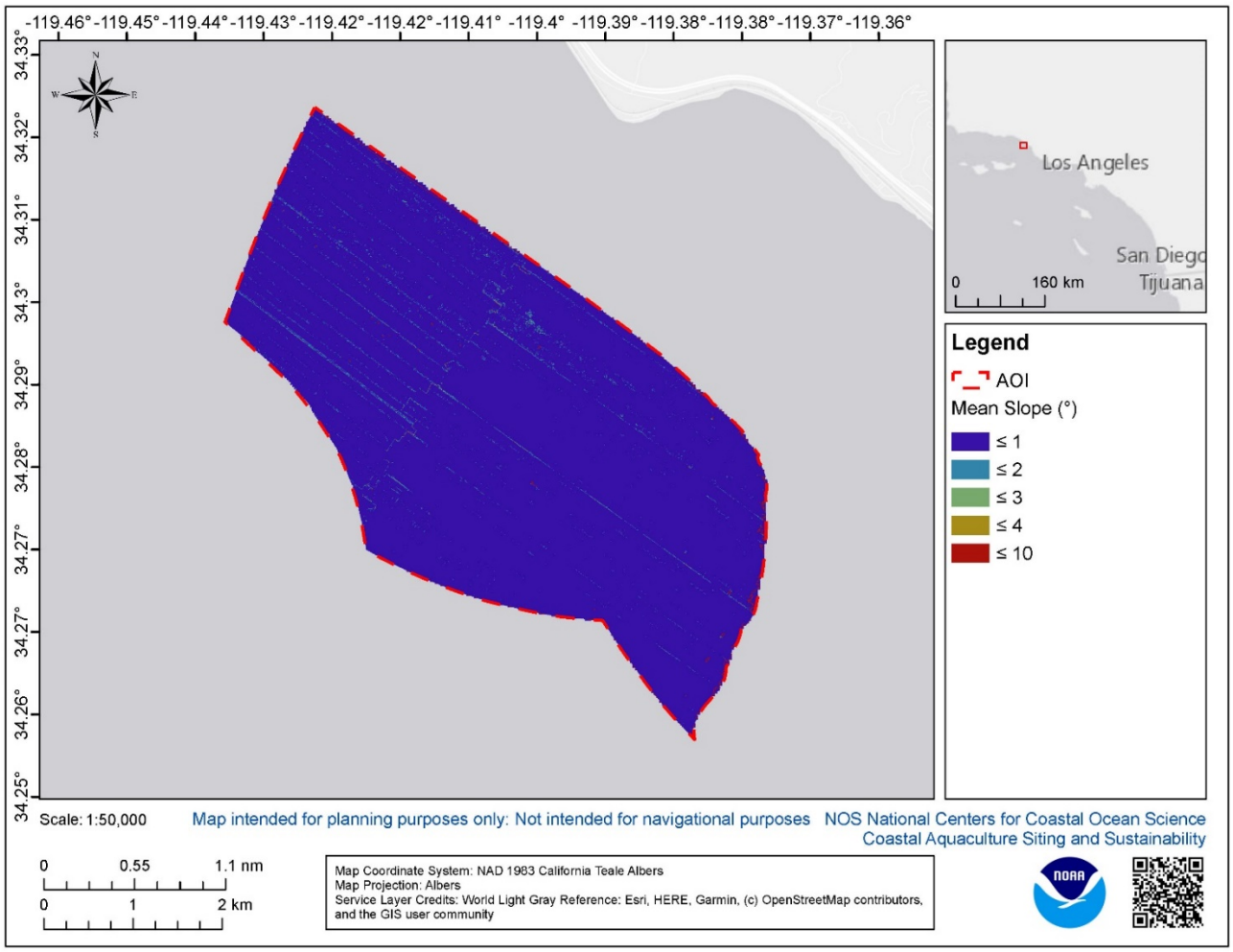


Figure 4. Slope data based on input bathymetry for AOI. The input bathymetry was at 10 m resolution.

Suitability Analysis

A relative suitability analysis, a variant of the commonly used Multi-Criteria Decision Analyses (MCDA) for aquaculture siting (Longdill et al., 2008; Radiarta et al., 2008; Gimpel et al., 2015; Bwadi, 2019) was performed using a one-hectare hexagonal grid (Figure 3). The data inventory was assessed, examining layers that overlapped with the AOI (see Table 2 for layers that were in the vicinity but did not overlap with the AOI). Spatial data layers containing known potential space-use conflicts with marine aquaculture operations (e.g., active military areas, maritime navigation, ocean industries, etc.) were collated and assigned scores based on aquaculture compatibility of 0 (low suitability), 0.5 (medium suitability), and 1 (high suitability) (Table 3). The three-level suitability scoring approach provides a conservative method as data with indeterminate suitability receives a score of 0.5. Indeterminate suitability scores are given to data layers that may have some conflict with aquaculture but that conflict may be mitigable through the

[6] https://www.ndbc.noaa.gov/station_page.php?station=46053

permitting process. This fractionally reduces the score and provides contrast to cells with a larger proportion of high suitability scores (values of 1). Datasets not present in the AOI or having an unknown conflict with aquaculture were not included in the suitability analysis, and if relevant, were set aside for further review to characterize the ocean neighborhood or individual farm sites.

For discrete data, each grid cell was evaluated to determine if a feature was present or absent in each grid cell and the corresponding score assigned if present (Table 3). For continuous data (e.g., bathymetry), scoring breaks were created based on operational constraints (Table 4). In the case of vessel traffic, a value of either vessel density or transits per grid cell was calculated and scores were assigned based on the 25%, 50%, and 75% quartiles (Tables 5-8).

The scores for each data set were integrated by summing all individual values for grid cells across all data sets and dividing by the total number of data sets, providing a proportion from 0 to 1, with 0 representing 'low suitability' and 1 representing 'high suitability' relative to the other grid cells. Therefore, the final proportion calculation provides the relative suitability of that cell to the other grid cells. Any grid cell that contained a data layer with a score of zero was assigned an overall score of zero and was considered to be unsuitable for aquaculture regardless of the other scores, as this indicates a complete incompatibility of aquaculture in that cell.

A Local Index of Spatial Association (LISA) analysis, which identifies statistically significant ($p = 0.05$) clusters and outliers within a grid, was performed on the final results of the relative suitability analysis (Anselin, 1995). Esri™ ArcGIS Pro's 'Cluster and Outlier Analysis' tool was used to calculate the LISA values (Esri, 2020). To ensure all grid cells were included in this analysis, the inverse distance spatial conceptualization was utilized; however, proximal cells have more influence than distant cells. The function inputs were a 150 m search radius and 999 iterations with row standardization and a false discovery rate correction applied to allow for more conservative and robust results. Statistically significant clusters of the highest suitable scores were identified (high-high clusters) and lowest suitability scores (low-low clusters). Additional visual assessments and fine-tuning were performed, this process comprises drawing a polygon around the high clustered areas and inspecting the resulting shape for overlap with data layers. Through the steps listed above the final location (i.e., most suitable) was identified.

Table 2. Discrete spatial data layers and the layer source examined in the area, but not used for the suitability model.

Parameter / Data Layer	Data Source*
Anchorage Areas	NOAA
Aquaculture Farm Sites	CDFW
Artificial Reefs	NOAA OCM
Audubon Important Bird Areas	National Audubon Society
Boat Launches	CDFW
California Aquaculture Leases	CDFW
California Eelgrass	CDFW
Cetacean Biologically Important Areas	NOAA
California Dive Sites	CDFW
Danger Zones and Restricted Areas	USN
Kelp Canopy Persistence (1989 – 2014)	CDFW
Habitat Area of Particular Concern	NOAA
Military Training Routes	FAA
Navigable Waterways	USCG

Oil and Gas Leases	SLC / BOEM
Oil and Gas Pipelines	BOEM
Oil and Gas Drilling Platforms	BOEM
Pilot Boarding Areas	NOAA
Point Mugu Sea Range	USN
Sailing Race Markers	SCYA
San Pedro Channel Operations Area	USN
Shipping Lanes and Traffic Separation Schemes	NOAA OCM
Southern California Ferry Routes	OSM
Special Use Airspace	USN
Unexploded Ordnance (FUDS)	NOAA
Waste Water Treatment Plant Outfall	EPA
West Coast EFH	NOAA
** Bureau of Ocean Energy Management (BOEM), California Department of Fish and Wildlife (CDFW), Environmental Protection Agency (EPA), Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), Open Street Maps (OSM), Southern California Yachting Association (SCYA), US Coast Guard (USCG), US Navy (USN)*	

Table 3. Discrete spatial data layers included in the relative suitability analysis with scores ranging from 0 (low suitability), 0.5 (medium suitability), and 1 (high suitability).

Parameter / Data Layer	**Inside cell score**	**Outside cell score**	**Data Source***
Active oil and gas wells 500 m Buffer	0	1	CalGEM
Halibut Trawl Grounds	0.5	1	CDFW
Hard Bottom	0	1	CDFW
Deep Sea Corals	0	1	NOAA
Squid Landings 2012 - 2017	0.5	1	CDFW
** California Geologic Energy Management Division (CalGEM)*			

Table 4. Continuous spatial data layers included in the relative suitability analysis with scores ranging from 0 (low suitability) to 1 (high suitability).

Parameter	Value	Score	Source
Bathymetry (m)	> -30	0	USGS
	≤ -30 and ≥ -150	1	
	< -150	0.5	
Slope (°)	< 0.17	1	NOAA
	≥ 0.17 and < 0.21	0.7	
	≥ 0.21 and < 0.27	0.3	
	≤ 0.27	0.1	
**US Geological Study*			

Table 5. Recreational fishing annual vessel density for Commercial Passenger Fishing Vessel (CPFV) and Private vessels from California Recreational Fishing Surveys (CRFS) categories and scoring schema ranging from 0.2 (low suitability) to 1 (high suitability).

Parameter	Value	Score	Source
Mean CPFV vessel density	0	1	CDFW
	< 0.2	0.8	
	≥ 0.2	0.6	
	-	0.4	
	-	0.2	
Mean CRFS vessel density	0	1	CDFW
	< 0.5	0.8	
	≥ 0.5 and < 0.6	0.6	
	≥ 0.6 and < 0.8	0.4	
	≥ 0.8	0.2	

Table 6. The commercial fishing effort from Vessel Monitoring System (VMS) categories and scoring schema ranging from 0.2 (low suitability) to 1 (high suitability).

Parameter	Value	Score	Source
VMS trawl density	0	1	CDFW
	< 5	0.8	
	≥ 5 and < 8	0.6	
	≥ 8 and < 12	0.4	
	≥ 12	0.2	

Table 7. Automatic Information System (AIS) vessel counts by vessel type categories are the count of the vessel that passed through a grid cell throughout 2019 with the corresponding scores ranging from 0.2 (low suitability) to 1 (high suitability).

Vessel Count Categories by Type				
Fishing	Passenger	Pleasure	Other	Score
0	0	0	0	1
< 1	< 6	< 3	< 3	0.8
≥ 1 and < 2	≥ 6 and < 8	≥ 3 and < 4	≥ 3 and < 5	0.6
≥ 2	≥ 8 and < 10	≥ 4 and < 5	≥ 5 and < 8	0.4
-	≥ 10	≥ 5	≥ 8	0.2

Table 8. Larger vessels with limited maneuverability are associated with established shipping lanes from the Automatic Information System (AIS) 2019. With scores ranging from 0.1 (low suitability) to 1 (high suitability).

Vessel Count Categories by Type			
Cargo	Tanker	Tug/ Tow	Score
0	0	0	1
-	-	-	0.7
-	-	-	0.5
-	-	-	0.3
> 0	> 0	> 0	0.1

RESULTS

Ocean Neighborhood Characterization

Oceanographic considerations

Based on 5-yrs of data from buoy station 46053, the significant wave height (Figure 5) defined as the mean wave height of the highest third of waves, ranges between 1 and 4 m. There are several periods in January (2016 and 2017) and November 2018 with significant wave heights above 4 m (Figure 5, red dotted line), the project requirement does not list a threshold for the wave height, instead, shallow water was chosen to minimize significant wave height. Mean daily sea surface temperature ranges from 12 to 22 ºC throughout the year (Figure 6), the project requirement is temperatures below 30 ºC with an optimal temperature of 20 ºC. The temperature is within the optimal temperature from July - November and does not exceed 30 ºC. Mean current velocity (Figure 7) range between 0.06 and 0.09 m^{-s}, the project requirement is current velocity between 0.025 – 0.1 m^{-s}.

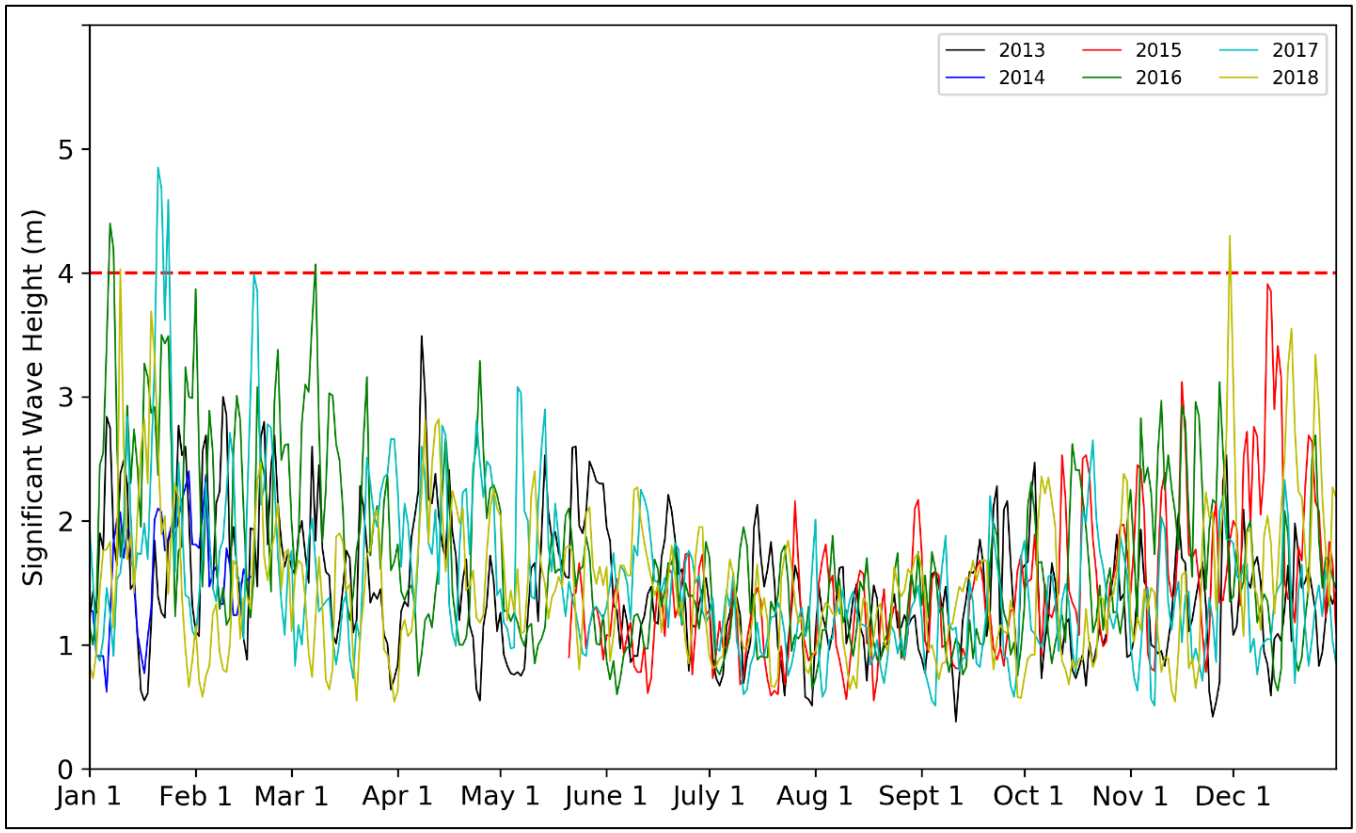


Figure 5. The daily maximum significant wave height 2013 to 2018 from data buoy Station 46053 (LLNR 196) - EAST SANTA BARBARA – 19 nm southwest of the AOI.

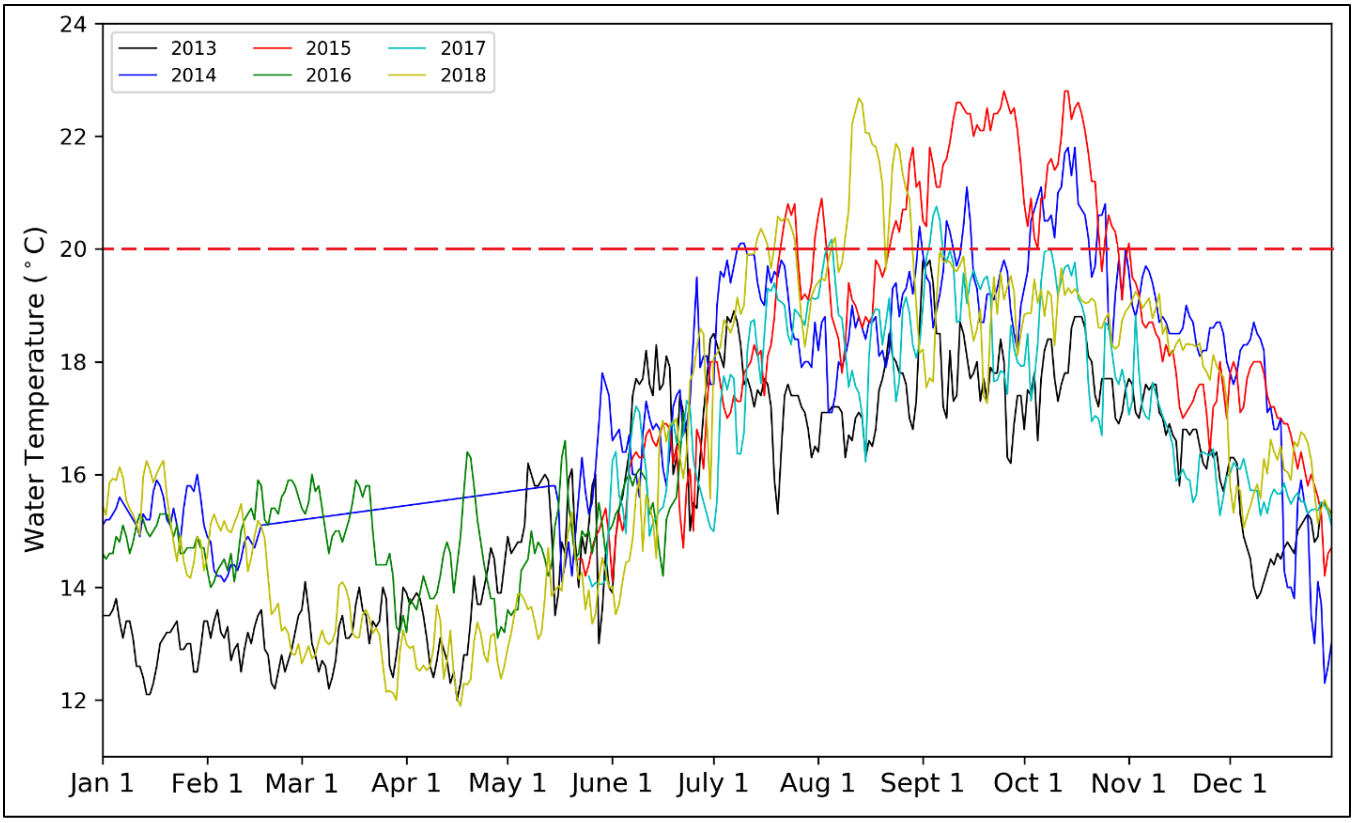


Figure 6. The Mean daily Temperature 2013 to 2018 from data buoy Station 46053 (LLNR 196) - EAST SANTA BARBARA - 19 nm southwest of the AOI.

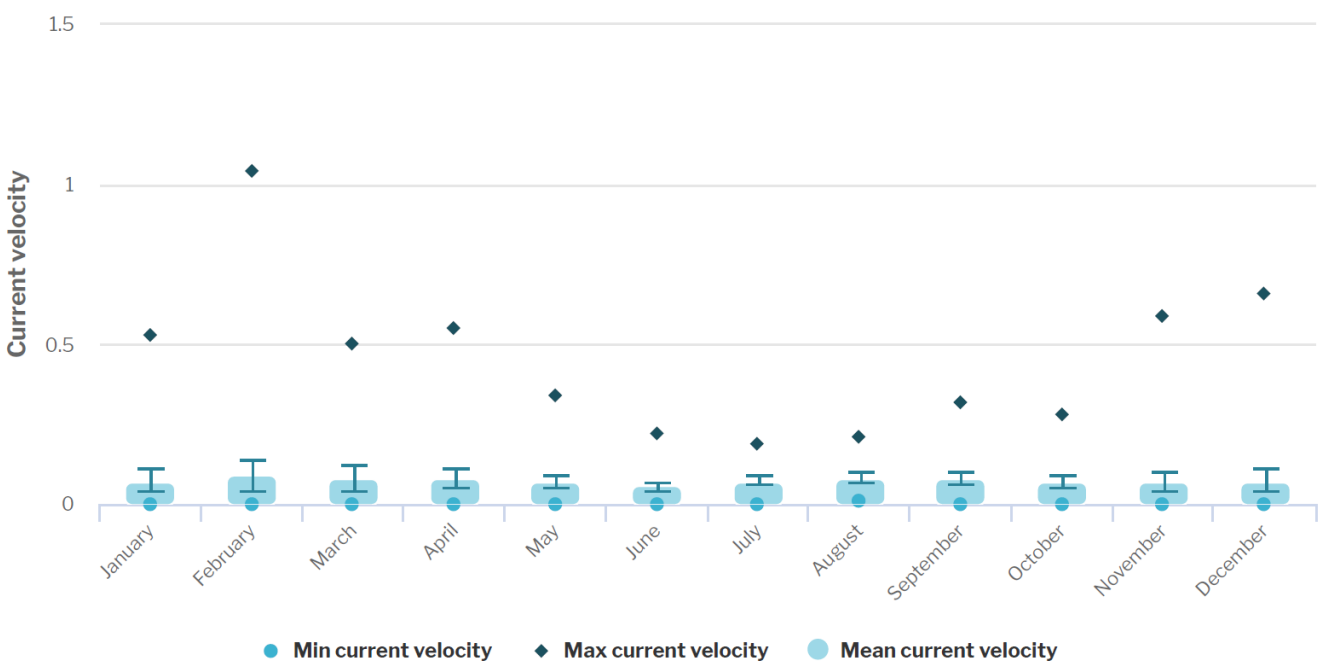


Figure 7. Minimum, maximum, and mean current (± SD) velocity (meters per second) data derived from the HYCOM + NCODA Global Re-analysis Model[7] via OceanReports[8].

[7] https://www.hycom.org/dataserver/gofs-3pt0/reanalysis
[8] https://coast.noaa.gov/digitalcoast/tools/ort.html

National Security Considerations

Military operational areas and areas of national security interest were reviewed in the AOI (Figure 8). There are several areas marked as unexploded ordnance to the west and southeast of the AOI. The Point Mugu Sea Range, San Pedro Channel Operating Area, and danger zones/ restricted areas do not intersect or overlap with the AOI. A military training route, which permits low flying high-speed military aircraft, overlaps the majority of the AOI[9].

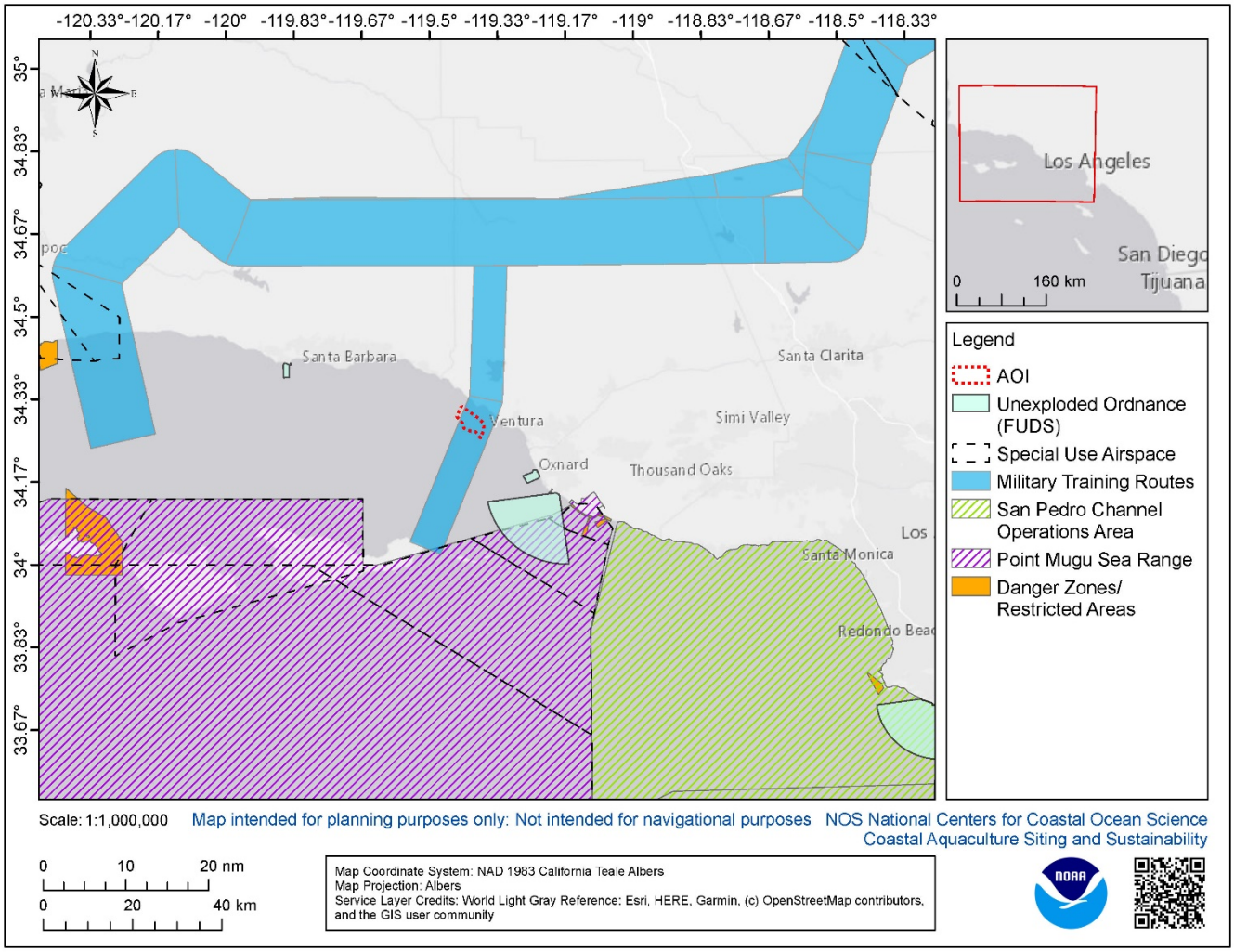


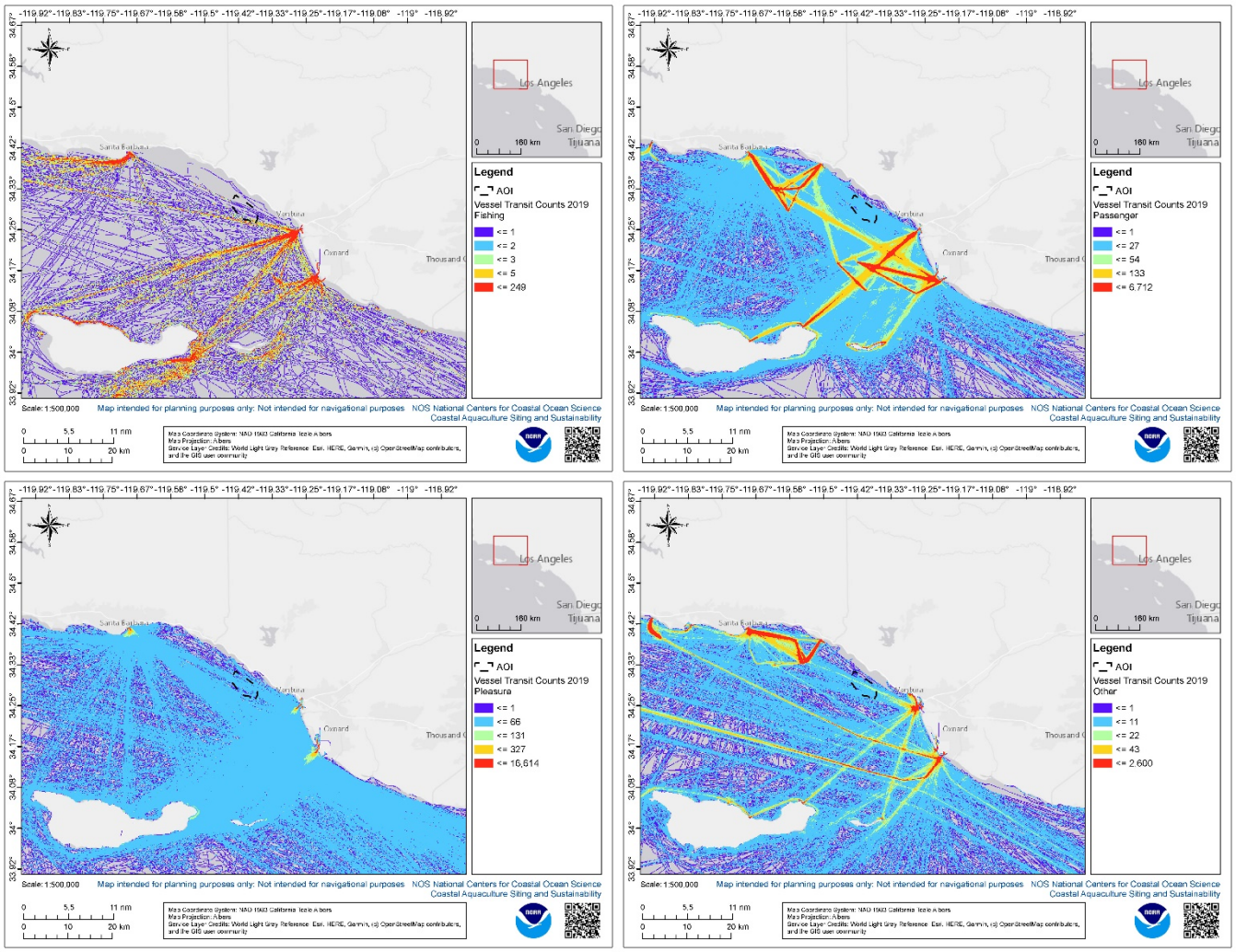
Figure 8. Military operational areas and areas of national security interest. Special use airspace, military training routes, danger zones/ restricted areas, San Pedro Channel Operations Area, Point Mugu Sea Range, Unexploded ordnance – FUDS.

Navigational Considerations

AIS data from 2019 shows that the majority of vessel traffic that transit through the AOI was from passenger, pleasure, and 'other' vessel categories (Figure 9). Lower transit numbers were present from the cargo and fishing with no transits from tanker or tug and tow categories. The majority of cargo traffic was outside of the AOI, with the highest vessel transits found in the traffic separation scheme (TSS). To view all of the AIS vessel transit maps individually, please refer to Appendix A Figure A3 (A-G). Other possible navigation conflicts were evaluated including shipping fairways or traffic separation schemes, pilot boarding areas, active anchorage areas, regulated navigational space, navigable waterways, ferry routes,

[9] https://www.faa.gov/air_traffic/publications/atpubs/aip_html/part2_enr_section_5.2.html

shipwrecks and obstructions, dive sites, and artificial reefs (Figure 10 and 11). There is an artificial reef to the north of the AOI, but no other navigational constraints were identified within the AOI.



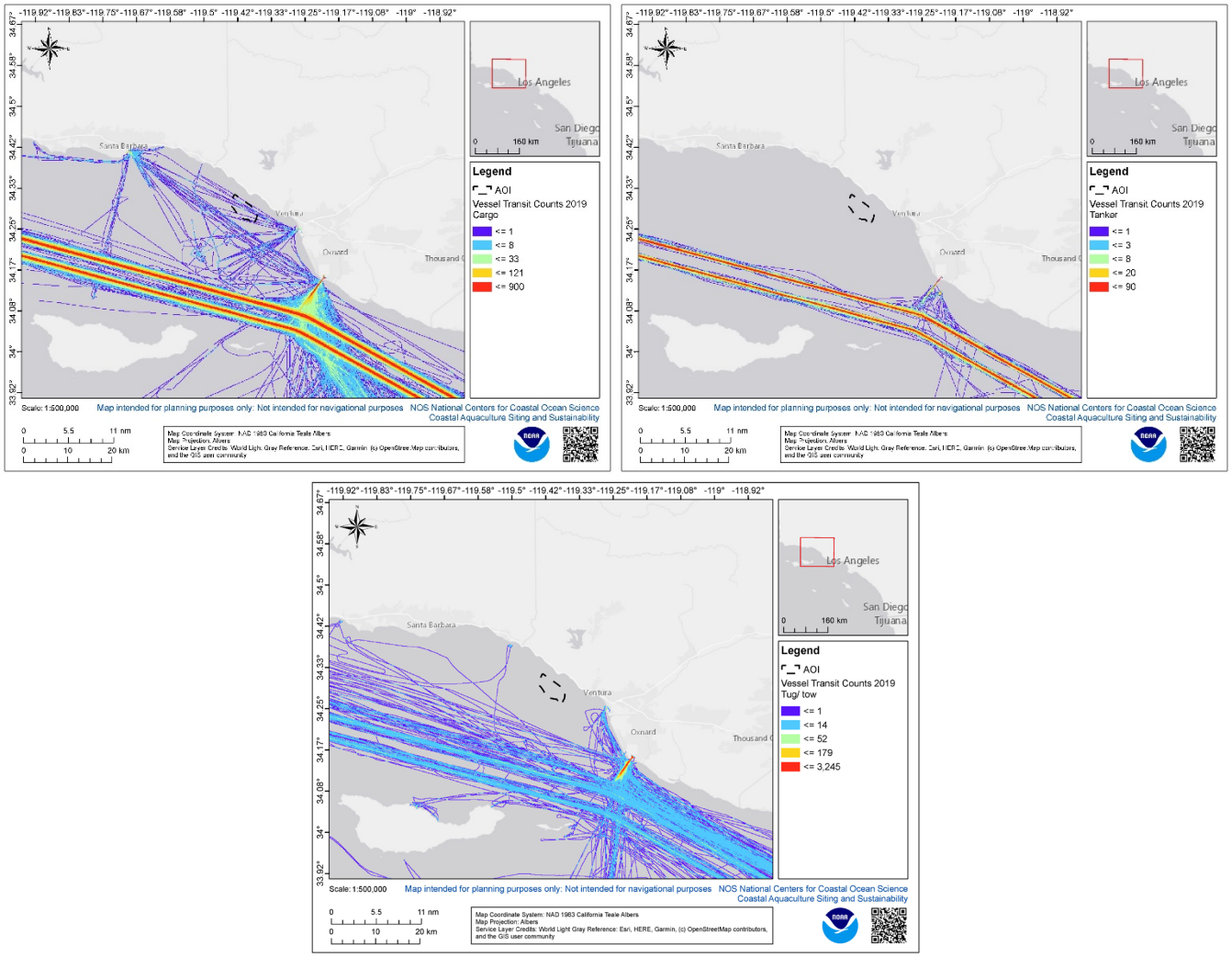


Figure 9. Automated Identification System (AIS) vessel transit density within the AOI and surrounding area. Represents the number of vessel transits per year by vessel type (fishing, passenger, pleasure, other, cargo, tanker, and tug and tow).

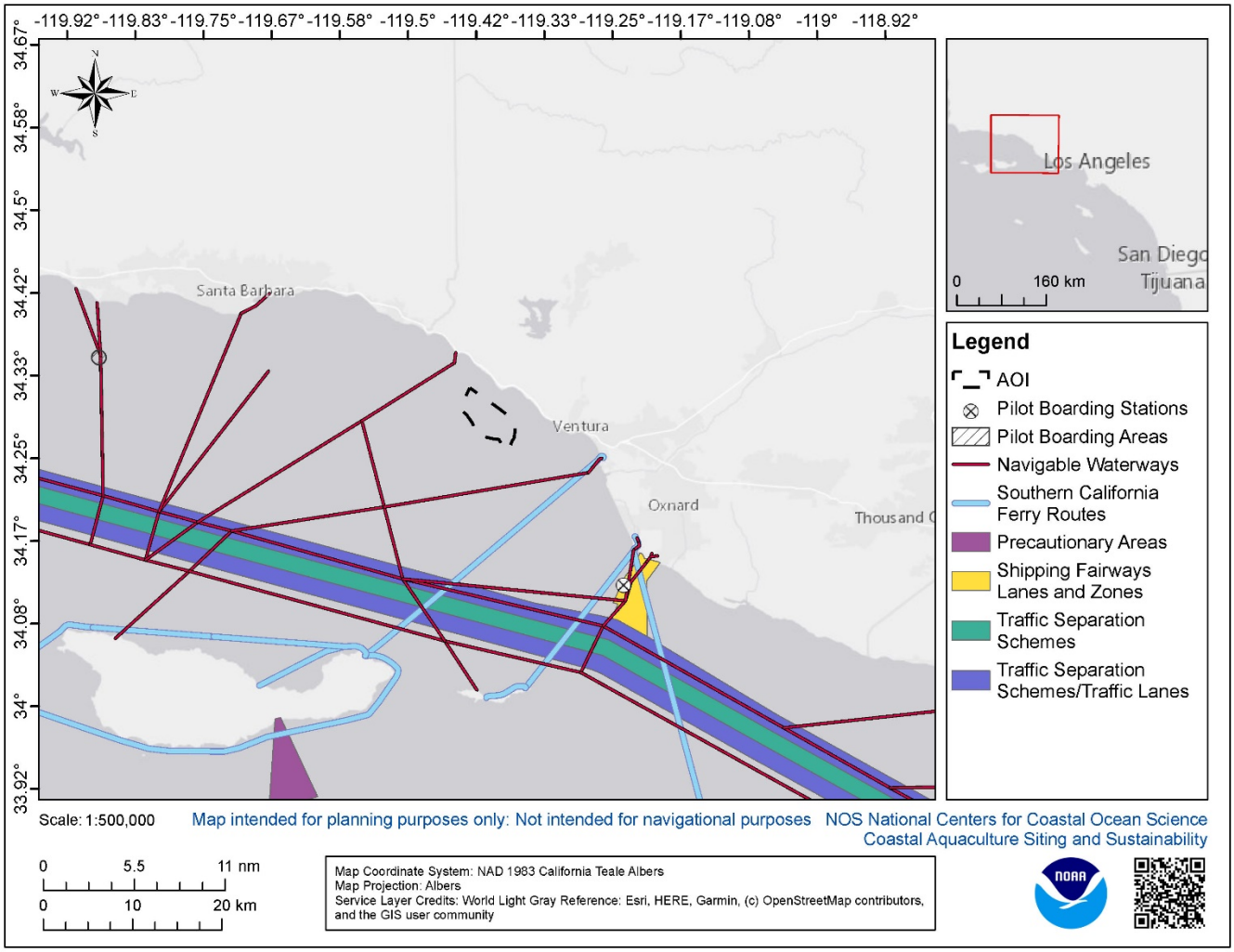


Figure 10. Navigation and transportation considerations within the ocean neighborhood of the AOI. Pilot boarding stations and areas, navigable waterways, ferry routes, precautionary areas, shipping fairways, traffic separation schemes.

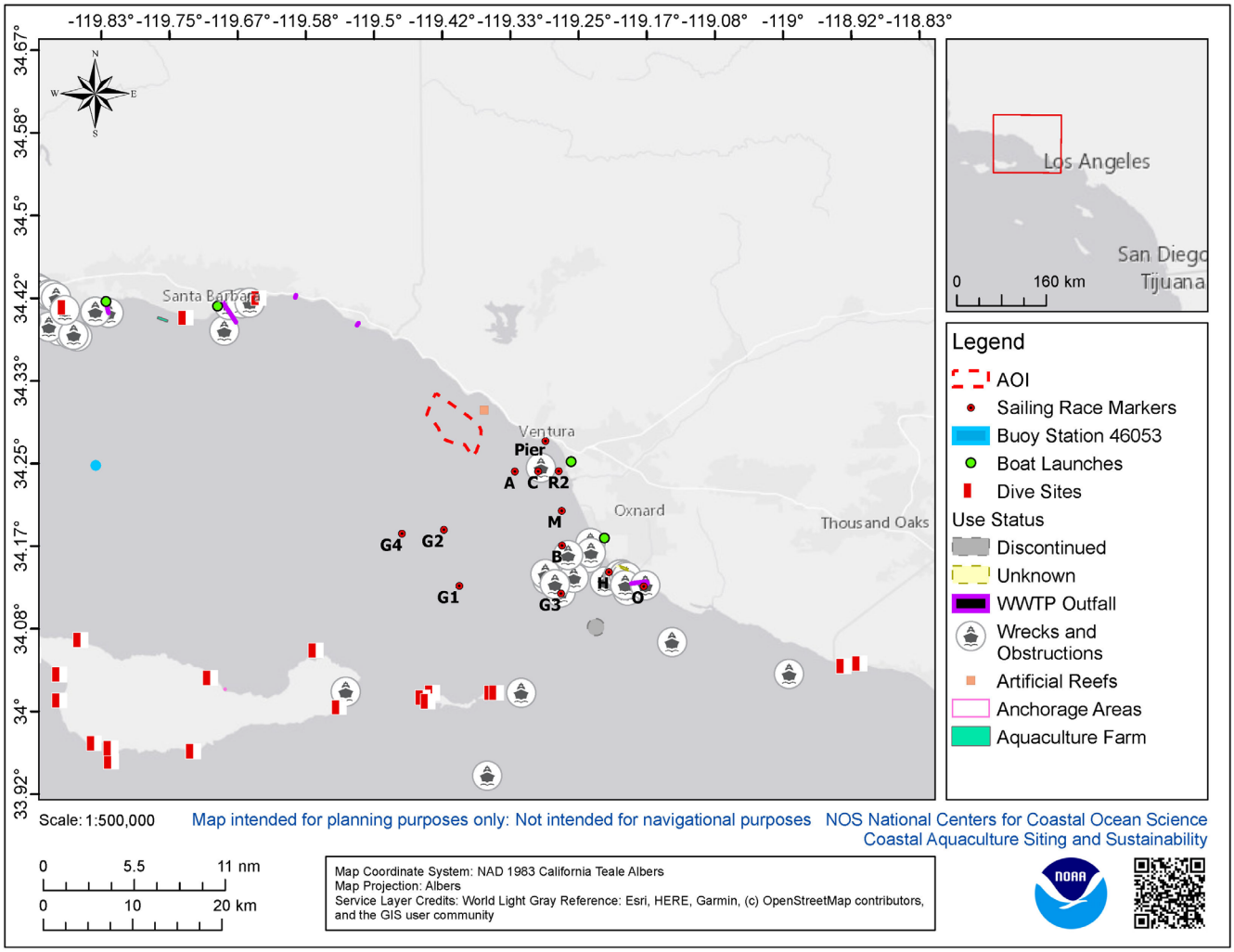


Figure 11. Navigation and transportation considerations within the ocean neighborhood of the AOI. Boat launches, dive sites, ocean disposal sites, sailing race markers, shipwrecks, artificial reefs, anchorage areas, and aquaculture farms.

Industry and Infrastructure Considerations

Oil and gas platforms, lease areas, submarine cables, oil and gas pipelines, and wastewater treatment facility outfall sites are found outside of the AOI (Figure 12). Several oil and gas wells are within the northwest region of the AOI. The major oil and gas platforms and associated pipelines and SLC and BOEM lease areas are found to the south and west of the AOI. Submarine fiber optic cables are found in the south of the AOI. Six wastewater treatment outfall sites are found close to shore to the northwest and southeast of the AOI, with the nearest outfall 6-nm northwest.

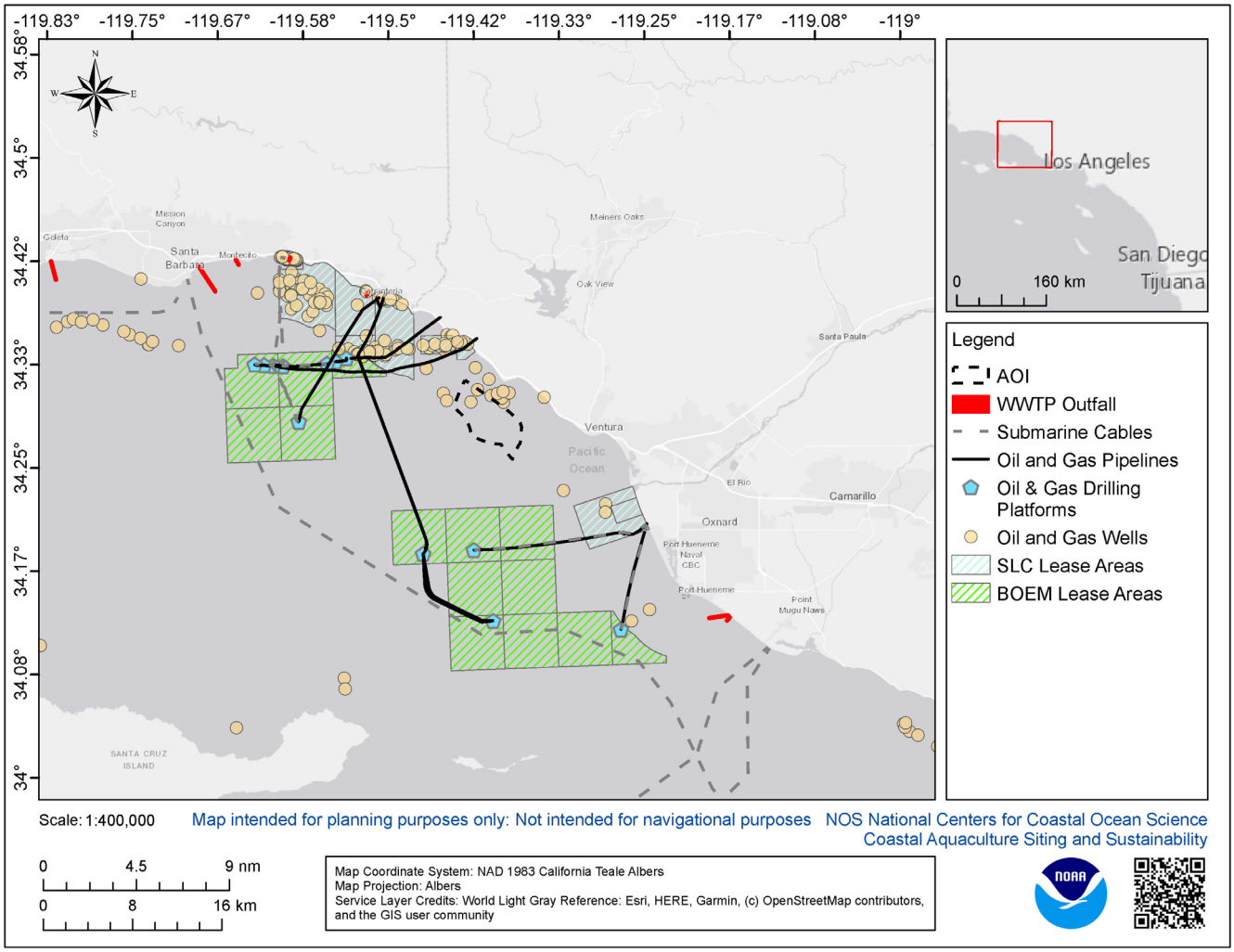


Figure 12. Characterization of industrial and energy infrastructure in and around the AOI. Wastewater treatment outfall structures, submarine cables, and oil and gas infrastructure: pipelines, platforms, wells, and SLC and BOEM lease areas.

Social and Cultural Considerations

As mentioned under *Navigational Considerations* above, cultural and recreational activities examined include dive sites, artificial reefs, shipwrecks, and sailing race marks. Within the AOI the data shows that these recreation and cultural considerations did not overlap with the AOI.

Recreational Fishing Considerations

Commercial Passenger Fishing Vessel (CPFV) annual mean density in 2010 - 2019 ranges from 0 to 0.4 vessels per year per micro-block (1 nm) within the AOI (Figure 13). California Recreational Fisheries Survey (CRFS) annual mean density in 2010 – 2019 ranges from 0 to 3.4 vessels per year per micro-block (1 nm) within the AOI (Figure 14). The CPRFV and CRFS density data suggest that within the AOI there is relatively low recreational fishing activity with no nearby hotspots.

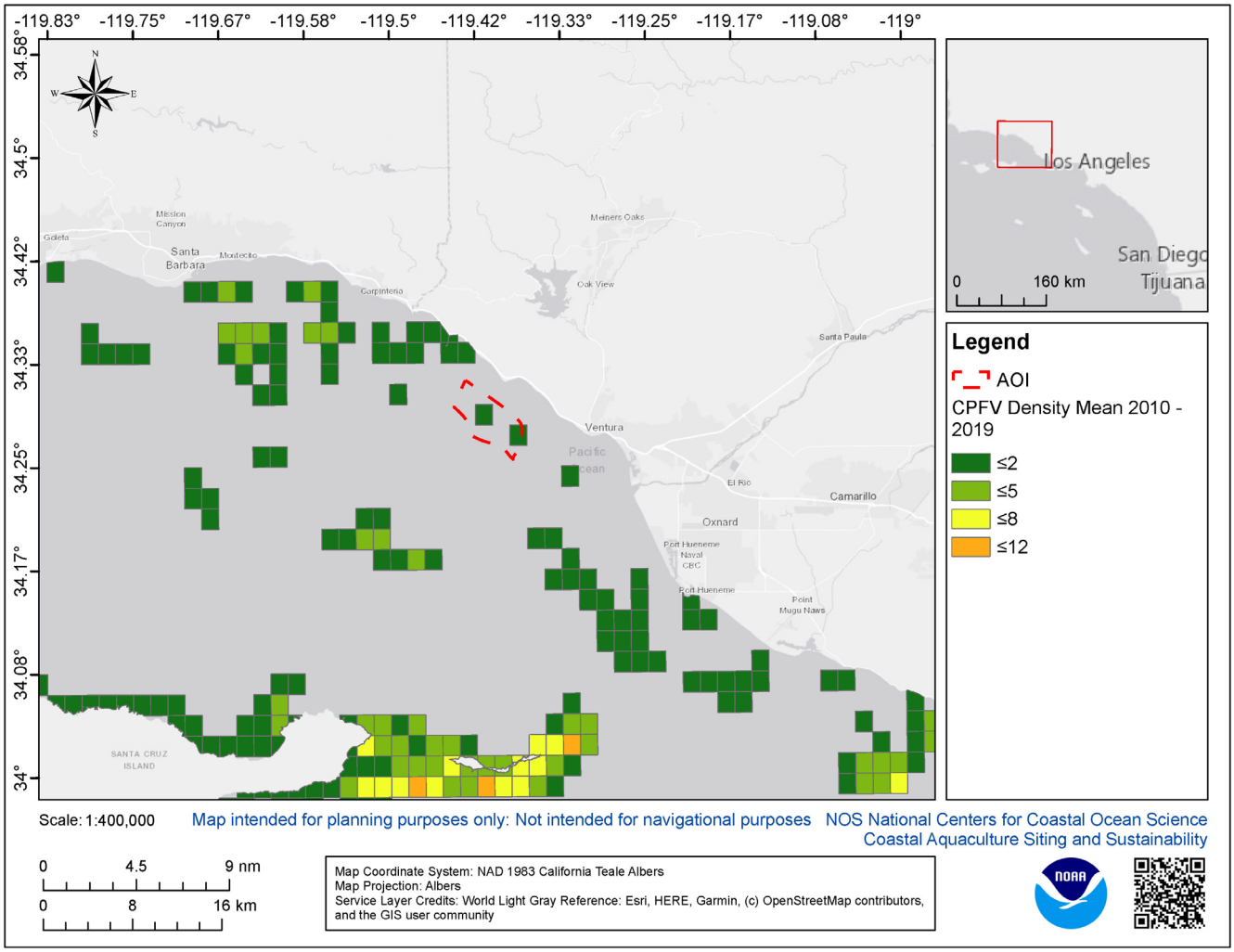


Figure 13. Characterization of recreational fishing in and around the AOI. CPFV annual mean density in 2010 – 2019.

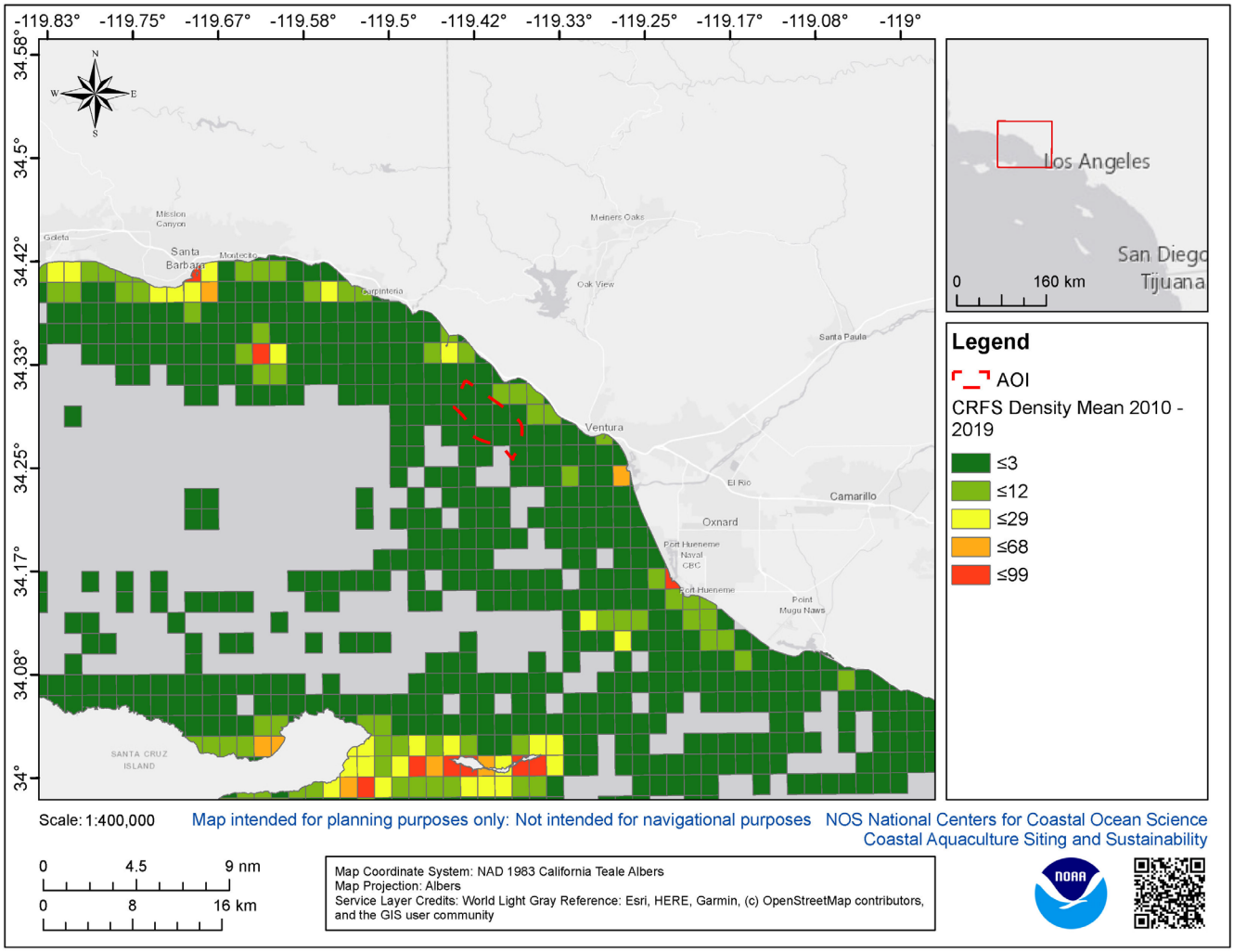


Figure 14. Characterization of recreational fishing in and around the AOI. CRFS annual mean density from 2010 – 2019.

Commercial Fishing Considerations

Several commercial fisheries are found in and around the AOI. The top commercial species by value landed in Ventura port (2019) were market squid, spot prawn, and spiny lobster, with the top 10 species listed in Table 9 in total catch and revenue. State-managed California halibut trawl grounds are located within state waters 1 to 3 nm from shore and overlap entirely with the AOI. VMS trawl density data from 2010 – 2016 depicts trawl activity within the AOI. Commercial squid landing data by micro-block was examined and found within a small area of the southeast portion of the AOI (Figure 15). Commercial fishing landing data by block (10 nm) were not used for this analysis due to the coarse resolution of available data but are included in Appendix A (Figure A1-2).

Table 9. California commercial landings in 2019 with the top 10 species by total value landed in the Ventura Port. The Ventura port total represents the total of all species landed. The table was modified from the original CDFW Table 19[10]

Species	Total Pounds	Total Value
Squid, market	5,895,721	$2,849,714
Prawn, spot	108,553	$1,564,603
Lobster, California spiny	95,664	$1,294,667
Prawn, ridgeback	383,146	$841,068
Halibut, California	51,177	$302,113
Crab, yellow rock	116,069	$205,095
Seabass, white	18,178	$84,567
Swordfish	12,259	$73,432
Sea cucumber, warty	10,168	$53,269
Mackerel, Pacific	359,721	$51,481
Ventura Port Totals:	**7,358,189**	**$7,554,427**

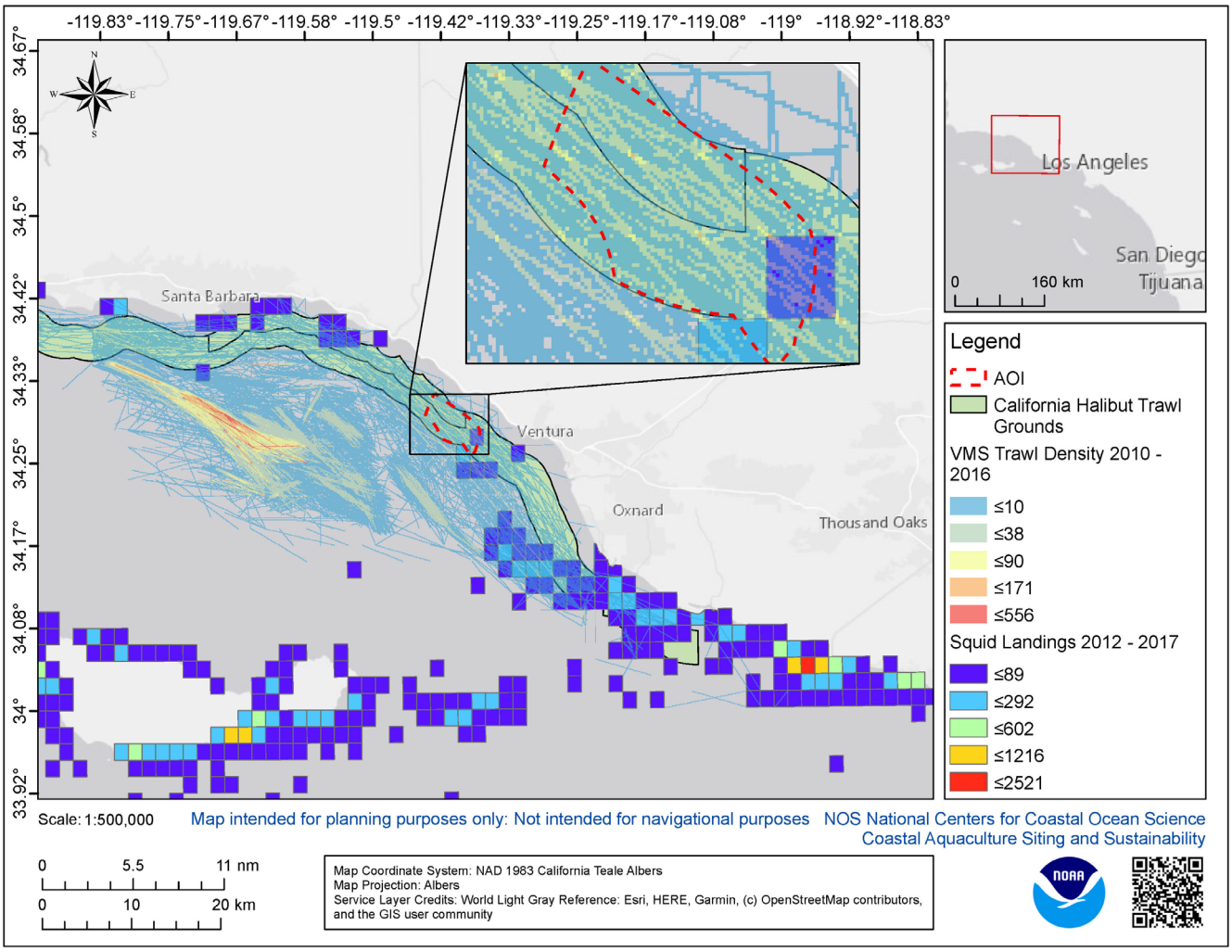


Figure 15. Characterization of commercial fishing in and around the AOI. VMS trawl density, squid landing, and halibut trawl grounds.

[10] http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=178028&inline

Essential Fish Habitat (EFH) and Fisheries Management Area Considerations

The Pacific Fishery Management Council has developed four main fishery management plans (FMPs) and a fishery ecosystem plan (FEP) for the west coast region of the United States (Washington, Oregon, and California). A total of 120 species are managed by the council through FMPs on coastal pelagic species, groundfish, highly migratory species, and salmon. Within the AOI there are five EFH management units addressed by three FMPs (Table 10). Sensitive habitats were considered for the analysis, including hard bottom habitat, canopy-forming kelp, habitat areas of particular concern (HAPC), deep-sea corals, and marine protected areas (MPAs) (Figure 16). There were deep-sea corals and hard bottom habitat found within the northern portion of the AOI. We did not include EFH considerations in the weighted spatial analysis due to the coarse resolution of available data.

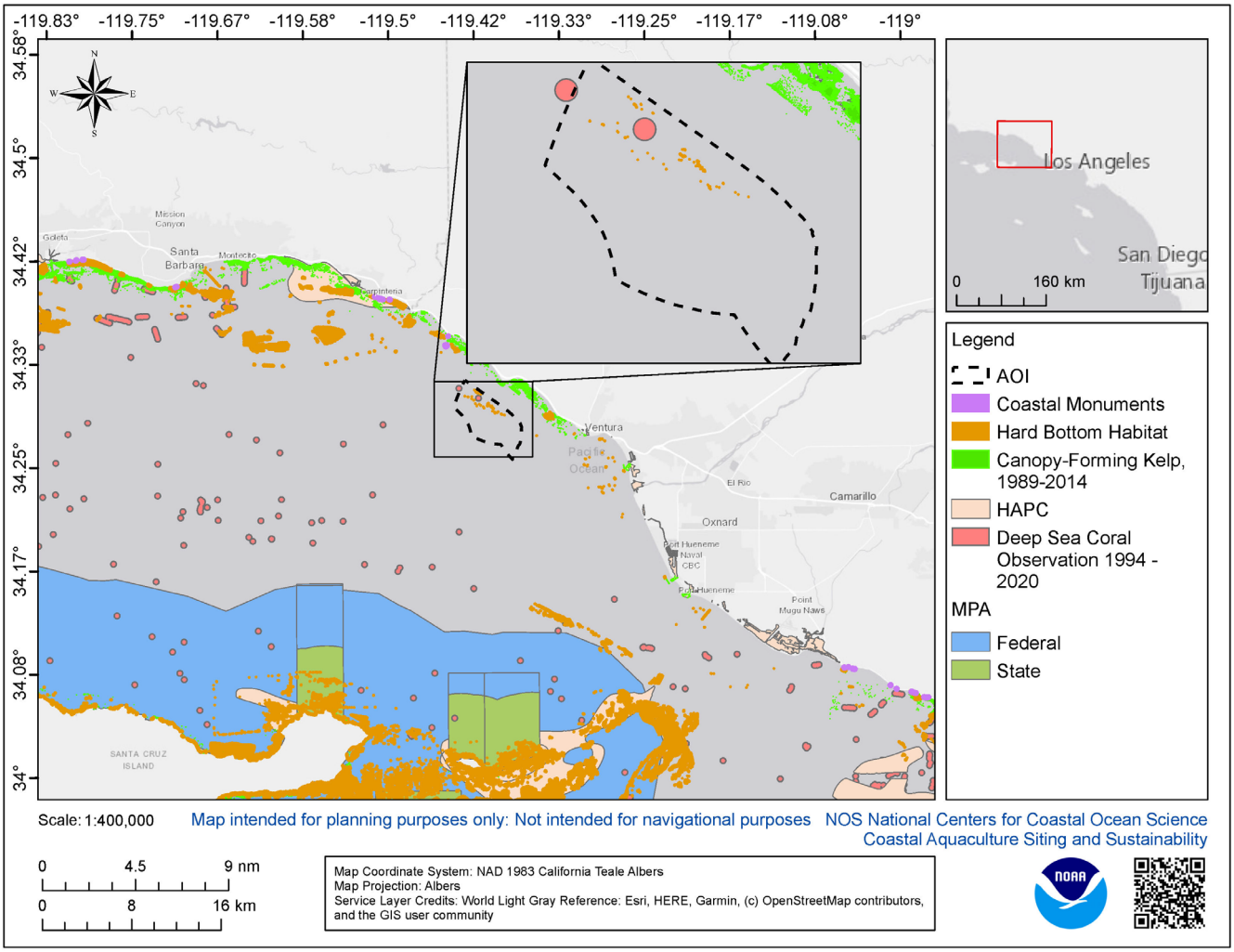


Figure 16. Characterization of sensitive habitat, habitat areas of particular concern (HAPC), hard bottom habitat, and deep-sea corals. The map pop out indicates two deep-sea coral observations (light red circles) along with hard bottom areas (orange).

Table 10. Essential Fish Habitat (EFH) management units that are within the Area of Interest (AOI). All management units listed are managed by the Pacific Fisheries Management Council (PFMC). The table was modified from the original NOAA Table[11].

EFH management units in the AOI		
Management Unit	**Management Council**	**FMP**
Pacific Highly Migratory Species	PFMC	Pacific Highly Migratory Species
Finfish	PFMC	Coastal Pelagic Species
Krill	PFMC	Coastal Pelagic Species
Coastal Pelagic Species	PFMC	Coastal Pelagic Species
Groundfish	PFMC	Groundfish

Protected Species

Protected species in the region include Federal Endangered Species Act (ESA) and California Endangered Species Act (CESA) listed species[12]. ESA and CESA species include anadromous fish (e.g., steelhead trout), ESA marine invertebrates (e.g., black and white abalone), ESA sea turtles (East Pacific Green, olive ridley, leatherback, and North Pacific loggerhead sea turtles), ESA whales (e.g. blue, fin, gray, humpback, North Pacific right, and sei whales), Marine Mammal Protection Act (MMPA) cetaceans (e.g. Dall's porpoise, Pacific white-sided dolphin), and MMPA, ESA, and CESA pinnipeds (e.g. California sea lion, Guadalupe fur seal). Cetacean biologically important areas (BIA) and coastal Audubon important bird areas (IBA) were examined for alternative site description, but not included in the suitability analysis (Figure 17, Figure 18). Other data sources depict cetacean density and point observations with *Becker et al. 2020* and the ODIS-SEAMAP data[13]. We did not include protected resources considerations in the weighted spatial analysis due to the coarse resolution of available data.

[11] https://www.habitat.noaa.gov/protection/efh/efhmapper/

[12] https://www.fisheries.noaa.gov/species-directory/threatened-endangered

[13] http://seamap.env.duke.edu/

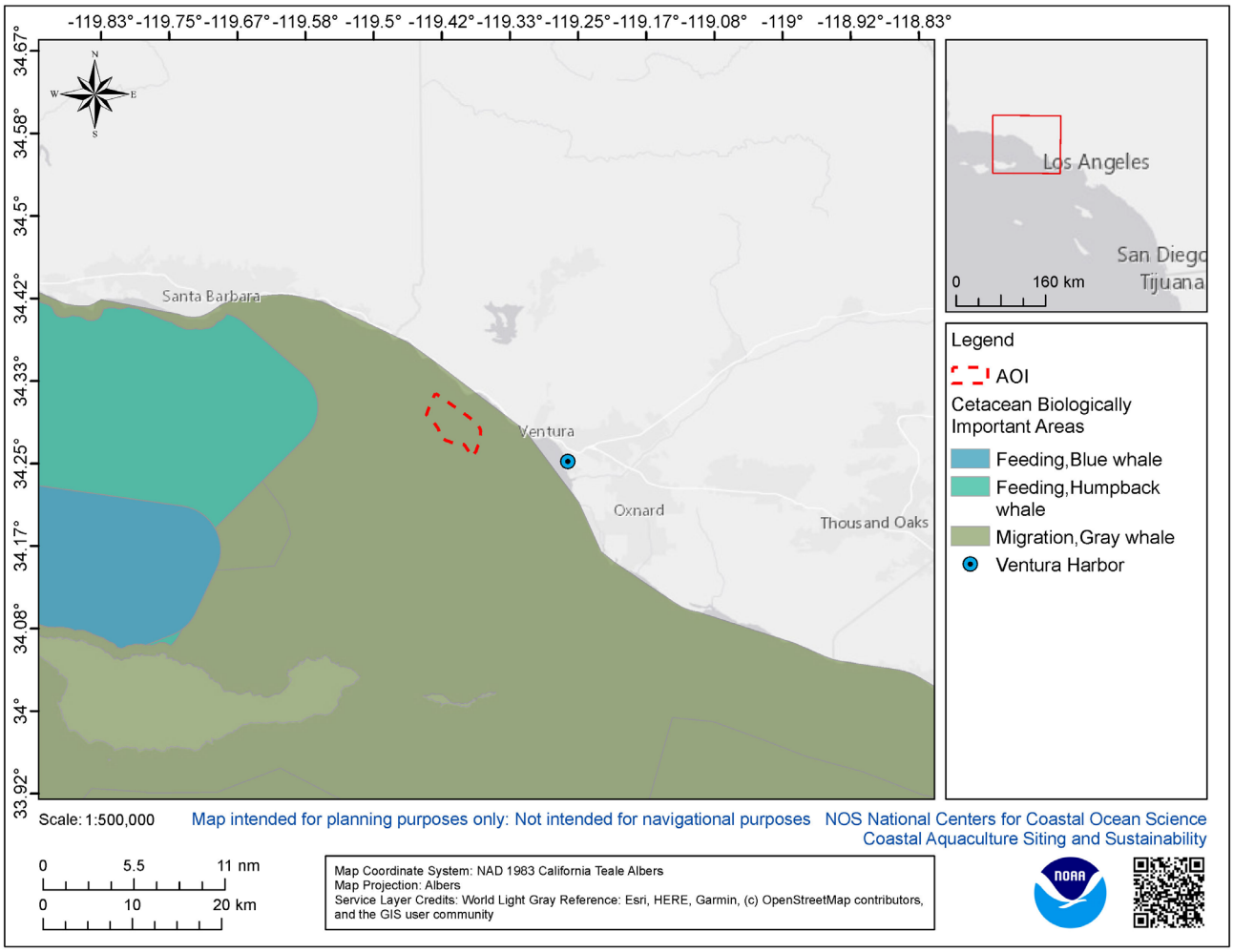


Figure 17. Cetacean biologically important areas relative overlap with the AOI. There is an overlap with the migratory Gray Whale Cetacean BIA.

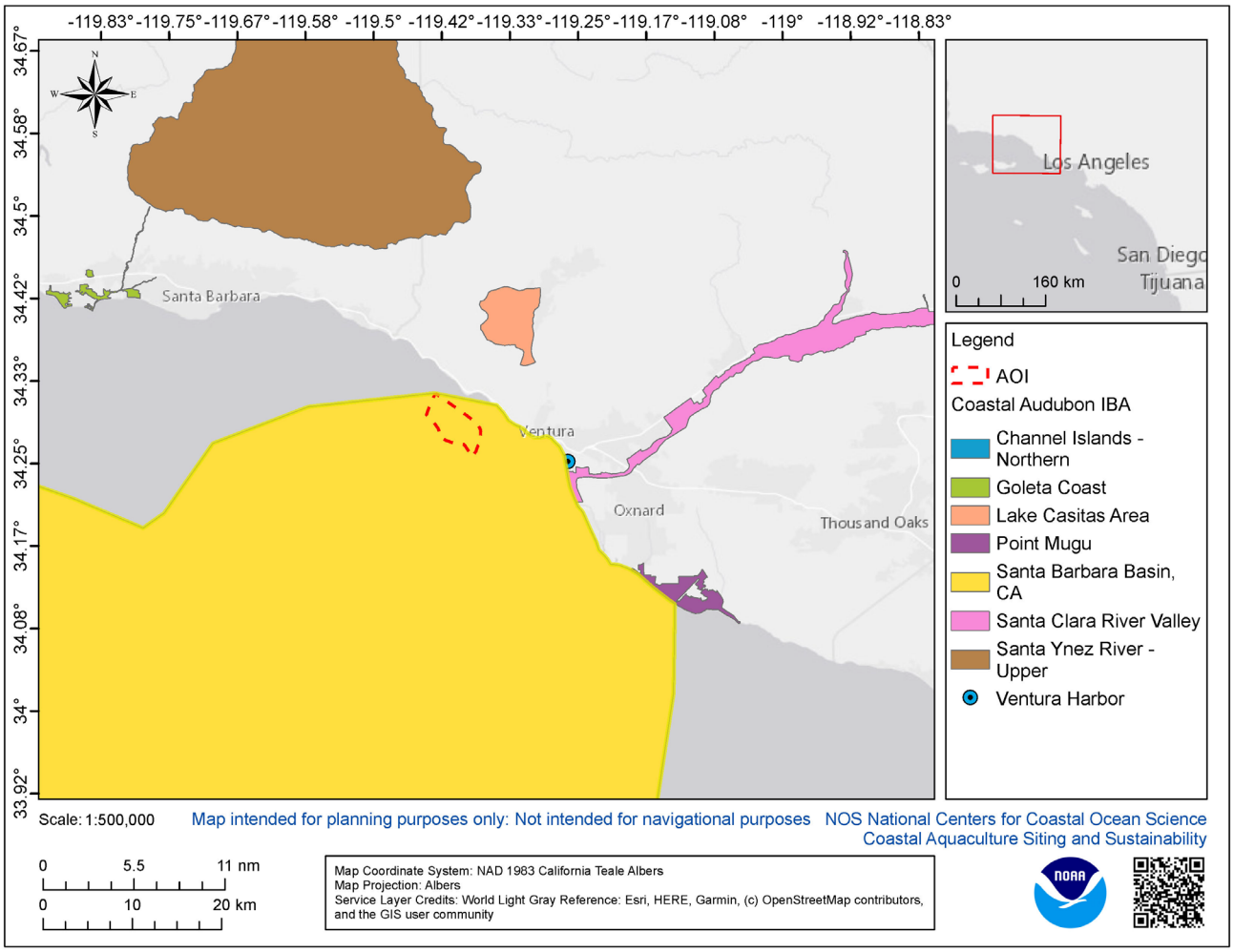


Figure 18. Coastal Audubon important bird areas were not included in the suitability analysis itself, simply due to uncertainties concerning the nature of the interaction of birds with aquaculture.

Relative Suitability Results

The relative suitability analysis identified a large portion of the southern section of the AOI as having the highest suitability for aquaculture (Figure 19). Due to the presence of oil and gas wells, hard bottom habitat, and deep-sea coral observations the northwest portion of the AOI was unsuitable for aquaculture development. Other areas contained hard bottom habitat as well as increased fishing activity and high slope, which led to low suitability scores, an average < 0.8. The cluster analysis identified approximately 1,050 acres of the highest suitability clusters to investigate (Figure 20). Examining these clusters a large section of the southern portion of the AOI was identified and a site alternative shape was drawn encompassing these high clusters. The site alternative is approximately 2,400 acres (971.2 ha) and comprises the entire southern extent of the AOI (Figure 21). This site alternative meets the needed farm characteristics as well as avoids the observed deep-sea corals and hard bottom area in the western portion of the AOI.

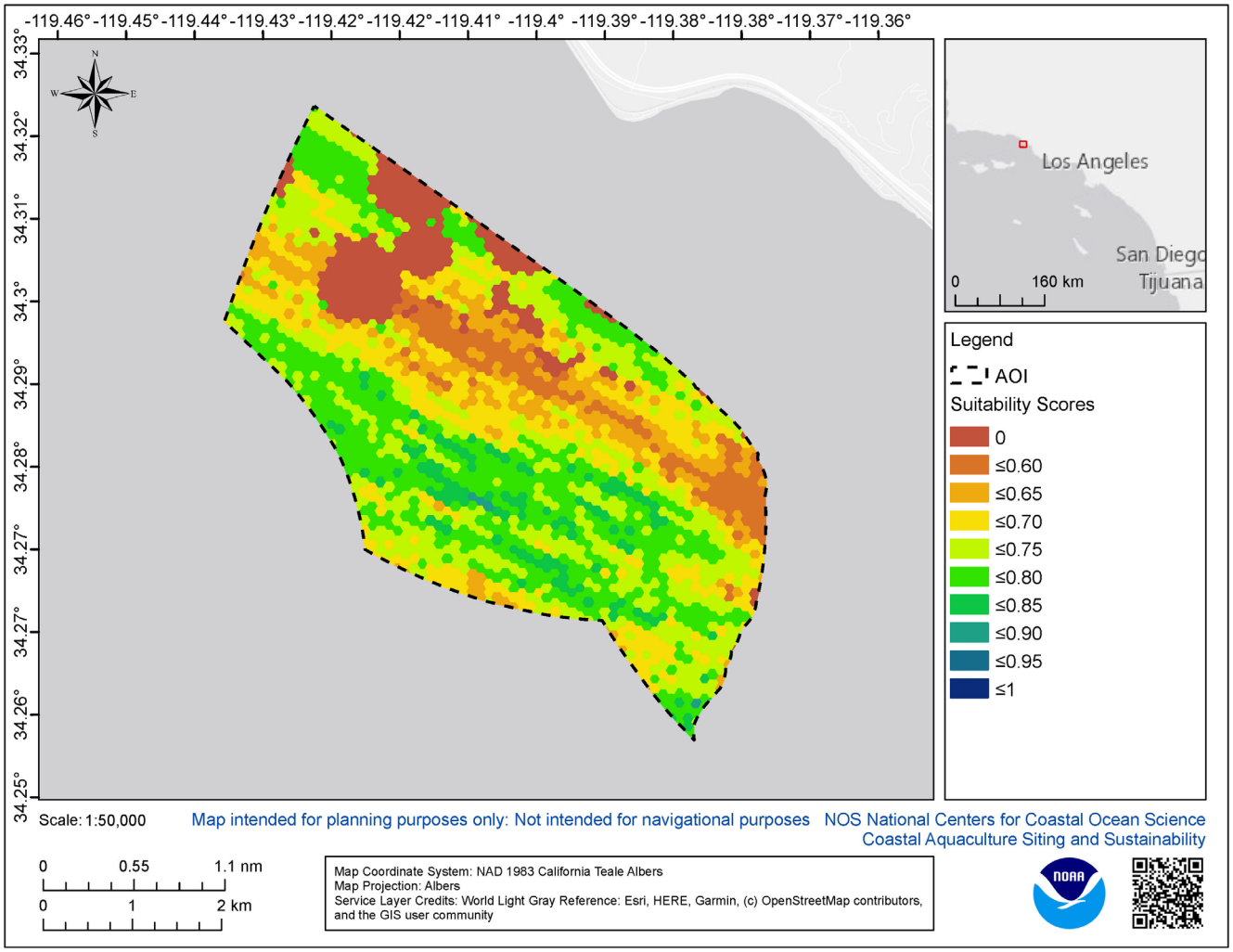


Figure 19. Final site suitability output for the AOI, where 0 is least suitable and 1 is most suitable.

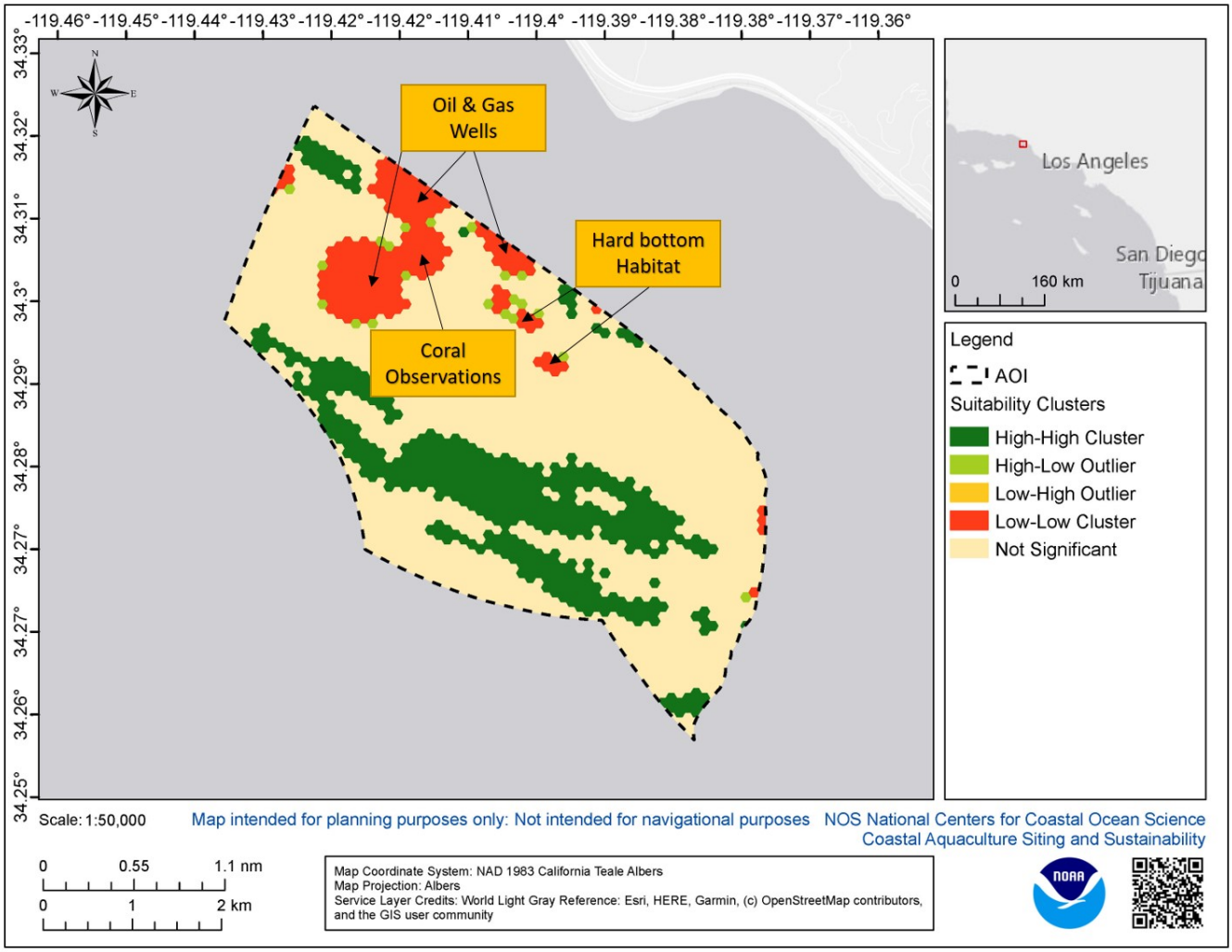


Figure 20. LISA analysis of the relative suitability scores identified high (green) and low clusters (red).

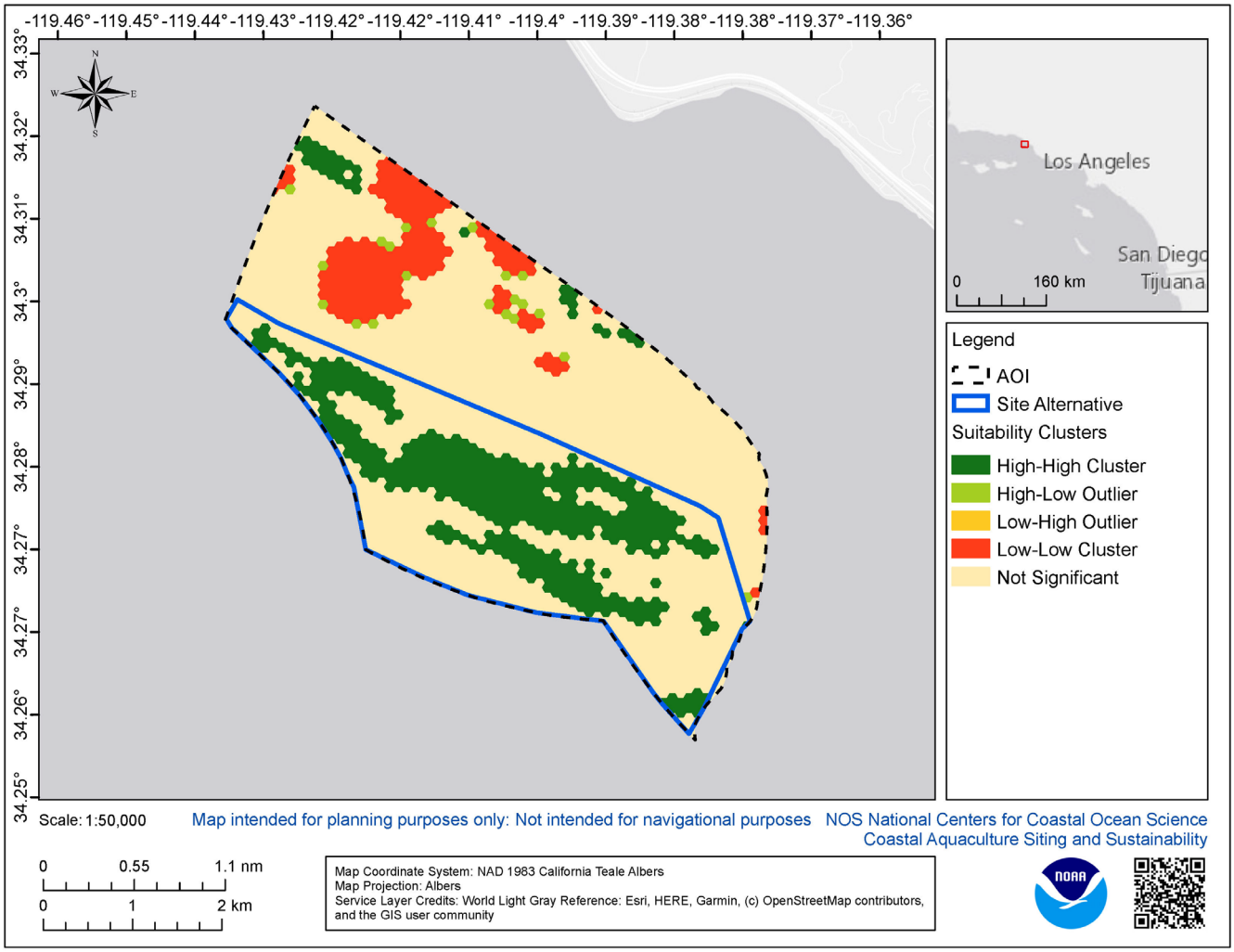


Figure 21 Farm site alternative (blue line) based on the results of LISA analysis.

Alternative Site Description

Within the site alternative location, several data layers were examined and summarized (Table 11). The depth ranged between 25 and 37 m with a mean of 31.1 m. The mean slope was 0.3 degrees, suggesting a flat bottom with a gentle transition to depth. The distance from Ventura harbor is 5.5 nm from the northwest edge of the site alternative. The total size of the site alternative is 2,442 acres, which meets the project requirements for 2,000 acres. However, the current farm configuration, using two sets of 10 x 100-acre farm sites separated by a navigation channel, did not fit within the irregular shape of the site alternative area (Figure 21 & Appendix A Figure A4).

Vessel Traffic

There were AIS tracks throughout the site alternative, the highest transit counts were from passenger and 'other' vessels with 132 and 177 respectively, pleasure vessels had 69 transits and fishing with 33. Of the vessels that typically have reduced maneuverability due to their large size, only 4 vessel transits were found within the site alternative, all were from cargo vessels transits.

Commercial and Recreational Fishing

Recreational fishing data comprised of CPFV and CRFS data. Within the site alternative, the data shows a relatively low reported recreational fishing activity compared to the surrounding area. Data for commercial fishing included VMS trawl transits, squid landing micro-block annual mean, and the presence of halibut trawl grounds. The alternative site is within the CDFW trawl grounds and data shows that 345 trawl transits have occurred from 2010 – 2016. An average of 132.6 short tons of squid was reported as being landed from a portion of the alternative site.

Other considerations

Examining the habitat considerations used for the siting analysis, within the site alternative there were no reported deep-sea corals or hard bottom substrate found. The site did fall within the cetacean BIA for Gray whale migration. There were no oil and gas wells within the site alternative.

Table 11. Site alternative data summary

Dataset	Site Alternative
Site Alternative area (acres)	2,442
Depth Minimum (m)	25.0
Depth Maximum (m)	37.0
Depth Mean (m)	31.1
Slope Mean (°)	0.3
Distance Ventura harbor (nm)	5.5
AIS Cargo transits	4
AIS Fishing transits	33
AIS Military transits	0
AIS Other transits*	132
AIS Passenger transits	177
AIS Pleasure transits	69
AIS Tanker transits	0
AIS Tug Tow transits	0
CPFV 2010 - 2019	0.8
CRFS 2010 - 2019	1.5
Squid landing annual mean 2012 - 2017 (short tons)	132.6
VMS Trawl transits 2010 - 2016	345
Halibut Trawl Ground	yes
Deep-sea corals	no
Hard bottom habitat	no
Oil gas wells	no
Audubon IBA (Santa Barbara basin)	yes
Cetacean BIA (Gray whale migration)	yes

* Other transits may include Dredging, Diving, Pilot Vessel, Search and Rescue, Law Enforcement, Offshore supply, Oil Recovery

Oceanographic Conditions

Oceanographic data were derived from buoy station 46053 (34.241 N 119.839 W), which is located 19 nm (35.2 km) southwest of the AOI. The values from 2013 – 2018 for daily maximum significant wave height (Figure 5) and mean daily temperature (Figure 6) were at or below the project requirements (Table 1). Mean and maximum current velocity data was available from the OceanReports tool[14]. Mean current velocity (Figure 7) range between 0.06 and 0.09 m^{-s}, the project requirement is current velocity between 0.025 – 0.1 m^{-s}.

CONCLUSIONS

This siting analysis identified an alternative site that meets the VSE requirements and was informed by a significant number of diverse data categories. Due to the irregular shape of the site alternative further investigation is needed to ensure the most recent farm configuration using two sets of 10 x 100 acres farm sites separated by a navigation channel, would be compatible with this site alternative (Appendix A Figure A4). Conservative approaches were taken when weighting each data layer using a three-tiered (low, medium, high) suitability. Caution should be taken when interpreting the actual suitability of each grid cell as this analysis provides a relative suitability approach. Actual suitability will be determined through the pre-application and application phases of permitting at which time additional review and inclusion of new data sets will further inform this analysis. Further investigation is needed for ocean areas or activities with the highest conflicts in the site alternative, including vessel traffic, commercial and recreational fishing, oil and gas infrastructure, and the extent of hard bottom habitat. Site-specific data and regional expertise will improve insights into potential conflicts and ensure interactions with aquaculture infrastructure are minimized.

[14] https://coast.noaa.gov/digitalcoast/tools/ort.html

Data Availability: All spatial data sets used in this analysis are available upon request. The exception being the VMS data, commercial fishing, and recreational fishing data sets as this data is sensitive and was made available by CDFW after a data-sharing agreement was in place. The study utilized the best available data at the time.

References

Anselin, L. (1995). Local Indicators of Spatial Association—LISA. *Geog. Anal.* 27, 93-115.

Becker E.A., Carretta J.V., Forney K.A., et al. Performance evaluation of cetacean species distribution models developed using generalized additive models and boosted regression trees. *Ecol Evol.* 2020;10:1–5784.

Bwadi, B.E., Mustafa, F.B., Ali, M. L., Bhassu, S. (2019). Spatial analysis of water quality and its suitability in farming giant freshwater prawn (*Macrobrachium rosenbergii*) in Negeri Sembilan region, Peninsular Malaysia. *Singapore J. Trop. Geog.* 40, 71-91.

Dunn, D. C., and Halpin, P. N. (2009). Rugosity-based regional modeling of hard-bottom Habitat. *Mar. Ecol. Prog. Ser.* 377, 1-11.

Esri. (2020). ArcGIS Pro: Release 2.5.0. Redlands, CA: Environmental Systems Research Institute.

Gimpel, A., Stelzenmüller, V., Grote, B., Buck, B.H., Floeter, J., Núñez-Riboni, I., et al. (2015). A GIS modeling framework to evaluate marine spatial planning scenarios: Co-location of offshore wind farms and aquaculture in the German EEZ. *Mar. Policy 55*, 102-115.

Kapetsky, J.M., Aguilar-Manjarrez, J., and Jenness, J. (2013). A global assessment of potential for offshore mariculture development from a spatial perspective. FAO Fisheries and Aquaculture Technical Paper No. 549. Rome, FAO. 181 pp.

Longdill, P.C., Healy, T.R., Black, K.P. (2008). An integrated GIS approach for sustainable aquaculture management area site selection. *Ocean Coastal Manage*, 51, 612-624.

Radiarta, I.N., Saitoh, S.I., Miyazono, A. (2008). GIS-based multi-criteria evaluation models for identifying suitable sites for Japanese scallop (*Mizuhopecten yessoensis*) aquaculture in Funka Bay, southwestern Hokkaido, Japan. *Aquacult.* 284, 127-135.

Appendix A: Additional Maps

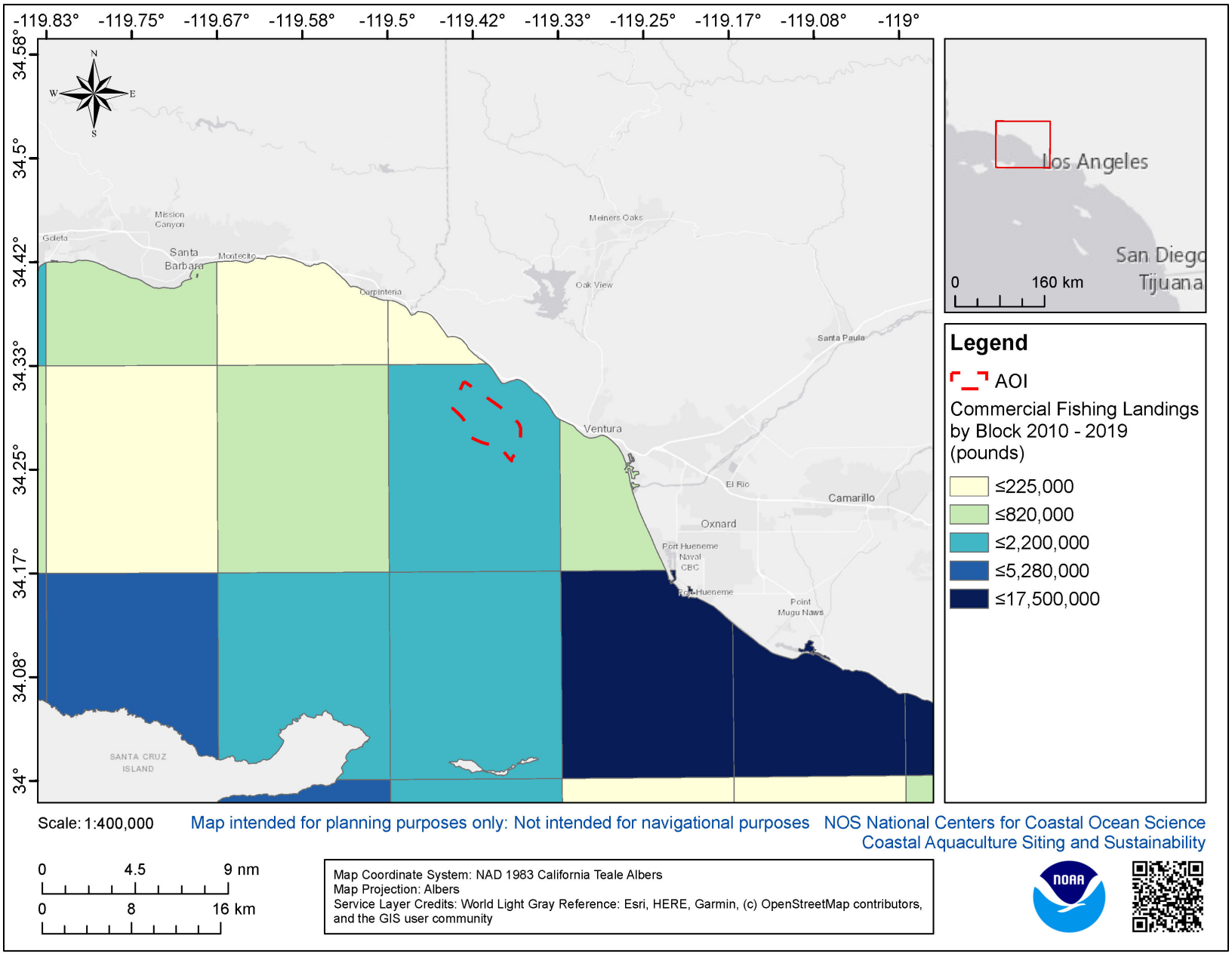


Figure A1. Commercial fishing block data from 2010 – 2019, showing average weight landed in pounds for all fisheries.

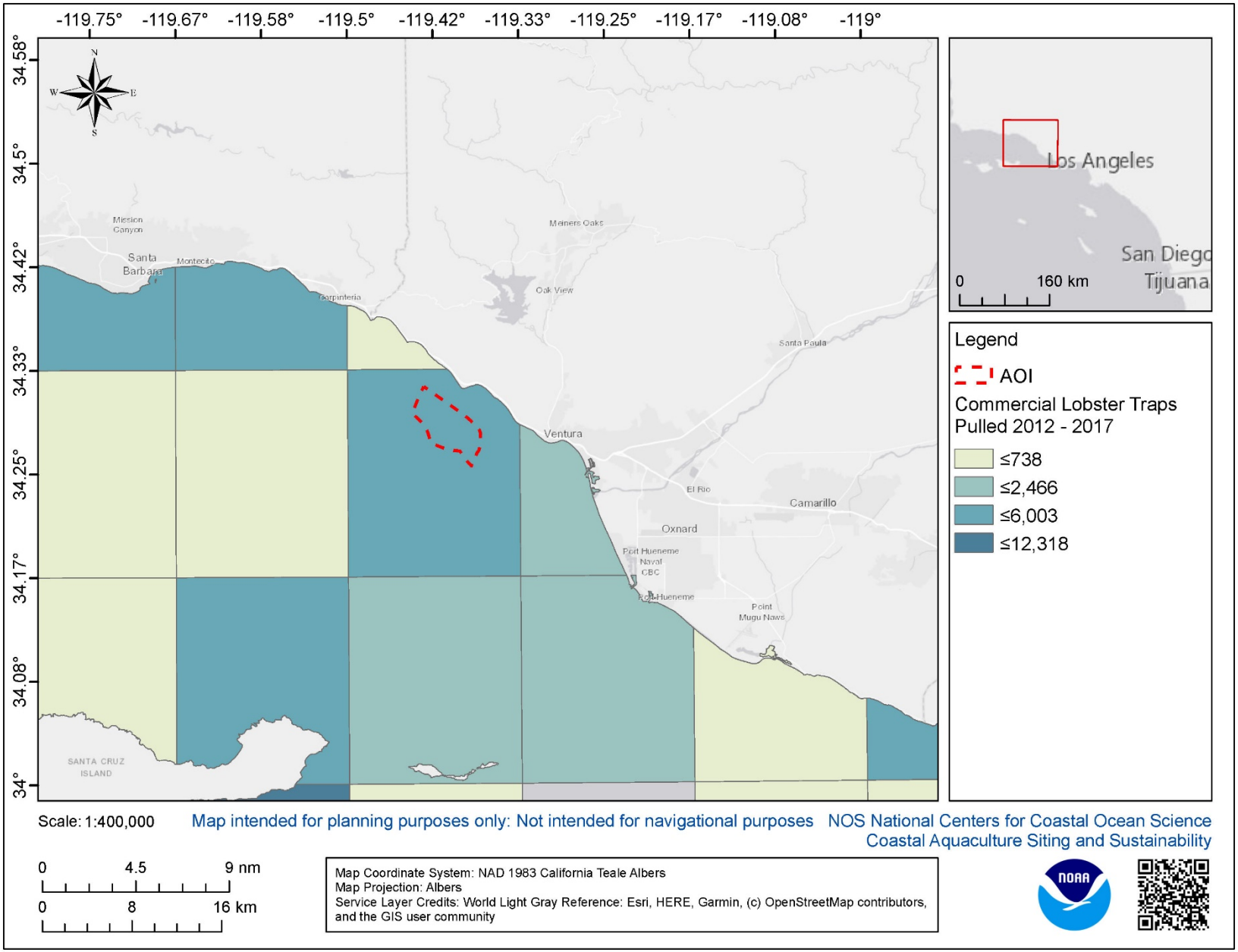
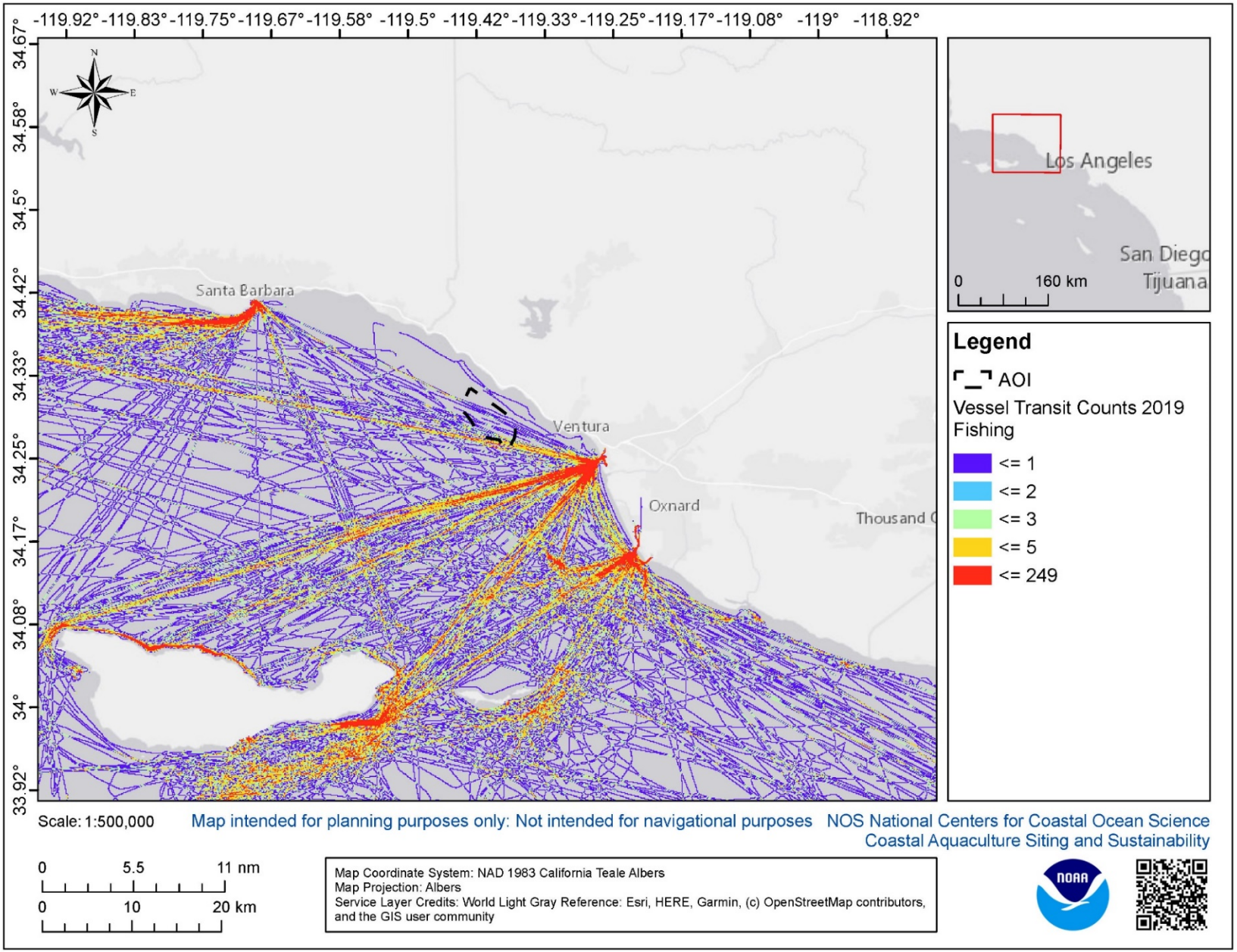
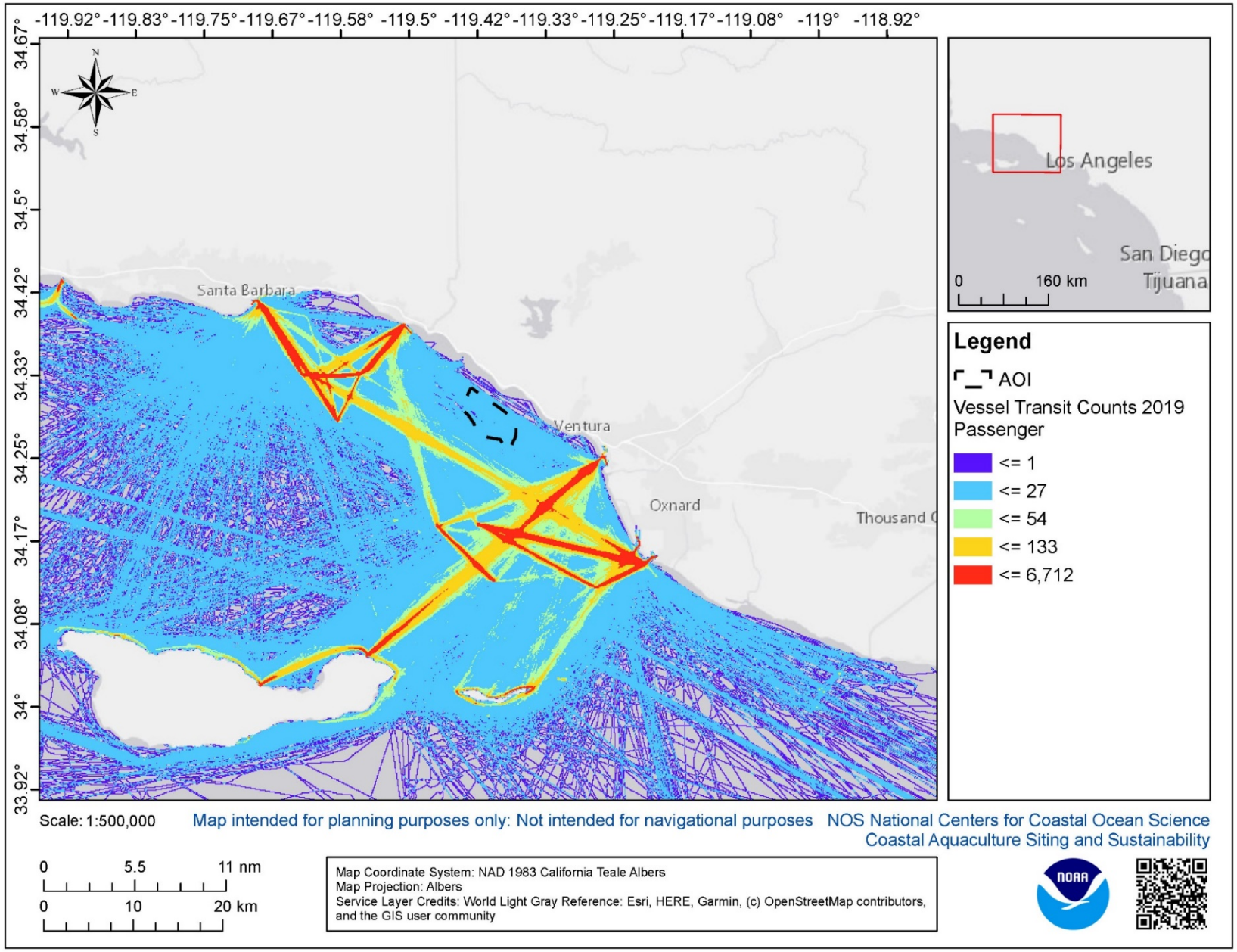


Figure A2. Commercial lobster fishing block data from 2012 – 2017, average traps pulled per year.

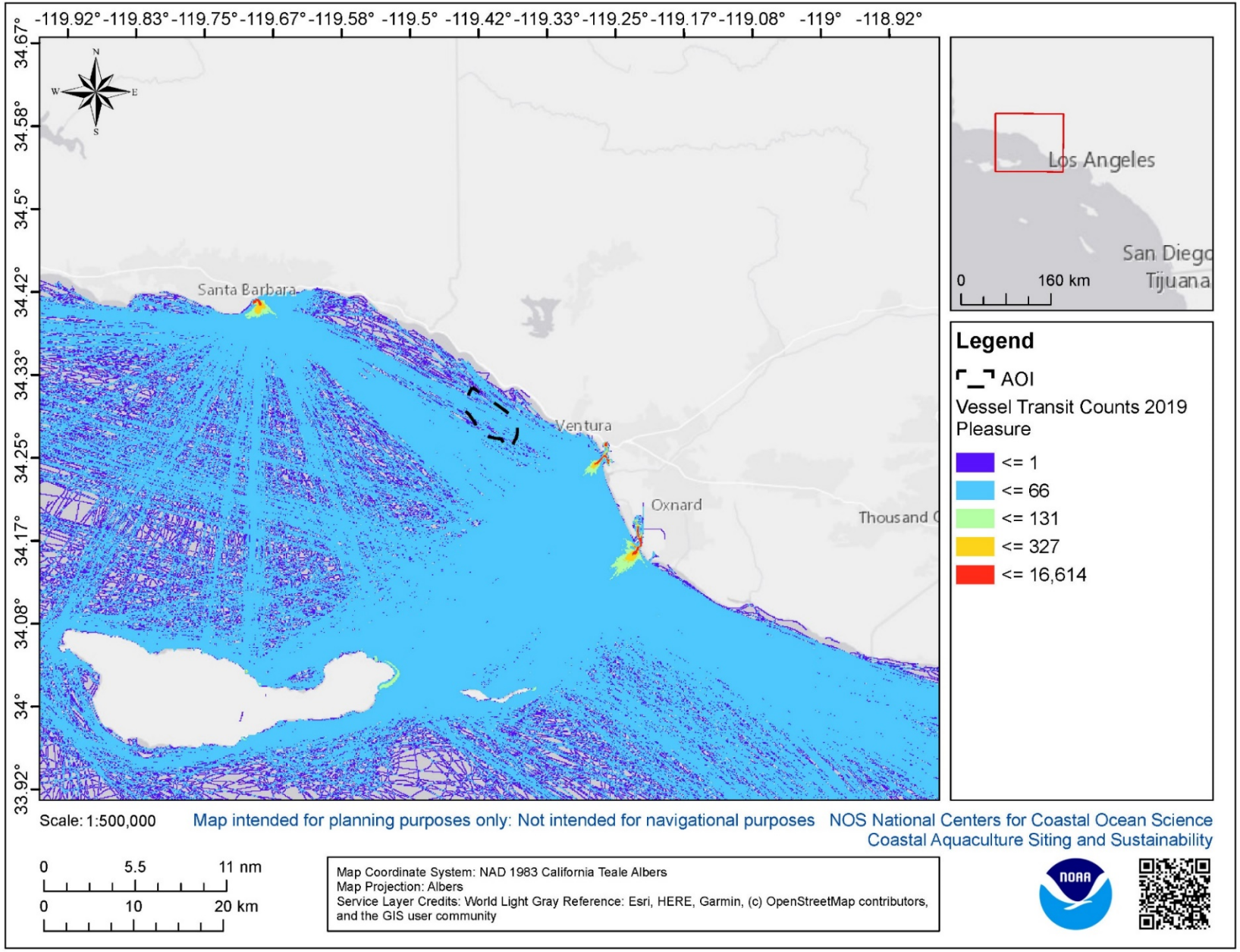


(A) AIS Transit Counts 2019 Fishing.

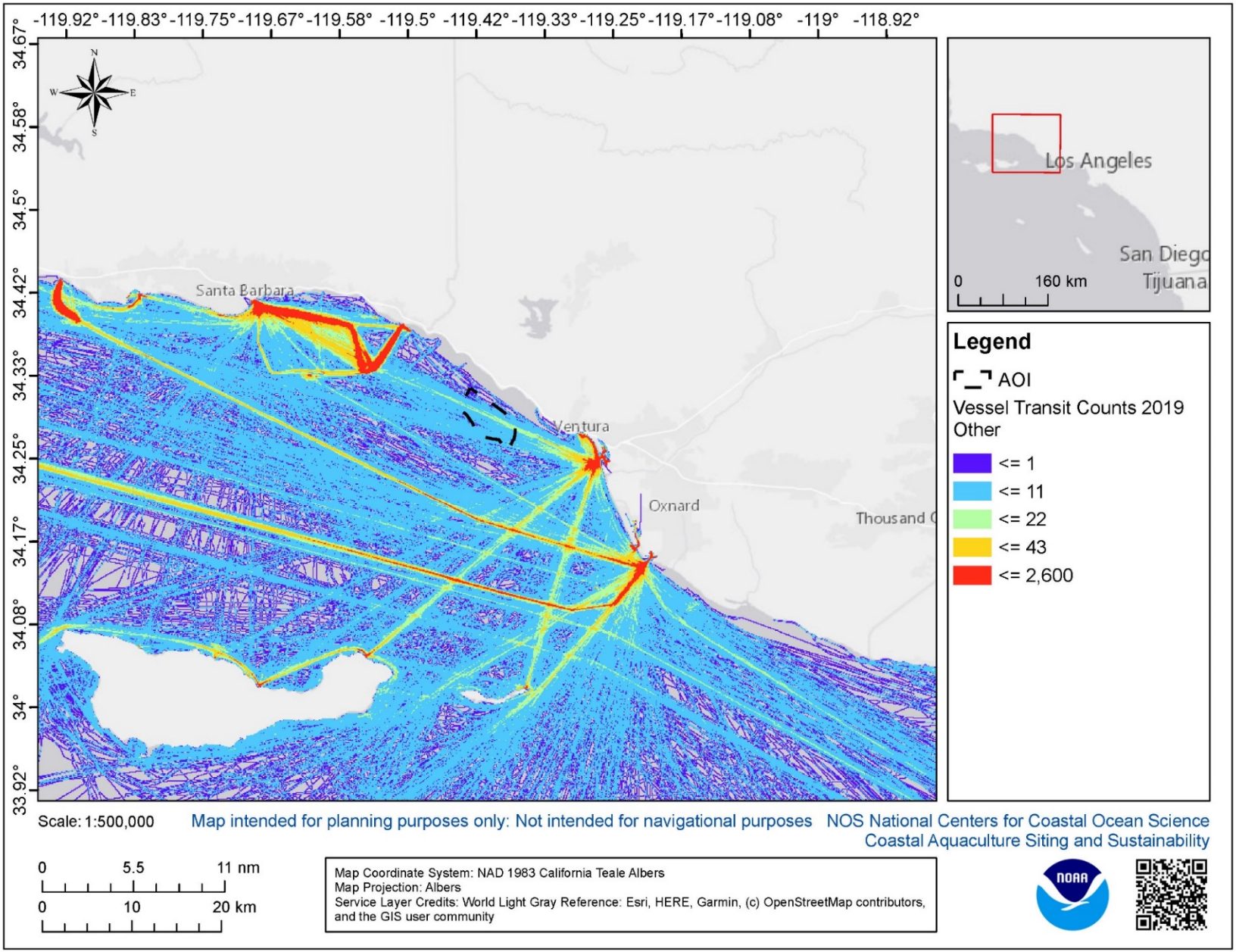
Figure A3. (A-G) Automated Identification System (AIS) vessel transit density within the AOI and surrounding area. Represents the number of vessel transits per year by vessel type (fishing, passenger, pleasure, other, cargo, tanker, and tug/ tow).



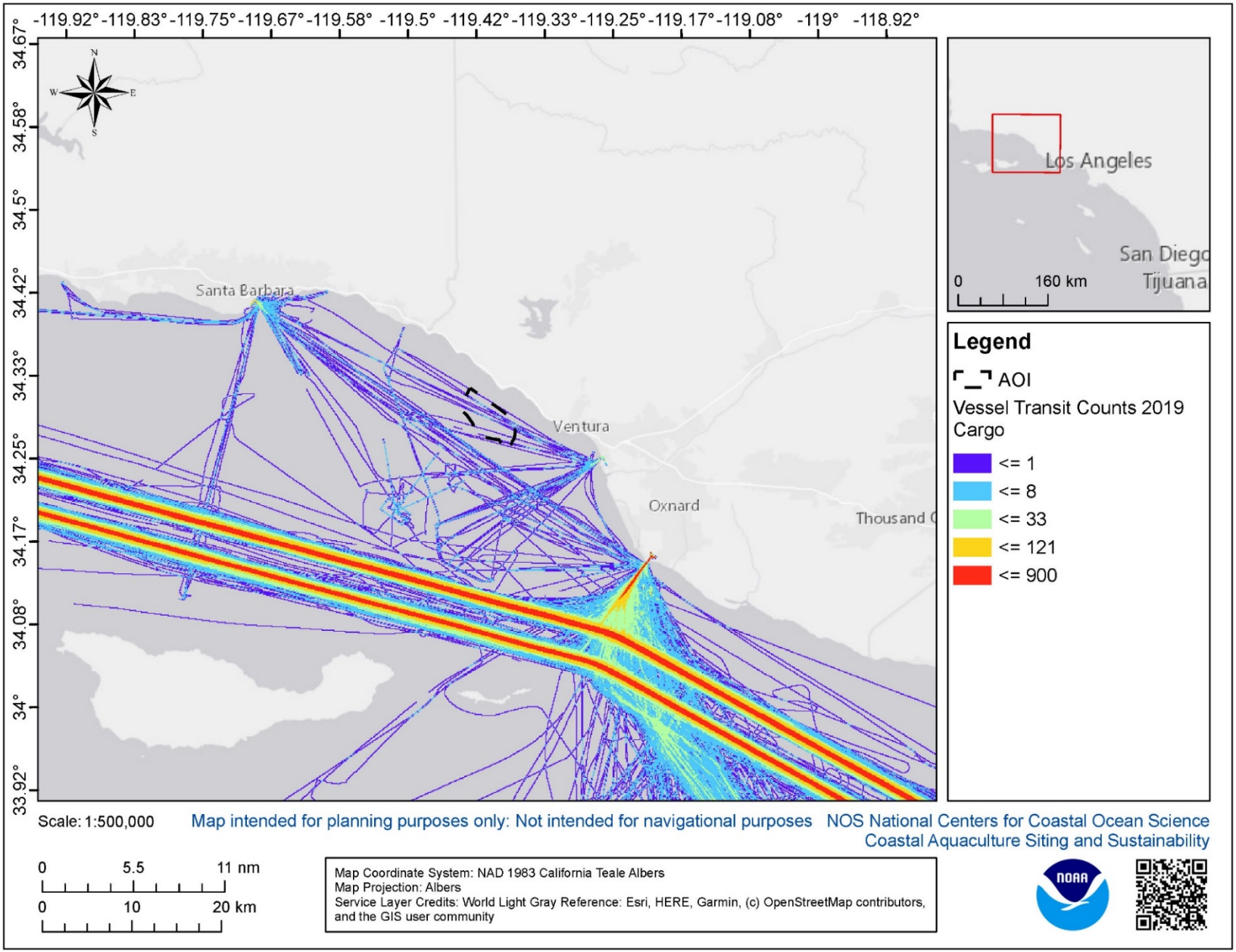
(B) AIS Transit Counts 2019 Passenger.



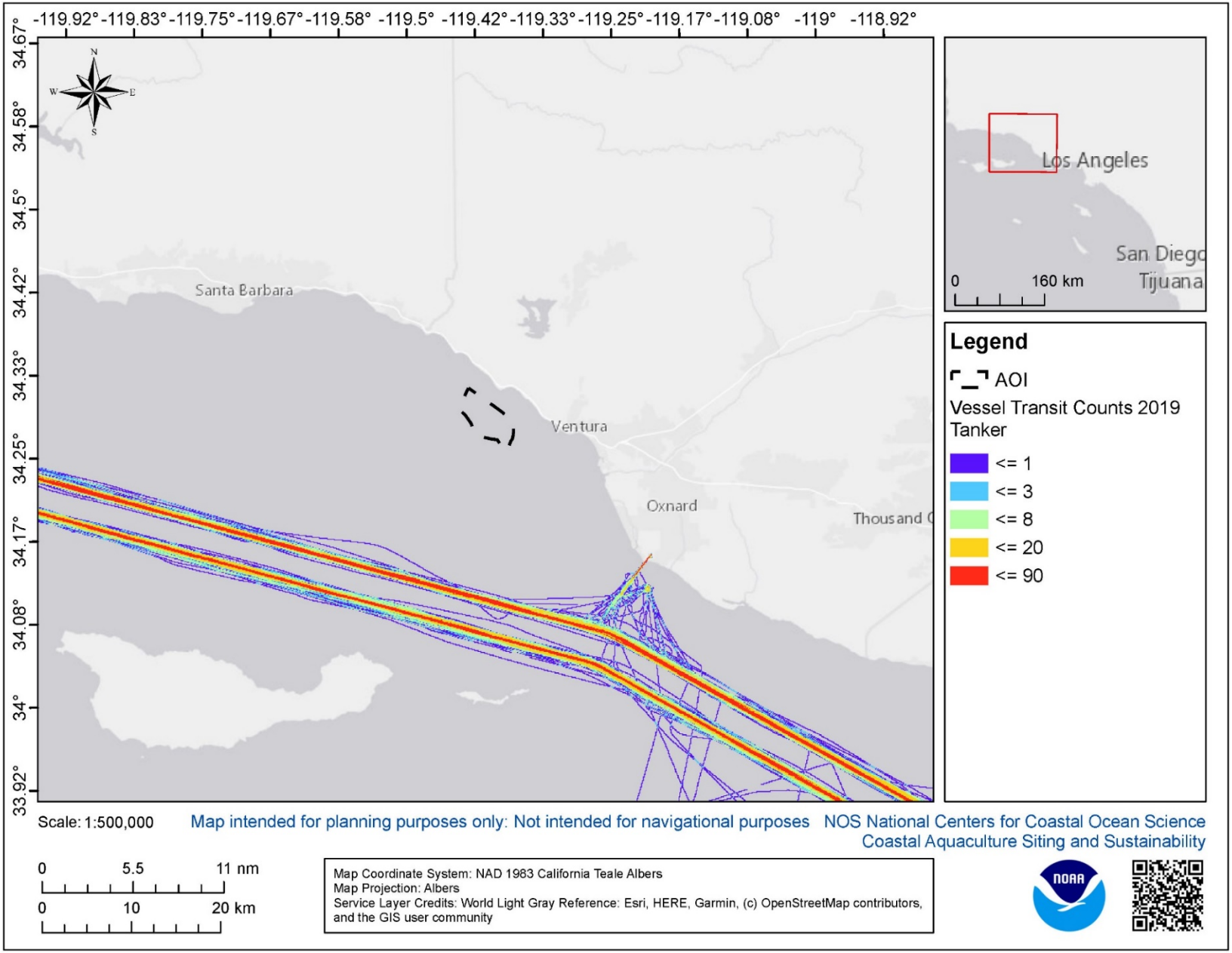
(C) AIS Transit Counts 2019 Pleasure Craft.



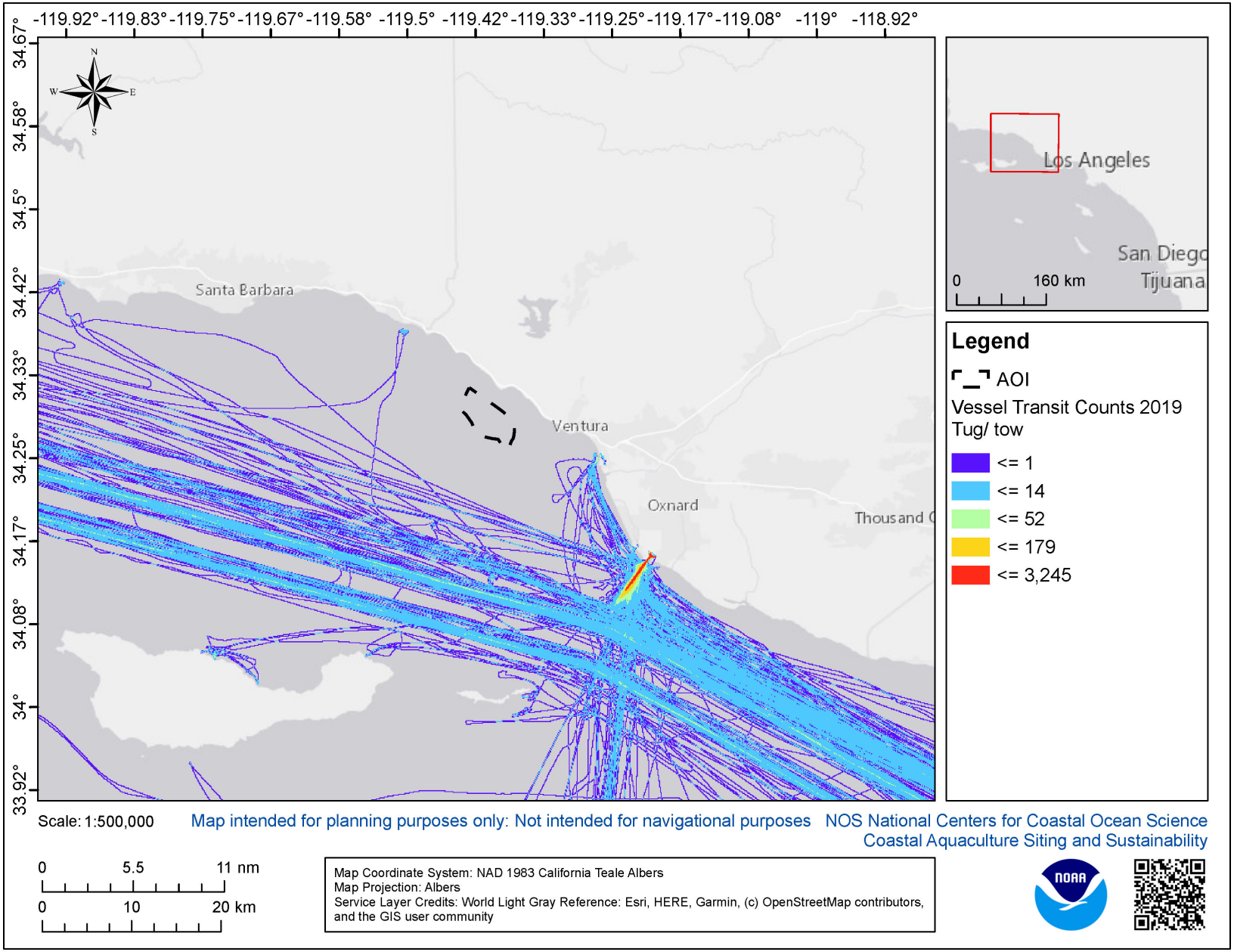
(D) AIS Transit Counts 2019 Other.



(E) AIS Transit Counts 2019 Cargo.



(F) AIS Transit Counts 2019 Tanker.



(G) AIS Transit Counts 2019 Tug and tow.

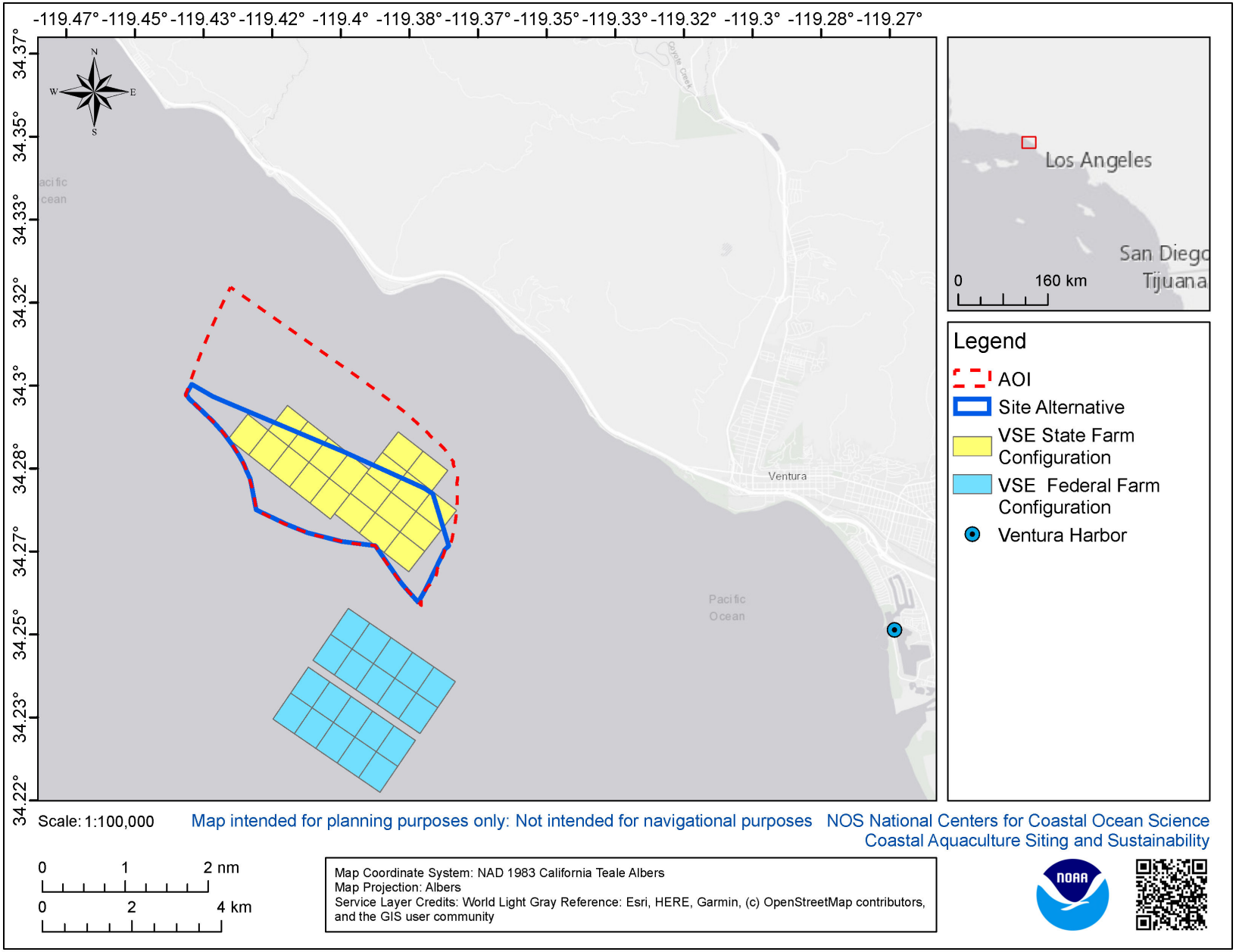


Figure A4. VSE state waters potential farm configuration (yellow) within the AOI (red dotted) and partially within the site alternative (blue) compared to the federal waters farm configuration (light blue).