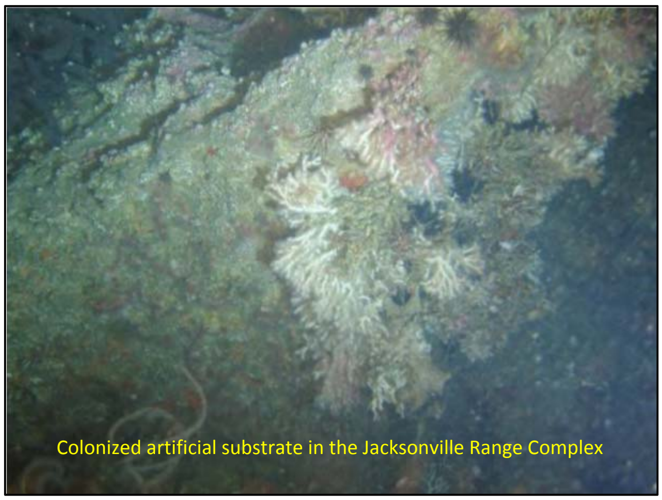
Building and Maintaining a Comprehensive Database and Prioritization Scheme for Overlapping Habitat Data – Focus on Abiotic Substrates



Colonized artificial substrate in the Jacksonville Range Complex

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Introduction

Geographic information system (GIS) data sources available within the Atlantic Fleet Training and Testing (AFTT) and Hawaii-Southern California Training and Testing (HSTT) study areas are variable in location, resolution, classification criteria, and accuracy. To ensure that best available data is used in the Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) analyses, an existing database was updated to include data fields for habitat feature classes (e.g., primary mapping method, validation methods, spatial resolution), which helped prioritize these data sources. Prioritizing data sources allows higher quality data to be used over lower quality data where they overlap. For example, Figure 1 shows that a much larger area of hard bottom was assumed and used in the Phase II analysis, whereas better quality survey data indicate that hard bottom is not present in these areas. The resulting refinement of "surveyed" habitat areas better reflect where different bottom types occur, improving the impact analysis within the Phase III AFTT and HSTT EIS/OEISs. The habitats resource section in the AFTT and HSTT EIS/OEISs focuses solely on abiotic substrates with other resource sections focusing on the associated biota (e.g., vegetation, invertebrates). Therefore, the information included herein to classify habitat data is limited to what is biologically relevant (in terms of taxa habitat affinities), stressor sensitive (e.g., crater formation, burial of expended materials), and distinguishable using available mapping techniques.

The AFTT/ HSTT Aquatic Habitat Database was developed to refine and prioritize overlapping habitat data used in the analysis of impacts (e.g., military expended materials (MEM) and bottom explosives). The database includes numerous data sources, ranging from broad- to fine-scale, that are combined to create a non-overlapping mosaic of habitat information that presents only the highest quality data for a given location. The database includes primarily polygons features, but also line and point features for selected habitat types (e.g., artificial substrate). The current database is limited to abiotic substrate types assessed in the Chapter 3 Habitats section for both AFTT and HSTT Phase III EIS/OEISs. This document provides a detailed description of the database and the ranking scheme used to prioritize data for the analysis in the AFTT and HSTT EIS/OEISs.

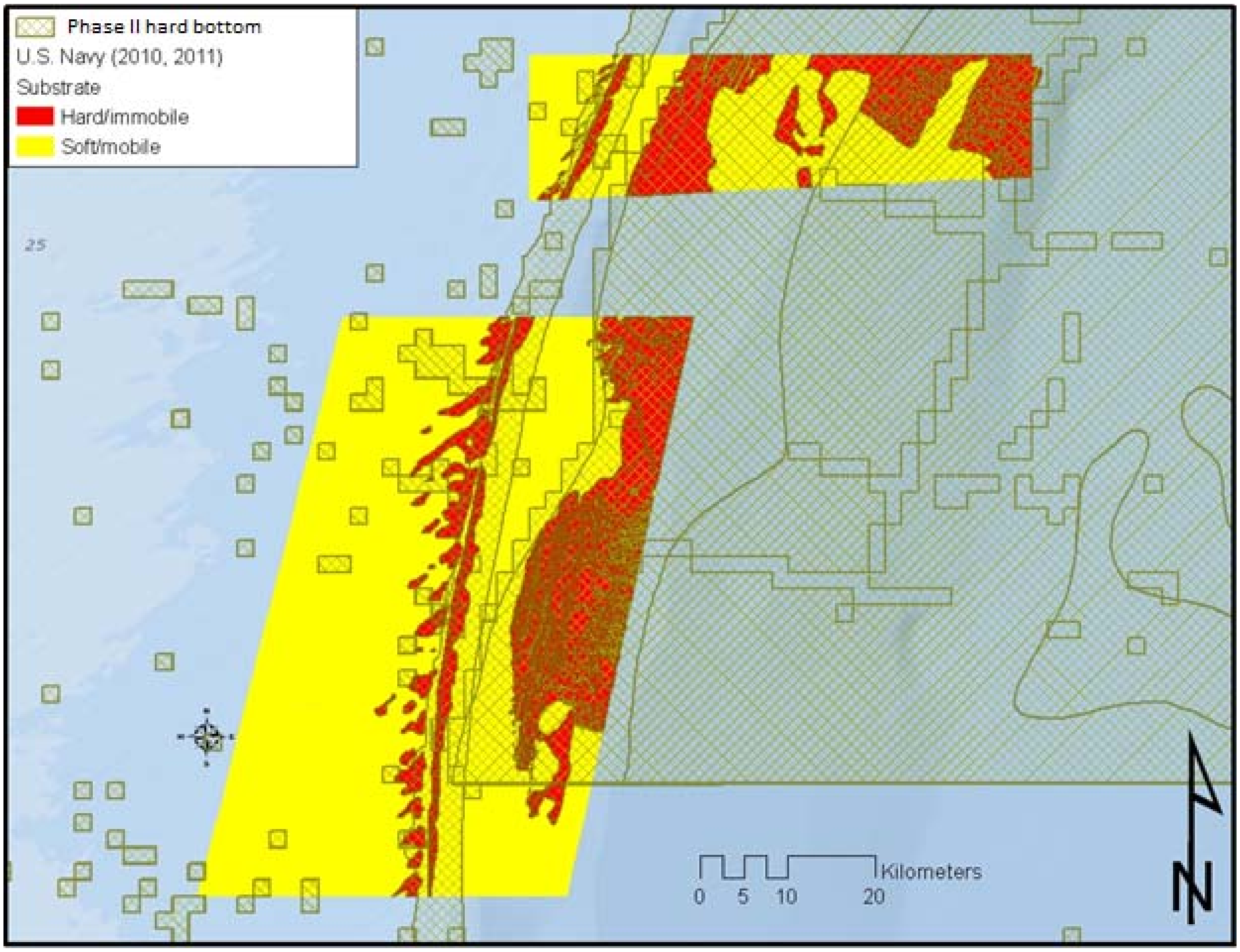

Figure 1. Comparison of Phase II hard bottom data (overlapping mosaic) and the USWTR and CC Range mapping of substrate types (U.S. Navy 2010a, 2011a).

Classification System

Although this report focuses on abiotic substrate, other themes or dimensions of aquatic habitat (for which the prioritization scheme may also be applied) provide important context. Figure 2 presents a standard classification scheme for overlapping dimensions (which are generally limited) of aquatic habitat developed for this report; within each dimension, overlapping data is ranked based on quality. Abiotic substrate forms the surface of bathymetric features (e.g., outcrops, ridges), and may have associated biotic features (e.g., seaweeds, corals, sponges, mussels). Water flow/quality (e.g., water column) has both horizontal (e.g., surface currents) and vertical dimensions (e.g., temperature stratification) with associated biotic features (e.g., Sargassum mats, phytoplankton biomass). Biotic feature dimensions associated with abiotic substrate types are analyzed in their respective chapter in the EIS/OEIS (e.g., Vegetation, and Invertebrates), and are not included in this report. This report only provides the data sources used to map abiotic substrate types in the AFTT and HSTT study areas.

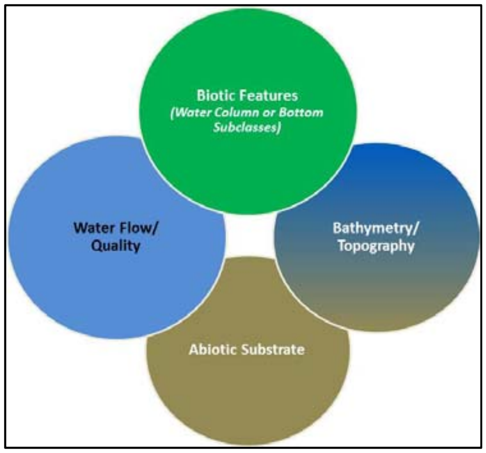

Figure 2. Basic thematic/dimensional aquatic habitat classification scheme. The different circles represent the different themes or dimensions of aquatic habitat that can overlap (e.g., water flows over the substrate but surface substrate types should be non-overlapping).

Abiotic substrate is defined as the non-living material forming the topography of a submerged surface. Although many classification schemes are available that span a range of spatial dimensions and granularity (Cowardin et al. 1979; Kennedy et al. 1987; Allee et al. 2000; Kendall et al. 2001; Valentine et al. 2005; UNESCO 2009; Howell 2010; FGDC 2012), three types of abiotic substrates are generally based on the grain size of unconsolidated material and degree of consolidation: “soft”, “intermediate”, and “hard” substrates. Soft substrate areas are dominated by mud (including clay and silt) or sand – substrate often too unstable for colonization by habitat-forming sedentary invertebrates (e.g., hard corals, oysters) or attached seaweed. Hard substrate areas are dominated by rocks or consolidated bedrock that is stable enough for colonization by habitat-forming sedentary invertebrates or attached seaweed. Intermediate substrate areas are dominated by unconsolidated material larger than sand but smaller than rocks (e.g., gravel). These areas may or may not be stable enough for habitat-forming sedentary invertebrates or attached seaweeds. Artificial substrate (e.g., shipwrecks, artificial reefs) is another type of abiotic substrate that is based on material type and origin. Spatial and temporal variation in abiotic substrate is created by the interplay of surficial geology, currents, and water quality at a location.

Although “soft bottom” and “hard bottom” can be used to convey both the abiotic substrate qualities and biological community of the bottom, the classification herein is limited to the abiotic substrate qualities.

Data Source Qualities

The Navy acquires data mapping aquatic habitats from various government (federal, state, and local) or private sources including but not limited to the National Oceanographic and Atmospheric Administration (NOAA), United States Geological Survey (USGS), Bureau of Ocean Energy Management (BOEM), state resources management agencies, government-funded marine laboratories, and private contractors working on projects with a federal nexus. The Navy has also conducted its own bottom mapping for specific projects and created some datasets based on expert knowledge of selected features (e.g., hard bottom on shelf break ridge and seamounts). The data sources are references in the section entitled "Summary of Data Sources." The mapping data sources were compiled and qualities of the data were documented in a database. Microsoft Access was used to create a form for documenting the variables needed to rank data quality (refer to section titled "Data Quality Ranking Scheme" for details). The data table can also be linked to an ArcGIS geodatabase for mapping sources to query for data quality attributes.

Description of Database Fields

1. AHD_ID – Unique identifier linking GIS data with Access record
2. Literature Citation – provides how the data source would be cited in text
3. HABITAT THEMES/DIMENSIONS
    a. Water Flow/Quality – selected if the feature theme(s) depicts flow or water quality parameters (e.g., current velocity/direction, temperature, salinity, phytoplankton density)
    b. Bathymetry/Topography – selected if the feature theme(s) depicts depth of the water column or topographic features of the bottom (e.g., outcrops, shelf breaks),
    c. Abiotic Substrate – selected if the feature theme(s) depicts a substrate classification (e.g., silt, sand, gravel, cobble, boulder/bedrock)
    d. Biotic Features – selected if the feature theme(s) depicts a biological feature of the water column or bottom (e.g., floating macroalgae mats, seagrass beds, reefs)
4. Year Data Collected– this is the year(s) that mapping data was collected (in the field) by the source reference and not necessarily the year of publication. The data could be a range (data for every year), multiple non-consecutive years, or a single year.
5. Method (Mapping) – methods that cover largest area of mapping theme
    a. Acoustic Sensor – includes use of devices that detect sound reflectance (e.g., sidescan sonar, single or multi-beam vertical sonar, sub-bottom profiler)
    b. Benthic Sampler – includes use of devices that extract a sample of the bottom composition, including sedentary or very slow-moving organisms (e.g., benthic grab, sediment core, dredge)
    c. Expert Knowledge – includes use of hand-drawn or digitized boundaries based on expert knowledge
    d. Line-based Interpolation – includes polygons interpolated between transects
    e. Modeling – Typically a combination of expert knowledge and some validation data in the form of points, lines, and/or polygons that do not cover the entire study area.
    f. Nekton Sampler – includes use of devices that captures large mobile organism in the water column or on the bottom (e.g., trawl, trap). Some organisms can be indicators of persistent aquatic habitat features (e.g., hard bottom).
    g. Other sensor – includes any technology not specifically covered by the specified methods (e.g., magnetometer).
    h. Plankton Sampler – includes use of devices that capture tiny organisms drifting in the water column

i. Point-based Interpolation – includes polygons interpolated among point samples
j. Visual Observation (direct) – includes direct observation by divers or use of device that captures video or photographic footage at a resolution similar to direct observation by divers (e.g., underwater video camera, remotely operated vehicle)
k. Spectral Sensor (remote) – includes use of devices that detect some part of the light spectrum from a remote platform (e.g., aerial photography, satellite multispectral scanner)
l. Water Flow/Quality Meters – includes use of devices that measure flow velocities or water quality parameters (e.g., temperature, salinity, turbidity, dissolved oxygen)

6. Method (Validation) – methods used to validate classification by the primary method
7. Mapping Coverage (%) – percentage of the mapping area covered by the primary method
8. Validation Coverage (%) – percentage of the mapping area covered by the validation method
9. Minimum Mapping Unit (m) – smallest area or resolution of the mapped classifications (e.g., macroalgae beds on hard substrate and areas of live deep-water coral species)
10. Assemblage Data –selected if the data represents a compilation of different sources
11. Subset Data – selected if the data represents a subset of a larger dataset
12. Acquisition Status – status with regard to acquiring the spatial data.
13. Data Rank by Theme(s) – a ranking from 0 (lowest quality) to 100 (highest quality) for the sources mapping a feature theme(s) in the database - See section below (Data Quality Ranking Scheme) for more information.
14. Processing Notes – Documentation for the conversion of data source classification into standard abiotic substrate categories.

<u>Description of fields included in GIS shapefile data for abiotic substrate types</u>:

1. AHD_ID – links to identical field in database (e.g., rank data quality)
2. AS_type – short for "abiotic substrate types"
   a. Soft – mud (clay or silt), sand
   b. Intermediate – gravel, cobble; or fine-scale mixture of soft and hard
   c. Hard – rock/boulder, bedrock
3. Artificial – subcategories: ship wreck, artificial reef, oil/gas platform, offshore military tower, or wind turbine
4. Acres

Data Quality Ranking Scheme

Each source of polygon data was given a rank from 0 (lowest quality) to 100 (highest quality) in order to determine the highest quality data in a given location, which was then used for subsequent analysis. The rank is based on a combination of minimum mapping unit (i.e., mapping resolution), mapping and validation method(s), compatibility of native classification system, and noted adjustments. Qualities of the datasets used to supporting the qualitative rankings are provided in Appendix B.

Mapping resolution is straight forward in terms of superiority: smaller minimum mapping units provide a better resolution of data. The minimum mapping units are ranked from 1 (lowest resolution/largest minimum mapping unit) to not greater than the number of datasets (highest resolution/smallest minimum mapping unit) if all the minimum mapping units are different. Data sources with equal minimum mapping units are given the same rank for mapping resolution.

As a comparison of mapping and validation method(s), consider a typical point-based interpolation (e.g., USGS 2000) compared to a highly detailed multibeam sonar, benthic grab, and remote operated vehicle (ROV) survey (e.g., U.S. Navy 2010, 2011). When data are available for the same location, the highly-detailed survey data (with a higher ranking score) would be used in the non-overlapping mosaic. Although, point-based interpolation data could be better than multibeam sonar if the points were close enough together, multibeam sonar data is generally considered to be of higher quality. The mapping and validation methods are ranked from 1 to 4, with four being the highest and best methods.

1. Point-based interpolation using benthic sampler validation or bathymetric interpolation and expert knowledge;
2. Line-based interpolation (e.g., depth or reflectance profiles) and validation by direct visual observation;
3. Bathymetric interpolation/modeling using validation from acoustic sensors, benthic samplers and direct visual observations or acoustic sensor/remote spectral sensor without validation; and
4. Acoustic sensor or remote spectral sensor using validation from direct visual observation or benthic samplers

Compatibility of native classification system was ranked from 1 (lowest rank) to 3 (highest rank) based on the following descriptions of original bottom type classifications:

1. Bottom classifications are all geologic indicators of abiotic substrate types (e.g., Todd 2006);
2. Bottom classifications can be directly translated into standardized categories or there is a strong correlation of stationary biota (e.g., hard corals, live hard bottom organisms) to a set of factors including hard substrate (e.g., Kinlan et al. 2013);
3. Bottom classification can be directly translated into standardized categories and there is reference to topography (e.g., high relief hard bottom) and relatively high concentration of stationary biota (e.g., Skidaway Institute of Oceanography 2004).

The component ranks are combined to yield a total rank from 0-100 using the following equation, assuming 50% is based on resolution, 30% on mapping and validation methods, and 20% on compatibility of native classification system. A bonus or penalty may also be added for additional factors considered for overlapping data.

$$(R/RH*50) + (M/MH*30) + (C/CH*20)$$

R=Resolution rank for individual source x
RH = Highest rank for resolution in the dataset
M=Methods rank for individual source
MH=Highest rank for method in the dataset
C=Classification rank for individual source

CH = Highest classification rank in the dataset

Summary of Data Sources

The following tables document the data sources and rankings for the AFTT and HSTT study areas (Table 1 and 2, respectively). For the AFTT study area, there were 26 point data sources, 3 line data sources, and 32 polygon data sources (including sources integrating numerous constituent data sources). For the HSTT study area, there were 4 point data sources and 6 polygons data sources (including sources integrating numerous constituent data sources). Note that equivalent ranks are allowed where polygon data sources do not overlap.

Table 1. Mapping data source for abiotic substrate types in the AFTT Phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
Points[1]	Berg & Berg (1989)	NA	Mapped points representing shipwreck centroids
	BOEM (2013)	NA	Mapped only oil and gas platforms with an installation date and no removal date
	Cerame Vivas (1988)	NA	Mapped points representing shipwreck centroids
	Delaware Division of Fish and Wildlife (2015)	NA	Mapped points representing artificial reef centroids
	FFWCC & FWRI (2014)	NA	Mapped points representing artificial reef material centroids
	Georgia Department of Natural Resources (2015)	NA	Mapped points representing artificial reef centroids
	Handler (2001)	NA	Mapped points representing artificial reef or shipwreck centroids
	Longley-Wood (2015)	NA	Mapped centroid of experimental wind turbines
	Louisiana Department of Wildlife and Fisheries (2015)	NA	Mapped points representing artificial reef centroids
	Massachusetts Division of Marine Fisheries (2015)	NA	Mapped points representing artificial reef centroids
	Mississippi Department of Marine Resources (2015)	NA	Mapped points representing artificial reef centroids
	NAVFAC Atlantic (2015a)	NA	Mapped centroid of offshore military towers
	New Jersey Division of Fish and Wildlife (2015)	NA	Mapped points representing artificial reef centroids

[1] NA = Not Applicable; Point are not assigned a qualitative rank because they did not precisely overlap.

Table 1. Mapping data source for abiotic substrate types in the AFTT Phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
	New York Department of Environmental Conservation (2015)	NA	Mapped points representing artificial reef centroids
	NOAA (2015)	NA	Mapped artificial or unknown wrecks or obstructions; Clipped to within 1 mile of the AFTT study area
	North Carolina Division of Marine Fisheries (2015)	NA	Mapped offshore points representing artificial reef centroids
	O.C. Reef Foundation (2013)	NA	Mapped points representing artificial reef centroids
	Outdoor Alabama (2015)	NA	Mapped points representing artificial reef material centroids
	Rhode Island Artificial Reef Program (2015)	NA	Mapped points representing artificial reef centroids
	Simonson (2000)	NA	Mapped points representing artificial reef or shipwreck centroids
	South Carolina Department of Natural Resources (2015)	NA	Mapped points representing artificial reef centroids
	Texas Parks and Wildlife Department (2015)	NA	Mapped points representing artificial reef centroids
	U.S. Navy (2002)	NA	Mapped points representing SINKEX vessel remains around Puerto Rico
	Veridian Corporation (2001)	NA	Mapped points representing shipwreck centroids
	Virginia Marine Resources Commission (2005, 2009)	NA	Mapped points representing artificial reef centroids
	Waterproof Charts, Inc. (1998)	NA	Mapped points representing shipwreck centroids
Line[2]	FSLTD and CSA (2011)	NA	Benthic habitat classification survey report for AM1 submarine cable system, Segment 1.1, Jacksonville, FL (BMH JKV to BU-1 Continental Shelf)
	Moser and Taylor (1995)	NA	Hard bottom habitat in North Carolina state waters: a survey of available data
	SEAMAP-SA (2001)	NA	Distribution of bottom habitats on the continental shelf from North Carolina through the Florida Keys

[2] NA = Not Applicable; Point are not assigned a qualitative rank because they did not precisely overlap.

Table 1. Mapping data source for abiotic substrate types in the AFTT Phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
Polygon	Ackerman et al. (2006)	75.0	High-resolution geologic mapping of the inner continental shelf; Boston Harbor and Approaches (Resolution 8, Methods 4, Classification Compatibility 3)
	Anderson and Eastlake (2011)	93.8	Benthic Habitats of The Florida Keys prepared from IKONOS Satellite Imagery (Resolution 14, Methods 4, Classification Compatibility 3)
	Anderson et al. (2010)	36.5	Benthic Habitats in the Northwest Atlantic Marine Ecoregional Assessment: Species, Habitats and Ecosystems (Resolution 5, Methods 1, Classification Compatibility 2)
	Barnhardt et al. (1996)	57.7	Surficial Geology of the Maine Inner Continental Shelf (Resolution 7, Methods 3, Classification Compatibility 2)
	Barnhardt et al. (2006)	74.6	High-resolution geologic mapping of the inner continental shelf: Nahant to Gloucester, Massachusetts (Resolution 10, Methods 4, Classification Compatibility 2)
	Barnhardt et al. (2009)	71.3	High-resolution geologic mapping of the inner continental shelf: Cape Ann to Salisbury Beach, Massachusetts (Resolution 10, Methods 4, Classification Compatibility 1.5)
	Chesapeake Bay Office-NOAA (2011)	74.4	Chesapeake Bay Benthic Habitat Integration (Resolution 11, Methods 4, Classification Compatibility 1.5)
	FFWCC-FWRI (2013)	65.8	Coral and hard bottom mapping (Resolution 12, Methods 2, Classification Compatibility 2)
	GMFMC (2004)	21.5	Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to Fishery Management (Resolution 1, Methods 2, Classification Compatibility 2, -10 for region of relatively poor data intruding on the Atlantic)
	GSMFC (2008)	42.1	Marine Benthic Substrates Geodatabase, Northern Gulf of Mexico (Resolution 2, Methods 3, Classification Compatibility 2)
	Kendall et al. (2005)	90.6	Benthic mapping using sonar, video transects, and innovative approach to accuracy assessment: a characterization of bottom features in the Georgia Bight (Resolution 13, Methods 4, Classification Compatibility 3)

Table 1. Mapping data source for abiotic substrate types in the AFTT Phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
	Kinlan et al. (2013a)	64.6	Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Gulf of Mexico (Resolution 6, Methods 3, Classification Compatibility 2, +10 for depicting habitat suitability for deep-sea hard corals)
	Kinlan et al. (2013b)	64.6	Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions (Resolution 6, Methods 3, Classification Compatibility 2, +10 for depicting habitat suitability for deep-sea hard corals)
	Kinlan et al. (2013c)	64.6	Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Southeast region (Resolution 6, Methods 3, Classification Compatibility 2, +10 for depicting habitat suitability for deep-sea hard corals)
	McMullen (2007)	93.3	Interpretation of sidescan Sonar and Bathymetric Data from Central Narragansett Bay (Resolution 16, Methods 4, Classification Compatibility 2)
	Messing et al. (2011)	65.6	Navy Cable Project: Deepwater Habitats (Resolution 13, Methods 2, Classification Compatibility 1.5)
	Moser and Taylor (1995)	44.0	Hard bottom habitat in North Carolina state waters: a survey of available data (Resolution 5, Methods 2, Classification Compatibility 2)
	National Ocean Service (2001)	90.2	Benthic habitats of Puerto Rico and the U.S. Virgin Islands (Resolution 15, Methods 4, Classification Compatibility 2)
	NAVFAC Atlantic (2013)	30.2	Hard bottom mapping (Southeast U.S. shelf break polygon). Digitized between bathymetric contours where shelf-break hard bottom was located, based on U.S. Navy (2010a) mapping (Resolution 3, Methods 1, Classification Compatibility 2)
	NAVFAC Atlantic (2016b)	24.0	Seamounts in the U.S. Atlantic EEZ (Resolution 1, Methods 1, Classification Compatibility 2)
	Poppe (2010)	71.3	Geological interpretation of the sea floor offshore of Edgartown, Massachusetts (Resolution 10, Methods 4, Classification Compatibility 1.5)

Table 1. Mapping data source for abiotic substrate types in the AFTT Phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
	Scanlon et al. (2003)	75	Texture, Carbonate Content, and Preliminary Maps of Surficial Sediments of the Flower Garden Banks Area, Northwestern Gulf of Mexico Outer Shelf (Resolution 8, Methods 4, Classification Compatibility 3)
	Skidaway Institute of Oceanography (2004)	62.5	Base geology of the northern Blake Plateau (Resolution 4, Methods 4, Classification Compatibility 3)
	Todd (2006)	67.9	Surficial geology polygons, Browns Bank 2006, Gulf of Maine, Scotian Shelf, offshore Nova Scotia, Canada (Resolution 10, Methods 4, Classification Compatibility 1)
	Todd and Kostylev (2011)	71.5	Surficial geology and benthic habitat of the German Bank seabed, Scotian Shelf, Canada (Resolution 9, Methods 4, Classification Compatibility 2)
	U.S. Navy (2010a)	81.3	JAX OPAREA USWTR Bottom Mapping and Habitat Characterization, Florida (Resolution 10, Methods 4, Classification Compatibility 3)
	U.S. Navy (2011a)	81.3	JAX OPAREA CC Range Bottom Mapping and Habitat Characterization, Florida (Resolution 10, Methods 4, Classification Compatibility 3)
	U.S. Navy (2011b)	81.3	Jacksonville USWTR Nearshore Bottom Mapping (Resolution 10, Methods 4, Classification Compatibility 3)
	USGS (2000)	24.0	USGS East-coast sediment analysis: Procedures, database, and georeferenced displays (Resolution 1, Methods 1, Classification Compatibility 2)
	USGS-SCSGC (2007)	80.6	SEAFLOORENV - Distribution of Seafloor Environments within the inner shelf of Long Bay, South Carolina (Resolution 13, Methods 4, Classification Compatibility 1.5)
	Walker et al. (2006)	70.2	Coral Reef Burial in Southeast Florida (Resolution 11, Methods 3, Classification Compatibility 2)

Table 2. Mapping data source for abiotic substrate types in the HSTT phase III study area.

Geometry	Source	Data Rank (0-100)	Description (Rank Components)
Point[3]	CDFW (2007)	NA	Mapped points representing artificial reef centroids
	California State Lands Commission (2012)	NA	Mapped points representing shipwreck locations, but deleted points coincident with NOAA (2015)
	HDAR (2015)	NA	Mapped points representing artificial reef centroids
	NOAA (2015)	NA	Mapped artificial only (limited to shipwreck locations regardless of accuracy)
Polygon	CSU Seafloor Mapping Lab (1987)	37.5	California continental shelf geology (Resolution 1, Methods 1, Classification Compatibility 2)
	CSUMB, USGS, Fugro Palagos, Ocean Imaging, SanDAG, MLML, CDFW (2006)	62.5	Predicted Substrate of Southern California (Resolution 2, Methods 3, Classification Compatibility 2)
	KTU-A LA&P, MN, SDNHMP, and SanDAG (2002)	82.5	Seafloor Substrate of the San Diego Region Nearshore Coastal Zone (Resolution 4, Methods 3, Classification Compatibility 2)
	Merkel and Associates (2014)	100.0	Benthic Habitat Mapping for West Cove Naval Auxiliary Landing Field, San Clemente Island Naval Base Coronado, California (Resolution 5, Methods 4, Classification Compatibility 2)
	NCCOS (2007)	72.5	Northwestern Hawaiian Island Shallow-water Coral Reef Ecosystem Map Development Procedures (2004-2007 data) (Resolution 3, Methods 3, Classification Compatibility 2)
	NOAA/NOS/NCCOS/CCMA (2007)	100.0	Mapping of Benthic Habitats for the Main Eight Hawaiian Islands (Resolution 5, Methods 4, Classification Compatibility 2)

Description of Non-overlapping Mosaic

Thousands of acres of low quality data were superseded by high quality data in the process of creating the non-overlapping abiotic substrate maps for the AFTT and HSTT study areas. The process identified substrate distribution within Large Marine Ecosystems, which was used as a basis for the analyses in the AFTT and HSTT EIS/OEISs. Developing a data quality ranking scheme also allowed for identifying over- or under-estimation of habitat types, by comparing areas of higher and lower quality data. Point and line

[3] NA = Not Applicable; Point are not assigned a qualitative rank because they did not precisely overlap.

features were also included in the dataset because they are inherently non-overlapping in terms of area. Refer to Appendix A for regional substrate maps from the AFTT and HSTT EIS/OEISs.

AFTT Study Area

Within the AFTT study area, more than 20,000 artificial substrate points have been identified (Table 3 and Appendix A1-A4), including shipwrecks (11,607), artificial reefs (4,225), oil/gas platforms (2,674), military towers (18), wind turbines (5), and unspecified obstructions (2,578). For artificial reefs, the center point of the small permitted area[4] (for small permit areas; less than 80 acres) or concentrations of material (for large permit areas) were used. The 80 acres threshold is based on a buffer of 320 meters around the center points of accurate wreck locations, for planning bottom-placed explosives used in AFTT/HSTT training and testing activities. The shipwreck data could include some of the same wrecks with slightly different positions as well as omission of some artificial substrate points, notably wrecks that are "address restricted" due to status on the National Registry of Historic Places (e.g., Gen. C.B. Comstock located in Texas state waters) and most wrecks created from Naval sinking exercises in the vicinity of Puerto Rico/Vieques (at least 26 Navy vessels were deliberately sunk in this area). Sunken naval vessels do not appear in any of the 26 point datasets for the AFTT study area, presumably because they were not considered "shipwrecks" and most were sunk in open ocean areas where bottom impacts would be minimal. A high profile exception is the USS Killen located in shallow water off Vieques.

Table 3. Number and type of artificial substrate points documented in Large Marine Ecosystems and Open Ocean Areas of the AFTT study area. Data were unavailable for the remaining ecosystems and ocean areas not listed within the table.

Large Marine Ecosystem or Open Ocean Area	Training or Testing Locations	Military Towers	Artificial Reef	Oil/Gas Platform	Shipwreck	Wind Turbines	Shipwreck or Obstruction	*Grand Total*
Caribbean	Ocean areas	0	25	0	377	0	99	***502***
Gulf of Mexico	St. Andrews Bay	0	2	0	58	0	30	***90***
	Ocean areas	6	3148	2598	5103	0	689	***11555***
	Other bays/estuaries	0	56	76	929	0	174	***1235***
Gulf Stream Open Ocean Area	Ocean areas	0	0	0	94	0	1	***95***
Northeast U.S. Continental Shelf	Lower Chesapeake Bay and tributaries (James and York Rivers)	0	9	0	467	0	233	***709***
	Ocean areas	4	26	0	2355	5	763	***3167***

[4] Artificial Reef permit areas are locations where permit holders (typically state resource management agencies) have legally deployed artificial reef material (e.g., concrete demolition materials, reef balls).

Table 3. Number and type of artificial substrate points documented in Large Marine Ecosystems and Open Ocean Areas of the AFTT study area. Data were unavailable for the remaining ecosystems and ocean areas not listed within the table.

Large Marine Ecosystem or Open Ocean Area	**Training or Testing Locations**	**Military Towers**	**Artificial Reef**	**Oil/Gas Platform**	**Shipwreck**	**Wind Turbines**	**Shipwreck or Obstruction**	***Grand Total***
	Other bays/estuaries	0	5	0	9370	0	323	***1225***
Labrador Current and North Atlantic Gyre Open Ocean Areas	Ocean areas	0	0	0	14	0	1	***15***
Scotian Shelf	Ocean areas	0	0	0	20	0	0	***20***
Southeast U.S. Continental Shelf	Cooper River, SC	0	0	0	12	0	11	***23***
	Kings Bay, GA	0	0	0	2	0	9	***11***
	Port Canaveral, FL	0	0	0	1	0	0	***1***
	St. Johns River, Florida	0	0	0	8	0	7	***15***
	Ocean areas	8	954	0	1155	0	229	***2351***
	Other bays/estuaries	0	0	0	82	0	20	***102***
Grand Total		***18***	***4225***	***2674***	***11607***	***5***	***2578***	***21176***

Although most of the artificial structures are located in ocean portions of the AFTT study area, a significant number of structures are located in bays and estuaries (Table 3). The largest numbers are in the lower Chesapeake Bay, followed by the Gulf Coast/Panama City area. Oil and gas platforms are restricted to the Gulf of Mexico and a very small number of wind turbines are located in the Northeast U.S. Continental Shelf large marine ecosystem. Relatively few artificial structures are located in the various open ocean areas corresponding to the abyssal zone.

Southeast U.S. Continental Shelf Large Marine Ecosystem

Line data representing substrate types was available for only the Southeast U.S. Continental Shelf Large Marine Ecosystem (Moser and Taylor 1995; SEAMAP-SA 2001; FSLTD & CSA 2011). The source data from Moser and Taylor (1995) and SEAMAP-SA (2001) was dominated by low quality indicator species trawls whereas the FSLTD & CSA (2011) employed multibeam sonar and direct visual observations (e.g, remote operated camera) to acquire higher quality data. In terms of quality for bottom mapping, indicator trawls are inferior to multi-beam sonar data validated by direct visual observation by remote operated vehicles or drop cameras. The lower quality SEAMAP-SA (2001) data included more than 26,000 km of substrate types, whereas the FSLTD & CSA (2011) survey included only 260 km of data. The higher quality data delineated approximately 35% of the bottom as hard substrate (e.g., bedrock, rock outcrop) and 65% as soft substrate (e.g., fine or coarse sediment). This survey data indicates that the continental shelf was composed almost entirely of soft substrate, whereas the survey segment seaward of the shelf break was primarily hard substrate. For comparison, the lower quality data (SEAMAP-SA 2001) delineated over 11% as hard substrate (e.g., hard bottom), followed by 7% as intermediate (e.g., possible hard bottom), and 81% as soft (e.g., not hard bottom). As such, a good approximation for percent substrate available to hard bottom-associated organisms in the Southeast U.S. Continental Shelf large marine ecosystem would be 11-35%. However, the distribution of hard substrate is not uniform across the shelf, as noted from the FSLTD & CSA (2011) data that extends seaward of the shelf break and beyond the study area of SEAMAP-SA (2001).

The assemblage of polygon data for abiotic substrate (Appendix A5-A8) suggests a similar pattern of substrate distribution on the Southeast U.S. Continental Shelf large marine ecosystem. U.S. Navy (2011b) surveyed a corridor across the continental shelf north of the FSLTD & CSA (2011) data to map an area dominated by soft substrate (e.g., medium or coarse sand; Table 4). The FSLTD & CSA (2011) and U.S. Navy (2011b) suggest a percent substrate available for hard bottom organisms that is far less than 11% for the continental shelf. Abiotic substrate mapping in Gray's Reef National Marine Sanctuary suggests there are locations on the continental shelf that have up to 25% hard substrate (Kendall et al. 2005). The non-overlapping mosaic for the Southeast U.S. Continental Shelf (ocean portion) suggests 70% coverage by soft substrate and 20% hard substrate (Table 4). The bays and estuaries are almost exclusively soft or intermediate substrate. Although most of the data landward pf the shelf break is of poor quality, (USGS 2000), the limited higher quality data (U.S. Navy 2010, 2011a,b) corroborates the low percentage of hard bottom in the Southeast U.S. Continental shelf ecosystem. The relative scarcity of quality data on the continental shelf in the southeast region is likely due to the narrower "swath width" of echo sounders requiring more transects closer together to obtain high quality data; deeper areas can be mapped with fewer transects.

Table 4. Area and percent coverage of abiotic substrate types in Large Marine Ecosystems Open Ocean Areas of the AFTT Study Area.

Large Marine Ecosystem or Open Ocean Area	Training or Testing Location	Hard		Intermediate		Soft		Total Known (km^2)	Total Unknown (km^2)
		Km^2	% of Known	Km^2	% of Known	Km^2	% of Known		
Caribbean Sea	Ocean areas	12,714	37%	1,076	3%	20,649	60%	34,439	97,334
Gulf of Mexico	St. Andrews Bay	0	0%	1	1%	86	99%	87	4
	Other bays/estuaries	51	1%	203	5%	4,163	94%	4,417	560
	Ocean areas	54,382	5%	57,910	5%	1,012,649	90%	1,124,941	441,380
Gulf Stream Open Ocean Area	Ocean areas	6,601	1%	3,934	1%	438,748	98%	449,283	841,422
Labrador Current Open Ocean Area	Ocean areas	0	NA	0	NA	0	NA	0	1,086,121
Newfoundland-Labrador Shelf	Ocean areas	0	NA	0	NA	0	NA	0	614,479
Northeast U.S. Continental Shelf	Lower Chesapeake Bay and tributaries (James and York Rivers)	0	0%	81	4%	1,855	96%	1,935	8
	Other bays/estuaries	1,555	16%	1,731	17%	6,750	67%	10,037	312
	Ocean areas	15,915	6%	77,545	29%	174,735	65%	268,195	47
North Atlantic Gyre Open Ocean Area	Ocean areas	0	0%	0	0%	107,424	100%	107,424	5,489,835
Scotian Shelf	Ocean areas	72	1%	2,740	22%	9,861	78%	12,672	148,996
Southeast U.S. Continental Shelf	Cooper River, SC	0	0%	0	0%	13	100%	13	36
	Kings Bay, Georgia	0	0%	0	0%	27	100%	27	4
	Port Canaveral	0	0%	0	0%	2	100%	2	1
	St. Johns River,	0	1%	0	0%	13	99%	13	5

Table 4. Area and percent coverage of abiotic substrate types in Large Marine Ecosystems Open Ocean Areas of the AFTT Study Area.

Large Marine Ecosystem or Open Ocean Area	Training or Testing Location	Hard		Intermediate		Soft		Total Known (km^2)	Total Unknown (km^2)
		Km^2	% of Known	Km^2	% of Known	Km^2	% of Known		
	Florida								
	Other bays/estuaries	0	0%	0	0%	366	100%	366	287
	Ocean areas	53,320	20%	27,456	10%	186,878	70%	267,654	223
West Greenland Shelf	Ocean areas	0	NA	0	NA	0	NA	0	52,446
Grand Total		***144,610***	***6%***	***172,678***	***8%***	***1,964,202***	***86%***	2,281,490	***8,773,464***

Northeast U.S. Continental Shelf Large Marine Ecosystem

Within the Northeast U.S. Continental Shelf Large Marine Ecosystem, the distribution of substrate types is based mostly on a very large portion of low quality data, which indicates approximately 30% intermediate substrate (e.g., cobble/gravel) and 70% soft substrate (e.g., silt, sand) throughout the entire large marine ecosystem. The largest area of higher quality data (Barnhardt et al. 1996) is located in the northern portion of this large marine ecosystem, and it identifies significantly more hard substrate – 41% hard substrate (e.g., rock), 12% intermediate substrate (e.g., gravel), and 47% soft substrate (e.g., mud/sand). The rugged geology along the coastline of Maine explains some of the higher percentage of hard substrate and declining occurrence of hard substrate toward the southern end of the Northeast U.S. Continental Shelf large marine ecosystem. The intermediate substrate classification in these southern areas could potentially be masking some hard substrate given the lack of hard substrate classified within the lower quality data (Anderson et al. 2010) that was superseded by the higher quality data along the coast of Maine; the higher quality data does not corroborate the lower quality data in this case. The lower quality data covers almost the entire Northeast U.S. Continental Shelf large marine ecosystem where higher quality data was absent. Based on the subsampling of higher quality data, the 6% hard substrate available for hard bottom organisms in the offshore areas (Table 4) is likely underestimated in the Northeast U.S. Continental Shelf Ecosystem. The northeast bays and estuaries have a higher portion of harder substrate indicated on higher quality mapping.

Other AFTT Large Marine Ecosystems

Other large marine ecosystems have a significant portion of unknown substrate type based on lack of data. The Canadian Eastern Arctic – West Greenland, Labrador – Newfoundland, and Scotian Shelf ecosystems have little to no mapping data available to be included in the database; these areas also do not have established range complexes and have limited amount of training and testing activities. The remaining large marine ecosystems have established range complexes and include the Caribbean Sea and Gulf of Mexico. Mostly shallow areas of the Caribbean Sea ecosystem have documented substrate mapping – 37% hard, 3% intermediate, and 60% soft, based on mostly higher quality data (National Ocean Service 2001; Anderson and Eastlake 2011; FFWCC–FWRI 2013). More of the Gulf of Mexico has substrate mapping than the Caribbean and the data is mostly higher quality (GSMFC 2008) - 5% hard substrate (e.g., rock), 5% intermediate substrate (e.g., gravel), and 90% soft substrate (e.g., mud/sand). Bays and estuaries along the Gulf of Mexico are mapped as almost exclusively soft or intermediate substrate.

Habitat Suitability Models

To supplement the mapping surveys, additional data was employed that predict where hard substrate is very likely based on habitat suitability models for selected deep sea corals (Kinlan et al. 2013 a,b,c). The predictions are based on correlating the occurrence of various deep coral species with numerous environmental parameters, including slope and curvature of the bottom. The predictions fill some significant gaps in the suspected distribution of hard substrate along the continental shelf break, slope, and canyons throughout much of the study area. Slope and depth range for deep sea corals (Tittensor et al. 2009) was also used to delineate the location probable hard substrate on sea mounts in the study area (NAVFAC Atlantic 2016b) portion that was not covered by Kinlan et al. (2013 a,b,c).

AFTT Summary

The portion of the AFTT study area mapped for abiotic substrate encompasses most of the training and testing range area and indicates a benthic surface composed of 86% soft bottom and 6% hard bottom. The intermediate category of substrate (8%) could add to either the soft or hard bottom community, depending on other environmental variables affecting stability and supply of colonizing sedentary organisms and nutrition sources, which also affect hard substrate as a habitat for hard bottom organisms (to a lesser degree). Percent of bottom area, however, does not account for the vertical relief of some hard bottom areas, which contribute disproportionately to hard bottom community biomass. The data also does not account for the typically smaller dimensions of hard bottom features present in predominantly soft bottom areas. The SEAMAP-SA (2001) line data is based primarily on trawl samples that indicate hard bottom with the collection of species associated with hard bottom – suggesting there were numerous hard bottom features too small to be resolved by even the highest quality data in the study area. Kendall et al. (2005) and U.S. Navy (2011b) data and classification came the closest to finding these smaller areas of hard bottom attracting associated species.

<u>HSTT Study Area</u>

Within the HSTT study area, more than 300 artificial substrate points were identified (Table 5 and Appendix A9-A10), including mostly shipwrecks (316) and artificial reefs (17). No oil or gas platforms are located in the HSTT study area. The artificial reefs represent permitted area center points. Notable omissions from the artificial substrate points may include wrecks that are "address restricted" due to status on the National Registry of Historic Places and wrecks created from naval sinking exercises. However, the only known omissions of this nature were in the AFTT study area.

Table 5. Number and type of artificial substrate points documented in Large Marine Ecosystems of the HSTT study area.

Large Marine Ecosystem	Artificial Reef	Shipwreck	Grand Total
California Current	12	219	231
Insular Pacific/Hawaiian	5	97	102
Grand Total	*17*	*316*	*333*

The polygon data for abiotic substrate types in the HSTT study area is limited, such that only 2.64% of the study area has known substrate types (Appendix A11-A18). The mapped bottom areas of the Insular Pacific / Hawaiian large marine ecosystem are confined to shallow margins around the islands and other land features (e.g., atolls). The Pacific Basin Open Ocean Area is entirely unmapped in terms of abiotic substrate type. Even within large marine ecosystems, the largest portion of bottom area is unknown in substrate composition. Of the remaining mapped areas on the narrow continental or island shelf, a much greater portion of bottom is classified as hard or intermediate than soft (Table 6); the mapped portion of the California Current large marine ecosystem within the HSTT Study Area is 90% hard or intermediate substrate, and the Insular Pacific-Hawaiian shelf is 55% hard (remaining classified as soft). Percent of bottom area does not account for the vertical relief of some hard bottom areas, which contribute disproportionately to hard bottom community biomass.

Table 6. Percent coverage of abiotic substrate types in Large Marine Ecosystems and the Pacific Basin Open Ocean Area of the HSTT Study Area.

Large Marine Ecosystem or Open Ocean Area	Percent of Large Marine Ecosystem				Square Km (Total)
	Hard	Intermediate	Soft	Unknown	
California Current	3.46%	5.05%	0.85%	90.63%	324,914.49
Insular Pacific-Hawaiian	0.21%	0.00%	0.17%	99.62%	970,883.51
Pacific Basin Open Ocean Area	0.00%	0.00%	0.00%	100.00%	7,227,975.15
Grand Total	*1.03%*	*1.27%*	*0.34%*	*97.37%*	*8,523,779.58*

Literature Cited[5]

Ackerman, S., Butman, B., Barnhardt, W.A., Danforth, W.W., and Crocker, J.M., 2006, High-resolution geologic mapping of the inner continental shelf; Boston Harbor and Approaches. U.S. Geological Survey Open-File Report OF2006-1008. 1.

Allee, R. J., Dethier, M., Brown, D., Deegan, L., Ford, R. G., Hourigan, T. F. (2000). Marine and Estuarine Ecosystem and Habitat Classification. *NOAA Technical Memorandum NMFS-F/SPO-43* 43 pp.

Anderson, M., and Eastlake, R. 2011. Benthic Habitats of The Florida Keys prepared from IKONOS Satellite Imagery [GIS metadata]. Analytical Laboratories of Hawaii and Photo Science Inc. Kailua, Hawaii and St. Petersburg, Florida.

Anderson, M., Greene, J., Morse, D., Shumway, C., and Clark, M. (2010). Chapter 3: Benthic Habitats. Pages 3-1 to 3-61 in: Greene, J.K., M.G. Anderson, J. Odell, and N. Steinberg, eds. 2010. The Northwest Atlantic Marine Ecoregional Assessment: Species, Habitats and Ecosystems. Phase One. The Nature Conservancy, Eastern U.S. Division, Boston, MA. (TNC Marine Ecoregional Assessment folder).

Barnhardt, W.A., Belknap, D.F., Kelley, A.R., Kelley, J.T., and Dickson, S.M. 1996. Surficial Geology of the Maine Inner Continental Shelf. Department of Conservation, Maine Geology Survey. Note: See lettered references PDF attachment.

Barnhardt, W.A., Andrews, B.D. and Butman, B., 2006, High-resolution geologic mapping of the inner continental shelf: Nahant to Gloucester, Massachusetts: U.S. Geological Survey Open-File Report 2005–1293. Available on DVD and online at http://pubs.usgs.gov/of/2005/1293/.

Barnhardt, W.A., Andrews, B.D., Ackerman S.D., Baldwin, W.E., and Hein, C.J. 2009. High-resolution geologic mapping of the inner continental shelf: Cape Ann to Salisbury Beach, Massachusetts: U.S. Geological Survey Open-File Report 2005–1293. Available on DVD and online at http://pubs.usgs.gov/of/2007/1373/pdf/OFR2007-1373_report.pdf.

Berg, D. & Berg, D. (1989). Tropical shipwrecks. East Rockaway, New York: Aqua Explorers Inc.

BOEM [Bureau of Ocean Energy Management] (2013). Platform Locations - Gulf of Mexico [GIS metadata]. Available from http://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Index.aspx. Accessed in June 2015.

CDFW [California Department of Fish and Wildlife] Marine Region GIS Lab. (2007). HAB_SCSR_ArtificialReefs_Cen (artificial reef centers) [GIS metadata] Available from

[5] For sources identified with "[GIS metadata]", no supporting literature or documentation other than GIS metadata is available

https://www.wildlife.ca.gov/Conservation/Marine/GIS/Downloads. Accessed in August 2015.

California State Lands Commission. (2012). Database of California Shipwrecks. Available from http://shipwrecks.slc.ca.gov/ShipwrecksDatabase/Shipwrecks_Database.asp accessed in 2012.

California State University (CSU) Seafloor Mapping Lab. (1987). California continental shelf geology [GIS metadata]. Digitized from paper maps produced for the Division of Mines and Geology (DMG), the U.S. Geological Survey (USGS) and the California Coastal Commission (CCC). Available from http://arcims.csumb.edu/DATA_DOWNLOAD/CAGeologySeries.zip. Accessed in August 2015.

California State University, Monterey Bay (CSUMB), U.S. Geological Survey (USGS), Fugro Palagos, Ocean Imaging, San Diego Association of Governments (SanDAG), Moss Landing Marine Laboratories (MLML), California Department of Fish and Wildlife (CDFW). (2007). Predicted Substrate of Southern California. [GIS metadata] Available from https://www.wildlife.ca.gov/Conservation/Marine/GIS/Downloads. Accessed in August 2015.

Cerame Vivas, M. J. (1988). Coastal atlas of Puerto Rico. Boquerón, Puerto Rico: M.J. Cerame Vivas, Inc.

Chesapeake Bay Office - National Oceanographic and Atmospheric Administration (2011). Chesapeake Bay Benthic Habitat Integration [Website]. Available from http://chesapeakebay.noaa.gov/acoustic-seafloor-mapping/chesapeake-bay-benthic-habitat-integration as accessed on October 2011.

Cowardin, L. M., Carter, V., Golet, F. C. & LaRoe, E. T. (1979). Classification of wetlands and deepwater habitats of the United States. U.S. Department of Interior Fish and Wildlife Service. Washington, D.C. FWS/OBS-79/31.

Delaware Division of Fish and Wildlife. (2015). Delaware reef guide (2013-2014) [Website]. Available from http://www.dnrec.delaware.gov/fw/Fisheries/Documents/2013and14DEReefGuide.pdf. Accessed in July 2015.

Federal Geographic Data Committee [FGDC]. (2012). Coastal and Marine Ecological Classification Standard. FGDC-STD-018-2012. June 2012. 353 pages.

Florida Fish and Wildlife Conservation Commission and Fish and Wildlife Research Institute [FFWCC & FWRI]. (2014). Artificial Reefs Florida Point [GIS metadata]. Tallahassee, FL.

- Florida Fish and Wildlife Conservation Commission and Fish and Wildlife Research Institute [FFWCC & FWRI]. (2013). Coral and hard bottom mapping [GIS metadata]. Assemblage datasets include:Nova Southeastern University Oceanographic. 2004. benthic_broward_2004
- Nova Southeastern University Oceanographic Center. 2007. benthic_palmbeach_2002

- FWC-FWRI (Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute). Unpublished material. benthic_FKTR_2004
- U.S. Geological Survey. 2006. Benthic_fl_keys_usgs
- Florida Fish and Wildlife Conservation Commission (FWC), Fish and Wildlife Research Institute (FWRI), National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (CSC), Dade County. 2001. Benthic_south_fl
- Avineon, Inc. 2005. Benthic_flbay_2004
- Florida Fish and Wildlife Conservation Commission (FWC), Fish and Wildlife Research Institute (FWRI), Center for Spatial Analysis. 2000. Bottomtype.swcoast.fl
- Texas A & M Department of Oceanography. Unpublished material. Middle_ground_1979_reef
- U.S. Department of Interior, Minerals Management Service. 1983. Sediment_gulfofmexico
- Florida Fish and Wildlife Conservation Commission (FWC), Florida Marine Research Institute (FMRI), Coastal and Marine Resource Assessment (CAMRA). 1998. Seamap_poly1
- Florida Fish and Wildlife Conservation Commission - Florida Marine Research Institute; CAMRA subsection. 2011. SEAMAP One-minute grid
- Avineon, Inc. 2008. Benthic_tortugas_2006
- Avineon, Inc. 2008. Benthic_biscayne_2005
- Brian Walker. 2009. Benthic_n_miamidade_2009
- Southwest Florida Water Management District (SWFWMD). Unpublished data. Seagrass_springscoast_poly

FSLTD & CSA [Fugro Survey Limited and CSA International, Inc]. (2011). Benthic habitat classification survey report for AM1 submarine cable system, Segment 1.1, Jacksonville, FL (BMH JKV to BU-1 Continental Shelf). 87 pages.

Georgia Department of Natural Resources. (2015). Artificial Reef (Offshore) [Website]. Available from http://coastalgadnr.org/ArtificialReef. Accessed in July 2015.

Gulf of Mexico Fishery Management Council. (2004). Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment to the following Fishery Management Plans of the Gulf of Mexico (GOM): Shrimp Fishery of the Gulf of Mexico; Red Drum Fishery of the Gulf of Mexico; Reef Fish Fishery of the Gulf of Mexico; Stone Crab Fishery of the Gulf of Mexico; Coral and Coral Reef Fishery of the Gulf of Mexico; Spiny Lobster Fishery in the Gulf of Mexico and South Atlantic; Coastal Migratory Pelagic Resources of the Gulf of Mexico and South Atlantic). Tampa, Florida: Gulf of Mexico Fishery Management Council.

Gulf States Marine Fisheries Commission (2008). Marine Benthic Substrates Geodatabase, Northern Gulf of Mexico (2005-2008 GIS data). Retrieved from http://www.gsmfc.org. Accessed in August 2012.

Handler, M. (2001). Diving and snorkeling: British Virgin Islands. (2nd ed.). Melbourne, Australia: Lonely Planet Publications.

HDAR [Hawaii Division of Aquatic Resources]. (2015) Artificial Reef and FADS; Coordinates PDF. Available from http://dlnr.hawaii.gov/dar/files/2014/04/ARCoords.pdf. Accessed in August

2015.

Howell, K.L. (2010). A benthic classification system to aid in the implementation of marine protected area networks in the deep/high seas of the NE Atlantic. Biological Conservation 143: 1041–1056.

Kendall, M. S., Monaco, M. E., Buja, K. R., Christensen, J. D., Kruer, C. R., Finkbeiner, M. (2001). Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands U.S. National Oceanic and Atmospheric Administration. National Ocean Service, National Centers for Coastal Ocean Science Biogeography Program. Silver Spring, Maryland. 46 pp.

Kendall, M.S., Jensen, O.P., Alexander, C., Field, D., McFall, G., Bohne, R., and Monaco, M.E. (2005). Benthic mapping using sonar, video transects, and innovative approach to accuracy assessment: a characterization of bottom features in the Georgia Bight. Journal of Coastal Research. 21(6): 1154-1165.

Kennedy, M.P., Green, H.G., and Clarke, S.H. (1987). Geology of the California Continental Margin: Explanation of the California Continental Margin Geology Map series - Interpretive Methods, Symbology, Stratigraphic Units, and Bibliography. Prepared in cooperation with the U.S. Geological Survey and the California Coastal Commission for the California Department of Conservation, Division of Mines and Geology, Sacramento, California.

Kinlan B.P., Poti M., Etnoyer P., Siceloff L., Jenkins C., Dorfman D., and Caldow C. (2013a). Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Gulf of Mexico. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch. Released August 2013.

Kinlan B.P., Poti M., Drohan A., Packer D.B., Nizinski M., Dorfman D., and Caldow C. (2013b). Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch and NOAA National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC). Released August 2013. Available at: http://coastalscience.noaa.gov/projects/detail?key=35

Kinlan B.P., Poti M., Hourigan T., Dorfman D., and Caldow C. (2013c). Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Southeast region. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch. Released

August 2013. Available at: <http://coastalscience.noaa.gov/projects/detail?key=35>

KTU-A Landscape Architecture & Planning (LA&P), Moffatt Nichol (MN), San Diego Nearshore Habitat Mapping Program (SDNHMP), and San Diego Association of Governments (SDAG). (2002). Seafloor Substrate of the San Diego Region Nearshore Coastal Zone. [GIS metadata]. Available from http://atlas.ca.gov/casil/oceans/CSMW_GIS_Data_Packages/3.0/SD_Seafloor_Substrate_2002.zip. Accessed in Augusto 2015.

Longley-Wood, Kate. (2015). Block Island wind farm turbine locations - GIS metadata prepared for the Northeast Ocean Data Portal (www.northeastoceandata.org). 3 pages.

Louisiana Department of Wildlife and Fisheries. (2015). Artificial Reef Program [Website]. Available from http://www.wlf.louisiana.gov/fishing/artificial-reef-program. Accessed in July 2015.

Massachusetts Division of Marine Fisheries. (2015). Artificial Reefs [Website]. Available from http://www.mass.gov/eea/agencies/dfg/dmf/programs-and-projects/artificial-reefs.html. Accessed in July 2015.

McMullen, K.Y. (2007). H11310INT: Interpretation of NOAA H11310 Sidescan Sonar and Bathymetric Data from Central Narragansett Bay. Open-File Report 2006-1199. U.S. Geological Survey, Coastal and Marine Geology Program: Woods Hole Science Center, Woods Hole, MA. Available from http://pubs.usgs.gov/of/2006/1199/data/interpretation/mosaicinterp/mosaicinterp.zip as accessed in December 2014.

Merkel and Associates. (2014). Benthic Habitat Mapping for West Cove Naval Auxiliary Landing Field, San Clemente Island Naval Base Coronado, California. Prepared for Naval Facilities Engineering Command Southwest. Contract Number N62473-10-D-0805. 12 pages.

Messing, C., Reed, J., and Walker, B. (2011) Navy Cable Project: Deepwater Habitats [GIS Metadata]. Nova Southeastern University (unpublished data).

Mississippi Department of Marine Resources. (2015). Artificial Reefs [Website]. Available from http://www.dmr.state.ms.us/index.php/marine-fisheries/artificial-reef. Accessed in July 2015.

Moser, M.L., and B.L. Taylor (1995). Hard bottom habitat in North Carolina state waters: a survey of available data.

National Ocean Service (2001). Benthic habitats of Puerto Rico and the U.S. Virgin Islands (Vol. CDROM). Silver Spring, Maryland: National Oceanic and Atmospheric Administration. Available from http://ccma.nos.noaa.gov/products/biogeography/benthic/ as accessed on May 2012.

NAVFAC [Naval Facilities Engineering Command] Atlantic 2013. Hard bottom mapping (Southeast U.S. shelf break polygon). Digitized between bathymetric contours where shelf-break hard bottom was located, based on U.S. Navy (2010a) mapping.

NAVFAC Atlantic [Naval Facilities Engineering Command]. (2015). Department of Defense Tower Locations [GIS metadata]. Digitized from NOAA Nautical Charts. July 2015.

NAVFAC Atlantic. (2016b). Seamounts in the U.S. Atlantic EEZ [GIS metadata].

NCCOS [National Centers for Coastal Ocean Science]. (2007). Northwestern Hawaiian Island Shallow-water Coral Reef Ecosystem Map Development Procedures (2004-2007 data). Available from http://coastalscience.noaa.gov/datasets/e98/docs/NWHI_map_development.pdf Accessed in February 2016.

New Jersey Division of Fish and Wildlife. (2015). Locations of New Jersey's 15 artificial reefs. Available from http://www.state.nj.us/dep/fgw/pdf/reeflocs.pdf. Accessed in July 2015.

New York Department of Environmental Conservation. (2015). Artificial Reefs Managed by the New York Department of Environmental Conservation [Website]. Available from http://www.dec.ny.gov/outdoor/71702.html. Accessed in July 2015.

NOAA [National Oceanic and Atmospheric Administration] (2015). Automated Wreck and Obstruction Avoidance database. [Web Page] Available from http://www.nauticalcharts.noaa.gov/hsd/wrecks_and_obstructions.html. Accessed in August 2015.

National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS)/National Centers for Coastal Ocean Science (NCCOS)/Center for Coastal Monitoring and Assessment (CCMA). (2007). Mapping of Benthic Habitats for the Main Eight Hawaiian Islands [GIS metadata]. Prepared by BAE Systems Sensor Solutions Identification & Surveillance. 107 pages.

North Carolina Division of Marine Fisheries. (2015). Artificial Reef Guide [Website]. Available from http://portal.ncdenr.org/web/mf/artificial-reefs-program. Accessed in July 2015.

O.C. Reef Foundation (2013). Ocean -Artificial Reef Location (Maryland) [Website]. Available from www.ocreeffoundation.com. Accessed in July 2015.

Outdoor Alabama - Alabama Department of Conservation and Natural Resources. (2015). Artificial Reefs [Website]. Available from http://www.outdooralabama.com/artificial-reefs. Accessed in July 2015.

Poppe, L.J., McMullen, K.Y., Foster, D.S., Blackwood, D.S., Williams, S.J., Ackerman, S.D., Moser, M.S., and Glomb, K.A., 2010, Geological interpretation of the sea floor offshore of Edgartown, Massachusetts: U.S. Geological Survey Open-File Report 2009-1001. http://pubs.usgs.gov/of/2009/1001/titlepage.html

Rhode Island Artificial Reef Program [RISAA]. (2015). Artificial reef off Newport and Block Island [Website]. Available from http://www.risaa.org/reefs.html. Accessed in July 2015

Scanlon, K.M., Ackerman, S.D., and Rozycki, J.E. (2003). Texture, Carbonate Content, and Preliminary Maps of Surficial Sediments of the Flower Garden Banks Area, Northwestern Gulf of Mexico Outer Shelf. U.S. Geological Survey Open File Report OFR 03-002. Woods Hole, MA. Accessed from http://pubs.usgs.gov/of/2003/of03-002/ in December 2014.

Southeast Area Monitoring and Assessment Program—South Atlantic [SEAMAP-SA]. (2001). Distribution of bottom habitats on the continental shelf from North Carolina through the Florida Keys. (pp. 166). Washington, D.C.: SEAMAP—SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission.

Simonsen, S. (2000). Diving & snorkeling: Puerto Rico. Melbourne, Australia: Lonely Planet Publications.

Skidaway Institute of Oceanography. (2004). Base geology. Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute [GIS metadata]. Data available upon request from GISLibrarian@MyFWC.com.

South Carolina Department of Natural Resources. (2015). Marine - Artificial Reefs [Website]. Available from https://www.dnr.sc.gov/reefguide/artreefgraphic. Accessed in July 2015.

Texas Parks and Wildlife Department. (2015). Texas Artificial Reef [Interactive Mapping Application]. Accessible from http://tpwd.texas.gov/gis/ris/artificialreefs/. Accessed in July 2015.

Todd, B.J. (2006). Surficial geology polygons, Browns Bank 2006, Gulf of Maine, Scotian Shelf, offshore Nova Scotia, Canada [GIS metadata]. Unpublished material.

Todd, B.J., and Kostylev, V.E. 2011. Surficial geology and benthic habitat of the German Bank seabed, Scotian Shelf, Canada. Continental Shelf Research. 31: S54-S68.

UNESCO. (2009). Global Open Oceans and Deep Seabed (GOODS) - Biogeographic Classification. Paris, UNESCO-IOC. (IOC Technical Series, 84).

USGS [U.S. Geological Survey] (2000). USGS East-coast sediment analysis: Procedures, database, and georeferenced displays. USGS Eastern Publications Group.

U.S. Geological Survey and S.C. Sea Grant Consortium [USGS-SCSGC] (2007). SEAFLOORENV - Distribution of Seafloor Environments within the inner shelf of Long Bay, South Carolina [GIS metadata]. Online linkage to larger work: http://pubs.usgs.gov/of/2005/1346/

U.S. Navy. (2002). SINKEX shipwrecks around Puerto Rico [GIS metadata]. Data reported in the 2002 Marine Resource Assessment for Puerto Rico/St. Croix operating area.

U.S. Navy. (2010a). JAX OPAREA USWTR Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report. Norfolk, Virginia: Naval Facilities Engineering Command Atlantic.

U.S. Navy (2011a). JAX OPAREA CC Range Bottom Mapping and Habitat Characterization, Florida. Final Cruise Report. Naval Facilities Engineering Command Atlantic. Norfolk, Virginia.

U.S. Navy (2011b). Jacksonville USWTR Nearshore Bottom Mapping, Final Descriptive Report: Nearshore Trunk Cable Corridor. Naval Facilities Engineering Command Atlantic. Norfolk, Virginia. 149 pages.

Valentine, P. C., Todd, B. J. & Kostylev, V. E. (2005). Classification of marine sublittoral habitats, with application to the northeastern North American region. *American Fisheries Society Symposium, 41*( ): 183-200.

Veridian Corporation (2001). The global maritime wreck database. General Dynamics Corporation. Falls Church, Virginia.

Virginia Marine Resources Commission. (2005). Artificial Reef Program. Newport News, Virginia: Virginia Marine Resources Commission [Website]. Available from http://mrc.virginia.gov/vsrfdf/reef.shtm.

Virginia Marine Resources Commission. (2009). Shipwrecks and Artificial Reefs of Maryland and Virginia [Website]. Available from http://www.daybreakfishing.com/WrecksReefs.html

Walker, B.K., Dodge, R.E., and Gilliam, D.S. (2006). Coral Reef Burial in Southeast Florida [GIS Metadata]. Global Challenges Facing Oceanography and Limnology, American Society of Limnology and Oceanography, Victoria, British Colombia, Canada. June 4-9, 2006.

Waterproof Charts Inc. (1998). Waterproof Chart #53F: Eastern Puerto Rico to St. Thomas–fishing. Punta Gorda, Florida: Waterproof Charts, Inc.

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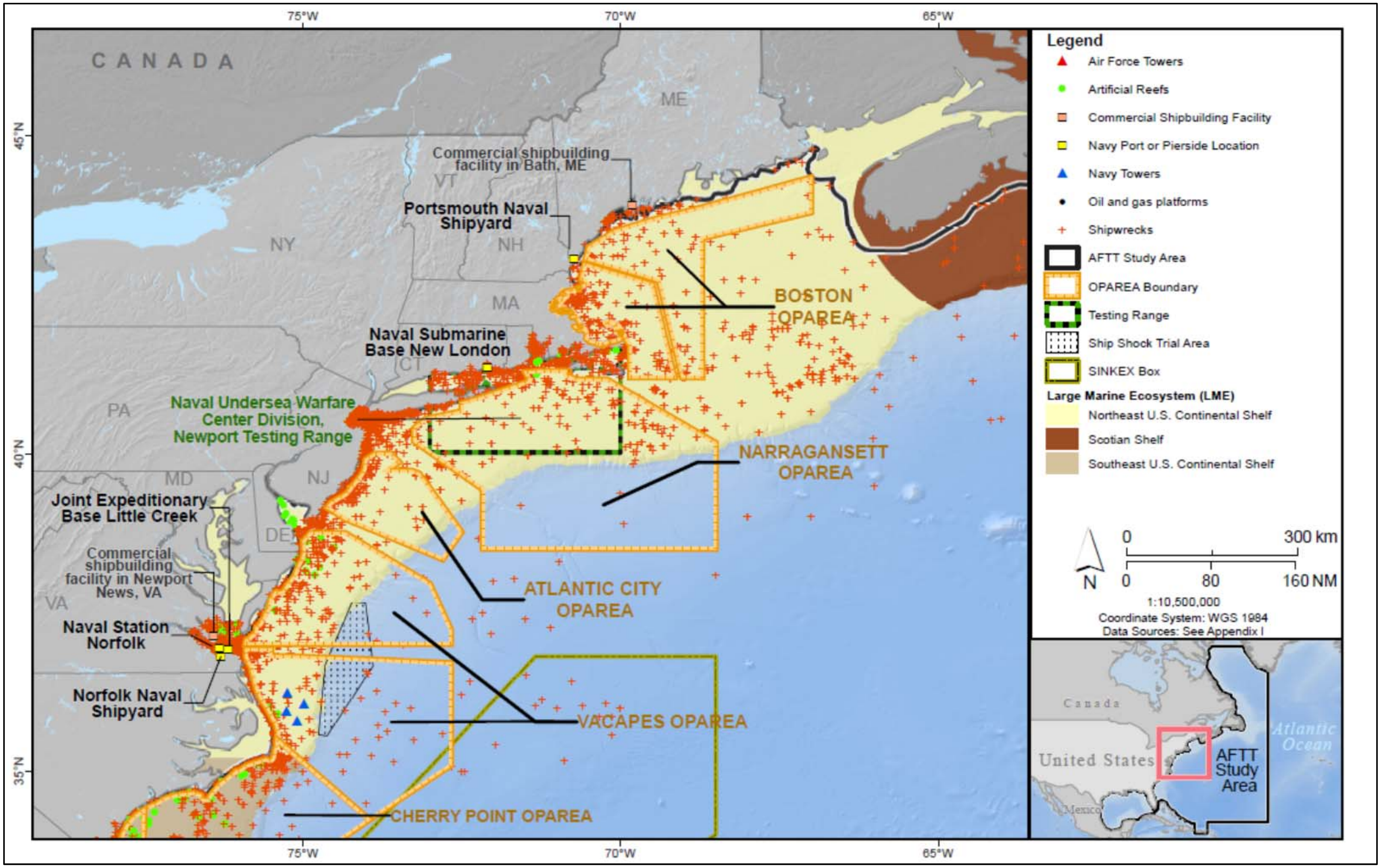
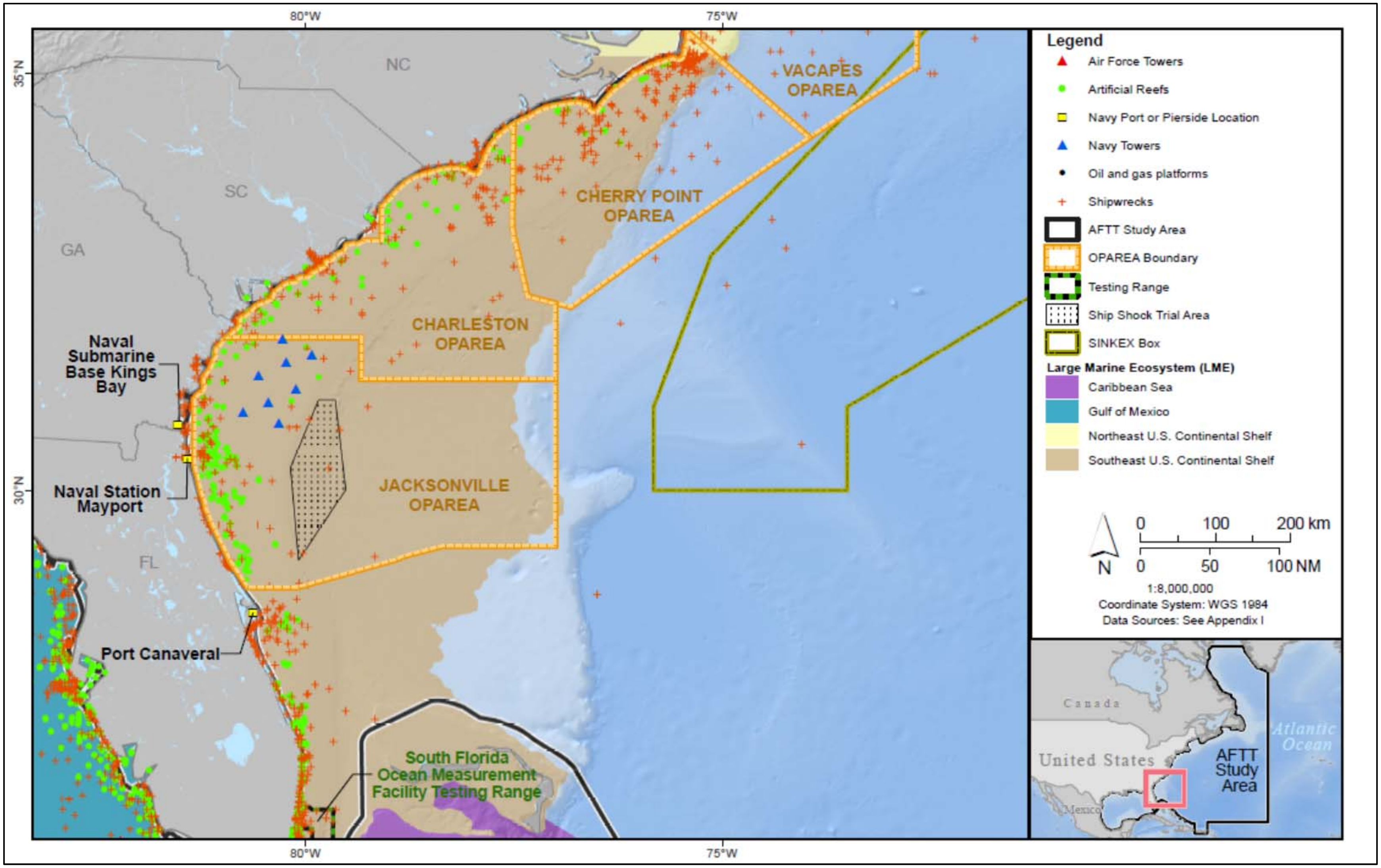
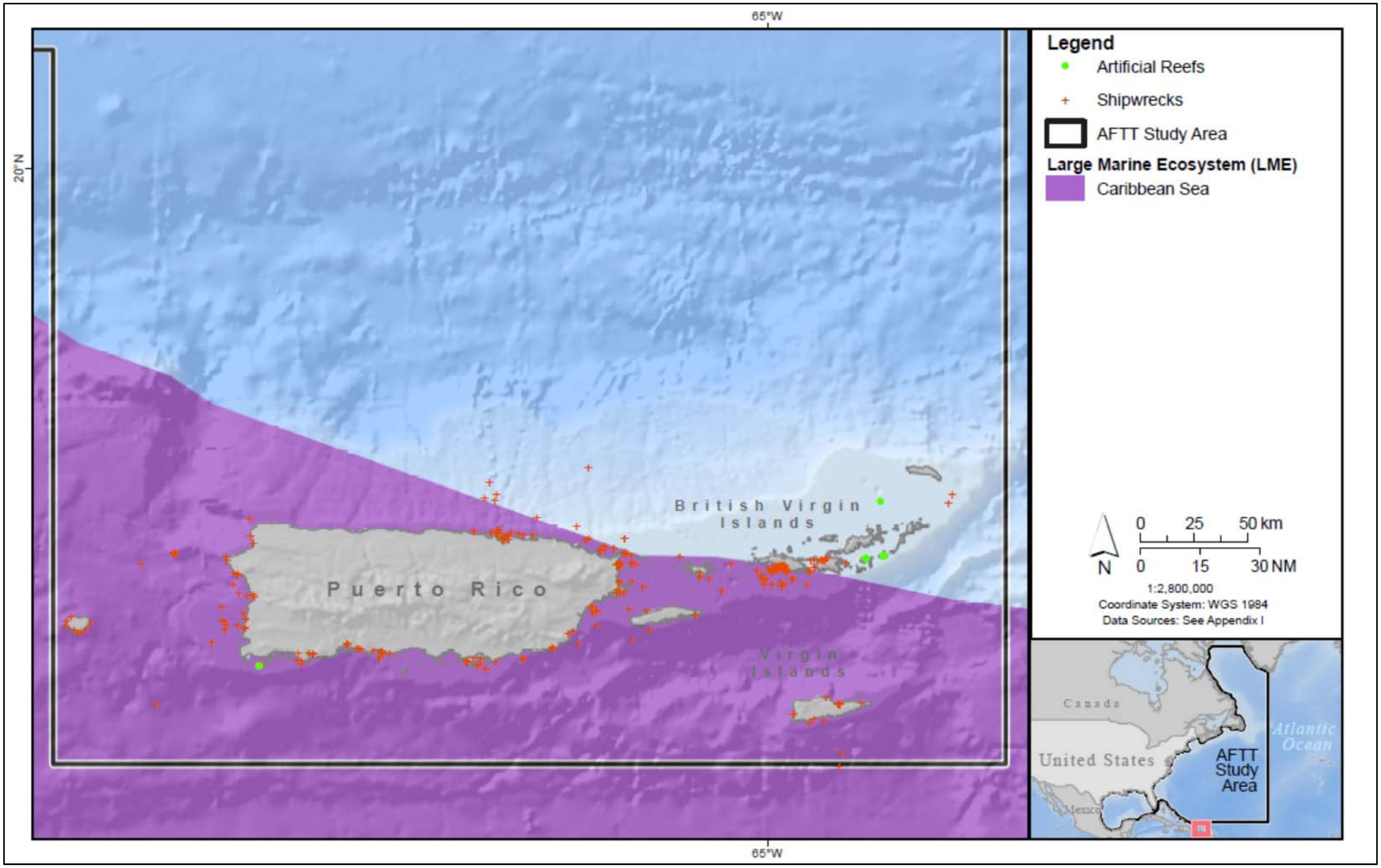
APPENDIX A - Abiotic Substrate Mapping by Region in the AFTT/HSTT Study Area



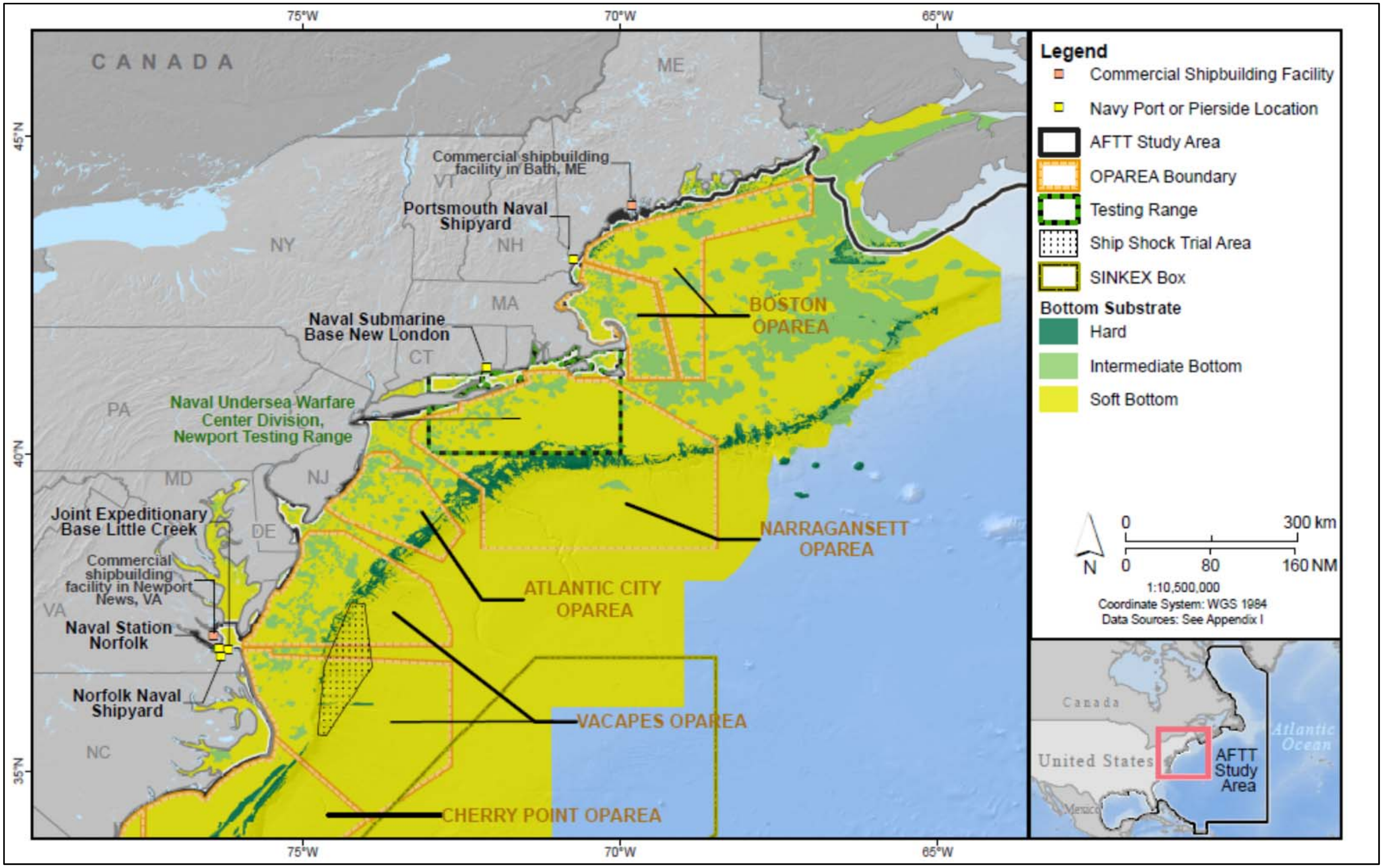
Appendix A1. Abiotic substrate (point geometry) mapping in the northeast region of the AFTT study area intersecting coastal Large Marine Ecosystems.



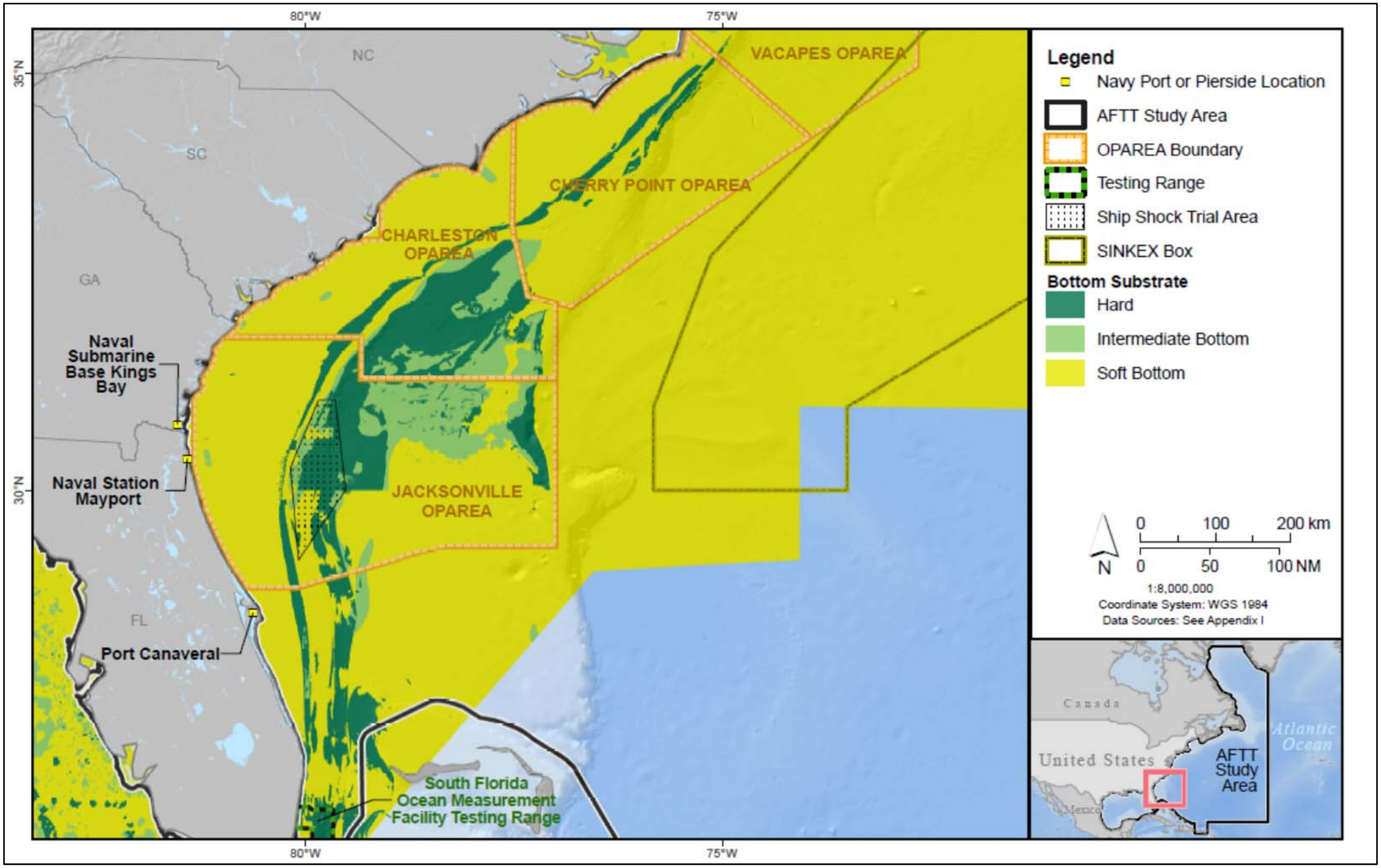
Appendix A2. Abiotic substrate (point geometry) mapping in the southeast region of the AFTT study area intersecting coastal Large Marine Ecosystems.



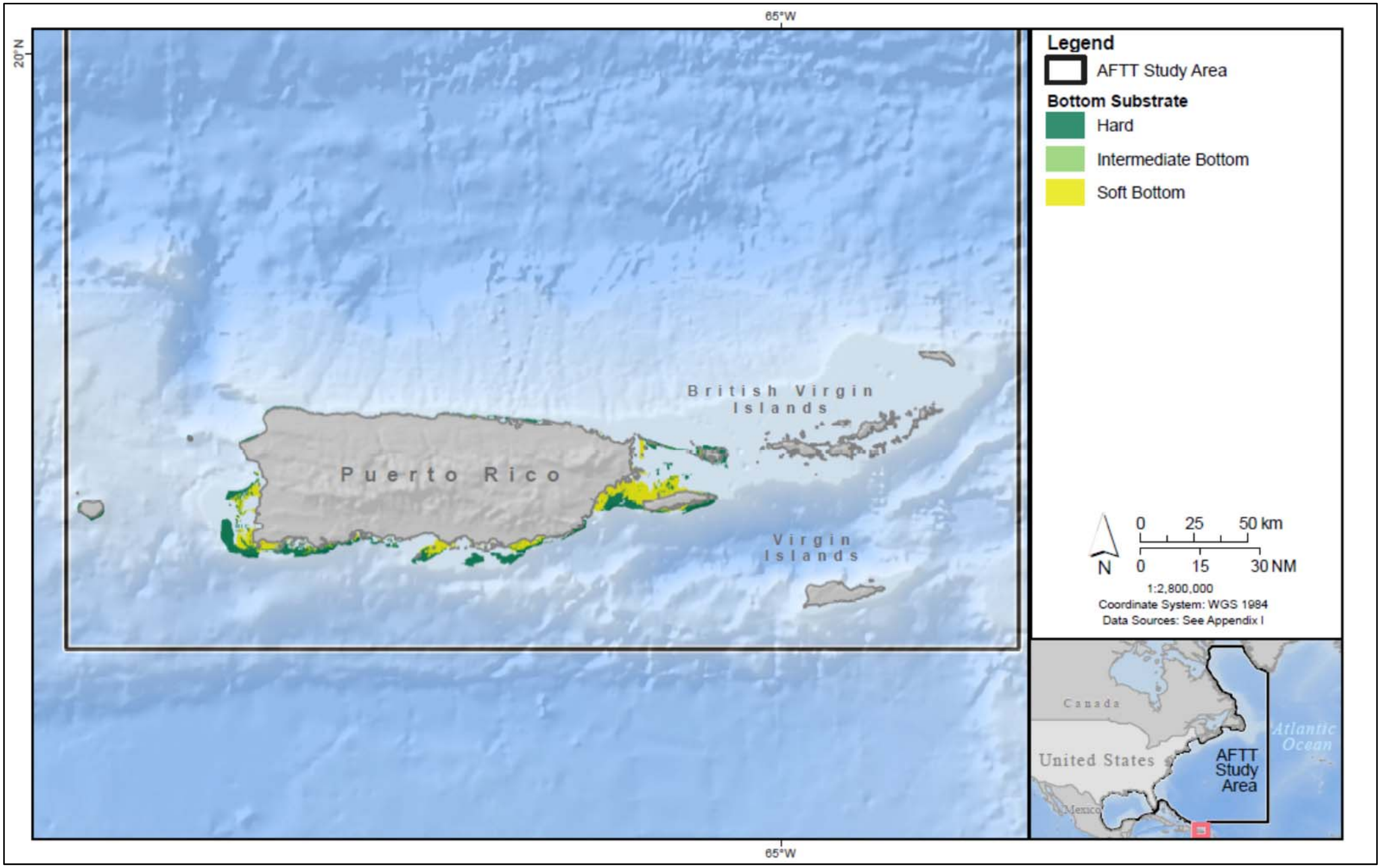
Appendix A3. Abiotic substrate (point geometry) mapping in the Puerto Rico region of the AFTT study area intersecting coastal Large Marine Ecosystems.



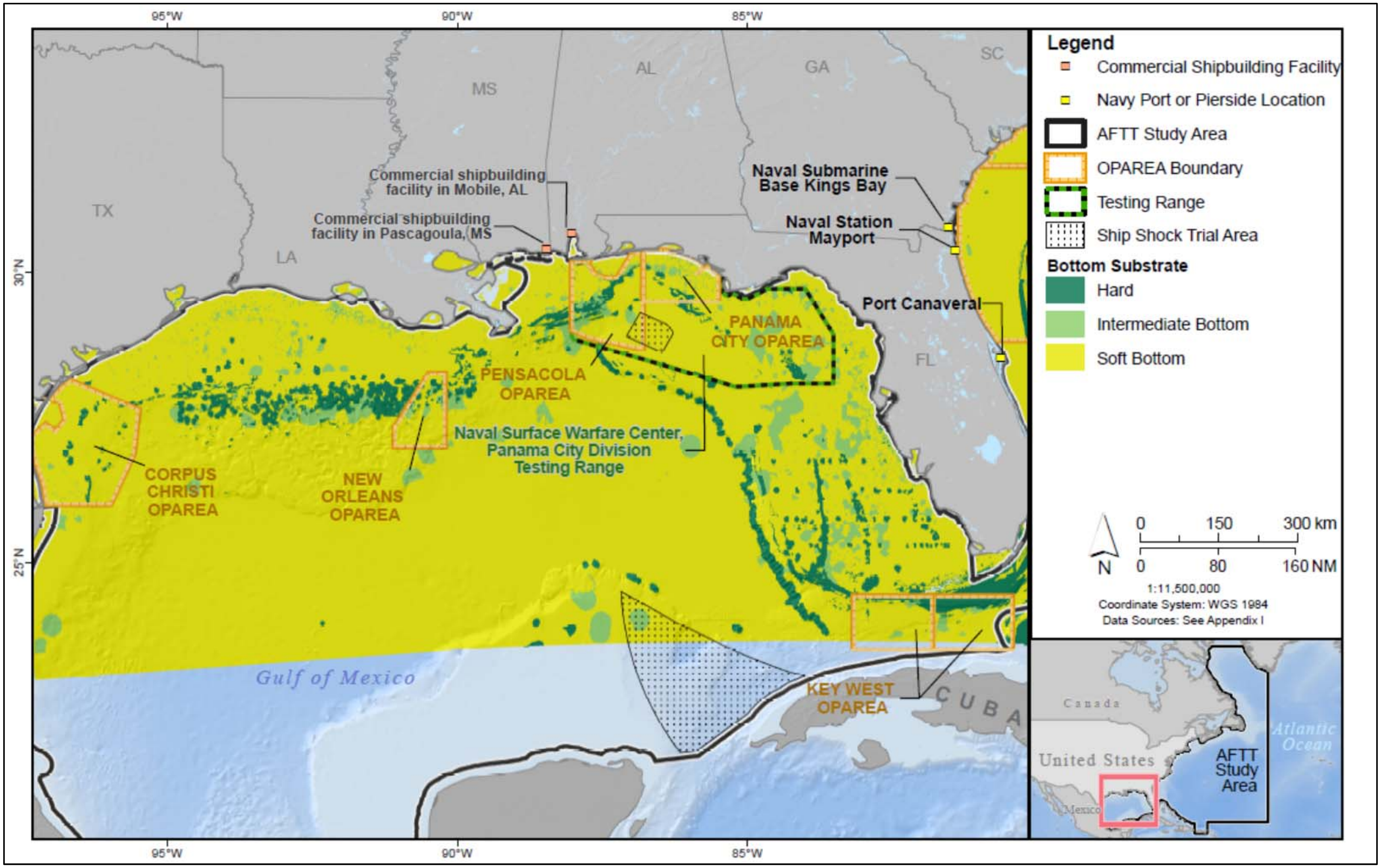
Appendix A5. Abiotic substrate (polygon geometry) mapping in the northeast region of the AFTT study area.



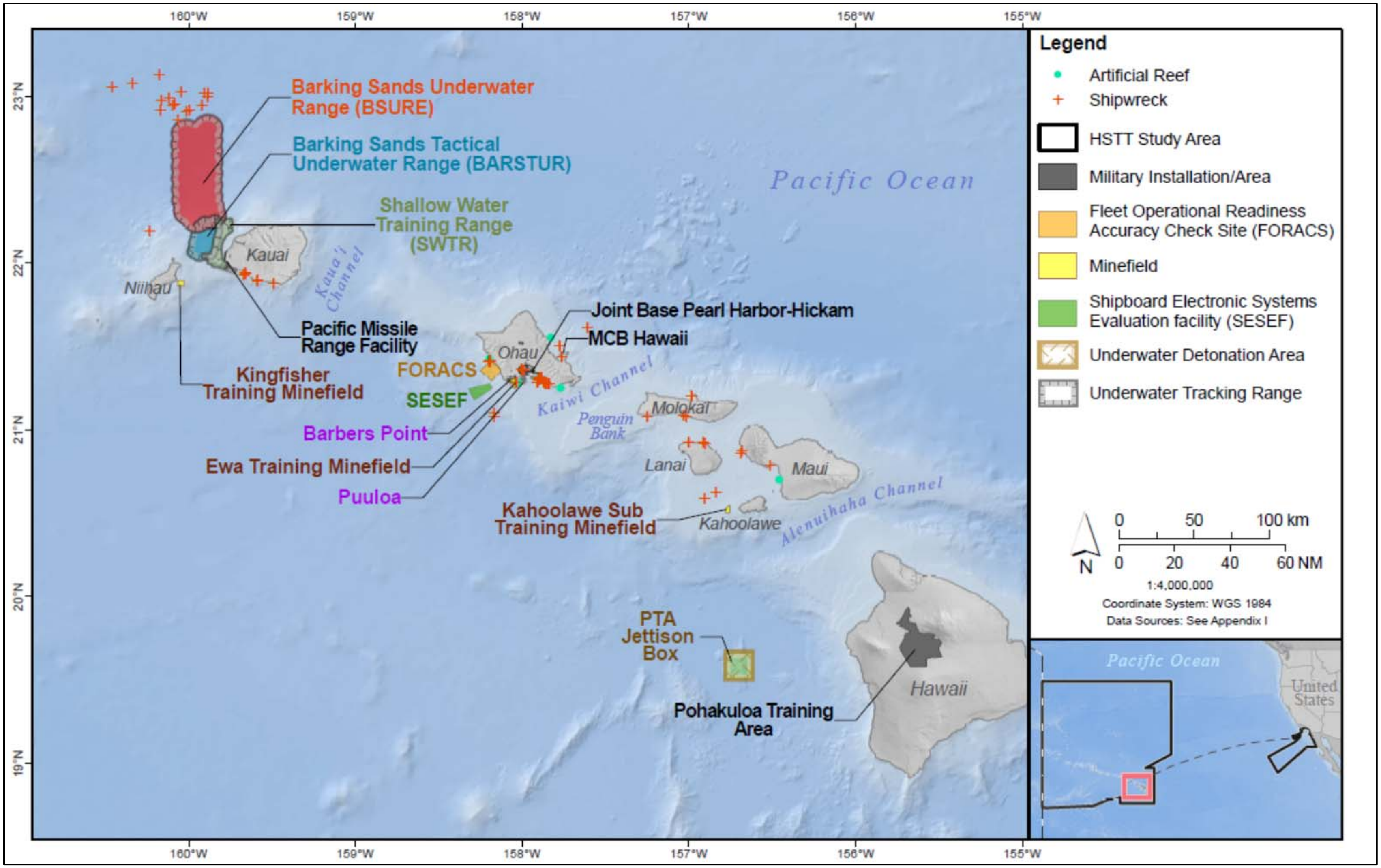
Appendix A6. Abiotic substrate (polygon geometry) mapping in the southeast region of the AFTT study area.



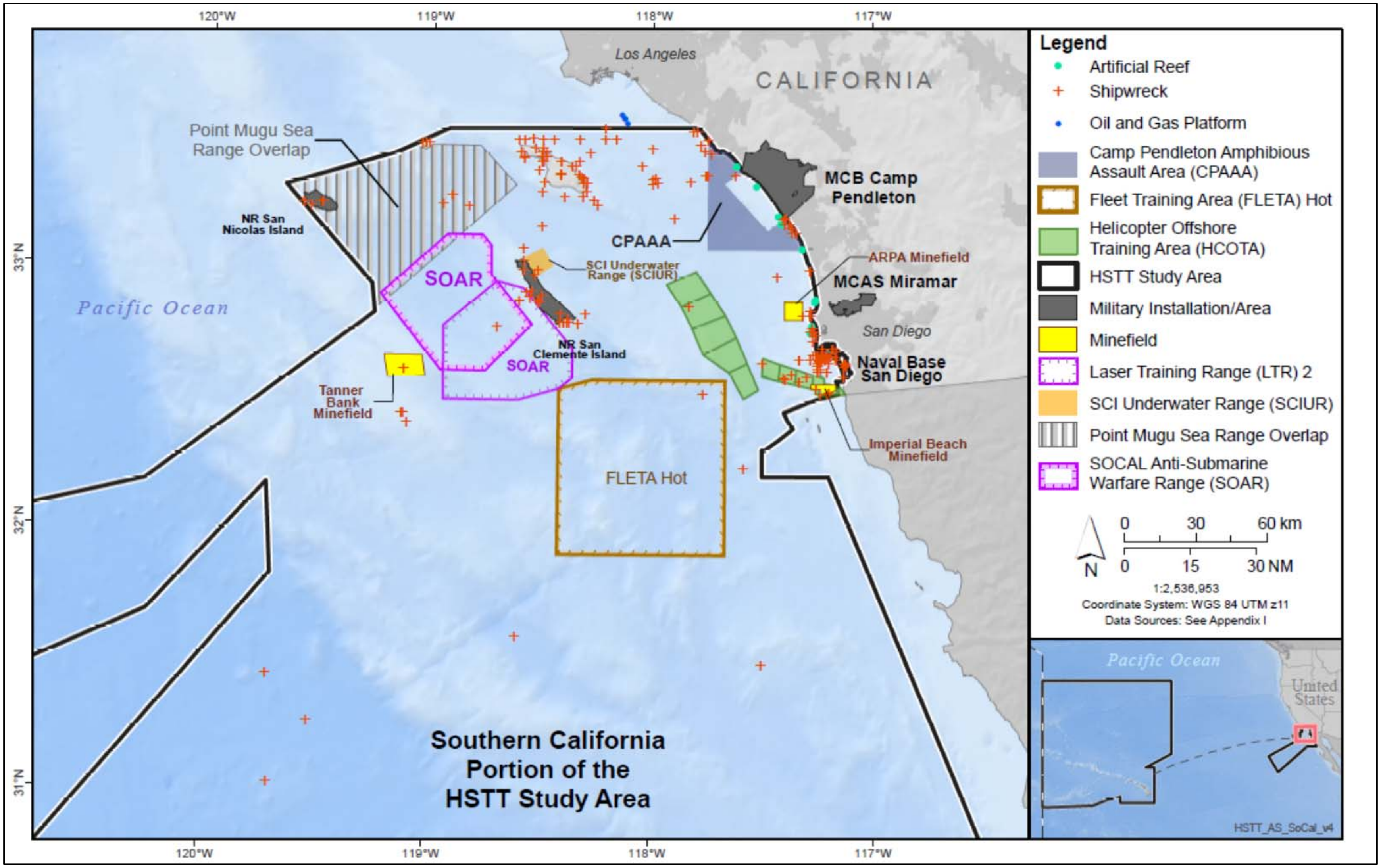
Appendix A7. Abiotic substrate (polygon geometry) mapping in the Puerto Rico region of the AFTT study area.



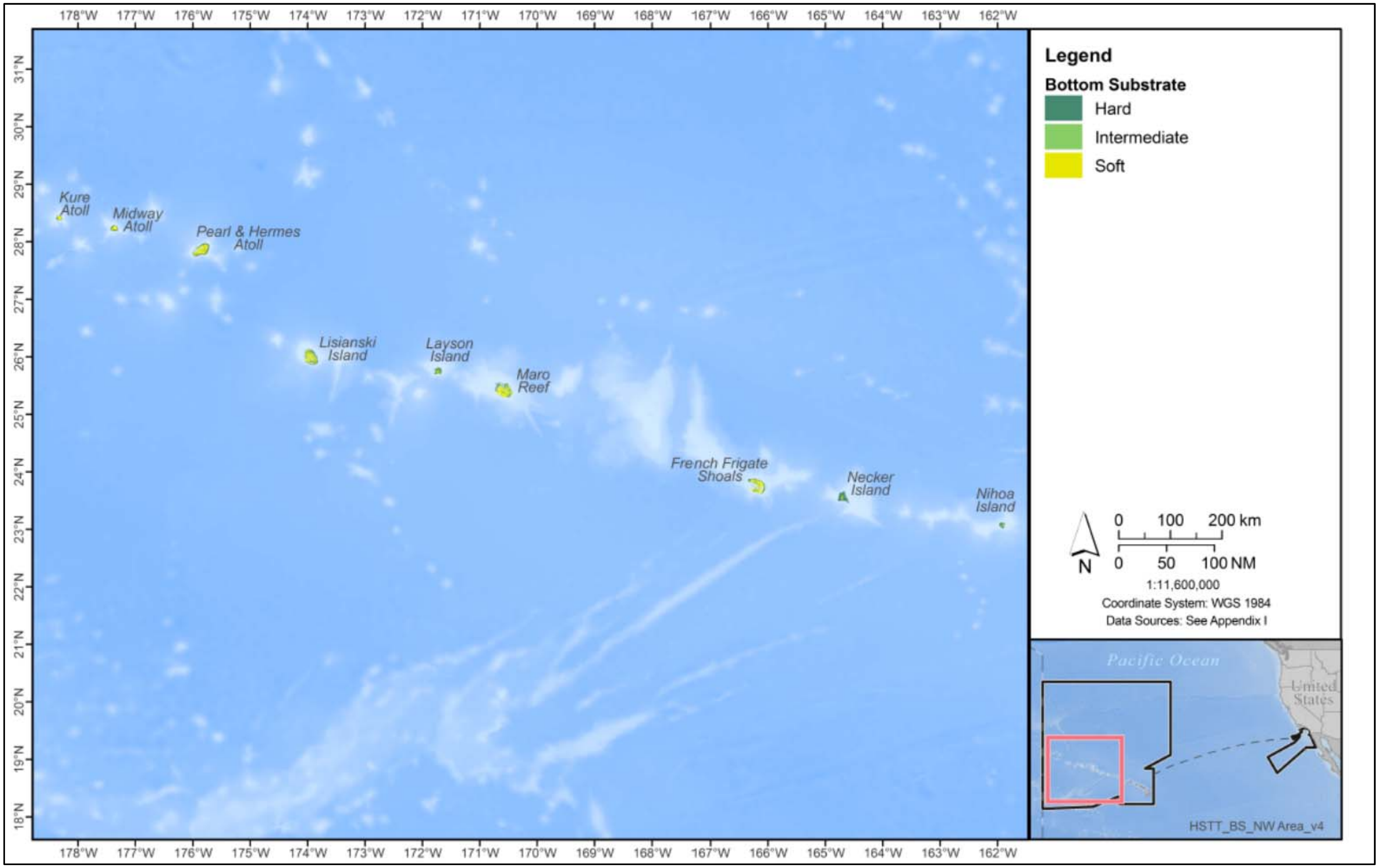
Appendix A8. Abiotic substrate (polygon geometry) mapping in the Gulf of Mexico region of the AFTT study area.



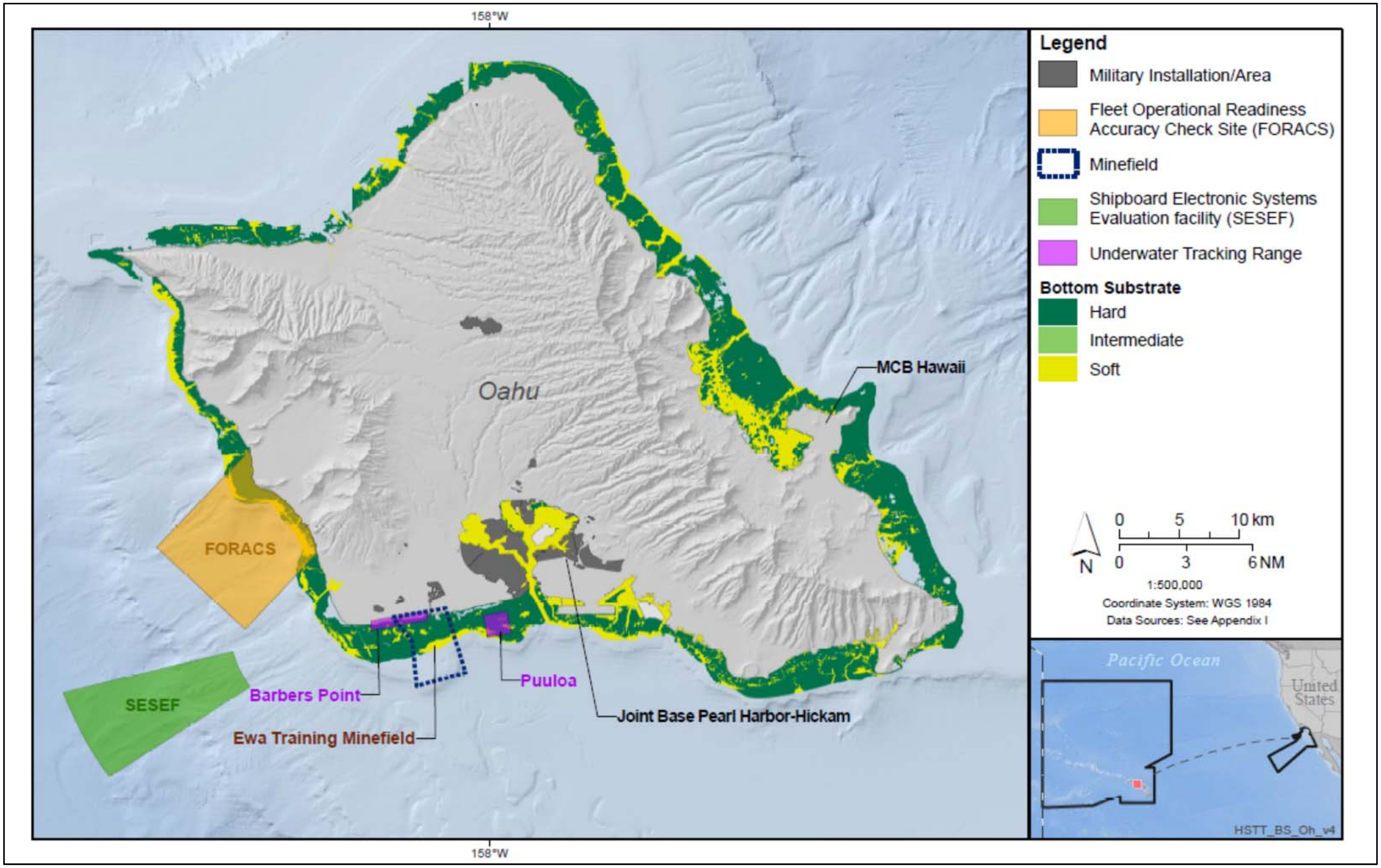
Appendix A9. Abiotic substrate (point geometry) mapping in the Hawaiian Islands region (Insular Pacific-Hawaiian Large Marine Ecosystem) of the HSTT study area.



Appendix A10. Abiotic substrate (polygon geometry) mapping in the Southern California region (California Current Large Marine Ecosystem) of the HSTT study area.



Appendix A11. Abiotic substrate (polygon geometry) mapping in the northwest Hawaiian Islands region (Insular Pacific-Hawaiian Large Marine Ecosystem) of the HSTT study area.



Appendix A12. Abiotic substrate (polygon geometry) mapping around Oahu Island in the HSTT study area.

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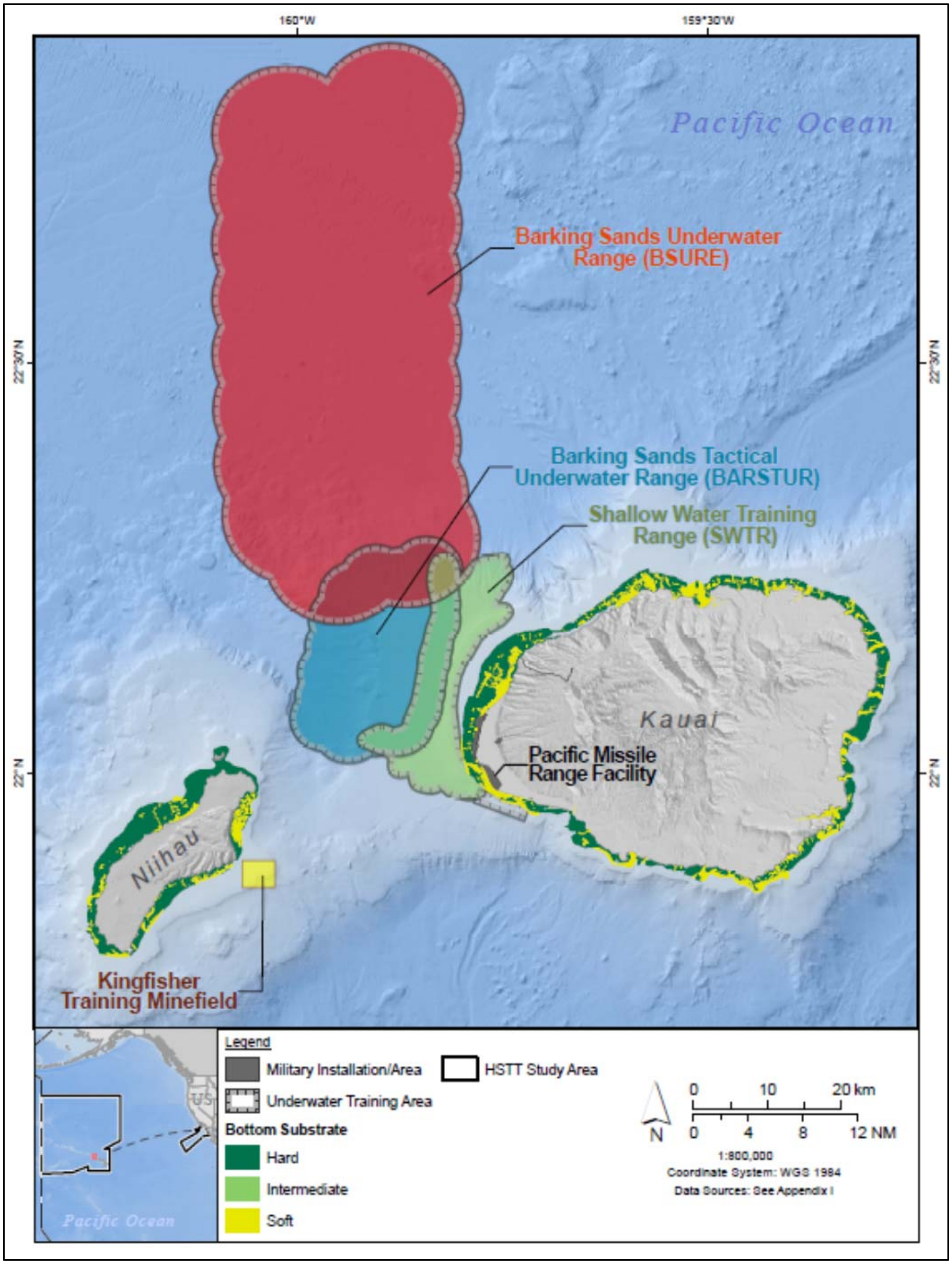

Appendix A13. Abiotic substrate (polygon geometry) mapping around Kauai and Niihau Islands in the HSTT study area.

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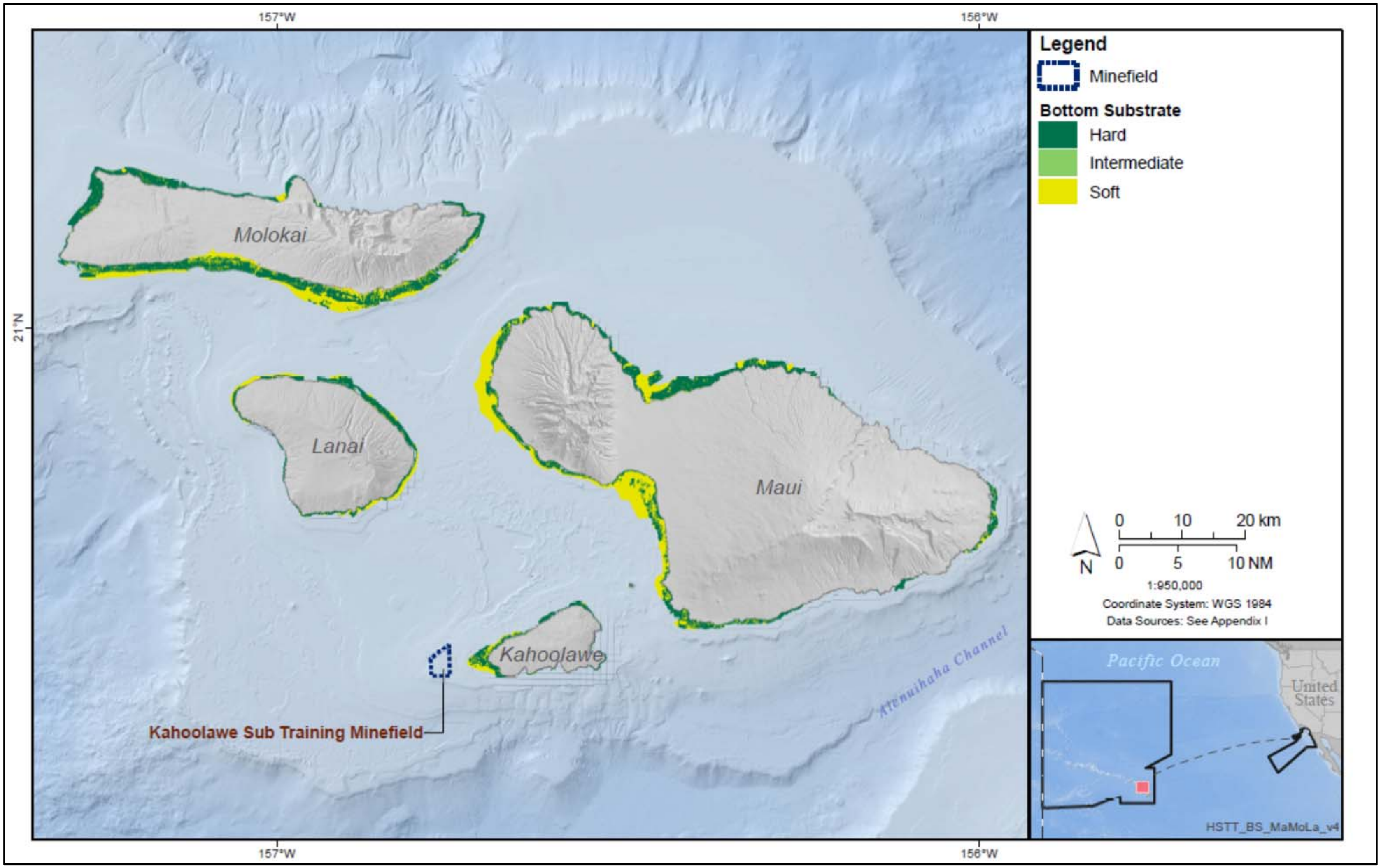
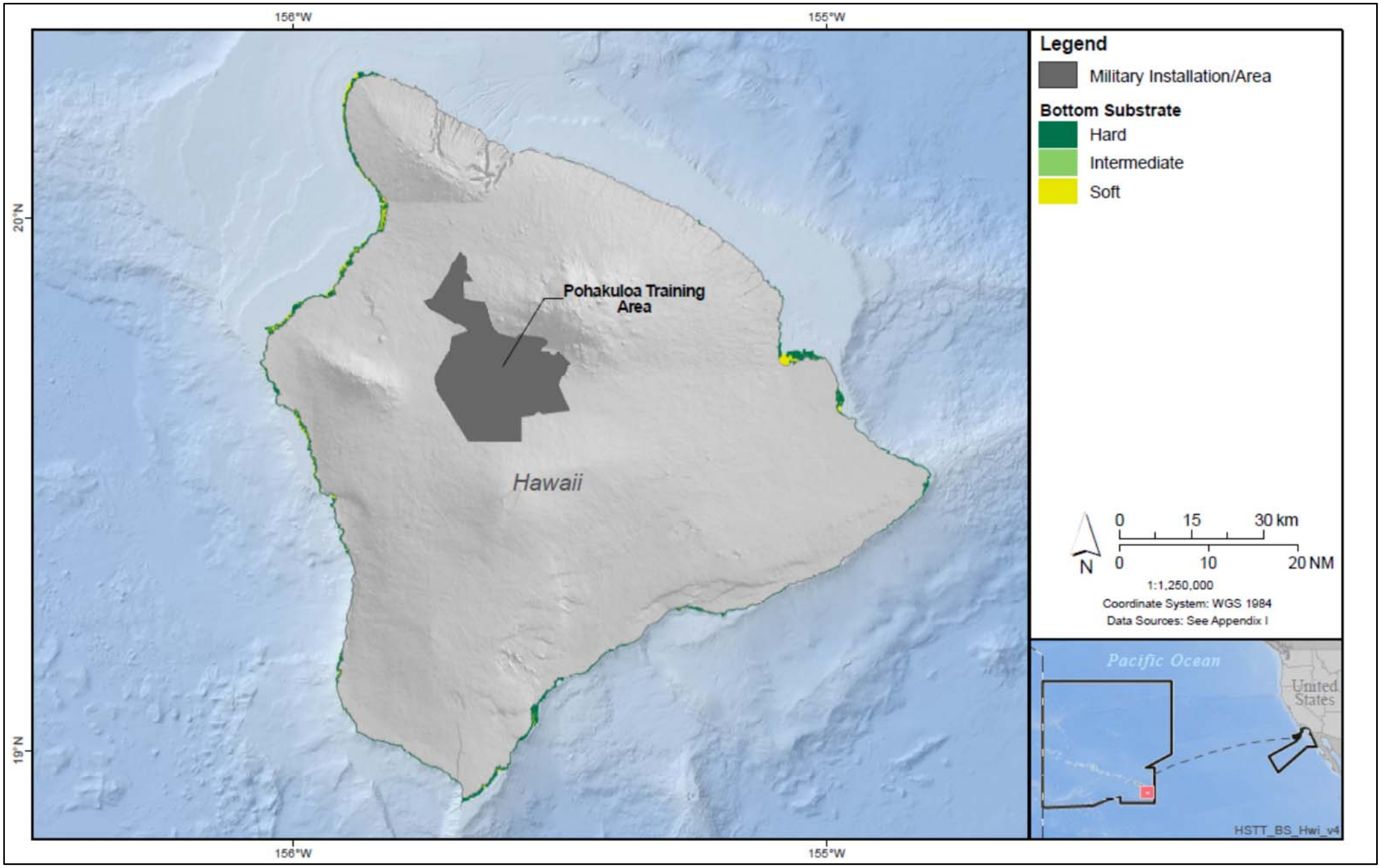
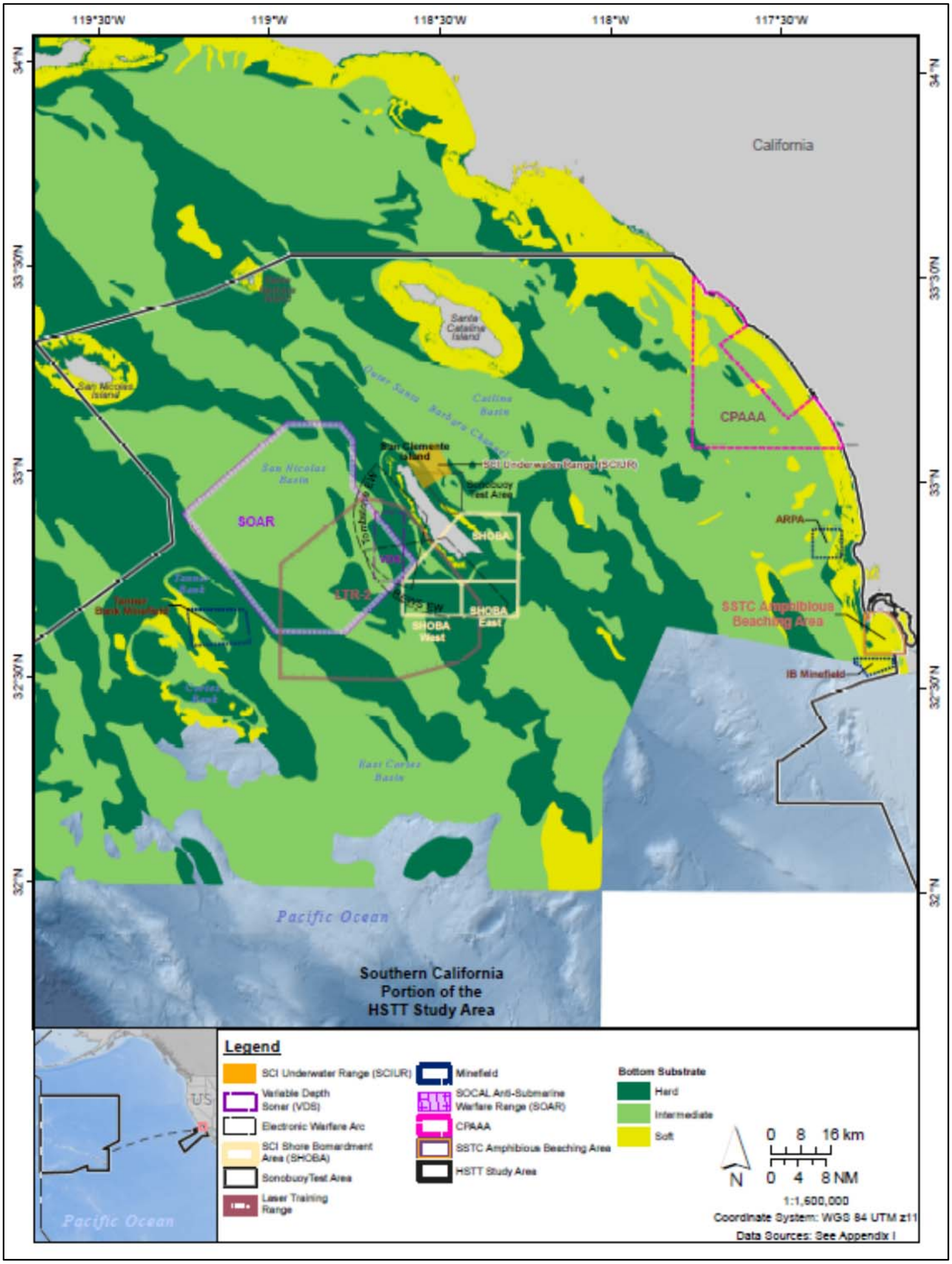


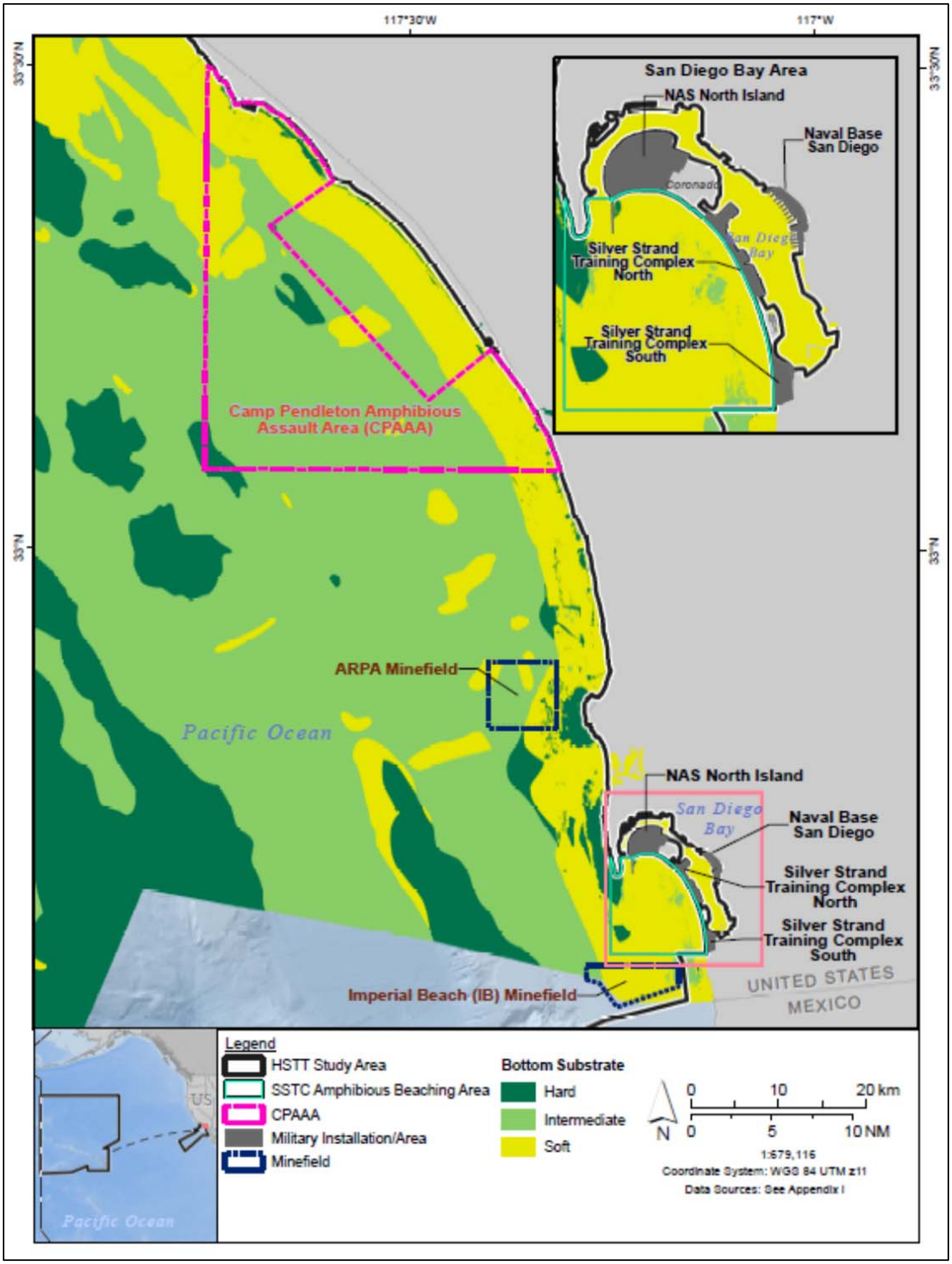
Appendix A14. Abiotic substrate (polygon geometry) mapping around Maui, Molokai, Lanai, and Kahoolawe Islands in the HSTT study area.



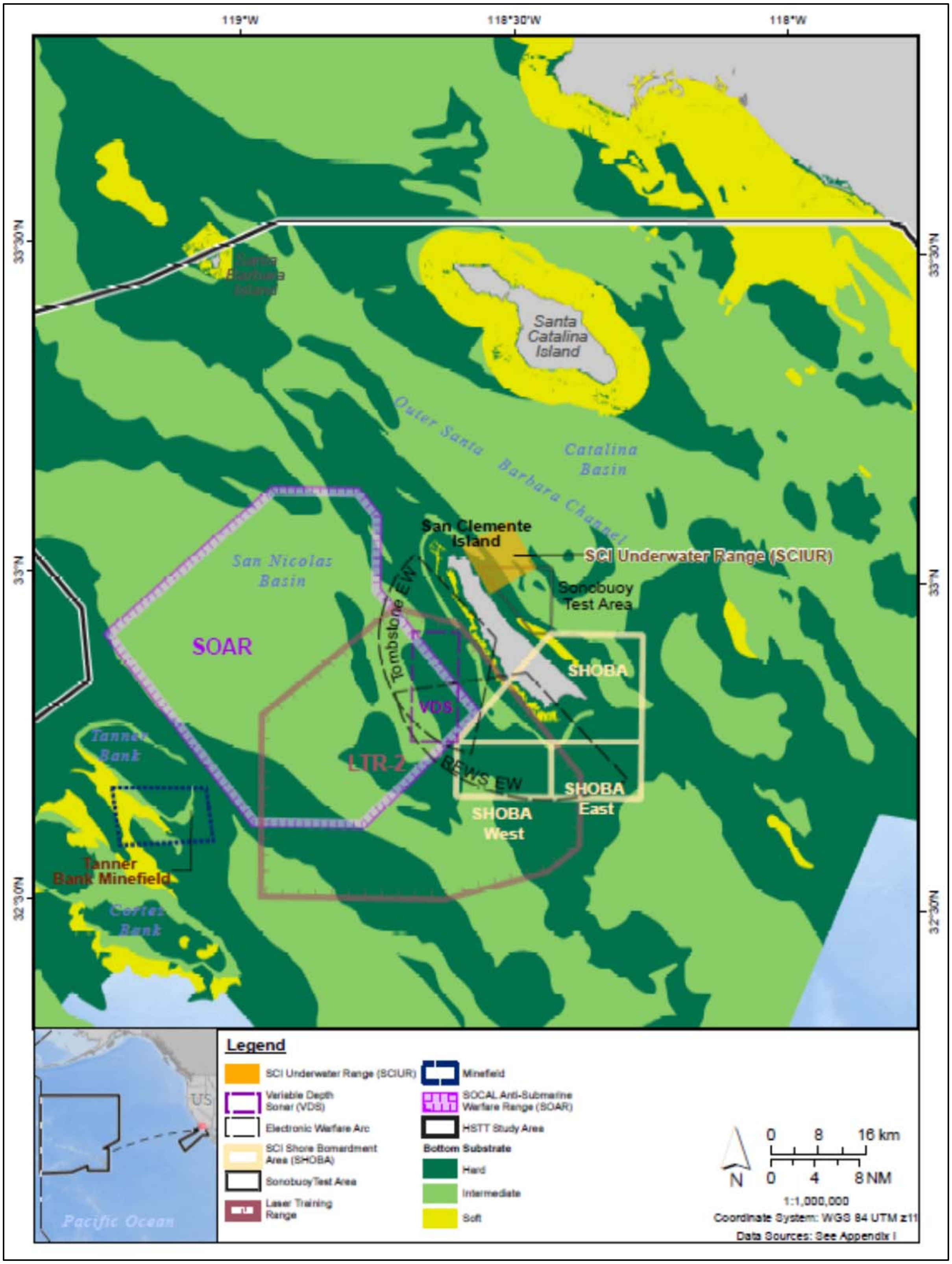
Appendix A15. Abiotic substrate (polygon geometry) mapping around Hawaii (main island) in the HSTT study area.



Appendix A16. Abiotic substrate (polygon geometry) mapping in Southern California portion of the HSTT study area.



Appendix A17. Abiotic substrate (polygon geometry) mapping in Southern California portion of the HSTT study area (nearshore portion).



Appendix A18. Abiotic substrate (polygon geometry) mapping in Southern California portion of the HSTT study area (offshore portion).

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APPENDIX B – Data source qualities supporting rank determinations.

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
Ackerman et al. (2006)	2001	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	200	AS_type: Soft as "Zone" = 'Anthropogenic modification' OR "Zone" = 'Low-relief mud' OR "Zone" = 'Low-relief sand'; Intermediate as "Zone" = 'Medium-relief boulder and cobble' OR "Zone" = 'Low-relief gravel and sand'; Hard as "Zone" = 'High-relief bedrock
Anderson and Eastlake (2011)	2006-2011	Spectral Sensor (remote)	Visual Observation (direct)	30	5	AS_type: MAJ_STRUCT field corresponded well to abiotic substrate types
Anderson et al. (2010)	2005	Line-based interpolation, Point-based Interpolation	Benthic Sampler	<1	500	AS_type: Soft as "Sand" or "Silt/mud"; Intermediate as "Gravel"
Barnhardt et al. (1996)	1984-1991	Bathymetric Interpolation	Acoustic Sensor, Benthic Sampler, Visual Observation (direct)	5	300	AS_type: Intermediate as "POLYTYPE" LIKE 'G%'; Soft as "POLYTYPE" LIKE 'S%' OR "POLYTYPE" LIKE 'M%'; Hard as "POLYTYPE" LIKE 'R%'
Barnhardt et al. (2006)	2003-2004	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	50	AS_type: Soft as "Sand/silt"; Intermediate as "Cobble/boulder"; Hard as "Ledge"
Barnhardt et al. (2009)	2004-2005	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	50	AS_type: Soft as ebb tidal delta or outer basin; Intermediate as nearshore ramp or shelf valley; hard as rocky zone
Chesapeake Bay Office-NOAA (2011)	1976-2010	Acoustic Sensor	Benthic Sampler	<1	30	AS_type: Intermediate as "Class" = 'Faunal_reef'; Soft as "Class" = 'Unconsolidated_substrate'; Hard as "Class" = 'Consolidated_substrate'; Artificial as "Class" = 'Artificial_reef''

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
FFWCC-FWRI (2013)	1960-2010	Acoustic Sensor, Line-based interpolation, Point-based Interpolation, Spectral Sensor (remote)	Benthic Sampler, Visual Observation (direct)	<1	20	AS_type: all categories (coral habitat only) = Hard
GMFMC (2004)	-2004	Acoustic Sensor, Line-based interpolation, Point-based Interpolation, Spectral Sensor (remote)	Benthic Sampler, Visual Observation (direct)	<1	5000	AS_type: Soft as [TYPE] = 'Sand' OR [TYPE] = 'Seagrass' OR [TYPE] = 'Silt' OR [TYPE] = 'Clay'; Hard as [TYPE] = 'Coral' OR [TYPE] = 'Hard Bottom' (Note: intertidal "shore" habitats not included)
GSMFC (2008)	2005-2008	Acoustic Sensor, Line-based interpolation, Point-based Interpolation, Spectral Sensor (remote)	Benthic Sampler, Visual Observation (direct)	<1	2500	AS_type: Soft as "sediment" LIKE 'Mud%' or "sediment" LIKE 'Sand%'; Intermediate as "sediment" LIKE 'Gravel%'; Hard as "sediment" LIKE 'Rock%'
Kendall et al. (2005)	2001	Acoustic Sensor	Visual Observation (direct)	<1	10	AS_type: Hard as "Densely colonized live bottom" or "Sparsely colonized live bottom"; Soft as "Flat Sand" or "Rippled Sand"
Kinlan et al. (2013a)	2012	Modeling	Acoustic Sensor, Benthic Sampler, Line-based interpolation, Other Sensor, Plankton Sampler, Point-based Interpolation, Spectral Sensor (remote), Visual Observation (direct), Water flow/Quality Meters	100	400	Hard as GRIDCODE >=3 (i.e., highly likely) using ALLFRAME shapefile

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
Kinlan et al. (2013b)	2012	Modeling	Acoustic Sensor, Benthic Sampler, Line-based interpolation, Other Sensor, Plankton Sampler, Point-based Interpolation, Spectral Sensor (remote), Visual Observation (direct), Water flow/Quality Meters	100	400	Hard as GRIDCODE >= 3 (i.e. highly likely) for ALCY and SCLER shapefiles combined; PENN shapefile not used because taxa grows in soft bottom
Kinlan et al. (2013c)	2012	Modeling	Acoustic Sensor, Benthic Sampler, Line-based interpolation, Other Sensor, Plankton Sampler, Point-based Interpolation, Spectral Sensor (remote), Visual Observation (direct), Water flow/Quality Meters	100	400	Hard as GRIDCODE >=3 (i.e., highly likely) using combined shapefile for SCLERFRAME, ANTI, ALCY, and OCULSPP
McMullen (2007)	2006	Acoustic Sensor	Benthic Sampler	<1	1	AS_type: Artificial as "INTERP" = 'BRIDGE' OR "INTERP" = 'PIER' OR "INTERP" = 'PIPELINE' OR "INTERP" = 'SHIPWRECK'; Hard as "INTERP" = 'ROCKY'; Intermediate as "INTERP" = 'MOTTLED' OR "INTERP" = HIGHBKSTR'; Soft as "INTERP" = 'LOWBKSTR'
Messing et al. (2011)	2011	Line-based interpolation	Visual Observation (direct)	<1	10	AS_type: Soft as Major_Comp = "unconsolidated"; Hard as "Major_Comp" = 'Hardbottom' AND "Slope" = 'High'; Intermediate as

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
						"Major_Comp" = 'Hardbottom' AND "Slope" = 'Low'
Moser and Taylor (1995)	-1995	Acoustic Sensor, Benthic Sampler, Expert Knowledge, Nekton Sampler, Visual Observation (direct)			500	AS_type: All polygon data was representing hard bottom
National Ocean Service (2001)	2001	Spectral Sensor (remote)	Visual Observation (direct)	30	>1	AS_type: assumed reef macroalgae habitat was hard substrate and seagrass habitat was soft substrate; excluded classifications for land and intertidal; other types were classifed as unknown
NAVFAC Atlantic (2013)	2013	Bathymetric Interpolation, Modeling	Acoustic Sensor, Expert Knowledge, Visual Observation (direct)	5	1500	AS_type: All polygon data was representing hard bottom
NAVFAC Atlantic (2016b)	2016	Bathymetric Interpolation, Expert Knowledge		100	5000	Seamount hard substrate; Outer boundary based on relatively steep slopes calculated from GEBCO 30 arc second bathymetry.
Poppe (2010)	2008-2009	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	50	AS_type: Soft as "FEATURES" = 'Bedforms'; Hard as "FEATURES" = 'Boulders'; Artificial as "FEATURES" = 'Shipwreck'
Scanlon et al. (2003)	1999-2001	Acoustic Sensor	Benthic Sampler	<1	200	AS_type: Hard as 0-1 (low to high-relief hard bottom); Intermediate as 2 (biogenic coarse); Soft as 3 (terrigenous fines)
Skidaway Institute of Oceanography (2004)	2004	Acoustic Sensor	Benthic Sampler, Spectral Sensor (remote)	<1	1000	Hard as “exposed hard pavement” OR “exposed hard pavement w/ limestone base or thinly covered hard substrate – high relief” OR “exposed

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
						hard pavement w/ siltstone base" OR "algal cemented reef >3 meters high"; Intermediate as "Rock/coral rubble" OR "thinly covered hard substrate – med to low relief"; Soft as "unconsolidated sand"
Todd (2006)	1996-1997	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	50	AS_type: Hard as "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'B'; Intermediate as "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'Icl' OR "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'Ict'; Soft as "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'PGssp' OR "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'Pgstk' OR "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'PGstk' OR "SURFICIAL_UNITS_BROWNS_BANK.CODE" = 'PGstn'
Todd and Kostylev (2011)	2000-2003	Acoustic Sensor	Benthic Sampler, Visual Observation (direct)	<1	100	AS_type: Hard as "Habitat" = 'Bedrock deep' OR "Habitat" = 'Bedrock shallow'; Intermediate as "Habitat" = 'Till deep' OR "Habitat" = 'Till shallow'; Soft as "Habitat" = 'Mud deep' OR "Habitat" = 'Mud shallow' OR "Habitat" = 'Sand deep' OR "Habitat" = 'Sand shallow'
U.S. Navy (2010a)	2010	Acoustic Sensor	Benthic Sampler, Spectral Sensor (remote)	<1	50	AS_type: Soft as "SedType" = 'coarse sand' OR "SedType" = 'medium sand' OR "SedType" = 'medium sand with sandwaves' OR "SedType" =

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
						'silt/clay/fine sand'; Intermediate as "SedType" = 'coral rubble' OR "SedType" = 'rubble' OR "SedType" = 'silt/clay/fine sand with rubble'; Hard as "SedType" = 'pavement' OR "SedType" = 'rock outcrop'
U.S. Navy (2011a)	2011	Acoustic Sensor	Benthic Sampler, Spectral Sensor (remote)	<1	50	AS_type: Soft as "Interp" = 'coarse sand' OR "Interp" = 'medium sand' OR "Interp" = 'silt/clay/fine sand'; Intermediate as "Interp" = 'coral rubble' OR "Interp" = 'rubble' OR "Interp" = 'sand with rubble'; Hard as "Interp" = 'pavement' OR "Interp" = 'rock
U.S. Navy (2011b)	2011	Acoustic Sensor	Benthic Sampler, Spectral Sensor (remote)	<1	50	AS_type: Soft as "Silt/clay/fine sand" OR "Coarse sand" OR "Medium sand"; Hard as "Pavement" OR "Rock outcrop"
USGS (2000)	1962-2000	Line-based interpolation, Point-based Interpolation	Benthic Sampler	<1	5000	AS_type: Soft as "SEDIMENT" = 'cl' OR "SEDIMENT" = 'sd/st/cl' OR "SEDIMENT" = 'cl-st/sd' OR "SEDIMENT" = 'sd-st/cl' OR "SEDIMENT" = 'sd-cl/st' OR "SEDIMENT" = 'sd' ; Intermediate as "SEDIMENT" = 'gr' OR "SEDIMENT" = 'gr-sd'; Hard as "SEDIMENT" = 'br'
USGS-SCSGC (2007)	1999-2003	Acoustic Sensor	Benthic Sampler	<1	10	AS_type: Soft as "Name" = 'Inlet-Associated Shoal' OR "Name" = 'Shore-Detached Shoal' OR "Name" = 'Mixed'; Intermediate as "Name" = 'Hardground'
Walker et al. (2006)	2001-2004	Acoustic Sensor, Spectral Sensor			30	AS_type: Intermediate as "Spoil area"

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
AFTT Study Area						
		(remote)				

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
HSTT Study Area						
CSU Seafloor Mapping Lab (1987)	1987	Point-based Interpolation	Benthic Sampler	<1	500	AS_type: Hard as BOTTOM = "hard_outcrop/pavement" or "hard_bottom"; Intermediate as BOTTOM = "mixed"; Soft as BOTTOM = "soft_sediment"
CSUMB, USGS, Fugro Palagos, Ocean Imaging, SanDAG, MLML, CDFW (2006)	-2006	Acoustic Sensor, Modeling, Spectral Sensor (remote)			15	AS_type: Hard as 'mapclass' = "Hard"; Soft as 'mapclass' = "Soft"
KTU-A LA and P, MN, SDNHMP, and SanDAG (2002)	2002	Acoustic Sensor, Spectral Sensor (remote)			6	AS_type: Hard as "Bedrock" or "Boulder" or "Kelp Canopy Obscuring Seafloor"; Intermediate as "Cobble" or "Pebble/Gravel/Granule"; Soft as "Sand" or "Mud"; Artificial as "Artificial Substrate"
Merkel and Associates (2014)	2013	Acoustic Sensor	Visual Observation (direct)	<1	3	AS_type: Hard as "Rocky Shore-Spray/Splash Zone" or "Boulder Over Bedrock" or "Bedrock"; Intermediate as "Mixed Sand/Rubble"; Soft as "Sand"
NCCOS (2007)	2004-2007	Spectral Sensor (remote)			10	Hard as "HABCOVER" = 'CCA on hardbottom' OR "HABCOVER" = 'hardbottom, unspecified cover' OR "HABCOVER" = 'live coral on hardbottom' OR "HABCOVER" = 'macroalgae on hardbottom' OR "HABCOVER" = 'uncolonized hardbottom'; Soft as "HABCOVER" = 'macroalgae on unconsolidated' OR “HABCOVER” = “unconsolidated”

Data Source	Year(s) Date Collected	Method (Mapping)	Method (Validation)	Validation Coverage (%)	Min. Mapping Unit (m)	Processing Notes
HSTT Study Area						
NOAA/NOS/NCCOS /CCMA (2007)	2007	Spectral Sensor (remote)	Visual Observation (direct)	<1	0.6-4	As_type: Hard as 'M_STRUCT'="Coral Reef and Hardbottom"; Soft as 'M_STRUCT'="Unconsolidated Sediment"; Artificial as 'D_STRUCT'="Artificial" AND 'ZONE' <> "Land"

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