FINAL REPORT

Population Assessment of Eastern Oysters (*Crassostrea virginica*) in the Seaside Coastal Bays

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EXECUTIVE SUMMARY

Declines of oyster populations and commercial harvest from the Virginia seaside coastal bays have followed similar patterns, though not as severe, as those in Chesapeake Bay. High prevalence of Dermo disease (*Perkinsus marinus*) and MSX disease (*Haplosporidium nelsoni*) coupled with over harvest and habitat destruction have dramatically reduced populations. Nevertheless, there are several promising signs that significant enhancement of the population could be achieved with well conceived restoration efforts.

Oyster habitat and population distribution were examined in the coastal bay system on the seaside of the Eastern Shore of Virginia. This system is composed of barrier islands, salt marshes, broad and shallow coastal bays, intertidal mud flats, and deeper water channels. Manmade shorelines such as bulkhead and rip rap are prevalent in limited areas.

This study provides the first quantitative assessment of oyster population abundance on a region wide scale in the coastal bays on the seaside of Virginia's Eastern Shore. Our estimate of 3.2 billion oysters in this region exceeds the most recent population estimate of 1.8 billion oysters for the entire Virginia portion of Chesapeake Bay produced by the VIMS CBOPE (http://web.vims.edu/mollusc/cbope/VAPDFfiles/VABasin2006.pdf). At the time of our sampling, Dec. 2007 – June 2008, the oyster population was comprised of a wide range of sizes representing several year classes that suggest a self-sustaining population with the potential for significant expansion.

The spatially-explicit oyster population GIS product developed through this work provides a valuable tool for guiding fisheries resource management and restoration activities for oysters in this region. The ultimate usefulness of this product lies in its integrative aspect as a GIS tool.

ACKNOWLEDGMENTS

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INTRODUCTION

Declines of oyster populations and commercial harvest from the Virginia seaside coastal bays have followed similar patterns, though not as severe, as those in Chesapeake Bay. High prevalence of Dermo disease (*Perkinsus marinus*) and MSX disease (*Haplosporidium nelsoni*) coupled with over harvest and habitat destruction have dramatically reduced populations. Nevertheless, there are several promising signs that significant enhancement of the population could be achieved with well conceived restoration efforts. Recruitment rates remain high and rapid growth allows oysters to reach reproductive size prior to disease mortality.

To plan a more a comprehensive restoration effort we need an estimate not only of the current standing stock of oysters, but also of their spatial distribution in the coastal bays. This is easier said than done in the complex of habitats that make up the coastal bays. Oysters in the area are naturally found in several intertidal habitats—patch reefs, fringing reefs and isolated, small clumps on mudflats and in marshes. In addition, private lease holders create a variety of habitats for planting and rearing oysters that include both subtidal and intertidal habitats. An increasing amount of man-made structures, such as rip-rap and bulkheads provide habitat for oysters. Traditional stock assessment methods have involved only determining the density of oysters on "public" oyster reefs and restoration sanctuary reefs. Arguably, the majority of oysters in the region are not counted by this method.

Obtaining reliable estimates of the distribution and abundance of oysters on the seaside are beyond the scope of Virginia Marine Resources Commissions' resources and until recently posed several technical challenges. Fortunately, we now possess the tools to develop reliable population and distribution estimates for oysters on the seaside. We employed aerial observations, Global Positioning Systems (GPS) and high resolution aerial images integrated with an ArcView-based Geographic Information System (GIS), to develop oyster distribution maps throughout the entire Virginia coastal bay system. Our provide spatially-explicit estimates of oyster populations throughout the region that can be used to help guide management and restoration efforts.

Our specific objectives for this research were to:

(1) Map potential oyster habitats (e.g. shell reefs/beds, marsh, mud flats, and manmade structures) in progressively finer resolution utilizing: 1-meter geo-referenced aerial images in an Arcview-based GIS; aerial surveys; and field mapping/ground-truthing (by boat and on foot);

(2) Develop habitat-specific quantitative estimates of the abundance, density and size distribution, of oyster populations in coastal bays; and,

(3) Incorporate both of these into an appropriate GIS dataset.

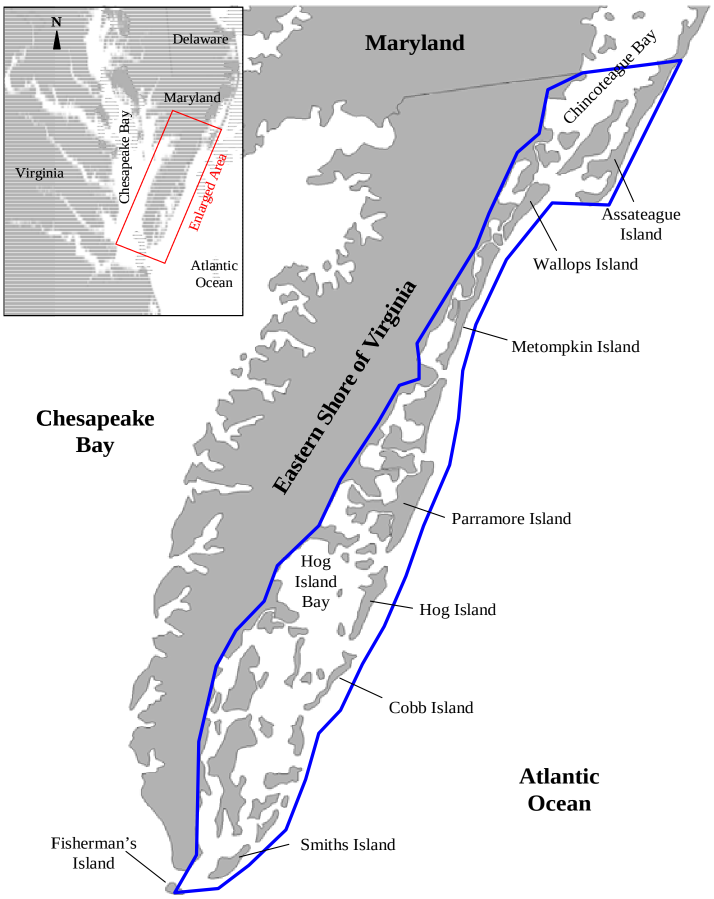
METHODS

Study Area

Oyster habitat and population distribution were examined in the coastal bay system on the seaside of the Eastern Shore of Virginia (Fig. 1). This system is composed of barrier islands, salt marsh dominated by *Spartina* spp., broad and shallow coastal bays, intertidal mud flats, and deeper water channels. Manmade shorelines such as bulkhead and rip rap are prevalent in limited areas. Overall, the study area encompasses approximately 900 km^2 (350 mi^2) and is bounded by Fisherman's Island in the south to mid-Chincoteague Bay in the north (bounding latitudes of N 37º 06' to N 38º 01').

Tidal amplitude generally ranges from 0.75-1.5 m, although the extreme northern end of the study area in Chincoteague Bay is as low as 0.3 m. Salinities approaching that of seawater (>30 psu) are encountered throughout this system, although they may be periodically lower near headlands following rain events.

Figure 1. Study area (outlined in blue) consisting of the coastal bays system on the seaside of the Virginia portion of the Delmarva Peninsula.

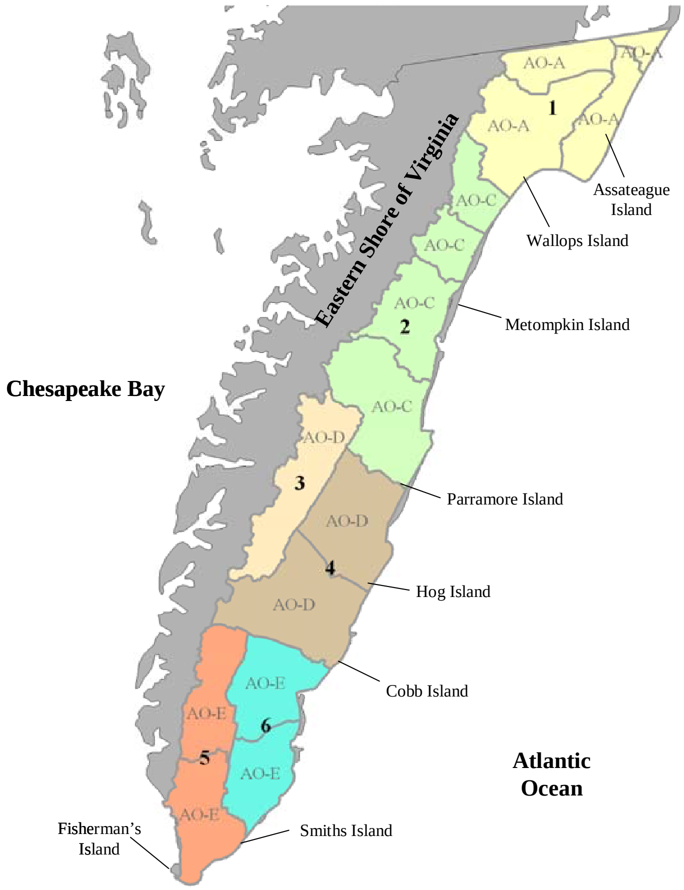


The relative sizes of the coastal lagoons and the surrounding contiguous marshes vary with latitude along the peninsula. Additionally, the distance from ocean inlets to less flushed tidal creeks/bays decreases northward in the study area. Some water quality parameters such as water temperature, dissolved oxygen and, to a lesser extent, salinity are likely affected by these spatial gradients.

This geographic variation could potentially impact the spatial distribution and density of oysters and the relative importance of different habitats to the oyster population. Therefore, the study area was divided into geographic regions based on sub-watershed hydrologic units of the National Watershed Boundary Dataset (NWBD; see Federal Standards for Delineation of Hydrologic Unit Boundaries-FDGC Proposal, 2004). We combined 15 of these sub-watersheds (VAHUC5 and VAHUC6 resolution) to form six regions which represent our *a priori* expectations of geographic variations in the oyster population (Fig. 2).

Oyster habitat was delineated throughout this marine system and up to the point where tidal creeks began to interface with the mainland. Oysters are undoubtedly found further upstream in limited numbers, but are not included in this assessment.

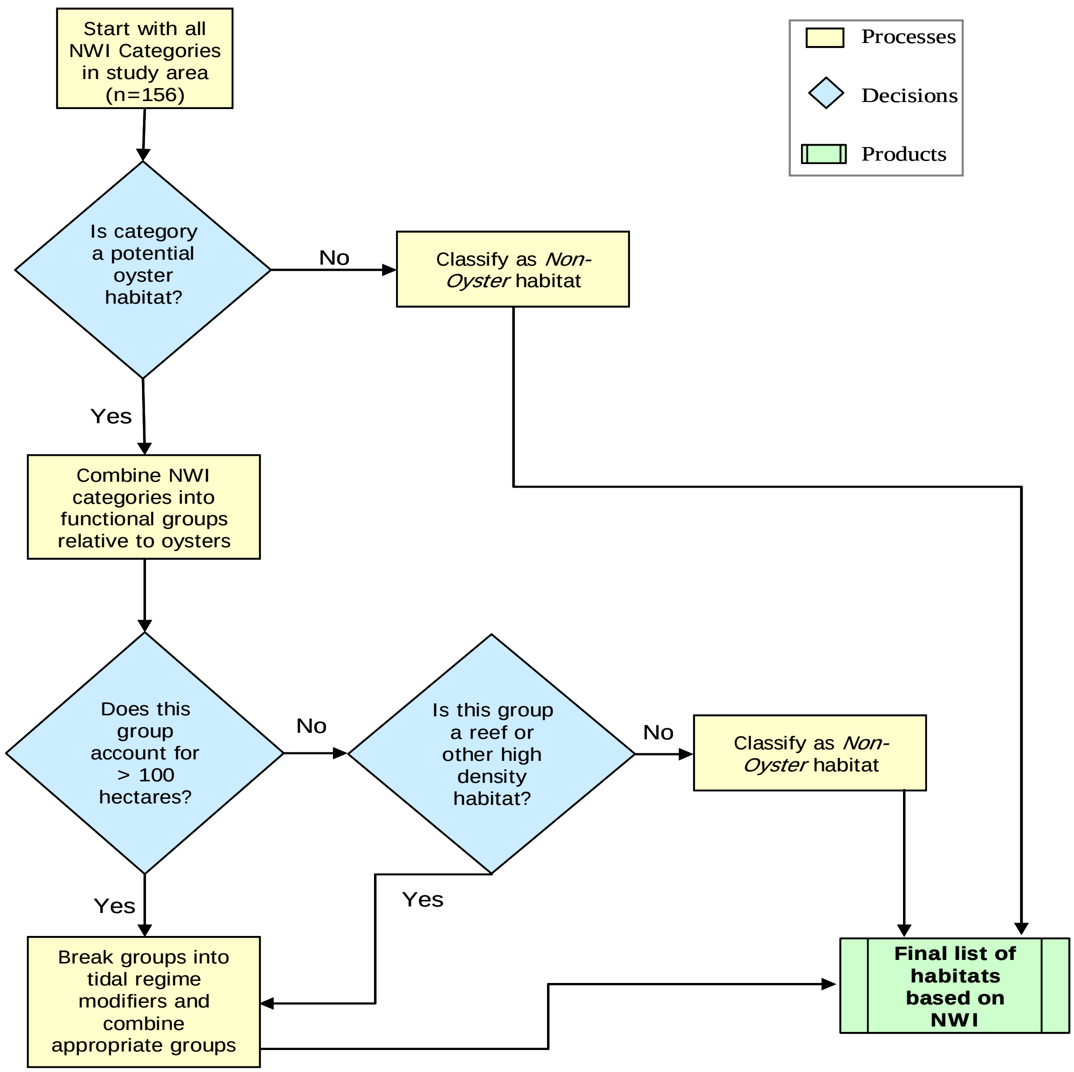
Figure 2. Study area divided into six regions (different colors with black numbers) based on sub-watershed hydrologic units of the National Watershed Boundary Dataset (gray lines and labels). See Methods sections



Habitat Mapping

We began by extracting GIS polygons from the National Wetlands Inventory (NWI) to use as the base map for potential oyster habitats (http://www.fws.gov/nwi/). The NWI habitat classification system (see Cowardin et al. 1979) suited a large portion of our mapping needs by including emergent marsh, intertidal bottom (called "flats" herein) and subtidal bottom as specific habitats (although there were multiple subdivisions of each grouping). These habitat categories represent the major types of habitats that oysters inhabit in varying densities in this study area. However, habitat classifications within the NWI were generally too detailed in their raw format (e.g. over 40 habitat codes were attached to polygons that were potential oyster habitat). Therefore, we grouped and/or re-classified them into basic habitat categories that were meaningful to oyster ecology (Fig. 3 and see <u>Habitat Classification</u> section). See Appendix I for details of these conversions for specific NWI codes. Additionally, NWI polygons often had tidal modifiers that helped delineate regularly inundated versus rarely inundated areas that we know to be different in terms of oyster demographics and therefore important to map separately. Some of the habitats not represented in these data will be discussed below.

Figure 3. Algorithm for re-classifying National Wetlands Inventory (NWI) habitat categories for this study (see Table 1 for final categories chosen for this project).



Since NWI polygons were created from data gathered approximately eight to ten years ago, we manually compared them to digital 1-m resolution aerial images from the Virginia Base Mapping Program that were taken in 2002 (see Fig. 4 for an example). Discrepancies in the NWI polygons consisted of two types: erroneous habitat identification and inaccurate polygon boundaries. Examples of erroneous identifications include light colored bare spots on high marsh (usually hypersaline pans) that were identified as open water or “unconsolidated subtidal bottom” (i.e. a small pond) or marsh polygons identified as “irregularly flooded” that were obviously flooded on most average tides. Many polygons had inaccurate boundaries. Some of these reflected erosion or sand movement near inlets and on the west side of barrier islands and some were in areas of no predicted oyster abundance; however, most stemmed from the scale and methodology of the NWI. Boundaries were adjusted in cases of large discrepancies on the order of 10 m, while those on the order of several meters were generally left unaltered, given the scale of the study area. Additionally, the tidal regime modifier for many marsh and flats type polygons was listed as “unknown”. We therefore made tidal inundation decisions based on a combination of VBMP images (color changes in the marsh were often indicative), personal experience and site visits in these areas. Approximately 700-800 of the >6,000 (~12-14%) polygons utilized for this study required manual adjustment.

Figure 4. Example of National Wetland Inventory polygons (red outlines) overlaid on 1-m resolution Virginia Base Mapping Program.

Although marshes, flats and subtidal bottom habitats were appropriately included in NWI, the classification system does not identify reefs within the context of other habitat categories. Therefore, we undertook mapping of these habitats utilizing existing VBMP imagery (both 2002 and 2007 versions) and systematic aircraft over flights at 100 m altitude within 1.5 hrs of low tide. The entire study area was surveyed for isolated patch reefs in this manner during 30 hrs of flying time in spring 2007. This technique was also used to map fringing reefs along creek banks adjacent to marsh edges. Aerial images and in-flight observations were effective at locating fringing reefs > 30 m^2 along major creek banks, but were less effective in locating smaller reefs and those located on the banks of very small creeks. Oysters in some of these missed fringing reefs were later captured in our ground-based surveys of marsh habitats (see below). Additionally, when possible, we categorized state restoration reefs separately and identified privately managed reefs when intensive activities entailing either substrate or oyster manipulation were known to be present. This category includes areas utilized for commercial oyster harvest and private restoration projects.

Once reefs were identified and located on aerial image printouts, they were digitized in GIS based on their outlines on the VBMP images (Fig. 5). When images had been collected near low tide, this task was relatively easy and the boundaries of most reefs were easily visible (Fig 6a). Otherwise, determining the exact boundaries was more difficult (Fig. 6b). We expected some observer error using this technique due to immersion of portions of the reefs and the presence of macroalgae beds and dark sediments that can be difficult to distinguish from oyster reefs, even during low altitude flight. Therefore, all surveys and

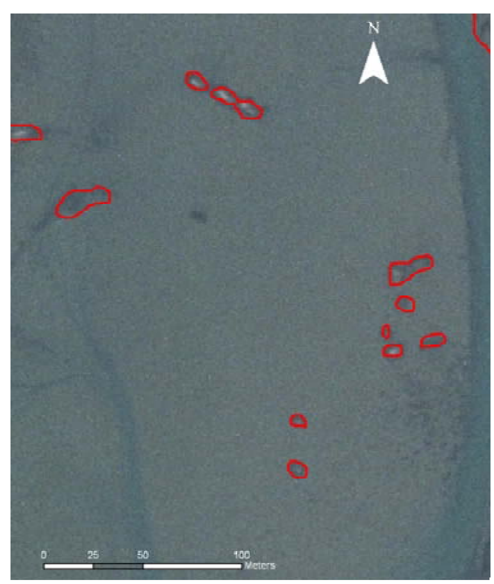
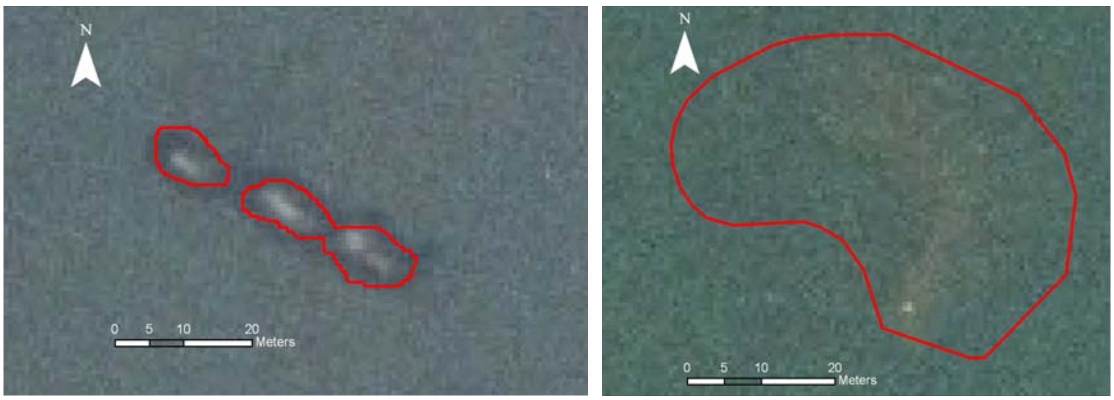


Figure 5. An area of *Patch Reefs* (see Table 1) visible on 1-m resolution Virginia Base Mapping Program aerial images and digitized as polygons (red outlines) in GIS.

digitizing were conducted by the same technician in an effort to maintain the same bias throughout the entire study. Within these limitation, this technique allowed for a census of the entire study area within the budget and time constraints of the project.

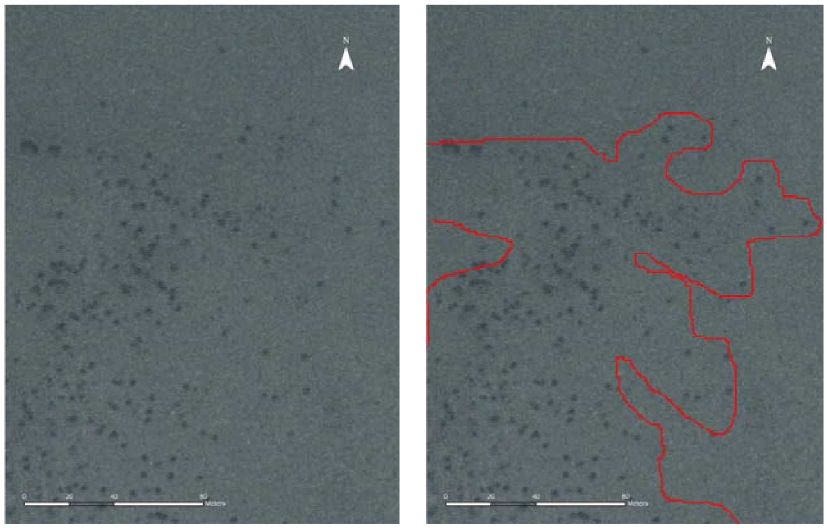
Figure 6. Images of *Patch Reefs* (see Table 1) visible on 1-m resolution Virginia Base Mapping Program aerial images that were collected at (A) low tide and (B) high tide, that presented varying digitizing challenges (red outlines).



In some cases during reef mapping, we encountered extensive areas of mud flat with many interspersed small (<10 m^2) patches of oysters (Fig. 7a). It was impractical to map each small patch, but it was also inappropriate to label such habitats as normal flats. We therefore created a category (*Small Patch Reefs*) and digitized polygons encompassing these areas (Fig. 7b) that were subsequently sampled differently than normal flats or typical patch reefs.

Following initial flights we conducted an evaluation of the patch reef mapping protocol prior to continuing. This initial groundtruthing was undertaken on 86 reefs in regions 5 and 6 during June 2007 (mapped using 2002 aerial images). Of the 86 reefs visited, 81 (94%) were patches containing at least 50% shell (most were contiguous shell) and considered correctly identified in over flights. Additionally, we searched for other potential patches that were missed in the initial mapping in the vicinity of these reefs. Ten patches were discovered that appeared to be reefs. Upon further investigation, four were algae beds or odd colored sediments that were not reefs.

Figure 7. An area of *Small Patch Reefs* (dark specks; see Table 1) visible on 1-m resolution Virginia Base Mapping Program (A) before and (B) after being digitized as a polygon (red outline) in GIS.



However, the other six were patch reefs. Four of these six were located in the low intertidal zone and did not show up well on the aerial images. Furthermore, during oyster sampling excursions to 60 randomly selected patch reefs throughout all regions, seven (12%) were found to be inaccurately mapped based on the 2002 VBMP images. In several of these cases, loose shell was interspersed on flats and comprised <50% of the aerial footprint and, therefore, did not meet our classification criteria as a reef. Over half of these erroneously mapped polygons were easily and accurately re-mapped based on the higher resolution 2007 VBMP images. This led us to re-examine every mapped reef using the newer images once they were available (February 2008). Based on our initial groundtruthing and comparisons using the 2007 images, we have high confidence that >95% of reefs are correctly identified as such.

The presence of manmade shoreline that was potential oyster habitat was not captured by the NWI. Such shorelines were generally composed of bulkhead (vertical shoreline armoring) or rip rap (sloping shoreline armoring with various aggregate materials) and were manually digitized as line features using VBMP aerial images. Most of these habitats were associated with harbors, marinas, boat landings, a residential development on Chincoteague Bay or the town of Chincoteague. Rip rap consisting of granite or concrete were grouped together. Another rip rap category consisting of clam/oyster shells placed on banks was separately identified and mapped.

Habitat Classification

Following the criteria above, we settled on 15 habitat categories which reflect a combination of NWI habitats, reefs, manmade shoreline, tidal inundation modifiers and our expectations for the oyster population (Table 1). Oysters on the seaside of the Eastern Shore are most prevalent in the intertidal zone (with some individuals found in the shallow subtidal). Their upper extent is determined by air exposure (desiccation or temperature extremes) and their lower extent is limited by predation and competition (e.g., Ortega 1981). We recently completed a similar oyster census in the Lynnhaven River, which is a tidal tributary in the lower Chesapeake Bay, and found that the duration of tidal inundation can be extremely important to the distribution of oysters (Ross and Luckenbach, In Prep). As a result, *Subtidal Bottom* habitat is generally described in Table 1. For purposes of this study, we focused on the immediate intertidal zone and assume that no significant oyster populations existed subtidally.

Table 1. Oyster habitat categories (in italics) and descriptions developed for this study.

	Habitat	Tidal Inundation	Description	GIS Type
Emergent Marsh	*High Marsh*	Periodically flooded during spring high tides	Emergent *Spartina* marsh and associated hypersaline "pans"	Polygon
Emergent Marsh	*Low Marsh*	Regularly flooded during average high tides	Emergent *Spartina* marsh	Polygon
	Flats-Marsh	Regularly exposed and flooded during average tides	Areas were delineations between marsh and flats (see above & below) are not distinct	Polygon
Tidal Flats	*High Tidal Flats*	Regularly exposed during average low tides	Unconsolidated sediment ranging from mud to sand	Polygon
Tidal Flats	*Low Tidal Flats*	Rarely exposed to periodically exposed during spring low tides and wind-induced events	Unconsolidated sediment ranging from mud to sand; very shallow during average low tides	Polygon
	Subtidal Bottom	Never exposed	Unconsolidated sediment ranging from mud to sand	Polygon
Reefs	*Patch Reefs*	Regularly flooded and exposed during average tides	Consolidated hard substrate patches (typically shell) isolated from emergent marsh	Polygon
Reefs	*Small Patch Reefs*	Regularly flooded and exposed during average tides	Small (< $5m^2$) consolidated hard substrate patches (typically shell) interspersed on flats	Polygon
Reefs	*Fringing Reefs*	Regularly flooded and exposed during average tides	Consolidated hard substrate patches (typically shell) adjacent to emergent marsh	Polygon
Reefs	*State Restoration Reefs*	Regularly flooded and exposed during average tides	*Patch* or *Fringing* reefs constructed or enhanced by the VA Marine Resources Commission	Polygon
Reefs	*Privately Managed Reefs*	Regularly flooded and exposed during average tides	*Patch* or *Fringing* reefs constructed or enhanced by private individuals or organizations	Polygon
Manmade Shoreline	*Bulkhead*	Regularly flooded and exposed during average tides	Vertical shoreline armoring using various materials	Line
Manmade Shoreline	*Rip Rap (non-shell)*	Regularly flooded and exposed during average tides	Shoreline armoring using aggregate on a sloping bank	Line
Manmade Shoreline	*Shell Rip Rap*	Regularly flooded and exposed during average tides	Shoreline armoring using shell (e.g. clam or oyster) on a sloping bank	Line
Manmade Shoreline	*Unknown*	Regularly flooded and exposed during average tides	Shoreline armoring where specific site visits were not undertaken (usually isolated instances)	Line

Habitats were often encountered in complex juxtapositions. In many cases, where one ends and another begins is subject for debate, but we tried to be consistent throughout the course of the study.

Modified NWI categories

Emergent salt marsh (dominated by *Spartina* spp.) was divided into three categories (Table 1). *High Marsh* is only periodically flooded during spring high tides and some above average tides. These areas are dominated by the short *S. alternaflora* variant and include *S.* patens and hypersaline "pans" with *Salicornia* spp. (Fig. 8a). *Low Marsh* is regularly flooded during average high tides. Both short and tall variants of *S. alternaflora* are present and the marsh is intersected by narrow and usually winding channels, locally called "drains" or "guts" (Fig. 8b). It was impractical to map all of the small channels that permeate these. Therefore, marsh habitat polygons generally included small creeks (<10 m and more often < 3 m across).

Figure 8. Photographic examples of marsh habitats utilized in this study: (A) *High Marsh*, (B) *Low Marsh* and (C) *Flats-Marsh*. See Table 1 and the Methods section for detailed descriptions.

Our subsequent oyster sampling took these sub-features into account and is described below. The *Flats-Marsh* category encompasses habitats where the boundary between flats and emergent marsh are not well defined or where many small (<100 m^2) marsh patches are interspersed within a portion of flat (Fig. 8c). In subsequent oyster sampling we addressed these habitats differently than either contiguous flats or marsh and therefore we mapped them as distinct habitats. By their nature, the marsh portions of the *Flats-Marsh* category were regularly flooded and the flat portions were regularly exposed during average tides.

Flats, which consist of unconsolidated sediments ranging from soft mud to hard sand that are intertidal or very high in the subtidal zone, were divided into two categories (Table 1). *High Tidal Flats* are regularly exposed during average low tides while *Low Tidal Flats* are rarely to periodically exposed during spring low tides and wind-induced events (Fig. 9).

Figure 9. Photographic examples of flats habitats utilized in this study: (A) *Low Tidal Flats* (light area below blue channel) and (B) *High Tidal Flats*. See Table 1 and the Methods section for detailed descriptions.

Reef categories

Five reef categories were established. *Patch Reefs* consist of consolidated hard substrate patches that are intertidal and spatially isolated from emergent marsh (Table 1). Patch Reefs are variable in size and tidal inundation, but are typically composed of >50% shell (Fig 10). They are often colloquially called oyster "rocks" or "bars".

Figure 10. Photographic example of *Patch Reefs* (white patches). See Table 1 and the Methods section for detailed descriptions.

Additionally, *Fringing Reefs* (those adjacent to or integrated into emergent marsh), *State Restoration Reefs* (state created projects) and *Privately Managed Reefs* (intensively managed for restoration purposes or commercially for harvest) were identified. Patches of fossil shell eroding from marsh or flats and wave accumulated shell piles that are in or above the high intertidal zone are not in this category. These hard substrates are not a potential oyster habitat because they are infrequently flooded.

As previously mentioned, we encountered extensive areas of mud flat with many interspersed small (<10 m^2) patches of oysters (Fig.7). Therefore, we created a category, *Small Patch Reefs* (Table 1), and digitized polygons encompassing these areas. Furthermore, each of these polygons was subjectively estimated to have *Low*, *Medium* or *High* density of clusters (5-20%, 21-35% or 36-50%, respectively). Areas with <5% clusters were considered as flats and those having >50% clusters were considered regular reefs.

Manmade shoreline categories

Manmade shoreline refers to shoreline armoring materials that are regularly flooded during average high tides (Table 1). The two most common are *Bulkheads* (Fig. 11) and *Rip Rap* of various materials (including *Shell Rip Rap*). Isolated manmade features, where site visits were not deemed appropriate, were grouped into an *Unknown Manmade* category.

Figure 11. Example of *Manmade Shoreline* (bulkhead in this case). See Table 1 and the Methods section for detailed descriptions.

Oyster Sampling

Once potential oyster habitats had been identified and mapped, we developed habitat-specific sampling protocols to quantify the oyster populations (see Table 2). Anticipating that reefs of various types would be the habitats with the most oysters, especially *Patch Reefs* and *Small Patch Reefs* the abundance of which outweighed other reef types, we allocated the greatest number of samples to these habitat types (Table 2).

Table 2. Habitat-specific oyster sampling design summary. Details for each habitat are discussed in the methodology. Habitat categories follow descriptions in Table 1 and the Methods section. "Quad" refers to quadrates.

Habitat		# Polygons Sampled	Sample Type	# Samples per Polygon	Total # Sampled	Size
Patch Reefs		60	Quad	Varies	348	Varied (S, M, L)*
Fringing Reefs	Large	6	Quad	4	24	Varied (S, M, L)*
	Small	6	Quad	2	12	Varied (S, M, L)*
Small Patch Reefs		3	Quad	Varies	11	0.33 m x 0.33 m
Priv. Managed Reefs		2	Quad	Varies	9	0.33 m x 0.33 m
State Rest. Reefs		2	Quad	3	6	0.33 m x 0.33 m
Low Marsh	Marsh	3	Transect	3	9	10 m x 1 m
	Channel (edge, side & channel)		Transect	3	9	1-10 m (variable width)
	Broadwater interface		Transect	3	9	1-10 m (variable width)
High Marsh	Marsh	2	Transect	2	4	10 m x 1 m
	Channel (edge, side & channel)		Transect	2	4	1-10 m (variable width)
	Broadwater interface		Transect	2	4	1-10 m (variable width)
Flats-Marsh	Marsh	3	Transect	2	6	10 m x 1 m
	Flat		Transect	2	6	10 m x 1 m
	Interface between flat & marsh		Transect	2	6	1-10 m x 1-2 m
Low Tidal Flats		2	Transect	2	4	10 m x 2 m
High Tidal Flat		2	Transect	2	4	10 m x 2 m

*quad sizes: S=small (0.33 m x 0.33 m); M=medium (0.5 m x 0.50 m); L=large (1 m x 1 m)

Patch Reefs

Patch Reefs in each region were grouped into five size categories: 0-300 m^2, 300-600 m^2, 600-1200 m^2, 1200-2000 m^2 and > 2000 m^2. The number of reefs sampled within each size category and region was roughly proportional to the abundance of different sized reefs. Overall, this led to sampling 31, 12, 10, 4 and 3 reefs, respectively, in the above size categories. In regions 1 - 6, we sampled 9, 6, 6, 14, 15 and 10 randomly selected reefs, respectively. It is important to note that this regional stratification of *Patch Reef* samples was not used to statistically test for differences between regions, but simply to ensure that proportional samples were taken from throughout the study area and, therefore, provide a more accurate estimate of oyster abundance throughout the entire system.

Replicate quadrate samples were collected during low tide at each sample reef from randomly selected points within reef polygons. Sample points were selected in GIS using Hawth's Tools (Beyer 2004). Replicate quadrate samples numbering 3, 6, 9, 12 and 15 were taken from reefs falling in the five size classes above, respectively. The size of quadrates were based on the density of oysters found on-site in an effort to utilize the smallest size possible while still enumerating oysters when present. For example, when oyster density was extremely low, a 1 m^2 quadrate was employed and centered on the randomly chosen location. If density was high, a 0.1089 m^2 quadrate was utilized the same way. In these cases, we often still enumerated several hundred oysters per sample. Had we used a larger quadrate in these high density sites, several thousand individuals would need enumerating, resulting in significantly higher processing times, with little practical increase in accuracy. For reefs with an intermediate density, a 0.25 m^2 quadrate was utilized. A total of 342 quadrate samples were collected representing 49.5 m^2 of reef surface.

Once a quadrate was deployed, all live and box (i.e., dead with shells still articulated) oysters were collected to a depth of 15 cm or until anoxic conditions were observed. Samples were placed in mesh bags (<5 mm mesh size) and transported back to the laboratory. All live and box oysters in a sample were counted and shell height (i.e., longest hinge to lip distance) was measured to the nearest mm.

Other Reefs

Small Patch Reefs, *Privately Managed Reefs* and *State Restoration Reefs* were generally sampled in the same manner as described for *Patch Reefs* above. The major difference was that sample reefs were not chosen from every region and selections were not random, but subjectively chosen to be representative of the habitat category.

Three *Small Patch Reefs* were chosen (one from the area encompassed by regions 1 and 2 combined; one from 3 and 4; and one from 5 and 6) and 0.1089 m^2 quadrate samples were haphazardly collected from individual patches of oysters (Table 2). Oyster samples were then processed as described above.

Two *Privately Managed Reefs* and two *State Restoration Reefs* were sampled, processed as described above and compared to *Patch Reefs*. Again, we selected representative reefs and quadrate (0.1089 m^2) sampling locations. Since oyster densities on these habitats were generally consistent with *Patch Reefs* (see Results), which were sampled much more intensively, we limited sampling effort in order to concentrate on other habitats. Oyster samples were then processed as described above.

Fringing Reefs were divided into two size categories: large and small. One representative polygon in each region was selected for each size category. On large reefs, four quadrate samples of variable size were collected, while two were taken on small reefs (Table 2). All live and box oysters were enumerated *in situ* and the first 50 of each were measured to the nearest mm.

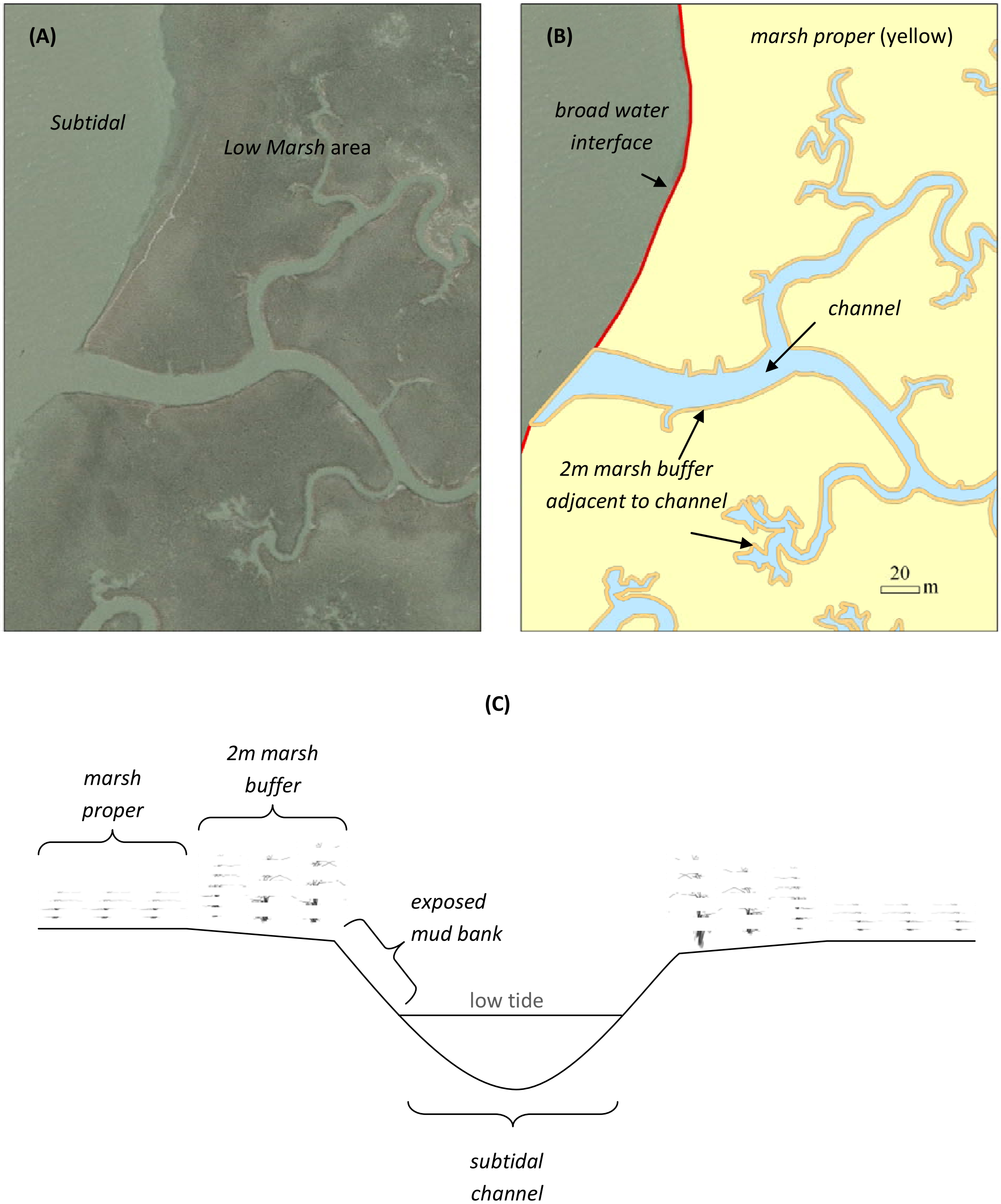
Flats & Marsh

Based on observations during mapping and sampling other habitats, it was apparent that both *High* and *Low Tidal Flats* contained very few, if any, oysters. However, instead of defaulting to a density estimate of zero, we decided to sample two representative areas of each via two replicate 10 m x 2 m transects (Table 2). Transects were haphazardly chosen and inventoried at low tide. All live and box oysters collected were counted and measured to the nearest mm.

Quantifying oyster abundances in marsh habitats posed a more complex challenge. Small channels that are located within these habitat polygons were not separately digitized, although they have the capacity to harbor oysters. We initially considered completely manually mapping this sub-habitat throughout the study area, but it quickly became obvious that it would be beyond the scope and logistics of the current project. Therefore, we chose to include this sub-habitat (along with several others) in a stratified sampling protocol. We selected two and three representative habitat polygons to sample for *High Marsh* and *Low Marsh*, respectively. Within each we sampled three strata: *marsh proper*, *channel* and *broad water interface* (areas where marsh was adjacent to large channels or bays mapped as *Subtidal Bottom* or adjacent to flats mapped as such; see Fig. 12 for an example). We further stratified *channel* sampling into (1) a 2-m marsh buffer adjacent to the channel, (2) the exposed mud bank and, (3) the shallow subtidal channel itself. We also further stratified the broad water interface into a 2-m marsh buffer adjacent to the broad water and the exposed mud bank. Transects of various dimensions (based on the oyster density encountered in the field) were then used the sample the various strata (Table 2). Details on how this sub-sampling was interpreted can be found below. All live and box oysters collected were counted and measured to the nearest mm.

Slight adjustments to this protocol were required for the *Flats-Marsh* habitat category. Three representative polygons were sampled in four strata: *marsh proper*, *flat proper* and the *marsh-flat interface*. Various sized transects were employed (Table 2) and all live and box oysters were counted and measured.

Figure 12. Example of sub-strata sampled within marsh habitats: (A) aerial image of a *Low Marsh* area, (B) the same area with sub-strata digitized in GIS and (C) a hypothetical channel cross section. See Methodology for details of how sub-strata were sampled.



Manmade Shoreline

Very little *Manmade Shoreline* was mapped relative to other potential oyster habitats. However, much of this shoreline has the potential to support high oyster densities. *Rip Rap* (both shell and non-shell) and *Bulkhead* shorelines were sampled using quadrates haphazardly allocated across the entire study area. Overall, thirty quadrates ranging in area from 0.1089-10.24 m^2 were sampled (size based on the actual band height of oysters; see Luckenbach and Ross 2007 for more details). All live and box oysters within quadrates were counted *in situ* and the first 50 encountered were measured to the nearest mm.

Habitat-specific Oyster Model

Oyster habitat maps and habitat-specific oyster demographics were combined into a simple, spatially-explicit model. This allowed a comparison of the relative importance of various habitats, an overall stock assessment for the study area, and a spatially-explicit GIS product showing how oysters were distributed throughout the study area. Oyster density and then size-specific data were used to model both numbers and dry tissue biomass (i.e., ash-free dry tissue weight) of oysters.

Density

Mean oyster density was calculated for *Patch Reefs* by region. This is the only habitat that has region-specific densities. For all other habitats, data were pooled for the entire study area to develop mean densities. For habitats divided into sub-strata (e.g. marsh categories), overall density was calculated using strata-specific density and the relative proportion of sub-strata within the habitat.

Dry Tissue Biomass

A sub-sample of oysters, covering the entire size range of those encountered in the field, collected in various habitats was used to develop size-biomass relationships. Shell height was measured to the nearest 0.1 mm. Oyster meats were completely shucked into individually labeled, pre-weighed aluminum pans and dried at 90 ºC for at least 48 hrs or until a constant weight was achieved. Tissues were then weighed to the nearest 0.001 g. Finally, the tissue samples were placed in a ~538º C muffle furnace for at least 5 hrs. They were then allowed to cool and were re-weighed to the nearest 0.001 g.

We developed separate shell height to biomass (ash-free dry tissue weight) relationships for each of the following habitat groupings: Flats (includes *High Intertidal Flats*, *Low Intertidal Flats* and *Flats-Marsh* habitats); Marsh (includes both *High* and *Low Marsh*); Patch Reefs (includes *Patch Reefs*, *Small Patch Reefs*, and *State Restoration Reefs*); *Privately Managed Reefs*; and *Fringing Reefs*. Best-fit power functions were applied to the data and the resulting equations were used to estimate biomass of individual oysters based on shell height. W then used size distributions and abundances to estimate dry tissue biomass within and across several habitats and region groupings, and for the entire oyster population throughout the region. Equations developed for *Patch Reefs* and *Fringing Reefs* were applied to non-shell *Rip Rap* and shell *Rip Rap* categories, respectively. Also, an equation developed from intertidal bulkheads in the Lynnhaven River during a previous study was applied to *Bulkheads* in our model.

Stock Assessment Abundance

Oyster abundance in terms of both the number of individuals and dry tissue biomass were calculated in GIS by multiplying the area (or length in the case of *Manmade Shorelines*) by oyster density estimates on a polygon-by-polygon basis. Overall study area abundance was estimated as:

$$\sum_{15}^{i=1} (\textit{Habitat Category Area}) * (\textit{Habitat-specific Oyster Density})$$

<u>GIS Product</u>

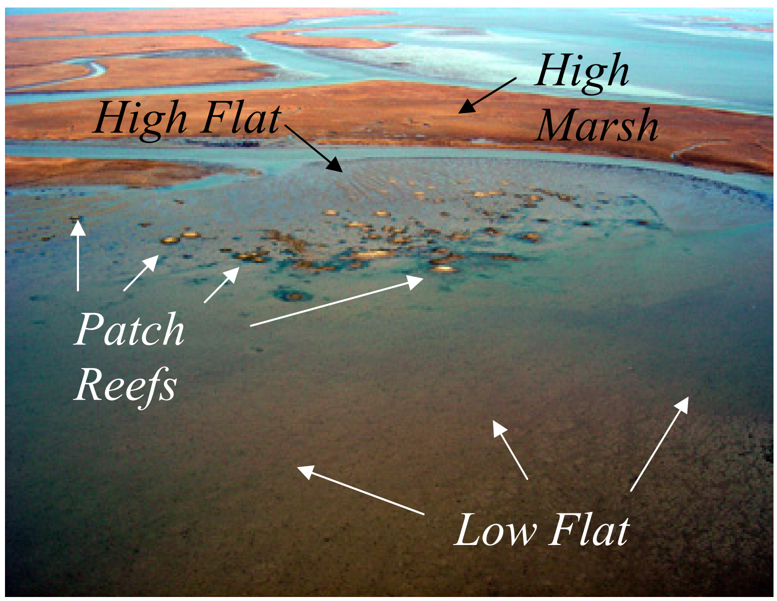
Regional stratification, habitat polygons and manmade shoreline (line features) were incorporated into ArcGIS (v. 9.2) as shape files projected in US State Plane Feet (Virginia South 4502, NAD83). Polygons from NWI data were extracted into GIS and modified according to the techniques described above. This includes a substantial modification of the attribute tables. In fact, these data are no longer recognizable as NWI data. Reef polygons identified from aerial over flights were manually “heads up” digitized in the most labor intensive part of the project. The GIS product accompanying this report includes extensive metadata (Appendix IV), but we recommend that this report be included along with the metadata in any distribution of the GIS product.

RESULTS

Habitat

Overall, 9,319 habitat polygons were delineated in this project along with 37.9 km of manmade shoreline features. The polygons cover 87,719 hectares (877 km^2 or 339 mi^2) of the seaside of Virginia’s Eastern Shore. Approximately 18,000 hectares (~21%) of this total was classified as *Subtidal Bottom* which we did not consider as suitable oyster habitat within the scope of this study.

Figure 13. Example of a common juxtaposition of varied oyster habitats. See Table 1 and the Methods section for detailed descriptions.



Terminology used to identify specific habitat categories was covered in the methodology section (including tidal inundation modifiers) and will follow names in Table 1. As mentioned previously, habitats were often encountered in complex juxtapositions (e.g. see Fig. 13).

In terms of aerial extent, *Low Tidal Flats* dominated the study area (39.9%) while *High Marsh* (20.9%) and *Subtidal Bottom* (20.7%) were also important (Table 3). Approximately 0.4% of the study area (377 hectares) was composed of the various reef categories.

Small Patch Reefs and *Patch Reefs* were dominant within the broad reef grouping (>80% combined, Table 4). *Privately Managed Reefs* and *Fringing Reefs* comprised 13.3% and 4.5% of this group, respectively. While we mapped only 2 hectares of *State Restoration Reefs*, we know that this is quite low. However, it was difficult to ascertain which reefs should be included in this category because locations have not been digitized to date. Those not grouped in that category are included in the Patch Reefs category. Features with *High*, *Medium* and *Low* cluster densities comprised 67%, 31% and 2% of the *Small Patch Reefs* category.

Table 3. Extent (hectares or km) and relative proportion for major oyster habitats mapped in this study.

Habitat Category	Total Area (Hectares)	Relative Proportion (%)
High Marsh	18,294	20.9
Low Marsh	11,862	13.5
Flats-Marsh	1,347	1.5
High Tidal Flats	2,698	3.1
Low Tidal Flats	34,961	39.9
Subtidal Bottom	18,180	20.7
All Reefs [a]	377	0.4
All Manmade Shoreline	37.9 [b]	n/a

[a] This includes *Patch*, *Small Patch*, *Fringing*, *State Restoration* and *Privately Managed* reefs (see Table 3 for details)
[b] In linear units of km, not hectares (see Table 4 for details)

Overall, 37.9 km of *Manmade Shorelines* were mapped. Bulkheads dominated these areas (73%) and mean contiguous stretches (136 m) tended to be much longer than the other *Manmade Shorelines* (Table 5). The area around the island of Chincoteague (Region 1) towards the northern end of the study area was found to have most of this type of habitat (29.7 km or 78%). Otherwise, most of the remainder was concentrated around several harbors.

Table 4. Total area, relative proportion within the reef category grouping and polygon summary statistics (n, mean and standard error) for oyster reef categories. Note that overall, these reef categories combined total ~ 0.4% of the total habitats mapped for this project (see Table 3).

Habitat Category	Total Area (Hectares)	Relative Proportion (%)	# Polygons	Mean Polygon Area (m^2)	SE Polygon Area (m^2)
Small Patch Reefs	176	46.7	265	6,637	1,359
Patch Reefs	132	35.0	2,939	448	16
Privately Managed Reefs	50	13.3	1,303	385	23
Fringing Reefs	17	4.5	289	583	49
State Restoration Reefs	2[a]	0.5	34	583	126

[a] Because locations of VMRC reefs have not been digitized to date, it was difficult to ascertain which reefs should be included in this category; therefore, this area may be substantially low with some grouped in the *Patch Reef* category above.

Table 5. Overall linear extent, relative proportion within the *Manmade Shoreline* category grouping and individual feature summary statistics (n, mean and standard error) for *Manmade Shoreline* categories.

Habitat Category	Total Length (km)	Relative Proportion (%)	# Features	Mean Feature Length (m)	SE Feature Length (m)
Bulkhead	27.9	73.6	205	136	22
Unknown	4.8	12.6	47	102	23
Rip Rap (non-shell)	3.9	10.2	57	68	8
Shell Rip Rap	1.3	3.5	16	83	18

Extensive *Low Tidal Flats* were the predominant habitat type from Hog Island Bay south, but they diminish in total area and dominance further north in the study area (Fig. 14). The prevalence of individual oyster *Patch Reefs* follows this general trend as well. North of Burton's Bay *High Marsh* habitat becomes more dominant (Fig. 14). Regional overviews follow with associated figures (See Appendices II & III for specific data).

In region 1 (Fig. 15), *Subtidal Bottom* that is generally fairly shallow predominates along with *High Marsh* and several extensive *Low Tidal Flat* areas. Substantial *Manmade Shoreline* was found associated with Chincoteague Island (including the causeway that provides vehicular access) and a residential development on the western side of Chincoteague Bay.

Region 2 (Fig. 16) tends to have relatively small coastal bays (which increase in size in a southerly direction) that are dominated by *Low Tidal Flats* and are separated by extensive areas of salt marsh of both tidal inundation regimes. *Patch Reefs* start to increase in number towards the southern portion of this region.

Region 3 encompasses Machipongo and Parting creeks (Fig. 17) and is dominated *High Marsh*, *Low Marsh* and *Flats-Marsh* assemblages and several areas of extensive flats that contain substantial *Patch Reefs*, largely privately managed for commercial purposes. Upland areas are typically in close proximity to *Subtidal Bottom* with relatively narrow marsh buffers. An area of manmade shoreline is concentrated at the town of Willis Wharf.

Figure 14. Potential oyster habitats mapped in GIS for the entire study area. See Table 1 and the Methods section for descriptions of habitat categories.

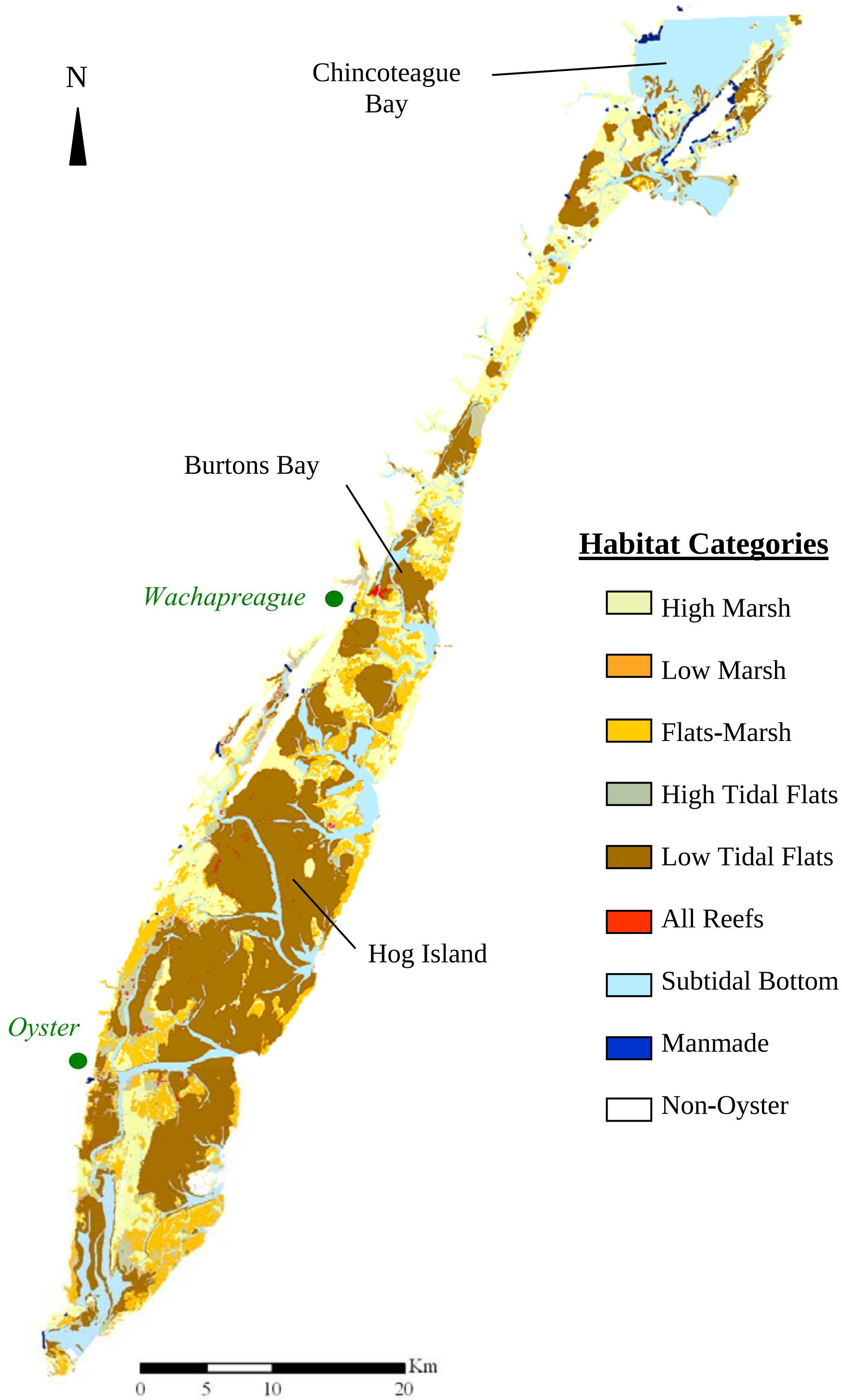


Figure 15. Potential oyster habitats mapped in GIS in the vicinity of Region 1. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.

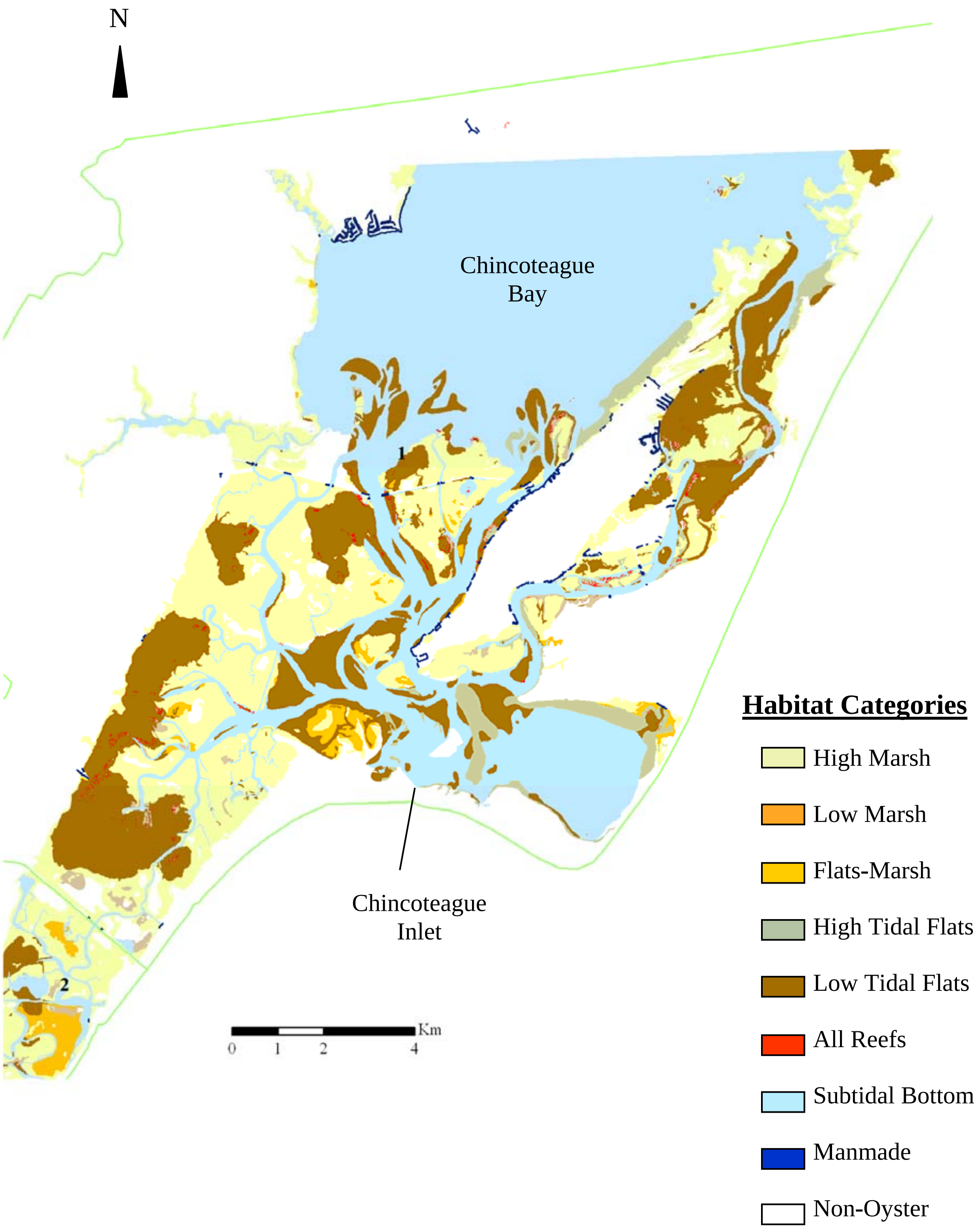


Figure 16. Potential oyster habitats mapped in GIS in the vicinity of Region 2. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.

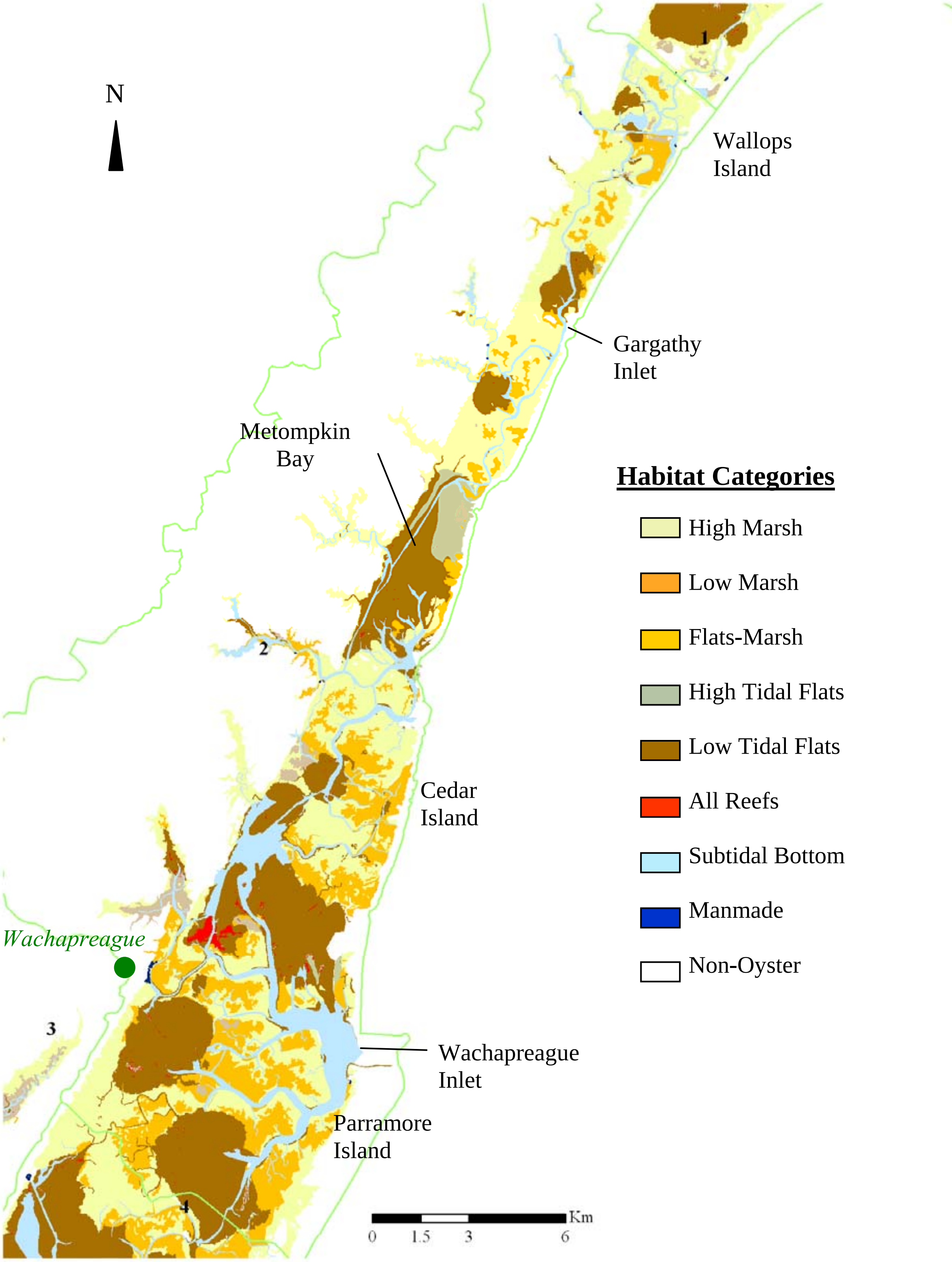
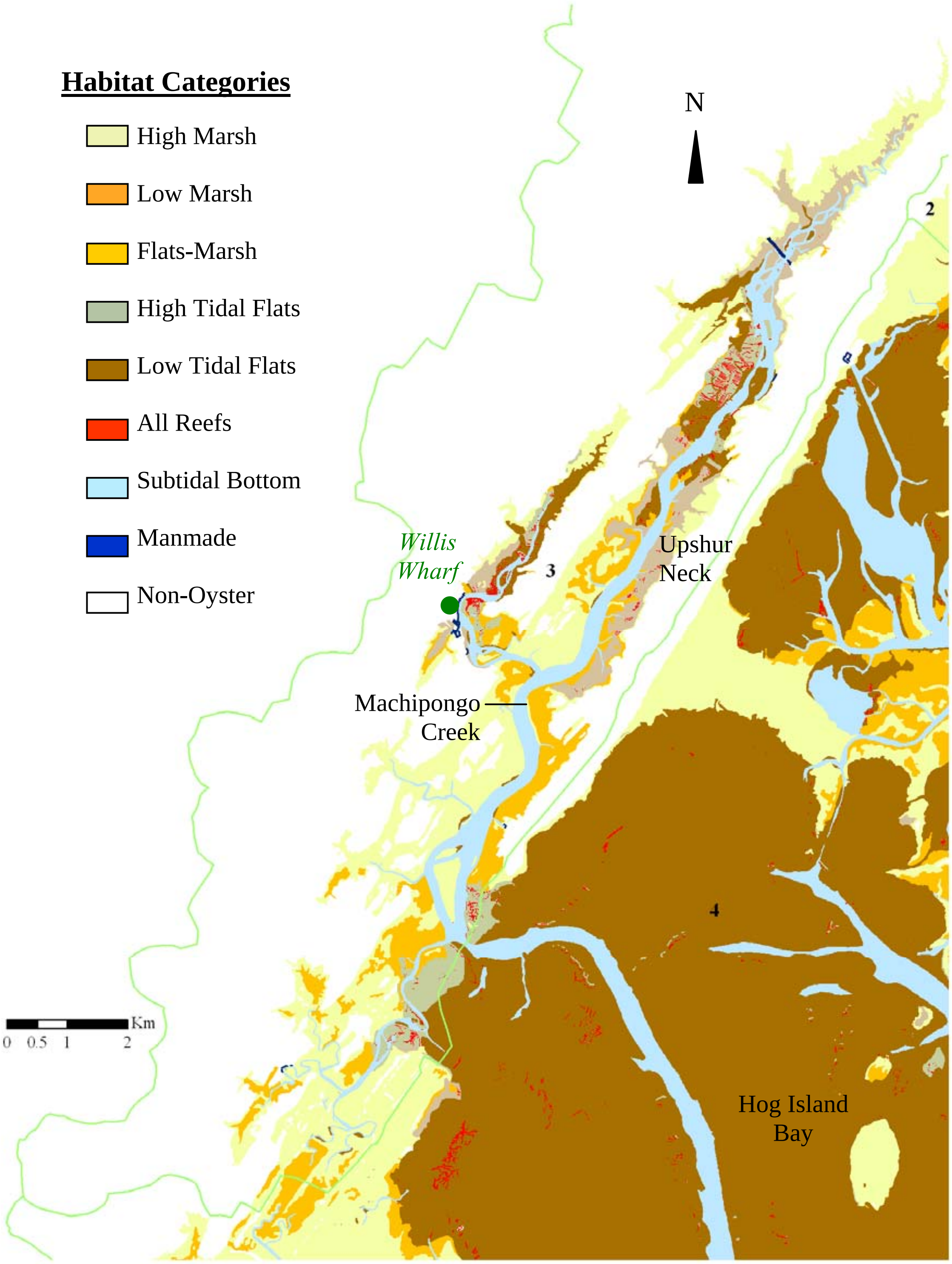


Figure 17. Potential oyster habitats mapped in GIS in the vicinity of Region 3. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.



Region 4 (Fig. 18) is dominated by Hog Island Bay and the *Low Tidal Flats* found in its vicinity. Major portions of these flats are rarely exposed (e.g. only during storm events). Scattered *Patch Reefs* were observed throughout the flats and marsh complexes the northern portion of the region, but concentrations shift westward towards the mainland as Hog Island Bay broadens to the southern portion.

Region 5 (Fig. 19) includes the extensive *High Tidal Flats* and *Low Tidal Flats* just north and south of the town of Oyster and Magothy Bay. Concentrations of *Patch Reefs* are found throughout both types of flats, although these diminish in the central and southern portions of Magothy Bay and around Fisherman's Island. A concentration of *Manmade Shoreline* was observed at Oyster Harbor.

Region 6 (Fig. 20) is dominated by the *Low Tidal Flats* of Cobb and South bays and the abundant *Low Marsh* on the west side of Smith Island. A large contiguous tract of *High Marsh* is located on the eastern and northern sides of Mockhorn Island. Although some scattered *Patch Reefs* were mapped throughout, the highest concentrations were associated with areas of marsh and flats near New Marsh, Man and Boy Marsh and Elkins/Eckichy Marsh.

Figure 18. Potential oyster habitats mapped in GIS in the vicinity of Region 4. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.

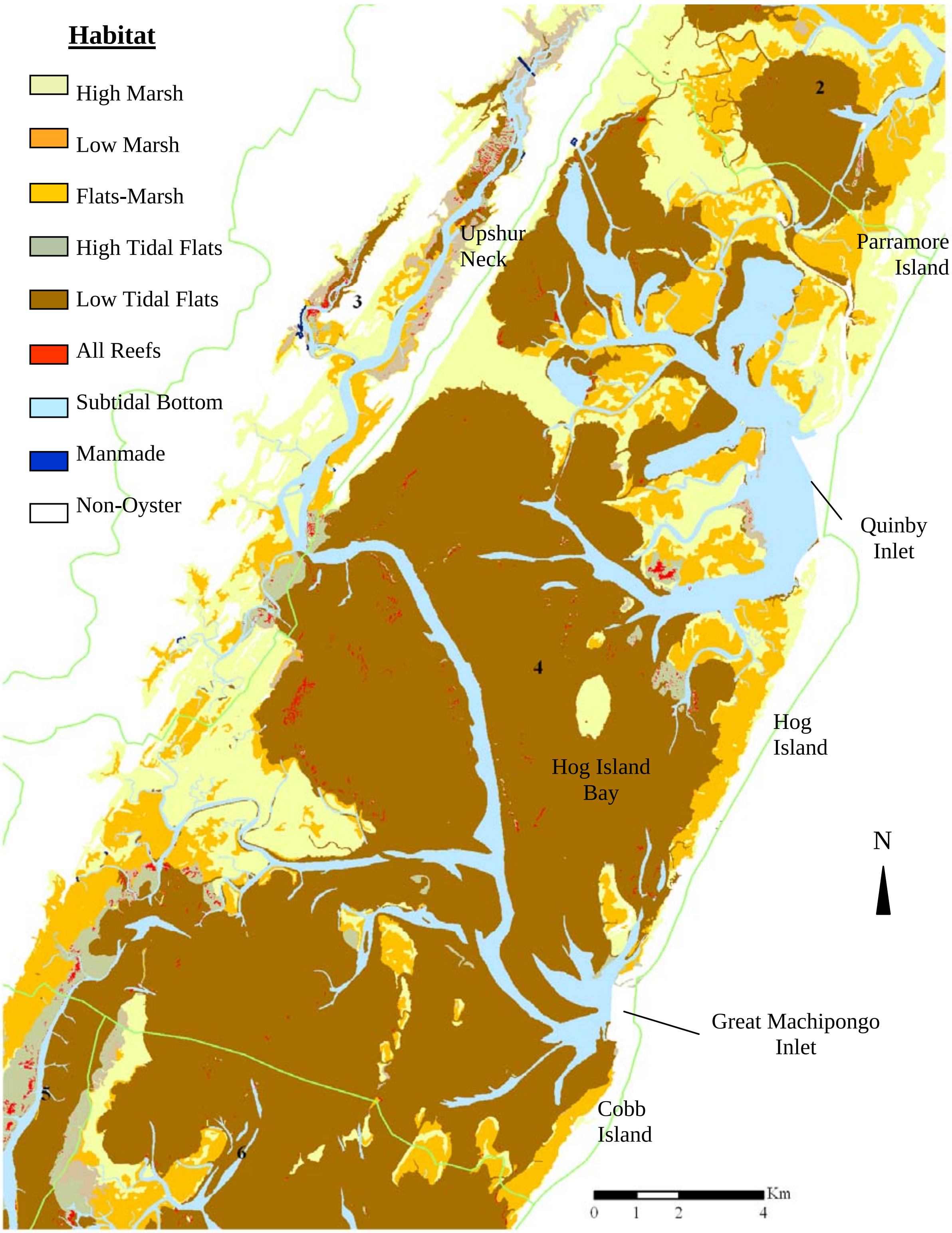


Figure 19. Potential oyster habitats mapped in GIS in the vicinity of Region 5. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.

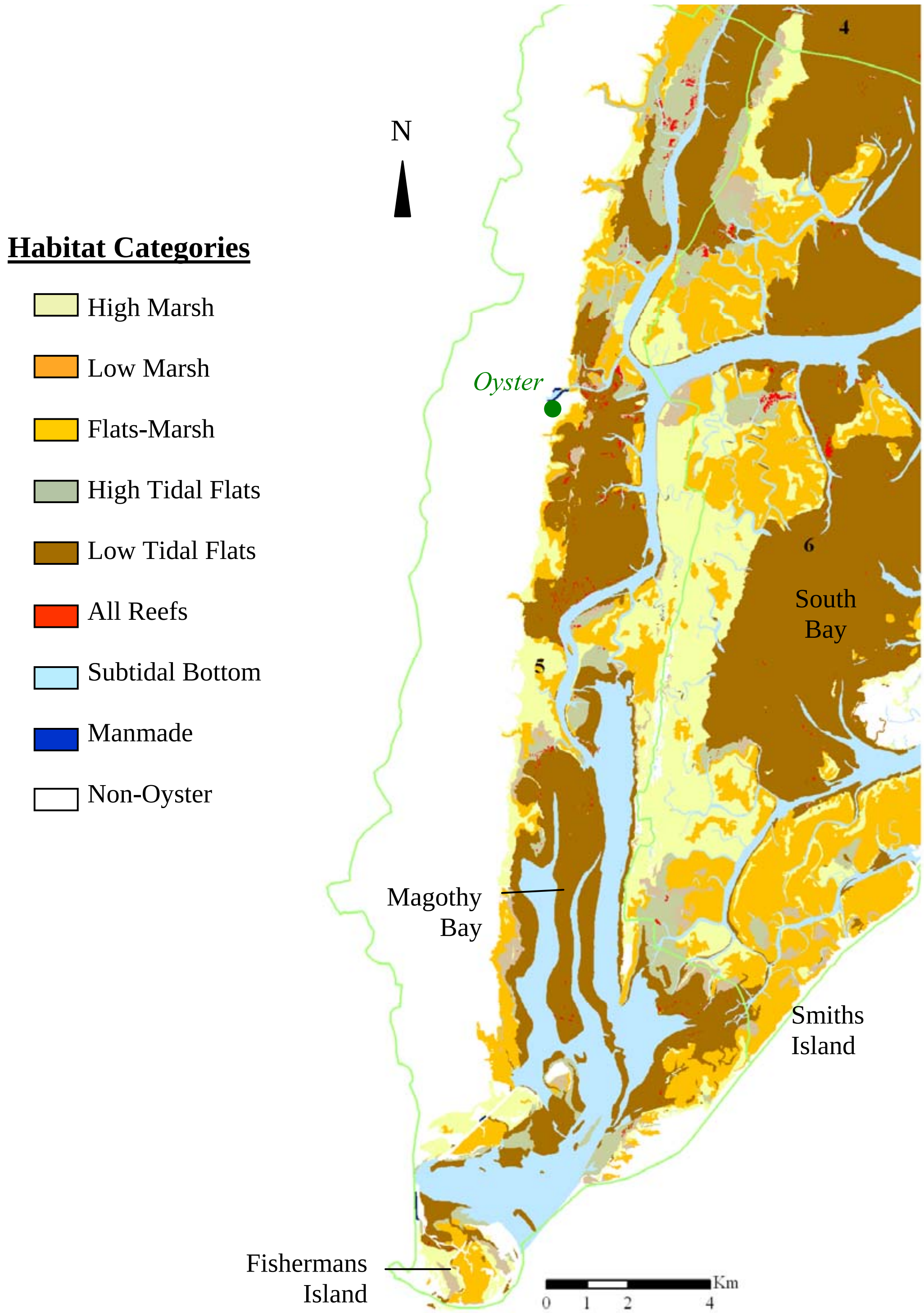
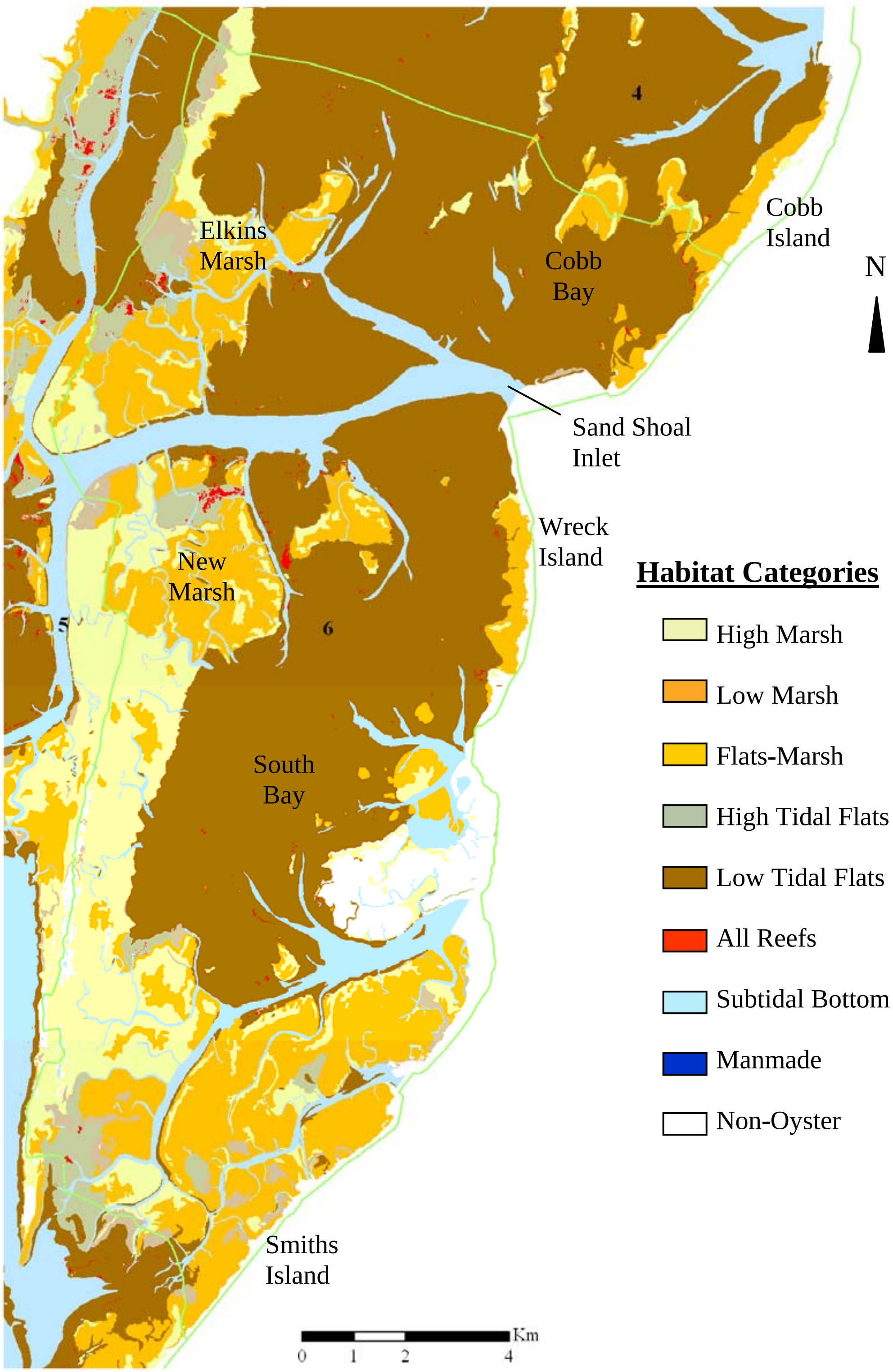


Figure 20. Potential oyster habitats mapped in GIS in the vicinity of Region 6. See Table 1 and the Methods section for descriptions of habitat categories and Figure 2 for regional stratification.



Oyster Demographics

Oyster sampling took place from November 30, 2007 to July 2, 2008. Overall, 45,994 and 11,370 live and box oysters, respectively, were counted and measured.

Habitat-specific Density and Size

Live oyster density ranged from 0.03 - 1,364 oysters/m^2 for non-manmade shoreline habitats and 363 - 927 oysters/linear m for *Manmade Shoreline* (Table 6). The highest densities were observed on the various reefs, especially *Patch Reefs*, *Privately Managed Reefs* and *State Restoration Reefs*. Marsh and flats habitats lower in the intertidal zone had higher oyster densities as well.

Box oyster densities ranged from 0.01-334 oyster/m^2 for non-manmade shoreline habitats that were sampled and 70-111 oysters/linear m for *Manmade Shoreline* (Table 6). Similar patterns were seen as described above for live oyster density.

Although we spread sampling throughout the study area for all habitats, we specifically stratified *Patch Reef* samples regionally as described previously. Live and box oyster density ranged from 477-1,364 oysters/m^2 and 143-334 oysters/m^2, respectively. The highest densities were seen in Regions 3 and 4 (Table 7).

Small Patch Reefs with a low, medium and high density of patches had live oyster densities of 210, 468 and 710 oysters/m^2, respectively; and box oyster densities of 49, 110 and 166 oysters/m^2, respectively. Developing sub-strata for marsh sampling proved very important in determining overall densities for those habitats. As expected much higher densities were observed in and adjacent to the small channels that bisect marsh, at the marsh open water interface and in areas where marsh and flats meet (e.g. see Table 8).

Table 6. Estimated live and box oyster densities (#/m^2) for all habitat categories included in this study (see Table 7 for densities on *Patch Reefs* by region and the Results text for *Small Patch Reefs* by patch density categories).

	Habitat	**Live Oyster Density (#/m^2)[a]**	**Box[b] Oyster Density (#/m^2)[a]**
Marsh	*High Marsh*	0.21	0.01
	Low Marsh	2.24	0.24
	Flats-Marsh	5.56	1.07
Tidal Flats	*High Tidal Flats*	0.03	0.13
	Low Tidal Flats	0.04	0.06
	Subtidal Bottom[c]	0	0
Reefs	*Patch Reefs*	477-1,364	143-334
	Small Patch Reefs	210-710	49-166
	Fringing Reefs	84	23
	State Restoration Reefs	543	181
	Privately Managed Reefs	889	173
Manmade Shoreline	*Bulkhead*	694	70
	Rip Rap (non-shell)	927	111
	Shell Rip Rap	363	85
	Unknown[d]	694	70

[a] Density units for all the *Manmade Shoreline* categories are #/linear m of shoreline as opposed to #/m^2
[b] Box oysters are dead, but with shell valves still articulated
[c] Densities for this category are assumed and were not measured within the scope of this study
[d] Data for *Bulkheads* used to estimate this category

Table 7. Estimated live and box oyster densities (#/m^2) on *Patch Reefs* for the six regions in this study.

Region	Live Oyster Density (#/m^2)	Box[a] Oyster Density (#/m^2)
1	801	239
2	639	143
3	1,364	334
4	1,342	328
5	848	217
6	477	148

[a] Box oysters are dead, but with shell valves still articulated

Table 8. Example of estimated live and box oyster densities (#/m^2) within sub-strata in a *Low Marsh* area. Relative proportion (% area) of sub-strata refers to this specific *Low Marsh* area only. See Methodology and Figure 13 for more details on sub-strata.

Sub-strata	%	Live Oyster Density (#/m^2)	Box[a] Oyster Density (#/m^2)
Marsh Proper	68.8	0.47	0
Channel Buffer (2m marsh adjacent to small channels)	10.3	0.63	0
Channel (mud bank exposed at low tide and subtidal area)	19.8	0.19	0.02
Broad Water Interface (2m marsh & bank exposed at low tide adjacent to *Subtidal* or *Flats* habitats)	1.0	61.12	5.40
Overall Weighted Estimate	*100*	*1.03*	*0.06*

[a] Box oysters are dead, but with shell valves still articulated

Mean live and box oyster shell height ranged from 27-43 mm and 39-51 mm, respectively (Table 9). Size frequency distributions of live oysters tended were skewed to smaller sizes (especially those < 50 mm) for most habitats, generally reflecting a high abundance of 0 – 1year class oysters (Fig. 21). Box oyster distribution shifted slightly towards larger sizes for each category (Fig. 22).

Table 9. Number of oysters sampled and mean (± SE) shell height for live and box oysters for all habitat categories included in this study.

		Live Oyster Shell Height (mm)		Box[a] Oyster Shell Height (mm)	
	Habitat	**n**	**Mean (SE)**	**n**	**Mean (SE)**
Marsh	*High Marsh*	148	36 (2)	29	46 (5)
	Low Marsh	1,735	31 (1)	387	46 (2)
	Flats-Marsh	731	41 (1)	182	53 (2)
Tidal Flats	*High Tidal Flats*	2	35 (14)	10	41 (5)
	Low Tidal Flats	3	32 (2)	5	48 (8)
Reefs	*Patch Reefs*	39,164	27 (0.1)	9,748	39 (0.2)
	Small Patch Reefs	1,602	36 (1)	374	48 (1)
	Fringing Reefs	339	30 (1)	164	44 (2)
	State Restoration Reefs	355	42 (1)	118	50 (2)
	Privately Managed Reefs	618	38 (1)	107	51 (2)
Manmade Shoreline	*Bulkhead*	968	35 (1)	178	42 (1)
	Rip Rap (non-shell)	251	36 (1)	54	39 (2)
	Shell Rip Rap	78	43 (2)	14	46 (3)
	Unknown[b]	.	.	.	.

[a] Box oysters are dead, but with shell valves still articulated.
[b] This category not sampled, but in subsequent models values from the *Bulkhead* category are used for this category.

Figure 21. Size distribution (shell height, mm) of live oysters for several habitat category groupings with the number of individual oysters sampled for each noted in the upper right hand corner of each graph.

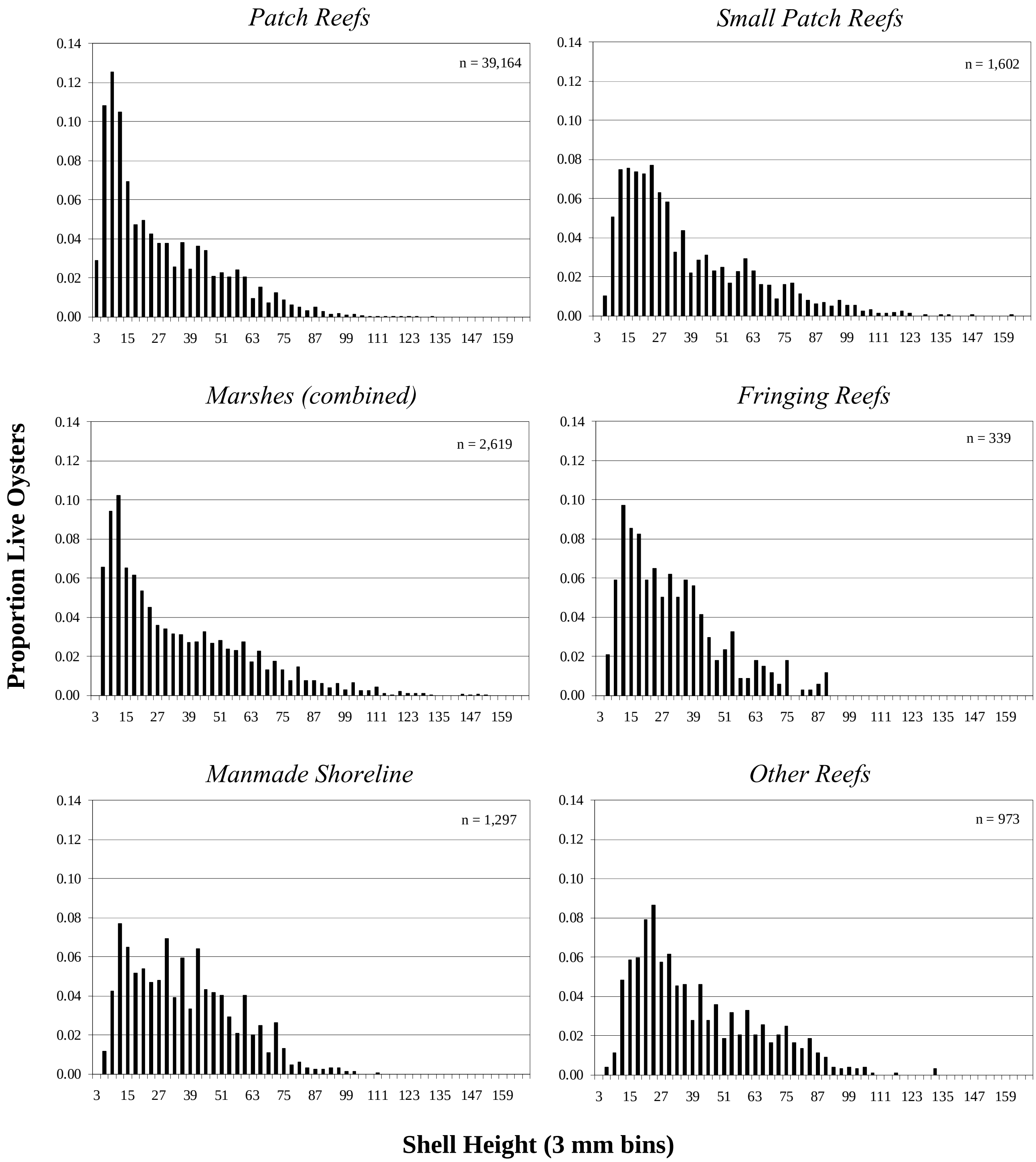
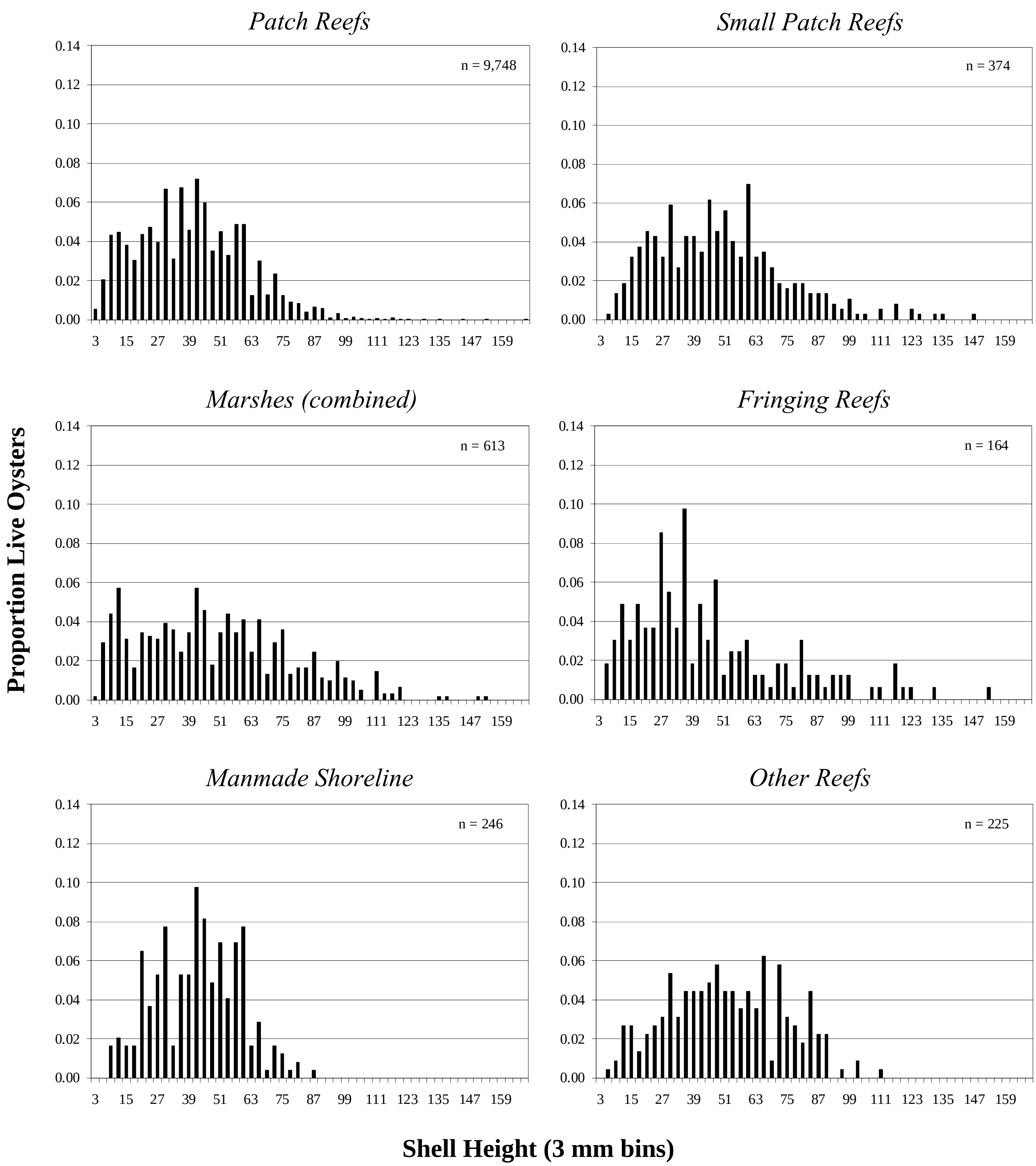


Figure 22. Size distribution (shell height, mm) of box oysters for several habitat category groupings with the number of individual oysters sampled for each noted in the upper right hand corner of each graph.



Biomass relationships

We estimated dry tissue biomass density (g/m^2) based on individual oyster shell height and size-dry tissue biomass equations generated for habitat groupings (Table 10). Mean individual oyster biomass ranged from 0.06-0.33 g (Table 11). The lowest and highest individual oyster biomasses were measured from *Low Tidal Flats* and *Bulkheads*, respectively. Biomass density ranged from <0.01 g/m^2 on tidal flats to ~100 g/m^2 on *Patch Reefs* and *Small Patch Reefs* (Table 11).

Table 10. Shell height-dry tissue biomass relationships used for this study. Equations and R^2 values were derived from best-fit power function regressions (where x=shell height [mm] and y=dry tissue biomass [g]).

Habitat	Size-Biomass Relationship Used	Equation (x=shell height, mm)	R^2
High Marsh *Low Marsh*	*High* & *Low Marsh* pooled data	$y=0.000007*x^{2.67}$	0.89
Flats-Marsh *High Tidal Flats* *Low Tidal Flats*	*Flats-Marsh* data	$y=0.000009*x^{2.54}$	0.94
Patch Reefs *Small Patch Reefs* *State Restoration Reefs*	*Patch, Small Patch and State Restoration Reef* pooled data	$y=0.00001*x^{2.45}$	0.90
Fringing Reefs	*Fringing Reefs*	$y=0.000005*x^{2.79}$	0.77
Privately Managed Reefs	*Privately Managed Reefs*	$y=0.000009*x^{2.59}$	0.87
Bulkhead *Unknown*[b]	*Bulkhead* (from Lynnhaven River)[a]	$y=0.00004*x^{2.41}$	0.74
Rip Rap (non-shell)	*Patch, Small Patch and State Restoration Reef* pooled data	$y=0.00001*x^{2.45}$	0.90
Shell Rip Rap	*Fringing Reefs*	$y=0.000005*x^{2.79}$	0.77

[a] Regressions developed using oyster on bulkheads in the Lynnhaven R. (Luckenbach and Ross, 2006)
[b] Data for *Bulkheads* used to estimate this category

Table 11. Mean (± SE) estimated individual oyster dry tissue biomass (g) and estimated dry tissue biomass density (g/m^2) for all habitat categories included in this study (see Table 12 for densities on *Patch Reefs* by region and the Results text for *Small Patch Reefs* by patch density categories).

	Habitat	Individual Oyster Dry Tissue Biomass (g)	Oyster Dry Tissue Biomass Density (g/m^2)[a]
Marsh	*High Marsh*	0.19 (0.03)	0.04
	Low Marsh	0.18 (0.01)	0.4
	Flats-Marsh	0.23 (0.01)	1.3
Tidal Flats	*High Tidal Flats*	0.10 (0.08)	0.003
	Low Tidal Flats	0.06 (0.01)	0.002
	Subtidal Bottom[b]	.	0
Reefs	*Patch Reefs*	0.07 (0.001)	33.9-96.8
	Small Patch Reefs	0.14 (0.02)	29.8-100.8
	Fringing Reefs	0.14 (0.01)	12.0
	State Restoration Reefs	0.15 (0.01)	79.3
	Privately Managed Reefs	0.21 (0.01)	184.0
Manmade Shoreline	*Bulkhead*	0.33 (0.01)	230
	Rip Rap (non-shell)	0.10 (0.01)	92
	Shell Rip Rap	0.25 (0.03)	90
	Unknown[c]	.	230

[a] Density units for all the *Manmade Shoreline* categories are g/linear m of shoreline as opposed to g/m^2
[b] Densities for this category are assumed and were not measured within the scope of this study
[c] Data for *Bulkheads* used to estimate this category

Although we spread sampling throughout the study area for all habitats, we specifically stratified *Patch Reef* samples regionally as described previously. Oyster biomass density ranged from 34 - 97 oysters/m^2 across these regions, with the highest densities in Regions 3 and 4 (Table 12). *Small Patch Reefs* with a low, medium and high density of patches had oyster biomass densities of 30, 66 and 101 g/m^2, respectively.

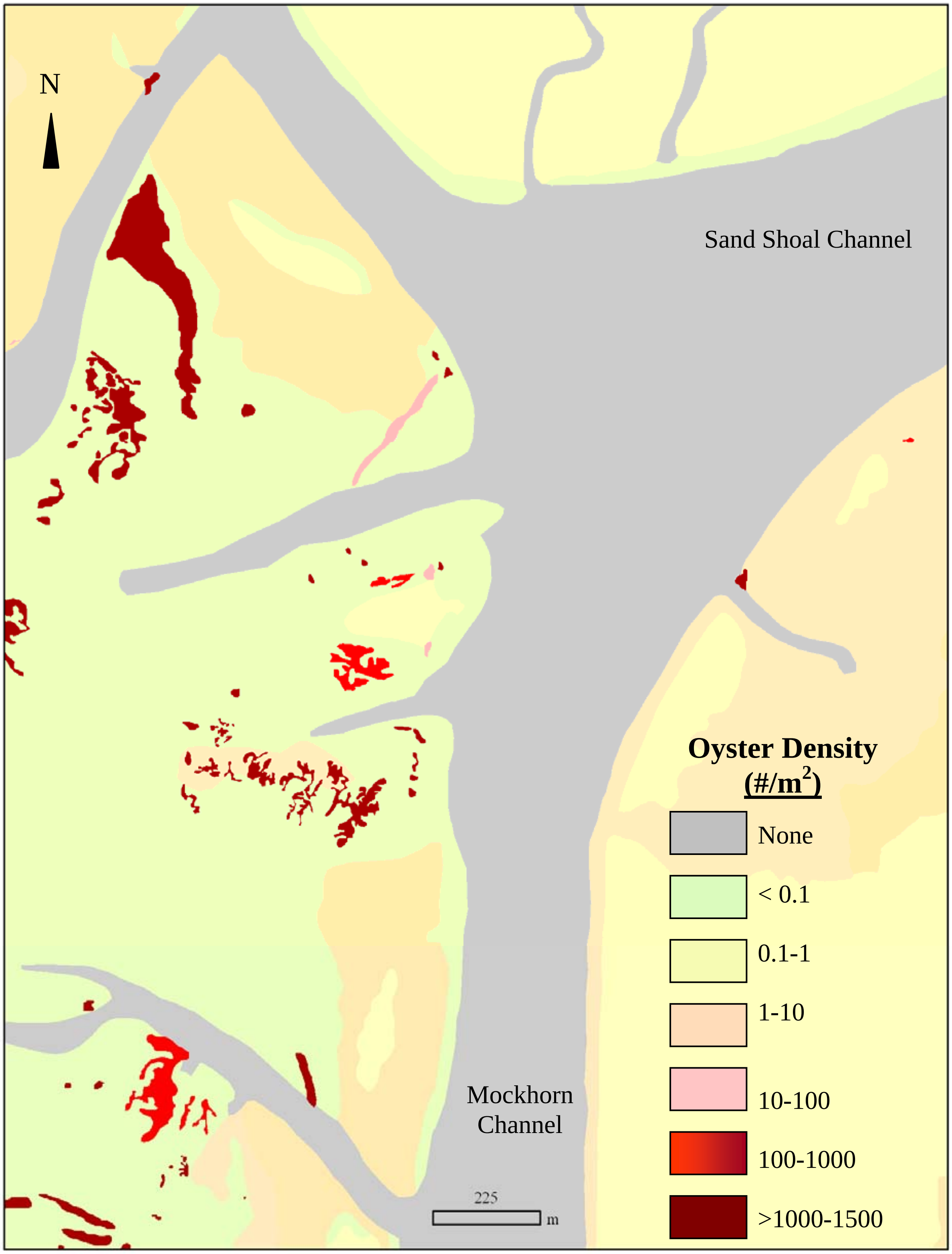
Table 12. Estimated oyster dry tissue biomass density (g/m^2) on *Patch Reefs* for the six regions.

Region	**Oyster Dry Tissue Biomass Density (g/m^2)**
1	57
2	45
3	97
4	95
5	60
6	34

Spatial distribution

The spatial distribution of live oysters throughout the study area is one of the most important products of this study. Fully exploring this distribution requires utilizing the accompanying GIS product. Here we present one example area for descriptive purposes (Fig. 23). This plot of an area near Oyster, VA was exported from ArcGIS and is similar in nature to the previous habitat distribution plots (see Figs. 15 - 20), except habitat-specific oyster density (#/m^2) estimates were used (as reported in Tables 6 and 7). Although this is one example of the potential GIS products, other metrics can be evaluated, including incorporation into various potential geospatial analyses.

Figure 23. Habitat-based oyster density distribution near Oyster, VA and mapped in GIS to provide an example of one of the final GIS products of this study.



Overall stock assessment

Habitat-specific oyster density estimates were combined with the aerial footprint of those habitats to produce estimates of the total number of oyster within the study area and by habitat. The results indicate that over 3.2 billion oysters with a dry tissue biomass of 419,700 kg are found in the study area. *Reef* habitats contain 87% of these oysters with ~12% found in the various *Marsh* habitats (Table 13). Accordingly, *Reef* habitats contain 81% of the oyster dry tissue biomass with > 15% found in the various *Marsh* habitats (Table 14). Over 1 billion oysters were estimated to inhabit *Patch Reefs* and *Small Patch Reefs* (Table 15). These two habitats account for 72% and 58% of oysters and dry tissue biomass, respectively (Table 15). Overall, 23.8 million oysters containing 7,100 kg of dry tissue biomass are estimated to inhabit *Manmade Shoreline* (Tables 13 & 14). Most of these are found on *Bulkheads* (Table 16).

Table 13. Estimated total live oyster abundance (#) and relative proportion of population (%) for major oyster habitats mapped in this study.

Habitat Category	**Live Oyster Abundance (millions)**	**Relative Proportion (%)**
High Marsh	38.4	1.2
Low Marsh	265.7	8.3
Flats-Marsh	74.9	2.3
High Tidal Flats	0.8	<0.1
Low Tidal Flats	14.0	0.4
Subtidal Bottom	0	0
All Reefs [a]	2,799.7	87.0
All Manmade Shorelines	23.8	0.7
Total	3,217.4	

[a] Includes *Patch*, *Small Patch*, *Fringing*, *State Restoration* and *Privately Managed* reefs

Table 14. Estimated total live oyster dry tissue abundance (kg) and relative proportion of the population (%) for major oyster habitats mapped in this study.

Habitat Category	Live Oyster Dry Tissue Biomass (thousands kg)	Relative Proportion (%)
High Marsh	7.3	1.7
Low Marsh	47.3	11.3
Flats-Marsh	17.5	4.2
High Tidal Flats	0.1	<0.1
Low Tidal Flats	0.9	0.2
Subtidal Bottom	0	0
All Reefs [a]	339.5	80.9
All Manmade Shoreline	7.1	1.7
Total	419.7	-

[a] This includes *Patch*, *Small Patch*, *Fringing*, *State Restoration* and *Privately Managed* reefs

Table 15. Total live oyster abundance (# and dry tissue biomass) and relative proportion (%) of the overall oyster population for different *Reef* categories.

Habitat Category	Abundance (millions)	Relative Proportion (%)	Dry Tissue Biomass (thousands of kg)	Relative Proportion (%)
Small Patch Reefs	1,101.9	34.2	156.5	37.3
Patch Reefs	1,226.6	38.1	87.1	20.7
Privately Managed Reefs	446.4	13.9	92.4	22.0
Fringing Reefs	14.2	0.4	2.0	0.5
State Restoration Reefs[a]	10.8	0.3	1.6	0.4

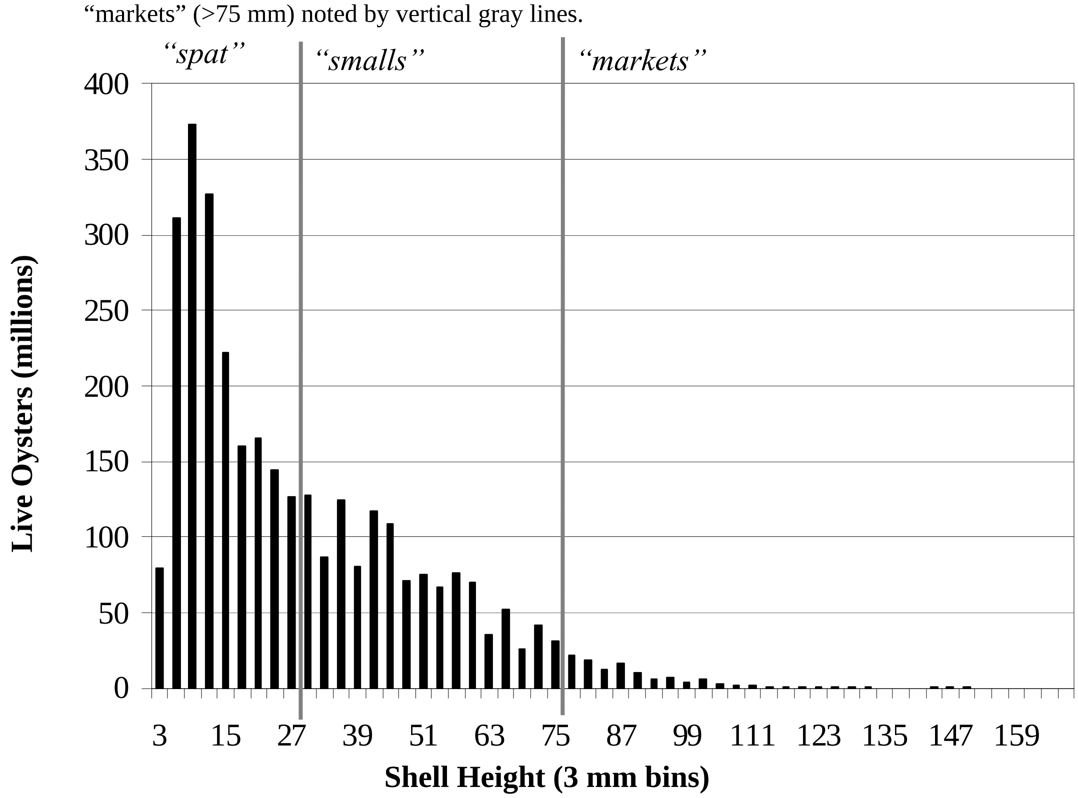
[a] Because locations of VMRC reefs have not been digitized to date, it was difficult to ascertain which reefs should be included in this category; therefore, this area may be substantially low with some grouped in the *Patch Reef* category above.

Table 16. Total live oyster abundance (# and dry tissue biomass) and relative proportion of the overall oyster population for different *Manmade Shoreline* categories.

Habitat Category	Abundance (millions)	Relative Proportion (%)	Dry Tissue Biomass (thousands of kg)	Relative Proportion (%)
Bulkhead	16.9	0.5	5.6	1.3
Unknown	3.1	0.1	1.0	0.2
Rip Rap (non-shell)	3.5	0.1	0.4	0.1
Shell Rip Rap	0.3	<0.1	0.1	<0.1

The overall estimated size distribution for the entire population in the study area reflects the habitat-specific size distributions (Fig. 21), with 1.9 billion (60%) of these oysters expected to be "spat" (i.e. oysters that settled during the summer of 2007; Fig. 24). Our data indicate that 147 million (5%) "market-sized" oysters (i.e. >75 mm) are spread throughout the study area (Figure 24).

Figure 24. Estimated total oyster abundance for entire study area by shell height (mm) with standard state stock assessment size categories of "spat" (<35 mm), "smalls" (35-75 mm) and "markets" (>75 mm) noted by vertical gray lines.



DISCUSSION

This study provides the first quantitative assessment of oyster population abundance on a region wide scale in the coastal bays on the seaside of Virginia's Eastern Shore. Our estimate of 3.2 billion oysters in this region exceeds the most recent population estimate of 1.8 billion oysters for the entire Virginia portion of Chesapeake Bay produced by the VIMS Chesapeake Bay Oyster Population Estimate (CBOPE: http://web.vims.edu/mollusc/cbope/VAPDFfiles/VABasin2006.pdf). At the time of our sampling, Dec. 2007 – June 2008, the oyster population was comprised of a wide range of sizes representing several year classes. The most abundant size class of oyster were those categorized as "spat" that measured <35 mm and are young-of-the-year that settled during the summer of 2007. Over 1 billion oysters are estimated to fall within the "small" category (35 – 75mm in shell height) and likely represent oysters between 1 and 2 years old in most cases. Our estimates also include nearly 150 million oysters in the "market-size" category. We note also that these estimates do not account for the numbers of oysters that were removed by legal and illegal harvest prior to and during our survey period. Perhaps more important than the fisheries size class designations is the fact that the size frequency distribution presented in Fig. 24 is one that suggests a self-sustaining growing population. Large numbers of recruits and reasonably good survival to reproductive age (which occurs well before oysters attain 75 mm) are indications that, if suitable habitat is available, the population has a significant potential to expand.

It is interesting to note that the dominance of *Patch Reefs*, in terms of oyster abundance, is similar to what we observed during a similar evaluation in the Lynnhaven River basin, which is a small tidal tributary near the mouth of Chesapeake Bay. In the Lynnhaven basin, like the seaside of the Eastern Shore, the majority of oysters are located in the intertidal zone. Oyster recruitment rates in both systems have been relatively high in recent years. Based on this previous study and our anecdotal observations, we made a decision to focus oyster sampling effort on *Patch Reefs*, and it appears this was important since nearly 90% of oysters were found within that habitat.

Although we are confident in the rigor of our mapping techniques and population estimates, there are several limitations to our study design that deserve discussion. This study focused entirely on intertidal oyster habitats; therefore, no subtidal habitats were included in our mapping or sampling. While there are undoubtedly some subtidal oysters present in this area, as with other high salinity areas of the lower Middle and South Atlantic coasts of the U.S., *C. virginica* in this area occurs predominantly in the intertidal zone (Coen et al., 1999; Coen and Grizzle, 2007), where the lower limit of its distribution is determined by predation and competition (Galtsoff and Luce, 1930; Chestnut and Fahy, 1952; Dame, 1979; Ortega, 1981; O'Beirn et al., 1996) and the upper limit by physiological tolerance of exposure (Nichy and Menzel, 1967; Michener and Kenny, 1991; Roegner and Mann, 1995; Shumway, 1996). Furthermore, of the intertidal habitats studied, *Fringe Reefs* (especially those <30 m^2) were likely underrepresented in our mapping. They were included in the marsh habitats when encountered during oyster sampling, but small fringing reefs along narrow channels may be important habitat that was under sampled in our study and should be a target of future monitoring.

We restricted oyster sampling to a period from December 2007 to June 2008 in an effort to evaluate every region after recruitment had occurred during the summer/fall 2007 and before settlement began during summer 2008. In doing so, we have avoided a population estimate that includes even higher numbers of recent recruits. Importantly, our assessment provides only a "snapshot" of the oyster population in the region. Intra- and inter-annual variation in recruitment dynamics can lead to highly variable oyster population size depending upon when samples are collected. The population assessment conducted here provides a benchmark against which to compare future stock assessments on regional or local scales.

Mapping and quantifying the oyster population with high a resolution over a scale as large as the seaside of Virginia's Eastern Shore required some practical compromises. For example, we started with the National Wetlands Inventory habitat maps and refined its categories based on aerial over flights and aerial imagery. The alternative of building this data from the "ground up" with oyster populations in mind might have been preferable, but was impractical with the resources available. Future focus on refining delineations of these habitats would be useful.

These limitations notwithstanding, the spatially-explicit oyster population GIS product developed through this work provides a valuable tool for guiding fisheries resource management and restoration activities for oysters in this region. We suggest that future efforts build on this product by refining specific habitat designations on smaller spatial scales. This would allow for refinements in habitat-specific oyster density estimates and improve the overall oyster population estimate. Ultimately, the usefulness of this product lies in integrating it with other GIS layers (e.g., hydrological, water quality, disease distributions, recruitment rates) to elucidate the factors affecting oyster distribution and abundance throughout the region. We recommend that it serve as a baseline against which to measure the success of local restoration efforts and evaluate region-wide changes in *C. virginica* populations related to such factors as fishing pressure, disease dynamics and climate change.

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LIST OF APPENDICES

APPENDIX I. National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report. Note that Project Group Code and Cat # are ESL coding that can be found in the final GIS products.

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2US2P	YES	INTER	UNC_SHORE	HIGH_INT	FLAT_H	4
E2USP	YES	INTER	UNC_SHORE	HIGH_INT	FLAT_H	4
E2US2M	YES	INTER	UNC_SHORE	LOW_INT	FLAT_LM	3
E2US2N	YES	INTER	UNC_SHORE	MID_INT	FLAT_LM	3
E2USM	YES	INTER	UNC_SHORE	LOW_INT	FLAT_LM	3
E2USN	YES	INTER	UNC_SHORE	MID_INT	FLAT_LM	3
E2US2U	YES	INTER	UNC_SHORE	UNK_INT	FLAT_UNK	2
E2USU	YES	INTER	UNC_SHORE	UNK_INT	FLAT_UNK	2
E2US/EM1N	YES	INTER	UNC_SHORE	MID_INT	FLATMARS	5
E2US/EM2N	YES	INTER	UNC_SHORE	MID_INT	FLATMARS	5
E2US/RF2N	YES	INTER	UNC_SHORE	MID_INT	FLATMARS	5
E2US1/EM1N	YES	INTER	UNC_SHORE	MID_INT	FLATMARS	5
E2US2/EM1N	YES	INTER	UNC_SHORE	MID_INT	FLATMARS	5
E2US2/EM1P	YES	INTER	UNC_SHORE	HIGH_INT	FLATMARS	5
E2US2/EM1U	YES	INTER	UNC_SHORE	UNK_INT	FLATMARS	5
E2US2/RF2N	YES	INTER	UNC_SHORE	MID_INT	FLATREEF	6
E1UBK6h	YES	SUB	UNC_BOT	SUB	IMPOUND	7
E2AB3K6h	YES	INTER	AQ_BED	ARTIFIC	IMPOUND	7
E2EM1P	YES	INTER	EMERGENT	HIGH_INT	MARSH_H	10
E2EM1/AB6N	YES	INTER	EMERGENT	MID_INT	MARSH_LM	9
E2EM1/ABN	YES	INTER	EMERGENT	MID_INT	MARSH_LM	9

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2EM1/US2N	YES	INTER	EMERGENT	LOW_INT	MARSH_LM	9
E2EM1N	YES	INTER	EMERGENT	MID_INT	MARSH_LM	9
E2EM1U	YES	INTER	EMERGENT	UNK_INT	MARSH_UN	8
E2RF2/USN	YES	INTER	REEF_UNK	MID_INT	REEF_NWI	12
E2RF2N	YES	INTER	REEF_UNK	MID_INT	REEF_NWI	12
E2RF2Nr	YES	INTER	REEF_UNK	MID_INT	REEF_NWI	12
E2RFM	YES	INTER	REEF_UNK	LOW_INT	REEF_NWI	12
E2RFN	YES	INTER	REEF_UNK	MID_INT	REEF_NWI	12
E1UB4L	YES	SUB	UNC_BOT	SUB	SUB_UBOT	11
E1UBL	YES	SUB	UNC_BOT	SUB	SUB_UBOT	11
E1UB4K6h	NO	SUB	NON_OYS		NON_OYS	0
E1UB4L6	NO	SUB	NON_OYS		NON_OYS	0
E1UBK6x	NO	SUB	NON_OYS		NON_OYS	0
E1UBL6	NO	SUB	NON_OYS		NON_OYS	0
E1UBL6x	NO	SUB	NON_OYS		NON_OYS	0
E1UBLh	NO	SUB	NON_OYS		NON_OYS	0
E1UBLx	NO	SUB	NON_OYS		NON_OYS	0
E2AB3/EM1K6h	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/3P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/3P6	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/AB3K6h	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/FO4P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/FO4P6	NO	INTER	NON_OYS		NON_OYS	0

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2EM1/FO4Pd	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS1P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS1P6	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS1Ph	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3K6h	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3P6	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3Pd	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3Ph	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS3Ps	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/SS4P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1/US2P	NO	INTER	NON_OYS		NON_OYS	0
E2EM1K6h	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Nh	NO	INTER	NON_OYS		NON_OYS	0
E2EM1P6	NO	INTER	NON_OYS		NON_OYS	0
E2EM1P6d	NO	INTER	NON_OYS		NON_OYS	0
E2EM1P6h	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Pd	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Ph	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Phs	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Ps	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Uh	NO	INTER	NON_OYS		NON_OYS	0
E2EM1Uhs	NO	INTER	NON_OYS		NON_OYS	0

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2EM1Ux	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/EM1P	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/EM1P6	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/SS1P	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/SS1P6	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/SS3P	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/SS3P6	NO	INTER	NON_OYS		NON_OYS	0
E2FO4/SS4P	NO	INTER	NON_OYS		NON_OYS	0
E2FO4P	NO	INTER	NON_OYS		NON_OYS	0
E2FO4P6	NO	INTER	NON_OYS		NON_OYS	0
E2FO4R	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/3P	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/3P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/EM1P	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/EM1P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/EM1P6d	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/EM1Pd	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/EM1R	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/FO4N	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/FO4P	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/FO4P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS1/US2P	NO	INTER	NON_OYS		NON_OYS	0
E2SS1K6h	NO	INTER	NON_OYS		NON_OYS	0

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2SS1P	NO	INTER	NON_OYS		NON_OYS	0
E2SS1P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS1P6h	NO	INTER	NON_OYS		NON_OYS	0
E2SS2P	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/1P	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/1P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/EM1P	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/FO4P	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/FO4P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS3/FO4Ps	NO	INTER	NON_OYS		NON_OYS	0
E2SS3K6h	NO	INTER	NON_OYS		NON_OYS	0
E2SS3P	NO	INTER	NON_OYS		NON_OYS	0
E2SS3P6	NO	INTER	NON_OYS		NON_OYS	0
E2SS3Pd	NO	INTER	NON_OYS		NON_OYS	0
E2SS3Phs	NO	INTER	NON_OYS		NON_OYS	0
E2SS3Uhs	NO	INTER	NON_OYS		NON_OYS	0
E2SS4/EM1P	NO	INTER	NON_OYS		NON_OYS	0
E2SS4P	NO	INTER	NON_OYS		NON_OYS	0
E2UB/AB3K6h	NO	INTER	NON_OYS		NON_OYS	0
E2UB/EM1K6h	NO	INTER	NON_OYS		NON_OYS	0
E2US/ABM	NO	INTER	NON_OYS		NON_OYS	0
E2US/ABN	NO	INTER	NON_OYS		NON_OYS	0
E2US/EM1K6h	NO	INTER	NON_OYS		NON_OYS	0

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
E2US/EM1P	NO	INTER	NON_OYS		NON_OYS	0
E2US/EM1Ps	NO	INTER	NON_OYS		NON_OYS	0
E2US/EM1Uhs	NO	INTER	NON_OYS		NON_OYS	0
E2US/EM1Us	NO	INTER	NON_OYS		NON_OYS	0
E2US2/SS1P	NO	INTER	NON_OYS		NON_OYS	0
E2US2K6h	NO	INTER	NON_OYS		NON_OYS	0
E2US4/EM1K6h	NO	INTER	NON_OYS		NON_OYS	0
E2US4/EM1N	NO	INTER	NON_OYS		NON_OYS	0
E2US4K6h	NO	INTER	NON_OYS		NON_OYS	0
E2US4M	NO	INTER	NON_OYS		NON_OYS	0
E2US4M6	NO	INTER	NON_OYS		NON_OYS	0
E2US4Mh	NO	INTER	NON_OYS		NON_OYS	0
E2US4Mx	NO	INTER	NON_OYS		NON_OYS	0
E2US4N	NO	INTER	NON_OYS		NON_OYS	0
E2USK6h	NO	INTER	NON_OYS		NON_OYS	0
E2USM6	NO	INTER	NON_OYS		NON_OYS	0
E2USN6	NO	INTER	NON_OYS		NON_OYS	0
E2USPs	NO	INTER	NON_OYS		NON_OYS	0
M1UBL	NO	SUB	NON_OYS		NON_OYS	0
M2AB1N	NO	INTER	NON_OYS		NON_OYS	0
M2AB6N	NO	INTER	NON_OYS		NON_OYS	0
M2US4M	NO	INTER	NON_OYS		NON_OYS	0
M2USM	NO	INTER	NON_OYS		NON_OYS	0

APPENDIX I (cont). National Wetlands Inventory codes in each of our habitat categories. Not all categories are presented and discussed in this report (e.g. AQ_BED which is "aquatic bed").

NWI CODE	Potential C.v. Habitat	Subtidal or Intertidal	General Habitat	Inundation Regime	Project Group Code	Cat. #
M2USN	NO	INTER	NON_OYS		NON_OYS	0
M2USP	NO	INTER	NON_OYS		NON_OYS	0
PUS/EM1Uhs	NO	NA	NON_OYS		NON_OYS	0
PUSAh	NO	NA	NON_OYS		NON_OYS	0
PUSCx	NO	NA	NON_OYS		NON_OYS	0
PUSUhs	NO	NA	NON_OYS		NON_OYS	0
Pf	NO	NA	NON_OYS		NON_OYS	0

Appendix II. Total area and relative proportion for oyster habitat categories (in order of habitat dominance) and total amount of manmade shoreline for the six regions of this study in order of habitat dominance (see Table 1 for category descriptions and Figure 2 for regional stratification).

Region	Habitat Category	Total Area (Hectares)	Relative Proportion (%)
1	*Subtidal Bottom*	7,387	50.4
	High Marsh	3,677	25.1
	Low Tidal Flats	2,803	19.1
	High Tidal Flats	506	3.4
	Low Marsh	161	1.1
	Flats-Marsh	97	0.7
	All Reefs	40	0.3
	All Manmade Shoreline	29.7 [a]	n/a
2	*High Marsh*	5,559	36.9
	Low Tidal Flats	4,009	26.6
	Low Marsh	2,800	18.6
	Subtidal Bottom	2,077	13.8
	High Tidal Flats	328	2.2
	Flats-Marsh	226	1.5
	All Reefs	77	0.5
	All Manmade Shoreline	2.1 [a]	n/a

[a] This metric is linear km instead of hectares

Appendix II (cont.). Total area and relative proportion for oyster habitat categories (in order of habitat dominance) and total amount of manmade shoreline for the six regions of this study in order of habitat dominance (see Table 1 for category descriptions and Figure 2 for regional stratification).

Region	Habitat Category	Total Area (Hectares)	Relative Proportion (%)
3	*High Marsh*	1,444	44.8
	Subtidal Bottom	511	15.9
	Low Marsh	482	15.0
	Flats-Marsh	321	10.0
	Low Tidal Flats	240	7.4
	High Tidal Flats	184	5.7
	All Reefs	37	1.2
	All Manmade Shoreline	3.3 [a]	n/a
4	*Low Tidal Flats*	15,409	57.7
	High Marsh	3,930	14.7
	Subtidal Bottom	3,601	13.5
	Low Marsh	3,189	11.9
	High Tidal Flats	387	1.5
	Flats-Marsh	75	0.3
	All Reefs	101	0.4
	All Manmade Shoreline	0.6 [a]	n/a

[a] This metric is linear km instead of hectares

Appendix II (cont.). Total area and relative proportion for oyster habitat categories (in order of habitat dominance) and total amount of manmade shoreline for the six regions of this study in order of habitat dominance (see Table 1 for category descriptions and Figure 2 for regional stratification).

Region	Habitat Category	Total Area (Hectares)	Relative Proportion (%)
5	*Low Tidal Flats*	3,774	34.8
	Subtidal Bottom	2,798	25.8
	Low Marsh	1,495	13.8
	High Marsh	1,485	13.7
	High Tidal Flats	883	8.2
	Flats-Marsh	326	3.0
	All Reefs	70	0.6
	All Manmade Shoreline	2.2 [a]	n/a
6	*Low Tidal Flats*	8,726	50.6
	Low Marsh	3,735	21.7
	High Marsh	2,199	12.8
	Subtidal Bottom	1,805	10.5
	High Tidal Flats	409	2.4
	Flats-Marsh	303	1.8
	All Reefs	50	0.3
	All Manmade Shoreline	0 [a]	n/a

[a] This metric is linear km instead of hectares

Appendix III. Total area and relative proportion for oyster reef habitat sub-categories (in order of dominance) for the six regions of this study in order of habitat dominance (see Table 1 for category descriptions and Figure 2 for regional stratification).

Region	Habitat Category	Total Area (Hectares)	Relative Proportion (%)
1	*Privately Managed Reefs*	29	0.2
	Patch Reefs	7	0.1
	Fringing Reefs	4	0.0
	Small Patch Reefs	0	0.0
	State Restoration Reefs	0	0.0
2	*Small Patch Reefs*	51	0.3
	Patch Reefs	24	0.2
	Fringing Reefs	2	0.0
	Privately Managed Reefs	0	0.0
	State Restoration Reefs	0	0.0
3	*Small Patch Reefs*	15	0.5
	Privately Managed Reefs	14	0.4
	Patch Reefs	7	0.2
	Fringing Reefs	1	0.0
	State Restoration Reefs	0	0.0

[a] Because locations of VMRC reefs have not been digitized to date, it was difficult to ascertain which reefs should be included in this category; therefore, this area may be substantially low with some grouped in the *Patch Reef* category above.

Appendix III (cont.). Total area and relative proportion for oyster reef habitat sub-categories (in order of dominance) for the six regions of this study in order of habitat dominance (see Table 1 for category descriptions and Figure 2 for regional stratification).

Region	Habitat Category	Total Area (Hectares)	Relative Proportion (%)
4	*Small Patch Reefs*	50	0.2
	Patch Reefs	41	0.2
	Fringing Reefs	6	0.0
	Privately Managed Reefs	4	0.0
	State Restoration Reefs	0	0.0
5	*Small Patch Reefs*	36	0.3
	Patch Reefs	30	0.3
	Fringing Reefs	2	0.0
	Privately Managed Reefs	1	0.0
	State Restoration Reefs	1	0.0
6	*Small Patch Reefs*	24	0.1
	Patch Reefs	21	0.1
	Fringing Reefs	3	0.0
	Privately Managed Reefs	2	0.0
	State Restoration Reefs	1	0.0

[a] Because locations of VMRC reefs have not been digitized to date, it was difficult to ascertain which reefs should be included in this category; therefore, this area may be substantially low with some grouped in the *Patch Reef* category above.

Appendix IV

NOAA Seaside Oyster Assessment-Modified National Wetlands Inventory (NWI) Habitats (clipped by reefs)

Metadata:

Identification_Information:
Citation:
Citation_Information:
Originator:
Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Publication_Date: 12/31/08
Title:
NOAA_Seaside_Oyster_Mapping_modifiedNWI_polygons_clipped by reefs
Geospatial_Data_Presentation_Form: vector digital data
Other_Citation_Details:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Online_Linkage:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2008\NOAA_Seaside_Oyster_Mapping_reefs_polygons_main.shp
Description:
Abstract:
These data are part of a comprehensive survey to describe and quantify oyster habitat and the oyster population on the Seaside of Virginia's Eastern Shore. Overall, we have included aquaculture, restoration and traditional natural reef structure in addition to other habitats: marsh and flats of varying tidal inundation regimes and manmade shoreline. The specific data in this shapefile represent non-reef features as polylgons: especially marshes and mudflats. Polygons were extracted from National Wetlands Inventory (NWI) data (for details and original metadata see <http://www.fws.gov/nwi/>) and re-classified and in some cases modified with respect to pertinent oyster habitat categories based on Virginia Base Map Program 1-m resolution aerial images (2002 & 2007). Tidal inundation modifiers were established based on aerial imagery and local knowledge. Companion datasets for oyster reef polygons and manmade shoreline data are available.
Purpose:

These data were developed to support ongoing oyster restoration and research by various federal, state and NGO groups within the marshes and coastal bays of the seaside portion of the Eastern Shore of Virginia as funded by the Virginia Coastal Zone Management Program.
Supplemental_Information:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 3/1/07
Ending_Date: 7/1/08
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -75.970353
East_Bounding_Coordinate: -75.282922
North_Bounding_Coordinate: 38.015916
South_Bounding_Coordinate: 37.070143
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: oyster
Theme_Keyword: oyster restoration
Theme_Keyword: population estimate
Theme_Keyword: shoreline survey
Theme_Keyword: oyster biomass
Theme_Keyword: stock assessment
Theme_Keyword: habitat
Theme_Keyword: NWI
Theme_Keyword: National Wetlands Inventory
Place:
Place_Keyword: Eastern Shore
Place_Keyword: coastal bays
Place_Keyword: mid-Atlantic United States
Place_Keyword: Virginia
Access_Constraints:
Access to be determined by funding agency: Virginia Coastal Zone Management Program
Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors

Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu
Data_Set_Credit:
Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Completeness_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 10 m (estimated on average)
Horizontal_Positional_Accuracy_Explanation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: n/a
Lineage:
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Process_Step:

Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Final, Lynnhaven Mapping\Lynnhaven Mapping-Line
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Lynnhaven Assessment-ESL Final GIS Data Bundle\Lynnhaven Mapping-Line
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Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml57.tmp
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Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml5B.tmp
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2007\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons
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Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons_main
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml37.tmp

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Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 4489

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Lambert Conformal Conic
Lambert_Conformal_Conic:
Standard_Parallel: 36.766667
Standard_Parallel: 37.966667
Longitude_of_Central_Meridian: -78.500000

Latitude_of_Projection_Origin: 36.333333
False_Easting: 11482916.666667
False_Northing: 3280833.333333
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000512
Ordinate_Resolution: 0.000512
Planar_Distance_Units: survey feet
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

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Detailed_Description:
Entity_Type:
Entity_Type_Label:
NOAA_Seaside_Oyster_Mapping_modifiedNWI_polygons_clipped by reefs
Entity_Type_Definition: Patch and fringe reefs with >50% shell-based footprint
Entity_Type_Definition_Source: Eastern Shore Lab (ESL)
Attribute:
Attribute_Label: INDBIO_g
Attribute_Definition:
Habitat-specific estimated individual oyster dry tissue biomass (g per oyster)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: AREA
Attribute_Definition: Feature area in square feet
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: PROJECT_GR

Attribute_Definition:
Specific reef habitat category: see companion report for details
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CAT___
Attribute_Definition: Habitat numeric code
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: REGION
Attribute_Definition: Study area region (1-6)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: AREA_M2
Attribute_Definition: Feature are in square meters
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVNUM_M2
Attribute_Definition: Habitat-specific oyster density estimate (# per square meter)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVBIO_kg
Attribute_Definition:
Total estimated oyster dry tissue biomass (kg) for the feature (based on feature area, oyster abundance and mean individual oyster biomass
Attribute_Definition_Source: VIMS-ESL
Attribute_Label: TOTCVNUM
Attribute_Definition:
Estimated total number of oysters per feature (based on area and habitat-specific oyster density)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: ATTRIBUTE
Attribute_Definition: Original NWI habitat code
Attribute:
Attribute_Label: CVBIOg_M2
Attribute_Definition: Oyster dry tissue biomass (g per m2)
Attribute_Definition_Source: VIMS-ESL
Overview_Description:
Entity_and_Attribute_Overview:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Entity_and_Attribute_Detail_Citation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.673

Metadata_Reference_Information:
Metadata_Date: 20081029
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Address:
Address_Type: mailing address
Address: PO Box 350
City: Wachapreague
State_or_Province: VA
Postal_Code: 23350
Country: USA
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: None
Metadata_Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

Generated by mp version 2.8.6 on Wed Oct 29 09:12:42 2008

Appendix V

NOAA Seaside Oyster Assessment-Reefs

Metadata:

Identification_Information:

Citation:

Citation_Information:

Originator:

Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory

Publication_Date: 12/31/08

Title: NOAA_Seaside_Oyster_Mapping_patchreefs_polygons_main

Geospatial_Data_Presentation_Form: vector digital data

Other_Citation_Details:

Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Online_Linkage:

\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2008\NOAA_Seaside_Oyster_Mapping_reefs_polygons_main.shp

Description:

Abstract:

These data are part of a comprehensive survey to describe and quantify oyster habitat and the oyster population on the Seaside of Virginia's Eastern Shore. Overall, we have included aquaculture, restoration and traditional natural reef structure in addition to other habitats: marsh and flats of varying tidal inundation regimes and manmade shoreline. The specific data in this shapefile represent isolated patch and finge reef features as polylgons. Polygons were digitized based on Virginia Base Map Program 1-m resolution aerial images (2002 & 2007). Aerials overflights were undertaken to evaluate the presence of reefs that were suspected based on these images. Companion datasets for oyster habitat polygons modified from National Wetlands Inventory and manmade shoreline data are available.

Purpose:

These data were developed to support ongoing oyster restoration and research by various federal, state and NGO groups within the marshes and coastal bays of the seaside portion of the Eastern Shore of Virginia as funded by the Virginia Coastal Zone Management Program.

Supplemental_Information:

Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Time_Period_of_Content:

Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 3/1/07
Ending_Date: 7/1/08
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -75.967180
East_Bounding_Coordinate: -75.314267
North_Bounding_Coordinate: 38.021424
South_Bounding_Coordinate: 37.084131
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: oyster
Theme_Keyword: oyster restoration
Theme_Keyword: population estimate
Theme_Keyword: shoreline survey
Theme_Keyword: oyster biomass
Theme_Keyword: stock assessment
Theme_Keyword: habitat
Place:
Place_Keyword: Eastern Shore
Place_Keyword: coastal bays
Place_Keyword: mid-Atlantic United States
Place_Keyword: Virginia
Access_Constraints:
Access to be determined by funding agency: Virginia Coastal Zone Management Program
Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu
Data_Set_Credit:

Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Completeness_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 5 m
Horizontal_Positional_Accuracy_Explanation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: n/a
Lineage:
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Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
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Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Final, Lynnhaven Mapping\Lynnhaven Mapping-Line
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Lynnhaven Assessment-ESL Final GIS Data Bundle\Lynnhaven Mapping-Line
Process_Step:

Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml57.tmp
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml5B.tmp
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2007\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons_main
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml70.tmp

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Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 4830

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Lambert Conformal Conic
Lambert_Conformal_Conic:
Standard_Parallel: 36.766667
Standard_Parallel: 37.966667
Longitude_of_Central_Meridian: -78.500000
Latitude_of_Projection_Origin: 36.333333
False_Easting: 11482916.666667
False_Northing: 3280833.333333
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000512
Ordinate_Resolution: 0.000512
Planar_Distance_Units: survey feet
Geodetic_Model:

Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: NOAA_Seaside_Oyster_Mapping_patchreefs_polygons_main
Entity_Type_Definition: Patch and fringe reefs with >50% shell-based footprint
Entity_Type_Definition_Source: Eastern Shore Lab (ESL)
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: AREA
Attribute_Definition: Feature area in square feet
Attribute_Definition_Source: VIMS-ESL
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Attribute_Label: SUBTIDAL_O
Attribute_Definition: Habitat modifier for ESL use
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: GENERAL_HA
Attribute_Definition:
General habitat type with specific reference to 2-D vs. 3-D structure
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: INUNDATION
Attribute_Definition:
Estimated tidal inundation: codes refer to low, mid or high intertidal (low exposed occasionally, mid exposed most low tides and high exposed for extended periods during every tidal cycle)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: PROJECT_GR
Attribute_Definition:

Specific reef habitat category: PAT="Patch Reef", MRC="Marine Resources Commission Restoration Reef", FRI="Fringing Reef", PSM="Small interspersed patches/clumps", PRI="Privately managed reefs-usually in reference to industry or restoration by private groups" (see companion report for detailed descriptions)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CAT___
Attribute_Definition: Habitat numeric code
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: REGION
Attribute_Definition: Study area region (1-6)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: AREA_M2
Attribute_Definition: Feature are in square meters
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVNUM_M2
Attribute_Definition: Habitat-specific oyster density estimate (# per square meter)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: INDBIO_G
Attribute:
Attribute_Label: CVBIO_KG
Attribute:
Attribute_Label: INDBIO_g
Attribute_Definition:
Habitat-specific estimated individual oyster dry tissue biomass (g per oyster)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVBIOG_M2
Attribute_Definition: Oyster dry tissue biomass (g per m2)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVBIO_kg
Attribute_Definition:
Total estimated oyster dry tissue biomass (kg) for the feature (based on feature area, oyster abundance and mean individual oyster biomass
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: TOTCVNUM
Attribute_Definition:
Estimated total number of oysters per feature (based on area and habitat-specific oyster density)
Attribute_Definition_Source: VIMS-ESL
Overview_Description:

Entity_and_Attribute_Overview:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Entity_and_Attribute_Detail_Citation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 0.673

Metadata_Reference_Information:
Metadata_Date: 20081029
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Address:
Address_Type: mailing address
Address: PO Box 350
City: Wachapreague
State_or_Province: VA
Postal_Code: 23350
Country: USA
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: None
Metadata_Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>

Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

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Appendix VI

NOAA Seaside Oyster Assessment-Manmade Shoreline

Metadata:

Identification_Information:
Citation:
Citation_Information:
Originator:
Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Publication_Date: 12/31/08
Title: NOAA_Seaside_Oyster_Mapping_manmade_polylines
Geospatial_Data_Presentation_Form: vector digital data
Other_Citation_Details:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Online_Linkage:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2008\NOAA_Seaside_Oyster_Mapping_reefs_polygons_main.shp
Description:
Abstract:
These data are part of a comprehensive survey to describe and quantify oyster habitat and the oyster population on the Seaside of Virginia's Eastern Shore. Overall, we have included aquaculture, restoration and traditional natural reef structure in addition to other habitats: marsh and flats of varying tidal inundation regimes and manmade shoreline. The specific data in this shapefile represent manmade shorelines as line features. They were digitized based on Virginia Base Map Program 1-m resolution aerial images (2002 & 2007). Most were subsequently visited via land or boat to assess the aerial % cover of oysters and to determine specific structure materials. Companion datasets for oyster habitat polygons modified from National Wetlands Inventory and oyster reef data are available.
Purpose:
These data were developed to support ongoing oyster restoration and research by various federal, state and NGO groups within the marshes and coastal bays of the seaside portion of the Eastern Shore of Virginia as funded by the Virginia Coastal Zone Management Program.
Supplemental_Information:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 3/1/07
Ending_Date: 7/1/08
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -75.969573
East_Bounding_Coordinate: -75.325003
North_Bounding_Coordinate: 38.021659
South_Bounding_Coordinate: 37.091316
Keywords:
Theme:
Theme_Keyword_Thesaurus:
REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.
Theme_Keyword: oyster
Theme_Keyword: oyster restoration
Theme_Keyword: population estimate
Theme_Keyword: shoreline survey
Theme_Keyword: oyster biomass
Theme_Keyword: stock assessment
Theme_Keyword: habitat
Place:
Place_Keyword: Eastern Shore
Place_Keyword: coastal bays
Place_Keyword: mid-Atlantic United States
Place_Keyword: Virginia
Access_Constraints:
Access to be determined by funding agency: Virginia Coastal Zone Management Program
Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu

Data_Set_Credit:
Ross, P.G. and Luckenbach, M.L., College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Native_Data_Set_Environment:
Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.1.0.722

Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Completeness_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Quantitative_Horizontal_Positional_Accuracy_Assessment:
Horizontal_Positional_Accuracy_Value: 5 m
Horizontal_Positional_Accuracy_Explanation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report: n/a
Lineage:
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Final, Humes\Humes Line
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Final, Lynnhaven Mapping\Lynnhaven Mapping-Line
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Lynnhaven Projects\Lynnhaven Data\Lynnhaven Assessment-ESL Final GIS Data Bundle\Lynnhaven Mapping-Line

Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml57.tmp
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml5B.tmp
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA Seaside Oyster Mapping-ESL 2007\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons
Process_Step:
Process_Description: Dataset moved.
Source_Used_Citation_Abbreviation:
\\V15895\Data 1\GIS Data and Projects\Eastern Shore Projects\Seaside Oyster Stock Assessment\NOAA_Seaside_Oyster_Mapping_patchreefs_polygons_main
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\pg\LOCALS~1\Temp\xml38.tmp

---

Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: String
Point_and_Vector_Object_Count: 325

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name: Lambert Conformal Conic
Lambert_Conformal_Conic:
Standard_Parallel: 36.766667
Standard_Parallel: 37.966667
Longitude_of_Central_Meridian: -78.500000
Latitude_of_Projection_Origin: 36.333333
False_Easting: 11482916.666667
False_Northing: 3280833.333333
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.000512
Ordinate_Resolution: 0.000512
Planar_Distance_Units: survey feet

Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: NOAA_Seaside_Oyster_Mapping_manmade_polylines
Entity_Type_Definition: Patch and fringe reefs with >50% shell-based footprint
Entity_Type_Definition_Source: Eastern Shore Lab (ESL)
Attribute:
Attribute_Label: TOTCVNUM
Attribute_Definition:
Estimated total number of oysters per feature (based on length and habitat-specific oyster density)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: Id
Attribute:
Attribute_Label: INIT_DENS
Attribute_Definition:
Initial oyster density category estimates (subjective visual estimates)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain:
Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: REGION
Attribute_Definition: Study area region (1-6)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVBIO_kg
Attribute_Definition:
Total estimated oyster dry tissue biomass (kg) for the feature (based on feature area, oyster abundance and mean individual oyster biomass
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: PROJ_GR
Attribute_Definition:
Specific reef habitat category (see companion report for detailed descriptions)
Attribute_Definition_Source: VIMS-ESL

Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: CAT_
Attribute_Definition: Habitat category code
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: INDBIO_g
Attribute_Definition:
Habitat-specific estimated individual oyster dry tissue biomass (g per oyster)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: LENGTH
Attribute_Definition: Length of manmade feature (ft)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: LENGTHM
Attribute_Definition: Length of manmade feature (m)
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVNUM_M
Attribute_Definition: Estimated oyster density per linear meter of manmade shoreline
Attribute_Definition_Source: VIMS-ESL
Attribute:
Attribute_Label: CVBIOg_M2
Attribute_Definition: Oyster dry tissue biomass (g per linear m)
Attribute_Definition_Source: VIMS-ESL
Overview_Description:
Entity_and_Attribute_Overview:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.
Entity_and_Attribute_Detail_Citation:
Companion report: Ross, Paige and M. W. Luckenbach. 2008. Population Assessment of Eastern Oysters (Crassostrea virginica) in the Seaside Coastal Bays. Final report submitted to the Virginia Coastal Zone Management Program.

Distribution_Information:
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:

Transfer_Size: 0.673

Metadata_Reference_Information:
Metadata_Date: 20081029
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person: P.G. Ross
Contact_Organization:
College of William and Mary, Virginia Institute of Marine Science, Eastern Shore Laboratory
Contact_Position: Marine Scientist, Sr.
Contact_Address:
Address_Type: mailing address
Address: PO Box 350
City: Wachapreague
State_or_Province: VA
Postal_Code: 23350
Country: USA
Contact_Voice_Telephone: 757-787-5816
Contact_Electronic_Mail_Address: pg@vims.edu
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: None
Metadata_Use_Constraints:
Under no circumstances can this data be published in any peer-reviewed outlet without the direct consent of the authors
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>
Profile_Name: ESRI Metadata Profile

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Appendix VII. Abbreviated metadata for the Virginia portion of the National Watershed Boundary Dataset used to delineate the six regions for this study.

```
Originator:
        Virginia Dept of Conservation and Recreation (VADCR)
        Division of Soil and Water Conservation (DSWC)
      Publication_Date:  20050318
      Title:  The Virginia Portion of the National Watershed Boundary Dataset (NWBD)
      Edition:  3
      Geospatial_Data_Presentation_Form:  vector digital data
      Series_Information:
        Series_Name:  hydrologic units
        Issue_Identification:  version 3 of sixth order units for Virginia
      Publication_Information:
        Publication_Place:  Richmond, Virginia
        Publisher:  Virginia DCR-DSWC
  Description:
    Abstract:
      These are the new national fifth and sixth order hydrologic units for
      Virginia.  They have been created in compliance with the new Federal
      Standards for Delineation of Hydrologic Unit Boundaries (1 October 2004) and
      therefore differ from the previous sixth order (14 digit) hydrologic units
      of Virginia as developed by DCR and the USDA in 1995 from the hydrologic
      unit delineation standards of 1992.
      This dataset covers the whole state and is seamless with surrounding
      state's NWBD product.  Revised first through fifth order units are
      obtainable from codes in this layer.
    Purpose:
      Developed as part of a seamless hydrologic unit product for the nation.
      To be used for more detailed watershed planning work in the state than
      can be performed using lower order units.
      This becomes the official statewide sixth order hydrologic unit
      delineation for Virginia.
    Supplemental_Information:
      Origin:
      Version 1 of the sixth order hydrologic units for Virginia were originally
      digitized at ISSL, VPI&SU in 1989 off of the USGS 7.5 minute quadrangle
      maps.  Delineations were made by the Virginia Department of Conservation
      and Recreation (DCR) and the USDA Soil Conservation Service, now the Natural
      Resources Conservation Service (NRCS).  The line and attribute data were
      delivered to the VA DCR in DLG3 format.  There were 492 units in Virginia
      at this version.  Units were uniquely identified by a three character string
      and were sequentially coded downstream to upstream.
  Status:
    Progress:  Complete but uncertified
    Maintenance_and_Update_Frequency:
      Changes to the linework detail are made whenever reason can be shown to
      do so. These changes are usually so minor as to only be visible at a
      very large scale display, and do not constitute a significant variance
      from the original form of this version.
  Spatial_Domain:
    Bounding_Coordinates:
      West_Bounding_Coordinate:  -83.675
      East_Bounding_Coordinate:  -75.176
      North_Bounding_Coordinate:  39.466
      South_Bounding_Coordinate:  36.541
```

```
Keywords:
  Theme:
    Theme_Keyword:  hydrologic units
    Theme_Keyword:  watersheds
    Theme_Keyword:  Watershed Boundary Dataset
    Theme_Keyword:  fifth order
    Theme_Keyword:  sixth order
  Place:
    Place_Keyword_Thesaurus:
      Counties and County Equivalents of the United States and the District of
      Columbia (FIPS Pub 6-3).
    Place_Keyword:  Virginia
Access_Constraints:  none
Use_Constraints:
  Linework and hydrologic unit codes should not be altered except by the
  developer, as this dataset constitutes the accepted digital version of these
  geographic units for all state and federal programs referencing the VA NWBD.
  Use at scales much greater than 1:24,000 is discouraged.  Crediting the
  VA DCR for dataset development is requested.
Point_of_Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Person:  Karl Huber
      Contact_Organization:  Virginia Dept. of Conservation & Recreation - DSWC
    Contact_Address:
      Address_Type:  mailing and physical address
      Address:  203 Governor Street, Suite 206
      City:  Richmond
      State_or_Province:  Virginia
      Postal_Code:  23219-2094
      Country:  USA
    Contact_Voice_Telephone:  804 371 7484
    Contact_Facsimile_Telephone:  804 371 2630
    Contact_Electronic_Mail_Address:  karl.huber@dcr.virginia.gov
    Hours_of_Service:  0900-1800
Data_Set_Credit:
  This dataset has been developed by the Virginia Department of Conservation
  and Recreation (DCR) with assistance from the Virginia Tech Biological
  Systems Engineering Dept.  It is built upon an earlier version developed
  by the VA DCR with assistance from the USDA NRCS and the VA DEQ.
Native_Data_Set_Environment:  UNIX (Solaris), ARC/INFO v7.2.1 thru ArcGIS 9
Cross_Reference:
  Citation_Information:
    Originator:  USDA-NRCS
    Publication_Date:  2000
    Title:  Enhanced DRGs of Virginia
    Edition:  2000
    Geospatial_Data_Presentation_Form:  digital raster graphic
    Series_Information:
      Series_Name:  Enhanced DRGs
      Issue_Identification:  Virginia Quads
    Publication_Information:
      Publication_Place:  Fort Worth, Texas
      Publisher:  USDA-NRCS
Cross_Reference:
  Citation_Information:
    Originator:  Virginia Dept. of Conservation and Recreation - DSWC
```

```
      Publication_Date:  19950601
      Title:  Virginia's Revised 14 Digit Hydrologic Unit Boundaries.
      Edition:  2
      Geospatial_Data_Presentation_Form:  vector digital data
      Series_Information:
        Series_Name:  hydrologic units
        Issue_Identification:  version 2
      Publication_Information:
        Publication_Place:  Richmond, Virginia
        Publisher:  Virginia DCR with USDA NRCS
      Other_Citation_Details:  Jointly developed by DCR and USDA NRCS.
  Cross_Reference:
    Citation_Information:
      Originator:  Virginia Dept. of Conservation and Recreation - DSWC
      Publication_Date:  19910901
      Title:  Virginia's (Original) 14 Digit Hydrologic Unit Boundaries.
      Edition:  1
      Geospatial_Data_Presentation_Form:  vector digital data
      Series_Information:
        Series_Name:  hydrologic units
        Issue_Identification:  version 1
      Publication_Information:
        Publication_Place:  Richmond, Virginia
        Publisher:  Virginia DCR with USDA NRCS
      Other_Citation_Details:  With contractual help of ISSL.
  Cross_Reference:
    Citation_Information:
      Originator:  U.S. Water Resources Council
      Publication_Date:  1974
      Title:  Hydrologic Unit Map of Virginia
      Geospatial_Data_Presentation_Form:  map
      Publication_Information:
        Publication_Place:  Reston, Virginia
        Publisher:  USGS
      Other_Citation_Details:  Only useful to the fourth order.
Metadata_Reference_Information:
  Metadata_Date:  20050311
  Metadata_Review_Date:  20060705
  Metadata_Contact:
    Contact_Information:
      Contact_Person_Primary:
        Contact_Person:  Karl Huber
        Contact_Organization:  VA Dept. of Conservation & Recreation - DSWC
      Contact_Address:
        Address_Type:  mailing and physical address
        Address:  203 Governor Street, Suite 206
        City:  Richmond
        State_or_Province:  Virginia
        Postal_Code:  23219-2094
        Country:  USA
      Contact_Voice_Telephone:  804 371 7484
      Contact_Facsimile_Telephone:  804 371 2630
      Contact_Electronic_Mail_Address:  karl.huber@dcr.virginia.gov
      Hours_of_Service:  0900-1800
  Metadata_Standard_Name:  FGDC Content Standard for Digital Geospatial Metadata
  Metadata_Standard_Version:  FGDC-STD-001-1998
  Metadata_Access_Constraints:  none
```

Appendix VIII. Metadata for the original National Wetlands Inventory polygons.

National Wetlands Inventory (NWI) Metadata

NOTE: This metadata document represents the static text elements of the National Wetlands Inventory (NWI) Metadata. Quad-specific metadata files are available through the FGDC Clearinghouse website.

Metadata:
Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Fish & Wildlife Service, National Wetlands Inventory

Publication_Date: Ranges from Oct. 1981 to present; information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title: National Wetlands Inventory -- Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Publication_Information:

Publication_Place: St.Petersburg, Florida
Publisher: U.S. Fish & Wildlife Service,
National Wetlands Inventory

Online_Linkage:
ftp://ftp.nwi.fws.gov/arcdata/
ftp://ftp.nwi.fws.gov/shapedata/

Description:

Abstract:
NWI digital data files are records of wetlands location and classification as developed by the U.S. Fish & Wildlife Service. The classification system was adopted as a national classification standard in 1996 by the Federal Geographic Data Committee. This dataset is one of a series available in 7.5 minute by 7.5 minute blocks containing ground planimetric coordinates of wetlands point, line, and polygon features and wetlands attributes. When completed, the series will provide coverage for all of the contiguous United States, Hawaii, Alaska, and U.S. protectorates in the Pacific and Caribbean. Coverage includes both digital data and hardcopy maps. The NWI maps do not show all wetlands since the maps are derived from aerial photointerpretation with varying limitations due to scale, photo quality, inventory techniques, and other factors. Consequently, the maps tend to show wetlands that are readily photointerpreted given consideration of photo and map scale. In general, the older NWI maps prepared from 1970s-era black and white photography (1:80,000 scale) tend to be very conservative, with many forested and drier-end emergent wetlands (e.g., wet

meadows) not mapped. Maps derived from color infrared photography tend to yield more accurate results except when this photography was captured during a dry year, making wetland identification equally difficult. Proper use of NWI maps therefore requires knowledge of the inherent limitations of this mapping. It is suggested that users also consult other information to aid in wetland detection, such as U.S. Department of Agriculture soil survey reports and other wetland maps that may have been produced by state and local governments, and not rely solely on NWI maps. See section on "Completeness_Report" for more information. Also see an article in the National Wetlands Newsletter (March-April 1997; Vol. 19/2, pp. 5-12) entitled "NWI Maps: What They Tell Us" (a free copy of this article can be ordered from U.S. Fish and Wildlife Service, ES-NWI, 300 Westgate Center Drive, Hadley, MA 01035, telephone, 413-253-8620).

Purpose:
The data provide consultants, planners, and resource managers with information on wetland location and type. The data were collected to meet U.S. Fish & Wildlife Service's mandate to map the wetland and deepwater habitats of the United States. The purpose of this survey was not to map all wetlands and deepwater habitats of the United States, but rather to use aerial photointerpretation techniques to produce thematic maps that show, in most cases, the larger ones and types that can be identified by such techniques. The objective was to provide better geospatial information on wetlands than found on the U.S. Geological Survey topographic maps. It was not the intent of the NWI to produce maps that show exact wetland boundaries comparable to boundaries derived from ground surveys. Boundaries are therefore generalized in most cases. Consequently, the quality of the wetland data is variable mainly due to source photography, ease or difficulty of interpreting specific wetland types, and survey methods (e.g., level of field effort and state-of-the-art of wetland delineation). See section on "Completeness_Report" for more information.

Time_Period_of_Content:

Time_Period_Information:

Multiple_Dates_Times:

Calendar_Date: Ranges from Feb. 1971 to Nov. 1997.
Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Currentness_Reference: Source photography date

Status:

Progress: Complete

Maintenance_and_Update_Frequency: Irregular

Spatial_Domain:

Bounding_Coordinates:

West_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

East_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

North_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

South_Bounding_Coordinate: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Keywords:

Theme:

Theme_Keyword_Thesaurus: None

Theme_Keyword: wetlands

Theme_Keyword: hydrologic

Theme_Keyword: land cover

Theme_Keyword: surface and manmade features

Place:

Place_Keyword_Thesaurus: USGS Quadrangle Names

Place_Keyword: Range includes all 50 states, Puerto Rico, Virgin Islands. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Access_Constraints: None

Use_Constraints:
Federal, State, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, State, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate Federal, State, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

Point_of_Contact:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: U.S. Fish & Wildlife Service,
National Wetlands Inventory Center

Contact_Position: Cartographer

Contact_Address:

Address_Type: Mailing and Physical address

Address: 9720 Executive Center Drive
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33702
Country: US

Contact_Voice_Telephone: 727-570-5400

Data_Quality_Information:

Attribute_Accuracy:

Attribute_Accuracy_Report:
The attribute accuracy is tested by manual comparison of the source with hard copy printouts and/or symbolized display of the digital wetlands data on an interactive computer graphic system. In addition, quality control verification software (USFWS-NWI) tests the attributes against a master set of valid wetland attributes.

Logical_Consistency_Report:
Polygons intersecting the neatline are closed along the border. Segments making up the outer and inner boundaries of a polygon tie end-to-end to completely enclose the area. Line segments are a set of sequentially numbered coordinate pairs. No duplicate features exist nor duplicate points in a data string. Intersecting lines are separated into individual line segments at the point of intersection. Point data are represented by two sets of coordinate pairs, each with the same coordinate values. All nodes are represented by a single coordinate pair which indicates the beginning or end of a line segment. The neatline is generated by connecting the four corners of the digital file, as established during initialization of the digital file. All data crossing the neatline are clipped to the neatline and data within a specified tolerance of the neatline are snapped to the neatline. Tests for logical consistency are performed by quality control verification software (USFWS-NWI).

Completeness_Report:
NWI maps do not show all wetlands, but attempt to show most photointerpretable wetlands given considerations of map/photo scale and wetland delineation practices. A target mapping unit (tmu) is an estimate of the size class of the smallest group of wetlands that NWI attempts to map consistently; it is not the smallest wetland mapped. Recognize that some wetland

types are conspicuous and readily mapped (e.g., marshes and ponds) and smaller ones may be mapped. Drier wetlands and forested wetlands (especially evergreen) are more difficult to photointerpret and larger ones may be missed. The tmu also varies with photo scale; in forested regions, the tmu may be 3-5 acres (1:80K photos), 1-3 acres (1:58K), or 1 acre (1:40K). NWI maps should show most wetlands larger than the tmu. In the treeless prairies, a 1/4 acre tmu is possible due to the openness of terrain and occurrence of wetlands in distinct depressions. Take notice of the photo scale/type used to make the maps (see legend) and realize that black and white photos tend to yield more conservative interpretations than color infrared film. Most farmed wetlands (e.g., mucklands) are usually not mapped, except for pothole-type wetlands, cranberry bogs, and diked former tidelands (Sacramento Valley). Partly drained wetlands are conservatively mapped due to photointerpretation limitations. No attempt was made to identify regulated wetlands from other wetlands. Recognize that maps produced through photointerpretation are not as accurate as one prepared from on-the-ground surveys, so NWI boundaries are generalized.

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: Horizontal

Lineage:

Source_Information:

Source_Citation:

Originator:
The Domain includes U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA), National Aeronautics and Space Administration (NASA), special project. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Publication_Date: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title:
The Domain includes National Aerial Photography Program (NAPP), National High Altitude Photography (NHAP), USDA, Farm Service Agency, Aerial Photography Field Office, NASA or special project photography. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Geospatial_Data_Presentation_Form: Remote-sensing image

Publication_Information:

Publication_Place: Reston, Virginia

Publisher: U.S. Geological Survey

Source_Scale_Denominator: Ranges from 20,000 to 132,000. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Type_of_Source_Media: Domain includes black and white, color infrared, or natural color aerial photograph film transparency. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Time_Period_of_Content:

Time_Period_Information:

Multiple_Dates_Times:

Calendar_Date: Ranges from Feb. 1971 to Nov. 1997. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Currentness_Reference: Photo date

Source_Citation_Abbreviation: PHOTOS

Source_Contribution: Wetlands spatial and attribute information

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S. Geological Survey

Publication_Date: Ranges from 1902 to 1995. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Title: topographic map

Geospatial_Data_Presentation_Form: map

Publication_Information:

Publication_Place: Reston, Virginia

Publisher: U.S. Geological Survey

Source_Scale_Denominator: Domain includes 20000, 24000, 25000, 30000, and 62500. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Type_of_Source_Media: stable-base material

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date_Time:

Calendar_Date: Ranges from 1902 to 1995.
Information for this element varies for each 7.5'
quad. See the quad-specific metadata file.

Source_Currentness_Reference: publication date

Source_Citation_Abbreviation: USGS QUAD

Source_Contribution: base cartographic data

Source_Information:

Source_Citation:

Citation_Information:

Originator: U.S.D.A. Natural Resources Conservation
Service

Publication_Date: Varies

Title: County Soil Surveys

Geospatial_Data_Presentation_Form: map

Publication_Information:

Publication_Place: Washington, DC

Publisher: Government Printing Office

Source_Scale_Denominator: Varies

Type_of_Source_Media: paper

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date_Time:

Calendar_Date: Varies

Source_Currentness_Reference: publication date

Source_Citation_Abbreviation: SOILS

Source_Contribution: wetlands location and classification

Process_Step:

Process_Description:
NWI maps are compiled through manual photointerpretation of NHAP or NAPP aerial photography supplemented by Soil Surveys and field checking of wetland photo signatures. Delineated wetland boundaries are manually transferred from interpreted photos to USGS 7.5 minute topographic quadrangle maps and then manually labeled. Quality control steps occur throughout the photointerpretation, map compilation, and map reproduction processes. Digital wetlands data are either manually digitized or scanned from stable-base copies of the 1:24,000 scale wetlands overlays registered to the standard U.S. Geological Survey (USGS) 7.5 minute quadrangles into topologically correct data files using Arc/Info software. Files contain ground planimetric coordinates and wetland attributes. The quadrangles were referenced to the North American Datum of 1927 (NAD27) horizontal datum. The scanning process captured the digital data at a scanning resolution of at least 0.001 inches; the resulting raster data were vectorized and then attributed on an interactive editing station. Manual digitizing used a digitizing table to capture the digital data at a resolution of at least 0.005 inches; attribution was performed as the data were digitized. The determination of scanning versus manual digitizing production method was based on feature density, source map quality, feature symbology, and availability of production systems. The data were checked for position by comparing plots of the digital data to the source material.

Source_Used_Citation_Abbreviation: PHOTOS

Source_Used_Citation_Abbreviation: USGS QUADS

Process_Date: Ranges from 1979 to 2001. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Source_Produced_Citation_Abbreviation: NWI

Spatial_Data_Organization_Information:

Direct_Spatial_Reference_Method: Vector

Point_and_Vector_Object_Information:

SDTS_Terms_Description:

SDTS_Point_and_Vector_Object_Type: Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:

Planar:

Grid_Coordinate_System:

Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:

UTM_Zone_Number: Ranges from 4 to 20. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Transverse_Mercator:

Scale_Factor_at_Central_Meridian: 0.9996

Longitude_of_Central_Meridian: Ranges from -159.0 to -63.0. Information for this element varies for each 7.5' quad. See the quad-specific metadata file.

Latitude_of_Projection_Origin: 0.0

False_Easting: 500000.0

False_Northing: 0.0

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: Coordinate pair

Coordinate_Representation:

Abscissa_Resolution: 0.61

Ordinate_Resolution: 0.61

Planar_Distance_Units: Meters

Geodetic_Model:

Horizonal_Datum_Name: North American Datum of 1927

Ellipsoid_Name: Clarke 1866

Semi_major_Axis: 6378206.4

Denominator_of_Flattening_Ratio: 294.9787

Entity_and_Attribute_Information:

Detailed_Description:

Entity_Type:

Entity_Type_Label: Wetland

Entity_Type_Definition: Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Entity_Type_Definition_Source: Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildlife Service. 103 pp.

Attribute:

Attribute_Label: Wetland classification

Attribute_Definition: Classification of the Wetland

Attribute_Definition_Source: Cowardin, L.M., V. Carter, F. Golet, and E. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildlife Service. 103 pp.

Attribute_Domain_Values:

Codeset_Domain:

Codeset_Name: Valid wetland classification code list

Codeset_Source: Photointerpretation Conventions for the National Wetlands Inventory, January 1995

Distribution_Information:

Distributor:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: Cooperator-Run Distribution Centers

Contact_Address:

Address_Type: List@www.nwi.fws.gov/Maps/distribution_ctrs.htm

Distribution_Liability: None

Standard_Order_Process:

Non_digital_Form: Hardcopy NWI wetlands maps at various scales, on diazo paper composited with USGS base map.

Digital_Form:

Digital_Transfer_Information:

Format_Name: Arc Export and Shapefile

Digital_Transfer_Option:

Online_Option:

Computer_Contact_Information:

Network_Address:

Network_Resource_Name:
ftp://ftp.nwi.fws.gov/arcdata/
ftp://ftp.nwi.fws.gov/shapedata/

Network_Resource_Name:
http://www.nwi.fws.gov/

Access_Instructions: Anyone with access to the Internet may connect to NWI's server via anonymous ftp and download available NWI digital wetlands data in Arc Export and Shapefile formats.
Indexes for NWI hardcopy maps and digital data are also available. Digital wetlands data can be downloaded for 7.5 minute quadrangles throughout the USA. To access: ftp to the NWI server, login as anonymous, enter your e-mail address at the password prompt, change to the arcdata directory for Arc Export data, or change to the shapedata directory for Shapefile data. Use the ftp 'get' command to transfer readme file for further instructions.
View the NWI home page by pointing your World Wide Web browser to the http address shown above.

Online_Computer_and_Operating_System: Sun Model 450 Unix server. Solaris 8 operating system.

Offline_Option:

Offline_Media: Arc Export Everything Tape - 8mm cartridge tape (5 Gb)

Recording_Capacity:

Recording_Density: 5

Recording_Density_Units: gigabytes

Recording_Format: tar

Metadata_Reference_Information:

Metadata_Contact:

Contact_Information:

Contact_Person_Primary:

Contact_Person: Andrew Paul

Contact_Organization: U.S. Fish & Wildlife Service,
National Wetlands Inventory Center

Contact_Position: Cartographer

Contact_Address:

Address_Type: Mailing and Physical address

Address: 9720 Executive Center Drive
City: St. Petersburg
State_or_Province: Florida
Postal_Code: 33702

Contact_Voice_Telephone: 727-570-5400

Contact_Facsimile_Telephone: 727-570-5420

Contact_Electronic_Mail_Address: Andrew_Paul@fws.gov

Metadata_Standard_Name: FGDC Content Standards for Digital
Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998