Appendix A
Characterization of Individual Sanctuaries

Oyster Management Review:

2016-2020

A Report Prepared by

Maryland Department of Natural Resources

Final Report

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Introduction

This appendix presents available data on oyster populations within the 51 individual sanctuaries as a means to examine the general characteristics, background information, and trends over time for each unique area. Recognizing that trends for any given area may shift as future environmental conditions change, an examination of oyster populations before and after 2011 (the first full year after the 2010 regulations) will facilitate informed discussion of the effectiveness of the management areas. This appendix presents detailed data on each sanctuary. Chapters 4 and 5 will provide interpretations of these data to assess the effectiveness of sanctuary locations against the original objectives for the sanctuary program.

Not all types of data are available for all sanctuaries, and the scientific value of the different types of data may vary. This report leverages data from partners and other department programs that have particular data on specific sanctuaries. These studies often have limitations related to short study duration, initiation after the creation of sanctuaries in 2010 (no pre-sanctuary data), or a study design that was designed for purposes other than the type of assessment presented in this report (e.g. bottom sonar surveys targeting derelict gear, but which could be used to characterize bottom substrate).

Data used in this assessment include the following: bay bottom characteristics, replenishment and restoration activities, oyster population characteristics (density, recruitment, size structure, and mortality), water quality, and ecosystem services.

The various data sources used in the assessment of each sanctuary are described below. For each data source, the objective and term of the sampling program are presented, the specific data sets derived from the program are described, and the value and limitations of each of the data sets for assessment purposes are identified.

Data Sources

Bay Bottom Surveys

Bay bottom mapping is important to determine the different substrate types of the bay bottom and, if possible, oyster bar boundary delineation. Three surveys are used in the sanctuary assessment: the Yates survey, which delineated oyster bars from 1906 to 1912, the Bay Bottom Survey, which categorized areas of the bay by bottom type from 1974 to 1983 (design and planning in 1974; survey conducted 1975 to 1983), and site-specific sonar surveys occurring between 2005 and 2020.

The Yates survey, conducted from 1906 to 1912, was the first comprehensive survey of Maryland's oyster bars. The primary objective of the survey was to delineate the legal boundaries of the oyster bars to facilitate leasing grounds outside of the bars for aquaculture.

Using a chain dragged over the bottom, the survey examined 350,000 acres of bay bottom and mapped 780 bars covering 216,000 acres over a six-year period. After the Yates survey, additional areas were mapped and bars delineated. These new bars were amended to the list of Maryland oyster bars. As of 1983, there were 1,105 historic bars covering 330,202 acres[1]. These 1,105 bars mapped by Yates as well as the additional areas are the current oyster bar boundaries in use today and are referred to as Maryland's historic oyster bars. It should be noted, however, that these historic oyster bars were not entirely populated by oysters even in Yates' time so the acreages only indicate the historic bounds of the bars and are not acreages of actual living historic oyster populations. Moreso today, after decades of habitat loss, the Yates bars do not represent current viable oyster habitat with oysters and substrate. It has been estimated that only 36,000 acres of the historic oyster habitat is viable today[2].

The department conducted the Bay Bottom Survey from 1975-1983 using a dragged acoustical device, sonar, and patent tongs to map the bottom types found in Maryland's portion of the Chesapeake Bay (approximately 630,000 acres). Bottom type categories included cultch (oyster shell), hard bottom, mud, mud with cultch, sand, and sand with cultch. Cultch and mixed cultch are important to oyster populations as these bottom types provide settlement substrate for oyster larvae. Cultch and hard bottom may serve as a platform for placing hatchery spat-on-shell. The greater the area of cultch, mixed cultch, and hard bottom, the greater the potential for restoration. A sounding pole or divers were used for ground-truthing.

Maryland Geological Survey (MGS) and National Oceanic and Atmospheric Administration (NOAA) conducted side-scan sonar surveys on 32 of the 51 oyster sanctuaries between 2005 and 2020. In some cases, a sub-bottom profiler was used to elucidate subsurface features. The results of these surveys were used in conjunction with ground-truthing Van Veen grab samples and underwater video to create maps of bottom type. In five large-scale restoration sanctuaries, NOAA used multi-beam sonar to create high-resolution bottom type maps of areas that appeared suitable for restoration (capable of supporting oysters or reef building substrate) based on the side scan sonar surveys.

In addition to surveying oyster sanctuaries to map bottom type, MGS also conducted sonar surveys for other purposes, such as the identification of derelict fishing gear. Where possible, the data collected from these surveys were re-analyzed to produce bottom type maps.

NOAA uses the Coastal and Marine Ecological Classification Standard (CMECS)[3] for bottom types. CMECS provides a comprehensive national framework for organizing information about coasts and oceans and their living systems. This information includes the physical, biological, and chemical data that are collectively used to define coastal and marine ecosystems. To compare

[1] Maryland Department of Natural Resources. 1997. Maryland's Historic Oyster Bottom: A Geographic representation of the traditional named oyster bars. http://dnr.maryland.gov/fisheries/Documents/maryland_historic_oyster_bottom.pdf

[2] U.S. Army Corps of Engineers, Norfolk District. 2009. Programmatic Environmental Impact Statement for Oyster Restoration in Chesapeake Bay Including the Use of a Native and/or Nonnative Oyster. http://dnr.maryland.gov/fisheries/Pages/eis.aspx

[3] Federal Geographic Data Committee (FGDC). 2012. Coastal and Marine Ecological Classification Standard. Report no. FGDC-STD-018-2012. https://www.fgdc.gov/standards/projects/cmecs-folder/CMECS_Version_06-2012_FINAL.pdf

the results of NOAA, MGS, and Bay Bottom Surveys, NOAA reclassified the MGS and Bay Bottom Survey bottom types to CMECS, matching categories as closely as possible. The Bay Bottom Survey categories of cultch, mud with cultch, and sand with cultch were classified as oyster reef, as were the MGS categories of shell, mud with shell, and sand with shell. Man-made reefs were also classified as oyster reef habitat. The bottom maps in this appendix present simplified results of the surveys, showing only oyster reef habitat and non-oyster reef habitat bottom. The bottom maps provide valuable information on habitat, and comparing the results of the Bay Bottom Survey with more recent MGS and NOAA sonar surveys allows the visual examination of change in habitat over time. Bottom maps will only be presented for each sanctuary if new information was collected since 2015.

Replenishment and Restoration Efforts

Almost every oyster bar in Maryland has been manipulated over time through replenishment and restoration efforts to improve oyster bar productivity. Replenishment efforts are conducted on public fishery bottom prior to an area becoming a sanctuary and were primarily intended to enhance the public fishery for economic benefit. Restoration efforts are conducted on sanctuary areas with the primary objective to restore oyster populations for ecosystem and ecological benefits. The types of enhancements employed in both replenishment and restoration include planting fresh and dredged shell, transplanting natural wild seed, and planting hatchery-reared spat in hopes of increasing oyster populations. Records of these activities date back to 1960, but shell and seed plantings only since 2006 will be presented in this appendix.

The amount of replenishment (prior to the areas becoming sanctuaries) and restoration activities (after the areas became sanctuaries) differs widely among the 51 sanctuaries. Some sanctuaries have received numerous plantings of both shell and seed over time, while others received very few or none of either. The annual planting information provides a general sense of how each sanctuary was manipulated over time. An analysis to determine if replenishment or restoration activities contributed to an increase in oyster population is beyond the scope of this report. Furthermore, not all replenishment or restoration planting have been monitored by the department. Monitoring projects by other organizations on replenishment and restoration plantings may be referenced when applicable.

Longevity of plantings should also be considered when examining replenishment activities. On average, it is thought that, in the absence of disease, oysters can live up to 20 years[4]. Even without disease related mortality, seed plantings in the Chesapeake Bay for harvest purposes are not likely to last more than three to five years due to harvest pressure. Longevity of shell can vary due to type of shell, pH and alkalinity, sediment burial, and attack from shell-boring organisms. The shell dissolution rate for fresh shell has been found to be much faster than for

[4] Buroker NE. 1983. Population genetics of the American oyster Crassostrea virginica along the Atlantic coast and Gulf of Mexico. Marine Biology 75:99-112.

dredged shell. The half-lives of shell were computed by Waldbusser et al (2011)[5] and the results ranged from roughly one year for fresh shell under mid and low pH to nearly 40 years. This rate however does not account for loss of shell due to burial, transport, and attack from sponges and other shell-boring organisms, all important sources of shell loss in Chesapeake Bay. A further understanding of the fate of historic plantings is important but beyond the scope of this report.

Another source of smaller-scale restoration planting data comes from the Marylanders Grow Oyster Program (MGO). MGO is an outreach and educational program designed to engage the public in oyster restoration by having them grow oysters at their piers in cages and then plant the oysters in local sanctuaries to enhance the oyster population. Growers (individuals in the program) receive spat in cages around September each year. The cages are tended to by the growers over the winter and spring. Around June, the approximately nine-month-old oysters are planted in sites within a sanctuary. The shell height of these oysters are approximately one to two inches.

The program began in 2008 in the Tred Avon River and has grown considerably since then. The MGO Program is large in terms of geographic scope (currently in 32 tributaries of the bay), the degree of public involvement (over 2,000 oyster growers and over 5,000 school students), and the effort invested to grow oysters (7,000 cages are being utilized). It is likely the largest community-based oyster growing program in the country but it is a small-scale program in terms of the acreage of sanctuary bottom restored and the number of oysters planted. Approximately two million oysters are planted on a few acres of oyster bottom annually. In comparison, large-scale restoration can plant two million oysters in a day (i.e. Harris Creek Sanctuary). However, in tributaries where large-scale restoration is absent, MGO may be the only source of restoration activity.

Annual Fall Oyster Dredge Survey

The purpose of the department's Annual Fall Oyster Dredge Survey (Fall Survey), conducted since 1939, is to assess the overall health of Maryland's oyster population. The Fall Survey represents the longest continuous and most geographically comprehensive oyster survey in Maryland.

The Fall Survey design included the sampling of spatfall and relative oyster abundance at a subset of Maryland's oyster bars. This report utilizes Fall Survey data since 2006; a 15-year time period with standardized survey methodologies. In the fall each year, approximately 300 to 400 samples are collected. Some sanctuaries may have samples taken on multiple bars annually, some sanctuaries have only one oyster bar sampled annually, and some sanctuaries have not been sampled at all by the Fall Survey. For each sample, one or (in the case of the 43 fixed disease and

[5] Waldbusser, G.G., R. A. Steenson, and M. A. Green. 2011. Oyster Shell Dissolution Rates in Estuarine Waters: Effects of pH and Shell Legacy. Journal of Shellfish Research, Vol. 30, No. 3, 659–669

biomass bars) two half-bushel subsamples of material are collected by an oyster dredge. Detailed methods for the fall survey may be found in Tarnowski (2020[6]).

For each sample collected by the Fall Survey, the number of live oysters per one bushel of material collected is counted. Oysters are classified as spat, small-sized oysters, or market sized oysters. Spat are less than one year old. Small-sized (sublegal) oysters are usually between one and three years old, and generally greater than 40 millimeters and always less than 76 millimeters. Market-sized (legal) oysters are equal to or greater than 76 millimeters and generally three years and older. Changes in the number of oysters over time can provide a general sense of change in oyster abundance and age/size structure. Relative density of live oysters can be estimated by standardizing the count of live oysters by the total volume of the sample, tow distance, width of the dredge, and a gear efficiency coefficient.

Samples taken on a fixed 43-bar subset of all the oyster bars sampled provide more detailed information on oyster sizes annually. Oyster shell height in millimeters is recorded for all oysters collected. Oyster size structure can be assessed by calculating the frequency distribution of oysters in each five mm size class. A healthy oyster population would have a size distribution with oysters in all, or at least most, size classes from five millimeters to greater than 120 millimeters. This would indicate multiple age classes in the population.

Biomass is a relative measure of how the oyster population is doing over time. It accounts for recruitment, individual growth, natural mortality, and harvesting in a single metric. In assessing the size of the population, biomass integrates both the abundance of oysters and their collective body weight. Biomass is estimated from field-collected oyster shell height using laboratory-derived height-weight relationships. Weight is calculated in grams of dry tissue weight. Increases in biomass may reflect increases in the number of oysters and/or oyster growth.

Total Observed Mortality is an indicator of annual mortality rates of small and market sized oysters. Mortality can occur from disease or other natural factors such as freshets. Mortality is estimated based on the total count of small and market-sized live oysters and the total count of small and market-sized boxes (dead oysters with the valves still articulated).

Cultch (oyster habitat) is crucial for providing hard substrate for oyster setting as well as habitat for the myriad other organisms associated with the oyster community. For the purpose of the Fall Survey, cultch is defined as primarily both oysters (live and dead) and shell. The collection of quantitative cultch data was initiated during the 2005 Fall Survey. During a sampling tow, the distance covered by the dredge while sampling on the bottom is measured using a handheld geographic positioning system (GPS) unit with an odometer function. After the dredge is retrieved, the total volume of oysters and shell is measured in bushel units. Since tow distances vary, the volume is standardized to a 100 ft. tow by dividing 100 by the actual tow distance and

[6] Tarnowski, 2020. Maryland Oyster Population Status Report, 2019 Fall Survey. https://dnr.maryland.gov/fisheries/Documents/19TextFinRevColFigs.pdf

multiplying the result by the total cultch volume. If the dredge is full that sample is dropped from the analysis.

Information on oyster diseases is collected from the same fixed subset of 43 bars on which shell heights are collected. Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) infection prevalence (the percentage of oysters infected) and intensity (the severity of infection) are measured from 30 oysters collected at each site. Disease prevalence and intensity both relate to mortality. For example, all of the oysters in a sample may be infected with a disease, but at such low intensity levels that few oysters are in danger of dying in the near future. Intensity is based on a 0 to 7 scale. Individual oysters with intensity greater than 5 may indicate lethal levels.

The Fall Survey data were used to explore general characteristics of the oyster populations within those sanctuaries that were sampled. Data presented will examine changes over time, based on the average number of oysters per a bushel of material, oyster shell height, live oyster biomass, recruitment, observed mortality, cultch, and disease on oyster bottom within each sanctuary. Data are summarized into three five-year time periods: 2006-2010, 2011-2015, and 2016-2020. These three time periods can be characterized baywide as:

- 2006-2010: Before the 2010 baywide management area regulation changes and through a rebuilding period after the four-year disease epizootic (1999-2002)
- 2011-2015: The first full year after the 2010 baywide management area regulation changes and a period of increasing abundance due to two relatively good spatsets in 2010 and 2012
- 2016-2020: After the 2010 baywide management area regulation changes and through a major freshet and one relatively good spat set in 2020.

Although this report only covers the last 15 years, oyster populations have varied over time.

- 1990-1994: This five-year period had three years of high streamflow (1990, 1993,1994) and two years of below average streamflow (1991,1992). The year 1991 was a high spatfall intensity year, being over four times the long term average spatfall. Years 1991-1993 had a high mean prevalence of dermo and MSX disease. Mortality correlated to the MSX frequency with an observed mortality >70% in 1992, which is a very high level of mortality.
- 1995-1999: 1995 was a period of low annual streamflow, followed by a high annual streamflow in 1996; 1999 was the first year of a 4-year drought; 1995 was a year of increased dermo disease with a prevalence; 1996-1998 had low disease and observed mortality, while 1999 began a four year disease epizootic and increase in observed mortality; 1997 was a high spatset year, with over five times the long term average spatfall.
- 2000-2005: This period of time began with a drought that lasted until 2002. It was followed by two years of record high streamflow in 2003 and 2004. Years 2000-2005 saw low recruitment with a spatfall intensity index below the long term average for all of the

years. The years 2000-2002 experienced a disease epizootic and high observed mortality. This was followed by a period of lower disease prevalence and reduced observed mortality (2003-2005).

Patent Tong Surveys

Patent tong population surveys have been conducted by the department since the establishment of the 2010 sanctuaries, however, only surveys occurring after 2015 will be presented for each sanctuary in this appendix. These surveys use hydraulic patent tongs to obtain spatially explicit estimates of oyster density, as well as information on oyster size and the volume of cultch present. Patent tong surveys conducted by the department used a stratified random sampling design, with strata based on substrate type. The number of sampling points for each survey on each sanctuary ranged from 50 to 300, depending on the area of potential oyster habitat present in each sanctuary. Most sanctuaries have been surveyed at least once, and two sanctuaries have had two surveys conducted prior to sanctuary establishment.

The fixed area of the patent tongs (one square meter) allows for the calculation of oyster density. An average density of oysters based on all samples collected within a sanctuary can be used to derive the overall density of oyster habitat in the entire sanctuary. The patent tong surveys also measure the volume of surface shell in each sample. Exposed oyster shell is the preferred settlement substrate for oyster larvae; therefore the greater the volume of exposed shell, the greater the potential for spat set.

Comparison of Fall Survey and patent tong survey results is difficult given the difference in sampling efficiency and area between the two gear types; therefore, in this appendix the results from the two surveys are presented separately.

In this appendix oyster density from the patent tong surveys will be presented, where available, along with the Fall Survey information. In addition to the patent tong surveys conducted by the department, additional patent tong surveys were conducted by Versar, Inc. and the Oyster Recovery Partnership using a systematic sampling design. Results of these surveys may be referenced in this appendix.

Water Quality

Water quality influences patterns in oyster life-history and disease. Oyster survival, growth, reproduction, and disease incidence are related to water quality parameters including salinity, temperature, and dissolved oxygen. Oyster reproduction (spat fall) and disease-caused mortality both decline with decreasing salinity. Therefore, in areas where reproduction is lowest, survival of mature oysters may be highest. In higher salinity areas where survival may be lower,

recruitment is usually higher. Monitoring water quality may also detect the effect of sanctuaries and active restoration efforts on the environment, as oysters also impact the quality of water in which they live. For example, some water quality characteristics such as clarity may be related to oyster biomass, as greater biomass results in a greater filtration rate. However, the association between water quality improvements and oyster population size is complex, since a number of other factors, such as land use practices and water treatment facilities, greatly impact water quality.

Water quality is monitored in Maryland through the department's Eyes on the Bay program. Although water quality data are collected throughout the bay, most of the sampling stations are located outside oyster sanctuaries. Only ten of the sanctuaries have water quality information within the sanctuary boundaries. There may be a water quality station located close to a sanctuary, but not within the boundary, therefore the corresponding NOAA Code (Appendix B) may have water quality information that could be considered relevant to the sanctuary. Parameters measured by the Eyes on the Bay program include temperature, salinity, dissolved oxygen concentration, pH, total suspended solids, Secchi depth, chlorophyll a concentration, and nutrient concentrations.

In addition to bay-wide water quality monitoring, there are two sanctuary-specific monitoring efforts. In Harris Creek, the first tributary chosen for large-scale oyster restoration, there were three water quality instruments or sondes, which were removed in 2020. Two were moored to the bottom, and one was mounted on a vertical profiler that takes samples throughout the water column. Additionally, biweekly water samples were collected in Harris Creek and alkalinity calculated based on total inorganic carbon. In the Tred Avon River, there is one sonde mounted on a vertical profiler. Each sonde measures temperature, salinity, dissolved oxygen concentration, pH, turbidity, fluorescence, and total chlorophyll concentration. Additionally, biweekly water samples were collected in Harris Creek and alkalinity calculated based on total inorganic carbon.

Oyster bars in Maryland are located in the mesohaline salinity classification (5-18 ppt). Within this mesohaline zone, Maryland oyster bars are further classified into three zones: Zone 1 has an average salinity less than 11 ppt; Zone 2 has an average salinity between 11 and 15 ppt; and Zone 3 has salinities greater than 15 ppt[7]. Data from Maryland Department of Natural Resources, Maryland Department of Environment, and Chesapeake Bay Program were used to create a Maryland-wide salinity dataset. Oyster sanctuaries are classified by salinity zone using average surface salinity from 2006 to 2020. Although bottom salinity would be more appropriate to use to classify salinity zones for oysters, surface salinity datasets had greater spatial and temporal coverage. Salinity zones were developed to be broad, general categories and some sanctuaries may fluctuate between salinity zones given weather patterns.

[7] Maryland Department of Natural Resources. 2019. Oyster Management Plan. 93 pp. https://dnr.maryland.gov/fisheries/Documents/MD_Oyster_FMP-2019.pdf

Sanctuaries within Zone 1 (22 sanctuaries and 119,186 surface acres) were chosen to increase oyster biomass through stocking and long-term survival. Oysters within Zone 1 are characterized by having lower levels of disease and better survival but low reproductive capability[8]. Oysters are also subject to intermittent freshets that can result in substantial mortality.

Sanctuaries within Zone 3 (4 sanctuaries and 18,351 surface acres) were chosen to attempt to foster disease resistance and enhance reproduction. Oysters in this zone have been subjected to heavy disease pressures, which historically resulted in high mortality[9]. In Zone 3, there are also high recruitment rates that provide a fairly constant influx of new oysters.

Sanctuaries within Zone 2 (25 sanctuaries and 115,470 surface acres) represent transition areas incorporating the goals of Zones 1 and 3. Oyster located in Zone 2 may have fluctuating characteristics based on the climatic variation between wet and dry years[10]. Annual spat settlement can range from low to moderate to high based on salinity. Mortality related to disease can also fluctuate from year to year. In years with low disease-caused mortality, the oyster populations in this area can recover as long as there is also successful recruitment. However, the reverse can also occur.

Baywide Streamflow

Freshwater inflow into the bay through streams and rainfall can impact water quality, and in particular salinity. The U.S. Geological Survey monitors freshwater streamflow into the bay annually[11] (Figure A.0-1).

Between 1990 and 1998, freshwater inflows were variable, with some years of high flows alternating with low flow years. A prolonged drought began in 1999 and persisted for four years, adversely affecting oyster populations and compounding mortalities associated with oyster disease. The years 2003 and 2004 were high flow years with little adverse effect on oyster mortality. Normal flow conditions persisted from 2005 to 2010 and from 2012 to 2017. High flows in 2011 and 2018 contributed to oyster mortalities. In 2011, higher mortalities were confined largely to the upper bay and in 2018 the highest mortalities occurred in the upper bay as well as the Potomac River. Higher flows persisted throughout the first half of 2019 but 2020 resulted in an average flow year.

[8] Maryland Department of Natural Resources. 2019. Oyster Management Plan. 93 pp. https://dnr.maryland.gov/fisheries/Documents/MD_Oyster_FMP-2019.pdf
[9] IBID
[10] IBID
[11] USGS. 2015. Estimated streamflow entering Chesapeake Bay above selected cross sections. United States Geological Survey Inflow Database. http://md.water.usgs.gov/waterdata/chesinflow/

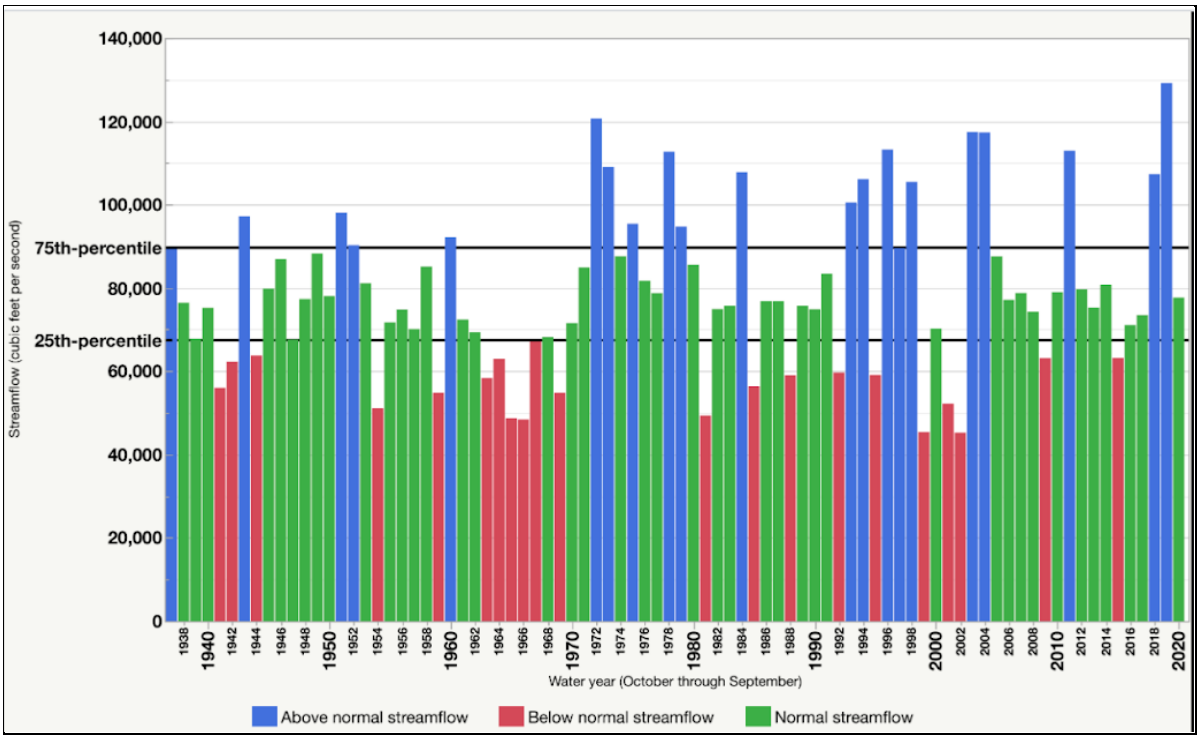

Figure A.0-1. Annual mean monthly freshwater flow into Chesapeake Bay.[12]

Ecosystem Services

Ecosystem services provided by oysters include: habitat for fish and invertebrate species; biogeochemical processes including denitrification; filtration and water clarity; adjacent shallow water habitat stabilization; and shoreline protection. Several studies assessing ecosystem services in Harris Creek and the Tred Avon River are underway. NOAA's Oyster Reef Ecosystem Services project is attempting to quantify and estimate the economic value that restored oyster reefs provide to other organisms and the environment. Researchers from the Virginia Institute of Marine Science and University of Maryland are quantifying macrofaunal productivity and nutrient removal associated with restored oyster reefs. Researchers from the University of Maryland are using computer models to estimate the theoretical larval supply from sanctuaries to public fishery areas. Scientists from the Smithsonian Environmental Research Center and the University of Maryland are assessing the effects of restored oyster reefs on chlorophyll uptake. Researchers from Morgan State University have been examining the economic impacts of restored oyster tributaries.

[12] USGS. 2021. Estimated streamflow entering Chesapeake Bay above selected cross sections. United States Geological Survey Inflow Database.
https://www.usgs.gov/centers/cba/science/freshwater-flow-chesapeake-bay?qt-science_center_objects=0#qt-science_center_objects

As these studies are ongoing, findings regarding ecological services will need to be addressed in a future report. However, current data can inform conversations about ecological services as a number of these services (e.g. water filtration and provision of habitat) can be linked to measurable parameters such as oyster density and total biomass.

Stock Assessment

The first Maryland oyster stock assessment was completed in December 2018 by the Maryland Department of Natural Resources and University of Maryland Center for Environmental Science [13]. The assessment developed a stage-structured oyster population model and biological reference points based on the biological characteristics of the population and other appropriate factors affecting the population. An independent peer review panel concluded that the results from the assessment can serve as an adequate basis for management decisions. An updated stock assessment was completed in June of 2020[14]. This update used the same oyster population model and biological reference points as the 2018 stock assessment, however, added two more years of data.

The stock assessments' stage-structured model and the reference point estimation models were applied separately to each NOAA Code to estimate time series of abundance, harvest fraction (fishing levels), and natural mortality rates of oysters. The modeled processes included recruitment (natural spat set and plantings), growth from small to market sizes, natural mortality (including disease-related mortality) of smalls and markets, the effect of fishing on small and market oysters (fishing levels), changes to habitat over time, effects of planting substrate and oysters, and the disarticulation of small and market boxes.

Target and threshold harvest reference points were developed in the assessment. The following sections of this appendix will not summarize these results due to the prohibition of harvesting oysters in sanctuaries. The threshold abundance reference point is the lowest estimated abundance each for NOAA Code for the years 1999-2017. NOAA Codes would be considered "depleted" if abundance falls below the lower limit abundance reference point.

Only NOAA Code 331 (Upper Chester River) has corresponding sanctuary and NOAA Code boundaries, thus stock assessment results can only be stated for two sanctuaries: Upper Chester River Sanctuary and Chester River ORA Sanctuary. Based on the 2020 update stock assessment, the NOAA Code 331 corresponding to these sanctuaries was below the threshold abundance reference point (depleted population status).

[13] Maryland Department of Natural Resources. 2018. A stock assessment of the Eastern Oyster, *Crassostrea virginica*, in the Maryland waters of Chesapeake Bay. Final Report November 2018. 359 pp https://dnr.maryland.gov/fisheries/Pages/oysters/Oyster_Stock_Assess.aspx

[14] Maryland Department of Natural Resources. 2020. Full Report of the 2020 Update Stock Assessment of the Eastern Oyster, *Crassostrea virginica*, in the Maryland waters of Chesapeake Bay. Final Report November 2018. 359 pp. https://dnr.maryland.gov/fisheries/Pages/oysters/Oyster_Stock_Assess.aspx

Section A.01: Big Annemessex Sanctuary

The Big Annemessex Sanctuary is located in a high-salinity (Zone 3) region of Maryland's lower eastern portion of Chesapeake Bay within NOAA Code 005. The sanctuary was created in 2010 and encompasses 749 acres of which 361 acres (48%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are four historic oyster bars within the sanctuary[15], two of which lie almost entirely outside the sanctuary and account for only 0.9% of the total area of the entire sanctuary and two of which lie almost entirely within the sanctuary boundary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.01-1)
- Bottom types map (Figure A.01-2)
- Density Survey (Figure A.01-3)

The Fall Survey took one sample in this area between 2006 and 2020. In 2015, one sample was collected and no oysters were found. No samples have been collected in the sanctuary since then.

A patent tong population survey was conducted in 2017 and found no live oysters in Big Annemessex and no surface shell volume.

This area has not received any active restoration or replenishment efforts since 2006. Water quality was monitored in the sanctuary between 2011 to 2013[16] and we are unaware of any monitoring since then. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[15] See chart 45 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[16] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

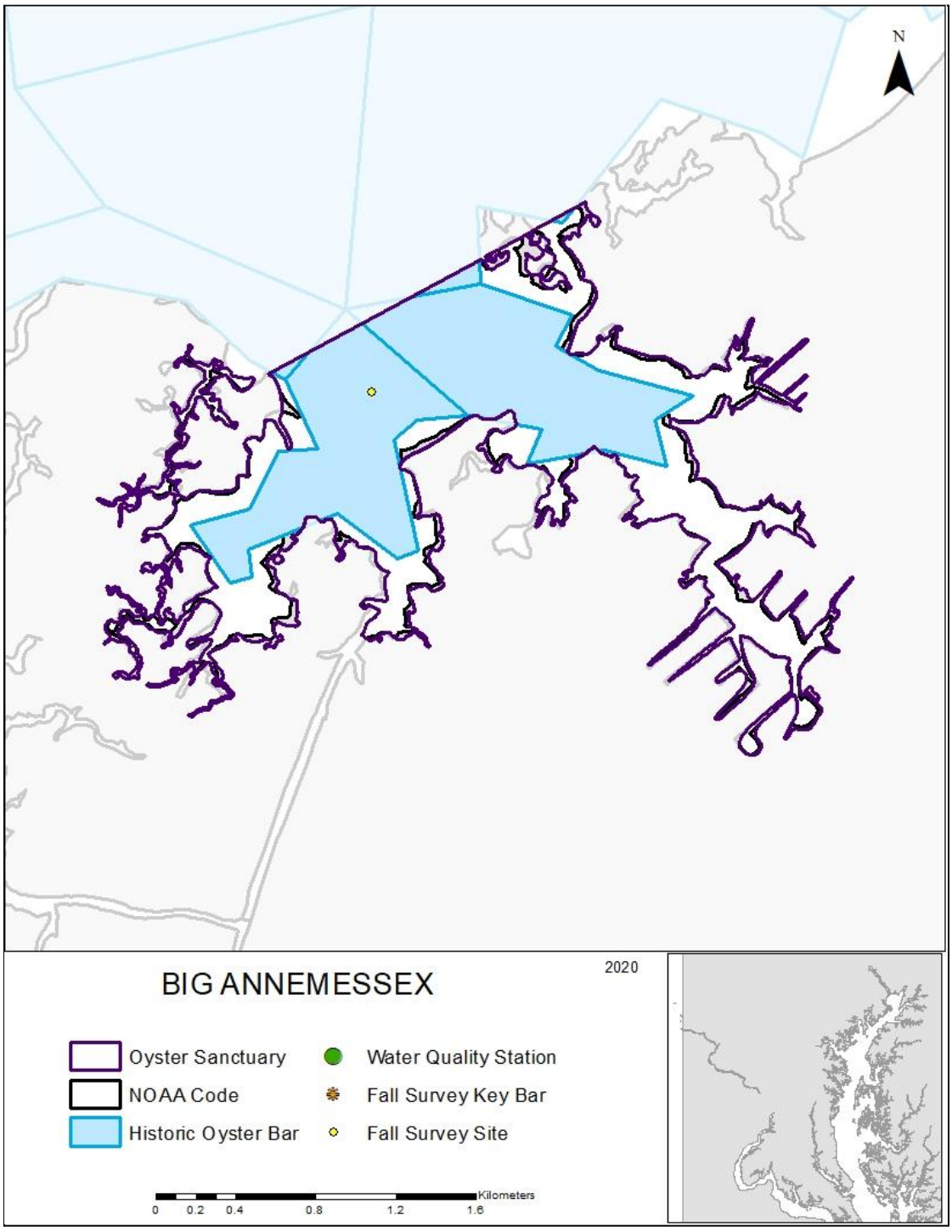

Figure A.01-1. Big Annemessex Sanctuary. The Fall Survey site was sampled in 2015.

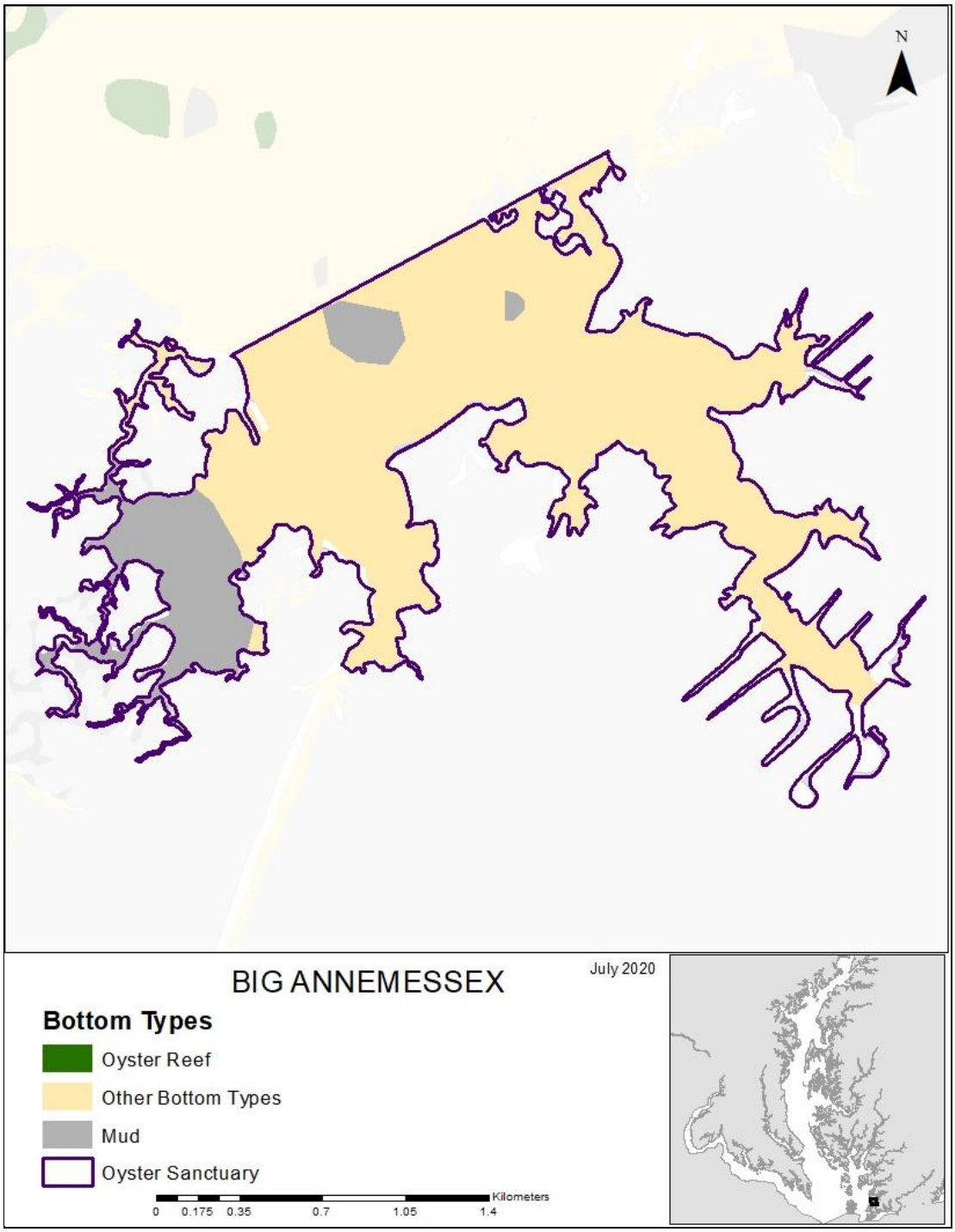

Figure A.01-2. Big Annemessex Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

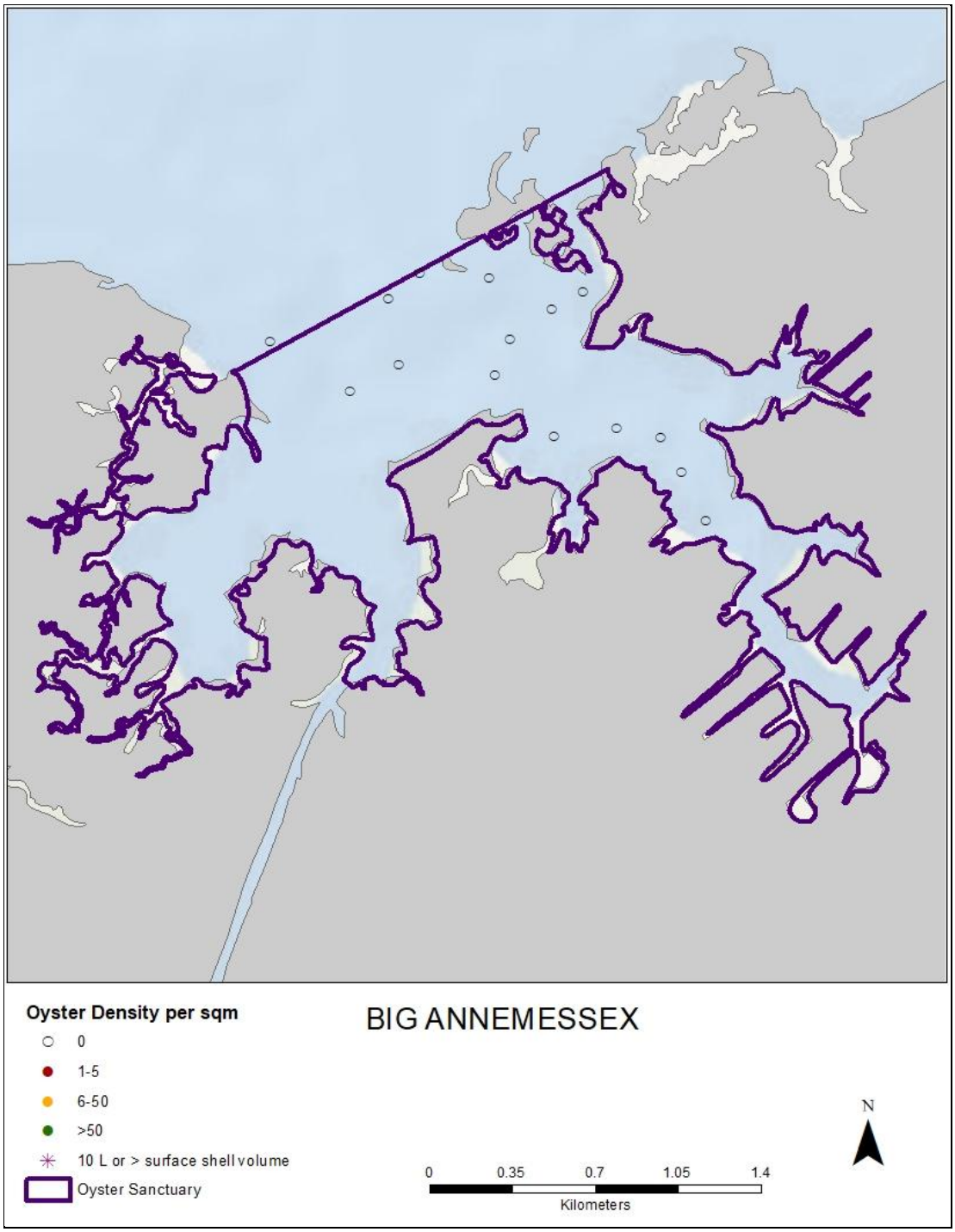

Figure A.01-3. Map of 2017 oyster density in the Big Annemessex Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.02: Breton Bay Sanctuary

The Breton Bay Sanctuary is located within Breton Bay on the north shore of Potomac River, a low-salinity (Zone 1) region, within NOAA Code 174. The sanctuary was created in 2010 and encompasses 3,212 acres, of which 888 acres (28%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 10 historic oyster bars within the sanctuary[17].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.02-1)
- Bottom types map (Figure A.02-2)
- Summary statistics (Table A.02-1)
- Abundance per year (Figure A.02-3)
- Density Survey (Figure A.02-4)
- Shell height frequencies (Figure A.02-5)
- Biomass per year (Figure A.02-6)
- Observed mortality (Figure A.02-7)
- Cultch per year (Figure A.02-8)

The Fall Survey sampled one bar in the sanctuary. The average density of live spat and small oysters was unchanged, while the average density of markets declined for 2016-2020. Biomass and cultch also declined. Observed mortality remained slightly above the bay-wide average. The percentage of oysters above 100 mm in shell height increased from 33% to 52% between the two time periods with data. A population patent tong survey was conducted by the department in 2018 and found no live oysters in Breton Bay. This patent tong survey also served to groundtruth the 2010 bottom type survey. There was a total of 11.15 liters of surface shell from the 237 samples taken, with a primary sediment of mud or sand.

This area has not received any replenishment or restoration planting activities with the exception of Marylanders Grow Oyster program. Marylanders Grow Oysters plantings have occurred annually since 2019.

Continual water quality monitoring occurred from 2006 to 2009[18] and we are unaware of any monitoring since then. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[17] See chart 34 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[18] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

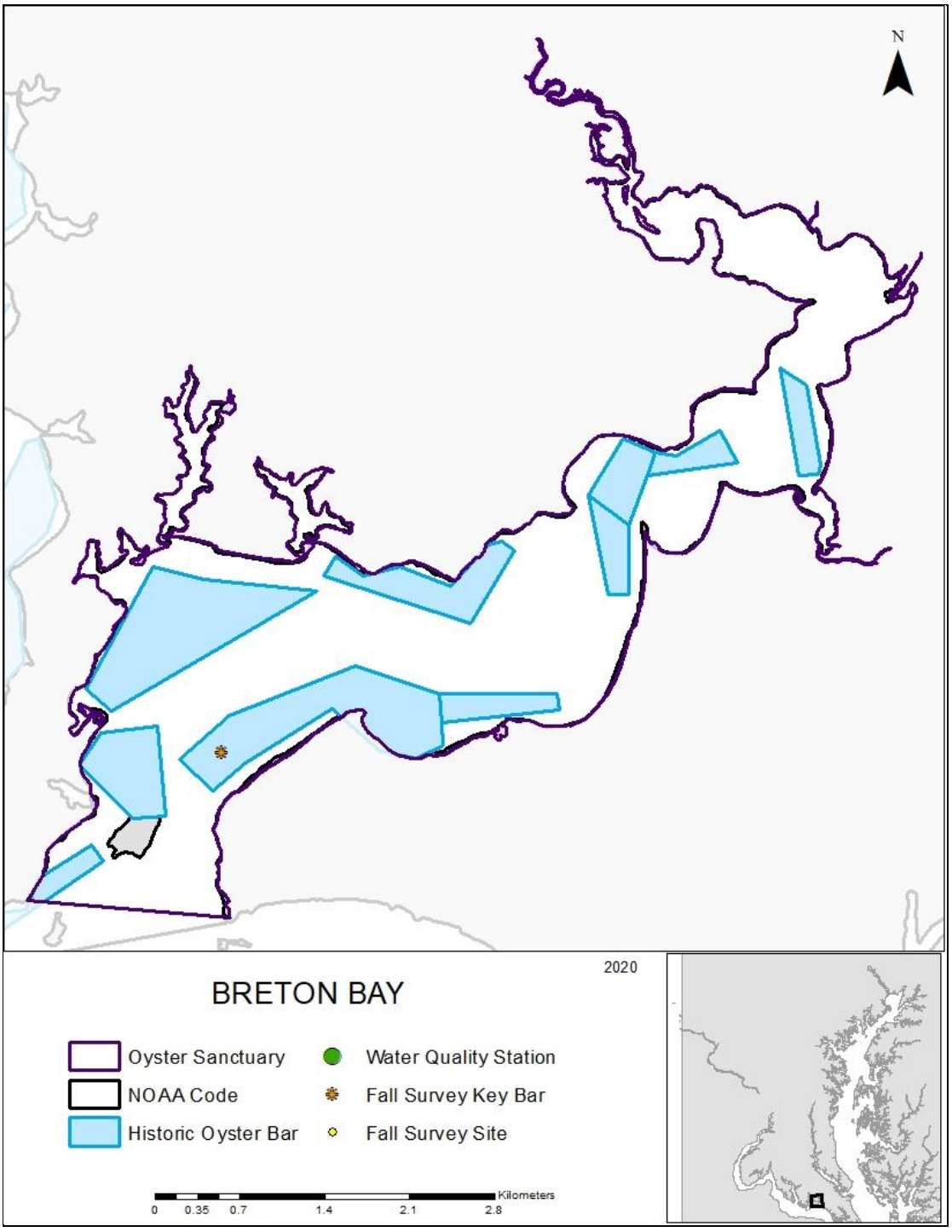

Figure A.02-1. Breton Bay Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

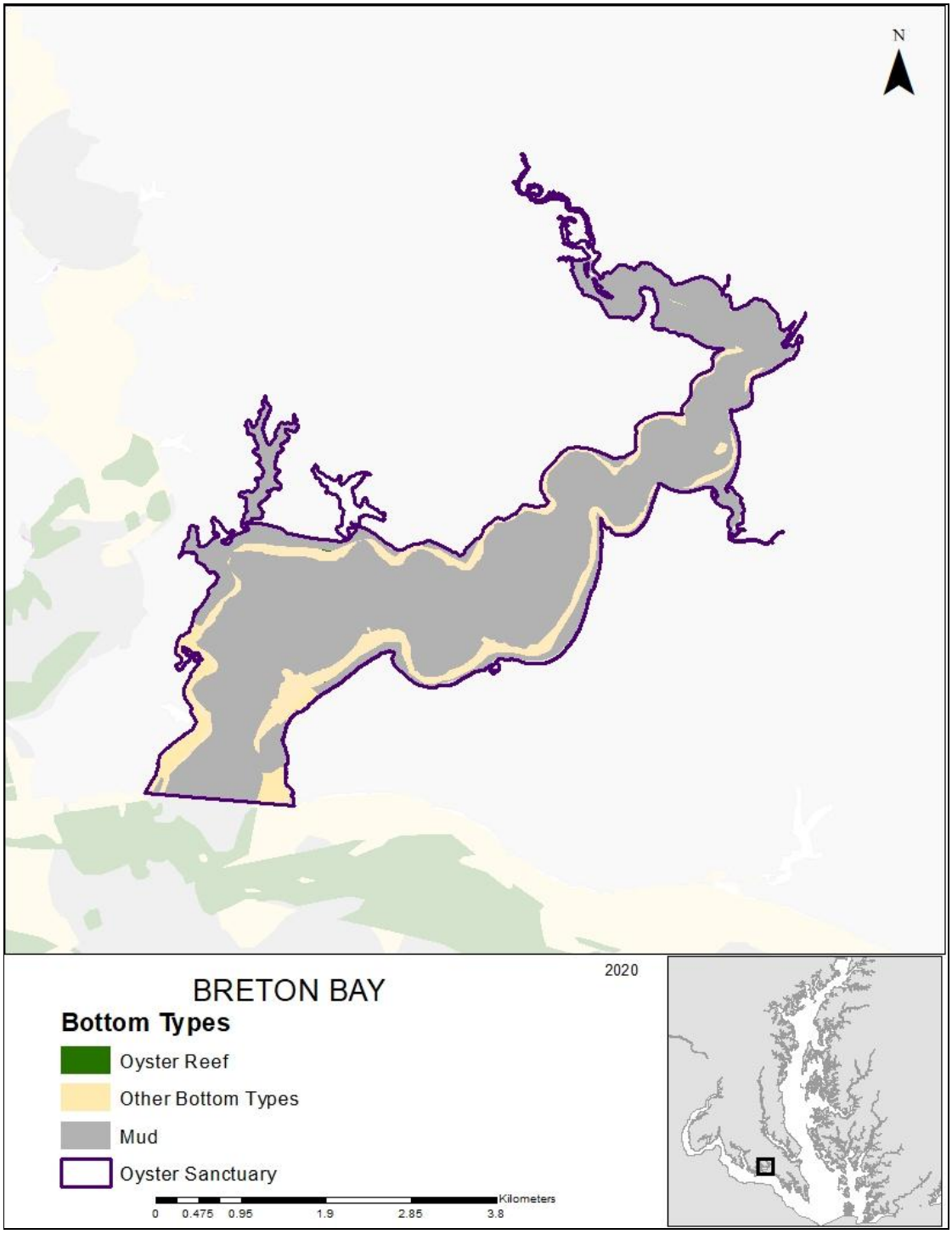

Figure A.02-2. Breton Bay Sanctuary bottom types. Data from Maryland Geological Survey from 2010.

Table A.02-1. Oyster population characteristics based on the Fall Survey in the Breton Bay Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	0 ± 0	0 ± 0	0 ± 0
Number of Live Small-Sized Oysters per square meter	0.1 ± 0.1	0.1 ± 0	0.1 ± 0
Number of Live Market-Sized Oysters per square meter	0.8 ± 0.2	0.9 ± 0.2	0.4 ± 0.1
Live Oyster Biomass (g Dry Weight per Bushel)	ND	50 ± 21	38 ± 12
Observed Mortality (%)	15 ± 10	17 ± 5	16 ± 5
Cultch (Bushels per 100 ft Towed)	0.7 ± 0.1	0.2 ± 0	0.1 ± 0
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

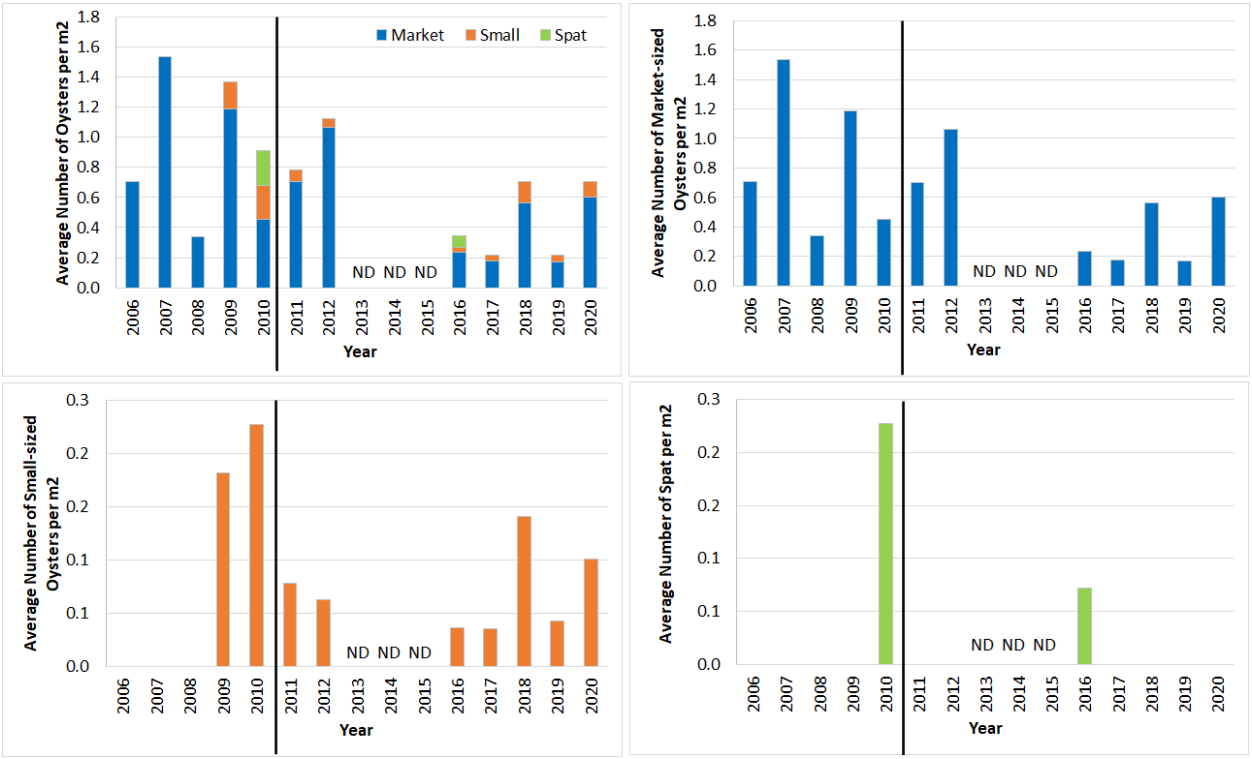

Figure A.02-3. Average number of live oysters per square meter by size class in the Breton Bay Sanctuary. Black line indicates the date the sanctuary was established. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

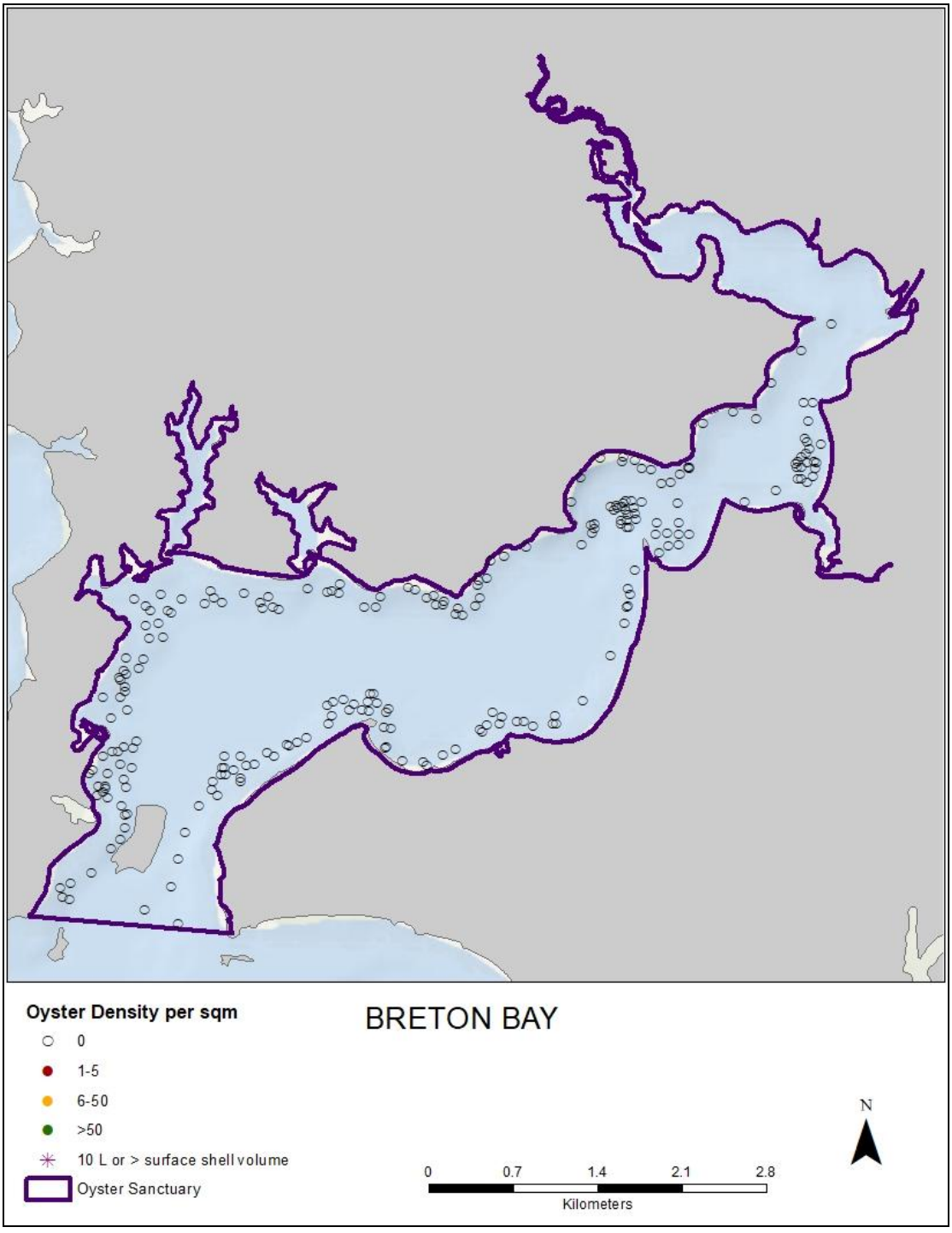

Figure A.02-4. Map of 2018 oyster density in the Breton Bay Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

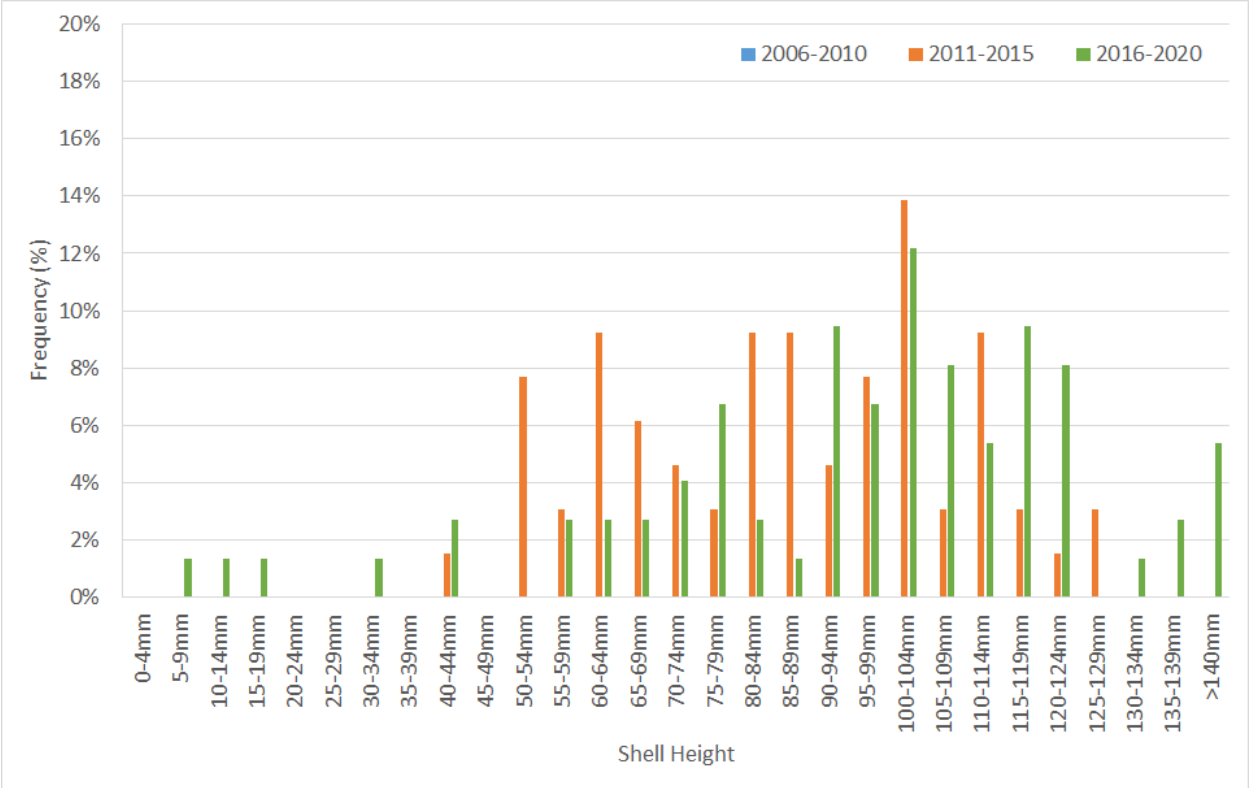

Figure A.02-5. Shell height frequencies of live oysters per bushel of material in the Breton Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Black Walnut bar. Data was not collected in 2006 to 2010 and 2015.

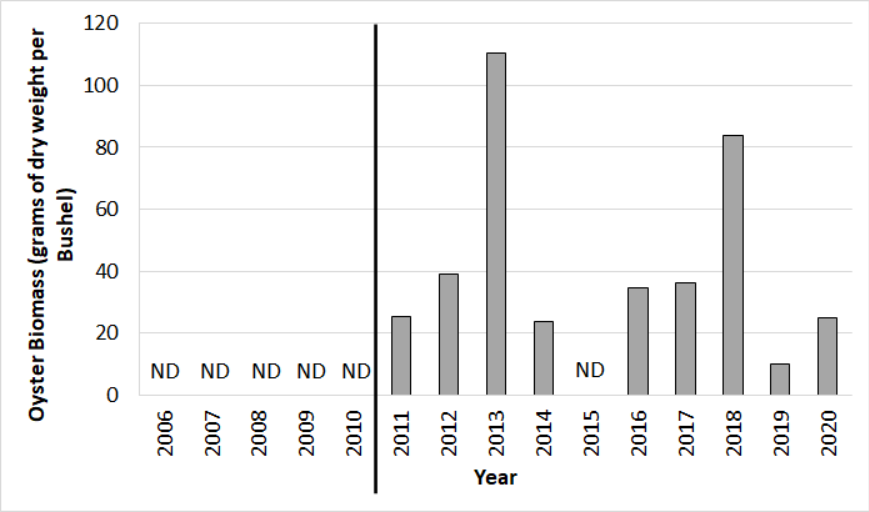

Figure A.02-6. Oyster biomass (grams of dry weight per bushel of material) in the Breton Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Black Walnut bar. Black line indicates the date the sanctuary was established. ND = No Data.

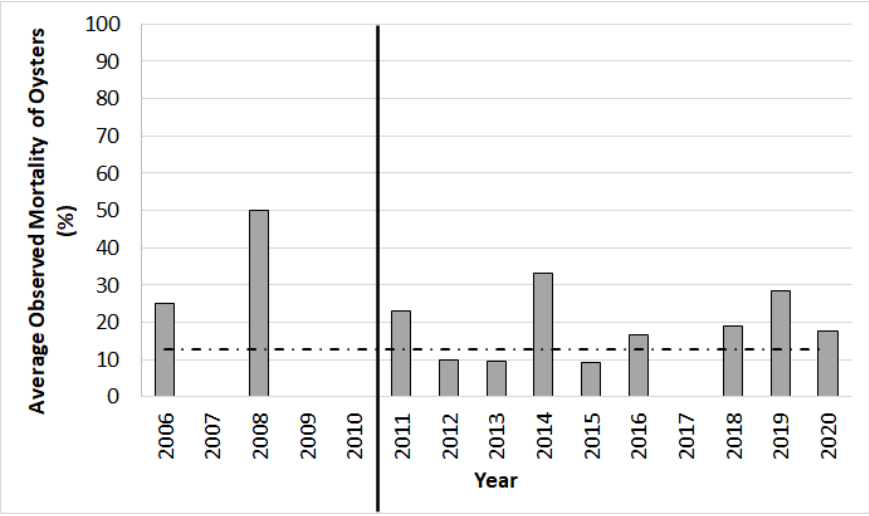

Figure A.02-7. Average annual observed mortality of market-sized and small-sized oysters in Breton Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality.

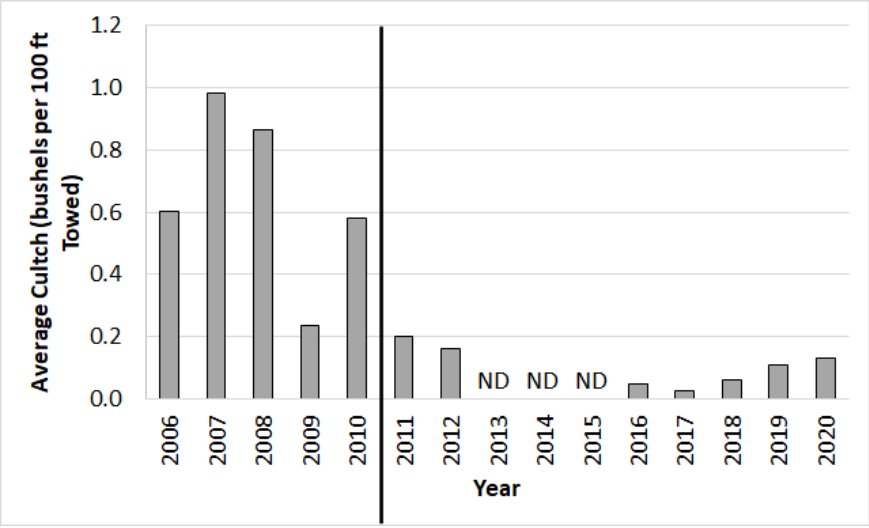

Figure A.02-8. Average cultch (live and dead oysters and loose shell) in the Breton Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. ND = No Data.

Section A.03: Calvert Shore Sanctuary

The Calvert Shore Sanctuary is located in the medium-salinity (Zone 2) region of Maryland's lower western portion of Chesapeake Bay within NOAA Code 027. The sanctuary was created in 2010 and encompasses 2,214 acres of which 673 (30.4%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar within the sanctuary, Flag Pond.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.03-1)
- Bottom types map (Figure A.03-2)
- Summary statistics (Table A.03-1)
- Abundance per year (Figure A.03-3)
- Shell height frequencies (Figure A.03-4)
- Biomass per year (Figure A.03-5)
- Observed mortality (Figure A.03-6)
- Dermo and MSX per year (Figure A.03-7)
- Cultch per year (Figure A.03-8)

The Fall Survey sampled the one bar in the Calvert Shore Sanctuary. The density of spat declined though the time period, but the density of small and market oysters increased, as did the biomass. Cultch declined throughout the time series. Observed mortality is slightly above the baywide average for 2016-2020. The percentage of oysters over 100 mm declined, largely due to the increase in the number of small oysters. The last patent tong population survey occurred in 2015 [19].

Between 2006 and 2010 no planting activities occurred to enhance the commercial public fishery. In 2017, approximately 11.4 million hatchery spat-on-shell were planted for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[19] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

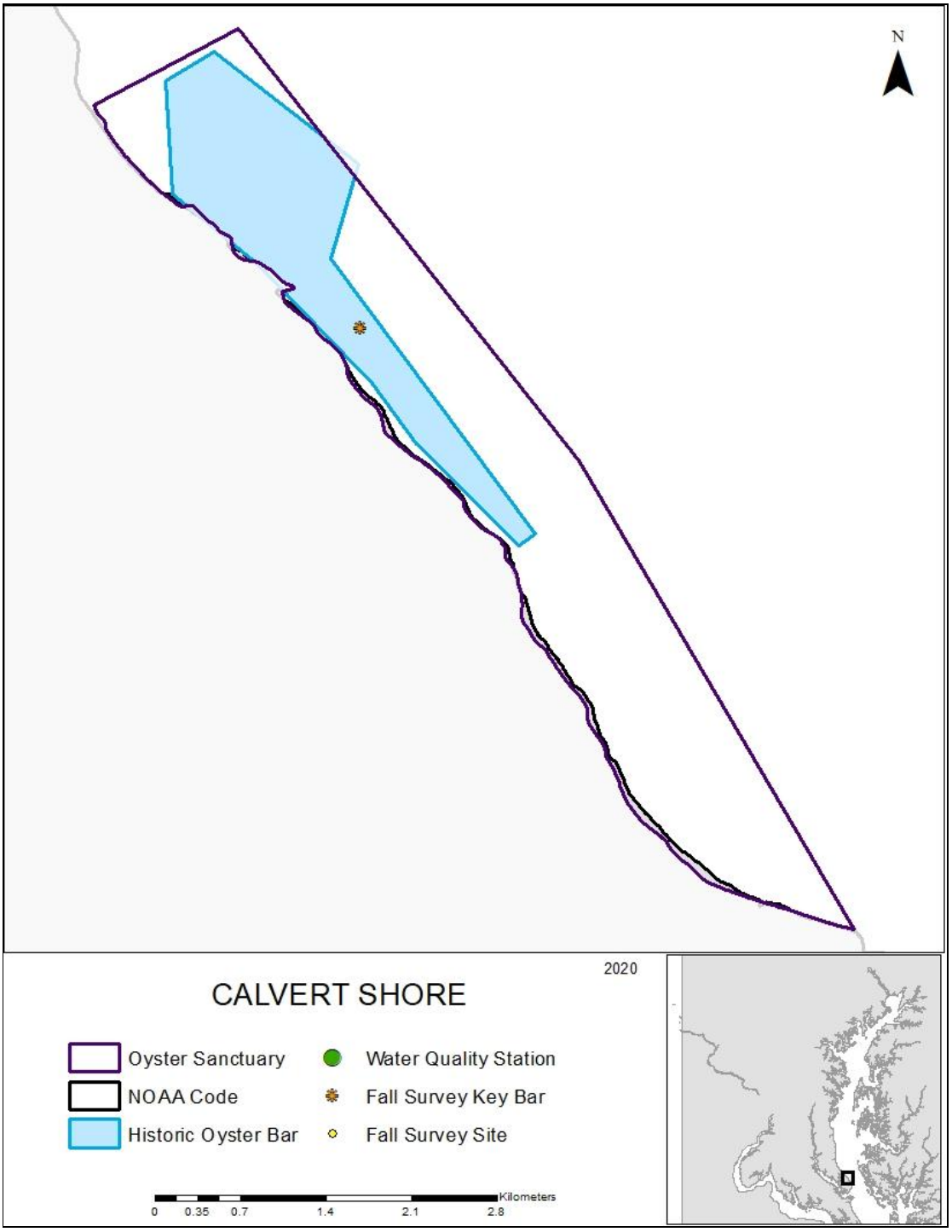

Figure A.03-1. Calvert Shore Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

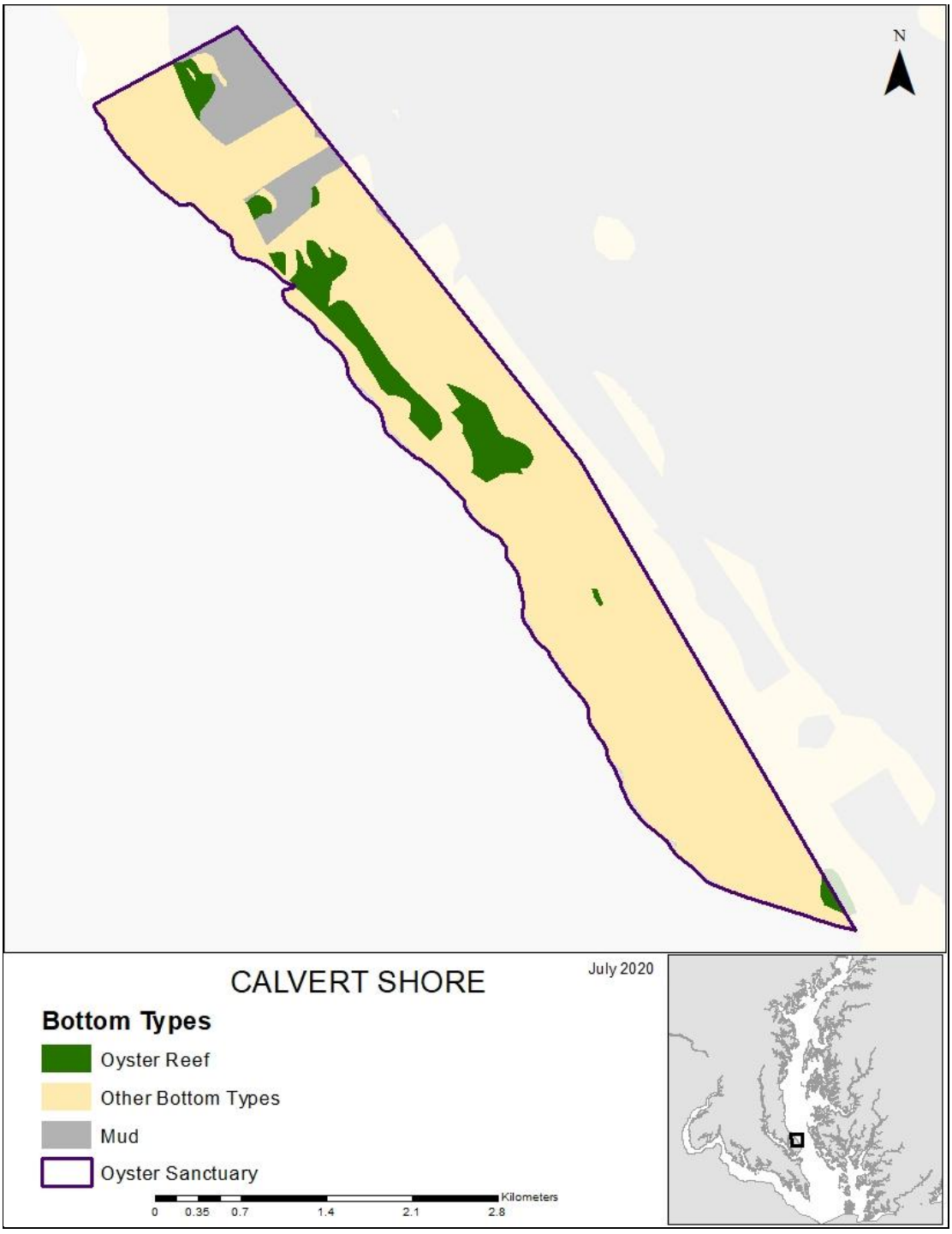

Figure A..03-2. Calvert Shore Sanctuary bottom types. Data from Maryland Geological Survey from 2009.

Table A.03-1. Oyster population characteristics based on the Fall Survey in the Calvert Shore Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	1.4 ± 1.4	ND	0.2 ± 0.2
Number of Live Small-Sized Oysters per square meter	0.5 ± 0.3	ND	1.9 ± 1.1
Number of Live Market-Sized Oysters per square meter	1.3 ± 0.7	ND	7.8 ± 6.2
Live Oyster Biomass (g Dry Weight per Bushel)	46 ± 19	98 ± 33	278 ± 75
Observed Mortality (%)	13 ± 5	9 ± 3	13 ± 9
Cultch (Bushels per 100 ft Towed)	0.4 ± 0.1	ND	0.1 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

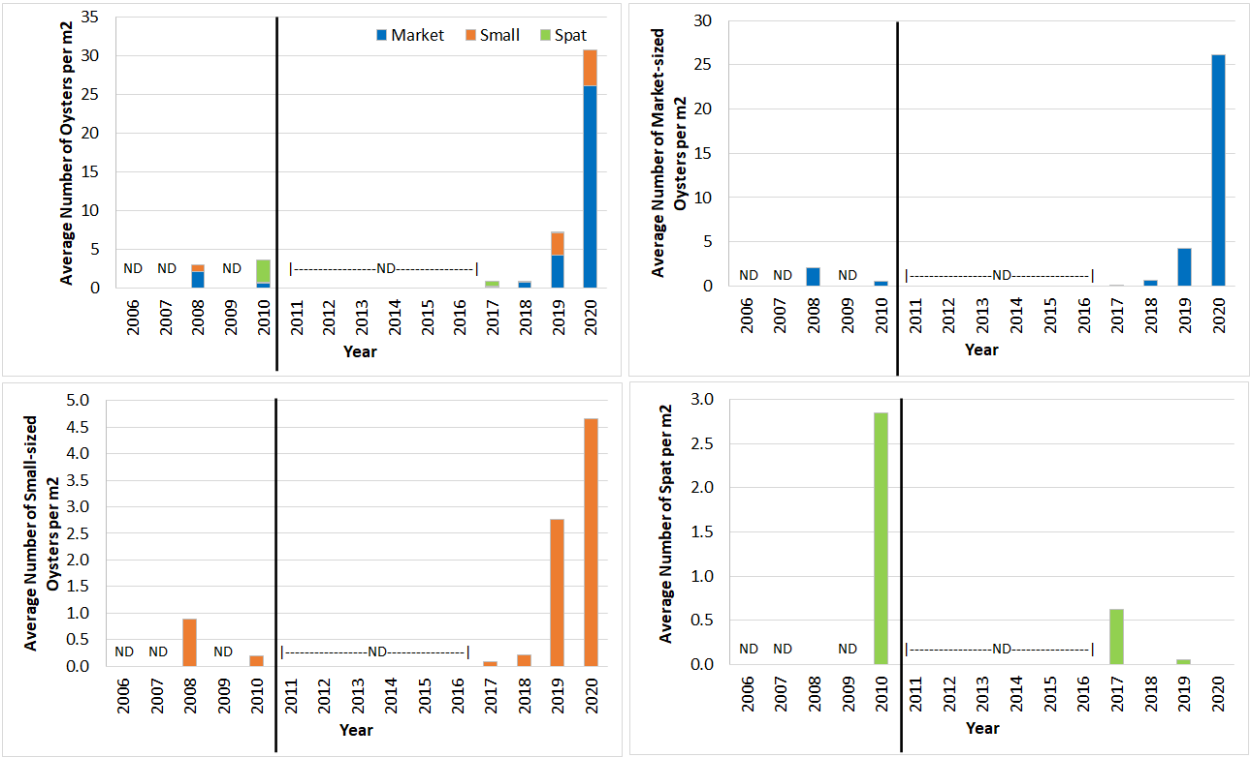

Figure A.03-3. Average number of live oysters per square meter by size class in the Calvert Shore Sanctuary. Black line indicates the date the sanctuary was established. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

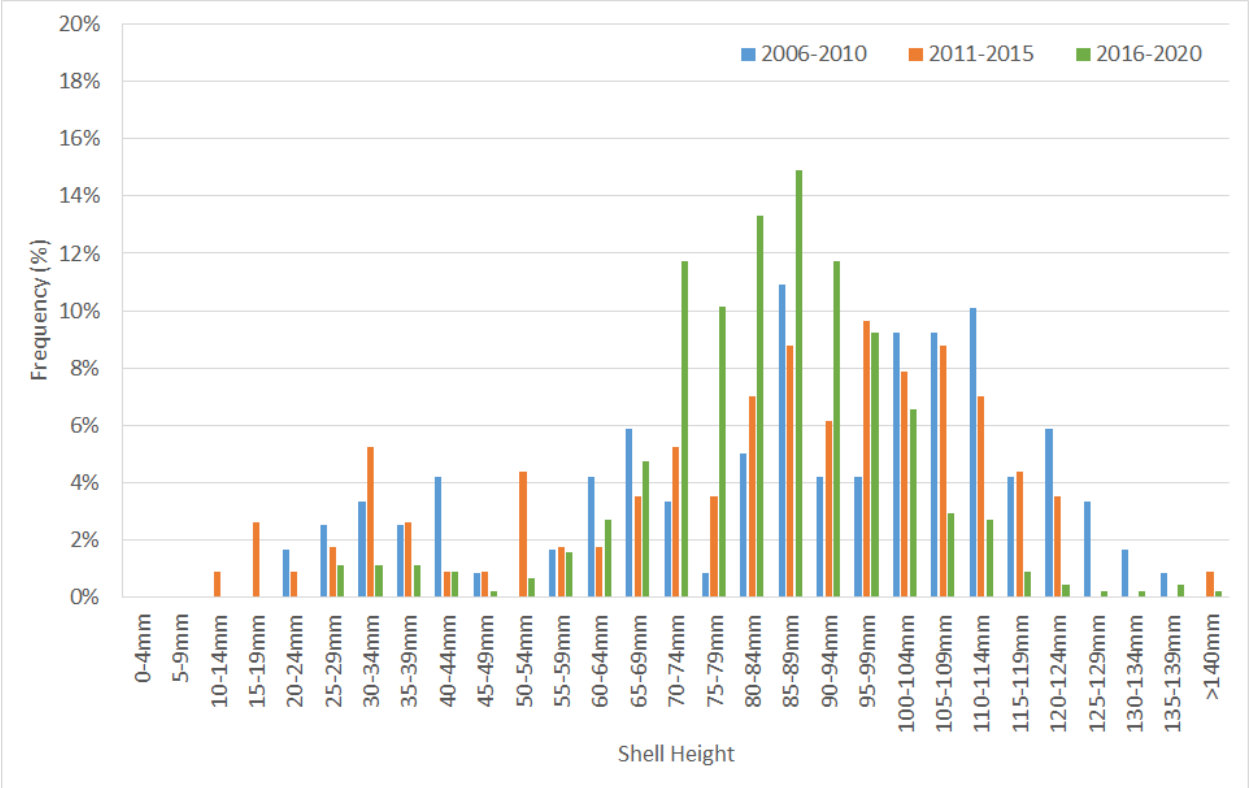

Figure A.03-4. Shell height frequencies of live oysters per bushel of material in the Calvert Shore Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Flag Pond bar.

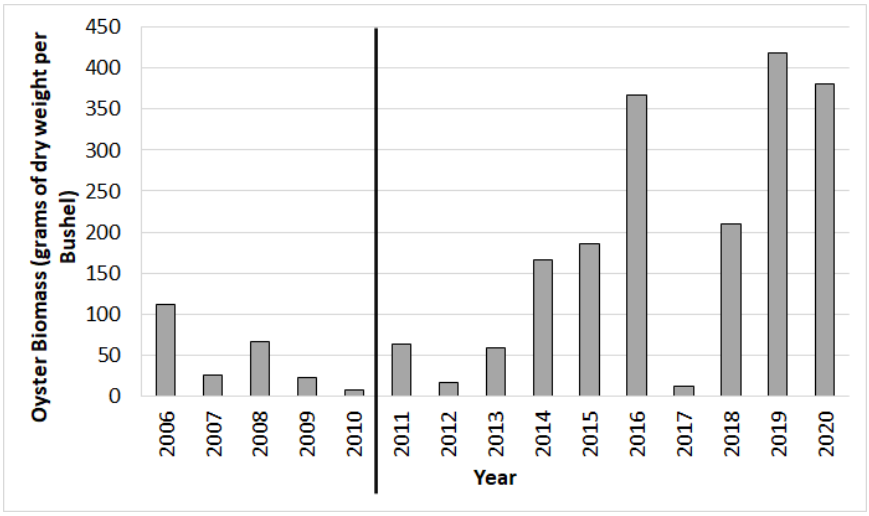

Figure A.03-5. Oyster biomass (grams of dry weight per bushel of material) in the Calvert Shore Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Flag Pond bar. Black line indicates the date the sanctuary was established.

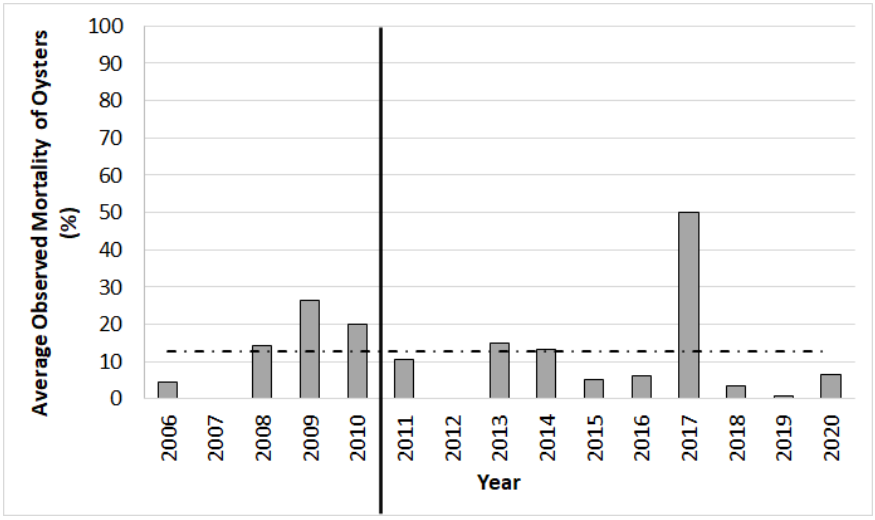

Figure A.03-6. Average annual observed mortality of market-sized and small-sized oysters in Calvert Shore Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality.

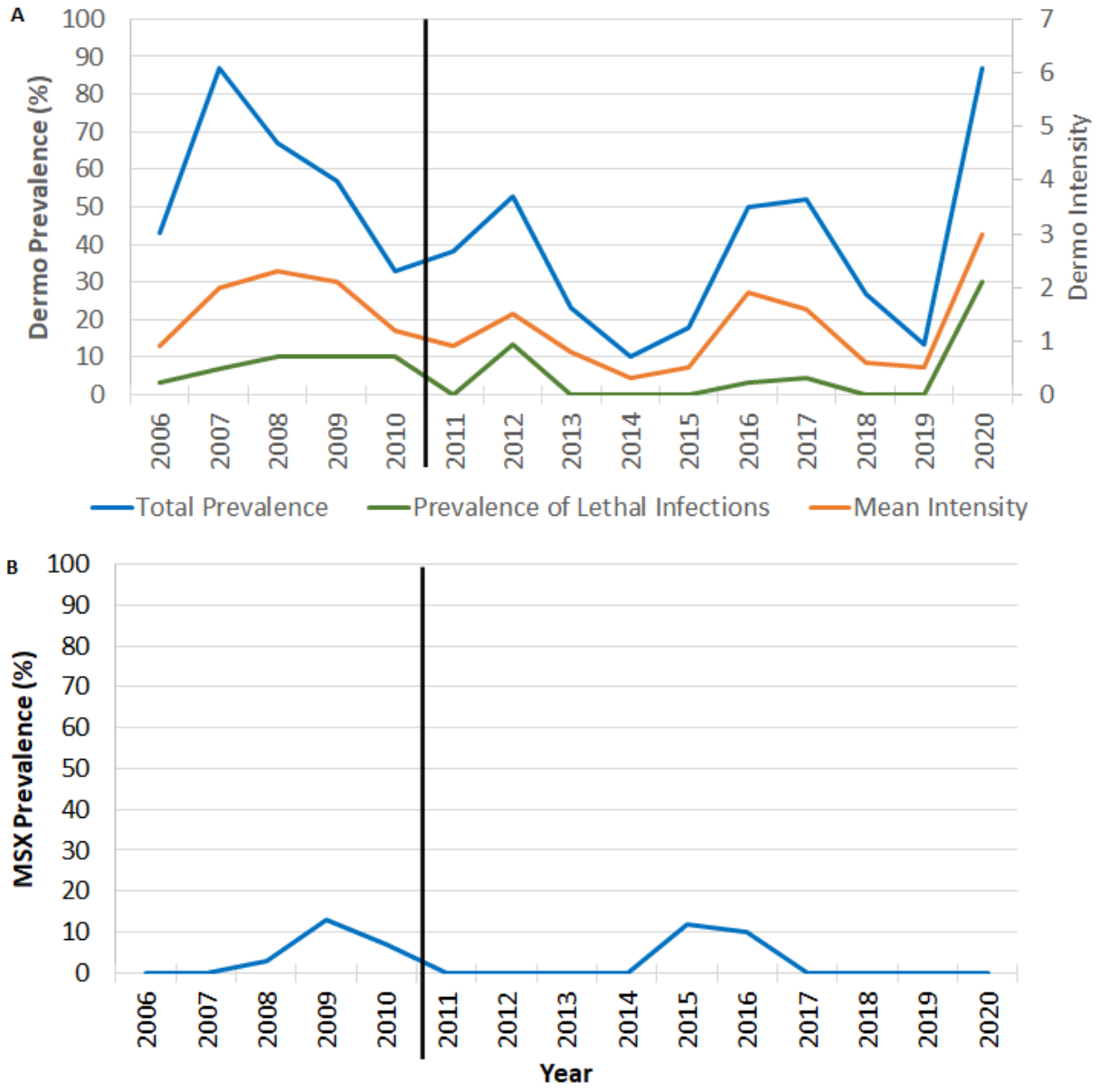

Figure A.03-7. Oyster disease prevalence and intensity in the Calvert Shore Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Flag Pond bar. Black line denotes the date the sanctuary was established.

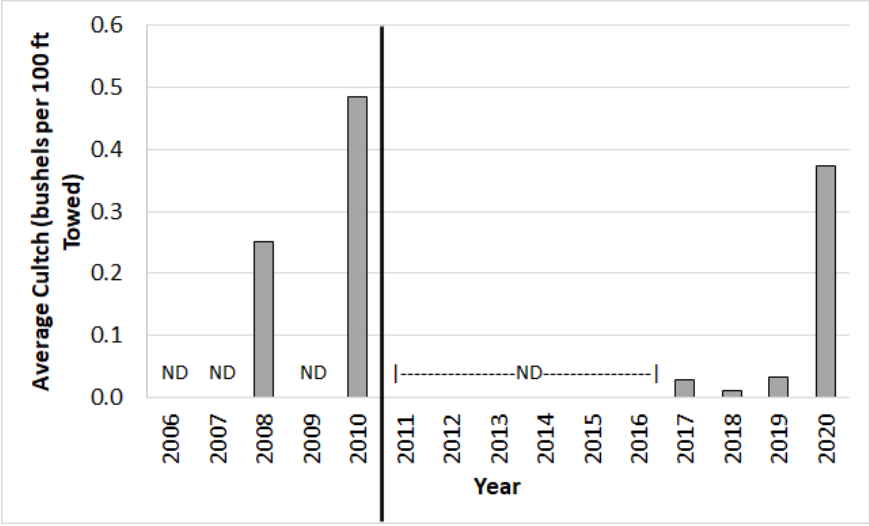

Figure A.03-8. Average cultch (live and dead oysters and loose shell) in the Calvert Shore Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. ND = No Data.

Section A.04: Cedar Point Sanctuary

The Cedar Point Sanctuary is located on the upper St. Mary's County Shore, a medium-salinity (Zone 2) region, within NOAA Code 229. The sanctuary was created in 2010 and encompasses 3,473 acres of which 2,839 (82%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are two historic oyster bars within the sanctuary[20]; however, one of the bars only has 40% of its area within the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.04-1)
- Bottom types map (Figure A.04-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in the sanctuary in 2013[21] and no new surveys have occurred since then. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[20] See chart 35 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[21] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

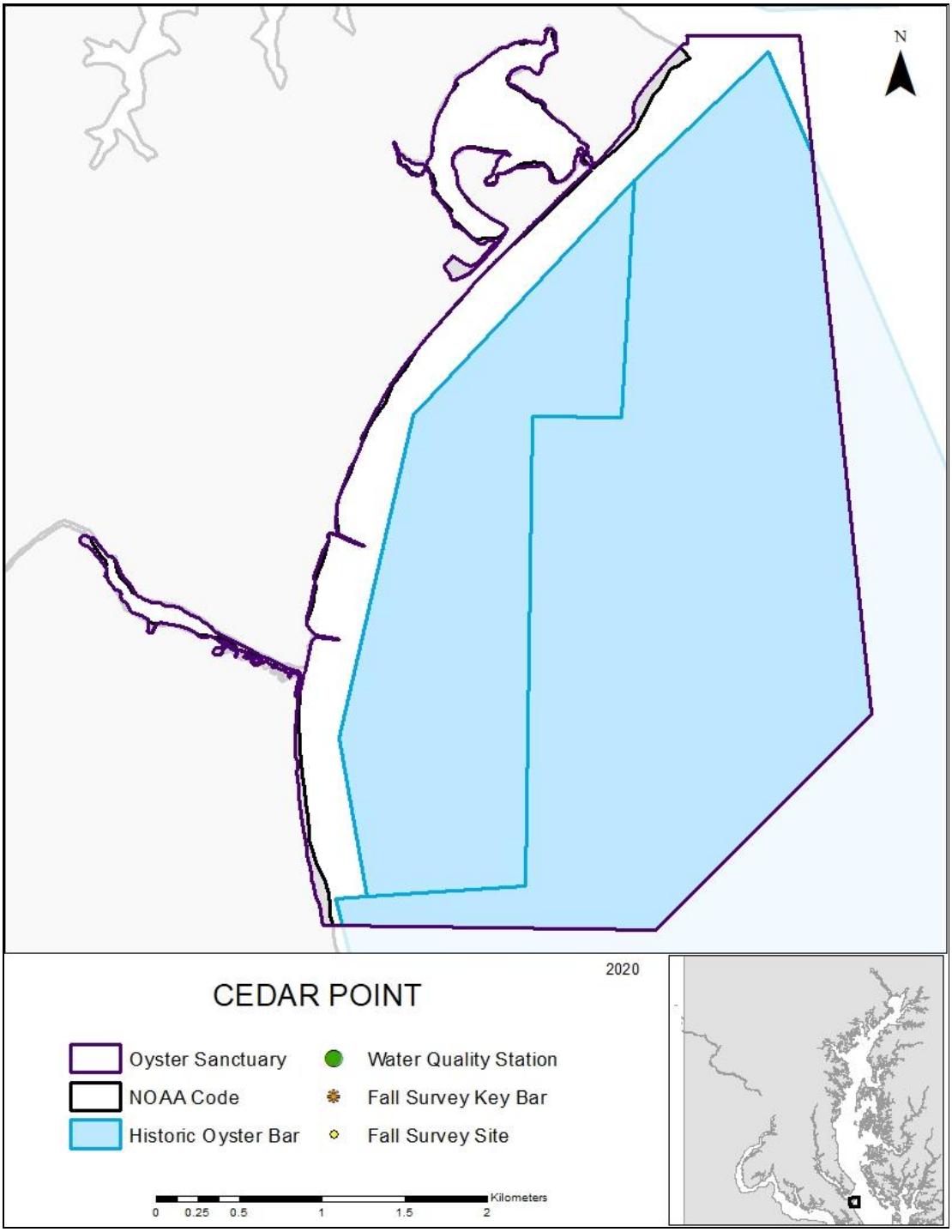

Figure A.04-1. Cedar Point Sanctuary.

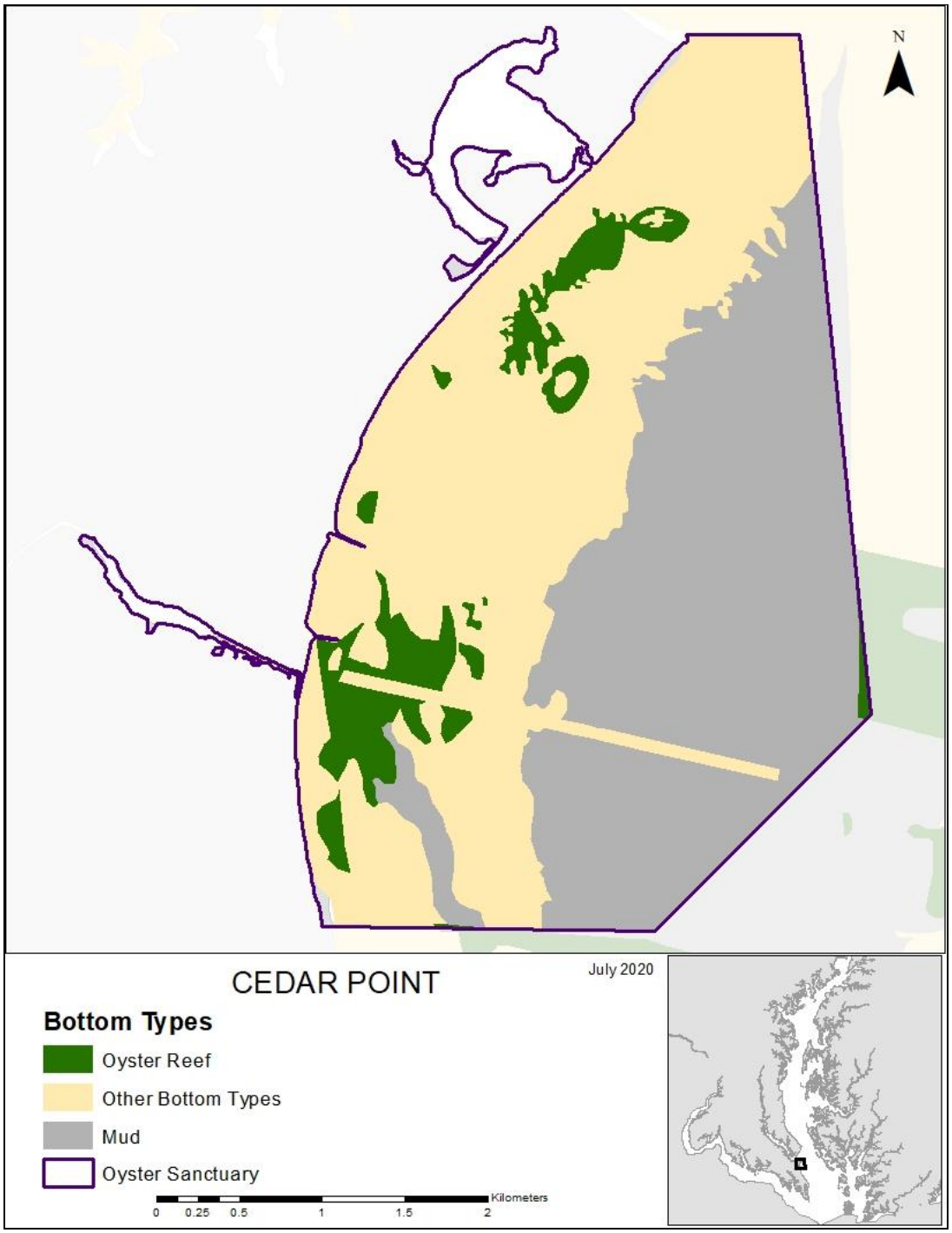

Figure A.04-2. Cedar Point Sanctuary bottom types. Data from Maryland Geological Survey from 2013.

Section A.05: Chester River ORA Zone A Sanctuary

The Chester Oyster Restoration Area (ORA) Zone A Sanctuary is located in the upper Chester River, a low-salinity (Zone 1) region of Maryland within NOAA Code 331. The sanctuary was created in 1996 to evaluate methods for oyster restoration, culture, and production as recommended by the Maryland Oyster Roundtable in 1993. The sanctuary encompasses 6,189 acres of which 184 (3%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are nine historic oyster bars within the sanctuary[22].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.05-1)
- Bottom types map (Figure A.05-2)
- Summary statistics (Table A.05-1)
- Abundance per year (Figure A.05-3)
- Observed mortality (Figure A.05-4)
- Cultch per year (Figure A.05-5)

The Fall Survey sampled two bars in the sanctuary. Spat and small oyster density remained unchanged, while the density of market oysters increased. Observed mortality increased for 2016-2020 to slightly above the baywide average. The amount of cultch decreased slightly from the previous five-year average. The last patent tong population survey occurred in 2012[23].

No restoration plantings have occurred since 2006. We are unaware of any studies explicitly examining oyster ecosystem services monitoring in this area. Continuous water quality monitoring has occurred at station ET4.1 (39.2437; -75.9249) in Chester River ORA Zone A Sanctuary, however, the site is located much further upstream than any historic oyster bottom.

[22] See chart 8 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[23] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

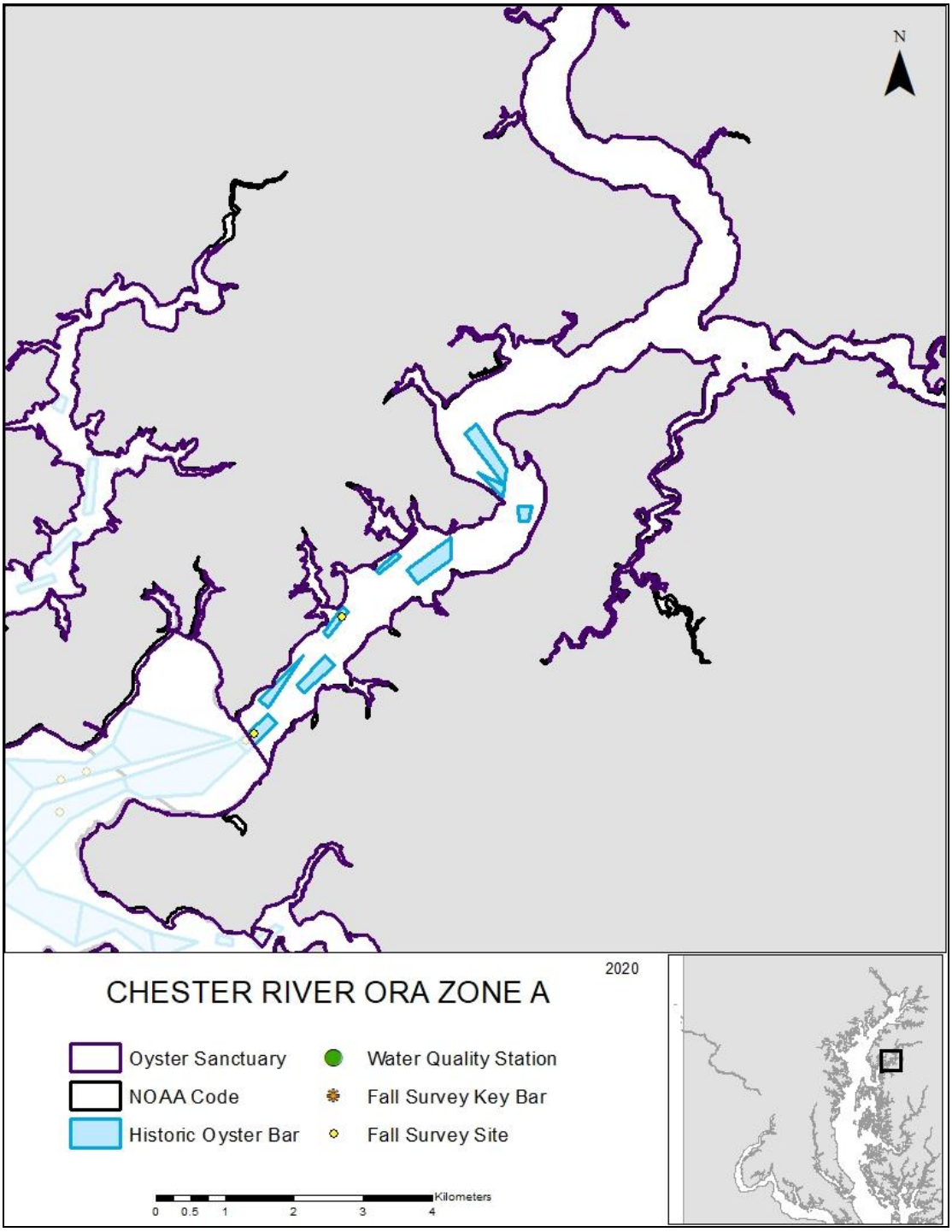

Figure A.05-1. Chester River ORA Sanctuary. Fall Survey sites may not be sampled every year.

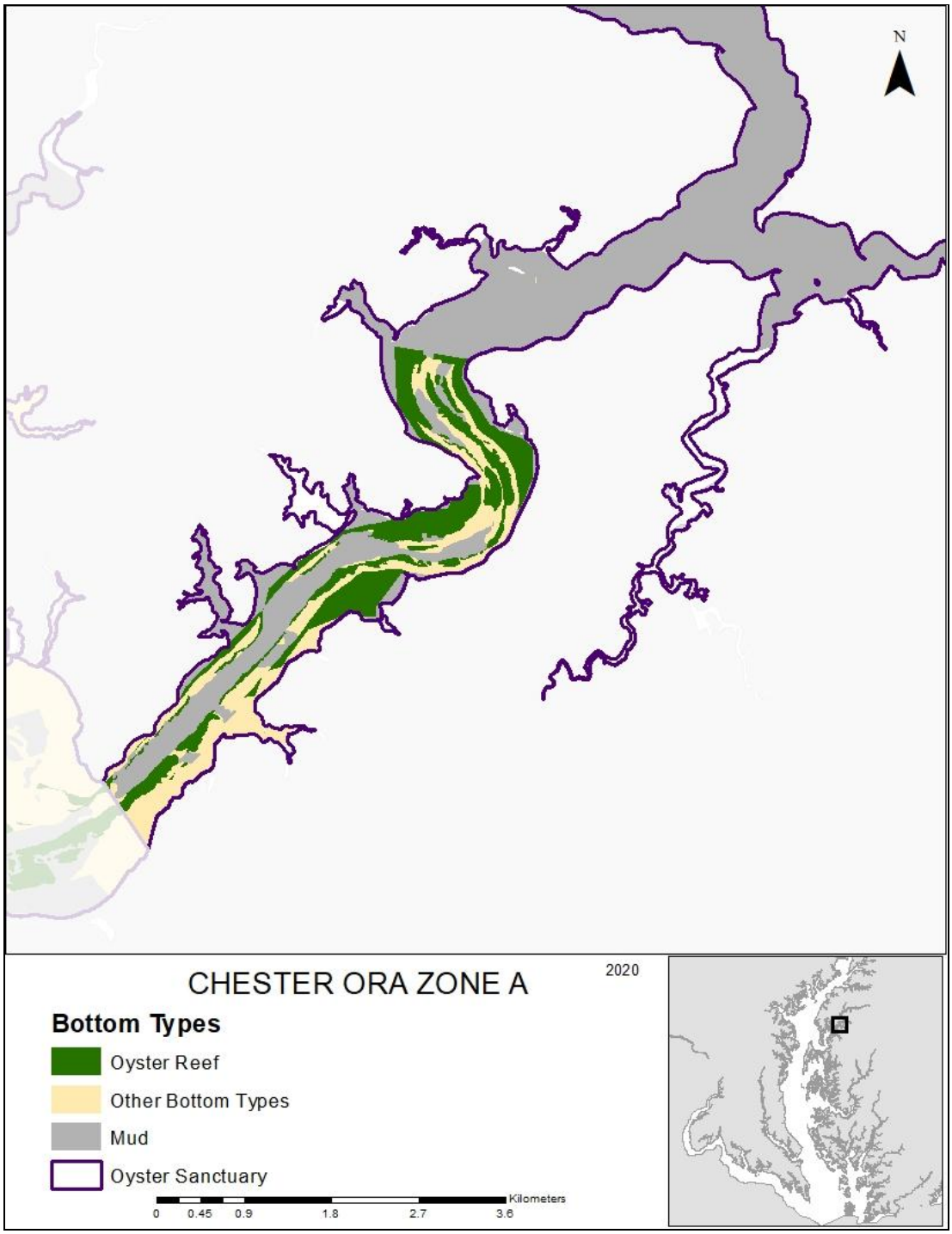

Figure A.05-2. Chester River ORA Sanctuary bottom types. Data from Maryland Geological Survey from 2012.

Table A.05-1. Oyster population characteristics based on the Fall Survey in the Chester River ORA Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 10
Number of Live Spat Oysters per square meter	0 ± 0	0 ± 0	0 ± 0
Number of Live Small-Sized Oysters per square meter	0 ± 0	2.3 ± 0.7	0 ± 0
Number of Live Market-Sized Oysters per square meter	8.9 ± 1.5	12.3 ± 4.6	14.3 ± 4.7
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	10 ± 5	11 ± 5	15 ± 3
Cultch (Bushels per 100 ft Towed)	1 ± 0.2	1.5 ± 0.5	1.3 ± 0.3
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

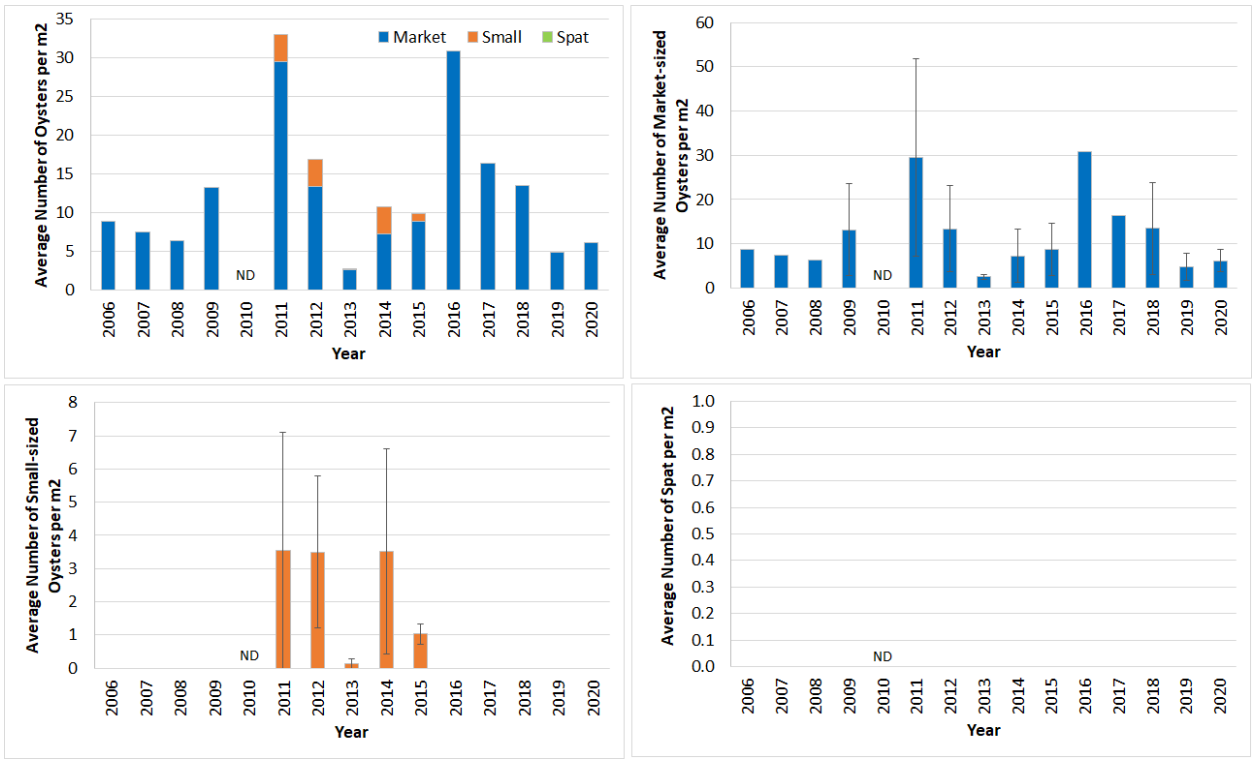

Figure A.05-3. Average number of live oysters per square meter by size class in the Chester River ORA Sanctuary. The sanctuary was established in 1996. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

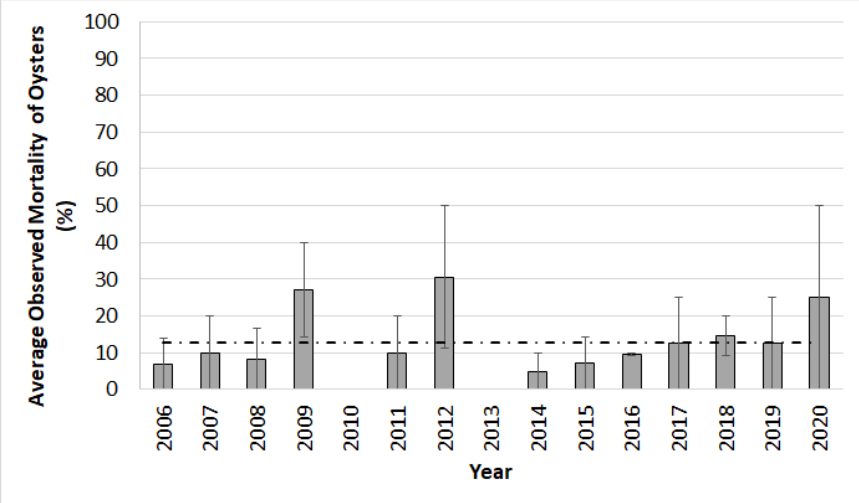

Figure A.05-4. Average annual observed mortality of market-sized and small-sized oysters in Chester River ORA Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The sanctuary was established in 1996. The dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

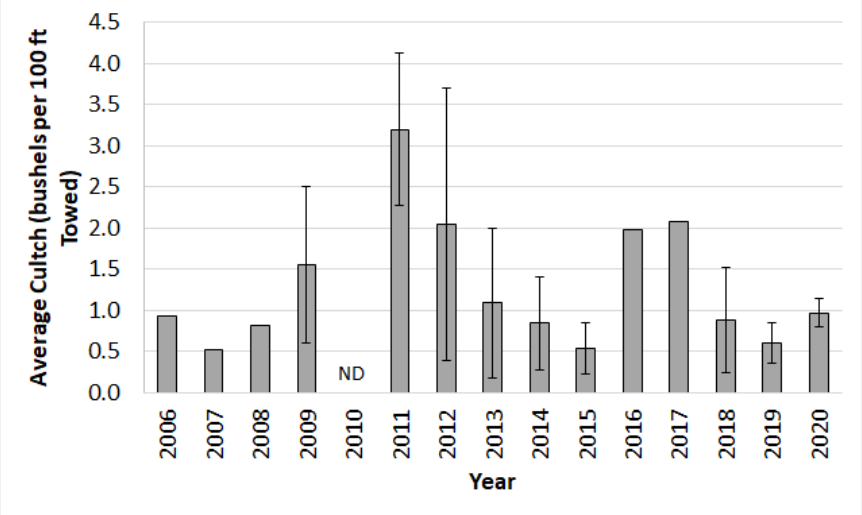

Figure A.05-5. Average cultch (live and dead oysters and loose shell) in the Chester River ORA Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The sanctuary was established in 1996. Error bars represent ± 1 standard error. ND = No Data.

Section A.06: Choptank River ORA Zone A Sanctuary

The Choptank River ORA Zone A Sanctuary is located in the upper Choptank River, a low-salinity (Zone 1) region of Maryland within NOAA Code 337. The sanctuary was created in 1996 to evaluate methods for oyster restoration, culture, and production as recommended by the Maryland Oyster Roundtable in 1993. The sanctuary encompasses 8,962 acres of which 236 (3%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are six historic oyster bars within the sanctuary[24].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.06-1)
- Bottom types map (Figure A.06-2)
- Summary statistics (Table A.06-1)
- Abundance per year (Figure A.06-3)
- Observed mortality (Figure A.06-4)
- Cultch per year (Figure A.06-5)

The Fall Survey sampled three bars in this sanctuary. Density of spat and small oysters decreased. Density of market oysters increased. An increase in observed mortality for 2016-2020 was possibly caused by a freshet in 2019. The amount of cultch declined slightly from the previous five-year average. The last patent tong population survey occurred in 2015[25].

Since 2006, approximately 15 million hatchery spat-on-shell were planted for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services. Continuous water quality monitoring has occurred at station ET5.1 (38.80645; -75.9097) in Choptank River ORA Zone A Sanctuary, however, the site is located much further upstream than any historic oyster bottom.

[24] See chart 21 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[25] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

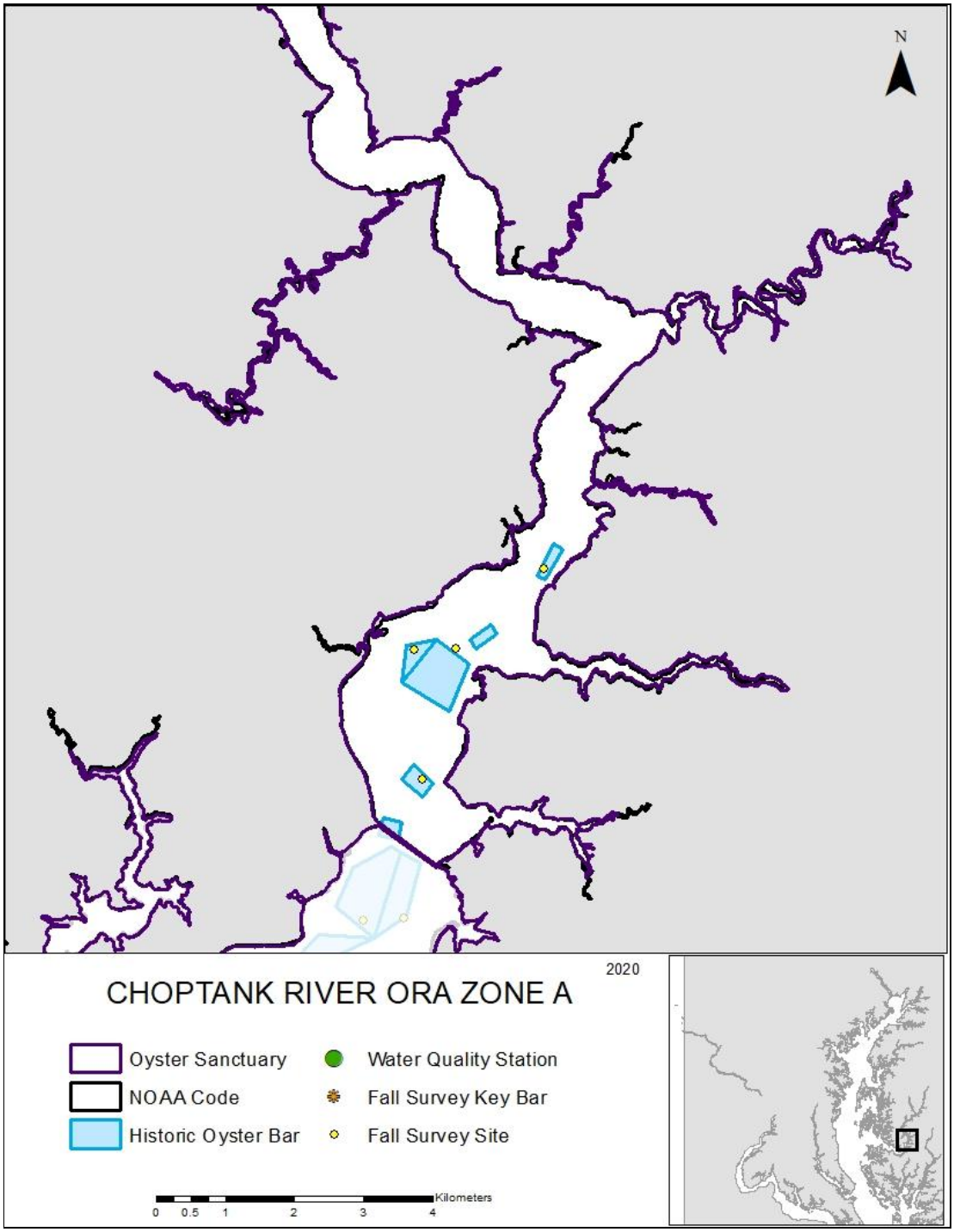

Figure A.06-1. Choptank River ORA Sanctuary. Fall Survey sites may not be sampled every year.

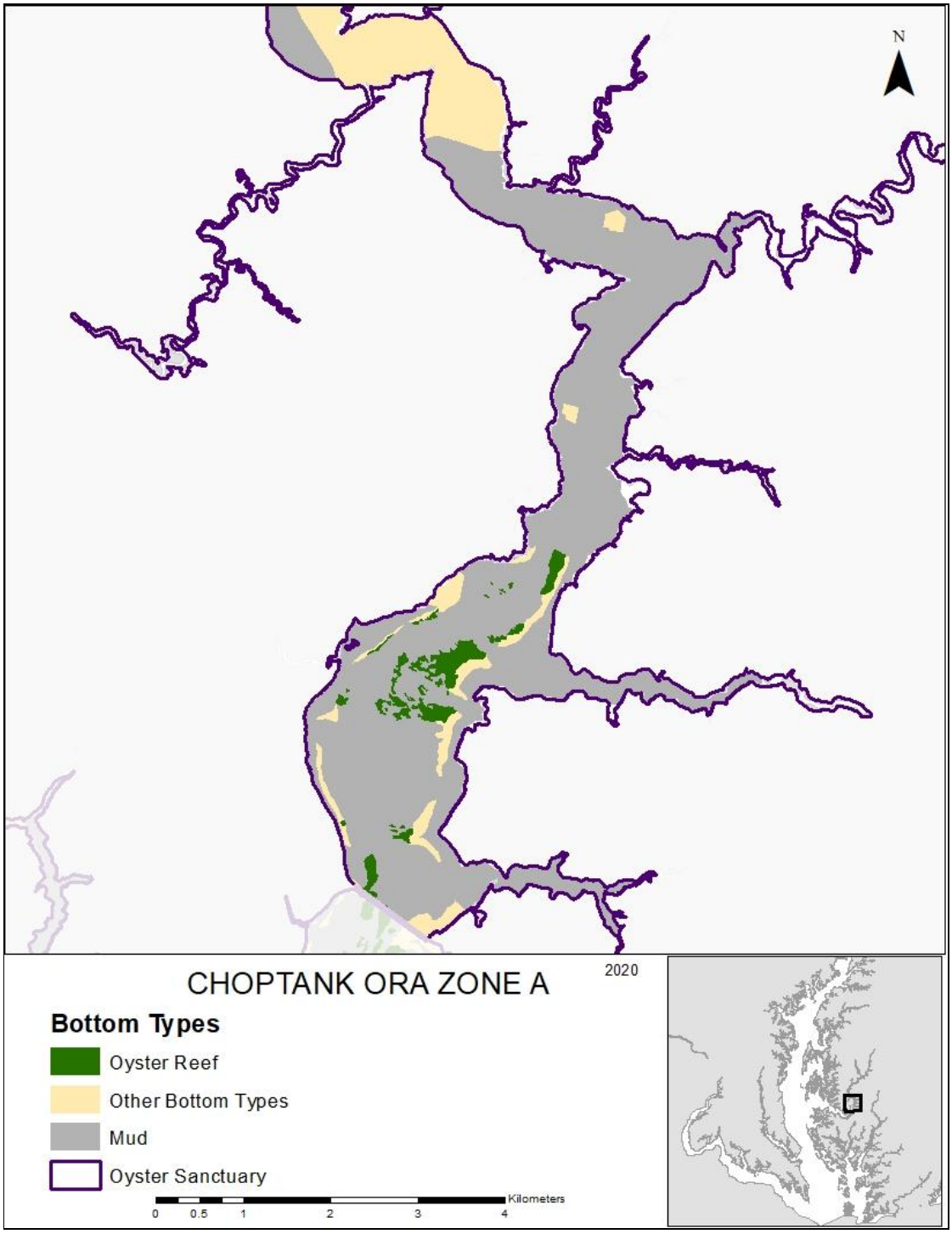

Figure A.06-2. Choptank River ORA Sanctuary bottom types. Data from Maryland Geological Survey from 2008.

Table A.06-1. Oyster population characteristics based on the Fall Survey in the Choptank River ORA Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 17	5 / 15	5 / 15
Number of Live Spat Oysters per square meter	0.6 ± 0.4	0.5 ± 0.4	0.2 ± 0.2
Number of Live Small-Sized Oysters per square meter	6 ± 2	41.4 ± 6.3	14.5 ± 5.4
Number of Live Market-Sized Oysters per square meter	4.6 ± 1.7	24.8 ± 5.4	37.3 ± 10.4
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	4 ± 2	5 ± 3	14 ± 11
Cultch (Bushels per 100 ft Towed)	1.2 ± 0.2	1.9 ± 0.1	1.5 ± 0.3
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

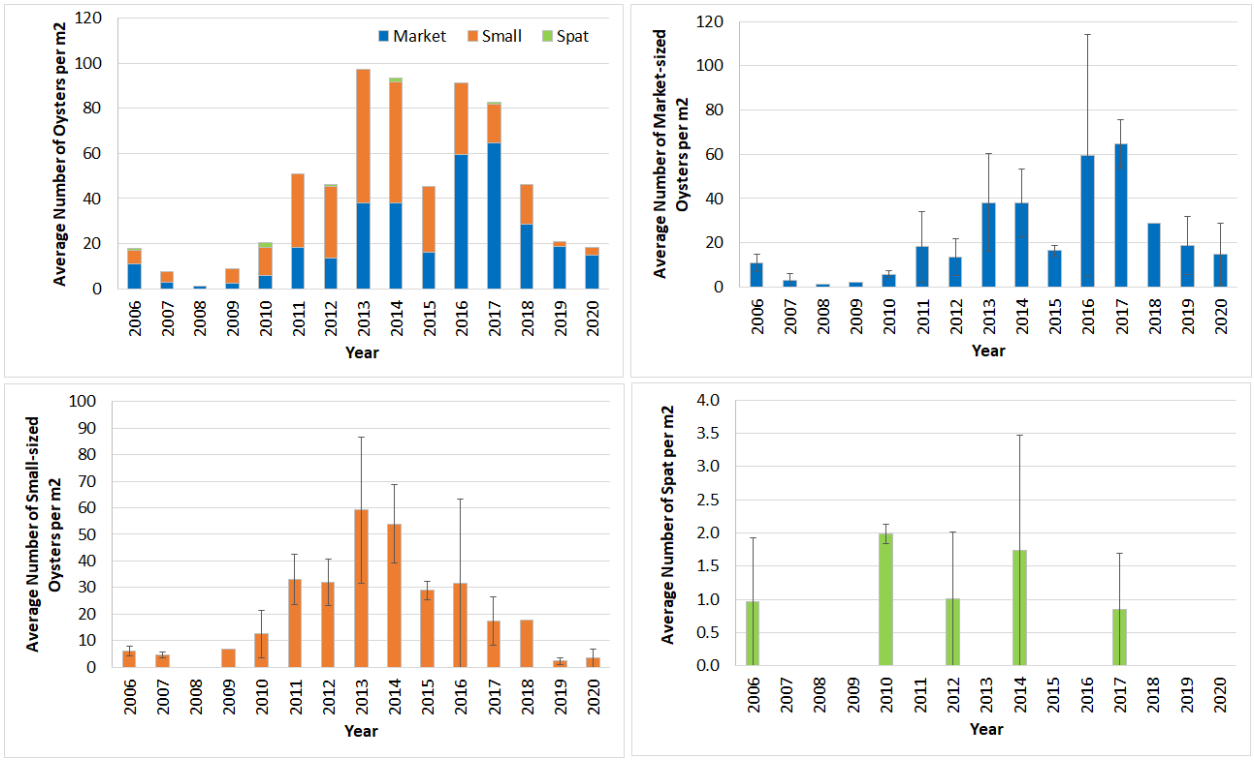

Figure A.06-3. Average number of live oysters per square meter by size class in the Choptank River ORA Sanctuary. The sanctuary was established in 1996. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

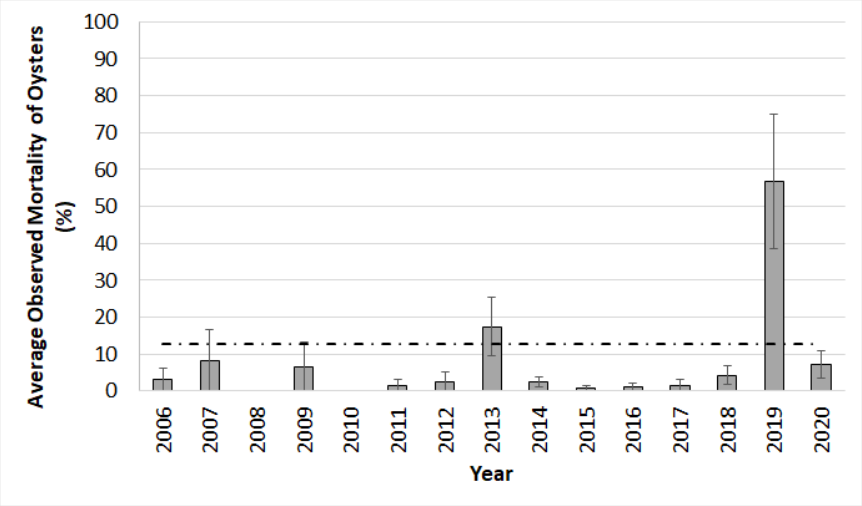

Figure A.06-4. Average annual observed mortality of market-sized and small-sized oysters in Choptank River ORA Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The sanctuary was established in 1996. The dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

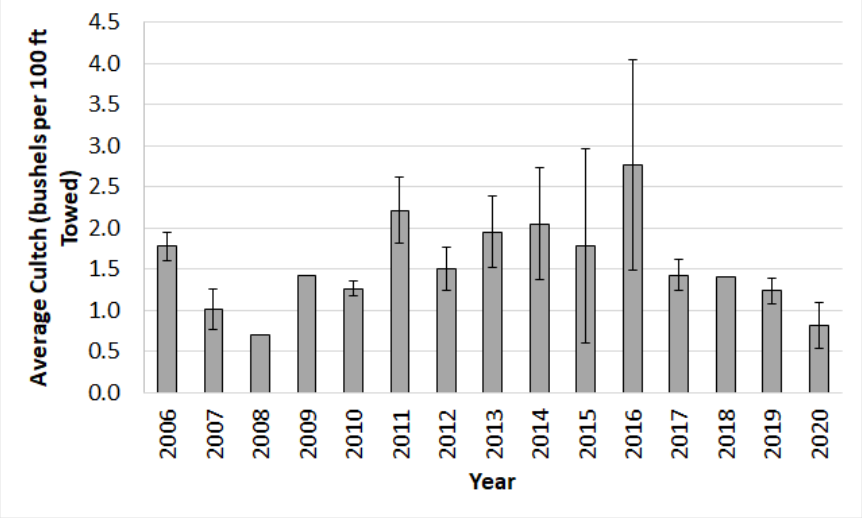

Figure A.06-5. Average cultch (live and dead oysters and loose shell) in the Choptank River ORA Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The sanctuary was established in 1996. Error bars represent ± 1 standard error.

Section A.07: Cook Point Sanctuary

The Cook Point Sanctuary is located in the lower Choptank River in a medium-salinity (Zone 2) region within NOAA Code 137. The sanctuary was originally established in 2001 with an area of 17 acres to accommodate an Environmental Protection Agency project examining three-dimensional oyster habitat. In 2010, the sanctuary was expanded to 814 acres of which 781 acres (96%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are two historic oyster bars within the sanctuary: Cook Point, 78% of which is within the sanctuary, and Todd Point Addition, of which 3% is within the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.07-1)
- Bottom types map (Figure A.07-2)
- Summary statistics (Table A.07-1)
- Abundance per year (Figure A.07-3)
- Shell height frequencies (Figure A.07-4)
- Biomass per year (Figure A.07-5)
- Observed mortality (Figure A.07-6)
- Dermo and MSX per year (Figure A.07-7)
- Cultch per year (Figure A.07-8)

The Fall Survey sampled one bar in the sanctuary. Density of spat, small, and market oysters as well as biomass declined from the previous five-year period. Observed mortality increased to more than twice the baywide average in 2016 and 2017, likely due to disease. Mean size of oysters declined slightly from the previous five-year average. No population patent tong survey has been conducted to date by the department.

Since 2006, the sanctuary has had restoration plantings consisting of reef balls, dredged shell, granite, and hatchery spat-on-shell plantings. From 2006 to 2013, approximately 161 million hatchery spat-on shell, 309 reef balls, and 196,000 bushels of shell were planted.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

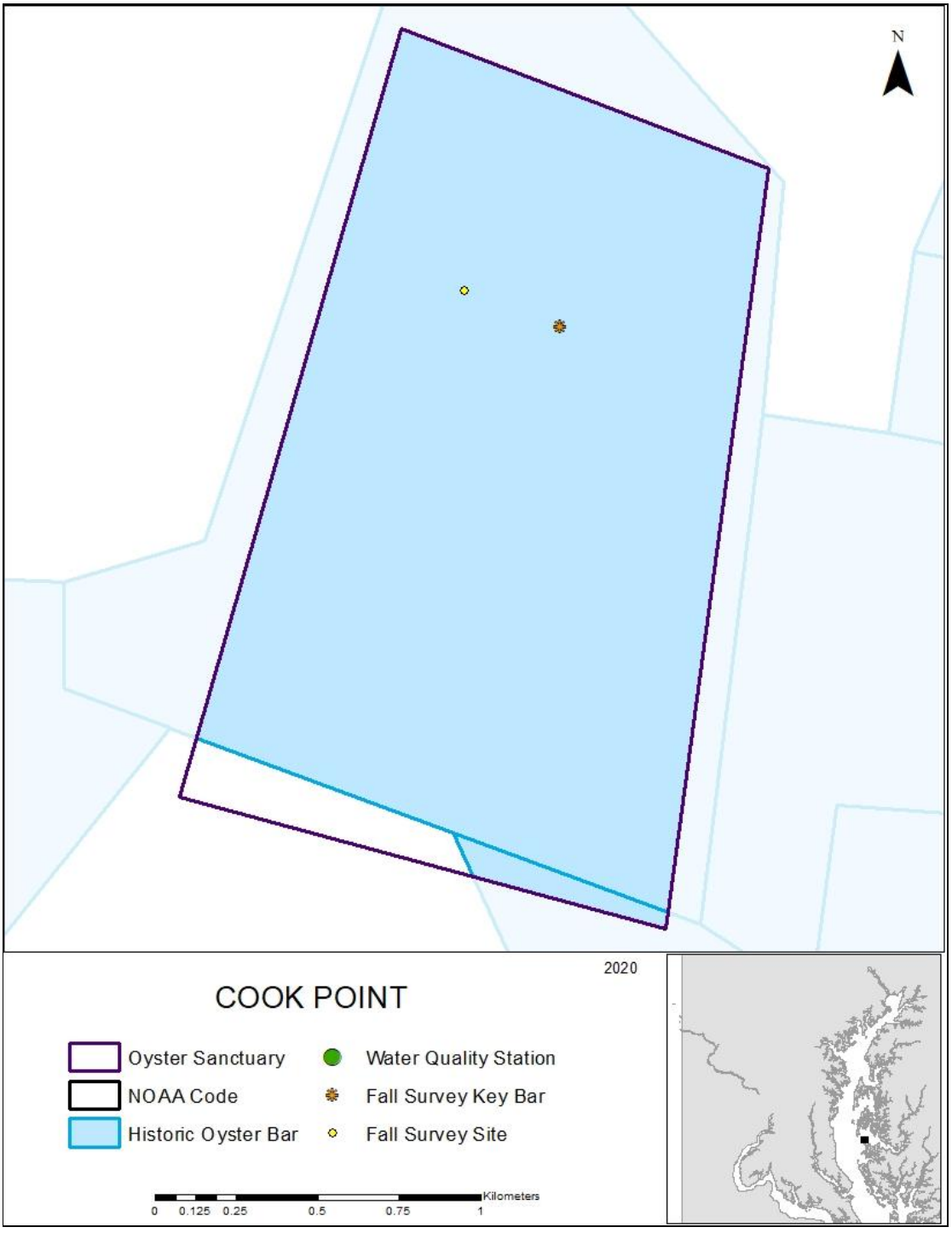

Figure A.07-1. Cook Point Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

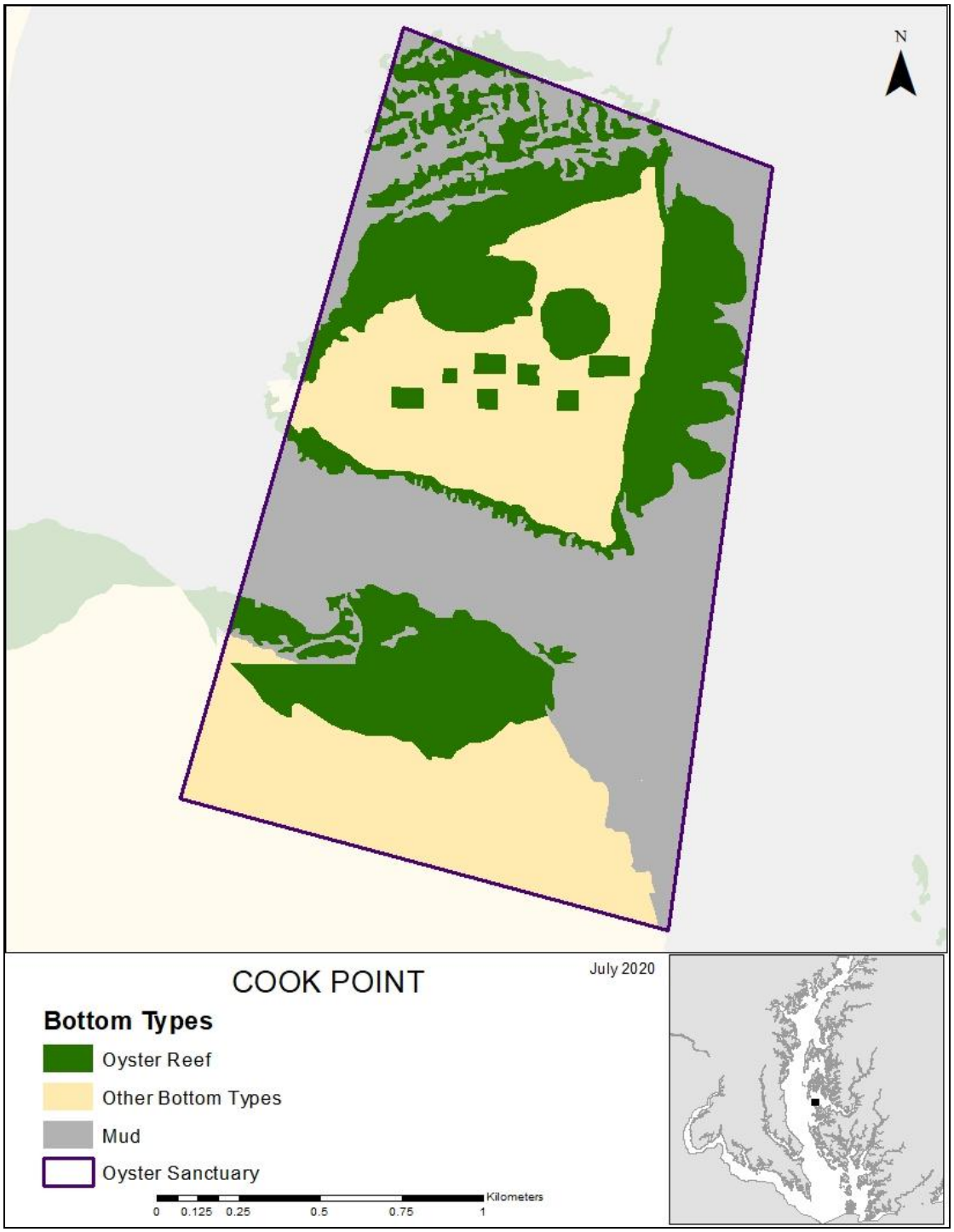

Figure A.07-2. Cook Point Sanctuary bottom types. Data from Maryland Geological Survey from 2013.

Table A.07-1. Oyster population characteristics based on the Fall Survey in the Cook Point Sanctuary. Values are given as an annual mean ± standard error.

	2006-10	2011-15	2016-20
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 10
Number of Live Spat Oysters per square meter	51.1 ± 48.5	4.4 ± 3.3	4.2 ± 2.3
Number of Live Small-Sized Oysters per square meter	8.9 ± 5.7	34.4 ± 16.3	4 ± 1.1
Number of Live Market-Sized Oysters per square meter	3.3 ± 1.4	32.6 ± 5.8	10.5 ± 2.1
Live Oyster Biomass (g Dry Weight per Bushel)	40 ± 16	228 ± 45	98 ± 16
Observed Mortality (%)	9 ± 3	11 ± 2	27 ± 8
Cultch (Bushels per 100 ft Towed)	0.6 ± 0.1	0.7 ± 0	0.4 ± 0.1

Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.

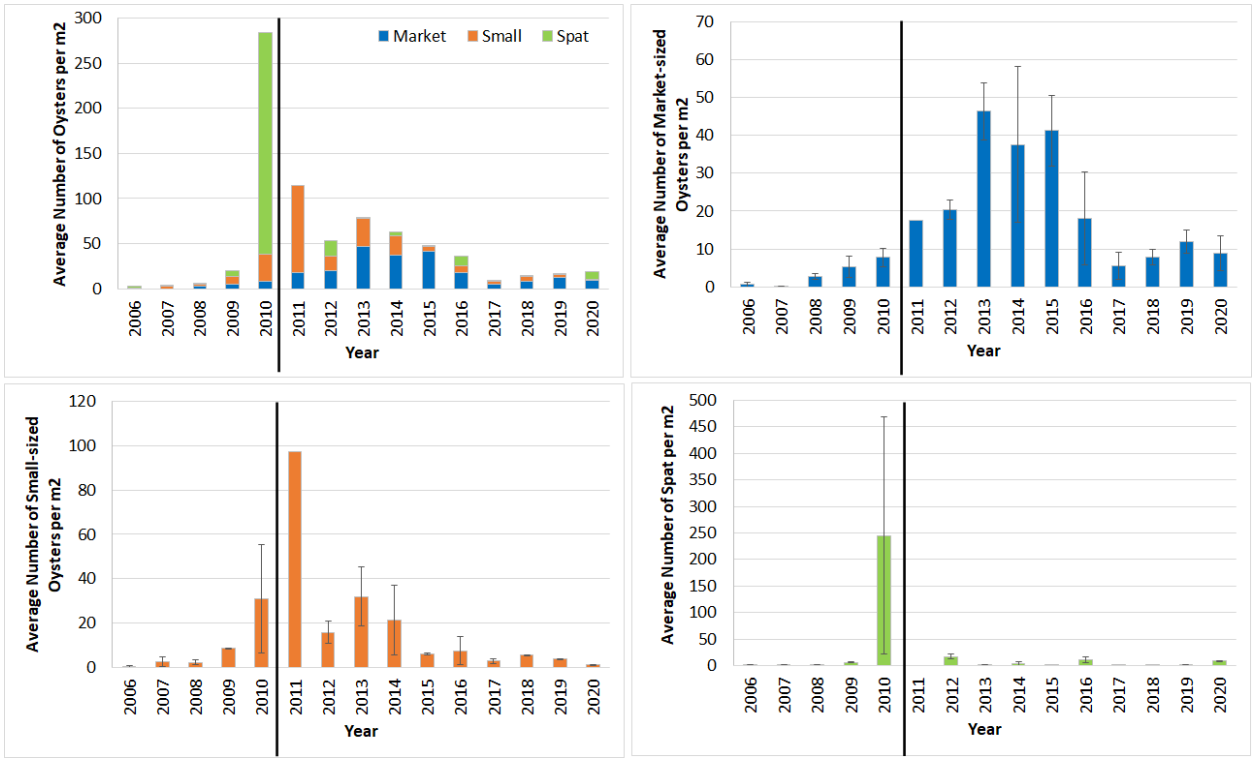

Figure A.07-3A. Average number of live oysters per square meter by size class in the Cook Point Sanctuary including the sample taken on the 2010 hatchery spat-on-shell planting. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

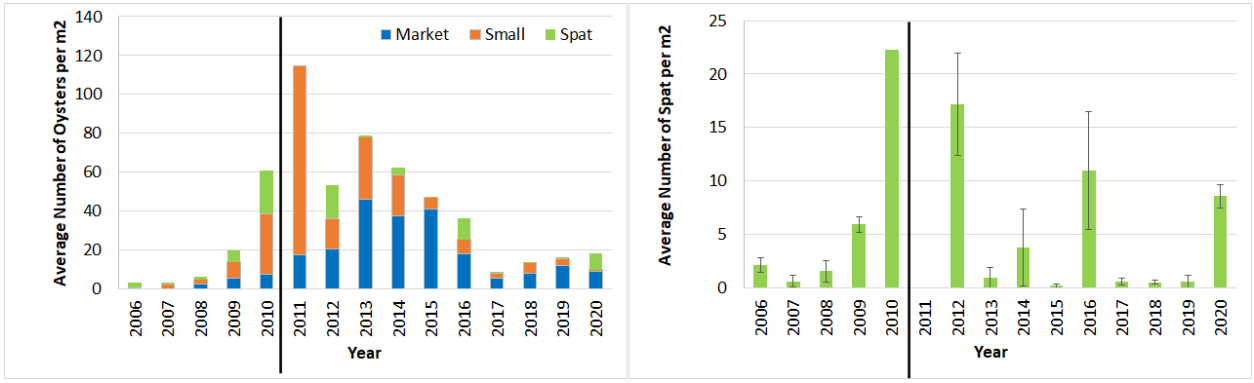

Figure A.07-3B. Average number of live oysters per square meter by size class in the Cook Point Sanctuary excluding the sample taken on the 2010 hatchery spat-on-shell planting. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

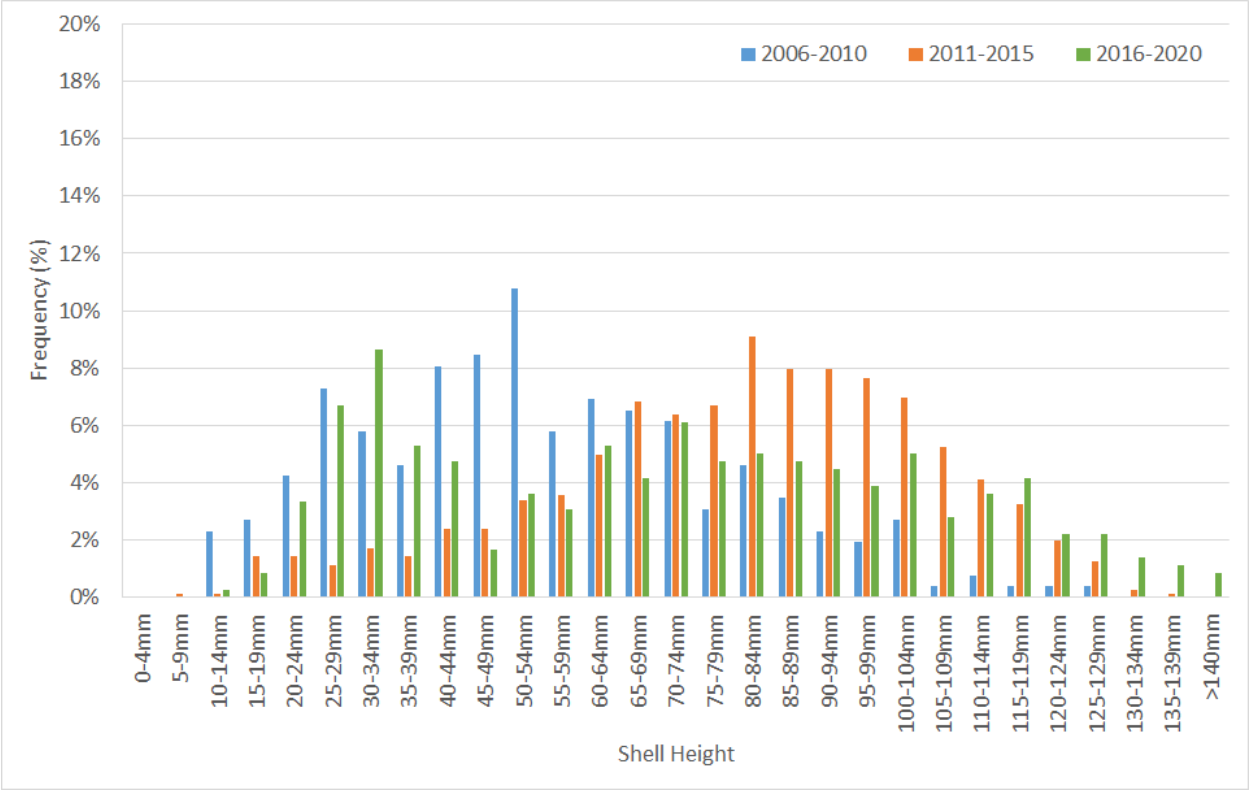

Figure A.07-4. Shell height frequencies of live oysters per bushel of material in the Cook Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Cook Point bar.

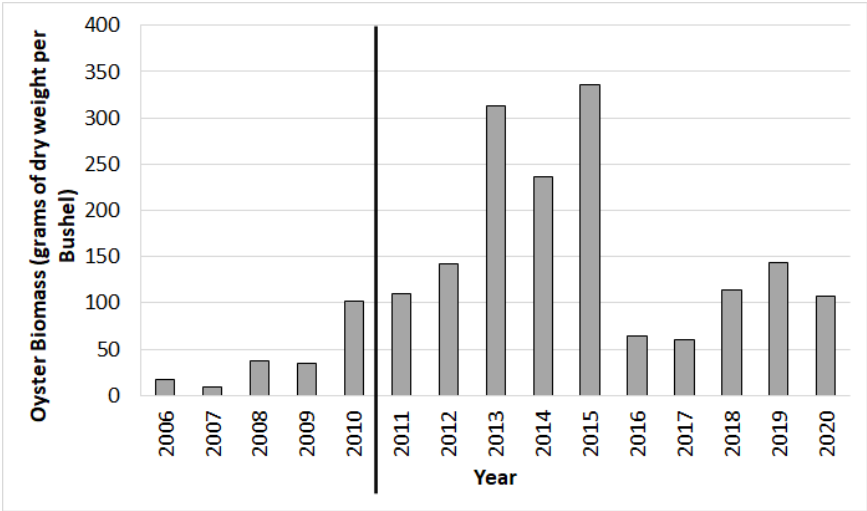

Figure A.07-5. Oyster biomass (grams of dry weight per bushel of material) in the Cook Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Cook Point bar. Black line indicates the date the sanctuary was established.

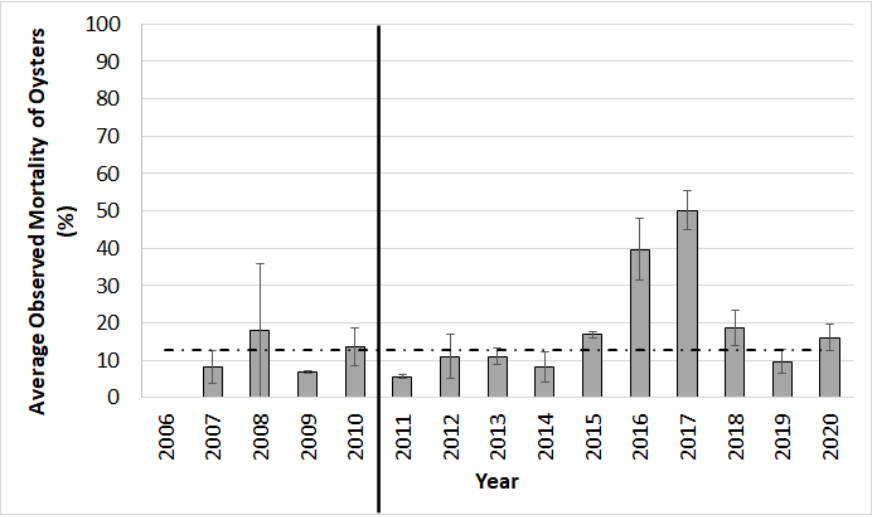

Figure A.07-6. Average annual observed mortality of market-sized and small-sized oysters in Cook Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

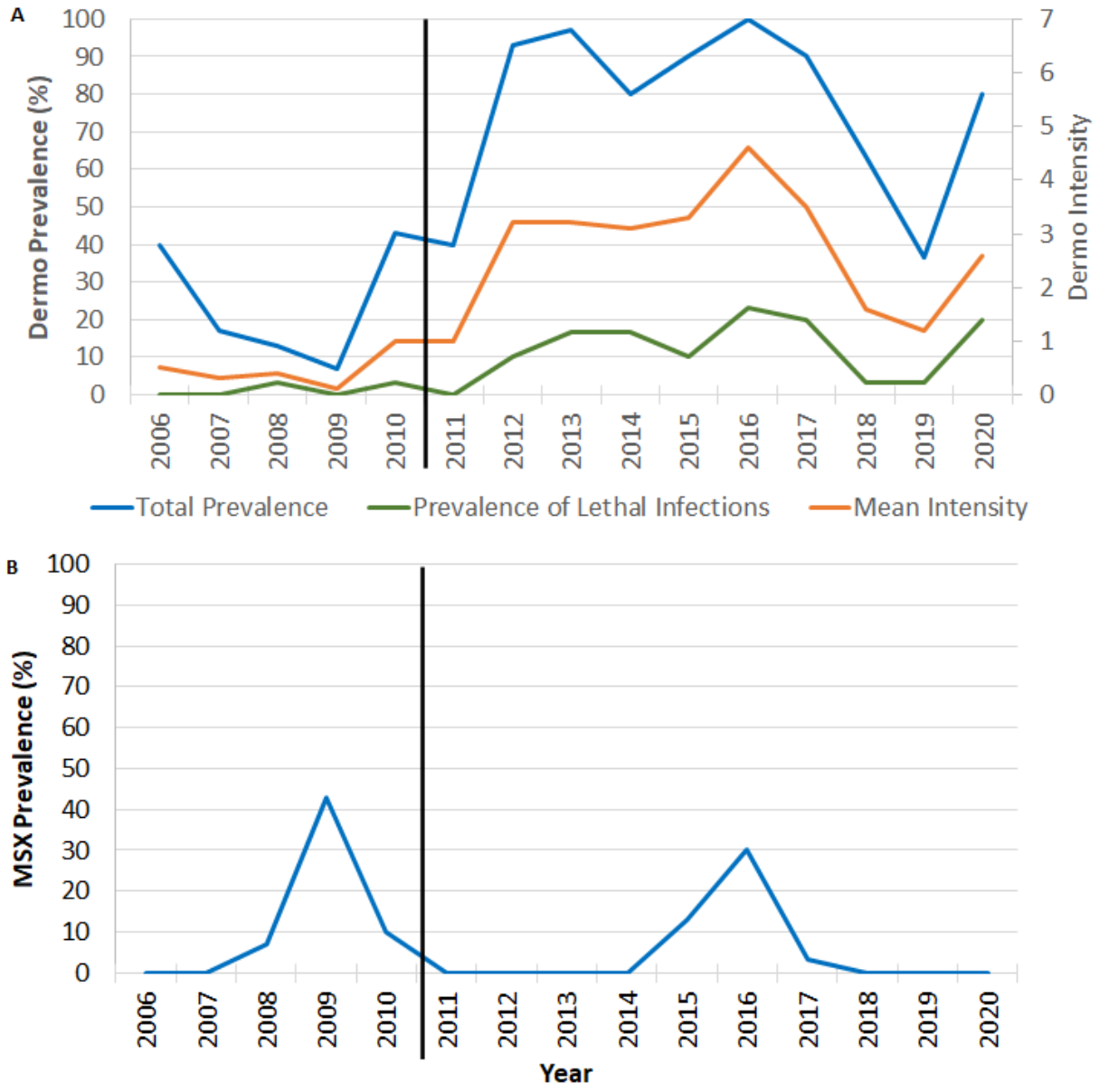

Figure A.07-7. Oyster disease prevalence and intensity in the Cook Point Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Cook Point bar. Black line denotes the date the sanctuary was established.

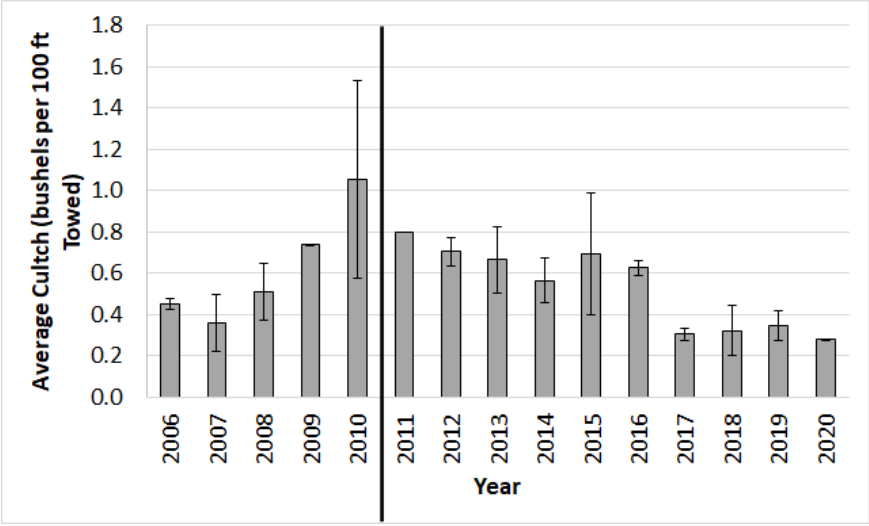

Figure A.07-8. Average cultch (live and dead oysters and loose shell) in the Cook Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.08: Cox Creek Sanctuary

The Cox Creek Sanctuary is located in a tributary of Eastern Bay, a low-salinity (Zone 1) region within NOAA Code 039. The sanctuary was created in 2010 and encompasses 2,112 acres of which 939 acres (45%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are nine historic oyster bars within the sanctuary, one of which (Ringgold Middleground) is located only partially within the sanctuary[26].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.08-1)
- Bottom types map (Figure A.08-2)
- Density Survey (Figure A.08-3)

The Fall Survey has collected two samples during this time period; one sample in 2006 and one in 2019. No spat were found in either sample, but some markets and smalls were collected (90 markets and 2 small oysters in 2006; 38 markets and 4 small oysters in 2019). Market density was 8 and 5 oysters per square meter for 2006 and 2019 respectively.

A patent tong population survey was conducted in 2014[27] and 2020. The 2020 survey found an average density of oysters of 1 per square meter, with a larger population of market-sized oysters than small-sized oysters (0.98 per square meter and 0.02 per square meter respectively). Of the 151 samples taken, 111 had no oysters and 51 had no surface shell volume. This is slightly increased from the 2014 survey, which found an average density of 0.6 per square meter.

No replenishment or restoration plantings have occurred since 2006 with the exception of Marylanders Grow Oysters. Marylanders Grow Oysters plantings occurred between 2011 and 2015.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area since 2006.

[26] See chart 11 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[27] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

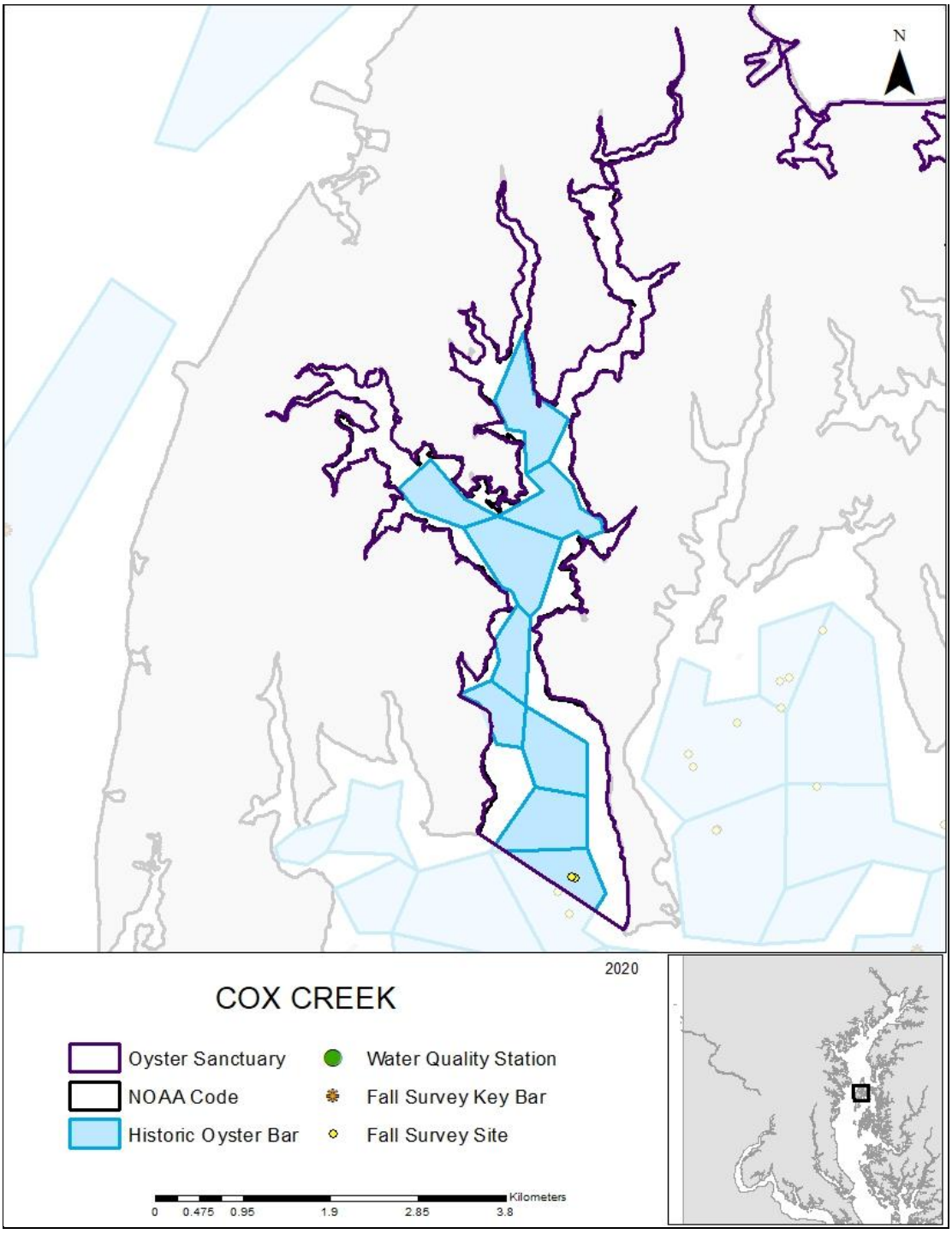

Figure A.08-1. Cox Creek Sanctuary. Fall Survey sites may not be sampled every year.

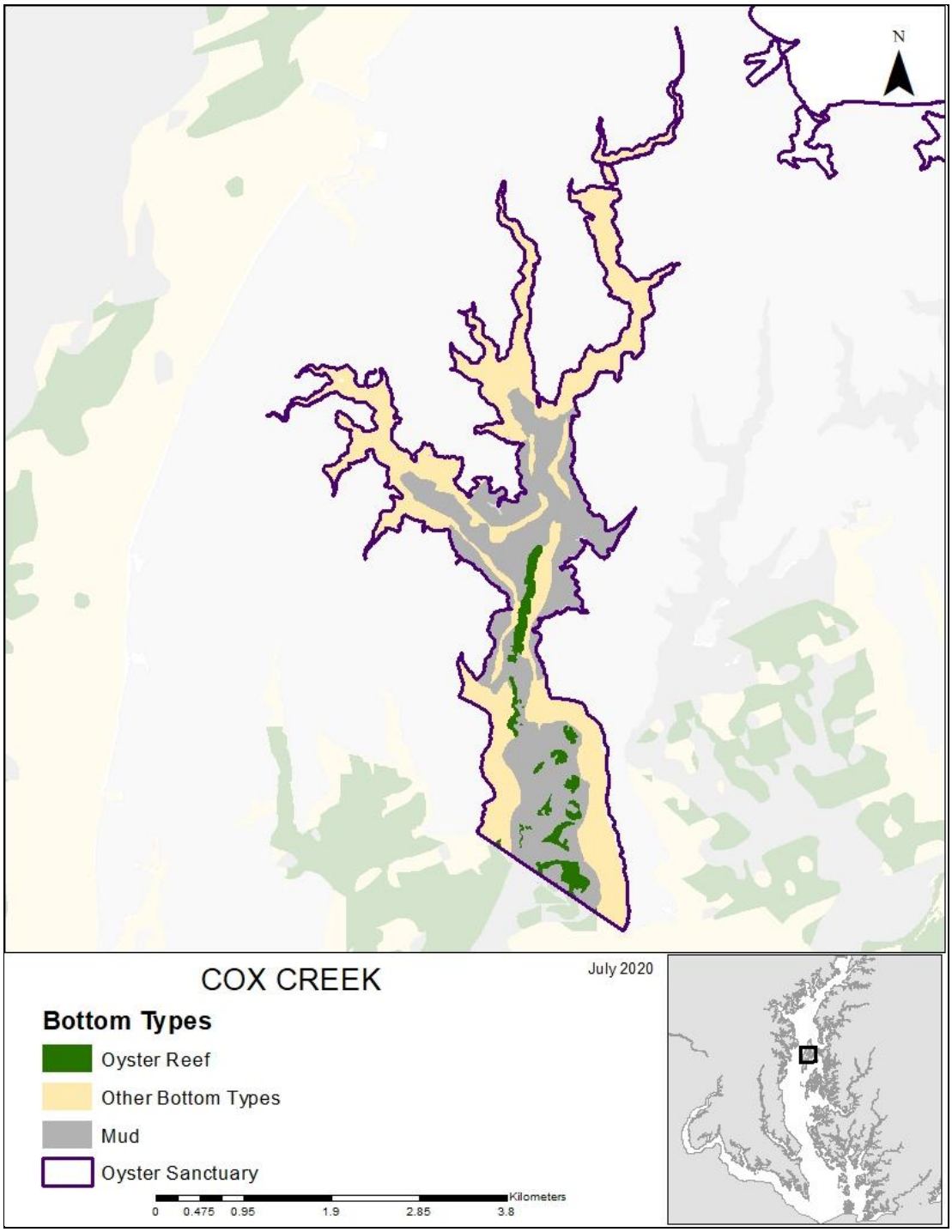

Figure A.08-2. Cox Creek Sanctuary bottom types. Data from Maryland Geological Survey from 2011.

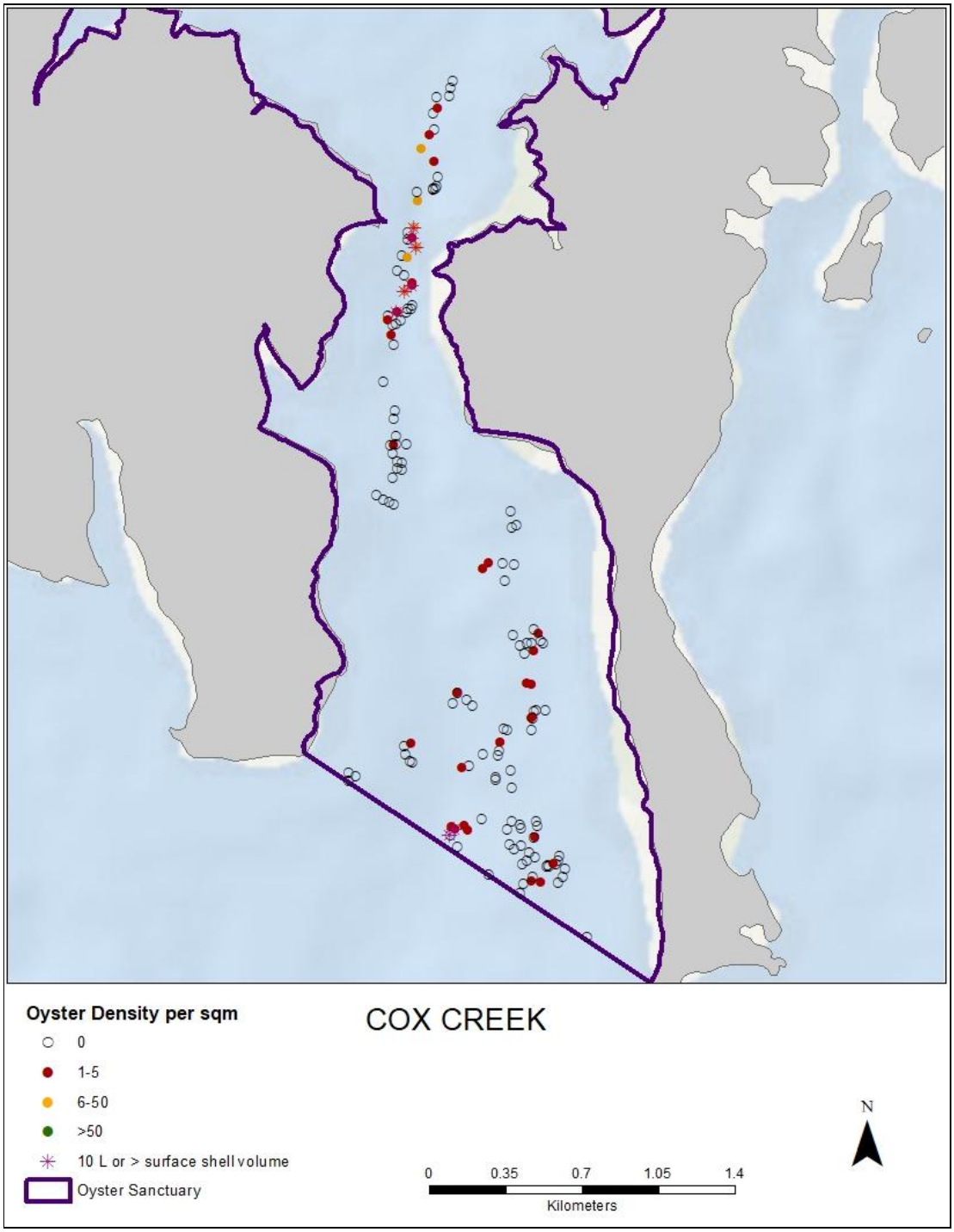

Figure A.08-3. Map of 2020 oyster density in the Cox Creek Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.09: Eastern Bay Sanctuary

The Eastern Bay Sanctuary is located along the southern shore of Eastern Bay, a medium-salinity (Zone 2) region within NOAA Codes 027 and 039. The sanctuary was created in 2010 and encompasses 4,521 acres of which 939 acres (21%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 7 historic oyster bars within the sanctuary[28].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.09-1)
- Bottom types map (Figure A.09-2)
- Density Survey (Figure A.09-3)

The Fall Survey did not sample this area between 2006 and 2020.

A patent tong population survey was conducted in 2014[29] and 2020. The 2020 survey found an average density of 0.07 per square meter, with 200 samples. Of those samples, 194 had no oysters and 85 had no surface shell volume. The 2014 survey found an average density of 0.5 per square meter.

This area received a restoration planting in 2020 of 16 million hatchery spat-on-shell. No other replenishment or restoration plantings have occurred from 2006 to 2020.

Water quality was monitored in the sanctuary in 2006[30] and we are unaware of any monitoring since then. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[28] See chart 11 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[29] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

[30] IBID

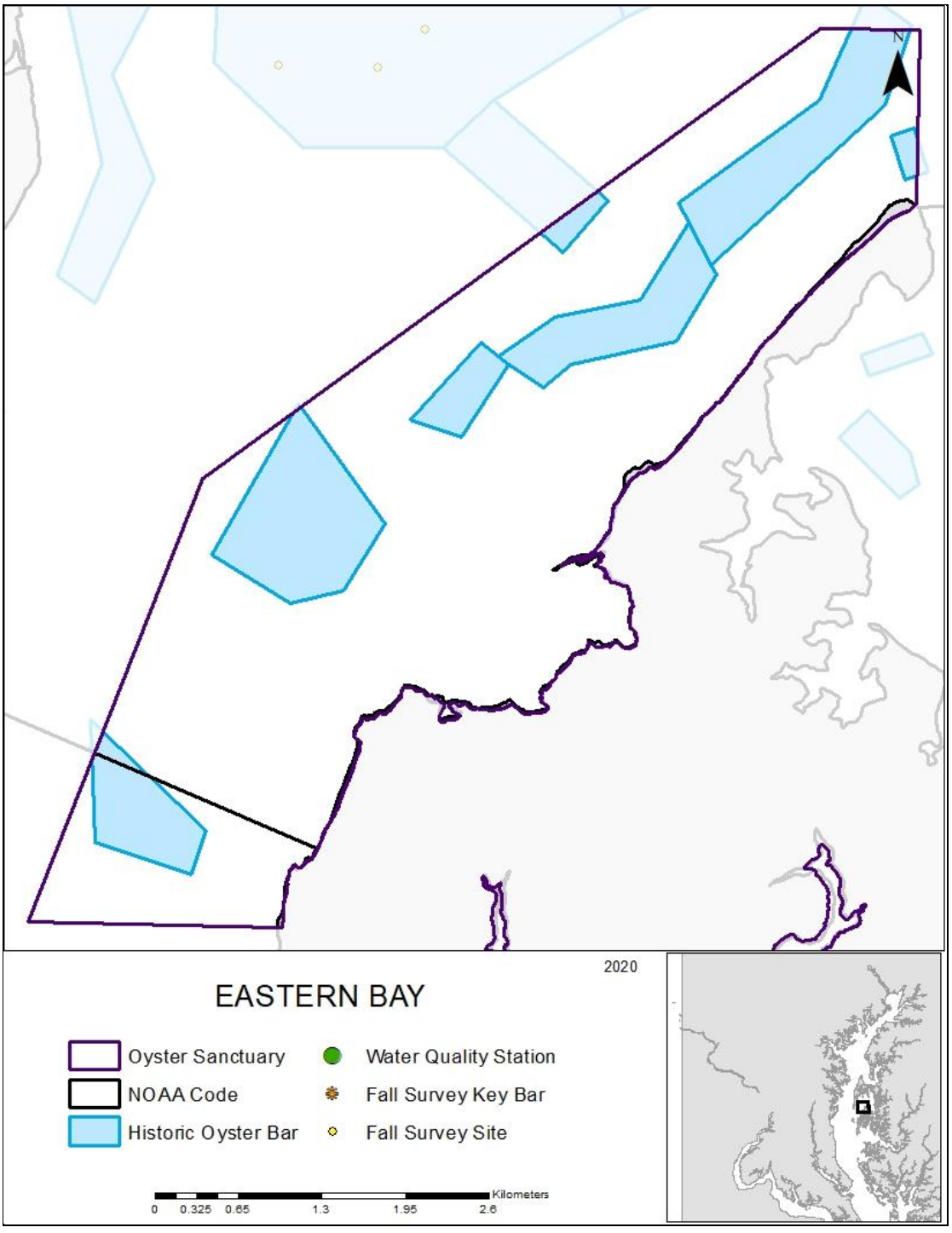

Figure A.09-1. Eastern Bay Sanctuary.

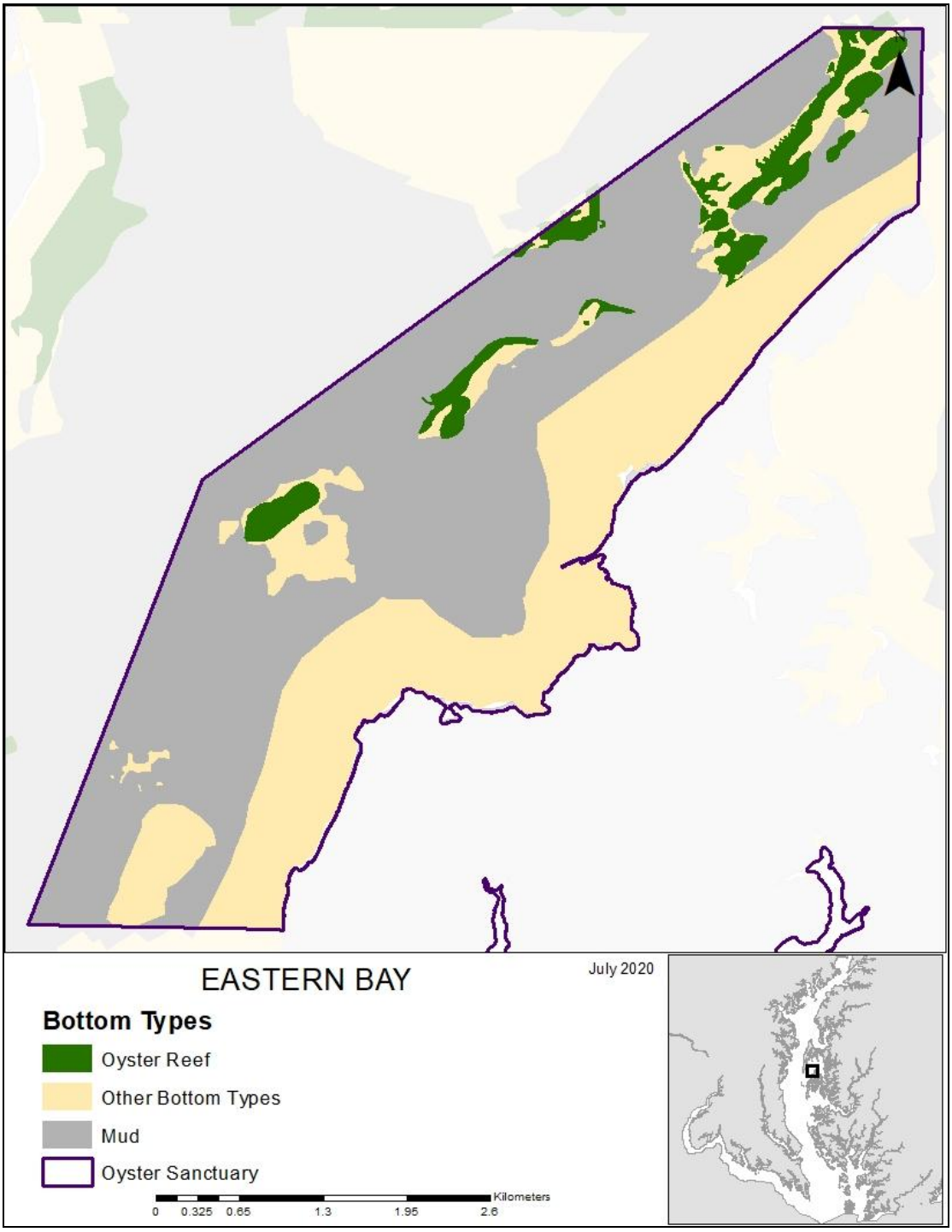

Figure A.09-2. Eastern Bay Sanctuary bottom types. Data from Maryland Geological Survey from 2011.

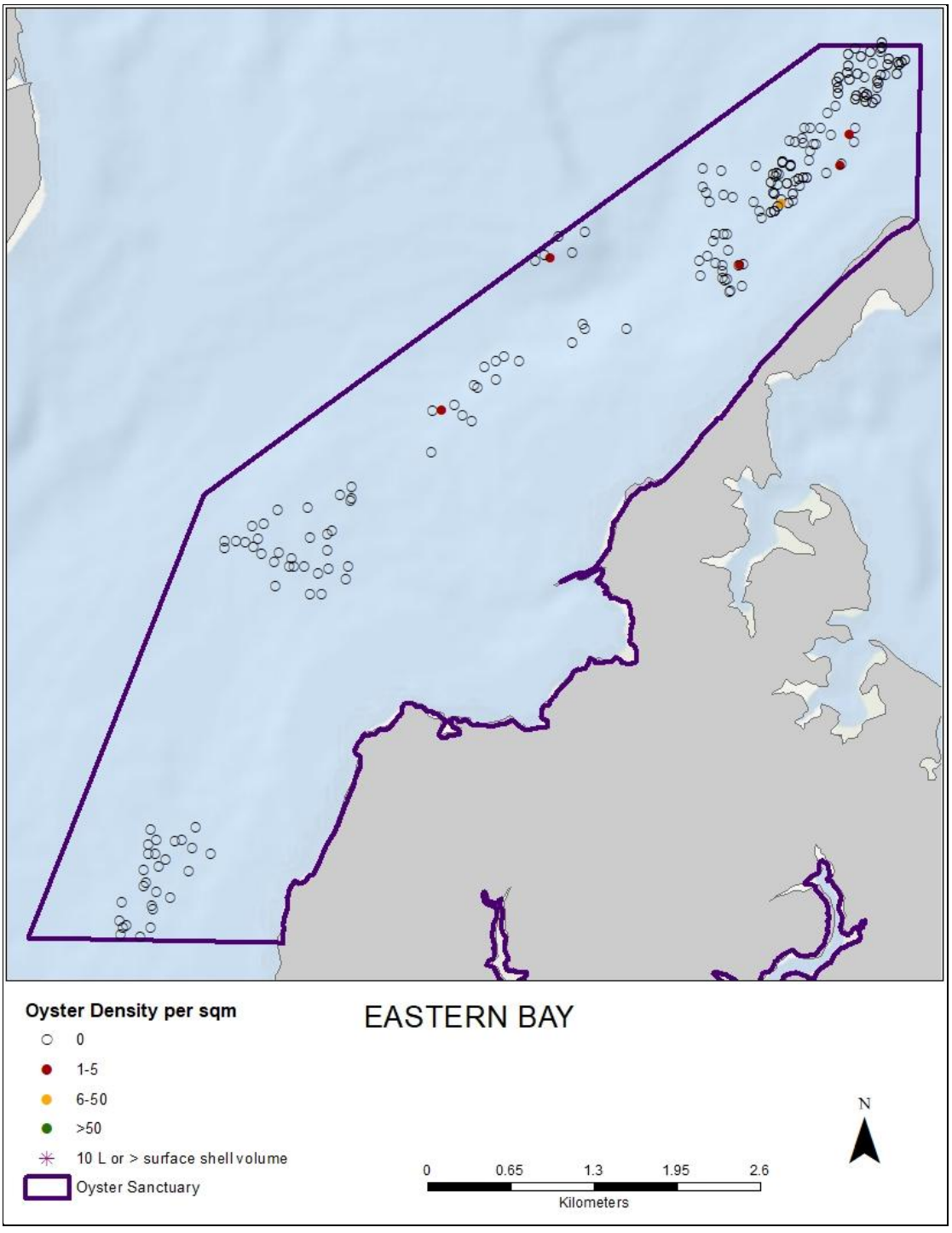

Figure A.09-3. Map of 2020 oyster density in the Eastern Bay. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.10: Fort Carroll Sanctuary

The Fort Carroll Sanctuary is located in the Patapsco River, a low-salinity (Zone 1) region within NOAA Code 025. The sanctuary was created in 1995 and encompasses 30 acres. There is no historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments) in the sanctuary. Fort Carroll Sanctuary was established for educational programs run by the Living Classrooms Foundation.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.10-1)

The Fall Survey has not sampled within this area since 2006. No patent tong surveys have occurred since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continuous water quality monitoring) or oyster ecosystem services in this area.

Restoration plantings have occurred annually in this area since 2006. Living Classrooms has planted in the area since 2006 and Marylanders Grow Oysters has planted the area since 2012.

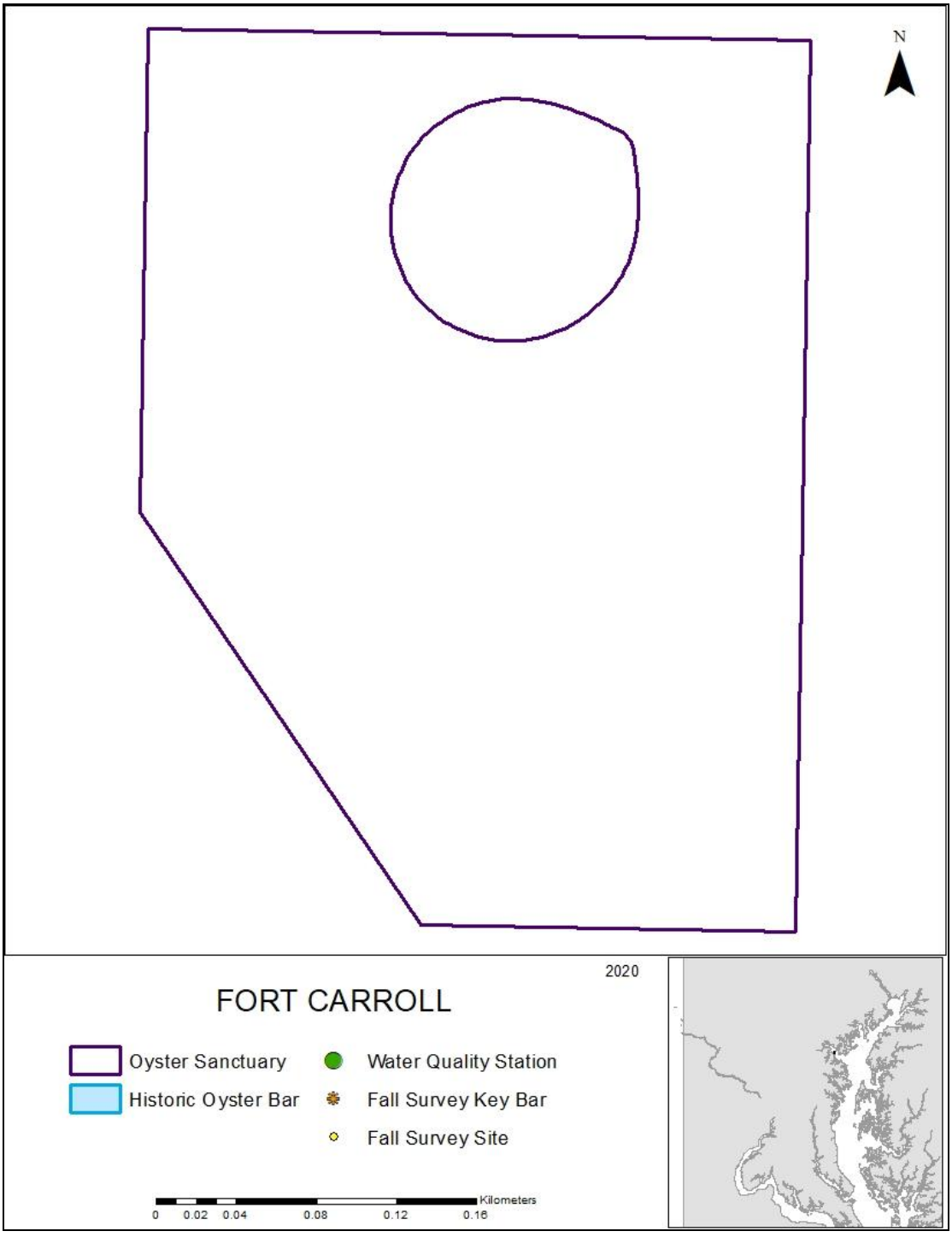

Figure A.10-1. Fort Carroll Sanctuary. The purple circle is the sanctuary boundary around the fort.

Section A.11: Harris Creek Sanctuary

The Harris Creek Sanctuary is located in a medium-salinity (Zone 2) tributary of the Choptank River within NOAA Code 437. The sanctuary was created in 2010 and encompasses 4,647 acres of which 1,998 acres (43%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 15 historic oyster bars within the sanctuary[31]. This sanctuary has been selected for large-scale oyster restoration under the 2014 Chesapeake Bay Watershed Agreement. Initial restoration of the sanctuary was completed in 2015 and the last hatchery spat-on-shell seeding occurred in 2020.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.11-1)
- Bottom types map (Figure A.11-2)
- Summary statistics (Table A.11-1)
- Abundance per year (Figure A.11-3)
- Shell height frequencies (Figure A.11-4)
- Biomass per year (Figure A.11-5)
- Observed mortality (Figure A.11-6)
- Dermo and MSX per year (Figure A.11-7)
- Cultch per year (Figure A.11-8)
- Water Quality (Figure A.11-9)

The Fall Survey sampled six bars in the Harris Creek Sanctuary, all of which received some restoration treatment, but could not sample sites that have received a reef base of granite as a restoration treatment. The density of spat and biomass increased in 2016-2020, while the density of small-sized oysters decreased but was still above the 2006-2010 average. The density of markets stayed relatively stable since 2014. Observed mortality doubled from 4% to 8%, yet remained below the long-term average. The amount of cultch declined slightly from the previous five-year average. The mean size of oysters declined slightly for 2016-2020 and the percentage of oysters over 100 mm declined from 18% to 10%.

The department has not conducted any population patent tong surveys since 2006, however, other organizations have been monitoring the restoration areas using patent tong and diver surveys. Results from these surveys (2015-2018 monitoring) indicate that three years post initial restoration 98% of reefs monitored met the minimum threshold success criteria for restoration of 15 oysters per square meter and 15 grams of dry weight (biomass) per square meter. Of the reefs that have received monitoring six years after initial restoration, 100% met this minimal threshold success criteria.[32]

Between 2006 and 2010, approximately 20,000 bushels of wild seed were planted to enhance the public oyster fishery. After the creation of the sanctuary areas in 2010, Harris Creek received substrate and hatchery spat-on-shell restoration plantings. Due to a shortage of fresh oyster shell,

[31] See chart 15 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[32] National Oceanic and Atmospheric Administration. 2020. 2019 Oyster Reef Monitoring Report Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland Collected from Fall 2019 through Summer 2020. https://www.chesapeakebay.net/documents/2019_MD_Oyster_Monitoring_Report_FINAL.pdf

reefs were restored using stone, Florida fossil oyster shell, clam shell, and mixed shell (clam and whelk). Over 2.49 billion hatchery spat-on-shell were placed in the sanctuary from 2011-2020 on 348 acres of restored oyster bottom. Several organizations participated in the restoration work including MDNR, U.S. Army Corps of Engineers, NOAA, Oyster Recovery Partnership, National Fish and Wildlife Foundation, Chesapeake Bay Foundation, The Nature Conservancy, and CSX Railroad.

Marylanders Grow Oysters, a public outreach program, has planted oysters since 2012 at one site in the sanctuary. From 2012 to 2020, The Phillips Wharf Environmental Center estimated planting a total of 750,800 oysters.

Many studies took place evaluating ecosystem services provided by large-scale oyster restoration, including, a nutrient cycling studies, a macrofaunal utilization study, a finfish utilization study, a qualitative index of oyster reef habitat quality was developed using images from restored and unrestored reefs, and as a study estimating the ecological benefits and socioeconomic impacts from oyster restoration.[33]

Continuous water quality monitoring has occurred at an upstream station and downstream station in Harris Creek from 2013 until 2019. A vertical profiler, station XFG4618, which was located midstream, monitored water quality from 2012 until 2019. During the 2012-2019 timeline, surface salinity recorded from the vertical profiler, ranged from 6.7 ppt to 17.1 ppt, with the lowest salinity being during the freshet of 2018-2019.

[33] Bruce, D. G., J. C. Cornwell, L. Harris, T. F. Ihde, M. L. Kellogg, S. Knoche, R. N. Lipcius, D. N. McCulloch-Prosser, S. P. McIninch, M. B. Ogburn, R. D. Seitz, J. Testa, S. R. Westby, and B. Vogt. 2021. A Synopsis of Research on the Ecosystem Services Provided by Large-Scale Oyster Restoration in the Chesapeake Bay. NOAA Tech. Memo. NMFS-OHC-8, 52 p.

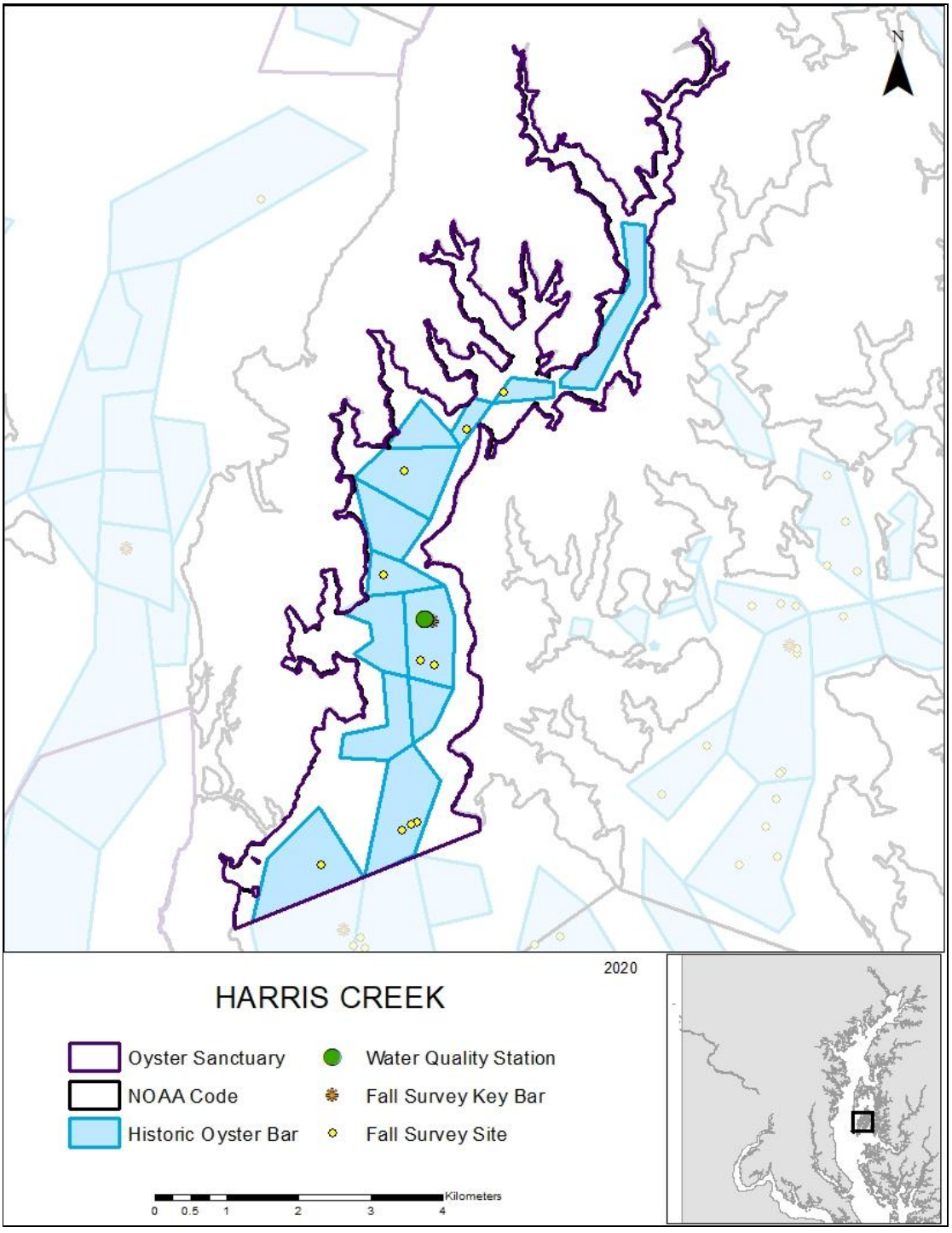

Figure A.11-1. Harris Creek Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

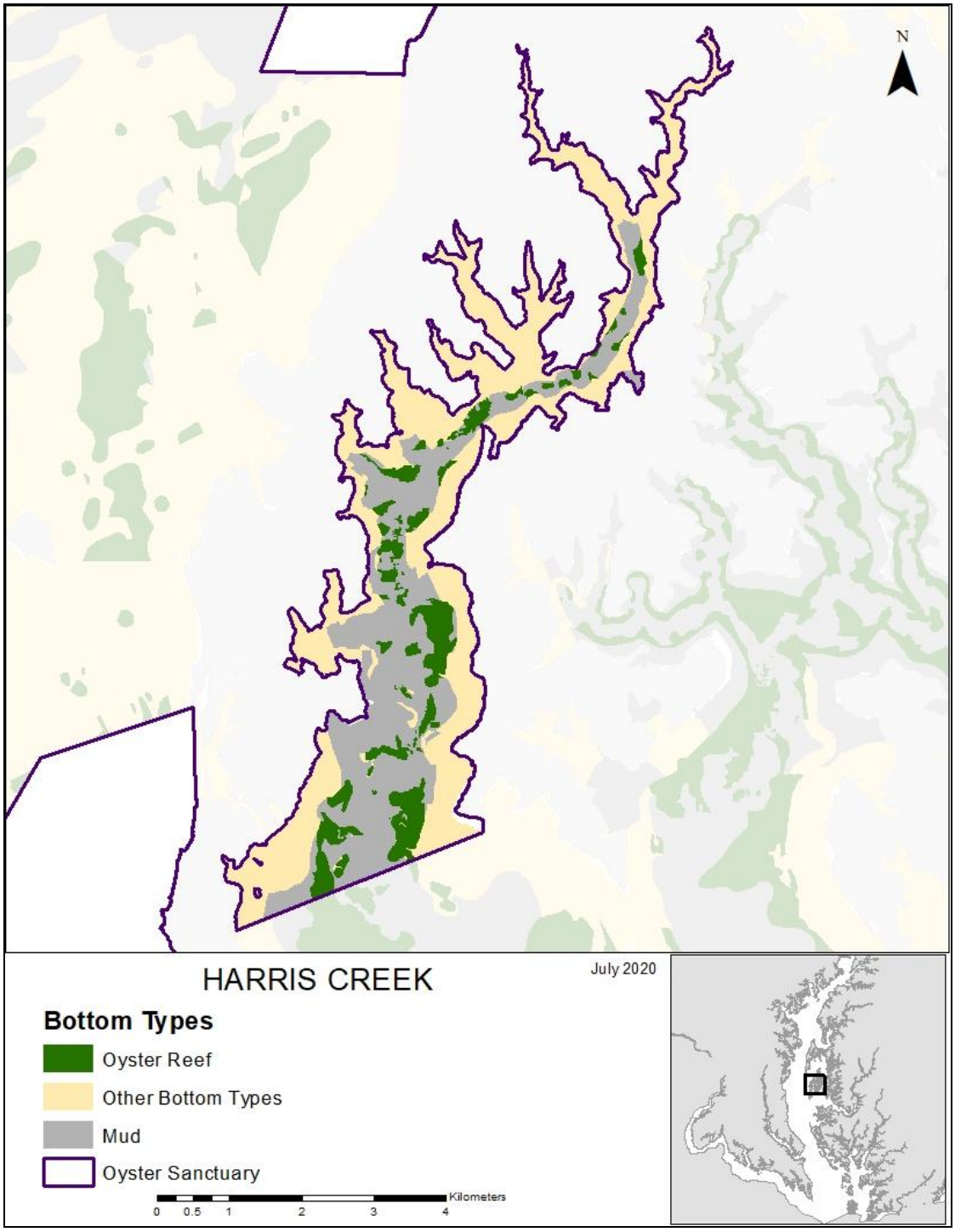

Figure A.11-2. Harris Creek Sanctuary bottom types. Data from NOAA's Chesapeake Bay Office from 2015.

Table A.11-1. Oyster population characteristics based on the Fall Survey in the Harris Creek Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 26	5 / 30	5 / 37
Number of Live Spat Oysters per square meter	26.4 ± 19.6	30.4 ± 13.4	66.9 ± 25.2
Number of Live Small-Sized Oysters per square meter	32.8 ± 13.2	257.5 ± 92.9	148.7 ± 37.4
Number of Live Market-Sized Oysters per square meter	21.9 ± 4.9	126.9 ± 26.2	115.9 ± 2.2
Live Oyster Biomass (g Dry Weight per Bushel)	ND	308 ± 97	357 ± 24
Observed Mortality (%)	8 ± 1	4 ± 1	8 ± 3
Cultch (Bushels per 100 ft Towed)	1.6 ± 0.4	2 ± 0.3	1.5 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

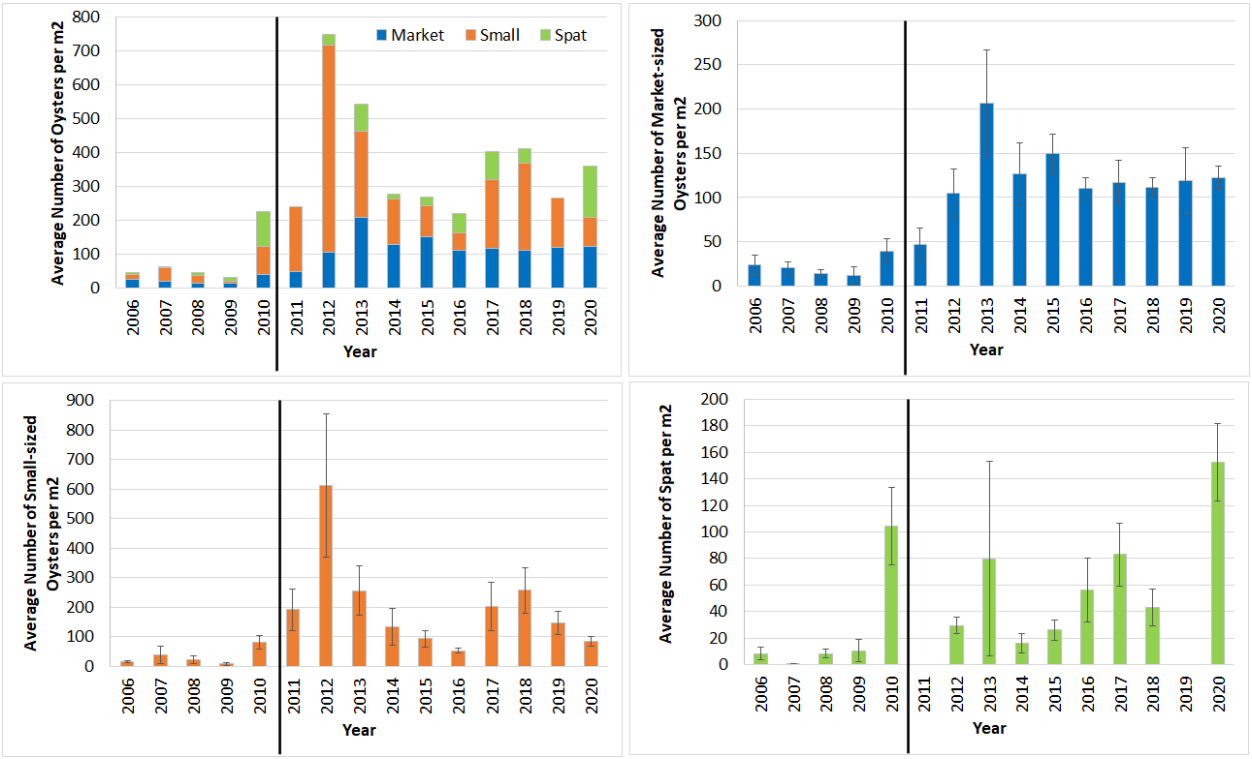

Figure A.11-3. Average number of live oysters per square meter by size class in the Harris Creek Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

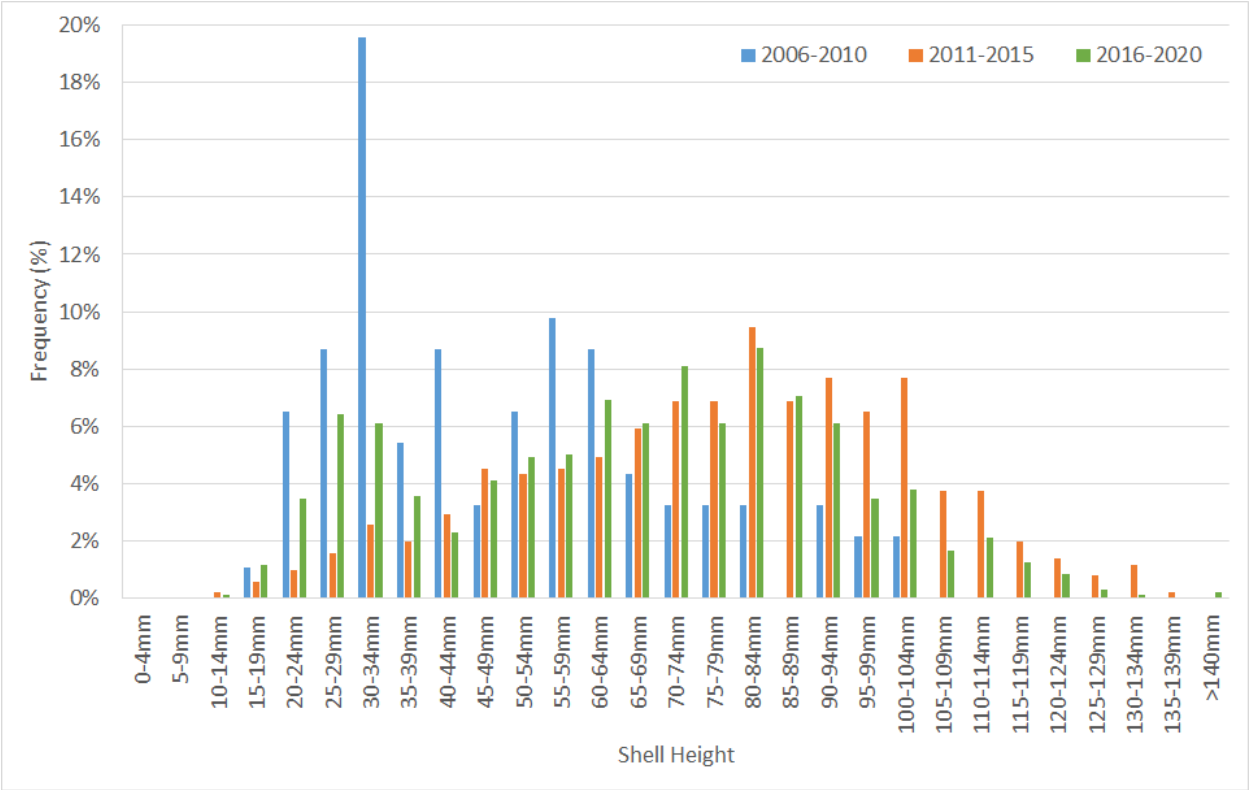

Figure A.11-4. Shell height frequencies of live oysters per bushel of material in the Harris Creek Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Mill Point bar. Data was not collected in 2006 to 2009.

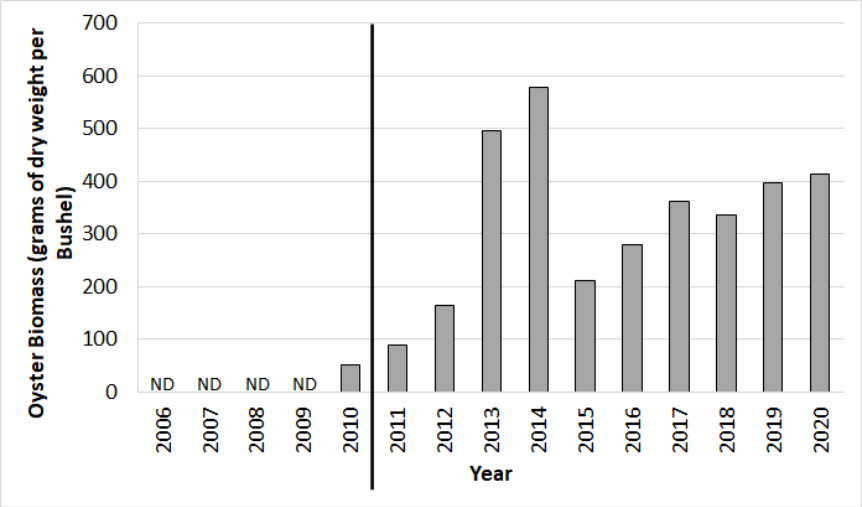

Figure A.11-5. Oyster biomass (grams of dry weight per bushel of material) in the Harris Creek Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Mill Point bar. Black line indicates the date the sanctuary was established. ND = No Data.

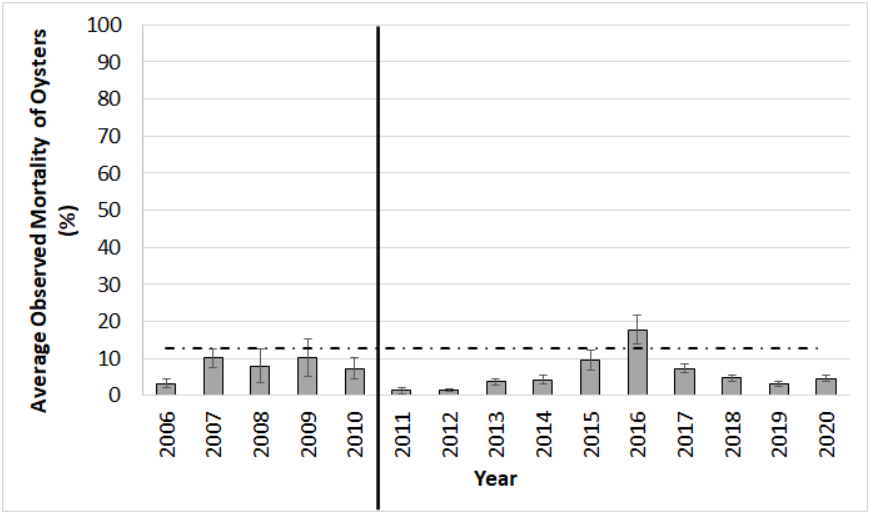

Figure A.11-6. Average annual observed mortality of market-sized and small-sized oysters in Harris Creek Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

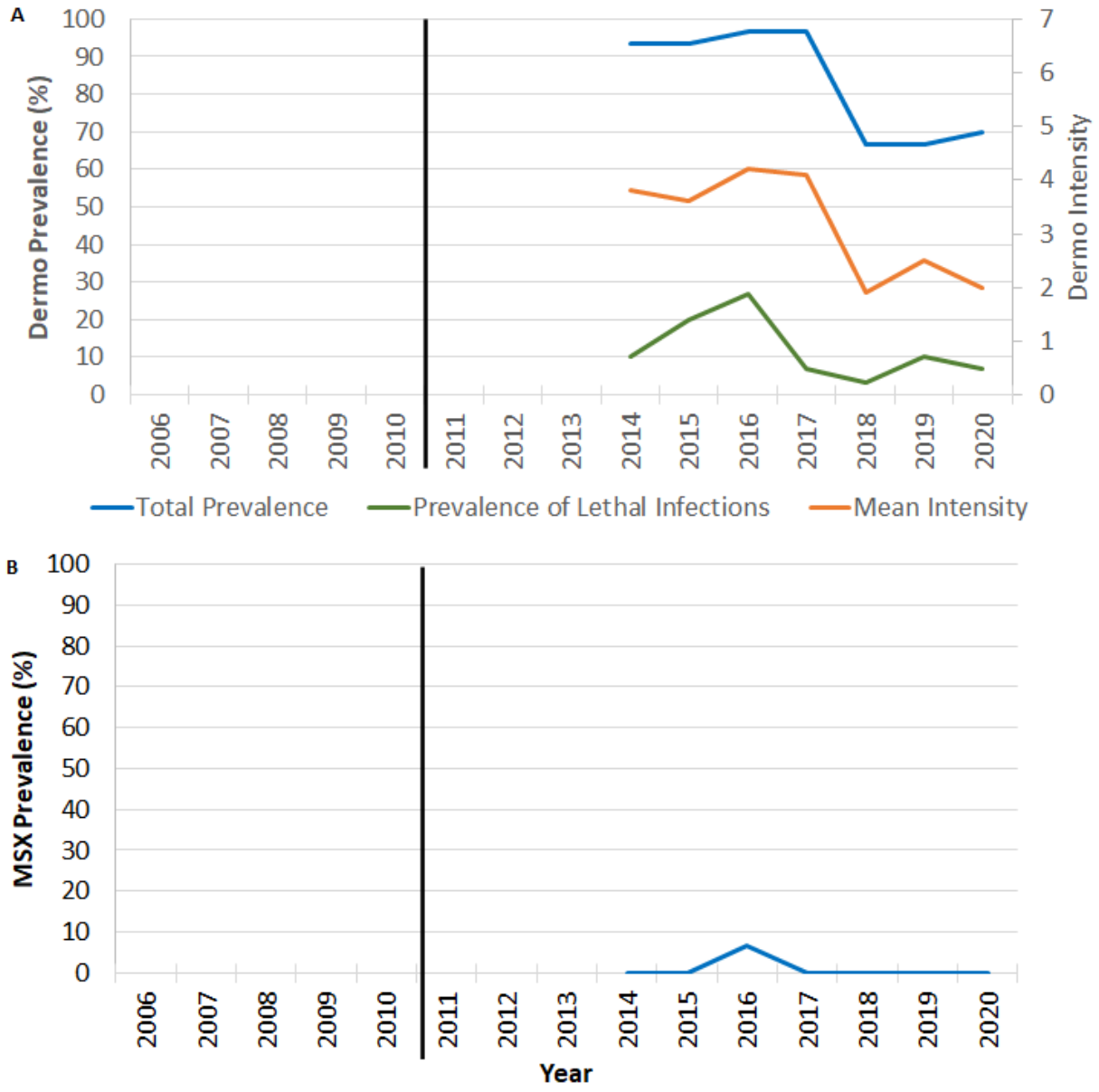

Figure A.11-7. Oyster disease prevalence and intensity in the Harris Creek Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Mill Point bar. Black line denotes the date the sanctuary was established. Data was not collected in 2006 to 2009.

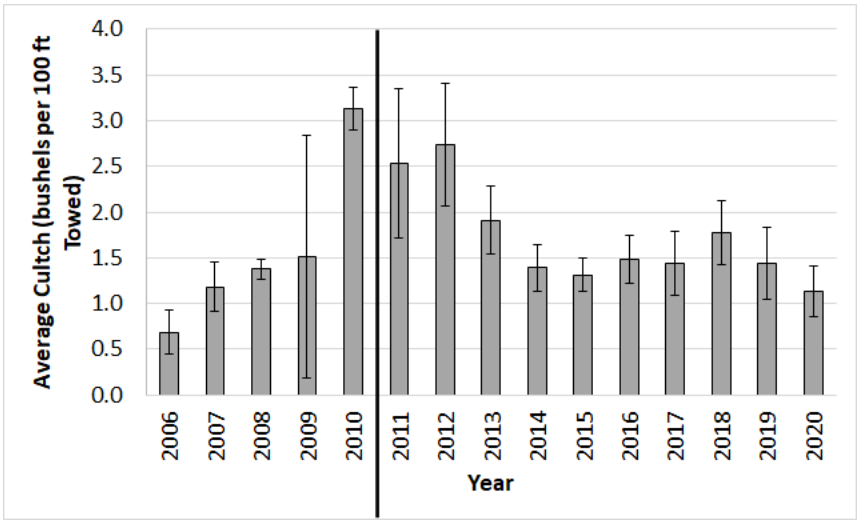

Figure A.11-8. Average cultch (live and dead oysters and loose shell) in the Harris Creek Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

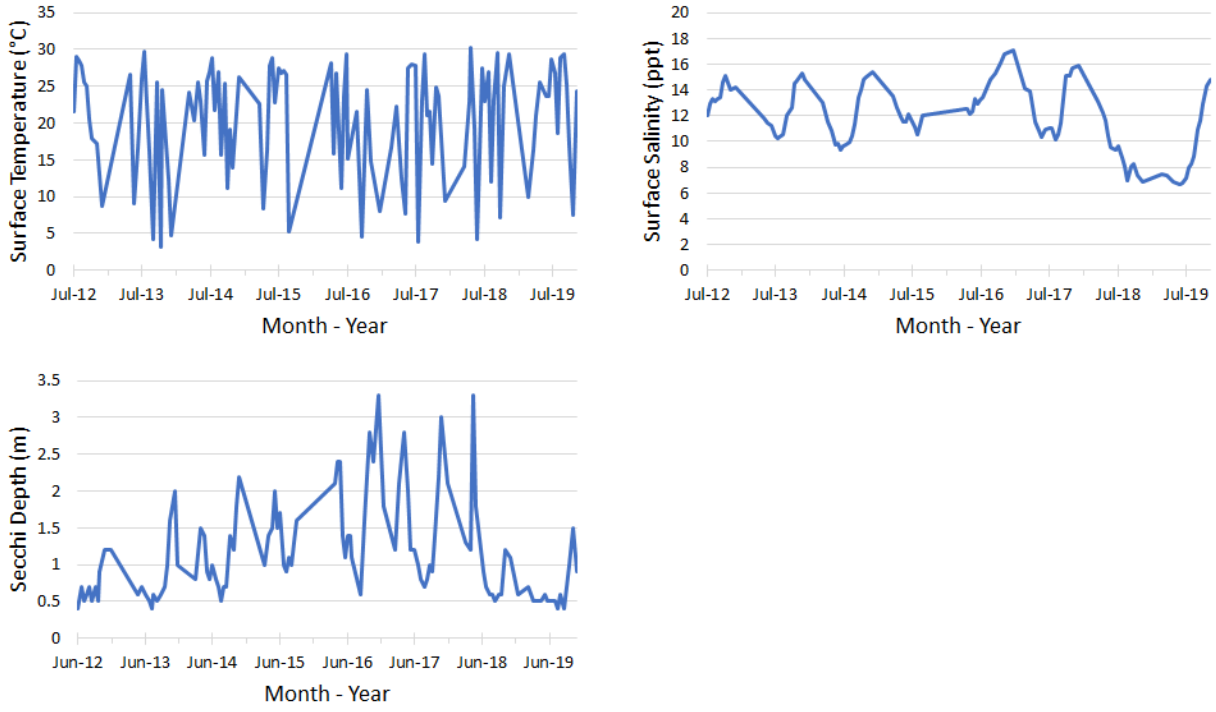

Figure A.11-9. Water quality data collected at XFG4618 in Harris Creek Sanctuary. Data from Chesapeake Bay Program Data Hub.

Section A.12: Herring Bay Sanctuary

The Herring Bay Sanctuary is located along the shore of lower Anne Arundel County and upper Calvert County within NOAA Codes 027 and 127, which is a medium-salinity (Zone 2) region. The sanctuary was created in 2010 and encompasses 16,792 acres of which 7,981 (48%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 8 historic oyster bars within the sanctuary[34].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.12-1)
- Bottom types map (Figure A.12-2)
- Summary statistics (Table A.12-1)
- Abundance per year (Figure A.12-3)
- Shell height frequencies (Figure A.12-4)
- Biomass per year (Figure A.12-5)
- Observed mortality (Figure A.12-6)
- Dermo and MSX per year (Figure A.12-7)
- Cultch per year (Figure A.12-8)
- Water Quality (Figure A.12-9)

The Fall Survey sampled one bar in this sanctuary. No oysters were found in 2019 and 2020 (except one spat) and only nine total in the three previous years. The last patent tong population survey conducted by the department occurred in 2014[35].

Between 2006 and 2010, no planting activities occurred to enhance the commercial public fishery. After the sanctuary was established, approximately 19 million hatchery spat-on-shell were planted for restoration purposes. Marylanders Grow Oysters plantings have occurred annually since 2012.

We are unaware of any studies explicitly examining oyster ecosystem services in this area. Continuous water quality monitoring has occurred at station CB4.1W (38.81498; -76.4627). During the 2006-2020 timeline, surface salinity ranged from 1.8 ppt to 17.5 ppt, with the lowest salinity being during the freshet of 2018-2019 and during the high rainfall year of 2011.

[34] See chart 13 and 17 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[35] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

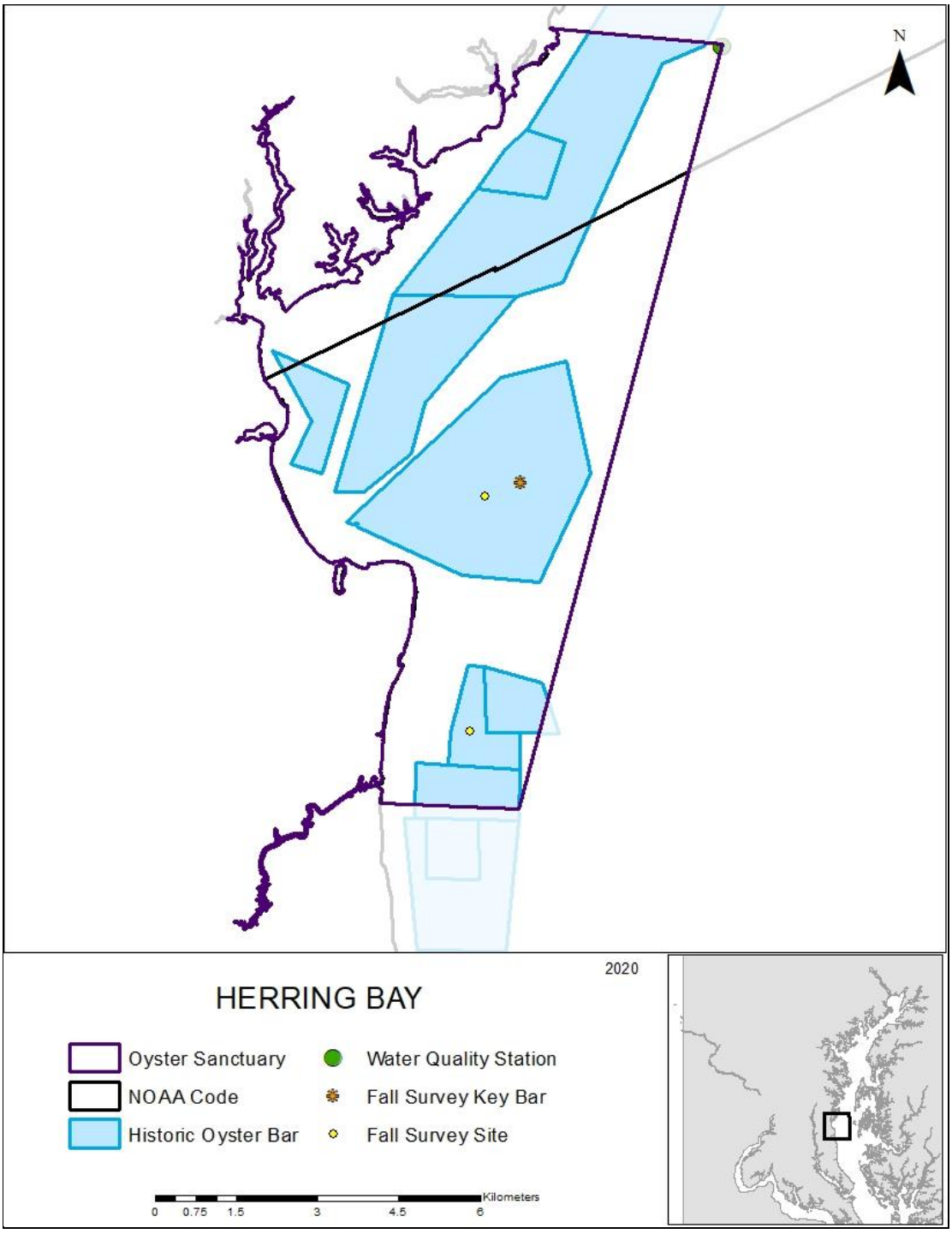

Figure A.12-1. Herring Bay Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

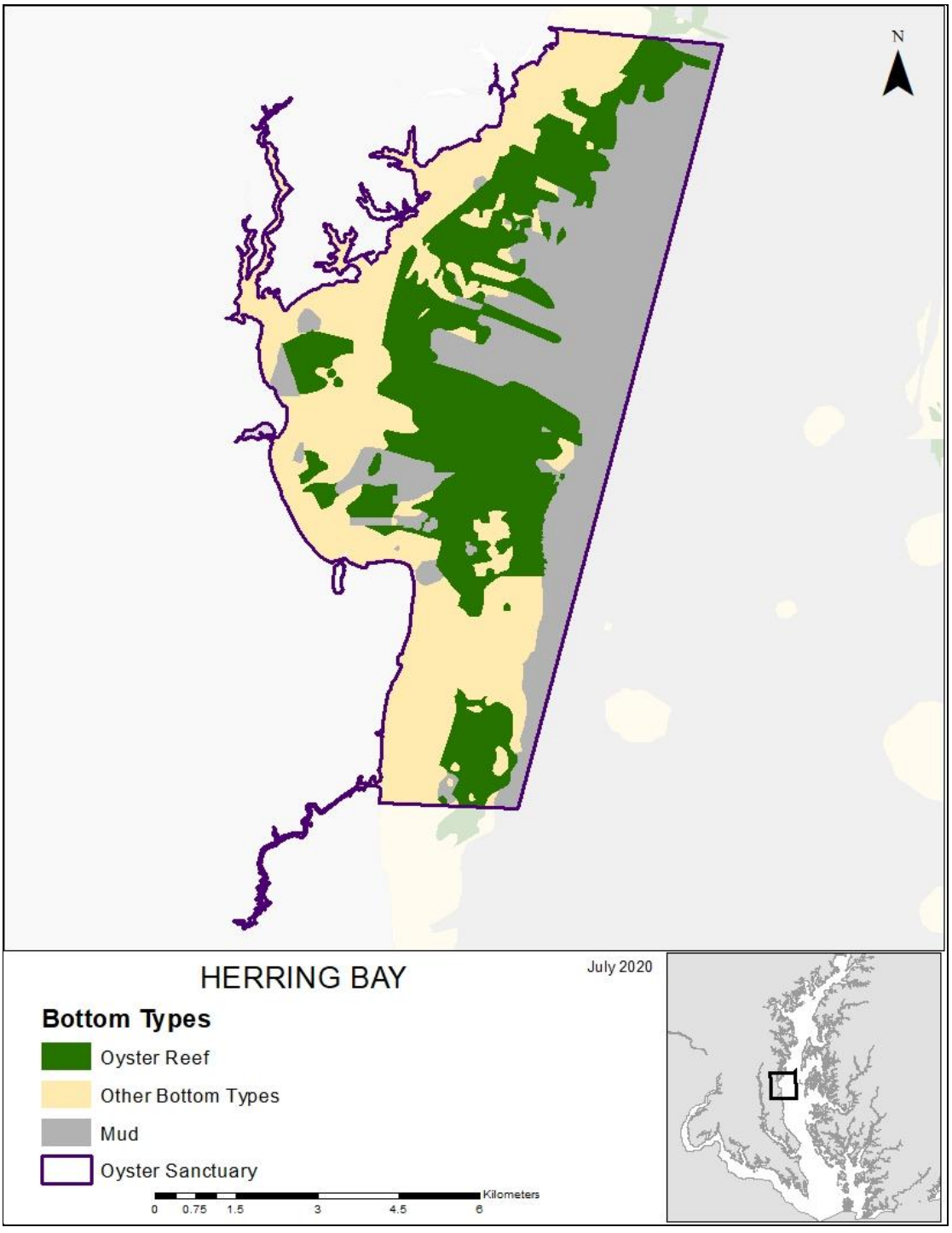

Figure A.12-2. Herring Bay Sanctuary bottom types. Data from Maryland Geological Survey from 2009.

Table A.12-1. Oyster population characteristics based on the Fall Survey in the Herring Bay Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 9	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.01
Number of Live Small-Sized Oysters per square meter	0.35 ± 0.18	0.00 ± 0.00	0.01 ± 0.01
Number of Live Market-Sized Oysters per square meter	1.22 ± 0.98	0.28 ± 0.26	0.01 ± 0.01
Live Oyster Biomass (g Dry Weight per Bushel)	19 ± 3	36 ± 15	4 ± 3
Observed Mortality (%)	2 ± 1	26 ± 8	10 ± 10
Cultch (Bushels per 100 ft Towed)	0.18 ± 0.07	0.03 ± 0.02	0.07 ± 0.02
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

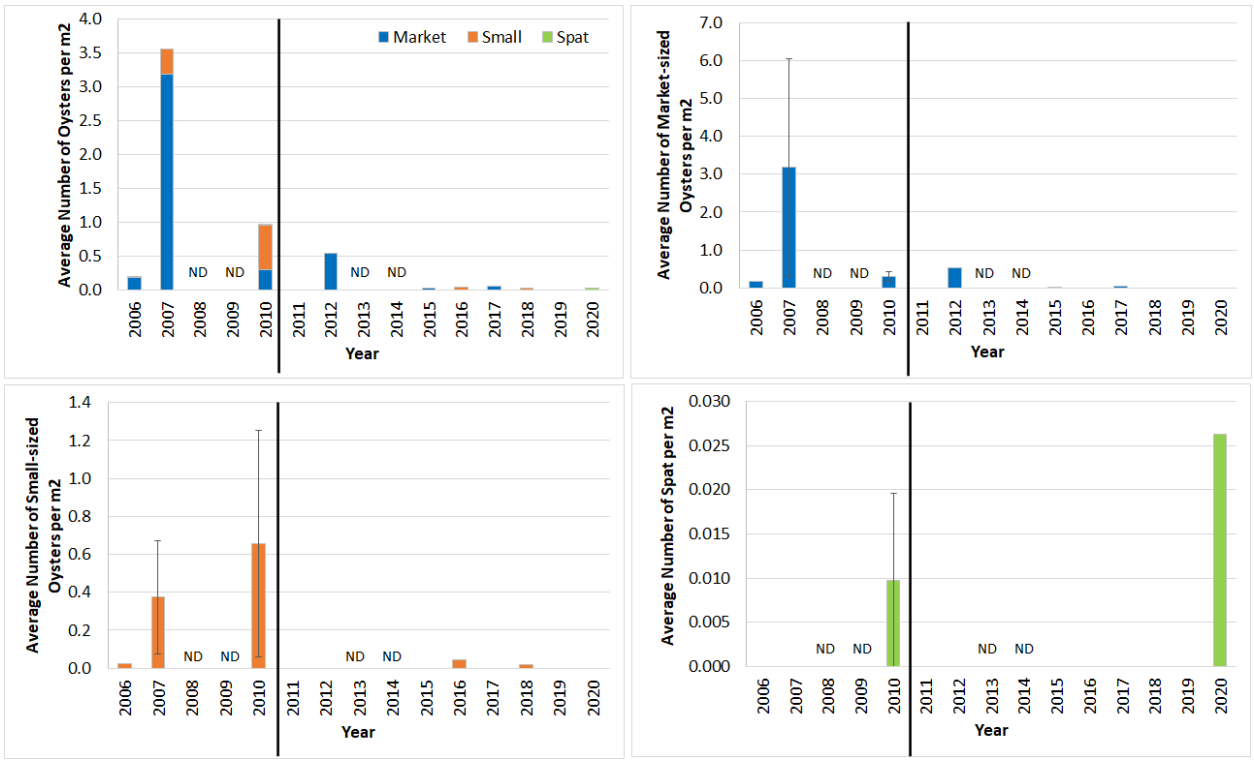

Figure A.12-3. Average number of live oysters per square meter by size class in the Herring Bay Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

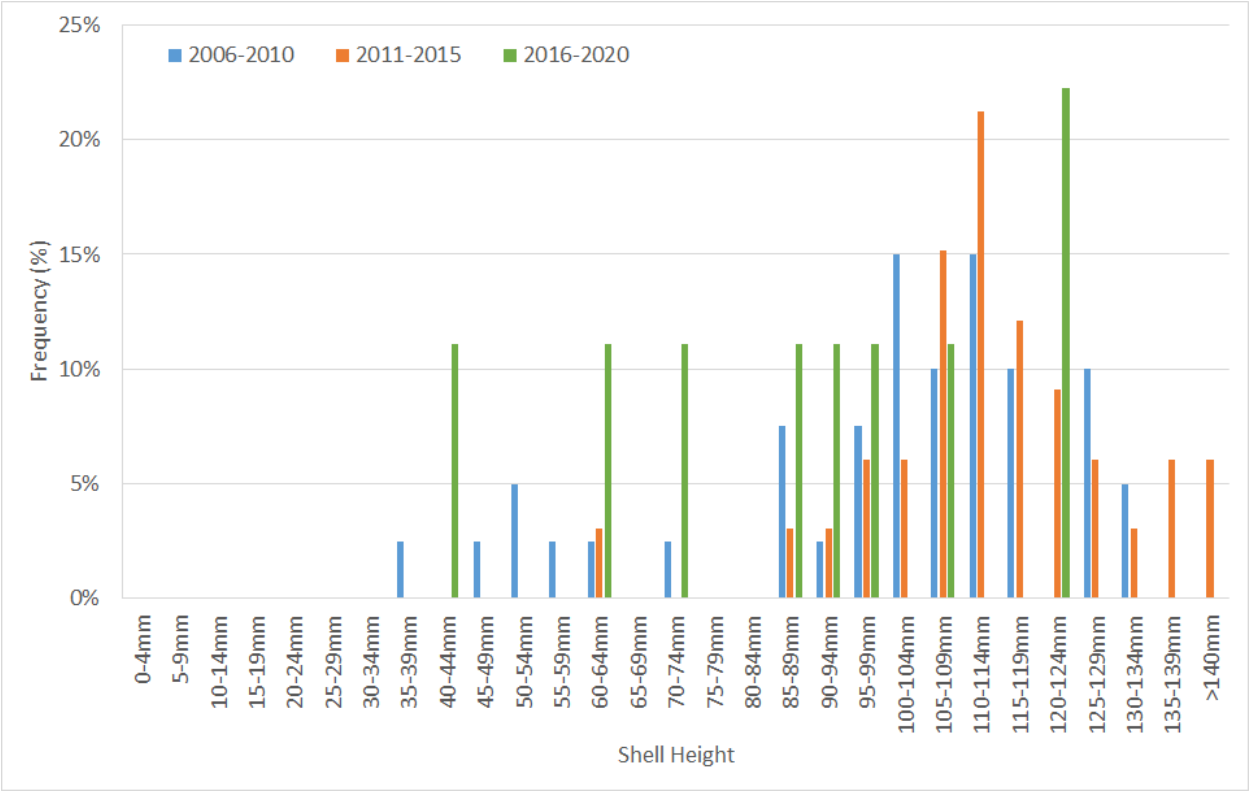

Figure A.12-4. Shell height frequencies of live oysters per bushel of material in the Herring Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Holland Point bar.

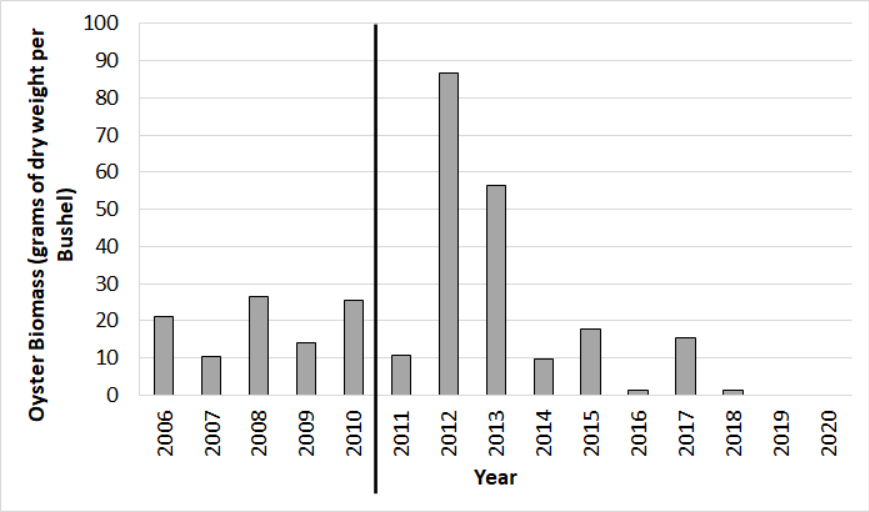

Figure A.12-5. Oyster biomass (grams of dry weight per bushel of material) in the Herring Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Holland Point bar. Black line indicates the date the sanctuary was established.

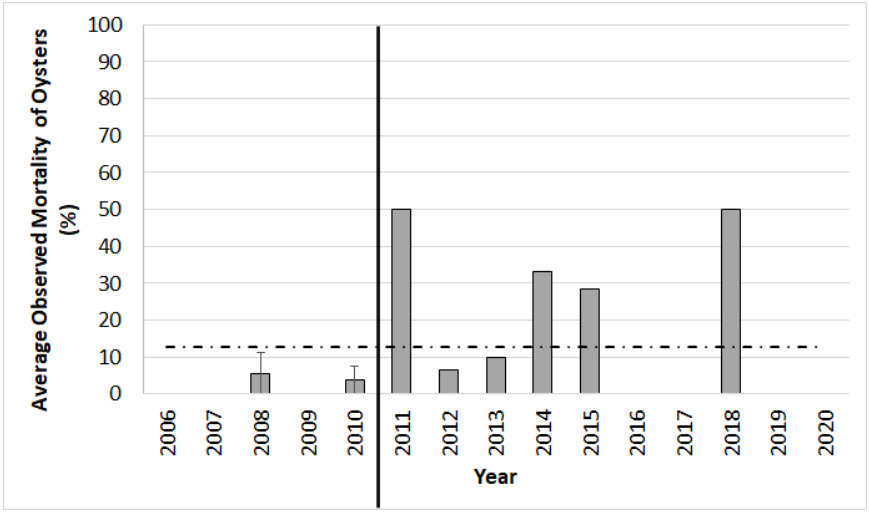

Figure A.12-6. Average annual observed mortality of market-sized and small-sized oysters in Herring Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

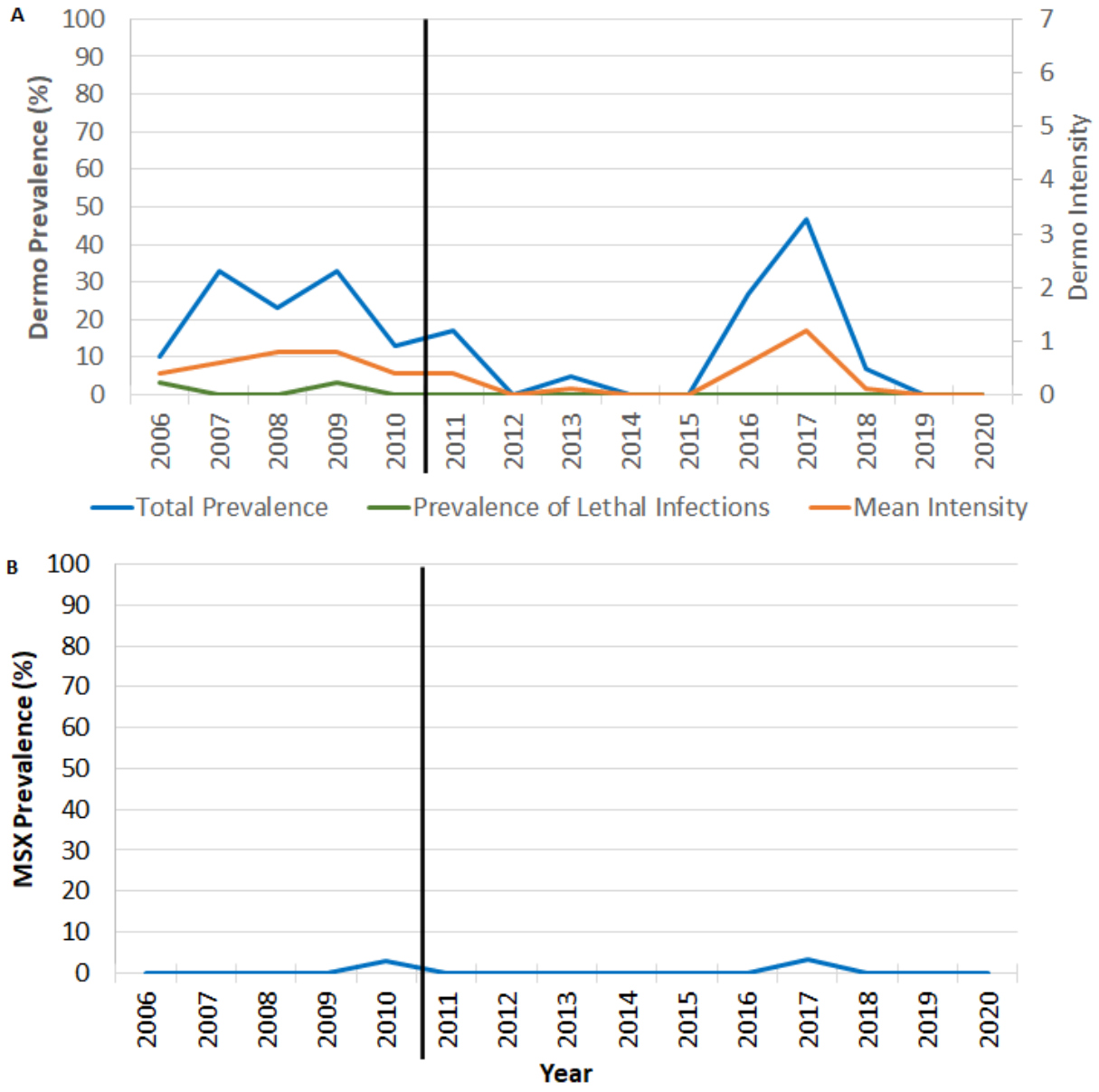

Figure A.12-7. Oyster disease prevalence and intensity in the Herring Bay Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Holland Point bar. Black line denotes the date the sanctuary was established.

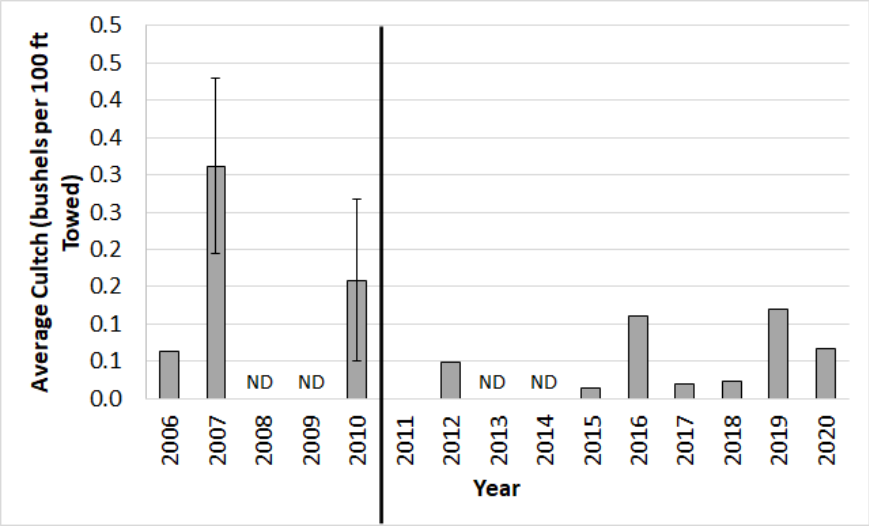

Figure A.12-8. Average cultch (live and dead oysters and loose shell) in the Herring Bay Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

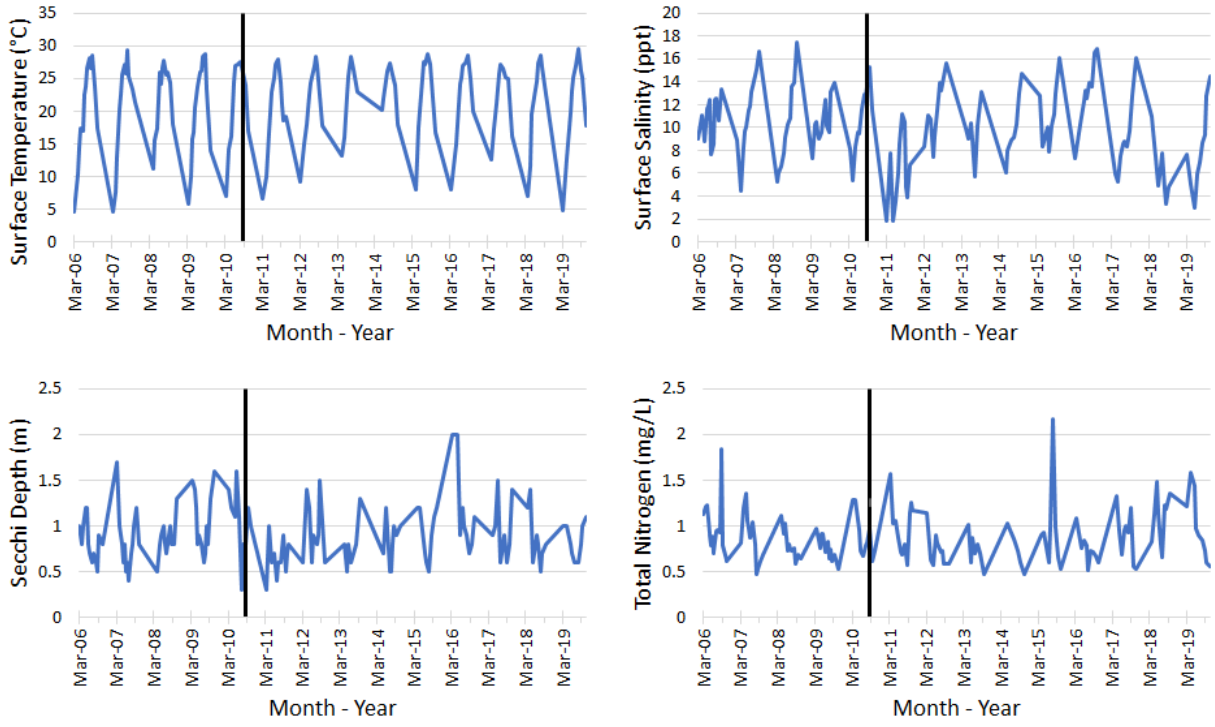

Figure A.12-9. Water quality data collected at CB4.1W in Herring Bay Sanctuary. Black line denotes the date the sanctuary was established. Data from Chesapeake Bay Program Data Hub.

Section A.13: Hooper Strait Sanctuary

The Hooper Strait Sanctuary is located in the lower eastern portion of Maryland's Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Codes 047 and 292. The sanctuary was created in 2009 and encompasses 7,307 acres of which 5,317 (73%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 15 historic oyster bars within the sanctuary[36].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.13-1)
- Bottom types map (Figure A.13-2)
- Summary statistics (Table A.13-1)
- Abundance per year (Figure A.13-3)
- Density Survey (Figure A.13-4)
- Observed mortality (Figure A.13-5)
- Cultch per year (Figure A.13-6)

The Fall Survey sampled two bars in this sanctuary. The density of spat remained relatively constant in the last five years compared to 2011-2015, while the density of small and market oysters increased. Observed mortality from 2013 to 2017 remained above the long-term average. The amount of cultch increased slightly over the previous five-year average. The department conducted a population patent tong survey in 2013[37] and again in 2020. Results indicated an increase in oyster density with an average density of 4.5 per square meter in 2020. The density of spat was much greater than small-sized and market-sized oysters (4.1 per square meter, 0.3 per square meter and 0.2 per square meter respectively). Of the 121 samples, 85 had no live oysters and 39 had no surface shell volume.

Between 2006 and 2008, no planting activities occurred to enhance the commercial public fishery. After the sanctuary was established, approximately 34 million hatchery spat-on-shell were planted for restoration purposes. We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[36] See chart 36 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[37] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

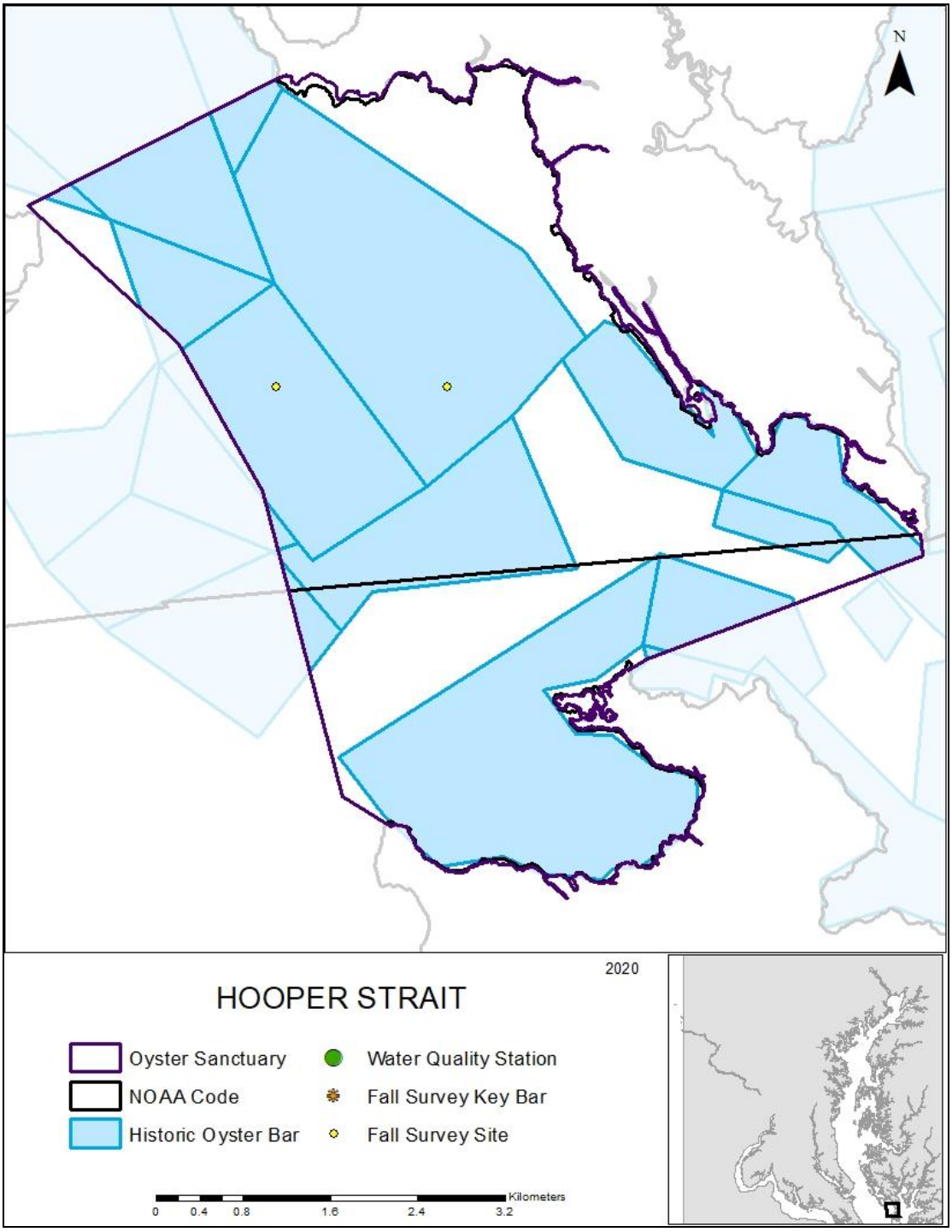

Figure A.13-1. Hooper Strait Sanctuary. Fall Survey sites may not be sampled every year.

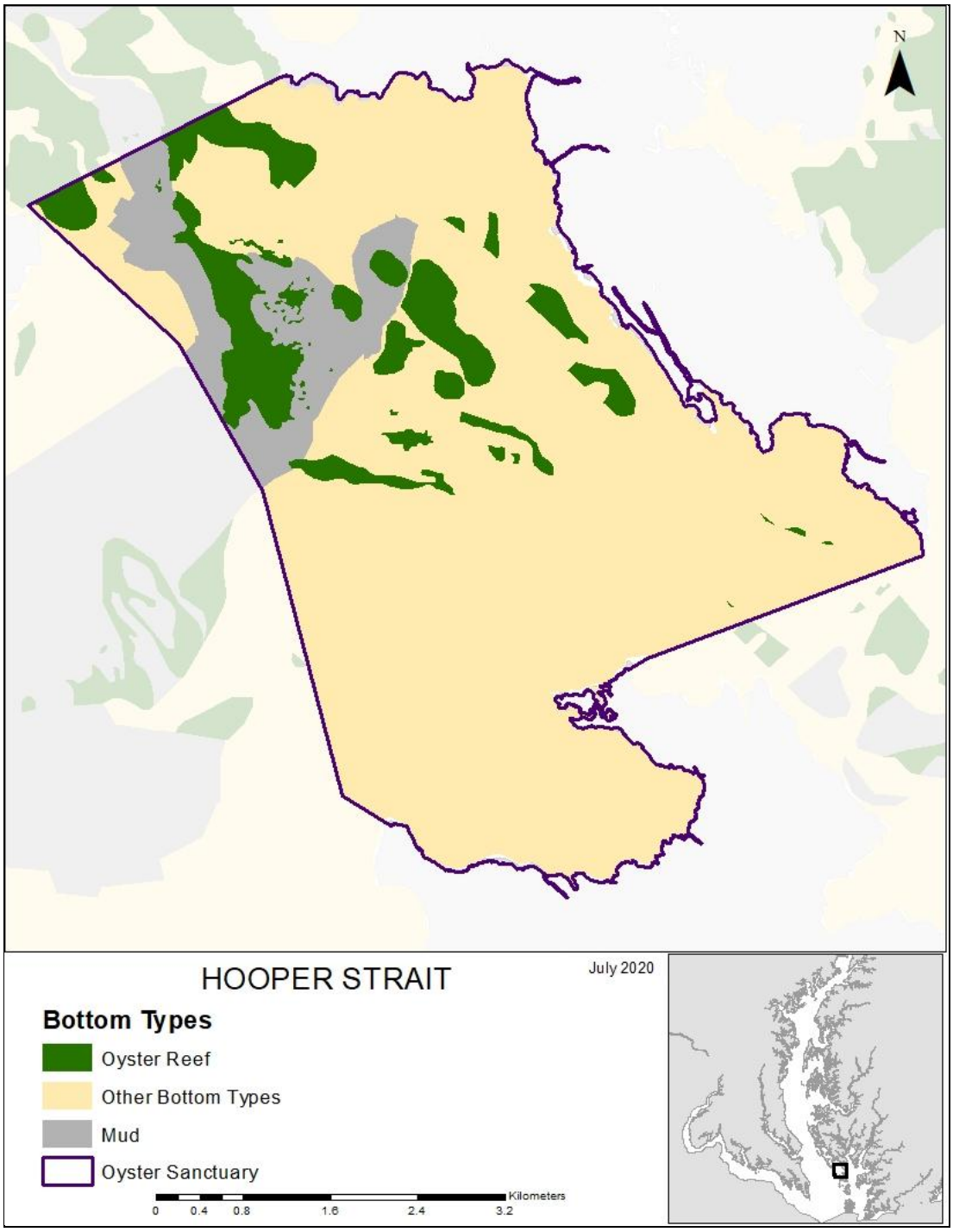

Figure A.13-2. Hooper Strait Sanctuary bottom types. Data from Maryland Geological Survey from 2010.

Table A.13-1. Oyster population characteristics based on the Fall Survey in the Hooper Strait Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 9
Number of Live Spat Oysters per square meter	82.5 ± 71.9	65.3 ± 18.3	58.5 ± 22
Number of Live Small-Sized Oysters per square meter	23.4 ± 8.4	51.5 ± 17.3	77.7 ± 36.9
Number of Live Market-Sized Oysters per square meter	4.8 ± 2.1	18 ± 4.5	25 ± 8.2
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	14 ± 9	27 ± 6	14 ± 6
Cultch (Bushels per 100 ft Towed)	0.4 ± 0.1	0.5 ± 0.1	0.7 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

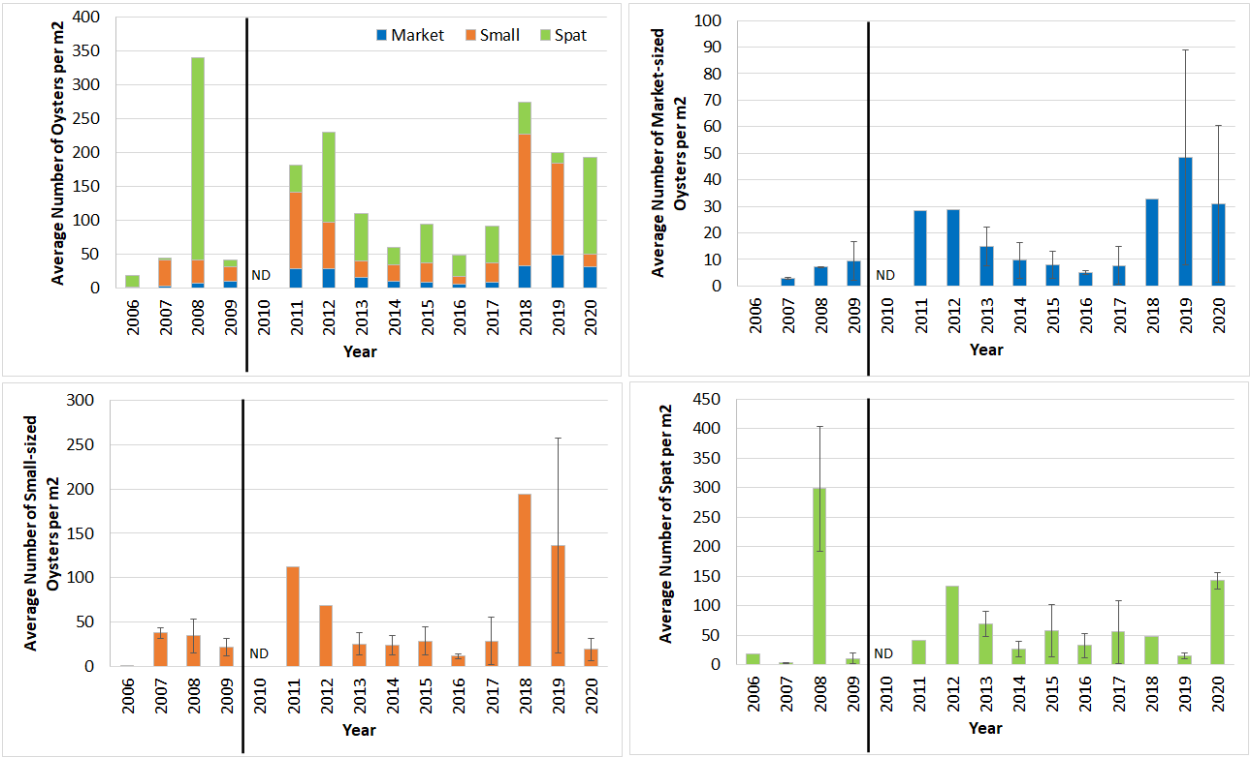

Figure A.13-3. Average number of live oysters per square meter by size class in the Hooper Strait Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

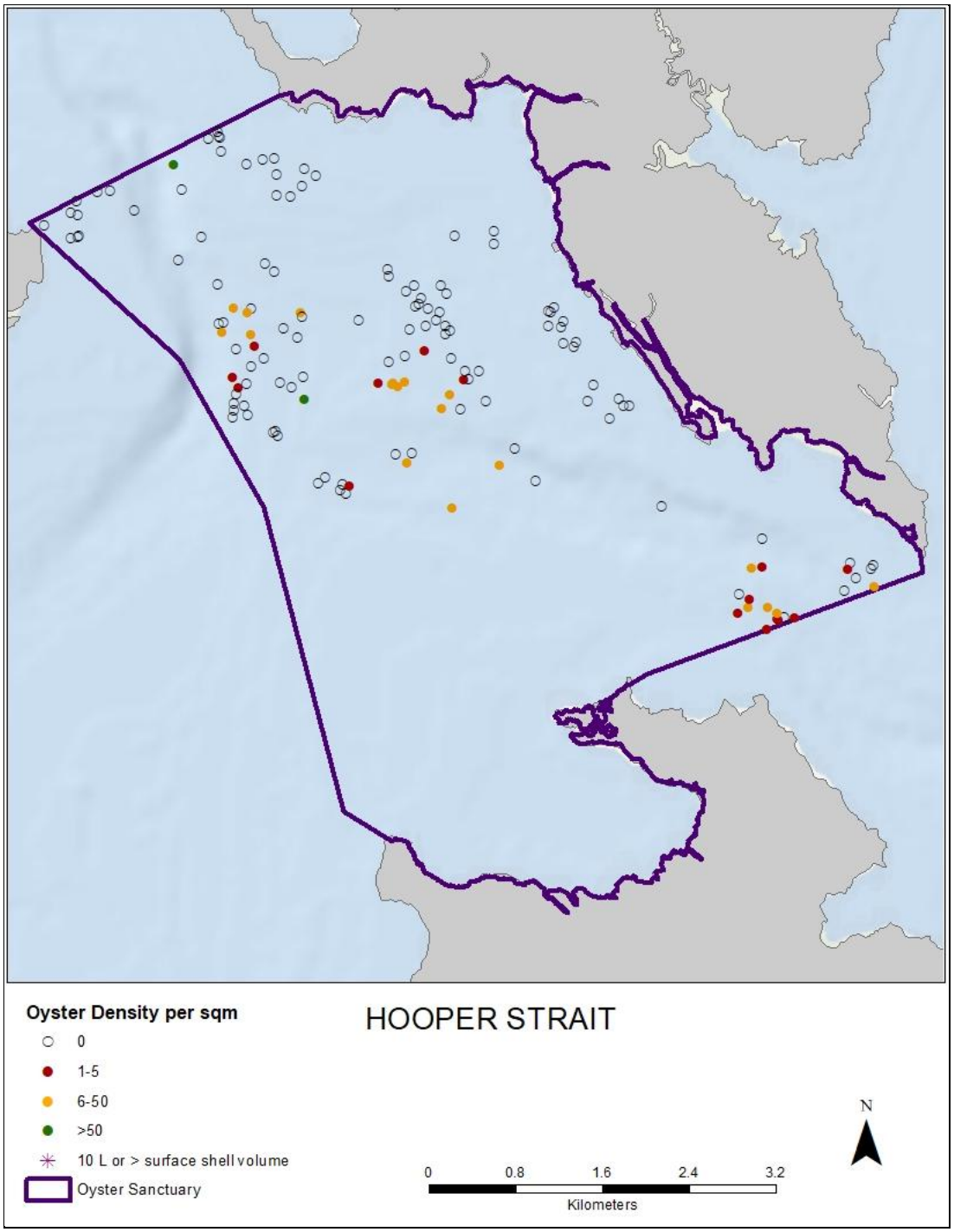

Figure A.13-4. Map of 2020 oyster density in the Eastern Bay. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

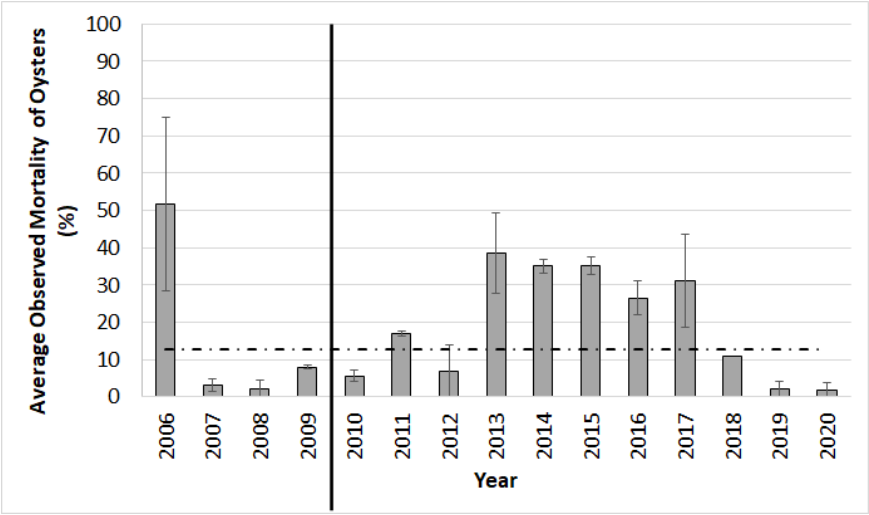

Figure A.13-5. Average annual observed mortality of market-sized and small-sized oysters in Hooper Strait Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

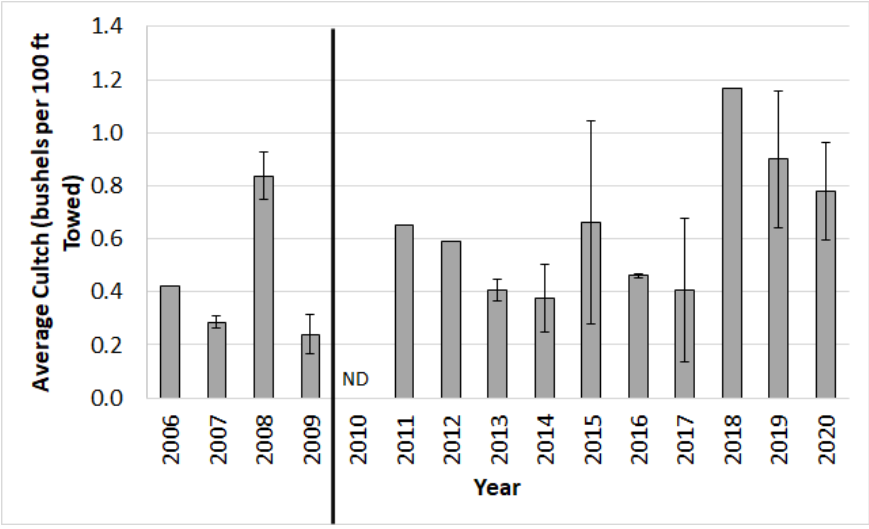

Figure A.13-6. Average cultch (live and dead oysters and loose shell) in the Hooper Strait Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

Section A.14: Howell Point Sanctuary

The Howell Point Sanctuary is located in the middle Choptank River, a low-salinity (Zone 1) region within NOAA Code 237. The sanctuary was created in 2001 and encompasses six acres of historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments), all located within the Beacons oyster bar. The Howell Point Sanctuary was established for the US Army Corps of Engineers to study the effectiveness of three-dimensional oyster habitat for use in oyster restoration.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.14-1)
- Bottom types map (Figure A.14-2)
- Summary statistics (Table A.14-1)
- Abundance per year (Figure A.14-3)
- Observed mortality (Figure A.14-4)
- Cultch per year (Figure A.14-5)

The Fall Survey has sampled this sanctuary since 2015. Density of spat and small oysters was higher in 2016-2020, while density of market oysters was lower. Observed mortality is slightly below the long term average. The department has not conducted any patent tong population surveys on the Howell Point Sanctuary since 2006.

Since 2006, approximately 79 million spat-on-shell were planted for restoration purposes. We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area since 2006.

Marylanders Grow Oysters, a public outreach program, has planted oysters since 2009 at one site in the sanctuary. The oysters were held in cages at docks in the nearby La Trappe Creek.

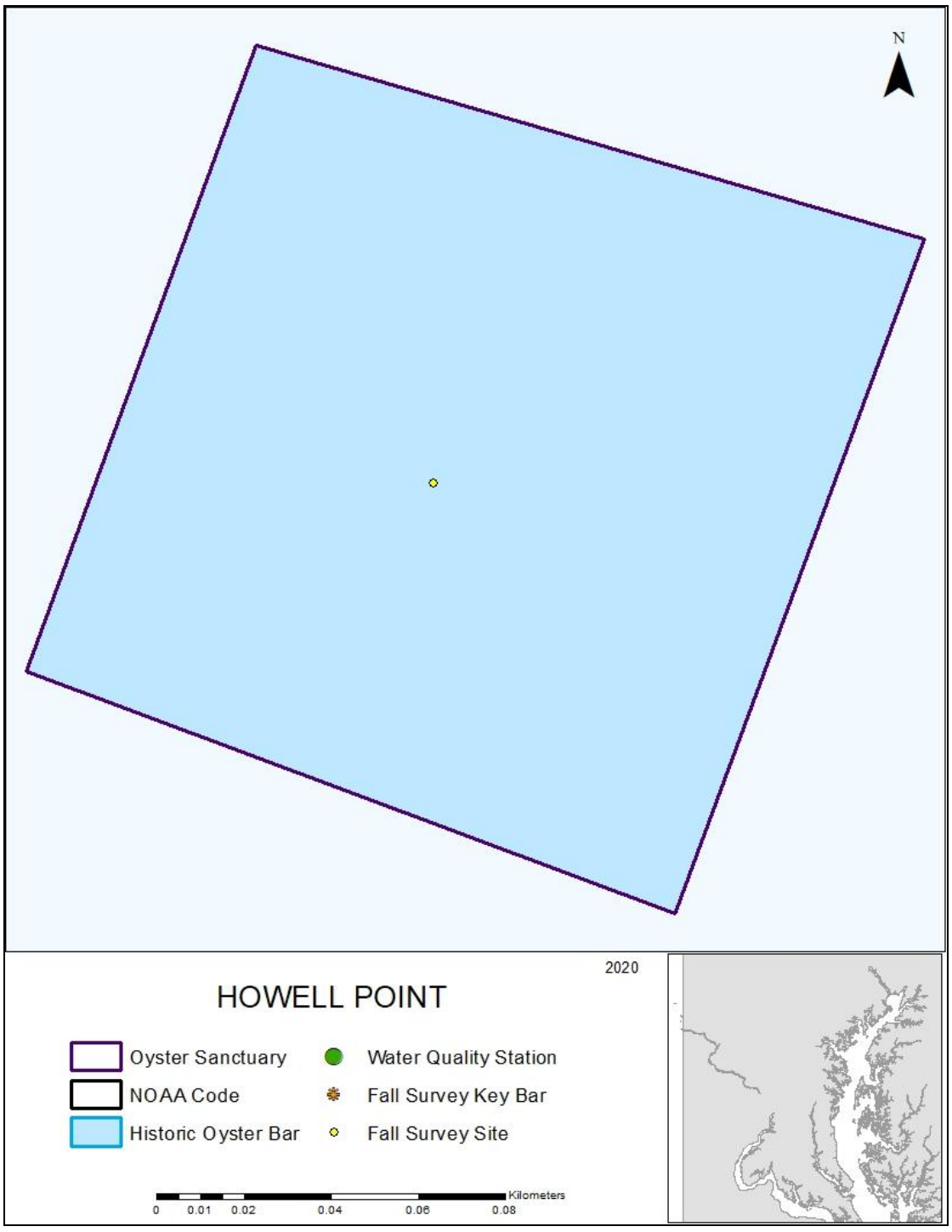

Figure A.14-1. Howell Point Sanctuary. Fall Survey sites may not be sampled every year.

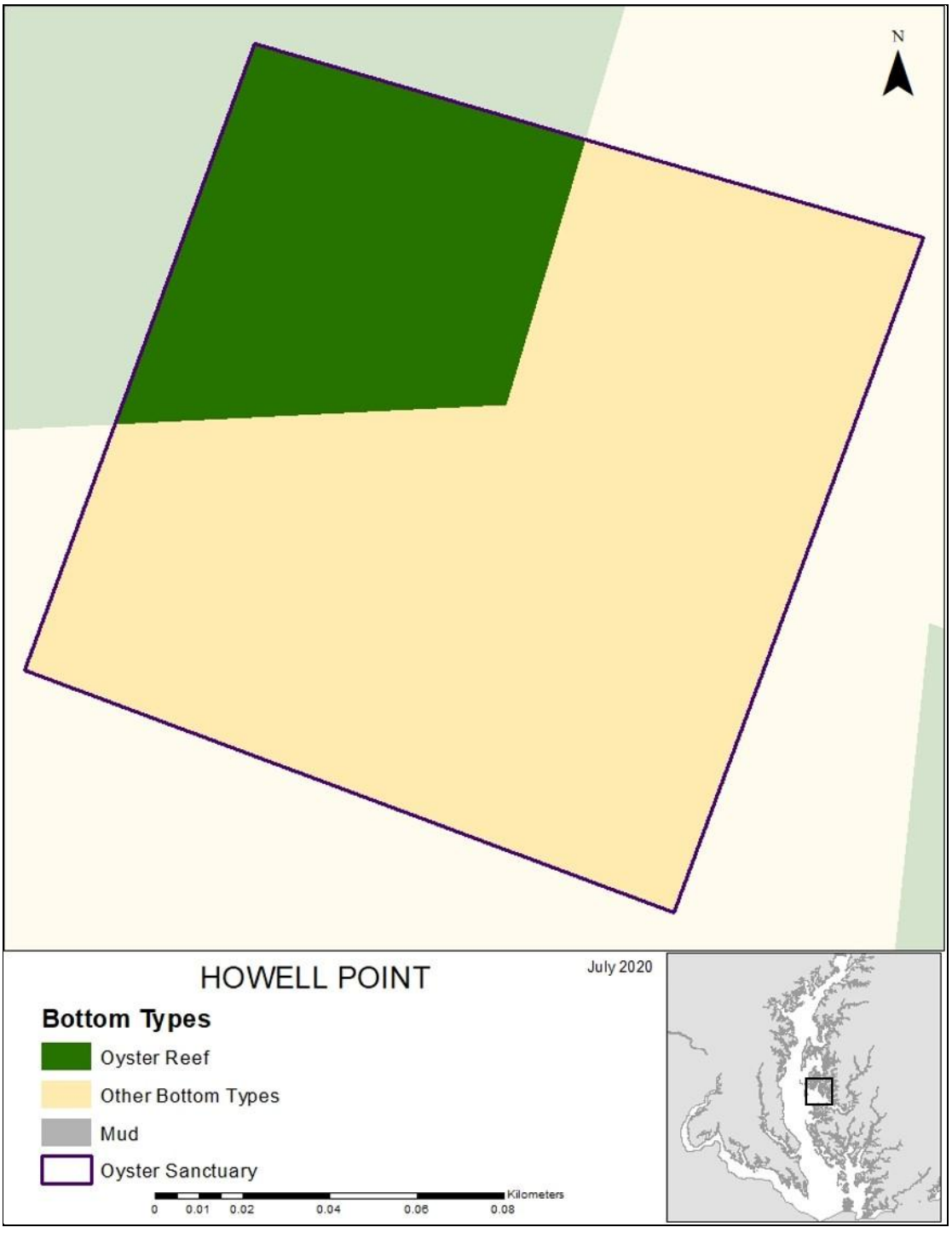

Figure A.14-2. Howell Point Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Table A.14-1. Oyster population characteristics based on the Fall Survey in the Howell Point Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	0 / 0	1 / 1	5 / 5
Number of Live Spat Oysters per square meter	ND	0	2.2 ± 1.5
Number of Live Small-Sized Oysters per square meter	ND	0	5 ± 2.6
Number of Live Market-Sized Oysters per square meter	ND	66.0	58.4 ± 12.8
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	ND	14	11 ± 2
Cultch (Bushels per 100 ft Towed)	ND	1.1	1.1 ± 0.3
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

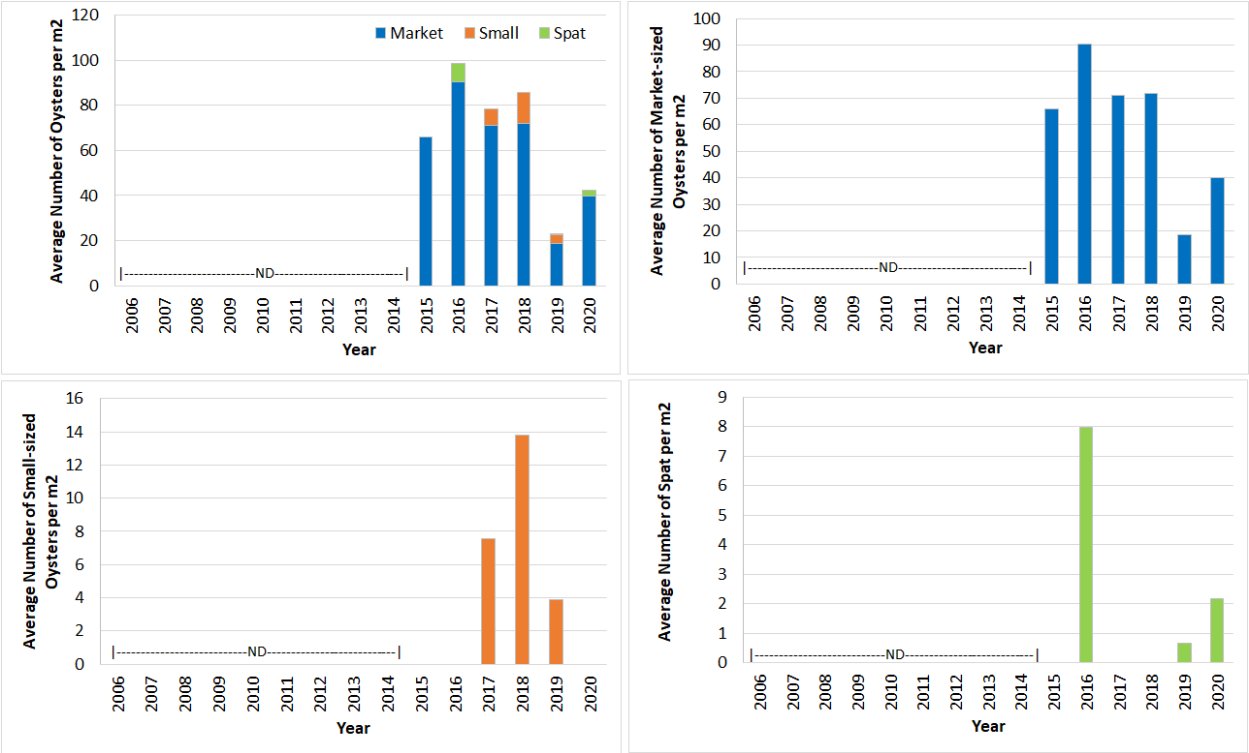

Figure A.14-3. Average number of live oysters per square meter by size class in the Howell Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

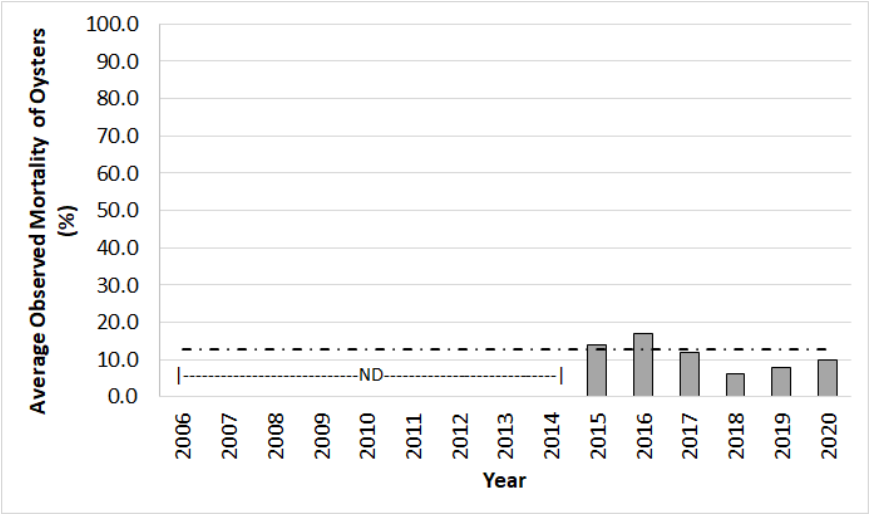

Figure A.14-4. Average annual observed mortality of market-sized and small-sized oysters in Howell Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The dashed line represents the 2006-2020 baywide average observed mortality. ND = No Data.

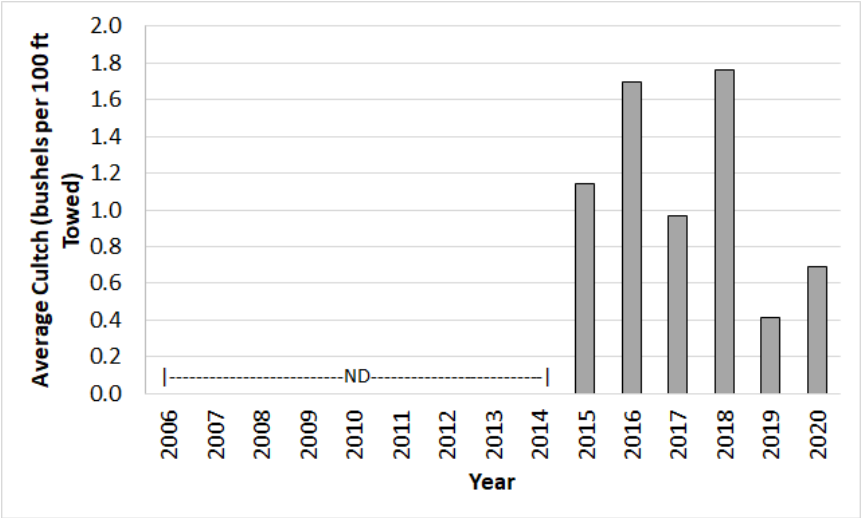

Figure A.14-5. Average cultch (live and dead oysters and loose shell) in the Howell Point Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. ND = No Data.

Section A.15: Kitts Creek Sanctuary

The Kitts Creek Sanctuary is located in the southeastern portion of Maryland's Chesapeake Bay, a high-salinity (Zone 3) region within NOAA Code 072. Kitts Creek empties into Pocomoke Sound. The sanctuary was created in 2001 and encompasses 1,181 acres of which 95 acres (8%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are two historic oyster bars within the sanctuary[38]. Kitts Creek Sanctuary was established due to local legislators' interest in oyster restoration with the intention of population enhancement through natural spatfall.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.15-1)
- Bottom types map (Figure A.15-2)
- Density Survey (Figure A.15-3)

The Fall Survey sampled this area twice during the time period; one sample in 2006 and one sample in 2007. Lack of samples makes it difficult to detect trends in this sanctuary. A population patent tong survey was conducted by the department in 2017. Results indicated an average oyster density of 2.0 per square meter, with a similar density of small-sized and market-sized oysters. Of the 61 samples taken, 40 had no oysters and 32 had no surface shell volume.

There has been no planting activity for this area since 2006. We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[38] See chart 49 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

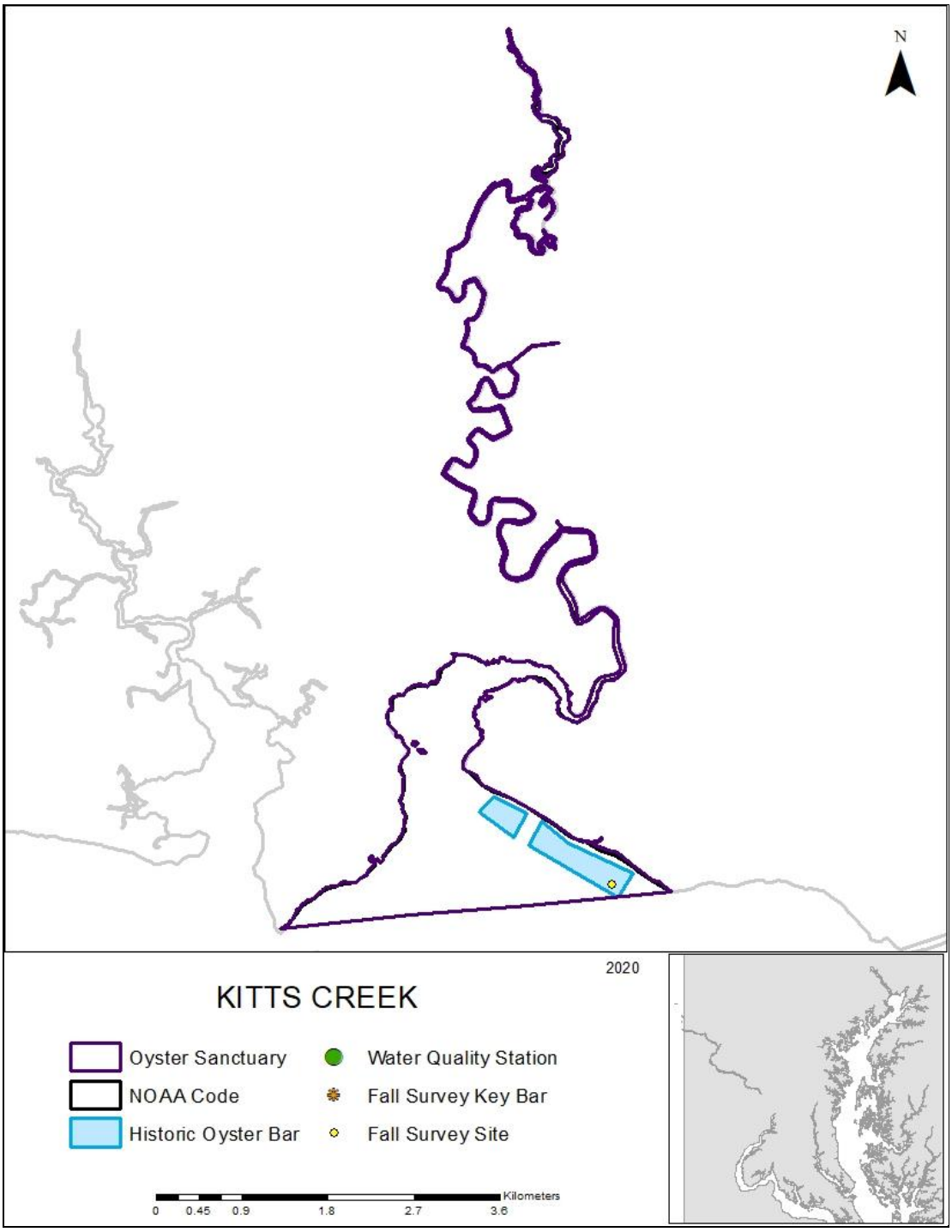

Figure A.15-1. Kitts Creek Sanctuary. Fall Survey sites may not be sampled every year.

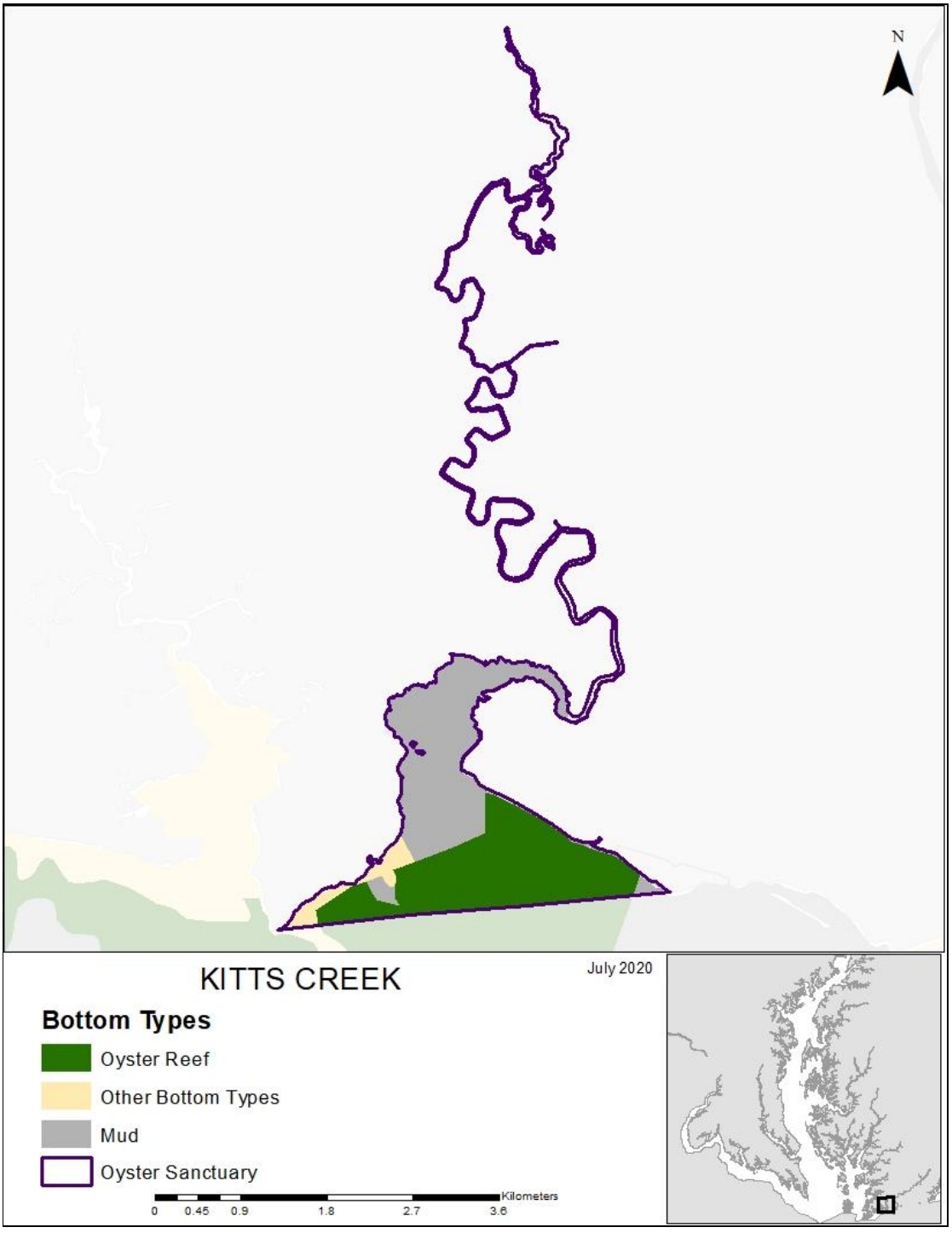

Figure A.15-2. Kitts Creek Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

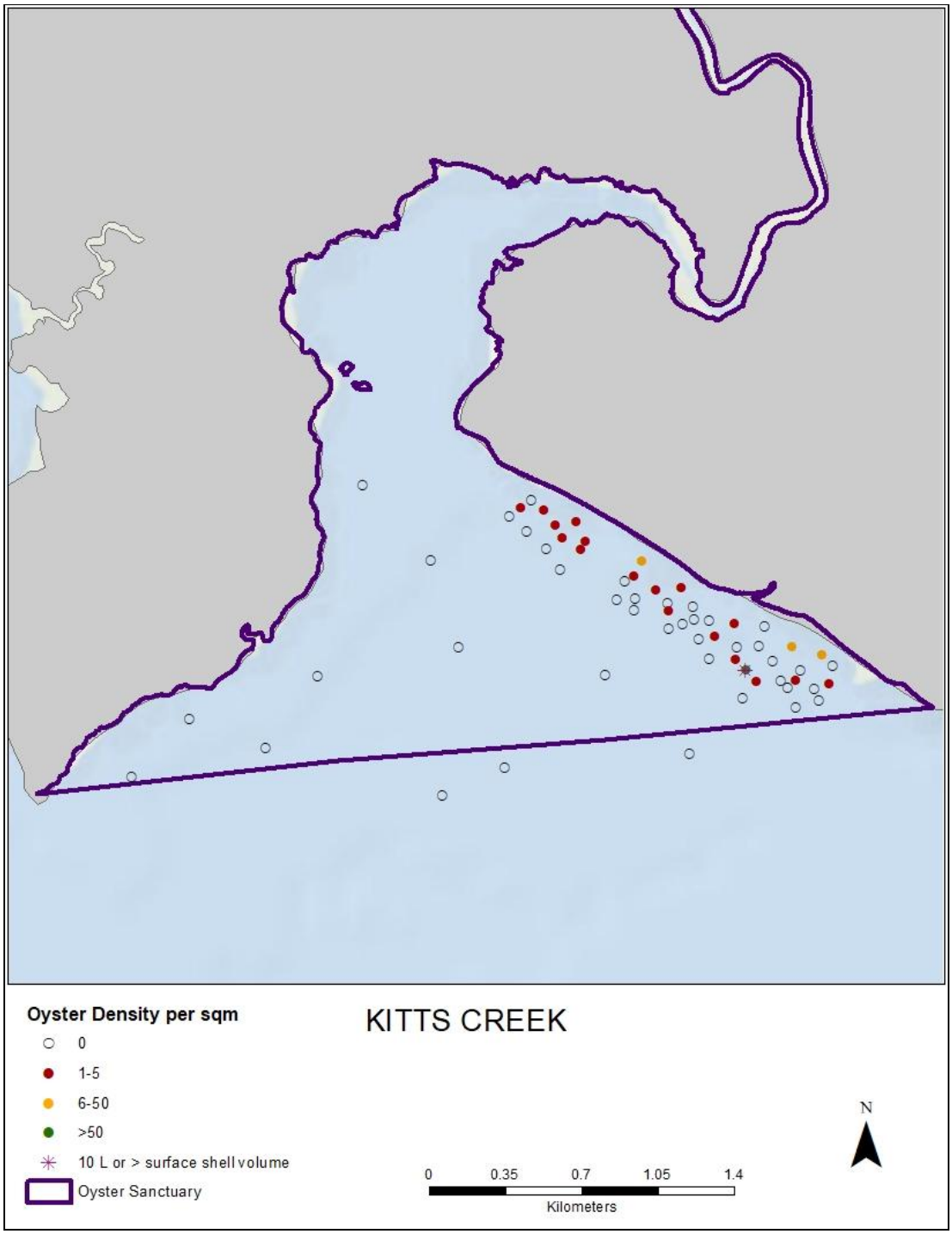

Figure A.15-4. Map of 2017 oyster density in the Kitts Creek Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.16: La Trappe Sanctuary

The La Trappe Sanctuary is located in La Trappe Creek, a tributary of the Choptank River. The sanctuary is in a low-salinity (Zone 1) region within NOAA Code 237. The sanctuary was created in 2010 and encompasses 377 acres of which 13 acres (3.5%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar located partially within the sanctuary (La Trappe bar).

Information available for this sanctuary includes:

- Sanctuary map (Figure A.16-1)
- Bottom types map (Figure A.16-2)

The Fall Survey has sampled the La Trappe Sanctuary one time since 2006 in 2015 when one sample was taken. No live or dead oysters were found. The department has not conducted any patent tong population surveys since 2006. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

Marylanders Grow Oysters, a public outreach program has been present in the creek since 2009. Spat raised by MGO is planted outside the river at the Howells Point Sanctuary.

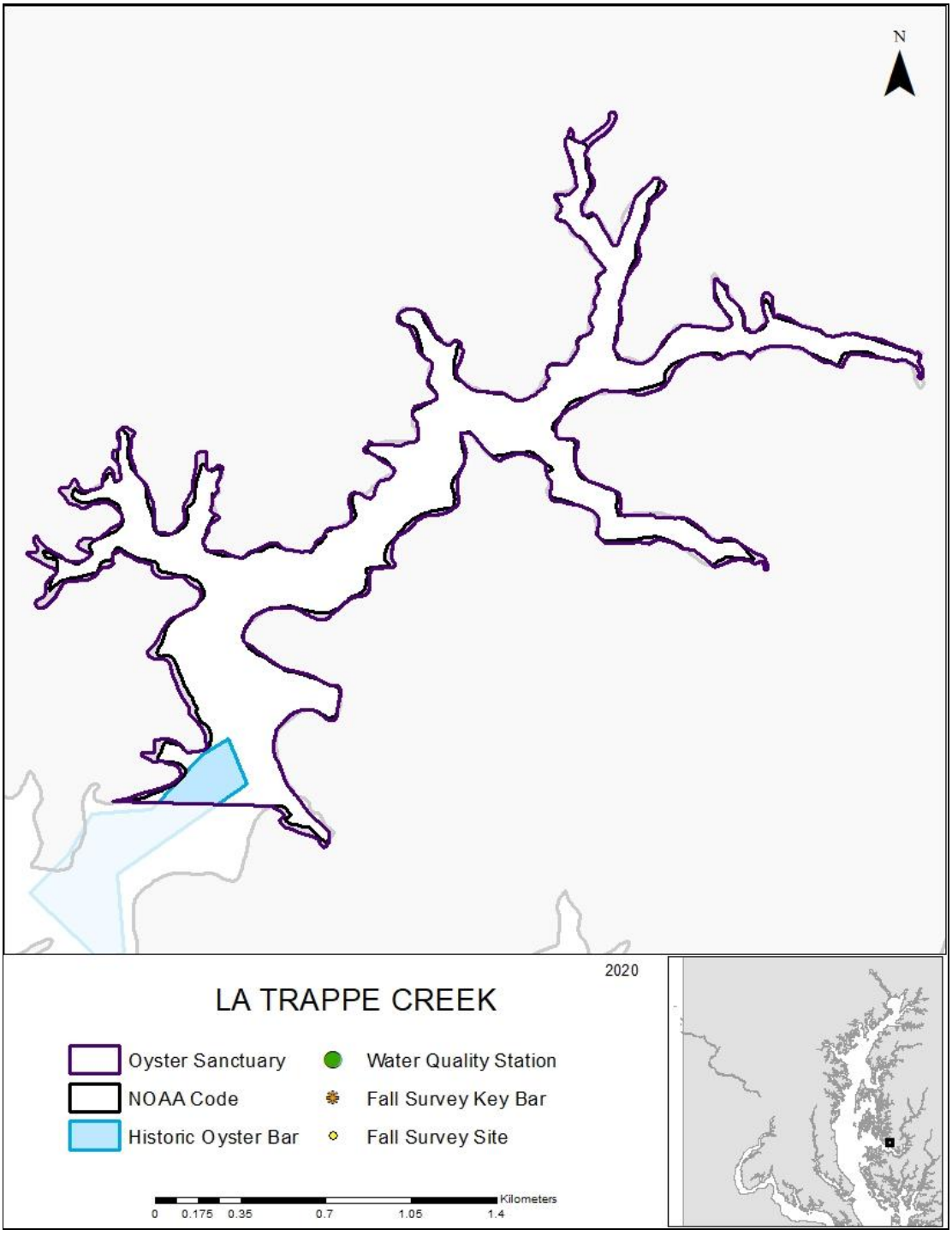

Figure A.16-1. La Trappe Sanctuary.

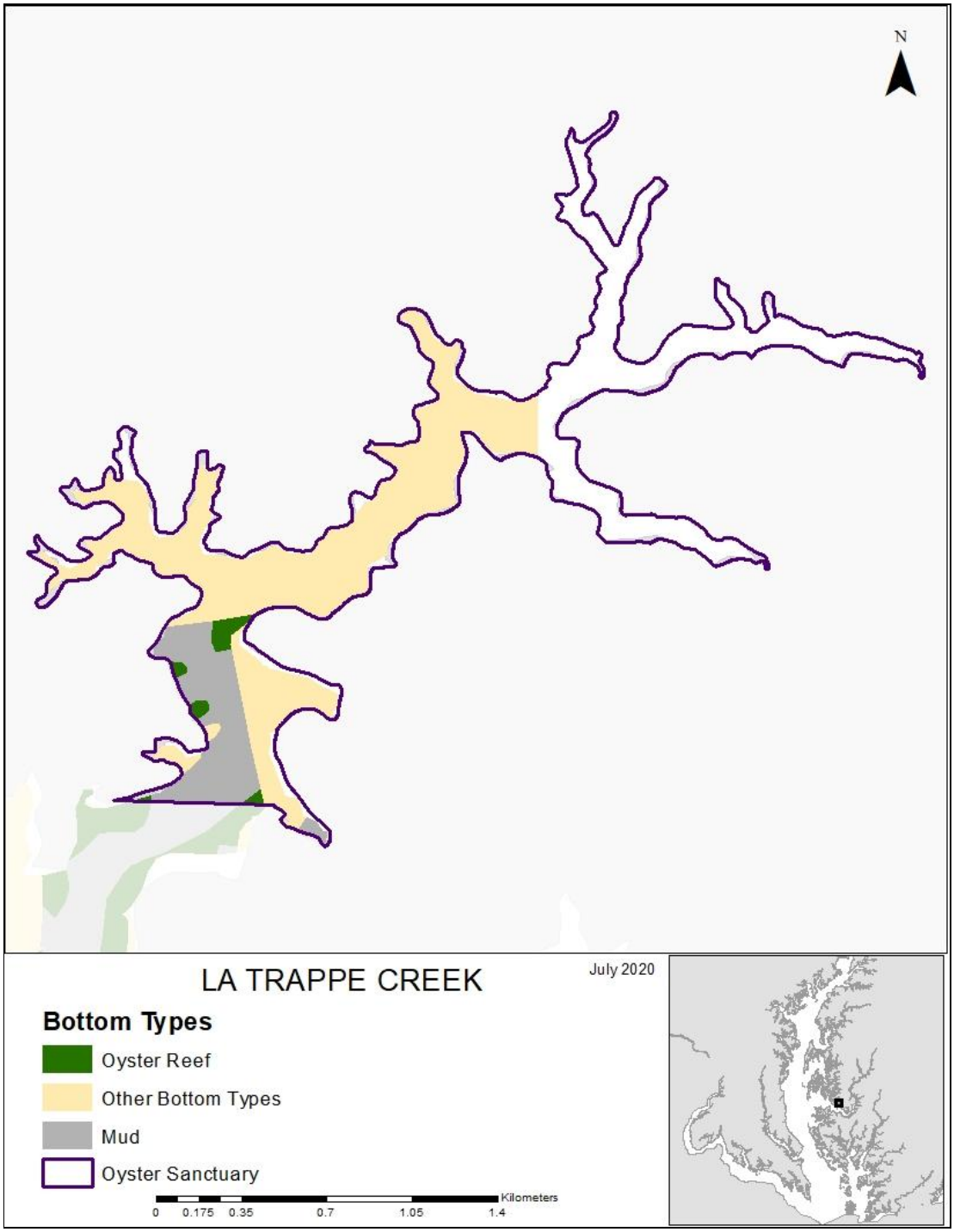

Figure A.16-2. La Trappe Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

Section A.17: Little Choptank River Sanctuary

The Little Choptank River Sanctuary is located in the central portion of Maryland's eastern shore of Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Code 053. The sanctuary was created in 2010 and encompasses 9,415 acres of which 1,713 (18%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 18 historic oyster bars within the sanctuary[39]. The Little Choptank River Sanctuary has been selected for large-scale oyster restoration under the 2014 Chesapeake Bay Watershed Agreement. Initial restoration of the sanctuary was completed in 2020, and planned second hatchery spat-on-shell seeding and monitoring is still ongoing.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.17-1)
- Bottom types map (Figure A.17-2)
- Summary statistics (Table A.17-1)
- Abundance per year (Figure A.17-3)
- Shell height frequencies (Figure A.17-4)
- Biomass per year (Figure A.17-5)
- Observed mortality (Figure A.17-6)
- Dermo and MSX per year (Figure A.17-7)
- Cultch per year (Figure A.17-8)

The Fall Survey sampled nine bars in the sanctuary, but did not sample sites with a restored stone reef base due to gear constraints. Spat density increased in 2016-2020, likely due to the high numbers of spat seen in 2020. Biomass increased, despite the decrease in density of market oysters. Density of small oysters remained similar to the previous time period. Observed mortality increased slightly but remained below the long-term baywide average. Cultch declined slightly from the previous five-year average. Average size of oysters declined in 2016-2020, from 72 mm to 64 mm as a result of higher numbers of spat.

The department conducted a population patent tong survey in 2014[40], but has not conducted any since. Other organizations have been monitoring the restoration areas using patent tong and diver surveys. Results from these surveys indicate three years after initial restoration, 97% of reefs meet the minimum threshold restoration criteria of 15 oysters per square meter and 15 grams of dry weight (biomass) per square meter[41].

Between 2006 and 2010, no planting activities occurred to enhance the public oyster fishery. After the creation of the sanctuary areas in 2010, Little Choptank Sanctuary received substrate and hatchery spat-on-shell restoration plantings. Due to a shortage of fresh oyster shell, reefs

[39] See chart 25 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[40] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

[41] National Oceanic and Atmospheric Administration. 2020. 2019 Oyster Reef Monitoring Report Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland Collected from Fall 2019 through Summer 2020. https://www.chesapeakebay.net/documents/2019_MD_Oyster_Monitoring_Report_FINAL.pdf

were restored using stone, Florida fossil oyster shell, clam shell, and mixed shell (clam and whelk). Over 1.78 billion hatchery spat-on-shell were placed in the sanctuary from 2011-2020 on 358 acres of restored oyster bottom. Several organizations participated in the restoration work including MDNR, U.S. Army Corps of Engineers, NOAA, Oyster Recovery Partnership, National Fish and Wildlife Foundation, Chesapeake Bay Foundation, The Nature Conservancy, and CSX Railroad.

Marylanders Grow Oysters, a public outreach program, has planted oysters at one site in the sanctuary between 2012 and 2019.

Many studies took place evaluating ecosystem services provided by large-scale oyster restoration, including, a study from May 2014 through September 2017 to assess how fish communities and abundance vary on restored and unrestored reefs, a qualitative index of oyster reef habitat quality was developed using images from restored and unrestored reefs, including those from the Little Choptank sanctuary, and as a study estimating the ecological benefits and socioeconomic impacts from oyster restoration.[42] We are unaware of any continual water quality monitoring in this area.

[42] Bruce, D. G., J. C. Cornwell, L. Harris, T. F. Ihde, M. L. Kellogg, S. Knoche, R. N. Lipcius, D. N. McCulloch-Prosser, S. P. McIninch, M. B. Ogburn, R. D. Seitz, J. Testa, S. R. Westby, and B. Vogt. 2021. A Synopsis of Research on the Ecosystem Services Provided by Large-Scale Oyster Restoration in the Chesapeake Bay. NOAA Tech. Memo. NMFS-OHC-8, 52 p.

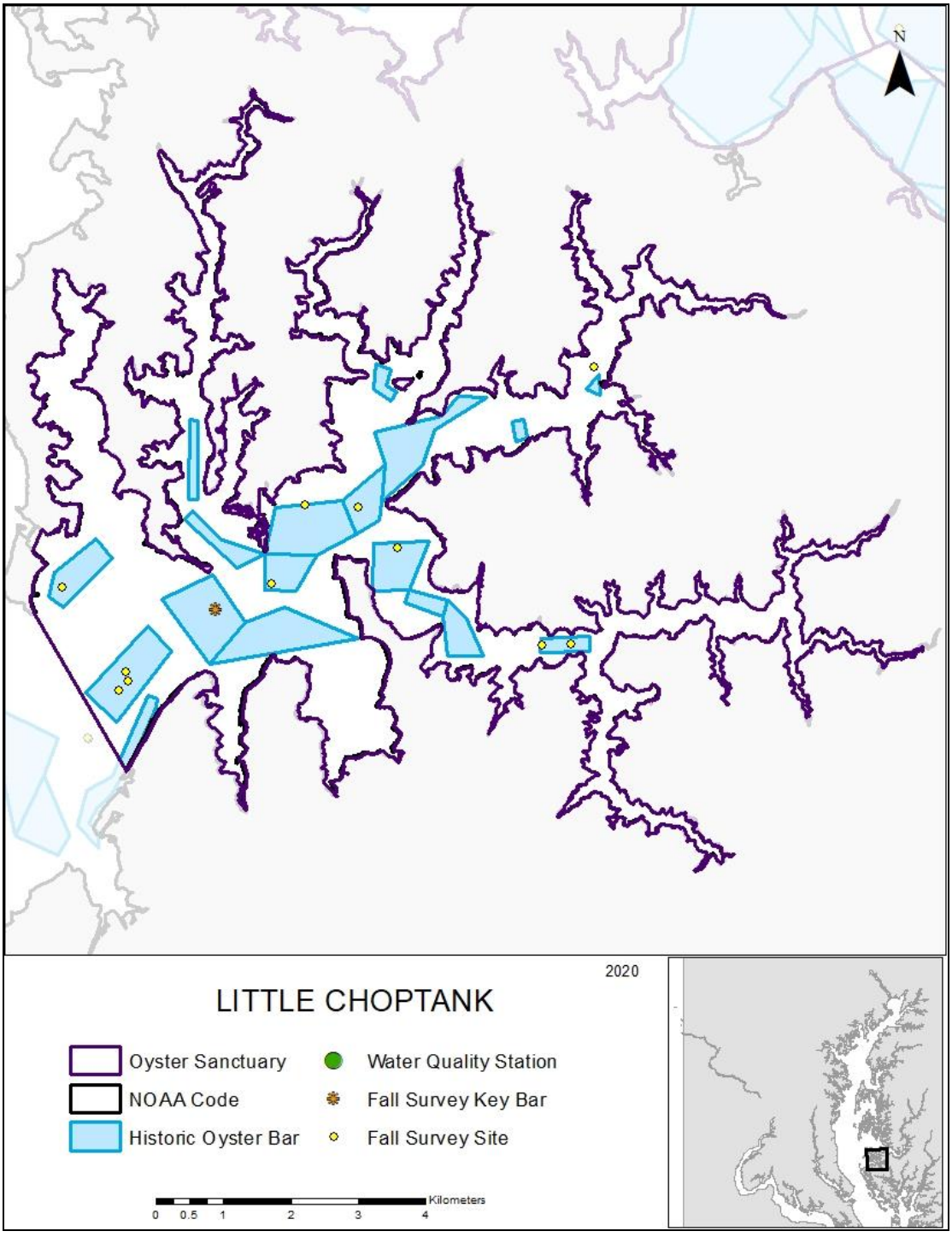

Figure A.17-1. Little Choptank Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

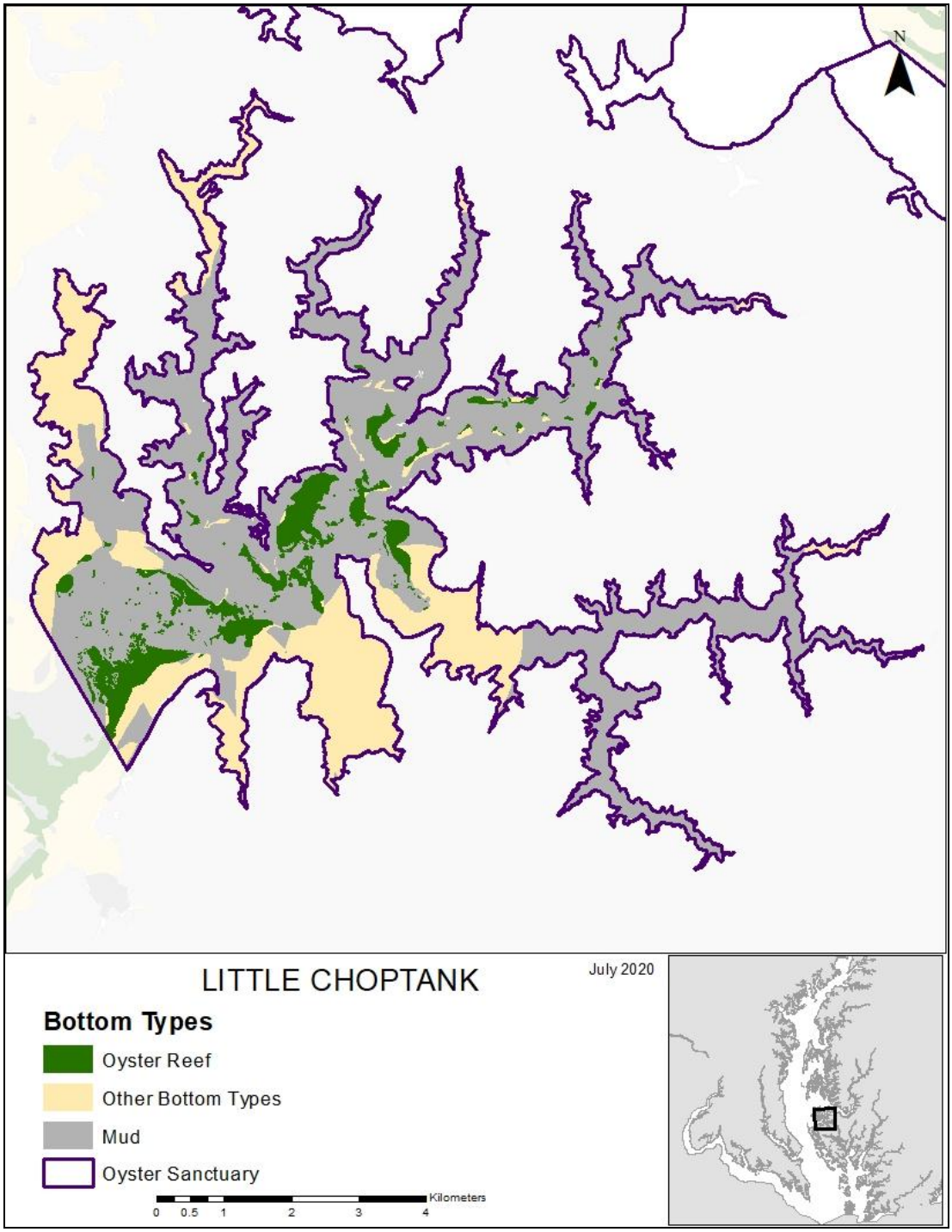

Figure A.17-2. Little Choptank Sanctuary bottom types. Data from Maryland Geological Survey from 2009, The Nature Conservancy, and the National Oceanic and Atmospheric Administration from 2012, 2014 and 2016.

Table A.171. Oyster population characteristics based on the Fall Survey in the Little Choptank Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 47	5 / 45	5 / 50
Number of Live Spat Oysters per square meter	24.1 ± 5.9	52.1 ± 37.5	138.2 ± 73.3
Number of Live Small-Sized Oysters per square meter	37.6 ± 11.1	151.1 ± 40.4	150.5 ± 35.7
Number of Live Market-Sized Oysters per square meter	29 ± 3.8	166.6 ± 36.1	96.1 ± 13.7
Live Oyster Biomass (g Dry Weight per Bushel)	145 ± 24	261 ± 31	279 ± 51
Observed Mortality (%)	15 ± 2	10 ± 1	11 ± 4
Cultch (Bushels per 100 ft Towed)	1 ± 0.2	2.1 ± 0.2	1.6 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

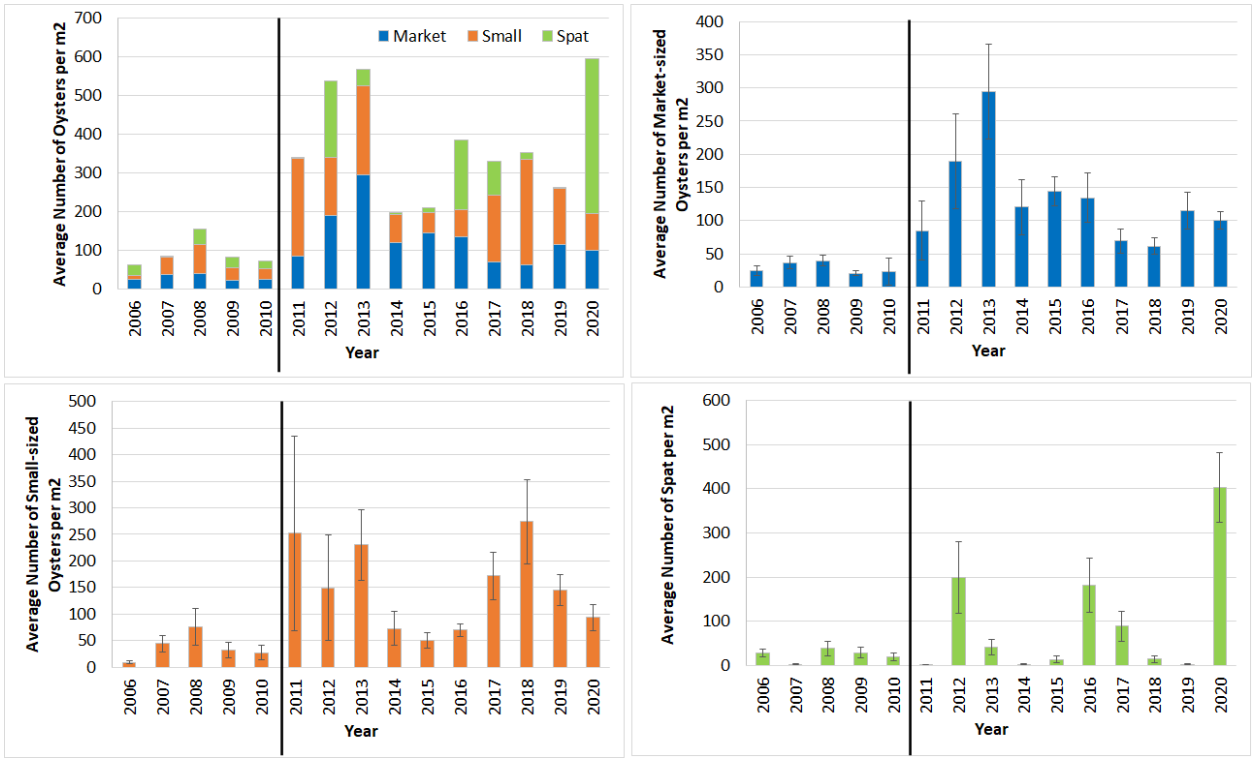

Figure A.17-3. Average number of live oysters per square meter by size class in the Little Choptank Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

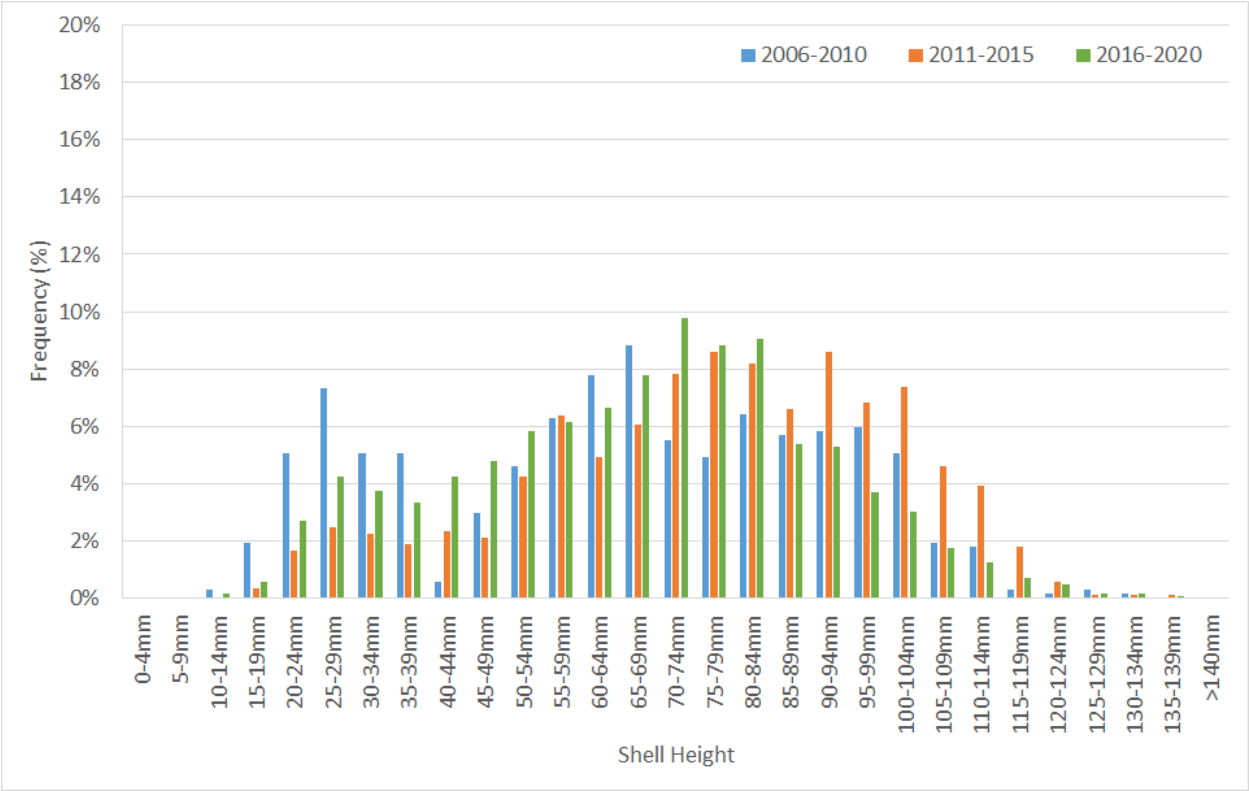

Figure A.17-4. Shell height frequencies of live oysters per bushel of material in the Little Choptank Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Cason bar.

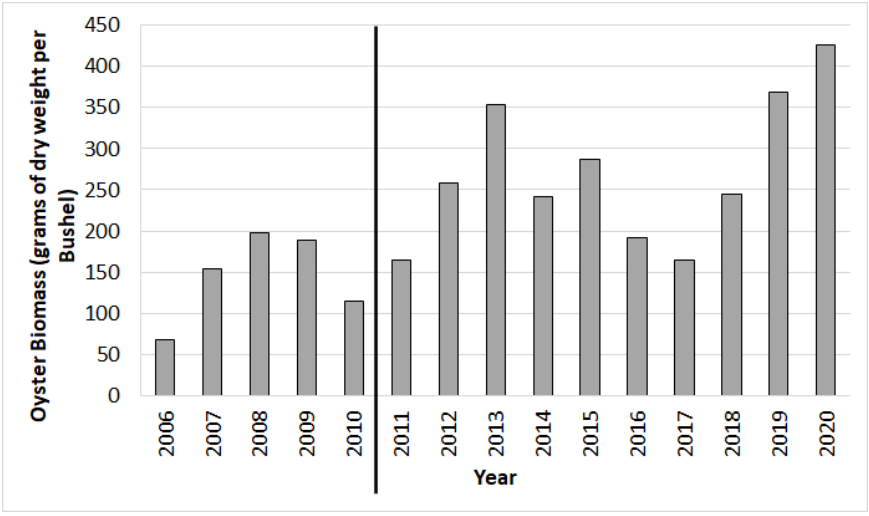

Figure A.17-5. Oyster biomass (grams of dry weight per bushel of material) in the Little Choptank Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Cason bar. Black line indicates the date the sanctuary was established.

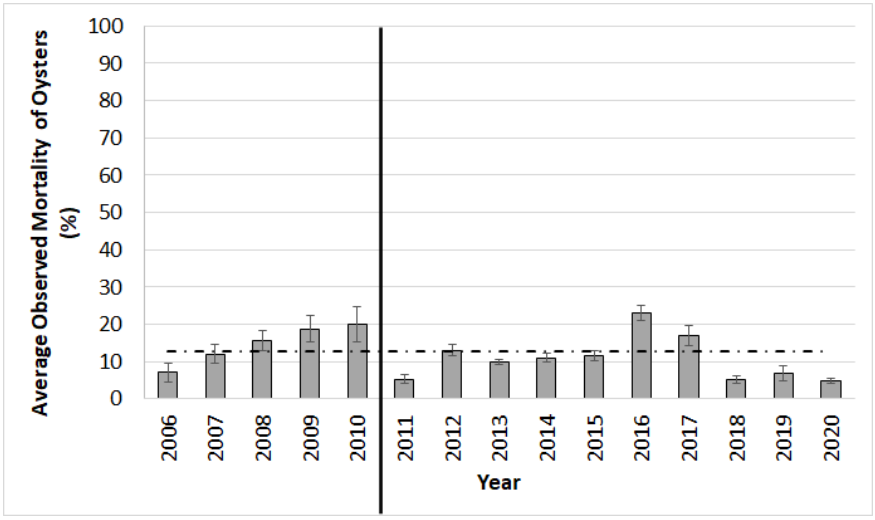

Figure A.17-6. Average annual observed mortality of market-sized and small-sized oysters in Little Choptank Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

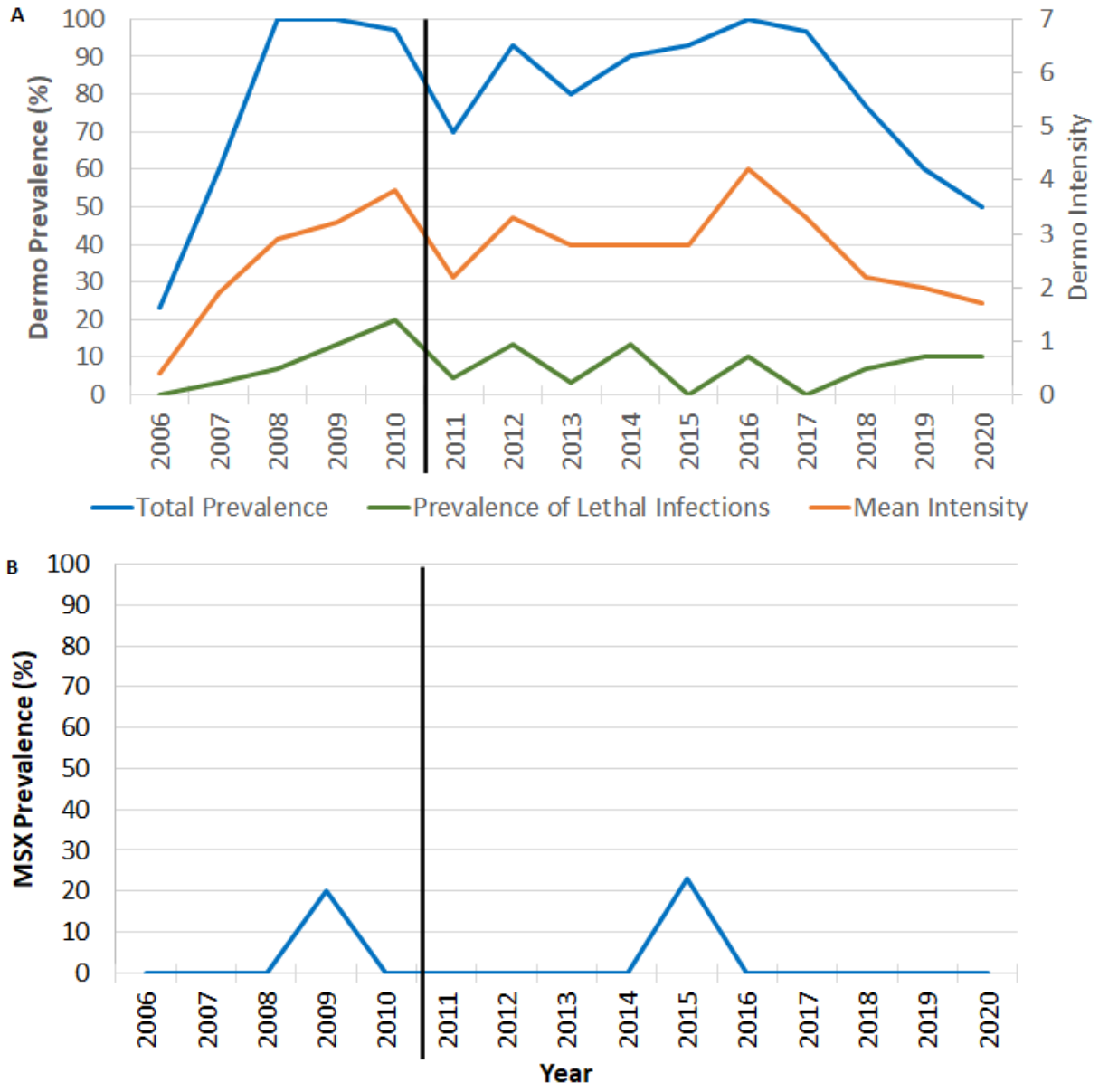

Figure A.17-7. Oyster disease prevalence and intensity in the Little Choptank Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Cason bar. Black line denotes the date the sanctuary was established.

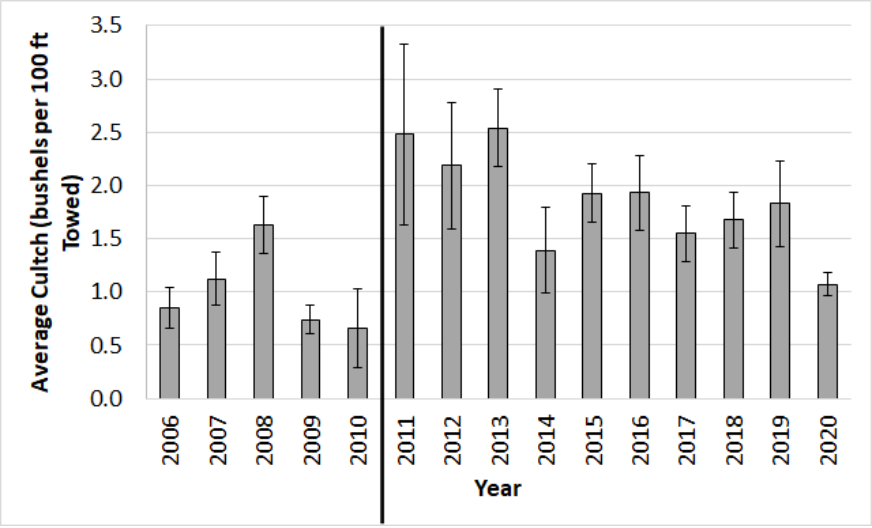

Figure A.17-8. Average cultch (live and dead oysters and loose shell) in the Little Choptank Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.18: Lower Chester River Sanctuary

The Lower Chester Sanctuary is located at the mouth of the Chester River, a low-salinity (Zone 1) area within NOAA Codes 025 and 131. The sanctuary was created in 2010 and encompasses 24,147 acres of which 6,930 (29%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 21 historic oyster bars within the sanctuary[43]. The Lower Chester includes two previously created sanctuaries: Strong Bay Sanctuary (created in 2003, 320 acres), and East Neck Sanctuary (created in 2007, 78 acres). After the two older sanctuaries into this sanctuary, the total surface area is 24,545 acres and the total historic oyster bottom is 7,189 acres.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.18-1)
- Bottom types map (Figure A.18-2)
- Summary statistics (Table A.18-1)
- Abundance per year (Figure A.18-3)
- Observed mortality (Figure A.18-4)
- Cultch per year (Figure A.18-5)

The Fall Survey sampled three bars in this sanctuary. Small and market oyster densities declined during 2016-2020 and no spat were found. Observed mortality increased to slightly above the long-term baywide average most likely due from the 2018-19 freshet. Cultch decreased slightly from the previous five-year average. The last patent tong population survey conducted by the department occurred in 2014[44].

In 2006, approximately 21 million hatchery spat-on-shell and 218,000 bushels of dredged shell were planted to enhance the commercial public fishery. After the sanctuary was established, approximately 244 million hatchery spat-on-shell were planted for restoration purposes. No plantings have been made since 2015.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area since 2006.

[43] See chart 7 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[44] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

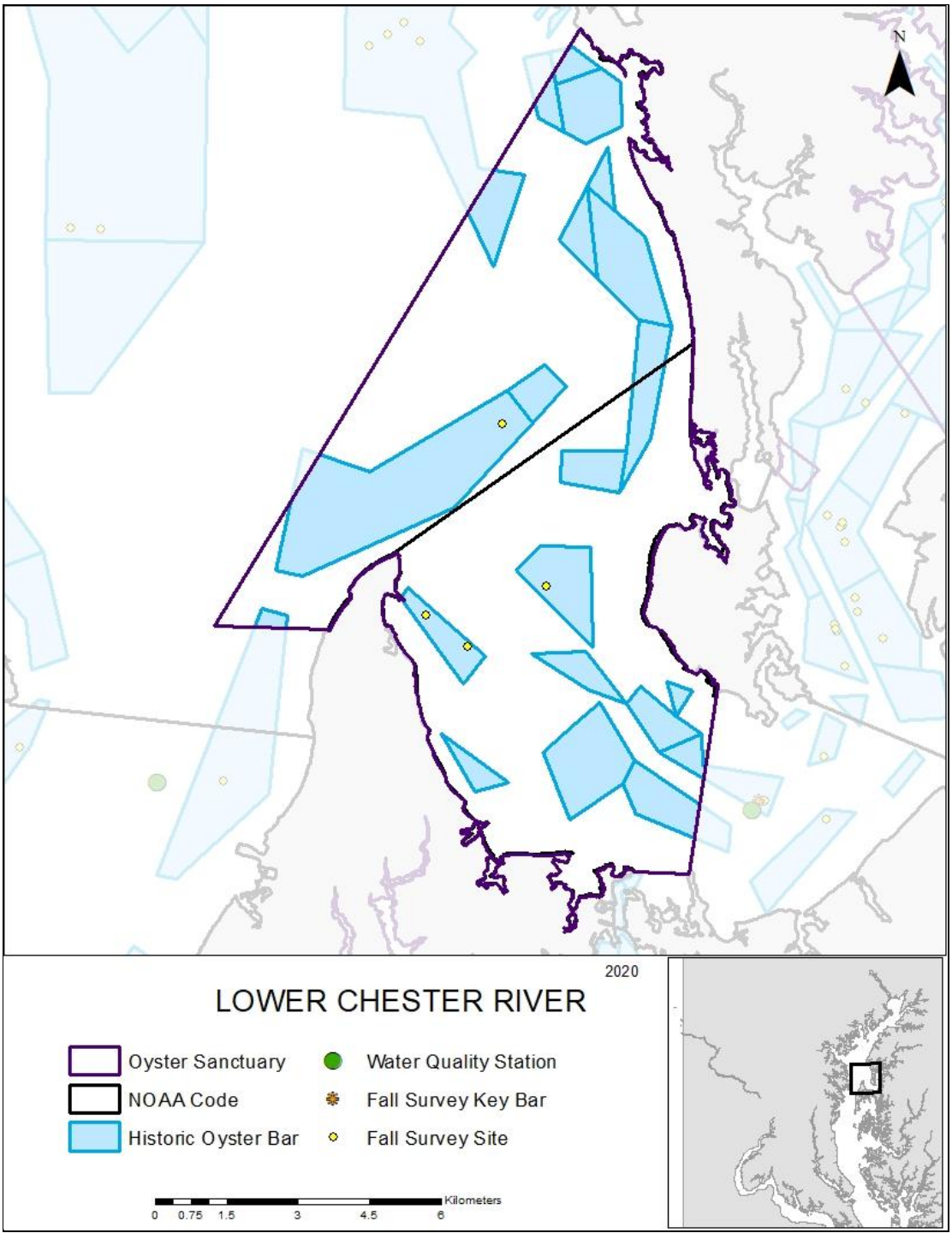

Figure A.18-1. Lower Chester Sanctuary. Fall Survey sites may not be sampled every year.

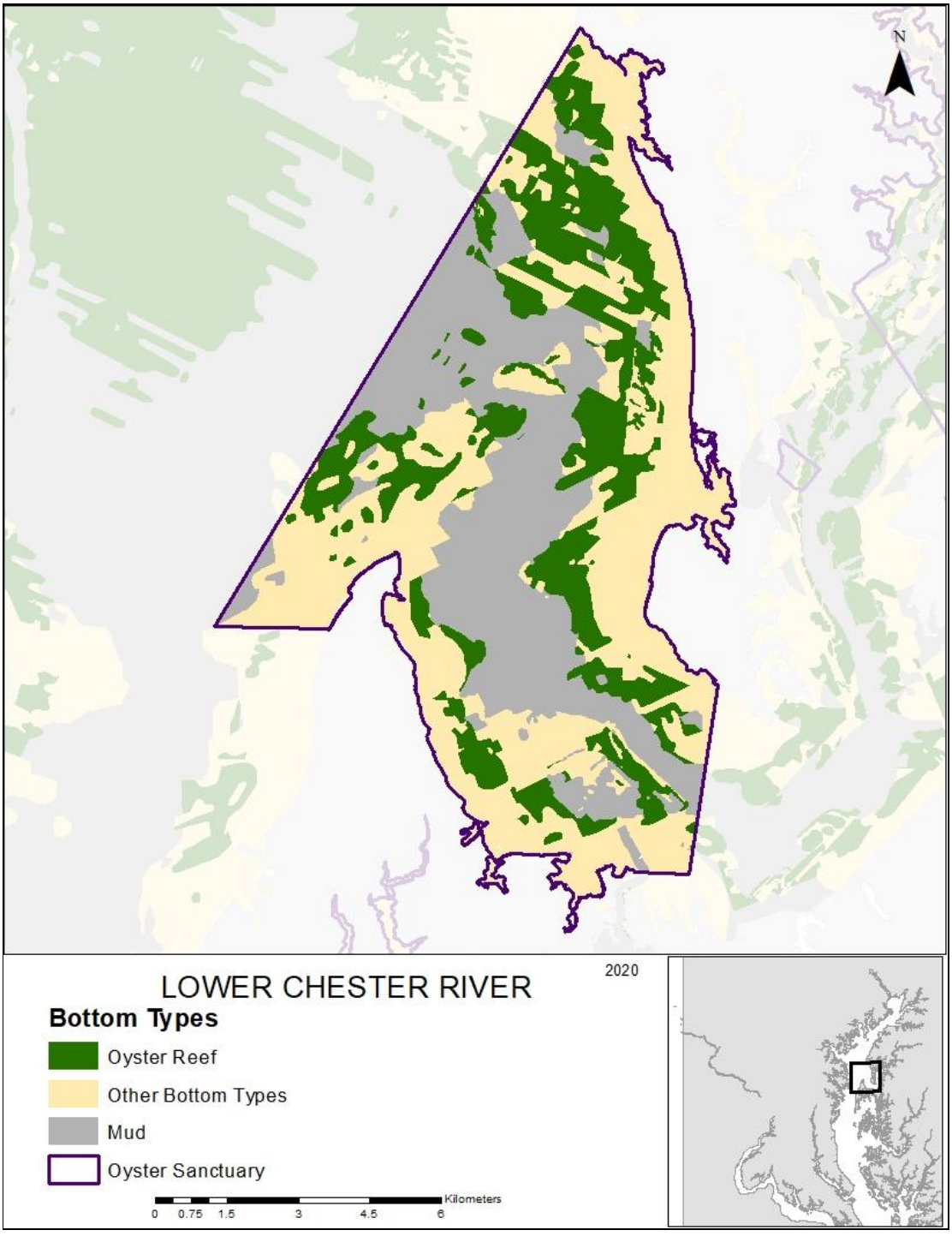

Figure A.18-2. Lower Chester Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983 with some areas being updated in 2010 by the Maryland Geological Survey.

Table A.18-1. Oyster population characteristics based on the Fall Survey in the Lower Chester Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.

	2006-10	2011-15	2016-20
Number of Years Sampled / Number of Samples	5 / 20	5 / 20	5 / 20
Number of Live Spat Oysters per square meter	4.2 ± 3.3	0 ± 0	0 ± 0
Number of Live Small-Sized Oysters per square meter	2.1 ± 1.3	2.6 ± 1.2	0.2 ± 0.1
Number of Live Market-Sized Oysters per square meter	15.1 ± 2.8	10.2 ± 1.7	6.8 ± 1.8
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	11 ± 2	11 ± 1	13 ± 3
Cultch (Bushels per 100 ft Towed)	0.4 ± 0	0.3 ± 0	0.2 ± 0

Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.

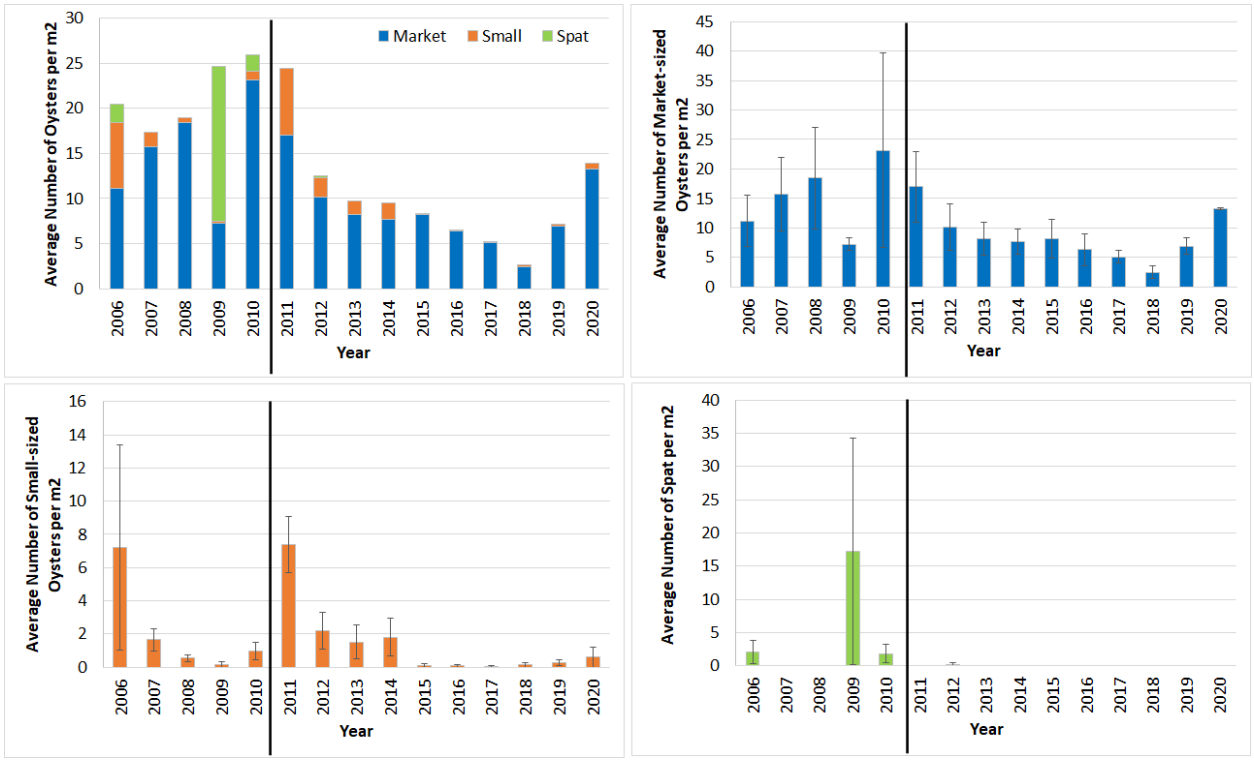

Figure A.18-3A. Average number of live oysters per square meter by size class in the Lower Chester Sanctuary including samples taken on hatchery spat-on-shell plantings. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

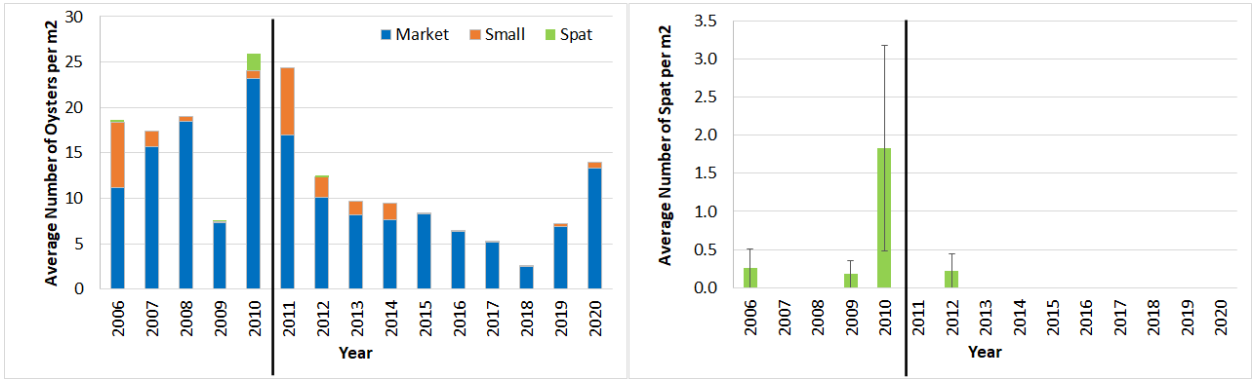

Figure A.18-3B. Average number of live oysters per square meter by size class in the Lower Chester Sanctuary excluding samples taken on hatchery spat-on-shell plantings. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

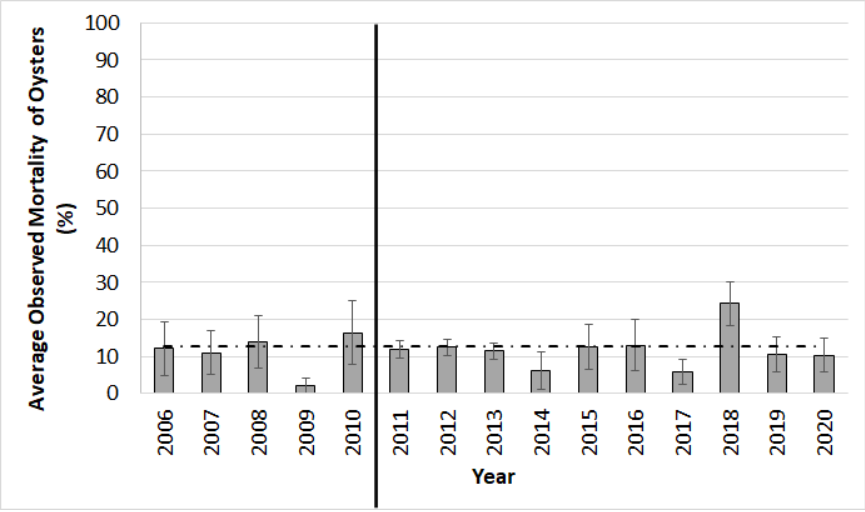

Figure A.18-4. Average annual observed mortality of market-sized and small-sized oysters in Lower Chester Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

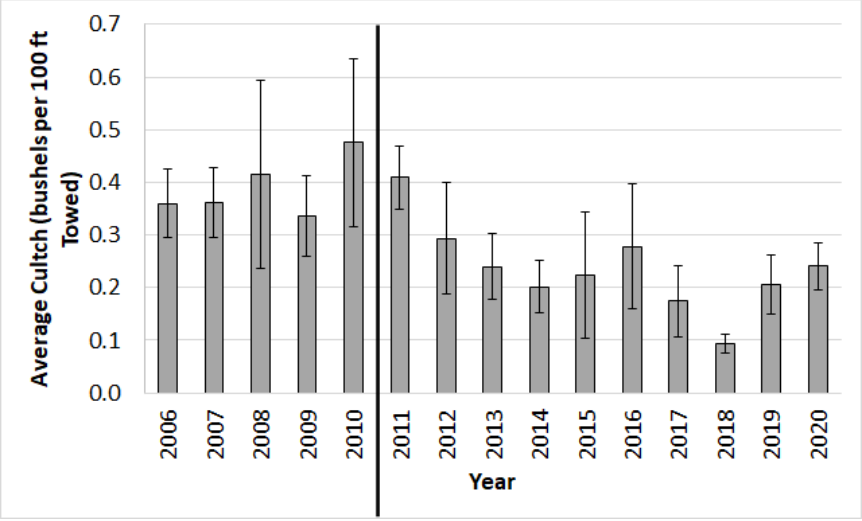

Figure A.18-5. Average cultch (live and dead oysters and loose shell) in the Lower Chester Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.19: Lower Choptank River Sanctuary

The Lower Choptank River Sanctuary is located on the south shore of the Choptank River at its mouth, a medium-salinity (Zone 2) area within NOAA Codes 137 and 237. The sanctuary was created in 2010 and encompasses 7,172 acres of which 4,217 (59%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 14 historic oyster bars within the sanctuary[45].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.19-1)
- Bottom types map (Figure A.19-2)
- Summary statistics (Table A.19-1)
- Abundance per year (Figure A.19-3)
- Observed mortality (Figure A.19-4)
- Cultch per year (Figure A.19-5)

The Fall Survey sampled one bar in this sanctuary. Density of small oysters declined but the density of market oysters increased in 2016-2020. Average density of spat remained constant from 2011-2015 to 2016-2020 driven by two spatsets in 2012 and 2020. Observed mortality rose about the long-term baywide average in 2016 and 2017, likely due to disease. The amount of cultch rose slightly over the last five-year average. The last patent tong population survey conducted by the department occurred in 2013[46].

Between 2006 and 2010 before the sanctuary was established, no planting activities occurred to enhance the commercial public fishery. In 2011, approximately 35 million hatchery spat-on-shell were planted for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[45] See charts 19 and 20 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[46] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

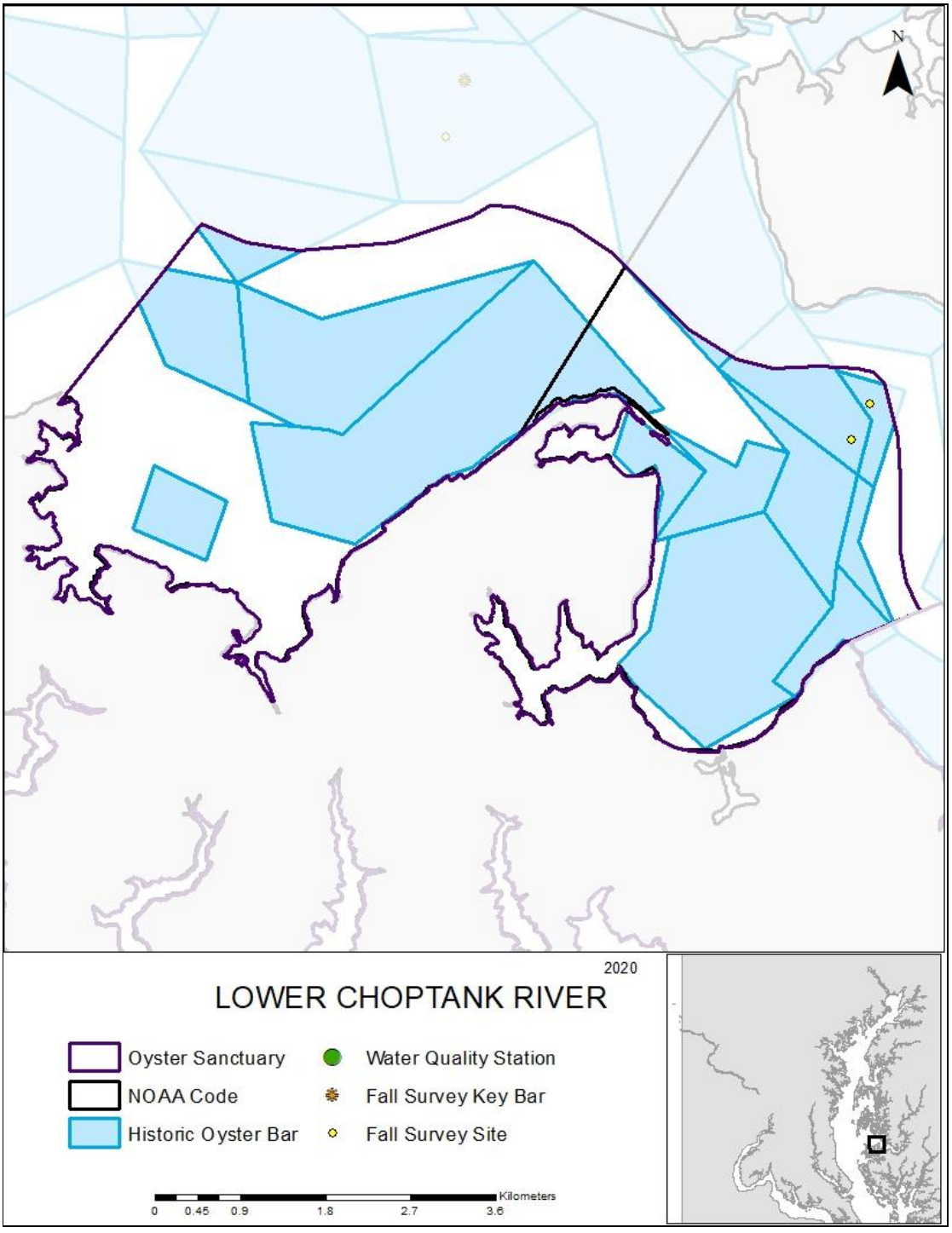

Figure A.19-1. Lower Choptank River Sanctuary. Fall Survey sites may not be sampled every year.

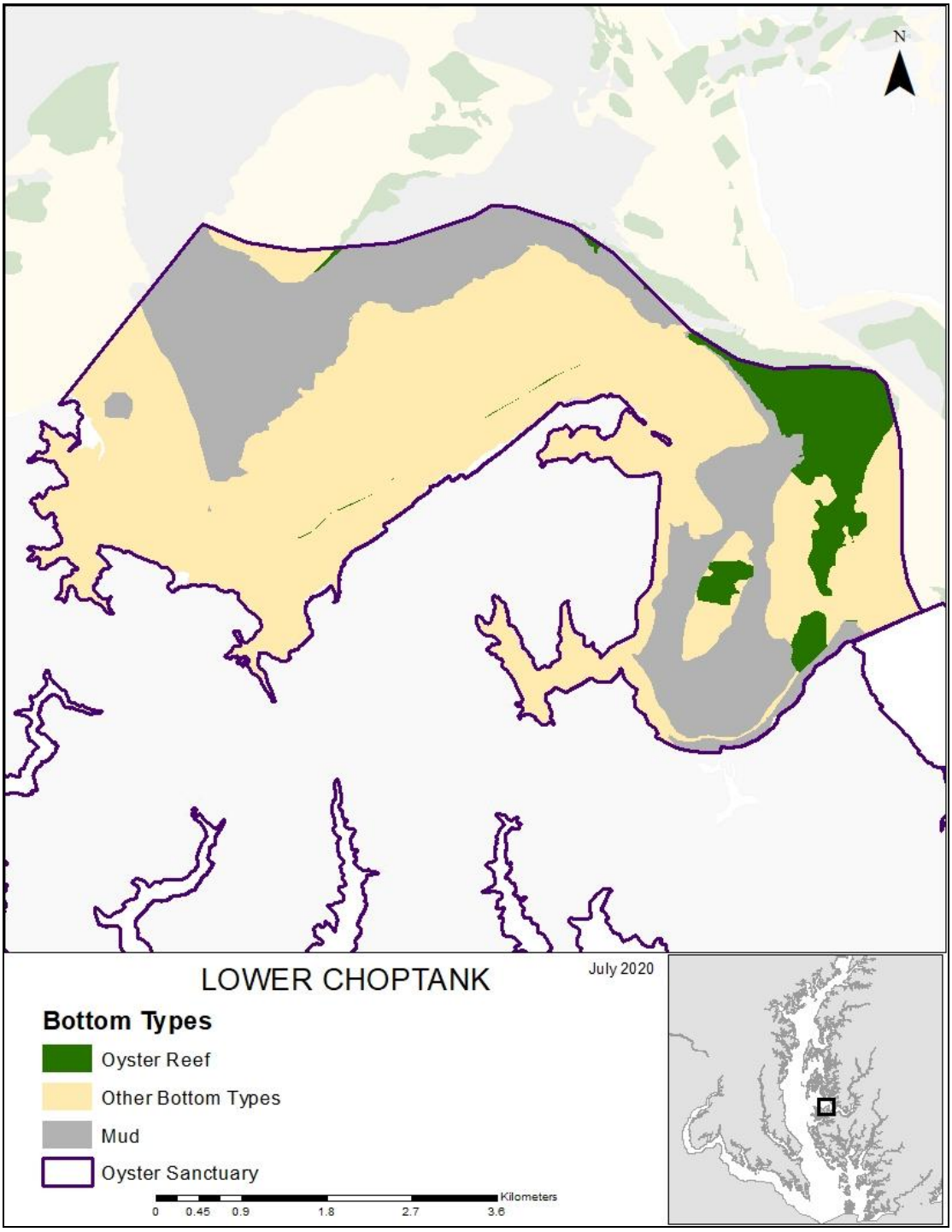

Figure A.19-2. Lower Choptank River Sanctuary bottom types. Data from Maryland Geological Survey from 2013.

Table A.19-1. Oyster population characteristics based on the Fall Survey in the Lower Choptank River Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	4.4 ± 2.7	2.9 ± 2.3	2.3 ± 2.1
Number of Live Small-Sized Oysters per square meter	7.5 ± 3.4	9.5 ± 4.5	1.9 ± 1.2
Number of Live Market-Sized Oysters per square meter	6.3 ± 1.4	18.5 ± 3.5	23.7 ± 5.7
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	2 ± 2	6 ± 0	17 ± 5
Cultch (Bushels per 100 ft Towed)	0.4 ± 0.1	0.3 ± 0.1	0.4 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

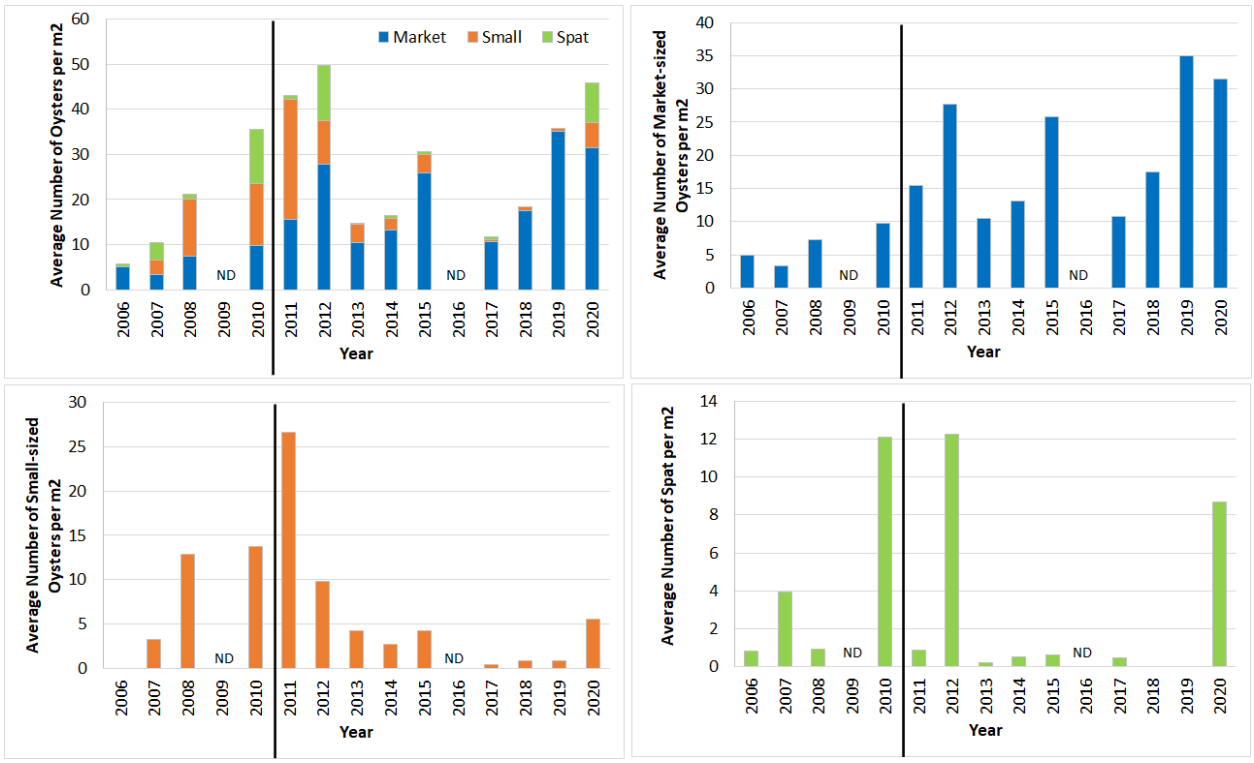

Figure A.19-3. Average number of live oysters per square meter by size class in the Lower Choptank River Sanctuary. Black line indicates the date the sanctuary was established. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No data.

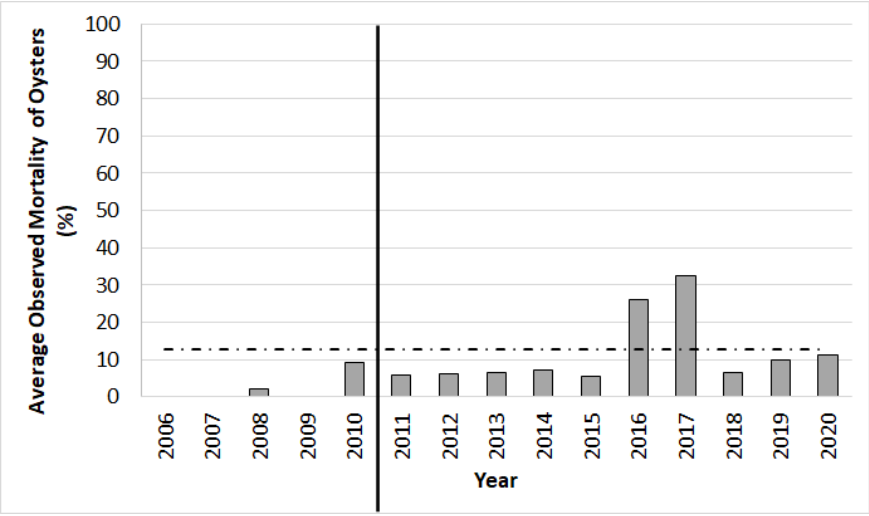

Figure A.19-4. Average annual observed mortality of market-sized and small-sized oysters in Lower Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality.

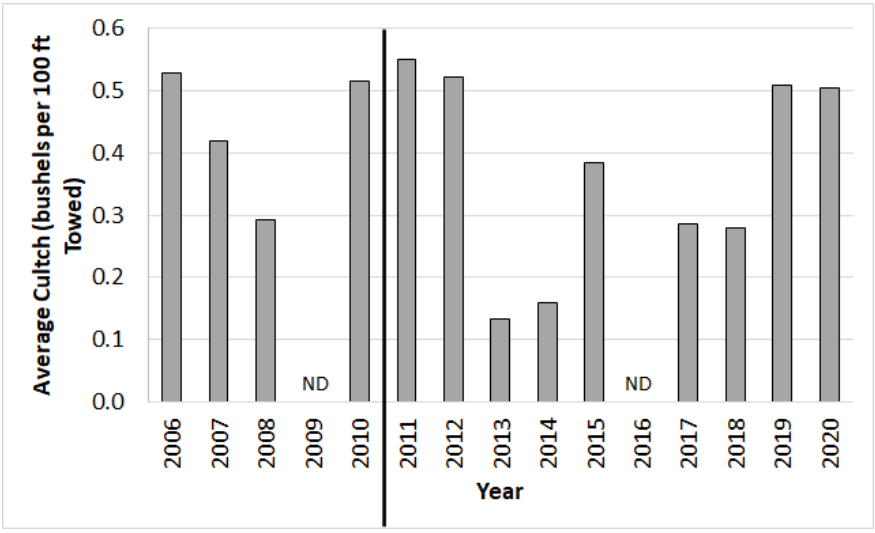

Figure A.19-5. Average cultch (live and dead oysters and loose shell) in the Lower Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. ND = No Data.

Section A.20: Lower Mainstem Sanctuary

The Lower Mainstem Sanctuary is located in the lower eastern portion of Maryland's Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Codes 129, 192, and 292. The sanctuary was created in 2010 and encompasses 38,290 acres of which 8,234 (22%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 6 historic oyster bars within the sanctuary[47].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.20-1)
- Bottom types map (Figure A.20-2)
- Summary statistics (Table A.20-1)
- Abundance per year (Figure A.20-3)
- Shell height frequencies (Figure A.20-4)
- Biomass per year (Figure A.20-5)
- Observed mortality (Figure A.20-6)
- Dermo and MSX per year (Figure A.20-7)
- Cultch per year (Figure A.20-8)

The Fall Survey sampled two bars in this sanctuary. Density of spat and small oysters increased for 2016-2020. Despite the decreased density of market oysters, biomass increased, possibly as a result of higher numbers of small oysters. Mean observed mortality declined but remained higher than the long-term baywide average. Cultch declined from the previous five-year average. The average size of oysters in this sanctuary is 46 mm. The last patent tong population survey conducted by the department occurred in 2015[48].

Before the sanctuary was established, approximately 88,000 bushels of dredged shell were planted to enhance the commercial public fishery. After the sanctuary was established, no planting activities occurred for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[47] See chart 41 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[48] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

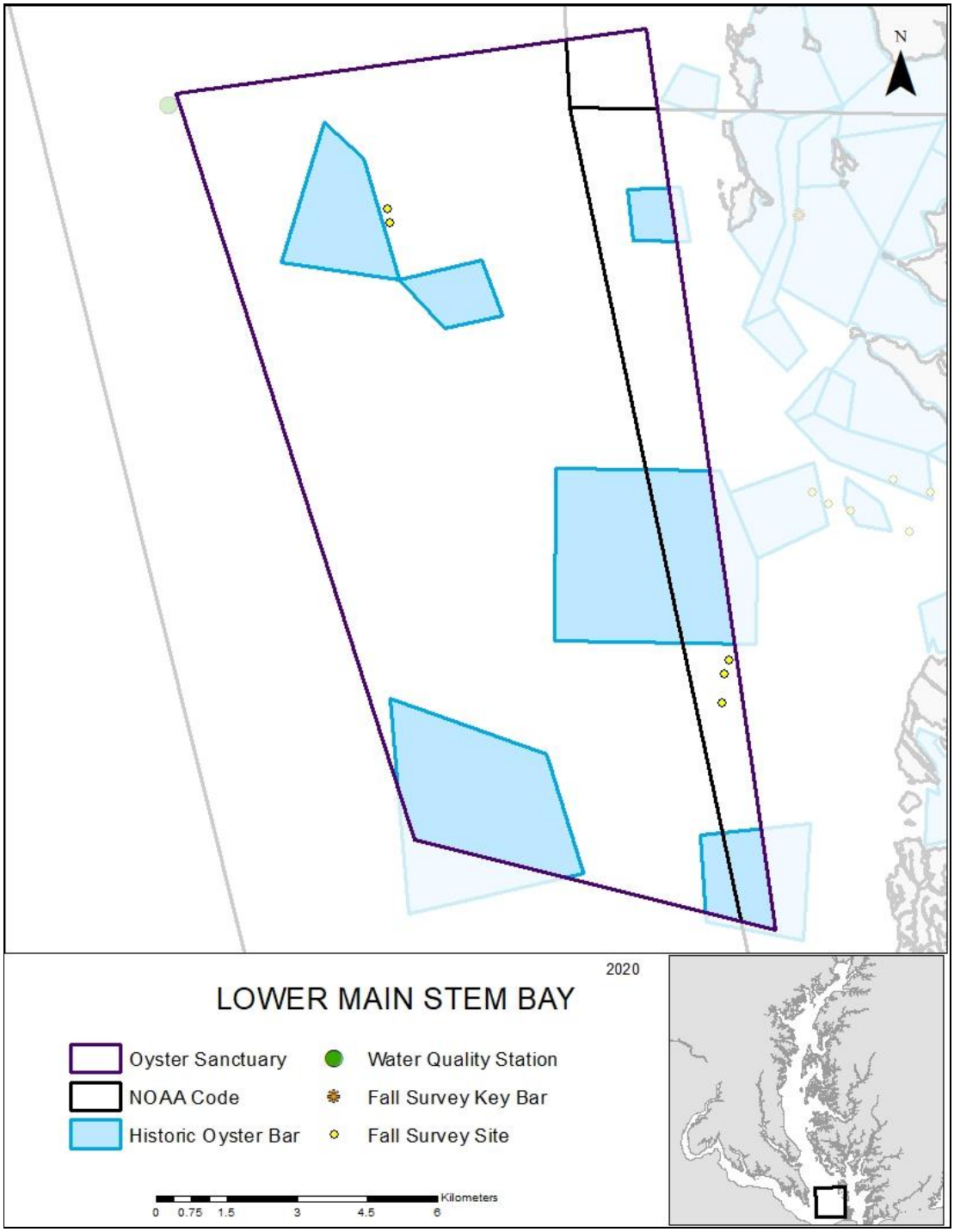

Figure A.20-1. Lower Mainstem Sanctuary. Fall Survey sites may not be sampled every year.

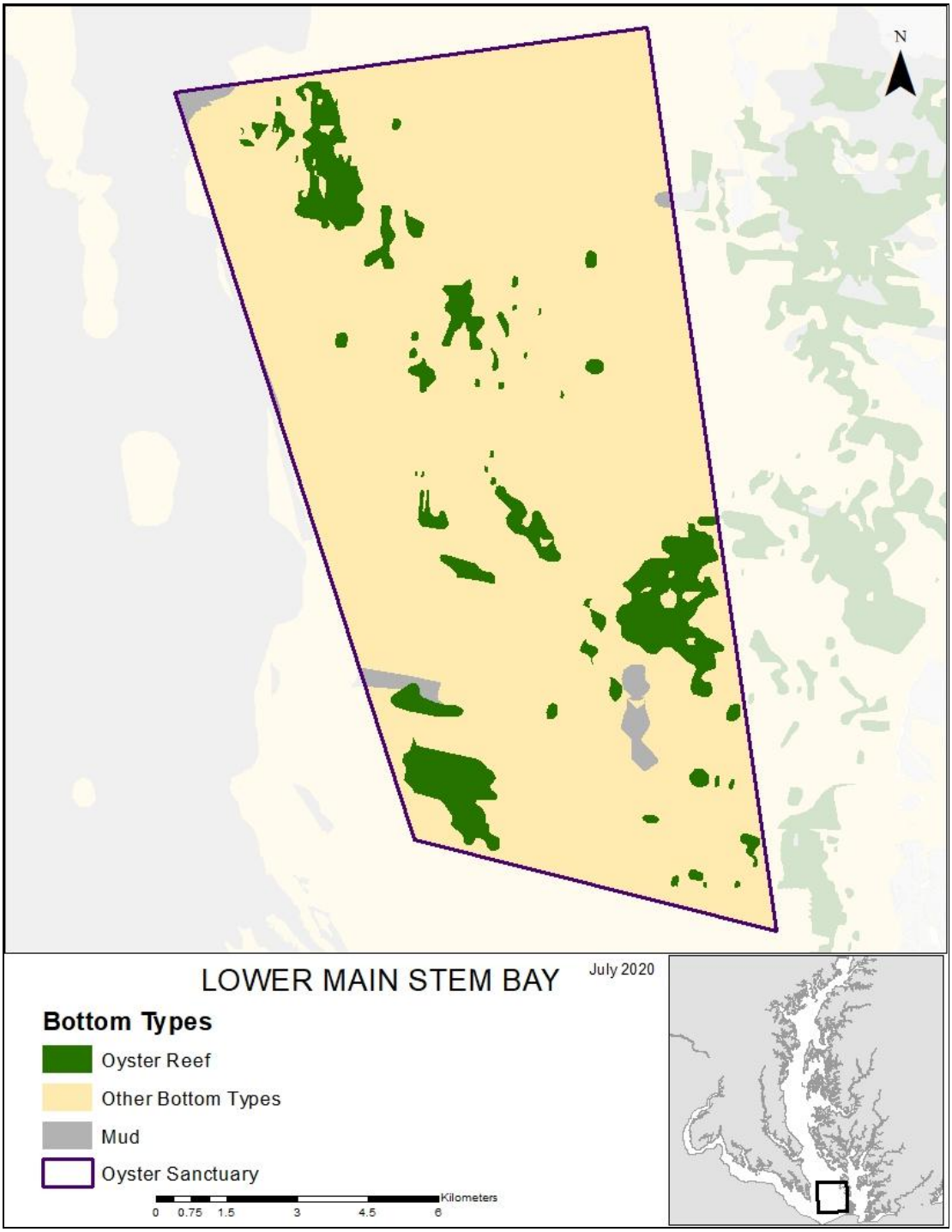

Figure A.20-2. Lower Mainstem Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Table A.20-1. Oyster population characteristics based on the Fall Survey in the Lower Mainstem Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 9
Number of Live Spat Oysters per square meter	39.1 ± 28.2	34.5 ± 12.4	59.7 ± 20.9
Number of Live Small-Sized Oysters per square meter	61.2 ± 24.7	45.4 ± 19.4	71.6 ± 32.3
Number of Live Market-Sized Oysters per square meter	8.2 ± 3.3	13.4 ± 4	11 ± 1.9
Live Oyster Biomass (g Dry Weight per Bushel)	ND	107 ± 26	263 ± 35
Observed Mortality (%)	25 ± 4	36 ± 11	16 ± 3
Cultch (Bushels per 100 ft Towed)	0.8 ± 0.2	0.6 ± 0.2	0.4 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

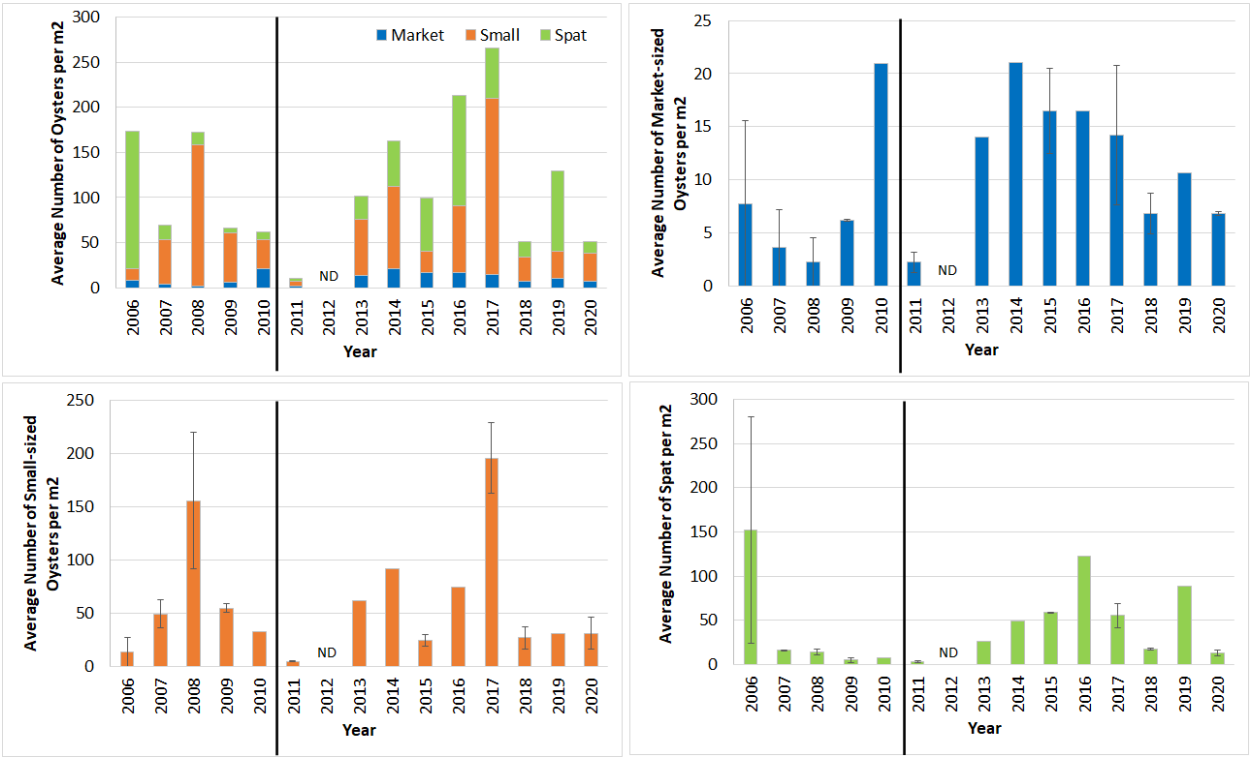

Figure A.20-3. Average number of live oysters per square meter by size class in the Lower Mainstem Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No data.

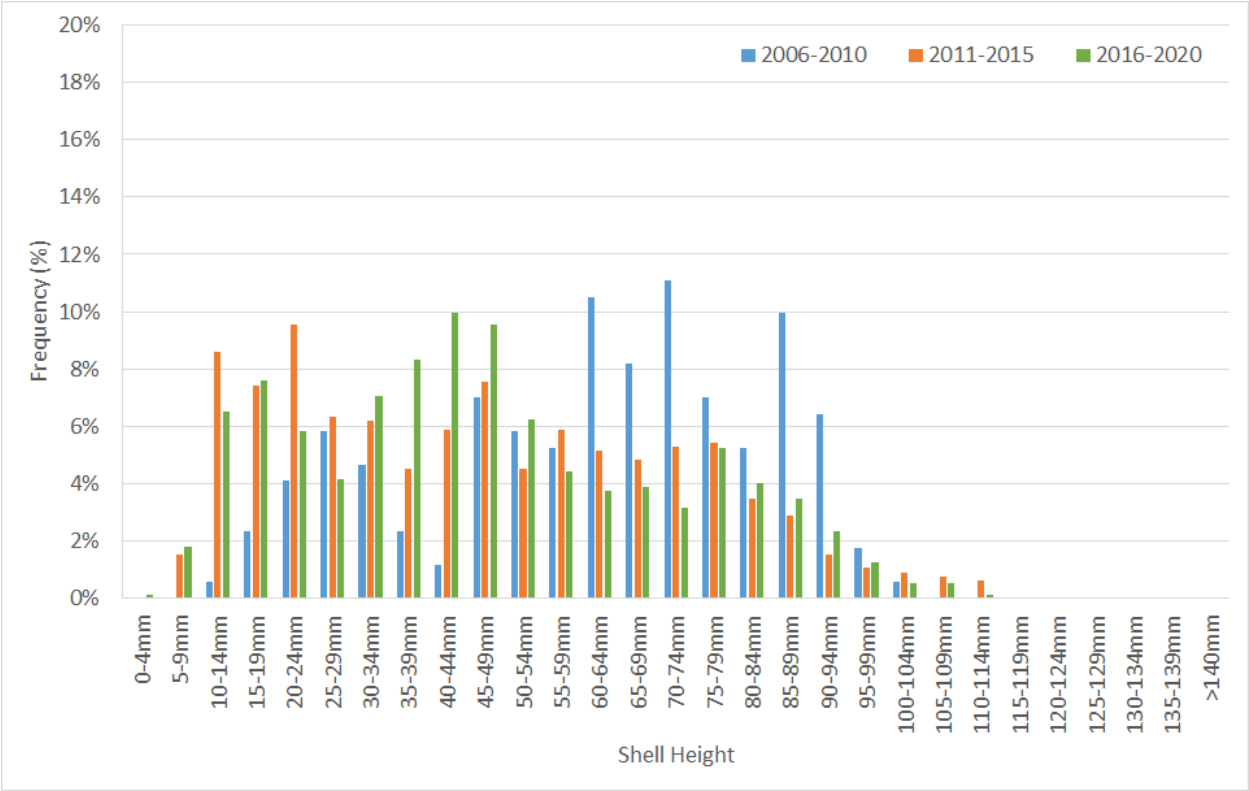

Figure A.20-4. Shell height frequencies of live oysters per bushel of material in the Lower Mainstem Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Northwest Middleground bar. No data was collected in 2006 to 2009, 2018 and 2019.

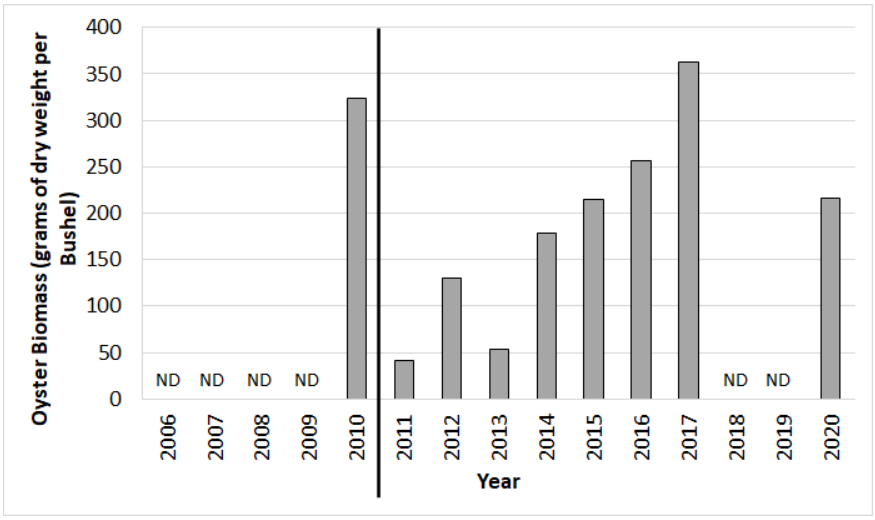

Figure A.20-5. Oyster biomass (grams of dry weight per bushel of material) in the Lower Mainstem Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Northwest Middleground bar. Black line indicates the date the sanctuary was established. ND = No Data.

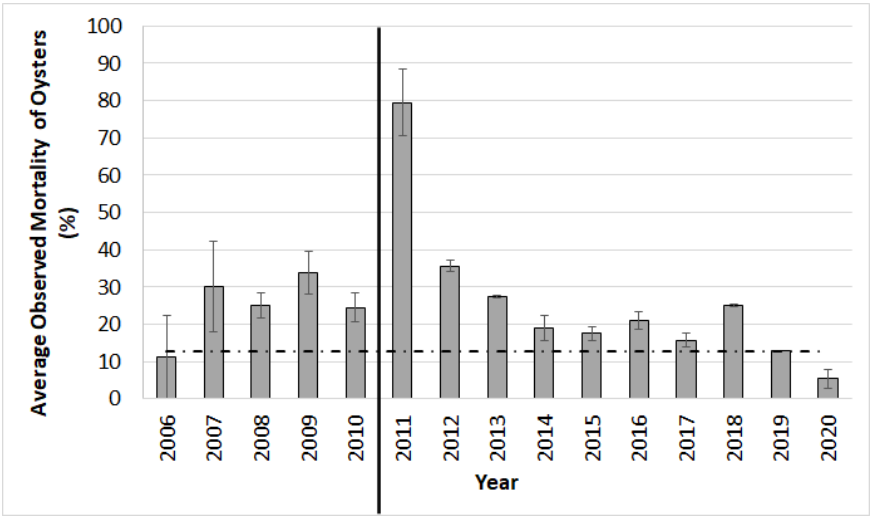

Figure A.20-6. Average annual observed mortality of market-sized and small-sized oysters in Lower Mainstem Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

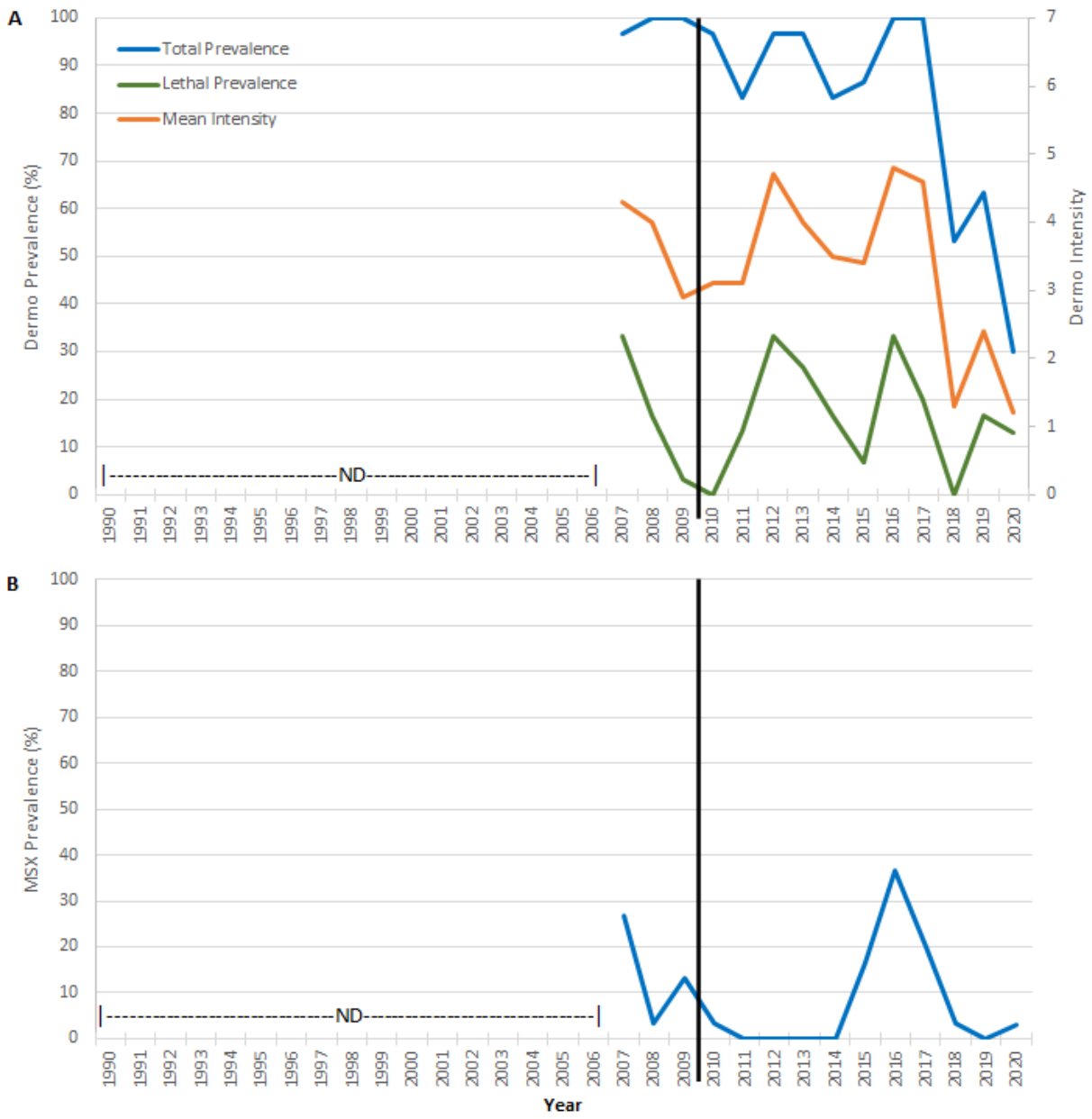

Figure A.20-7 Oyster disease prevalence and intensity in the Lower Mainstem Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Northwest Middleground bar. Black line denotes the date the sanctuary was established. No data was collected in 2006.

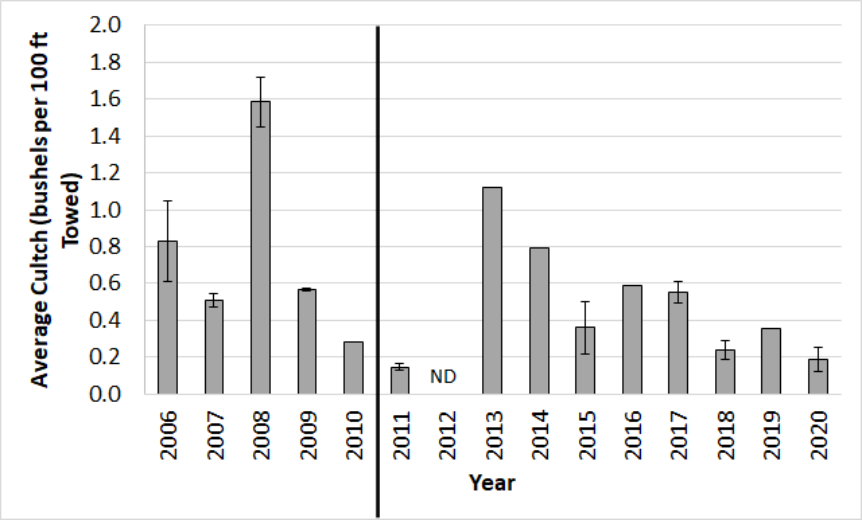

Figure A.20-8. Average cultch (live and dead oysters and loose shell) in the Lower Mainstem Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

Section A.21: Lower Patuxent River Sanctuary

The Lower Patuxent River Sanctuary is located on the southern shore of the Patuxent River near the river's mouth, a medium-salinity (Zone 2) region within NOAA Code 168. The sanctuary was created in 2010 and encompasses 335 acres of which 315 (94%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 2 historic oyster bars within the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.21-1)
- Bottom types map (Figure A.21-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in sanctuary in 2015[49] and no new surveys have occurred since then. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[49] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

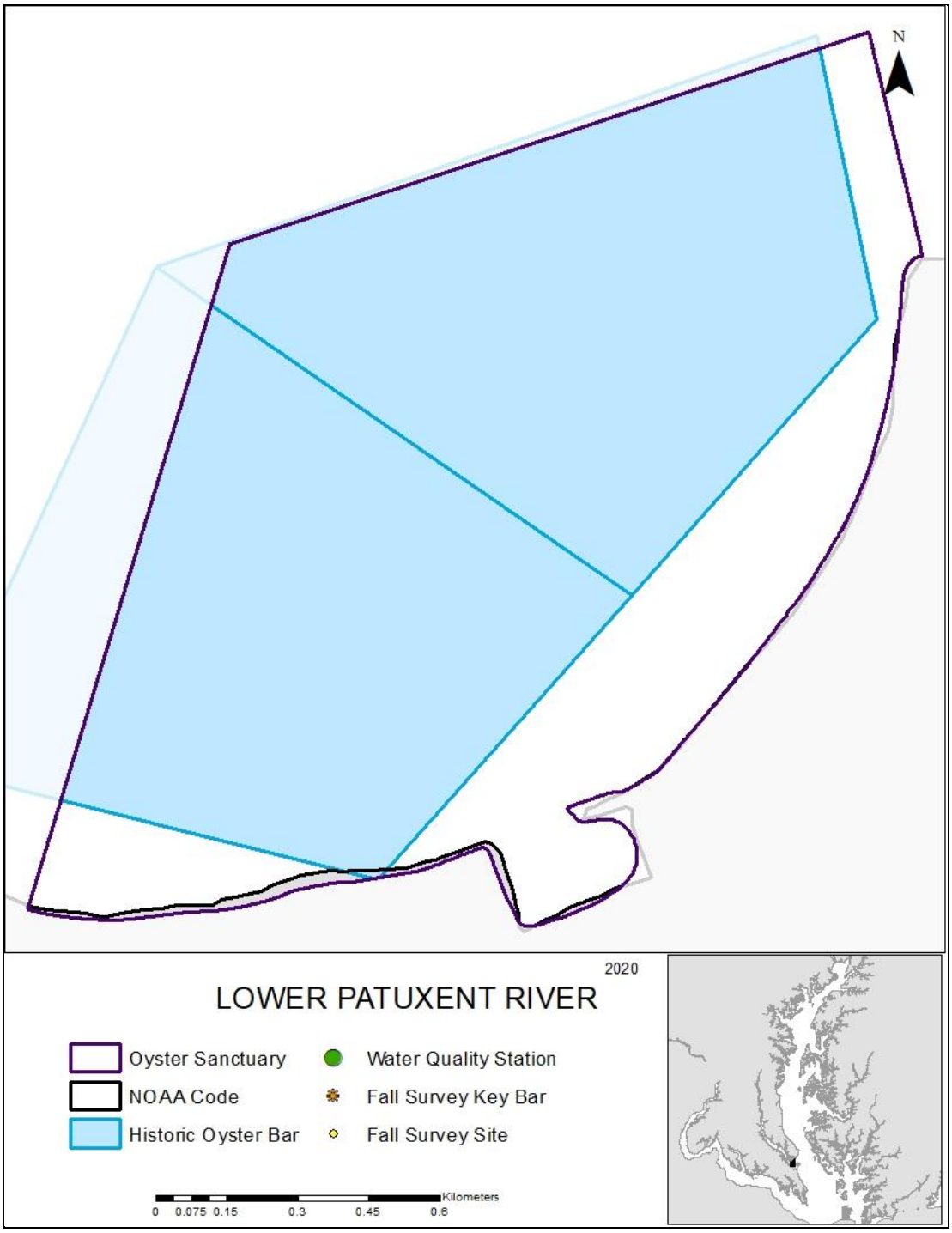

Figure A.21-1. Lower Patuxent River Sanctuary.

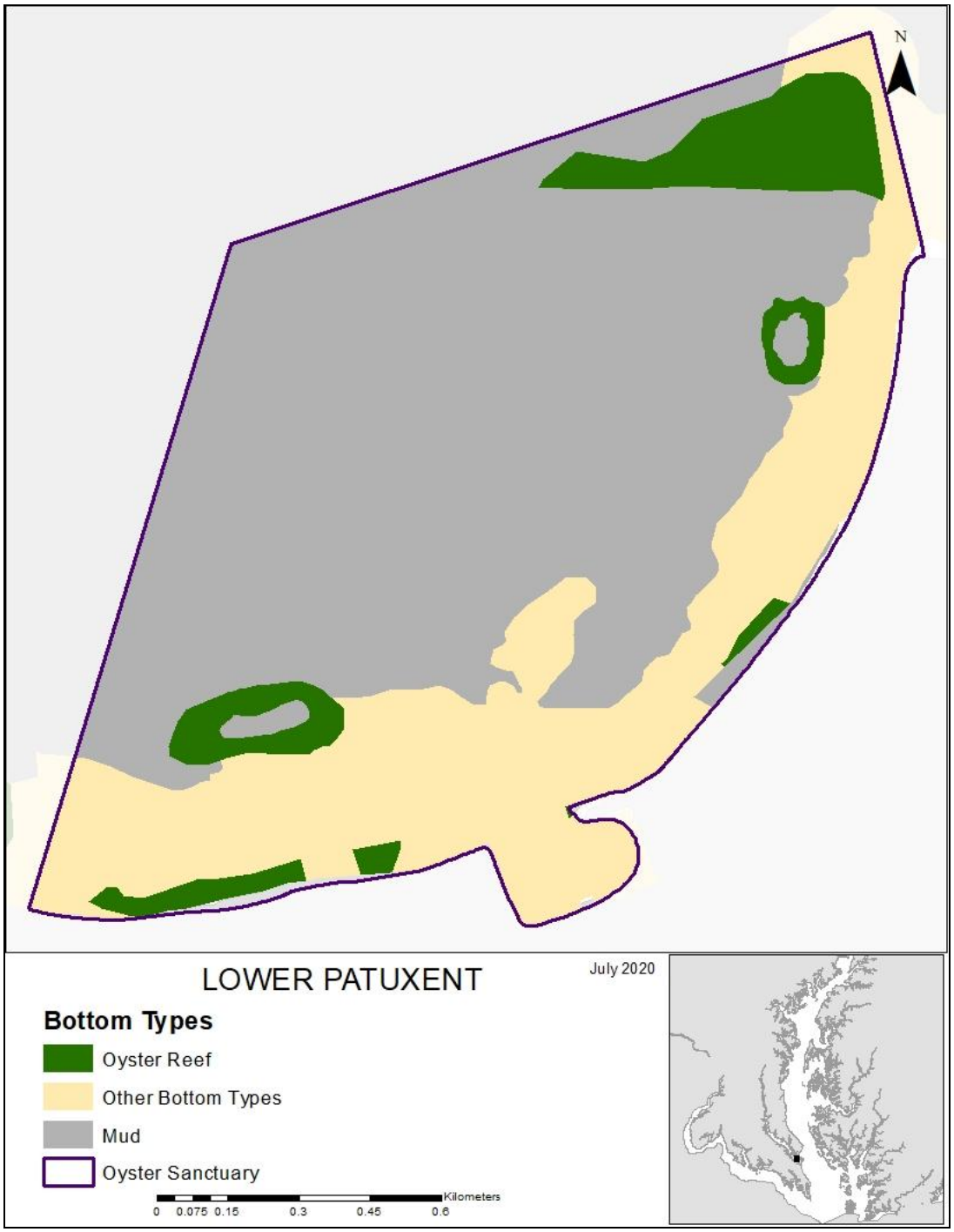

Figure A.21-2. Lower Patuxent River Sanctuary bottom types. Data from Maryland Geological Survey from 2011.

Section A.22: Magothy River Sanctuary

The Magothy River Sanctuary is located in the Magothy River, a low-salinity (Zone 1) region within NOAA Code 055. The sanctuary was created in 2010 and encompasses 5,607 acres of which 230 (4%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are eight historic oyster bars within the sanctuary[50].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.22-1)
- Bottom types map (Figure A.22-2)
- Density Survey (Figure A.22-3)
- Water Quality (Figure A.22-4)

The Fall Survey has not sampled any oyster bars in this area since 2006. A patent tong population survey was conducted in 2018 and found an average density of 2.9 oysters per square meter, this included the Marylanders Grow Oysters planting site, without including the planting, the average density was 0.5 per square meter. Of the 101 samples taken, 93 had no oysters and 66 had no surface shell volume.

Replenishment efforts to enhance the public fishery occurred in this area prior to 2010. Between 2006 and 2009, approximately 20 million hatchery spat-on-shell were planted. After the area became a sanctuary, in January 2021, 100 reef balls were placed by the Magothy River Association volunteers within the sanctuary. Marylanders Grow Oysters has planted oysters at one site in the sanctuary since 2009.

We are unaware of any studies explicitly examining oyster ecosystem services in this area. Continuous water quality monitoring has occurred at station WT6.1 (39.07851; -76.5101). During the 2006-2020 timeline, surface salinity ranged from 1.5 ppt to 14.7 ppt, with the lowest salinity being during the freshet of 2018-2019 and during the high rainfall year of 2011.

[50] See chart 6 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

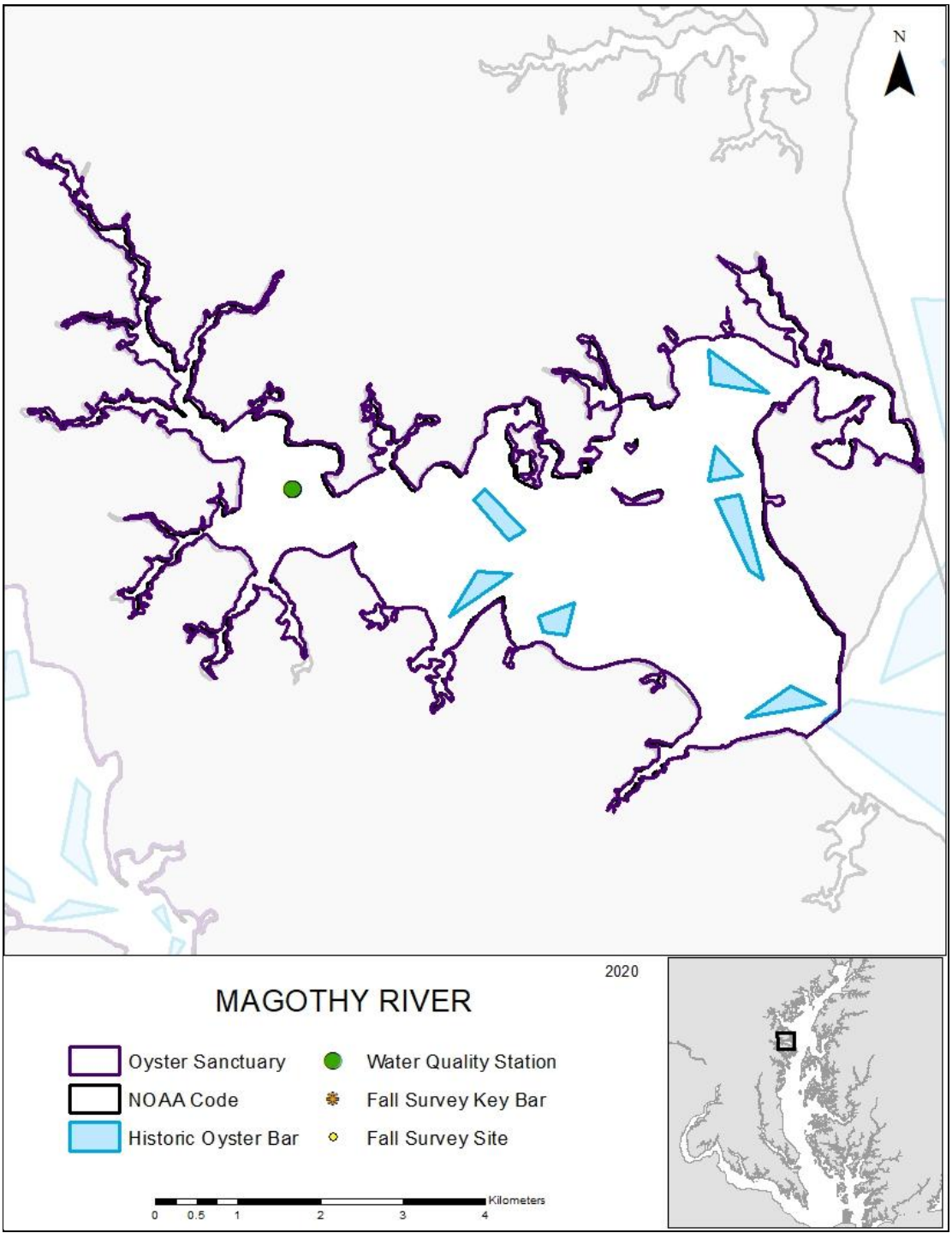

Figure A.22-1. Magothy River Sanctuary.

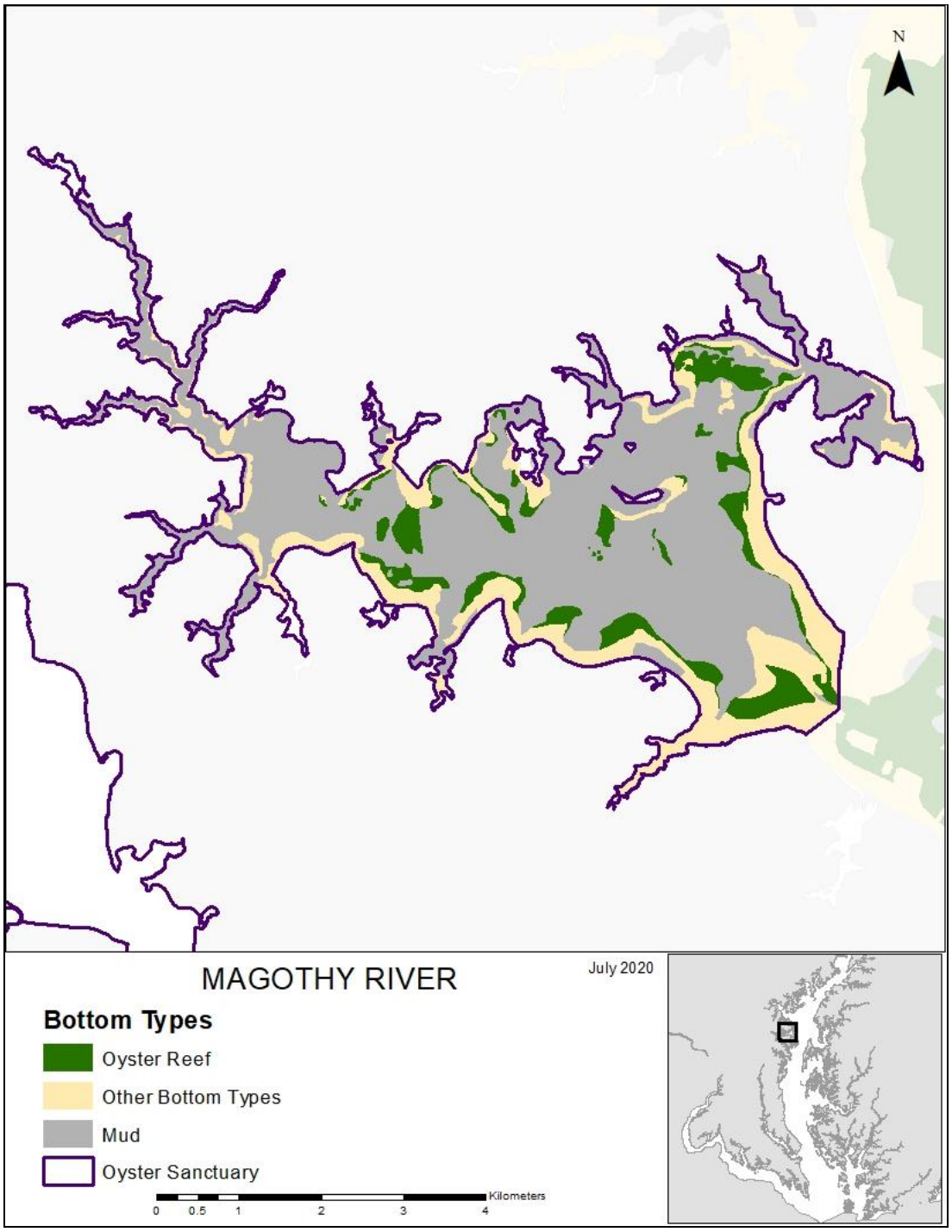

Figure A.22-2. Magothy River Sanctuary bottom types. Data from NOAA Chesapeake Bay Office from 2006-2008.

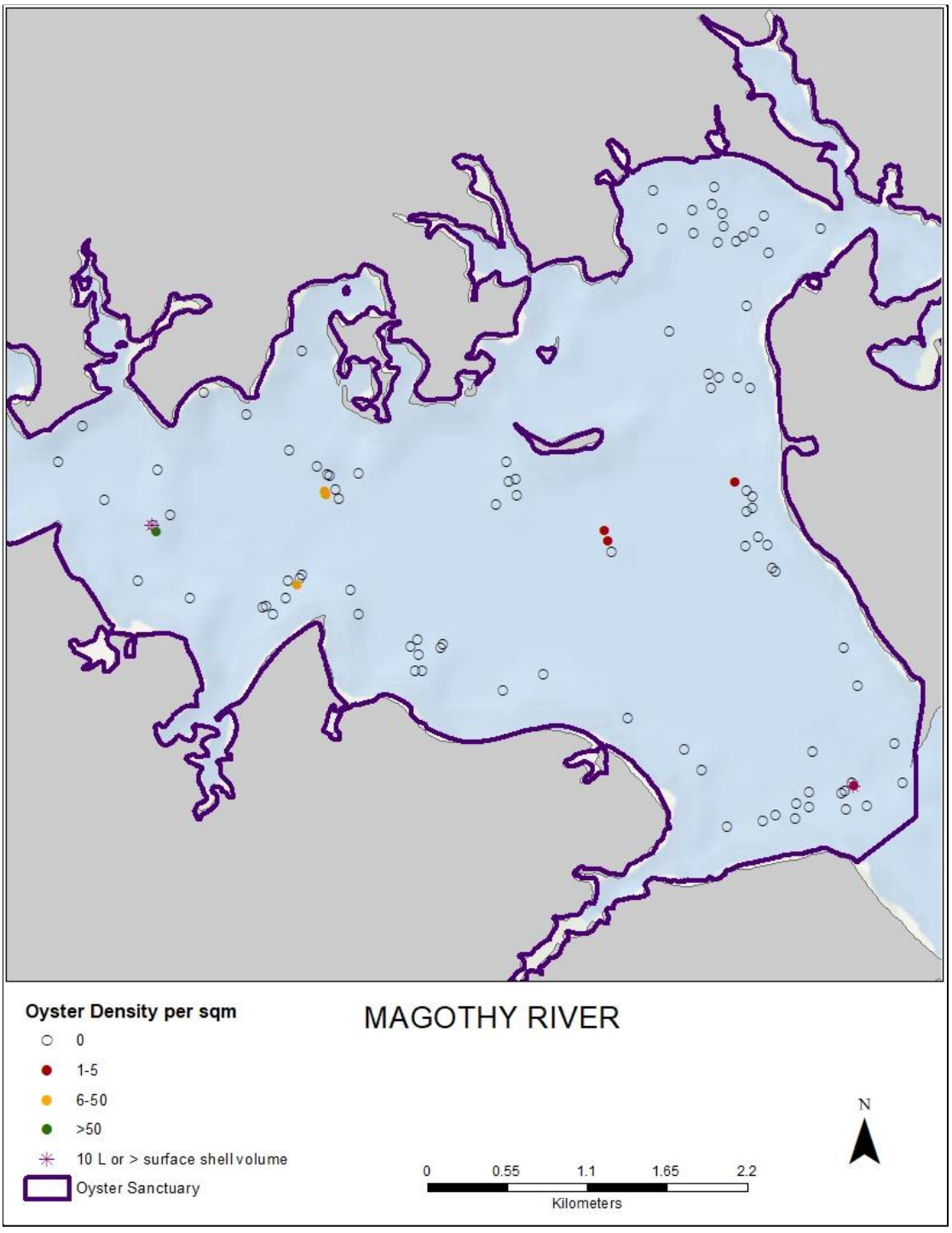

Figure A.22-3. Map of 2018 oyster density in the Magothy River Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

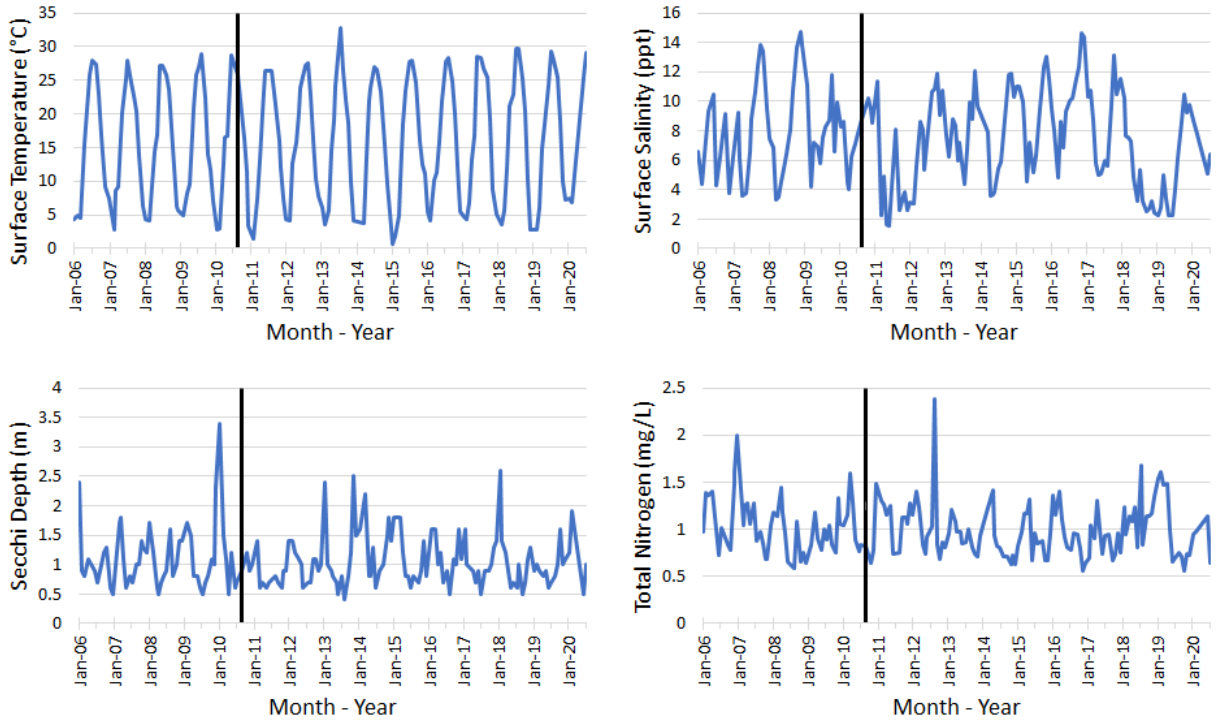

Figure A.22-4. Water quality data collected at Station WT6.1 in the Magothy River Sanctuary. Black line denotes the date the sanctuary was established. Data from the Chesapeake Bay Program Data Hub.

Section A.23: Manokin River Sanctuary

The Manokin River Sanctuary is located in the lower eastern portion of Maryland's Chesapeake Bay, a high-salinity (Zone 3) region within NOAA Code 057. The mouth of the river empties into the Tangier Sound. The sanctuary was created in 2010 and encompasses 16,320 acres of which 11,040 (68%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 19 historic oyster bars within the sanctuary[51]. In 2018, this sanctuary was selected to receive large-scale restoration to meet the 2014 Chesapeake Bay Watershed Agreement.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.23-1)
- Bottom types map (Figure A.23-2)
- Summary statistics (Table A.23-1)
- Abundance per year (Figure A.23-3)
- Density Survey (Figure A.23-4)
- Shell height frequencies (Figure A.23-5)
- Biomass per year (Figure A.23-6)
- Observed mortality (Figure A.23-7)
- Dermo and MSX per year (Figure A.23-8)
- Cultch per year (Figure A.23-9)
- Water Quality (Figure A.23-10)

The Fall Survey sampled five bars in the sanctuary. Density of spat was similar in 2016-2020 to the previous five years but higher than during 2006-2010. Density of small and market oysters increased in 2016-2020. Biomass was higher in the last 10 year compared to 2006 to 2010 while observed mortality remained below the long-term baywide average. The average size of oysters was 57 mm, nearly identical to the previous five-year average.

A population patent tong survey was conducted by the department in 2012[52], 2015[53], 2017, and 2018. Results indicate an increase in population from 2017 to 2018 with an average oyster density of 5.6 per square meter and 14.4 per square meter respectively with more small-sized oysters than market sized oysters in both years surveyed. In 2017, of the 163 samples taken, 132 had no oysters and 128 had no surface shell volume. In 2018, of the 140 samples taken, 59 had no oysters and 51 had no surface shell volume. A ground-truthing patent tong survey is currently ongoing by the Oyster Recovery Partnership to verify the restoration treatment type for each restoration reef[54].

Between 2006 and 2010 before the sanctuary was established, no planting activities occurred to enhance the commercial public fishery. After the sanctuary was established, no planting activities

[51] See chart 44 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx
[52] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf
[53] IBID
[54] For various reports, see https://dnr.maryland.gov/fisheries/Pages/oysters/manokin.aspx

occurred for restoration purposes, however, large-scale restoration plantings are expected to begin in 2021.

Maryland's Eyes on the Bay Program monitors monthly water quality at station ET8.1 (38.13794, -75.81411) in this area. Water quality has been suitable for oysters during the time period examined. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

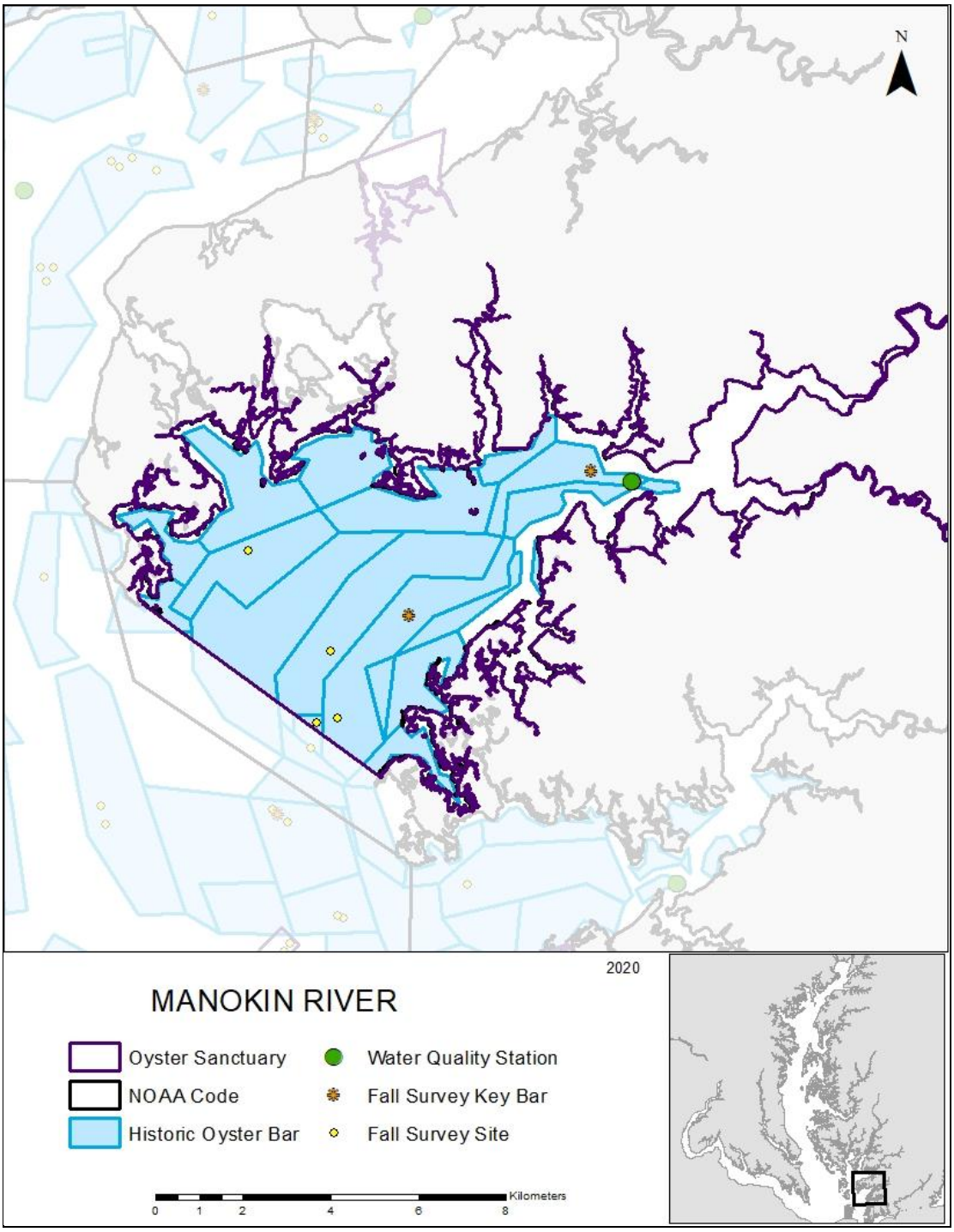

Figure A.23-1. Manokin River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

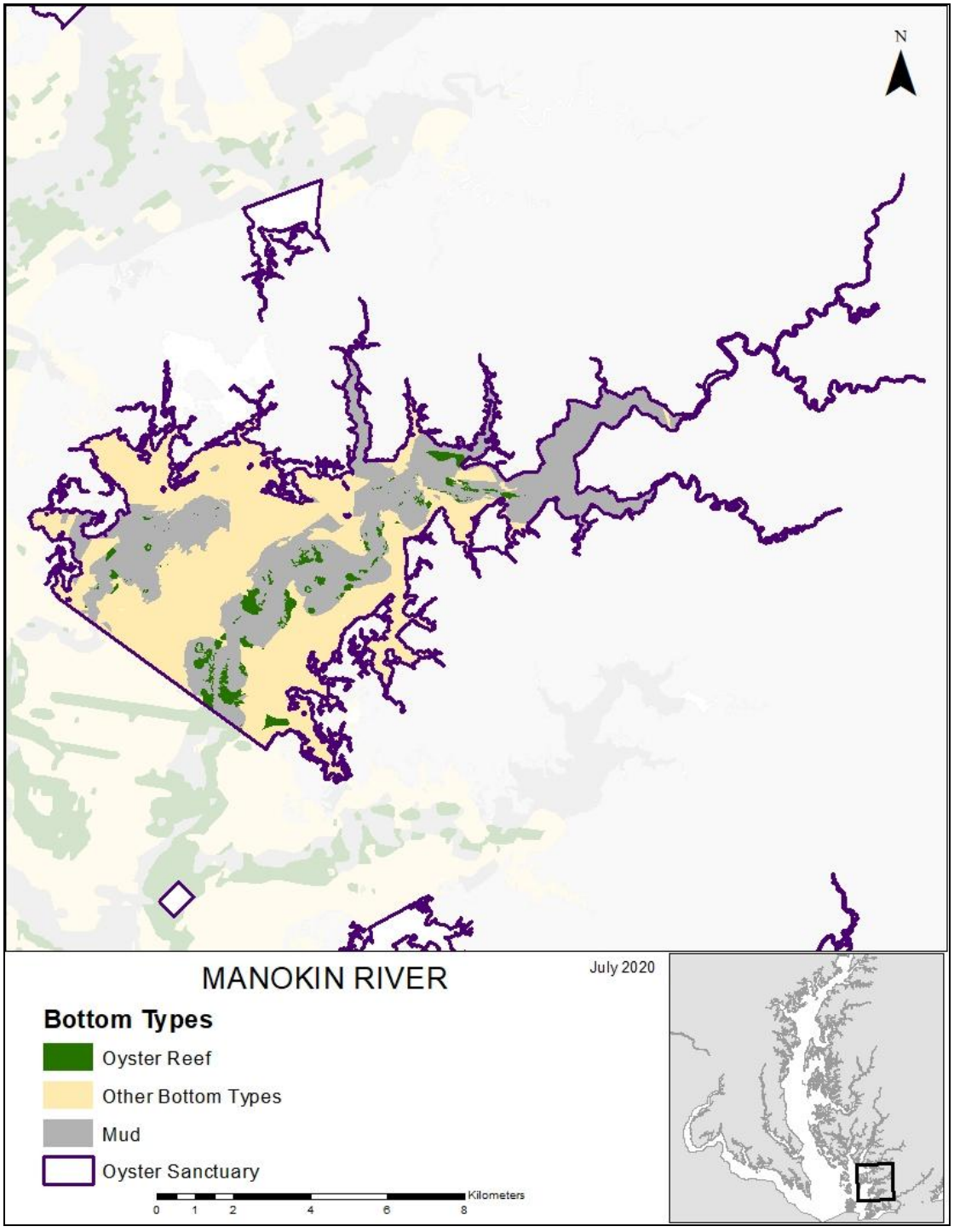

Figure A.23-2. Manokin River Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1883, Maryland Geological Survey from 2018.

Table A.23-1. Oyster population characteristics based on the Fall Survey in the Manokin River Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 30	5 / 37	5 / 30
Number of Live Spat Oysters per square meter	97.4 ± 35.9	161.6 ± 65.2	156 ± 41.4
Number of Live Small-Sized Oysters per square meter	53.3 ± 17.7	153 ± 28.2	169 ± 17
Number of Live Market-Sized Oysters per square meter	14.8 ± 5.2	70.3 ± 14.5	85 ± 15.6
Live Oyster Biomass (g Dry Weight per Bushel)	31 ± 7	333 ± 22	305 ± 56
Observed Mortality (%)	20 ± 5	12 ± 1	11 ± 2
Cultch (Bushels per 100 ft Towed)	1.1 ± 0.2	1.7 ± 0.2	1.7 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

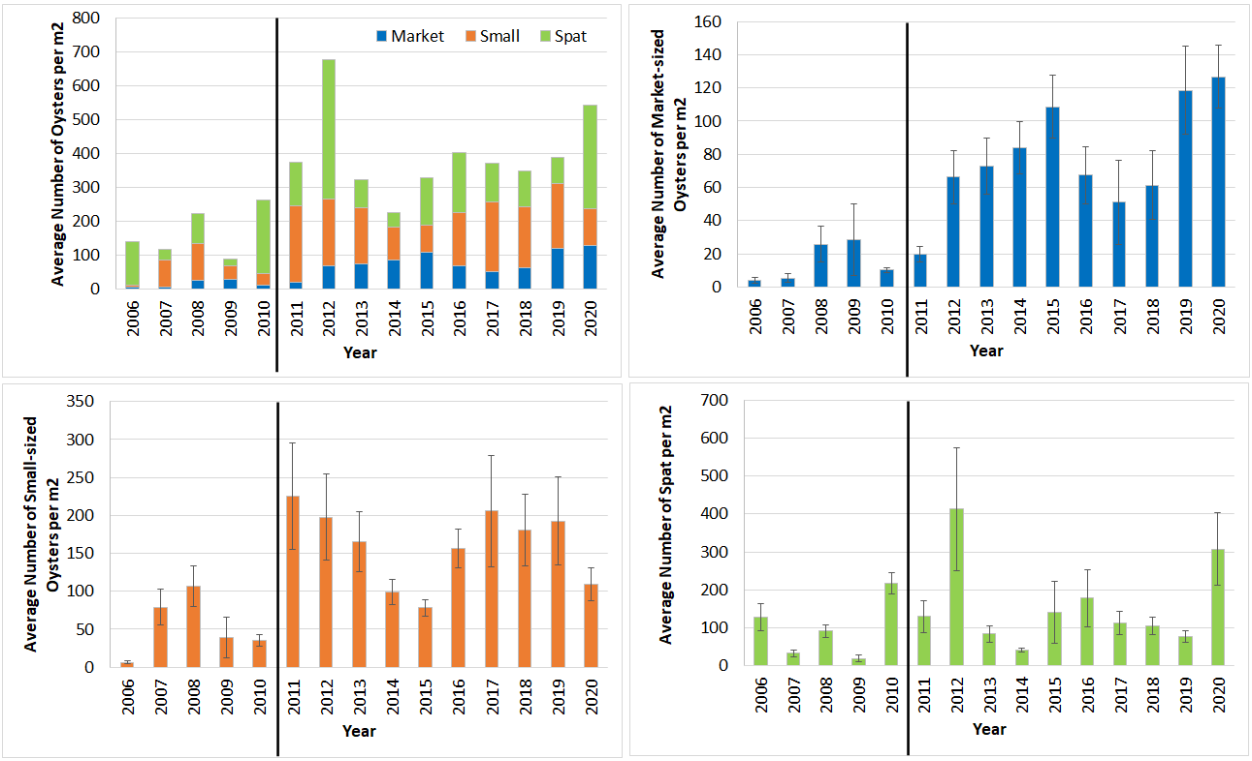

Figure A.23-3. Average number of live oysters per square meter by size class in the Manokin River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

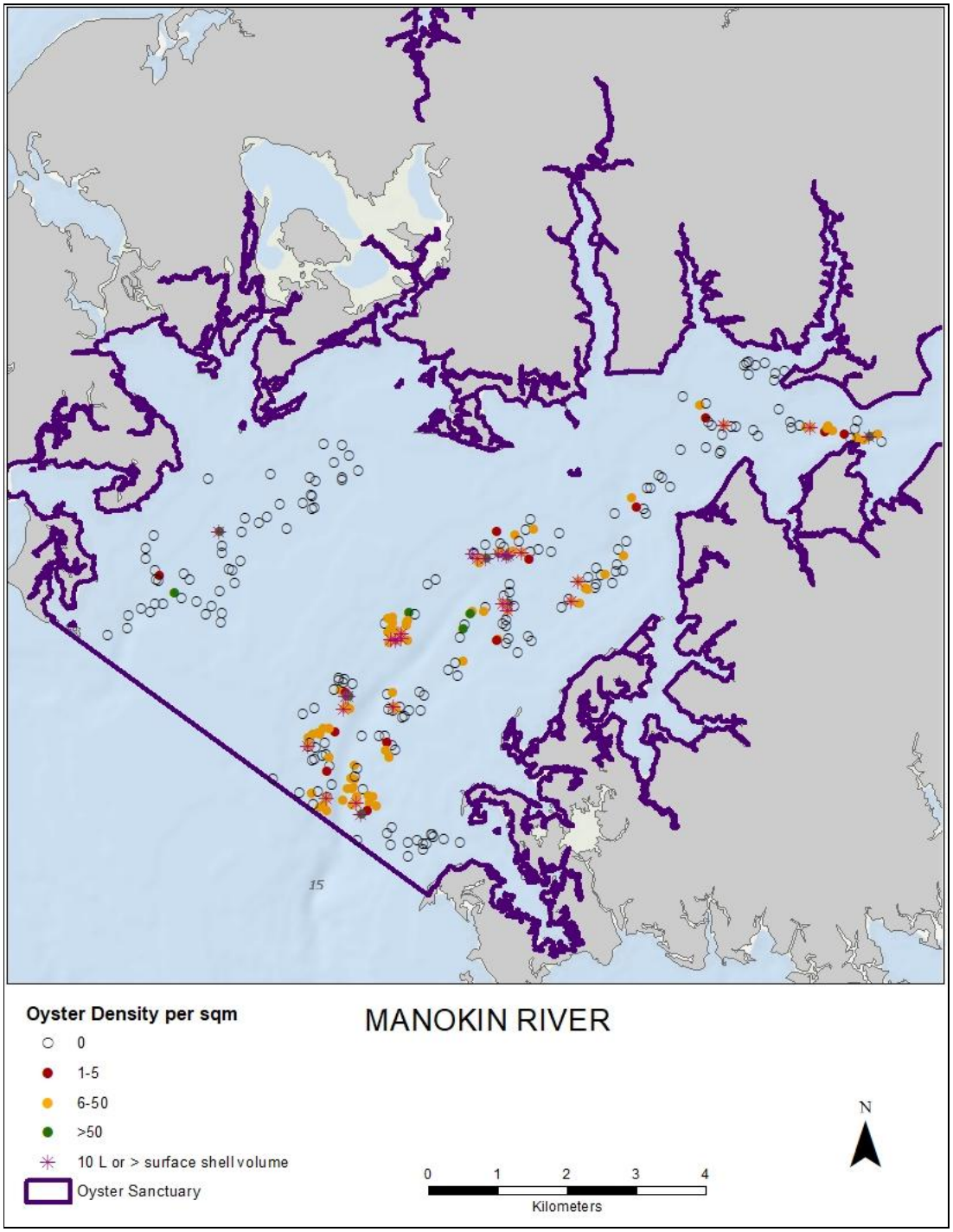

Figure A.23-4. Map of 2017 and 2018 oyster density in the Manokin River Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

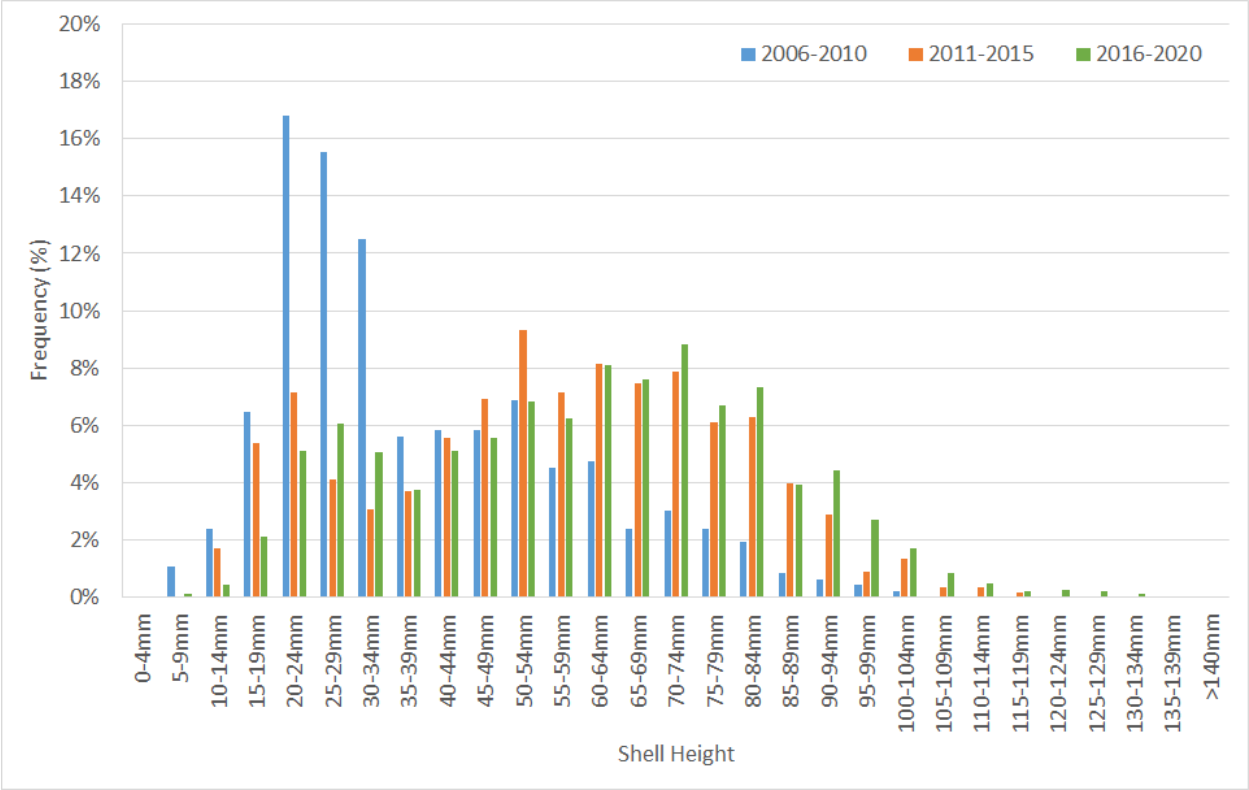

Figure A.23-5. Shell height frequencies of live oysters per bushel of material in the Manokin River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Georges bar.

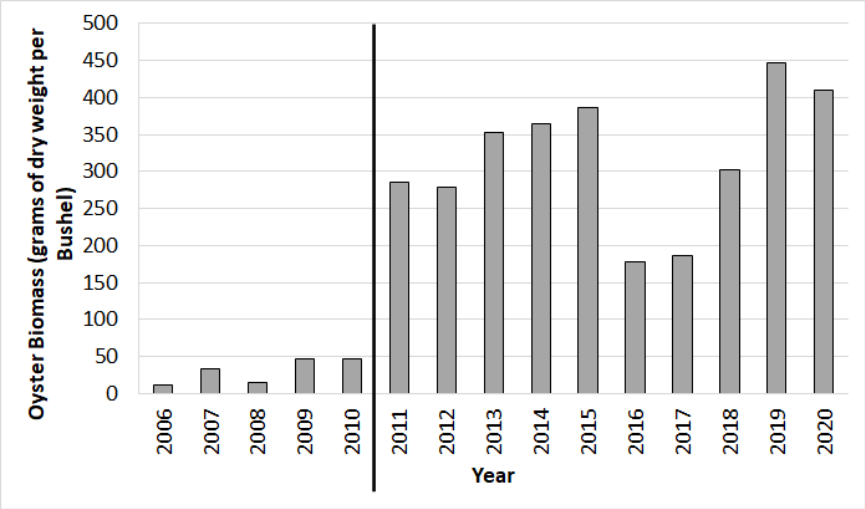

Figure A.23-6. Oyster biomass (grams of dry weight per bushel of material) in the Manokin River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Georges bar. Black line indicates the date the sanctuary was established.

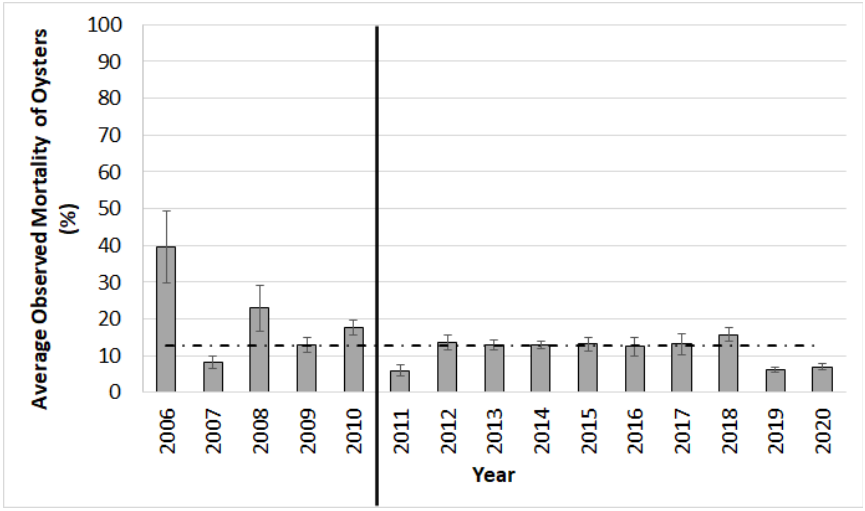

Figure A.23-7. Average annual observed mortality of market-sized and small-sized oysters in Manokin River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

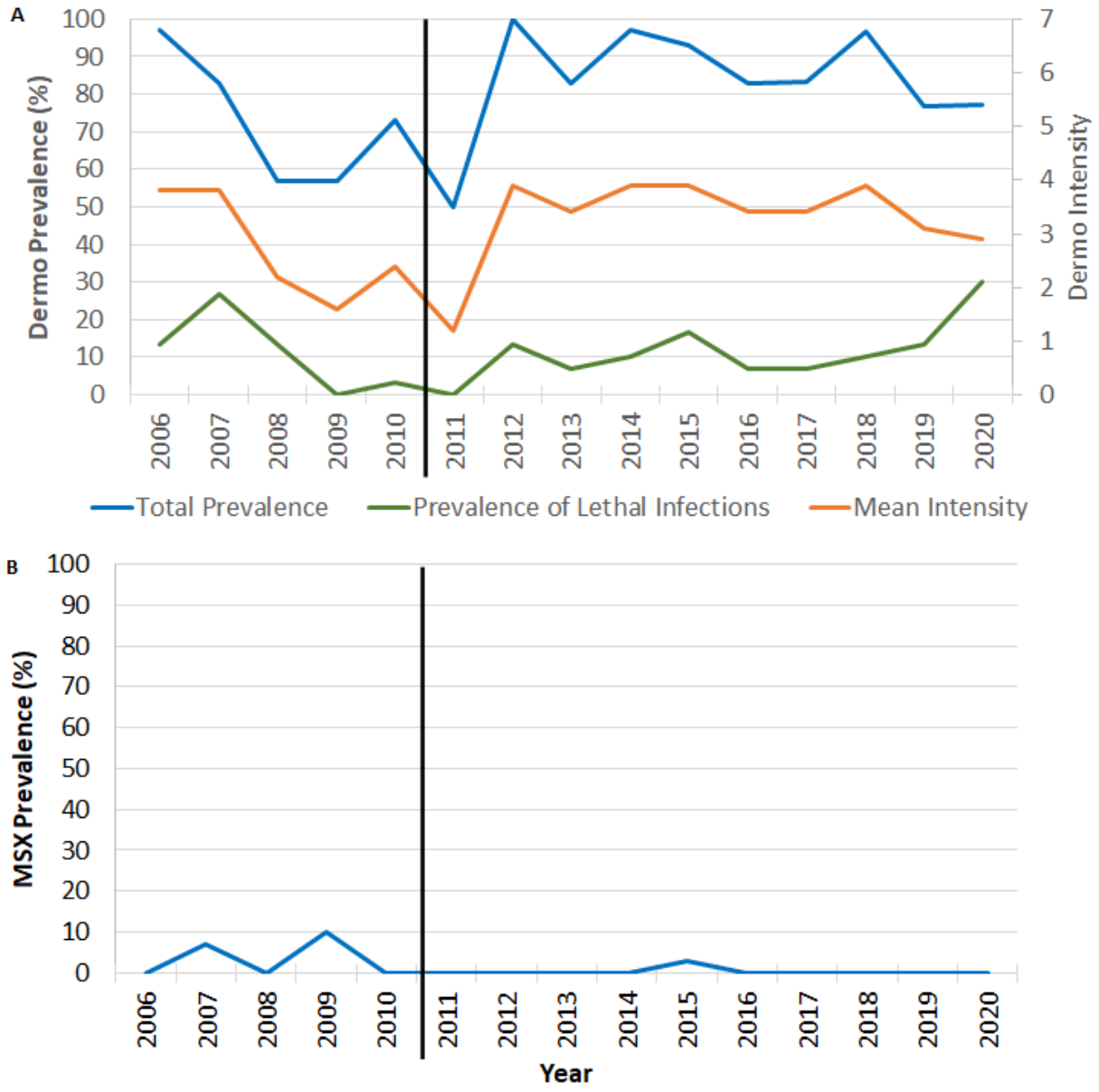

Figure A.23-8. Oyster disease prevalence and intensity in the Manokin River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Georges bar. Black line denotes the date the sanctuary was established.

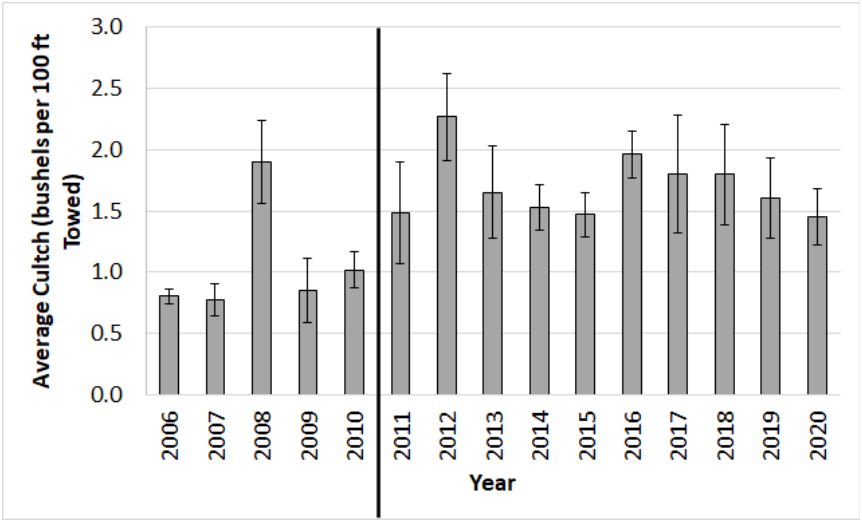

Figure A.23-9. Average cultch (live and dead oysters and loose shell) in the Manokin River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

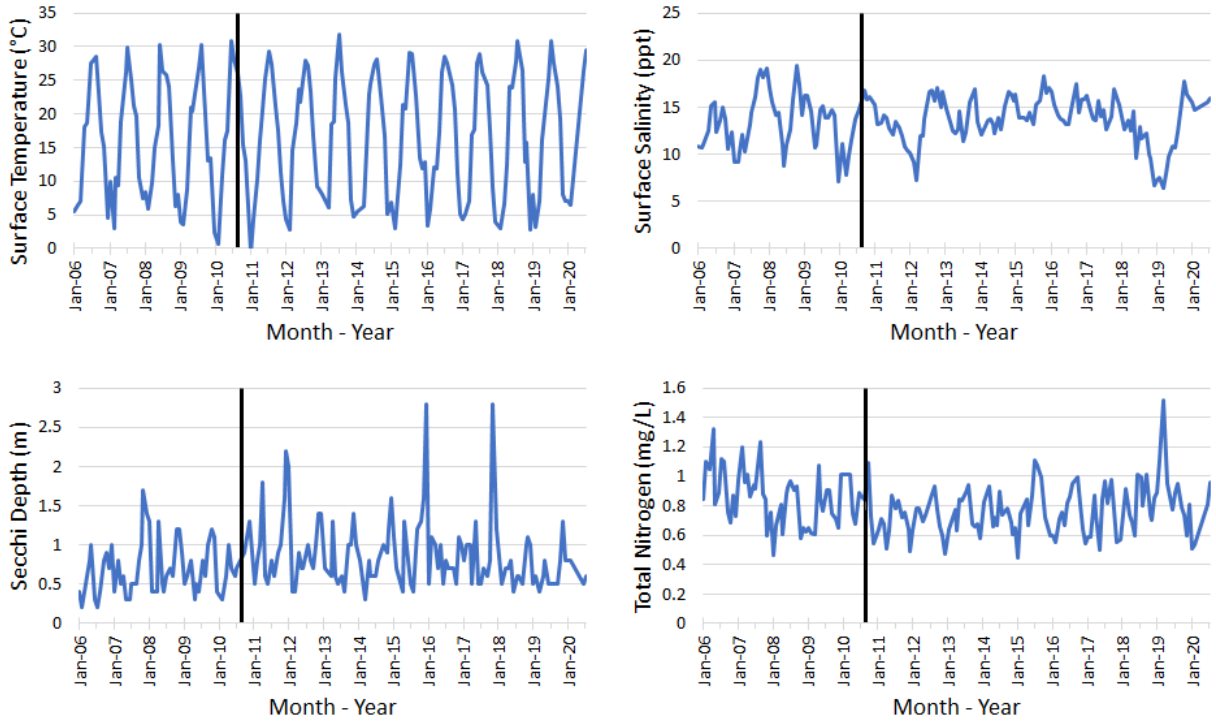

Figure A.23-10. Water quality data collected at ET8.1 in Manokin River Sanctuary. Black line denotes the date the sanctuary was established. Data from Chesapeake Bay Program Data Hub.

Section A.24: Man O War / Gales Lump Sanctuary

The Man O War / Gales Lump Sanctuary is located in upper Chesapeake Bay, a low-salinity (Zone 1) region within NOAA Code 025. Gales Lump (43 acres) constituted the original sanctuary area. In 2010, the sanctuary was expanded to 4,704 acres, of which 2,310 (49%) is historic oyster bottom as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments. Thus, the total surface area is 4,747 acres and the total historic oyster bottom is 2,353 acres. There are four historic oyster bars within the sanctuary[55].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.24-1)
- Bottom types map (Figure A.24-2)
- Density Survey (Figure A.24-3)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in the sanctuary in 2015[56] and 2016. Only a small portion of the sanctuary was sampled in 2016 as the survey was mostly focused on non-sanctuary bottom. Of the 17 samples taken within the sanctuary in 2016, none had any oysters present and all had some volume of surface shell. In 2015, only two oysters were found from 154 samples taken, with a density of 0.01 oysters per square meter. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[55] See chart 4 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[56] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

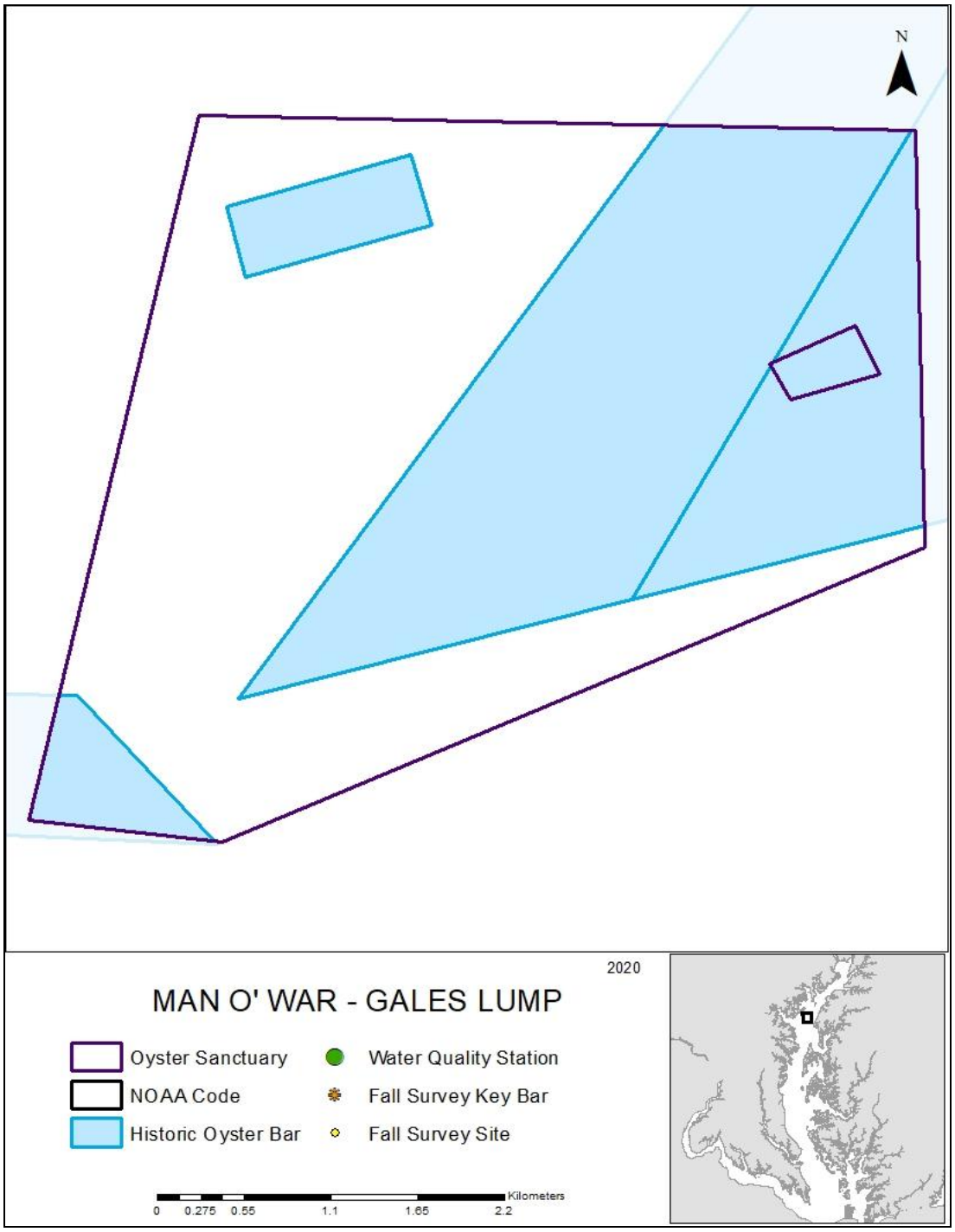

Figure A.24-1. Man O War / Gales Lump Sanctuary.

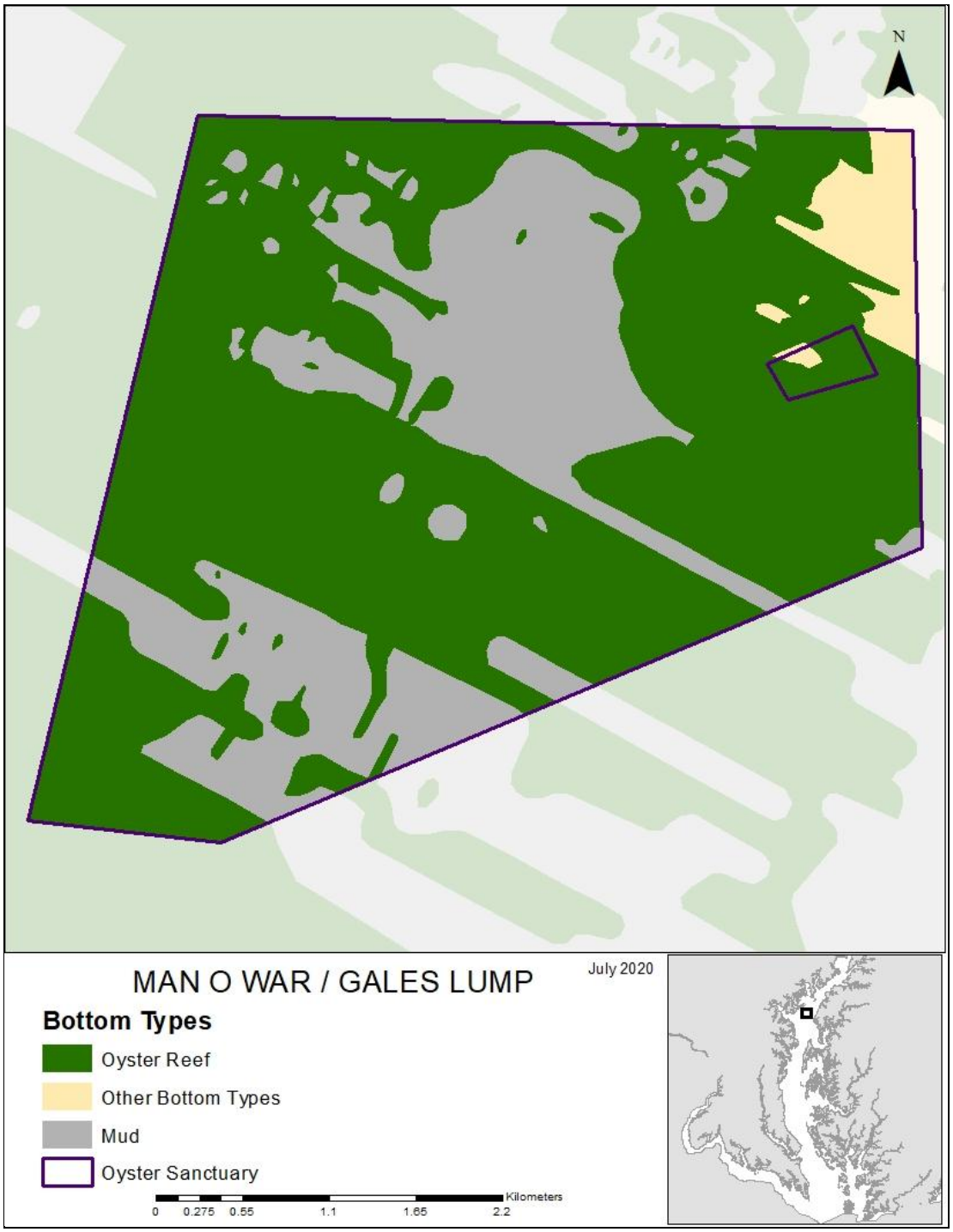

Figure A.24 -2. Man O War / Gales Lump Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

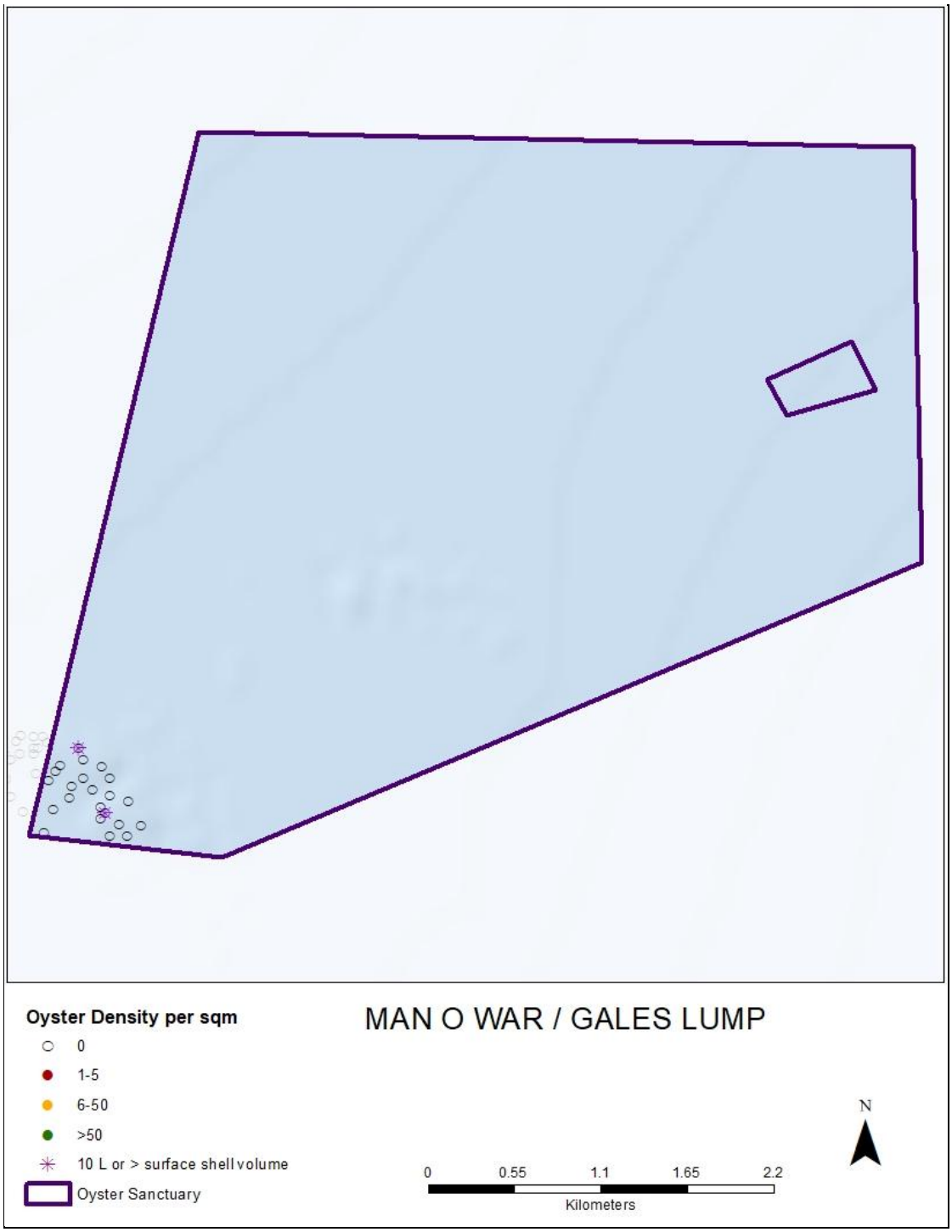

Figure A.24 -3. Map of 2016 oyster density in the Man O War / Gales Lump Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.25: Miles River Sanctuary

The Miles River Sanctuary is located in the upstream section of the Miles River, a tributary of Eastern Bay within NOAA Code 060. The sanctuary is in a medium-salinity (Zone 2) region. The sanctuary was created in 2010 and encompasses 3,449 acres of which 373 (11%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are five historic oyster bars within the sanctuary[57].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.25-1)
- Bottom types map (Figure A.25-2)
- Summary statistics (Table A.25-1)
- Abundance per year (Figure A.25-3)
- Density Survey (Figure A.25-4)
- Shell height frequencies (Figure A.25-5)
- Biomass per year (Figure A.25-6)
- Observed mortality (Figure A.25-7)
- Dermo and MSX per year (Figure A.25-8)
- Cultch per year (Figure A.25-9)

The Fall Survey sampled one bar in this sanctuary. No spat and very few small or market oysters have been found since 2015. In 2020, the survey found no oysters at the key disease bar site, but collected some oysters on an area planted with hatchery spat-on-shell in 2017. Observed mortality was slightly higher than the long-term baywide average. The amount of cultch declined to less than half of the previous five-year average. The average size of oysters measured during 2016-2020 was 122 mm; very few oysters were measured. The department conducted a population patent tong survey in 2014[58] and 2020. Results indicate little change in the population density with an average density of 0.09 oysters per square meter. Of the 150 samples taken, 148 had no oysters and 51 samples had no surface shell.

Between 2006 and 2010 before the sanctuary was established, no planting activities occurred to enhance the commercial public fishery. After the sanctuary was established, approximately 12 million hatchery spat-on-shell were planted for restoration purposes. Marylanders Grow Oysters have planted annually in the Miles River since 2010.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[57] See chart 12 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[58] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

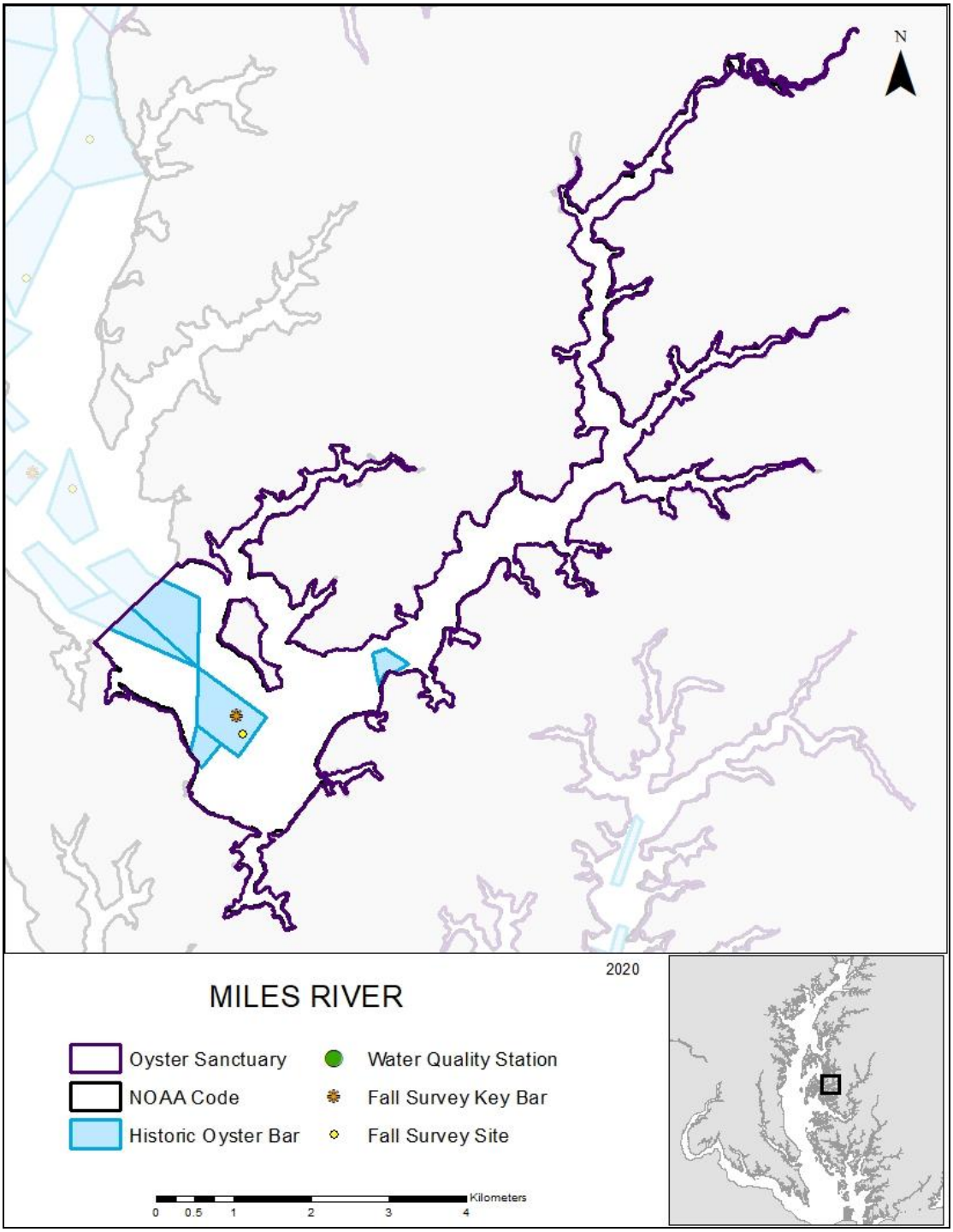

Figure A.25-1. Miles River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

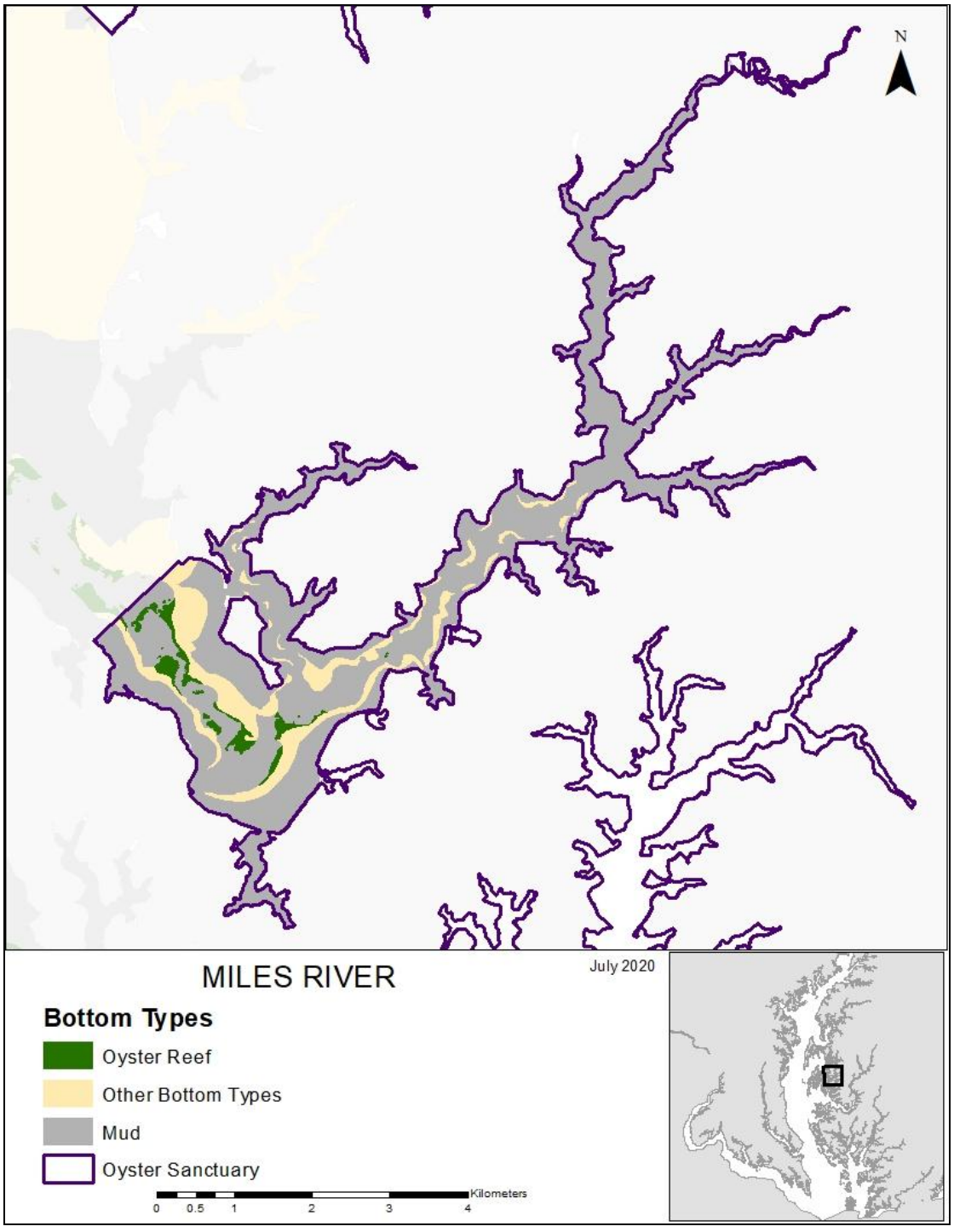

Figure A.25-2. Miles River Sanctuary bottom types. Data from NOAA Chesapeake Bay Office in 2011.

Table A.25-1. Oyster population characteristics based on the Fall Survey in the Miles River Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 6
Number of Live Spat Oysters per square meter	0.1 ± 0.1	0.2 ± 0.1	0 ± 0
Number of Live Small-Sized Oysters per square meter	0 ± 0	0.4 ± 0.2	0.7 ± 0.7
Number of Live Market-Sized Oysters per square meter	3.5 ± 2.2	1.5 ± 0.5	3.6 ± 3.3
Live Oyster Biomass (g Dry Weight per Bushel)	48 ± 19	23 ± 12	10 ± 3
Observed Mortality (%)	30 ± 6	11 ± 7	14 ± 6
Cultch (Bushels per 100 ft Towed)	0.4 ± 0.1	0.8 ± 0.3	0.3 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

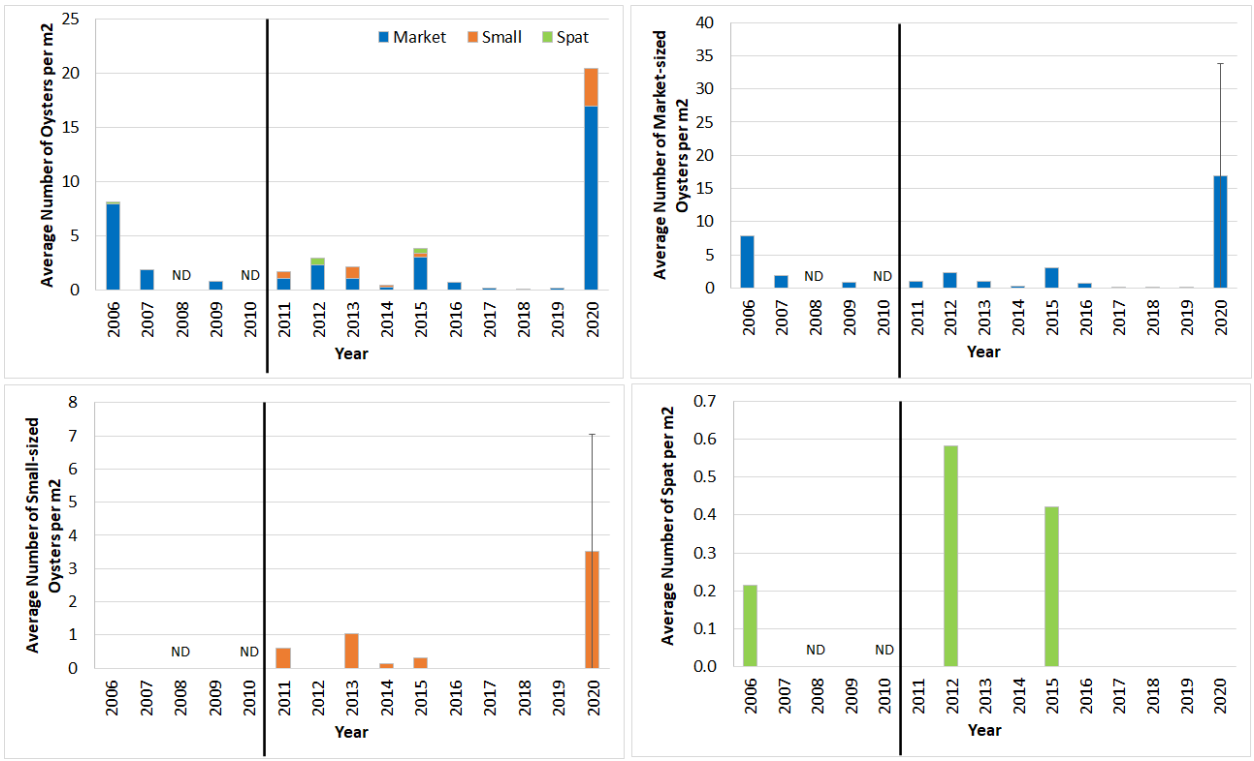

Figure A.25-3. Average number of live oysters per square meter by size class in the Miles River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

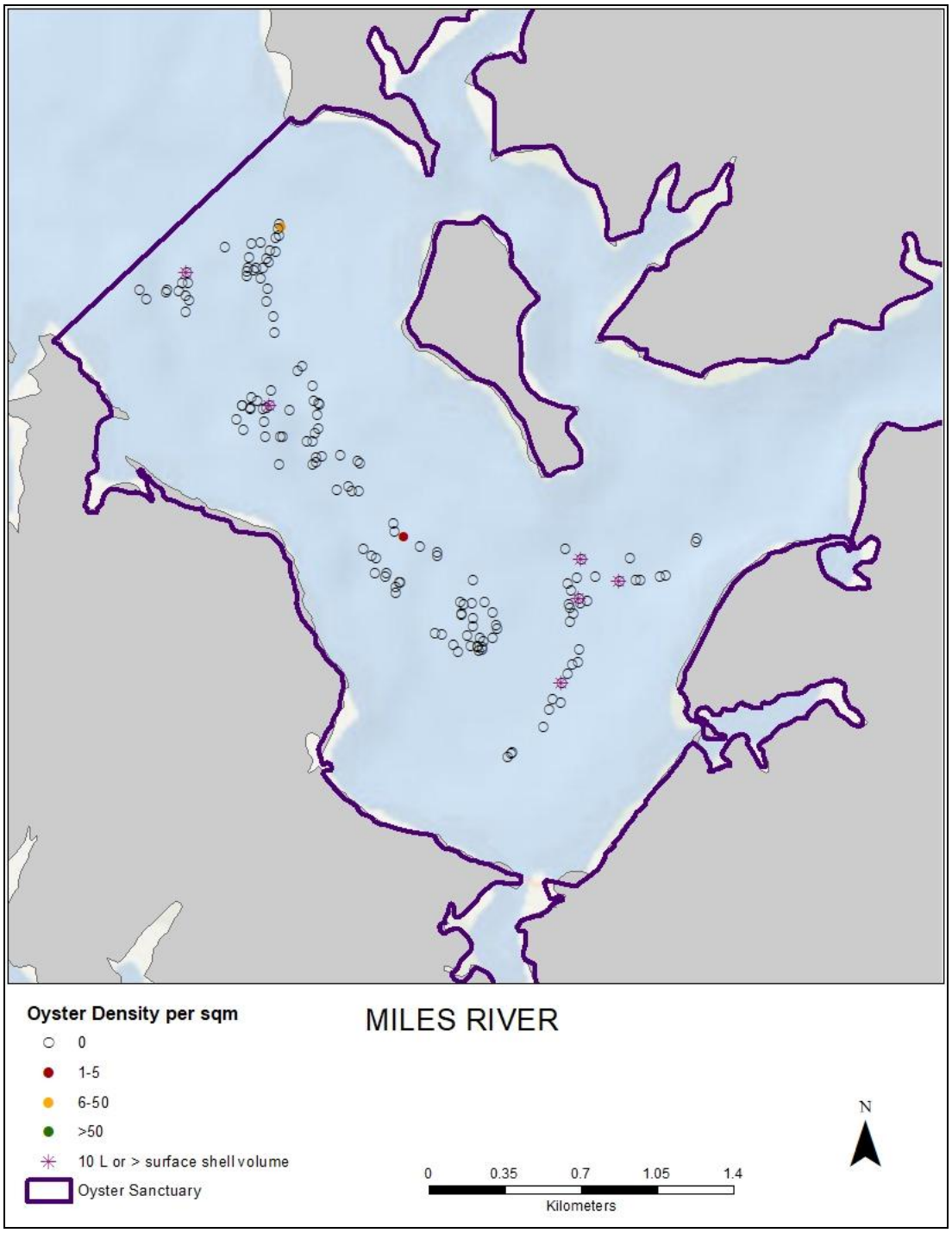

Figure A.25-4. Map of 2020 oyster density in the Miles River Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

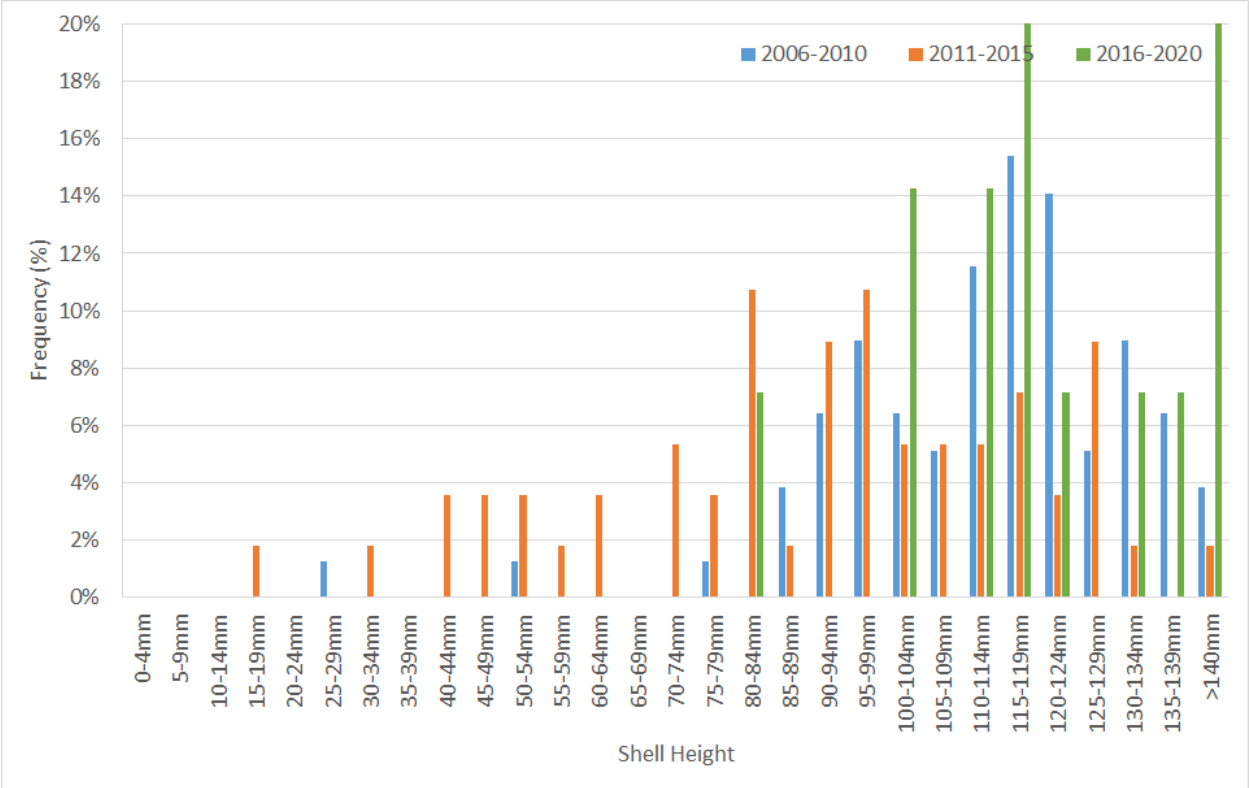

Figure A.25-5. Shell height frequencies of live oysters per bushel of material in the Miles River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Long Point bar.

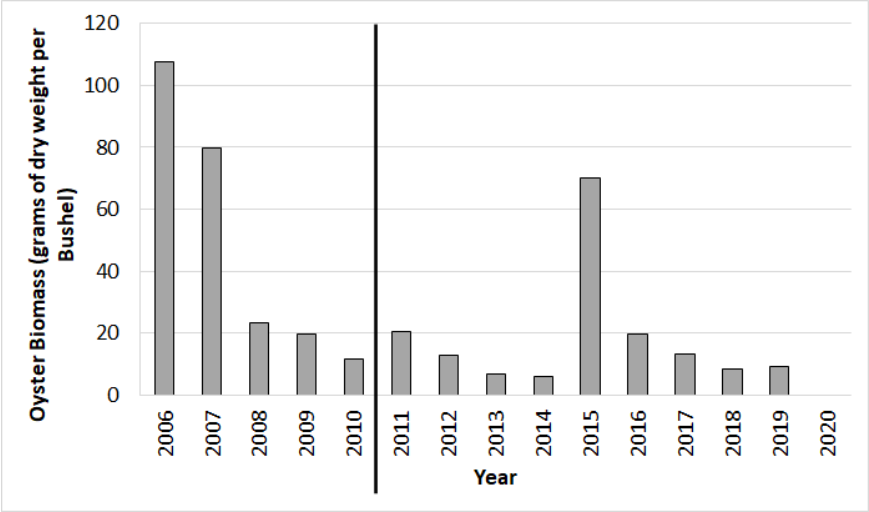

Figure A.25-6. Oyster biomass (grams of dry weight per bushel of material) in the Miles River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Long Point bar. Black line indicates the date the sanctuary was established.

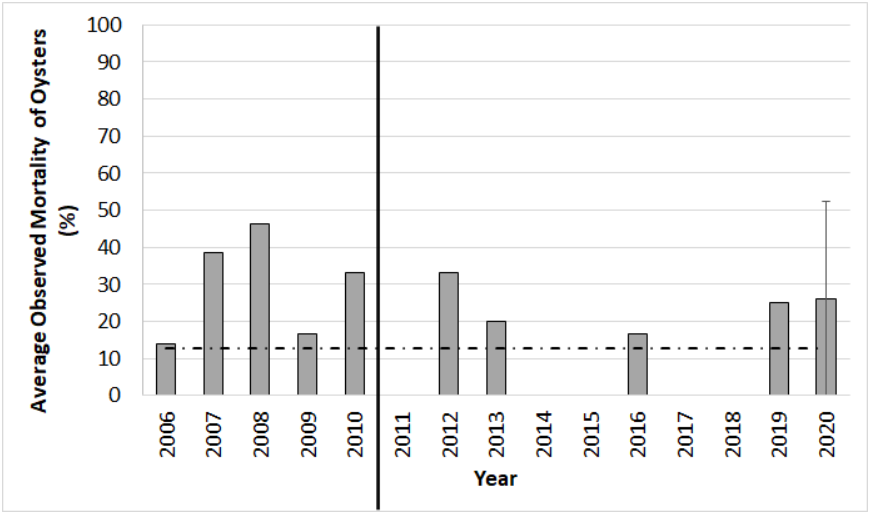

Figure A.25-7. Average annual observed mortality of market-sized and small-sized oysters in Miles River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

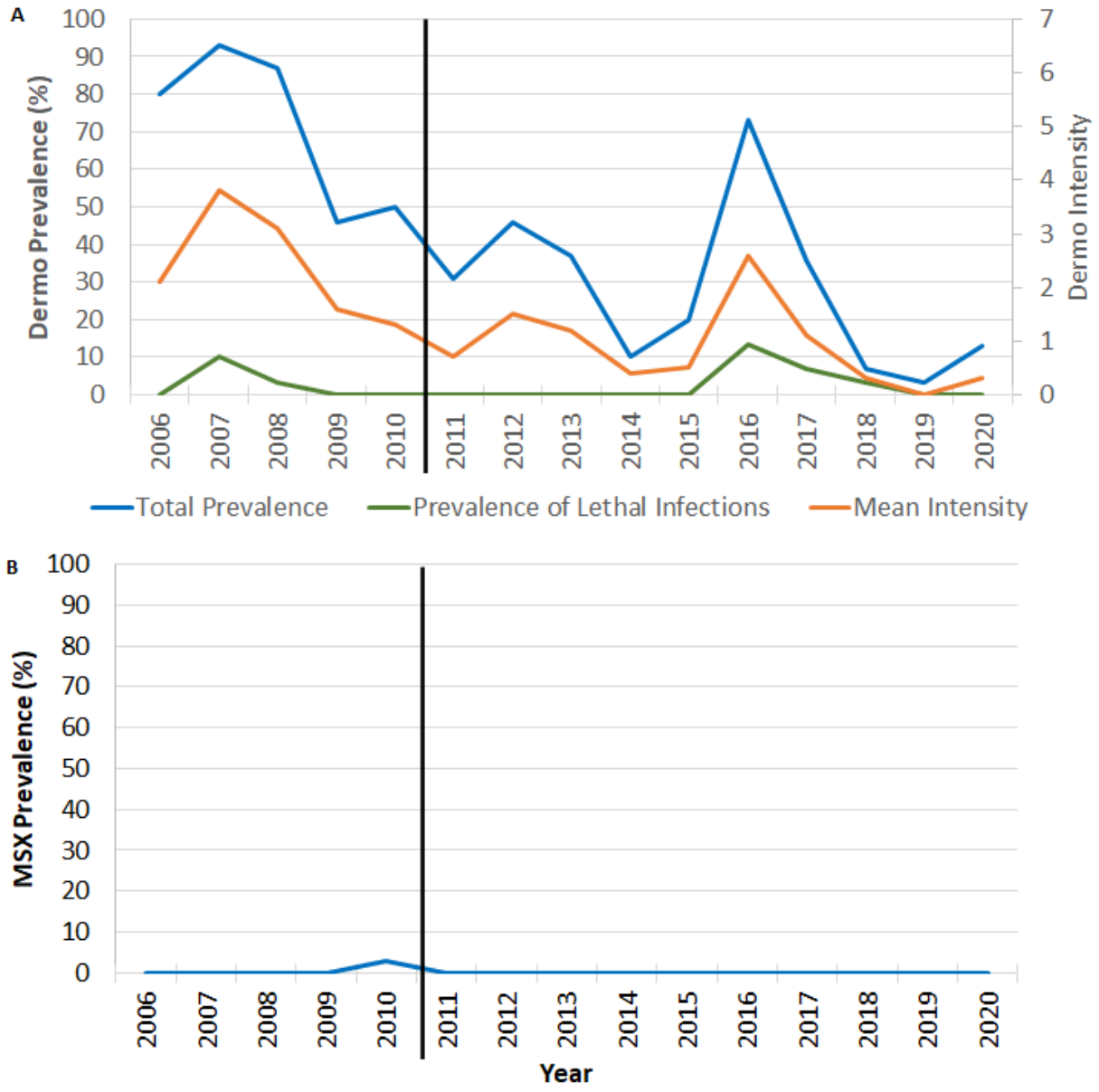

Figure A.25-8. Oyster disease prevalence and intensity in the Miles River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Long Point bar. Black line denotes the date the sanctuary was established.

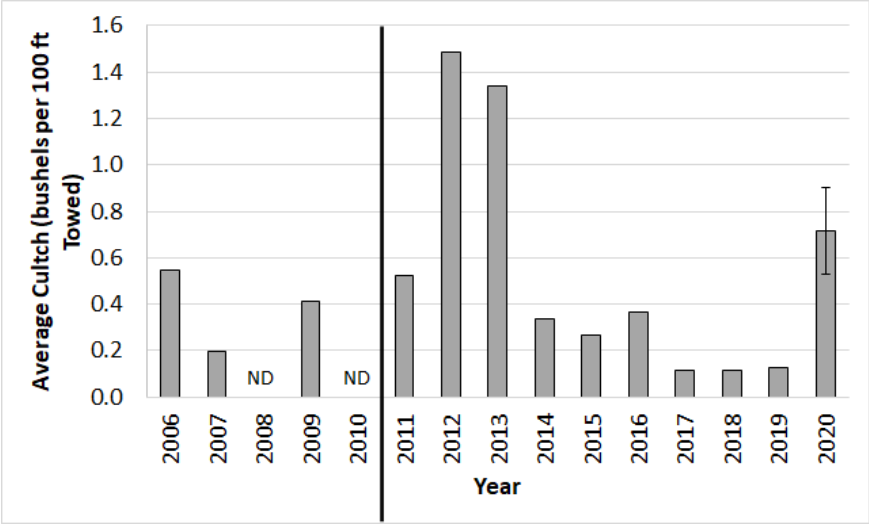

Figure A.25-9. Average cultch (live and dead oysters and loose shell) in the Miles River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

Section A.26: Mill Hill Sanctuary

The Mill Hill Sanctuary is located in Eastern Bay, a medium-salinity (Zone 2) region within NOAA Code 039. The sanctuary was created in 2000 for a US Environmental Protection Agency (EPA) project examining mounded habitat and alternative materials for oysters. The sanctuary encompasses 295 acres of which 188 (64%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are two historic oyster bars within the sanctuary although neither bar has the majority of its area within the sanctuary (Mill Hill 31% and Saw Mill Creek 9%).

Information available for this sanctuary includes:

- Sanctuary map (Figure A.26-1)
- Bottom types map (Figure A.26-2)
- Summary statistics (Table A.26-1)
- Abundance per year (Figure A.26-3)
- Density Survey (Figure A.26-4)
- Observed mortality (Figure A.26-5)
- Cultch per year (Figure A.26-6)

The Fall Survey sampled one bar in this sanctuary. Spat, small and market oyster density decreased in 2016-2020. Observed mortality increased and was similar to the long-term baywide average. The amount of cultch declined from the previous five-year average. A population patent tong survey was conducted by the department in 2013[59] and 2020. Results indicate an increase in the density of oysters since the last survey in 2020 to an average of 4.0 per square meter, with more market-sized oysters than small-sized oysters (3.2 and 0.8 per square meter respectively). Of the 45 samples taken, 22 had no oysters and 14 had no surface shell volume.

From 2006 to 2020, approximately 82 million hatchery spat-on-shell were planted for restoration purposes. In 2021, The Nature Conservancy planted approximately 237,113 aquaculture oysters in this sanctuary of which 61% were diploid as part of a nationwide program to help aquaculture farmers impacted by Covid19.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[59] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

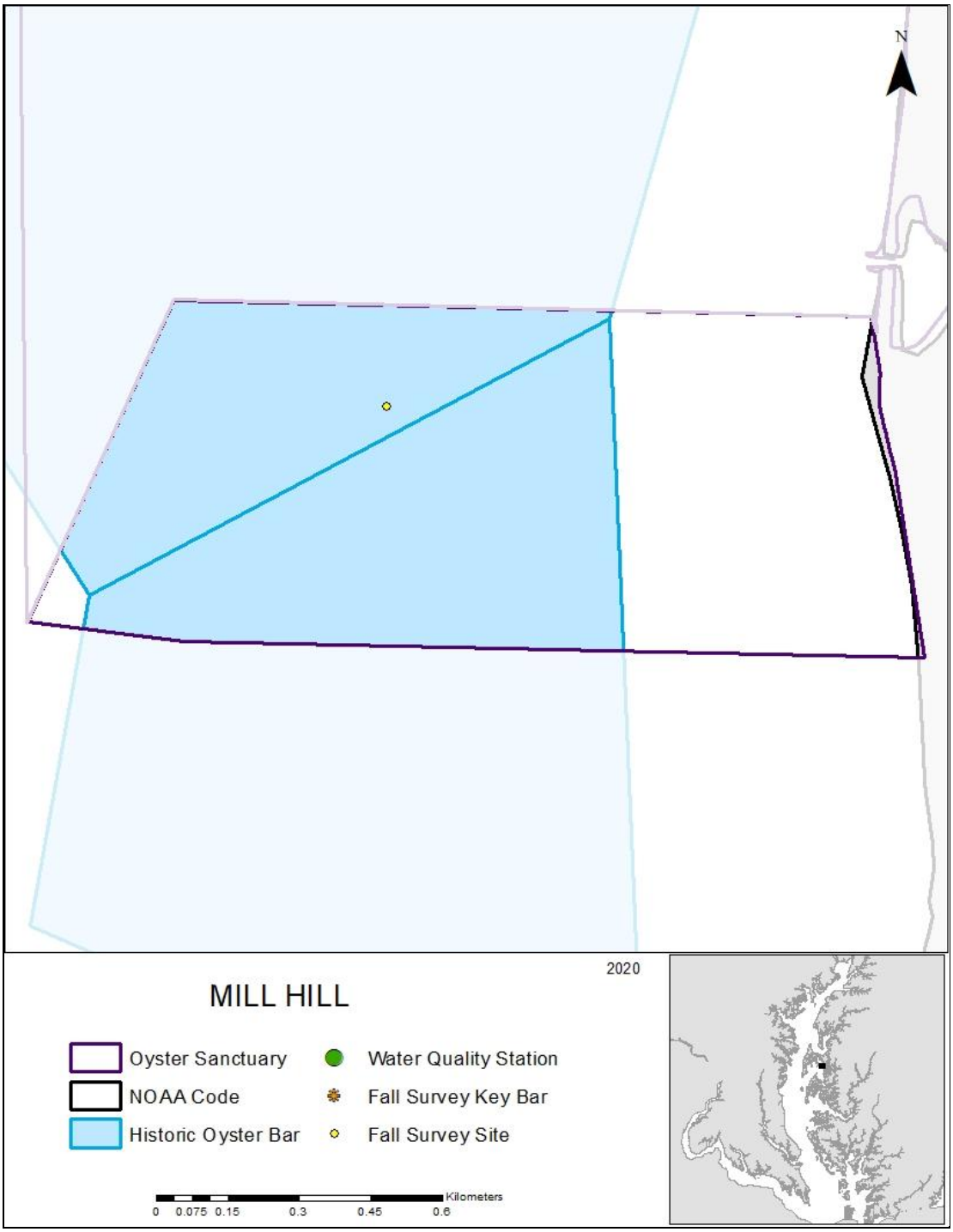

Figure A.26-1. Mill Hill Sanctuary. Fall Survey sites may not be sampled every year.

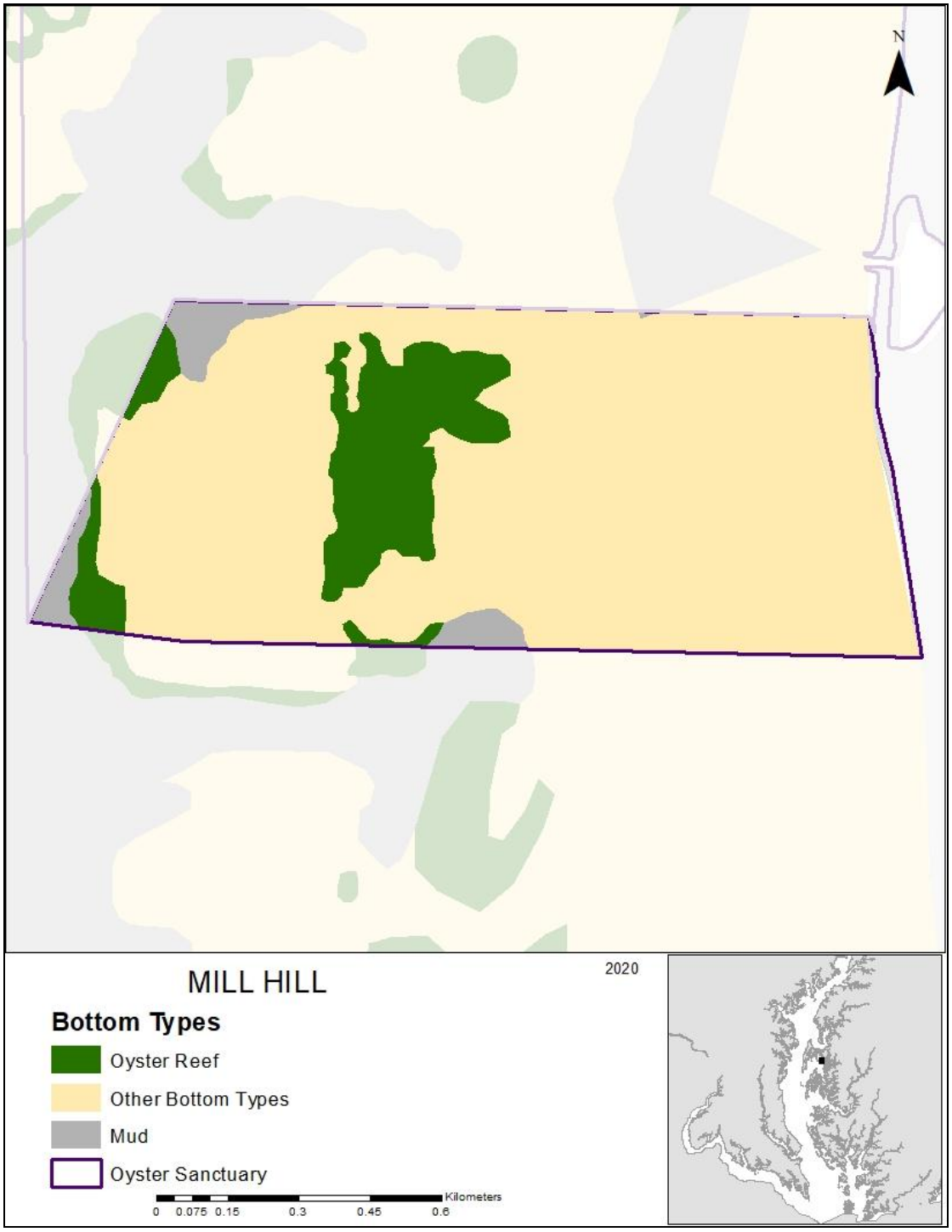

Figure A.26-2. Mill Hill Sanctuary bottom types. Data from NOAA Chesapeake Bay Office in 2012.

Table A.26-1. Oyster population characteristics based on the Fall Survey in the Mill Hill Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	7.7 ± 4.3	3.5 ± 2.2	0.1 ± 0.1
Number of Live Small-Sized Oysters per square meter	5.7 ± 3.6	10.6 ± 6.8	2.9 ± 1.2
Number of Live Market-Sized Oysters per square meter	4 ± 0.8	15.9 ± 2.8	10.9 ± 1.4
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	20 ± 7	6 ± 3	12 ± 4
Cultch (Bushels per 100 ft Towed)	0.4 ± 0	0.6 ± 0.1	0.2 ± 0
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

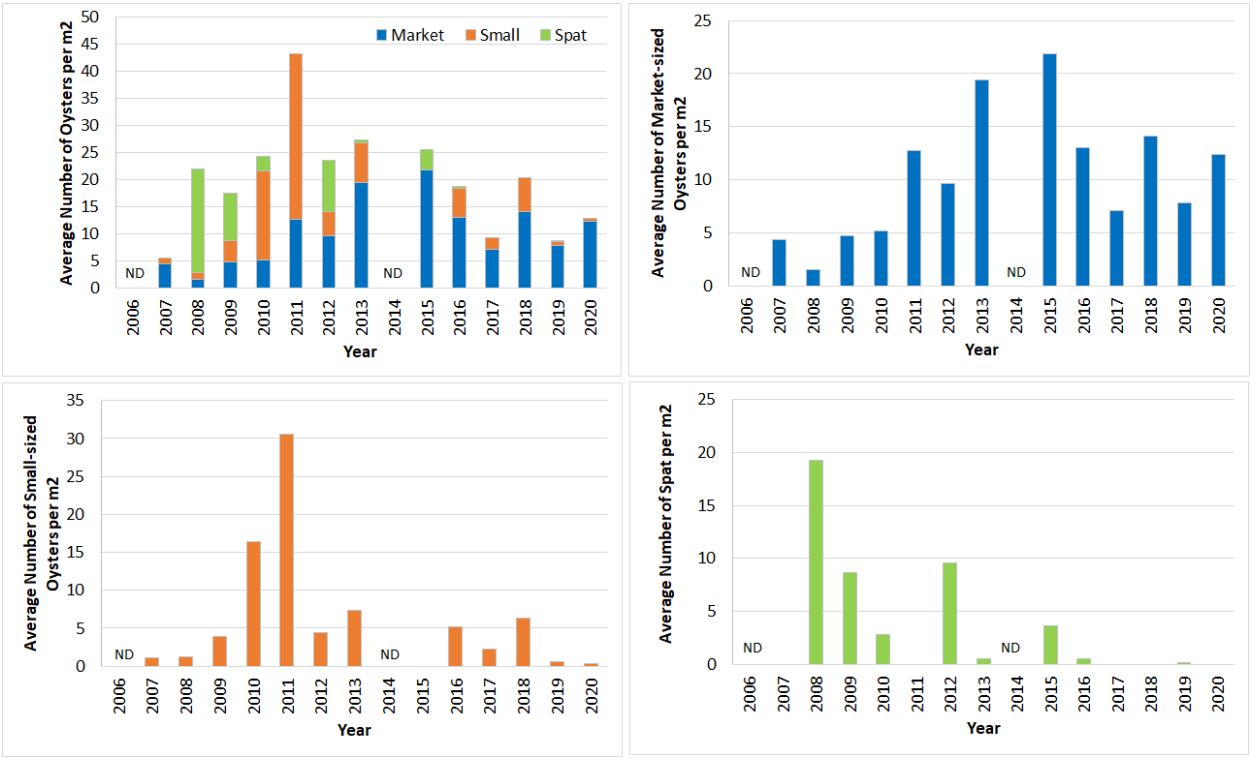

Figure A.26-3. Average number of live oysters per square meter by size class in the Mill Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

Figure A.26-4. Map of 2020 oyster density in the Mill Hill Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

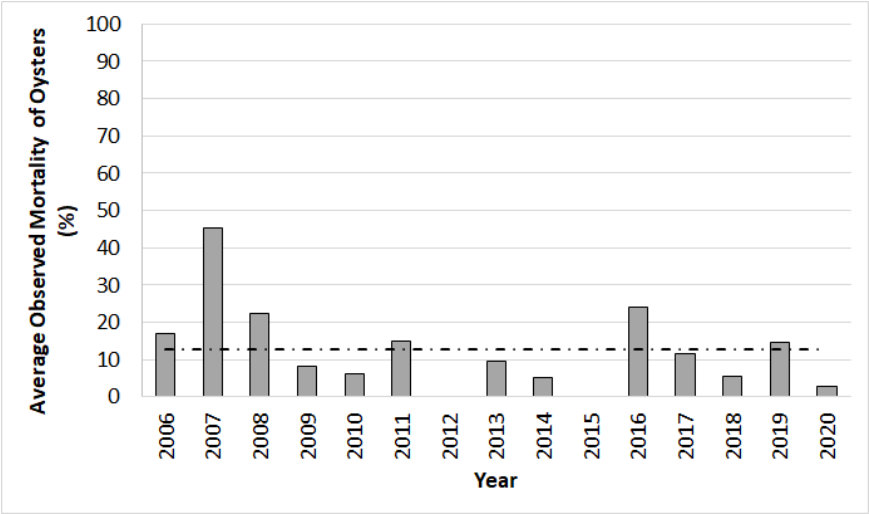

Figure A.26-5. Average annual observed mortality of market-sized and small-sized oysters in Mill Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The dashed line represents the 2006-2020 baywide average observed mortality.

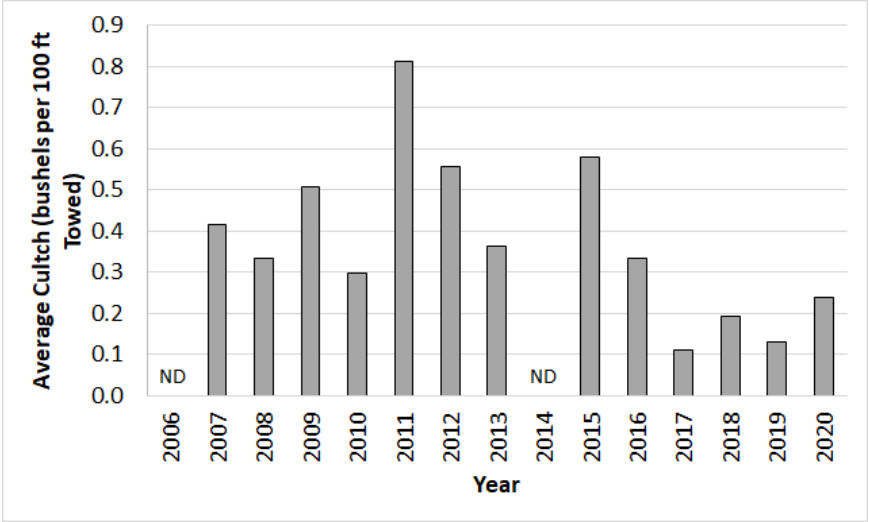

Figure A.26-7. Average cultch (live and dead oysters and loose shell) in the Mill Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey.

Section A.27: Nanticoke River Sanctuary

The Nanticoke River Sanctuary is located in the Nanticoke River, a low-salinity (Zone 1) region within NOAA Code 062. The sanctuary was created in 2010 and encompasses 16,699 acres of which 576 (3.4%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 19 historic oyster bars within the sanctuary[60].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.27-1)
- Bottom types map (Figure A.27-2)
- Summary statistics (Table A.27-1)
- Abundance per year (Figure A.27-3)
- Density Survey (Figure A.27-4)
- Shell height frequencies (Figure A.27-5)
- Biomass per year (Figure A.27-6)
- Observed mortality (Figure A.27-7)
- Dermo and MSX per year (Figure A.27-8)
- Cultch per year (Figure A.27-9)
- Water Quality (Figure A.27-10)

Fall Survey results indicate that oyster abundance and biomass in the Nanticoke River Sanctuary has increased steadily since becoming a sanctuary in 2010, most likely due to the cessation of harvest coupled with consistently strong spat sets relative to the Nanticoke River. Observed mortality has remained low and below the baywide average. Oyster shell height frequencies have shifted as there has been an increase in large oysters since sanctuary establishment. Prior to 2011, oysters larger than 100 mm comprised 13% of those measured, compared to greater than 30% for the oysters measured after 2011. Oyster Dermo disease trends have varied over time and have been on a downward trend since 2017. Average cultch, a relative measure of oyster habitat defined as the amount of oysters (live and dead) and loose shell, increased after the river was established as a sanctuary.

A population patent tong survey was conducted by the department in 2018 and found an average density of 10.5 oysters per square meter, with a greater density of market-sized oysters than small-sized oysters (6.8 per square meter and 2.4 per square meter respectively). Of the 131 samples, 67 had no oysters and 67 had no surface shell volume.

Between 2006 and prior to sanctuary establishment, approximately 6,000 bushels of wild seed were planted to enhance the commercial public fishery. In 2021 The Nature Conservancy planted approximately 511,596 aquaculture oysters in this sanctuary of which 58% were diploid as part of a nationwide program to help aquaculture farmers impacted by Covid19. Nanticoke River Sanctuary was intended to have small-scale restoration in 2019 (hatchery spat-on-shell plantings on about 15 acres); however, due to the freshet, which impacted hatchery larvae production, this

[60] See chart 31 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

planting is now scheduled for 2021. Marylanders Grow Oysters, a public outreach program that has been active in the river since 2009, planting oysters at one location annually.

Continuous water quality has been examined in Nanticoke River Sanctuary since 2006 at Station ET6.2 (38.34133; -75.8883). Water temperature and secchi depth ranges have remained relatively stable over the 15-year period. Salinity was more variable over the same period, but since 2011 has ranged between 0 and 13 parts per thousand. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

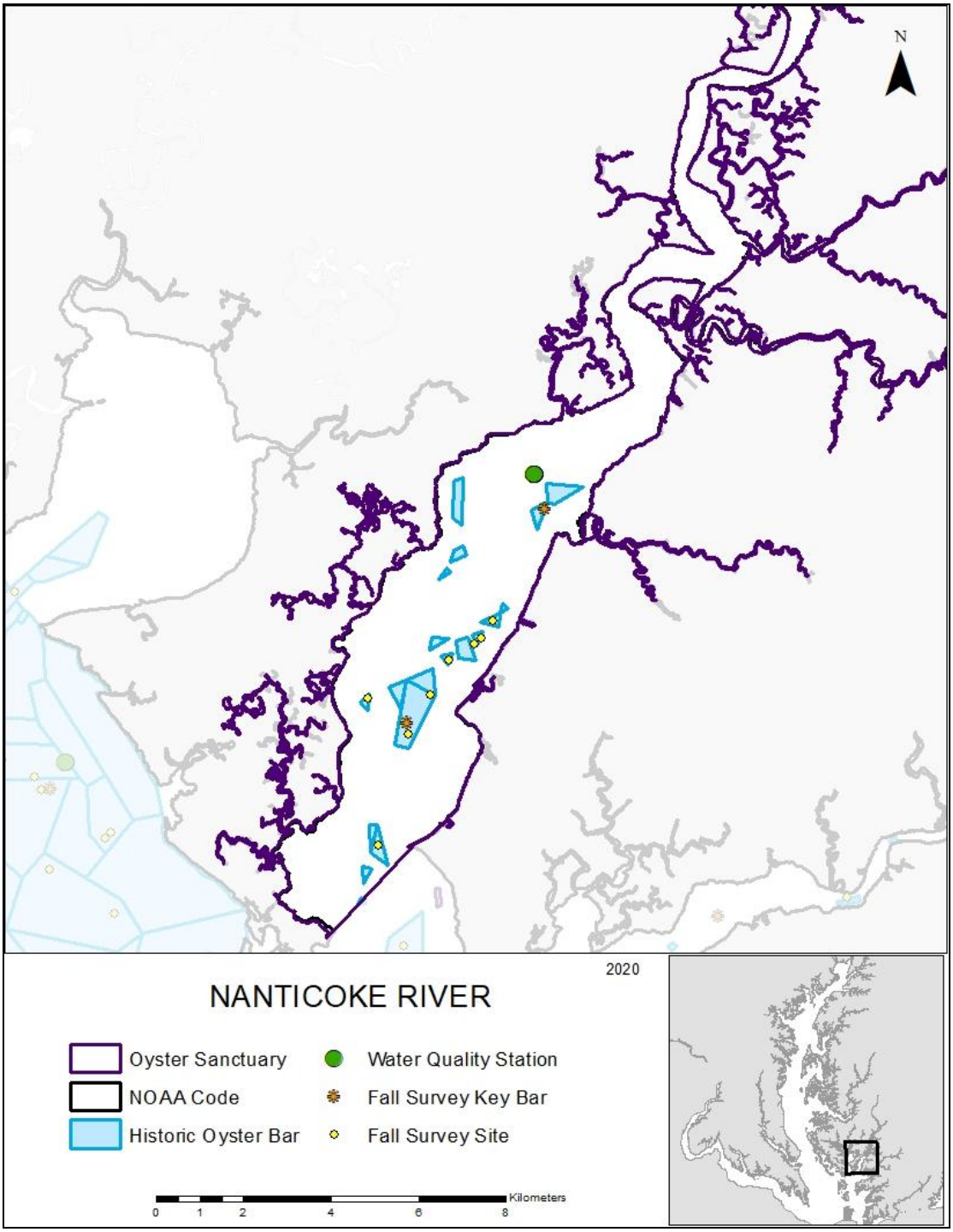

Figure A.27-1. Nanticoke River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

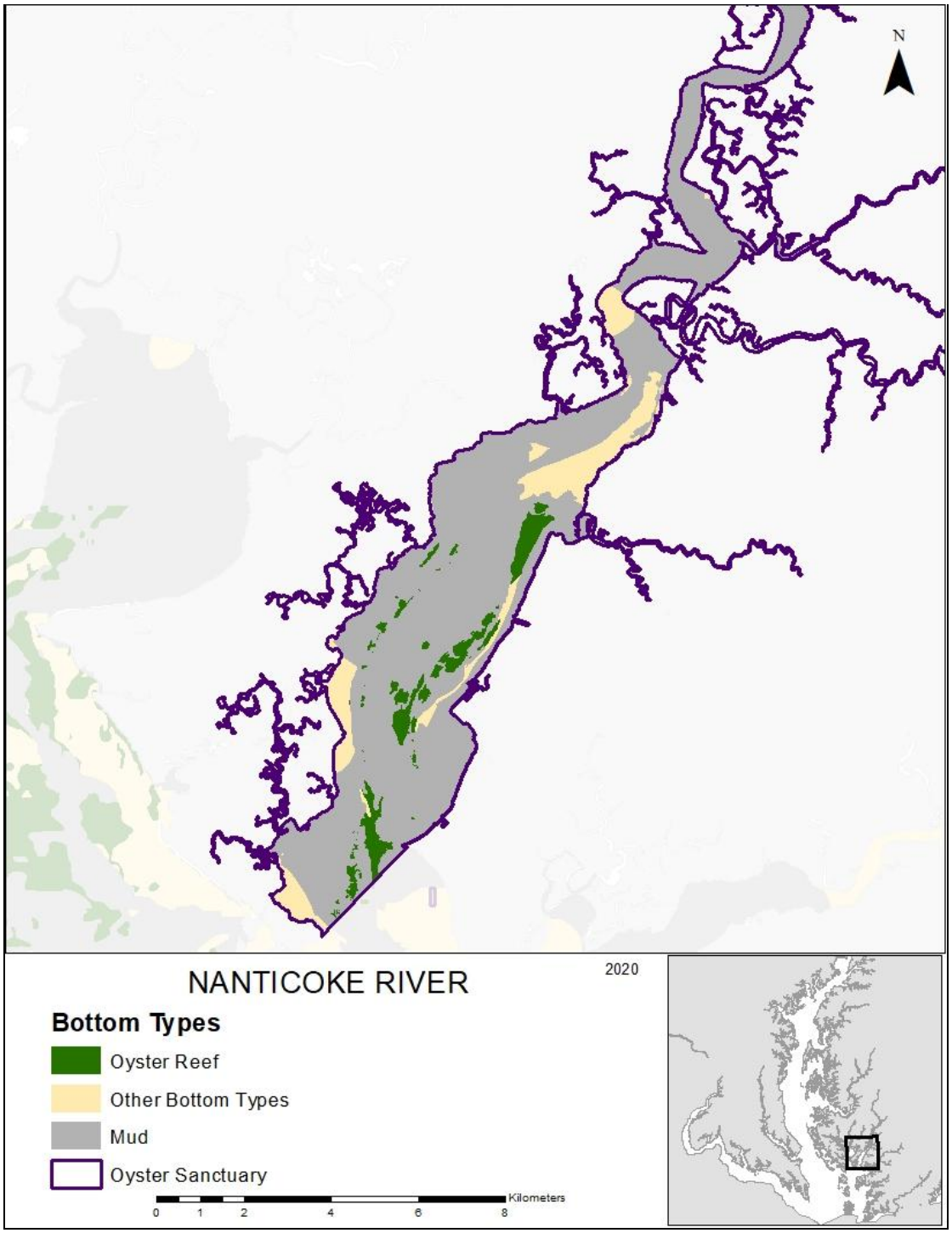

Figure A.27-2. Nanticoke River Sanctuary bottom types. Data from Maryland Geological Survey from 2011.

Table A.27-1. Oyster population characteristics based on the Fall Survey in the Nanticoke River Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 45	5 / 44	5 / 40
Number of Live Spat Oysters per square meter	10.7 ± 5.6	22.6 ± 2.7	45.3 ± 16.8
Number of Live Small-Sized Oysters per square meter	20.8 ± 7.5	59.9 ± 6	100.5 ± 29.1
Number of Live Market-Sized Oysters per square meter	33 ± 10.3	107.9 ± 27.4	161.3 ± 11.6
Live Oyster Biomass (g Dry Weight per Bushel)	107 ± 21	207 ± 58	311 ± 23
Observed Mortality (%)	7 ± 2	5 ± 1	8 ± 1
Cultch (Bushels per 100 ft Towed)	2 ± 0.4	2.8 ± 0.2	2.5 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

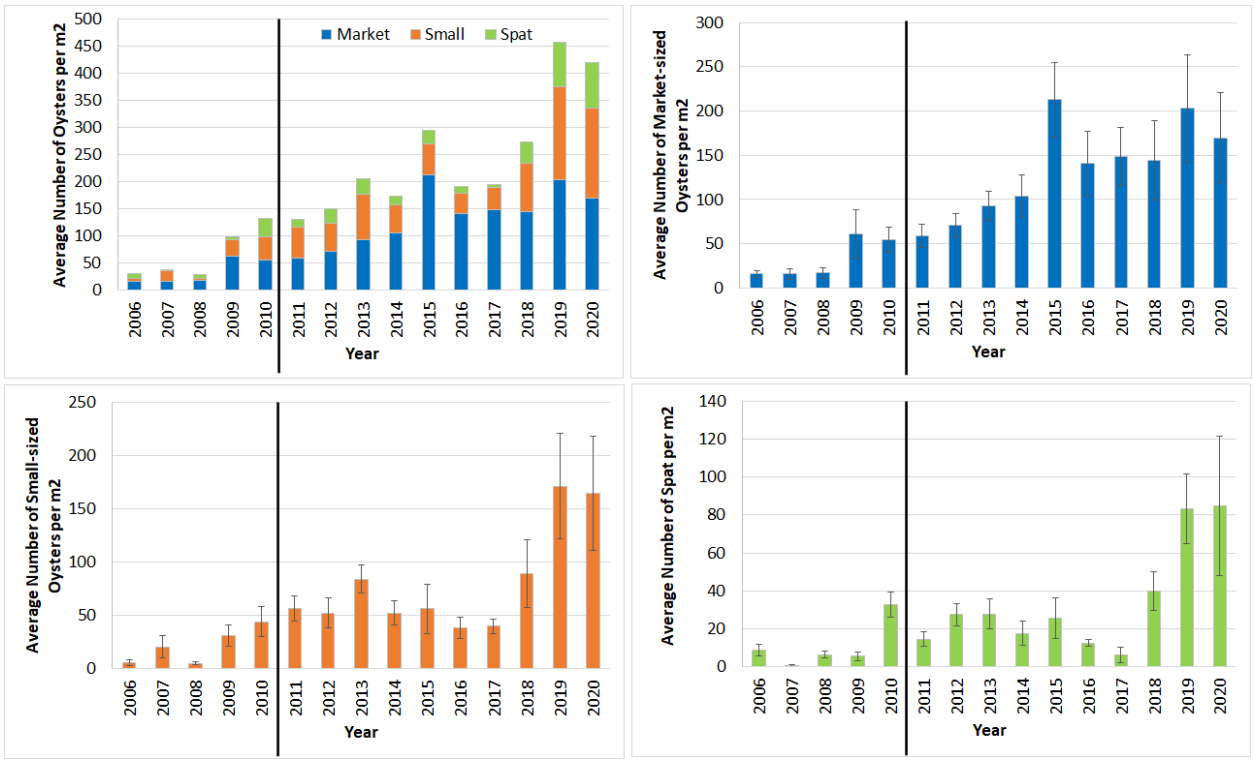

Figure A.27-3. Average number of live oysters per square meter by size class in the Nanticoke River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

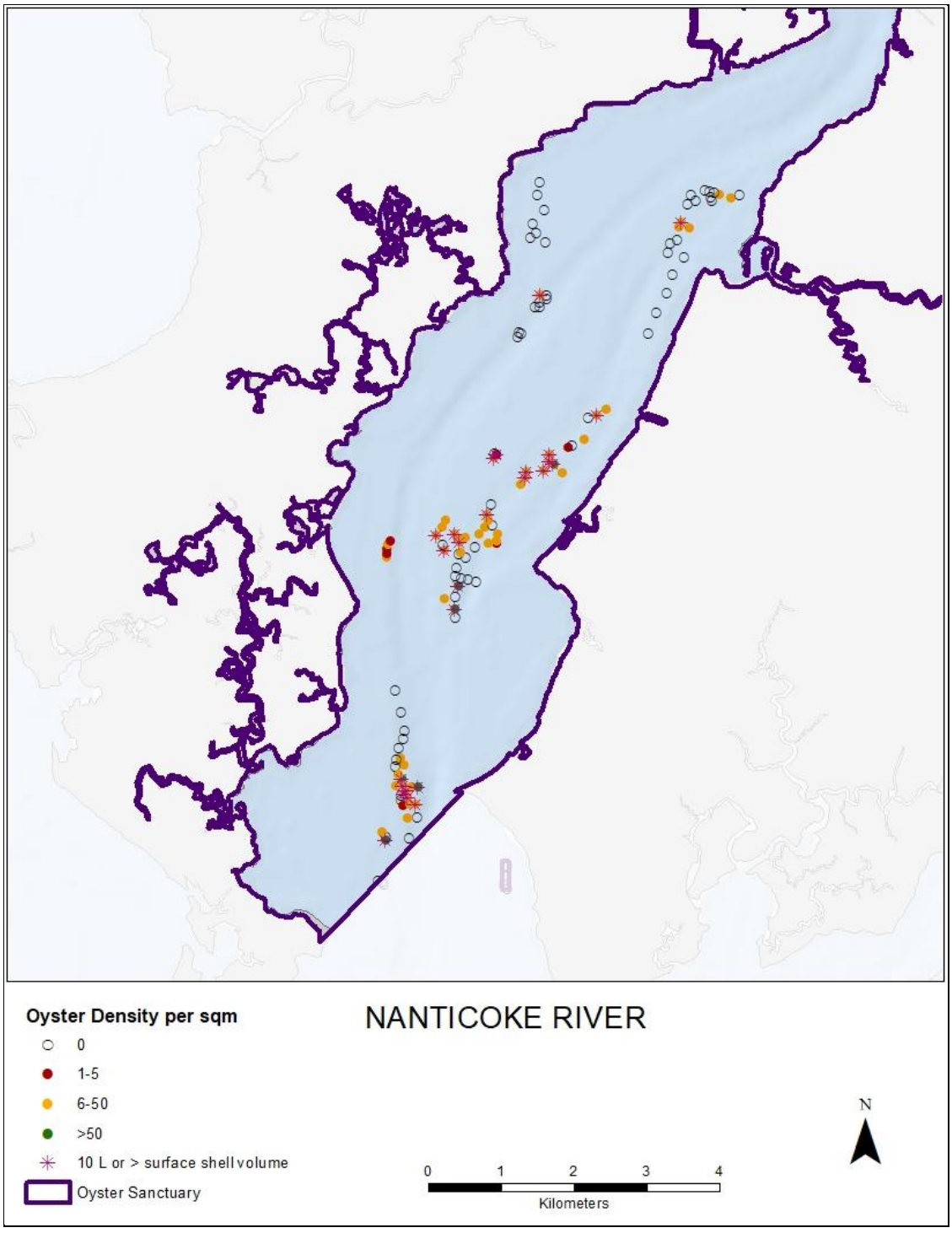

Figure A.27-4. Map of 2018 oyster density in the Nanticoke River Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

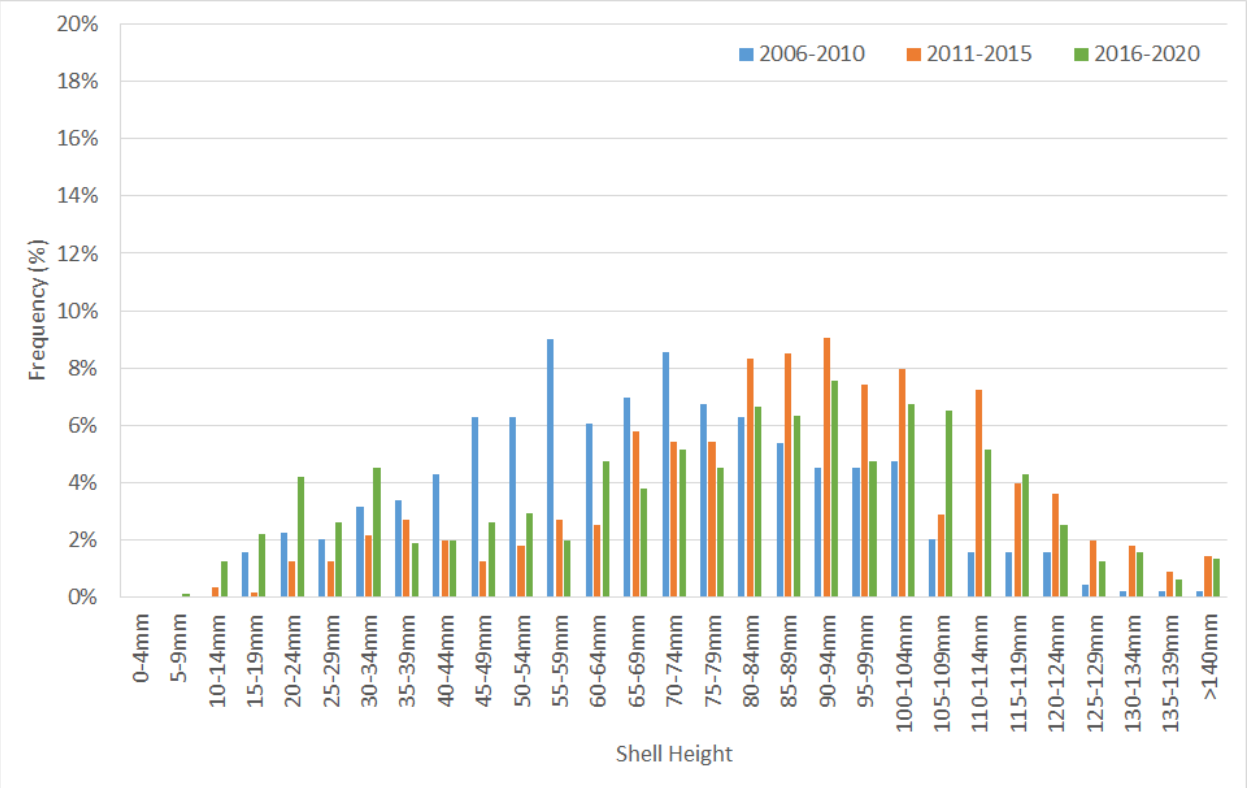

Figure A.27-5. Shell height frequencies of live oysters per bushel of material in the Nanticoke River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Wilson Shoal bar.

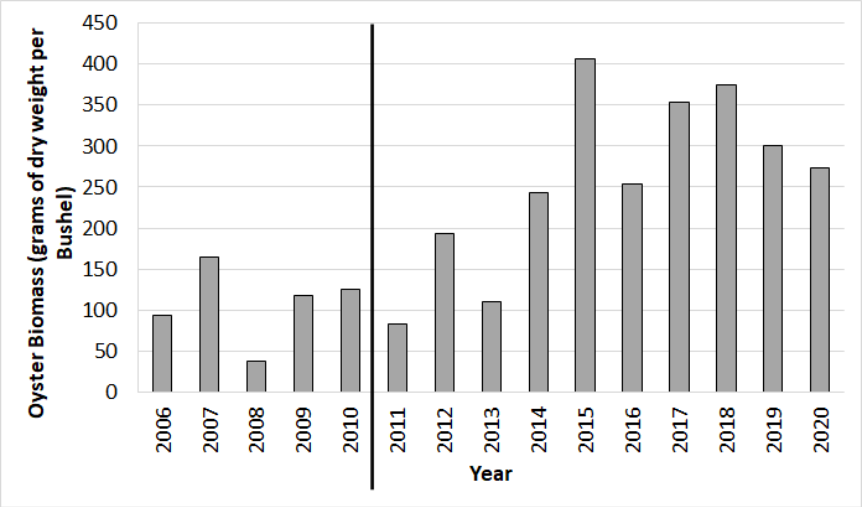

Figure A.27-6. Oyster biomass (grams of dry weight per bushel of material) in the Nanticoke River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Wilson Shoal bar. Black line indicates the date the sanctuary was established.

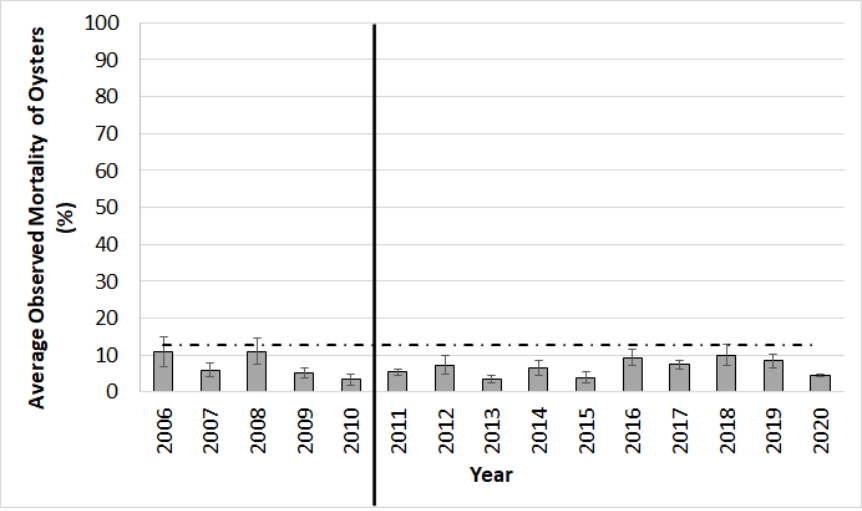

Figure A.27-7. Average annual observed mortality of market-sized and small-sized oysters in Nanticoke River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

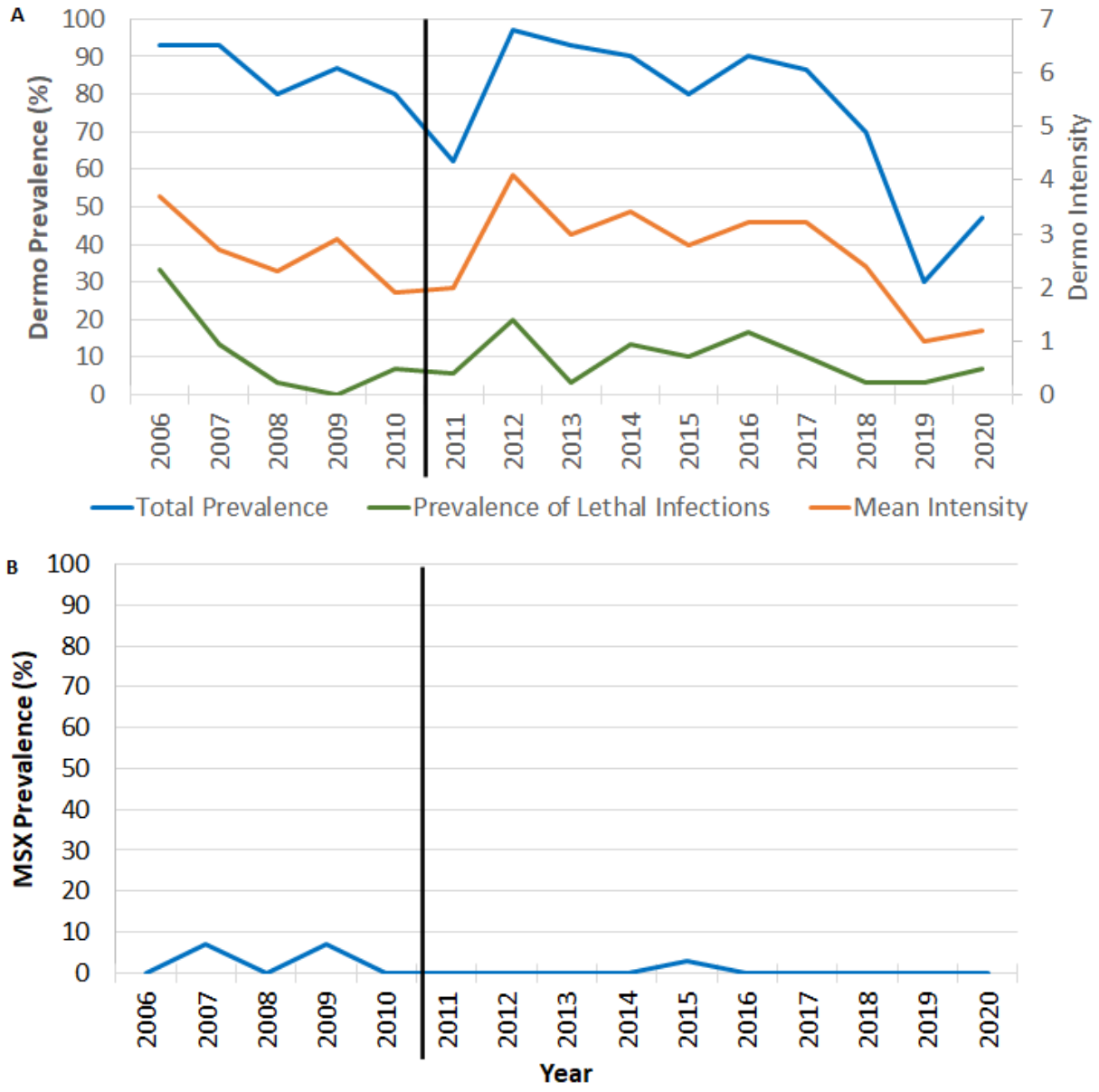

Figure A.27-8. Oyster disease prevalence and intensity in the Nanticoke River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Wilson Shoal bar. Black line denotes the date the sanctuary was established.

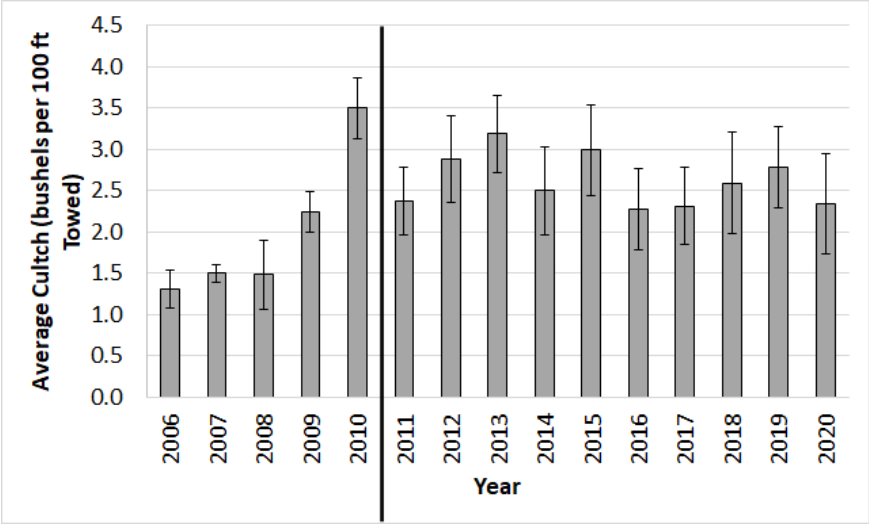

Figure A.27-9. Average cultch (live and dead oysters and loose shell) in the Nanticoke River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

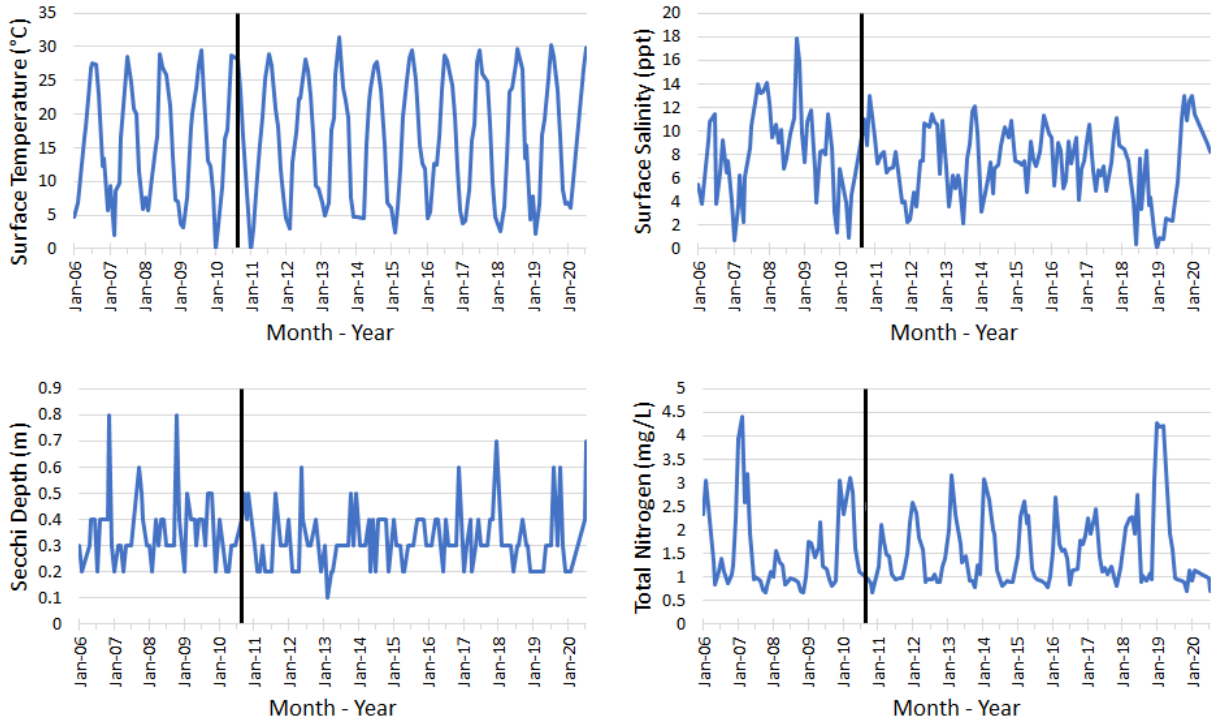

Figure A.27-10. Water quality data collected at Station ET6.2 in Nanticoke River. Black line denotes the date the sanctuary was established.

Section A.28: Neal Addition Sanctuary

The Neal Addition Sanctuary is located in the middle Patuxent River, a medium-salinity (Zone 2) region within NOAA Code 268. The sanctuary was created in 2001 as an Army Corps of Engineers project examining three-dimensional habitat. It encompasses seven acres all of which is one historic oyster bar (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments).

Information available for this sanctuary includes:

- Sanctuary map (Figure A.28-1)
- Bottom types map (Figure A.28-2)
- Summary statistics (Table A.28-1)
- Abundance per year (Figure A.28-3)
- Density Survey (Figure A.28-4)
- Observed mortality (Figure A.28-5)
- Cultch per year (Figure A.28-6)

The Fall Survey sampled one location in this sanctuary. Density of spat and small oysters increased for 2016-2020, while density of market oysters decreased. Observed mortality increased and was above the long-term baywide average for the time period. Observed mortality in 2020 was double that of the previous year. The amount of cultch was unchanged. A population patent tong survey was conducted by the department in 2018 and found an average density of 22.1 oyster per square meter, with a larger population of small-sized oysters than market-sized oysters (14.1 per square meter and 4.6 per square meter respectively). Of the 10 samples taken, 4 had no oysters and 4 had no surface shell volume.

Between 2006 and 2020 after the sanctuary was established, approximately 10 million hatchery spat-on-shell were planted for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

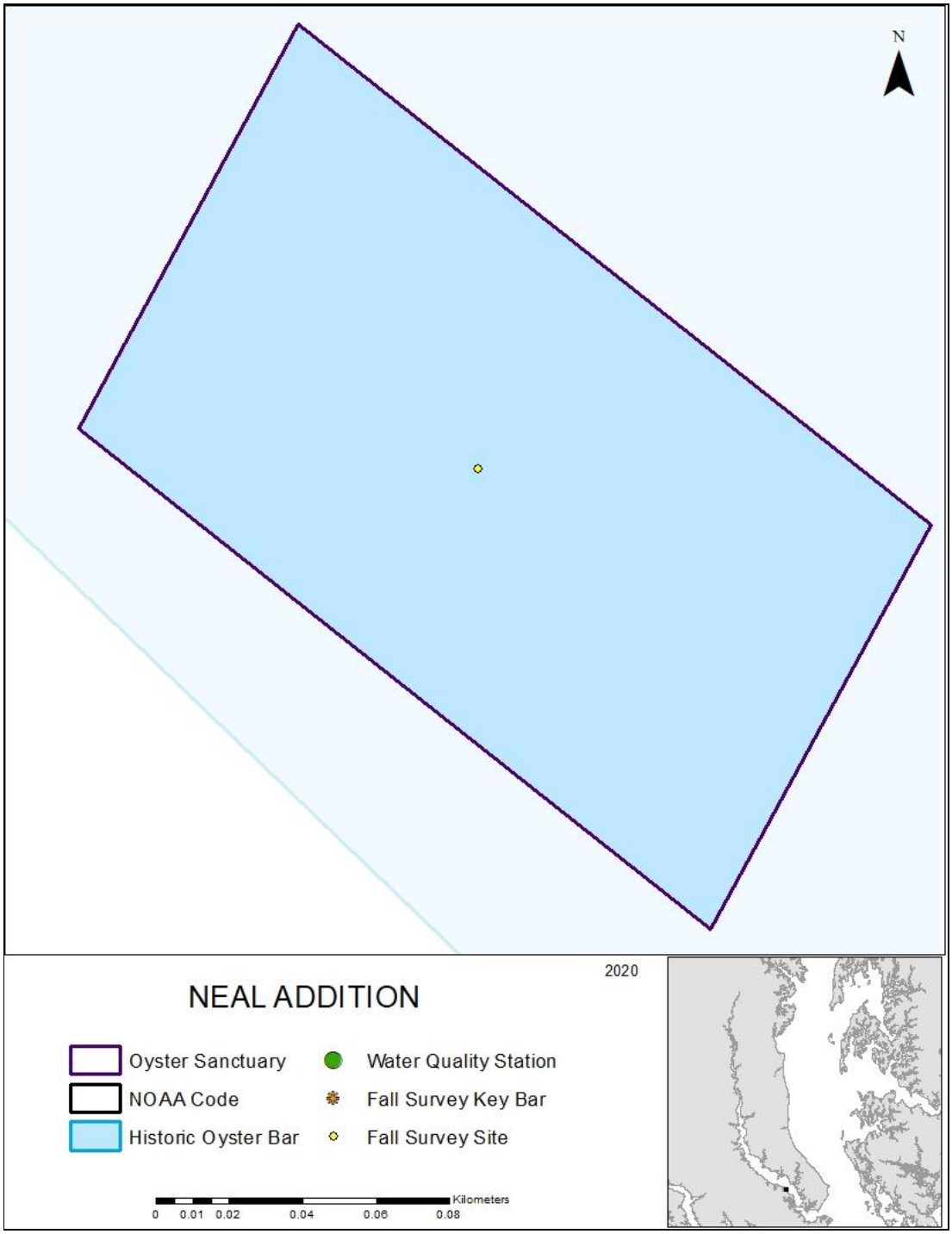

Figure A.28 -1. Neal Addition Sanctuary. Fall Survey sites may not be sampled every year.

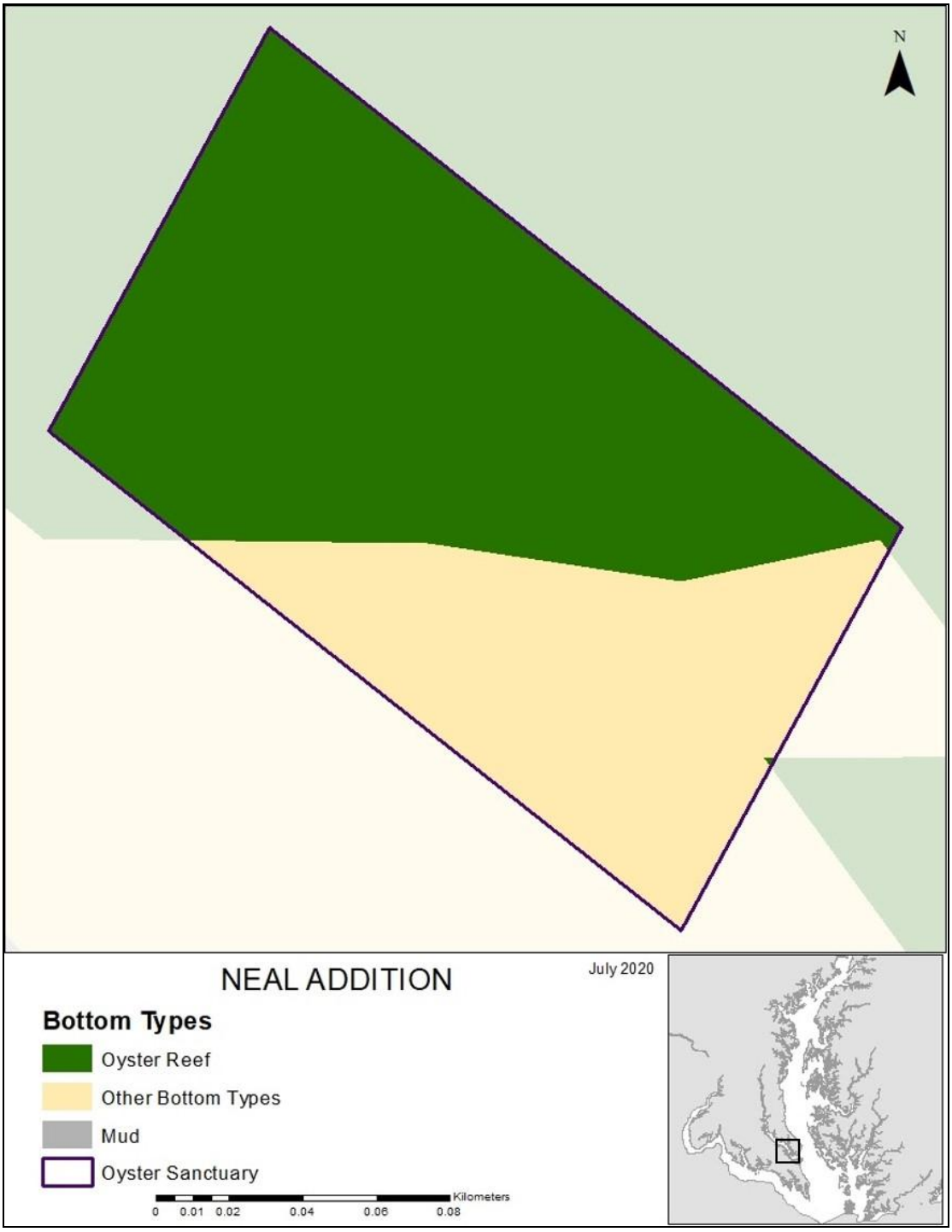

Figure A.28 -2. Neal Addition Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

Table A.28-1. Oyster population characteristics based on the Fall Survey in the Neal Addition Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	6.4 ± 4.4	4.3 ± 3	16.7 ± 15.4
Number of Live Small-Sized Oysters per square meter	154.2 ± 92.1	27.2 ± 11.5	44.2 ± 22.2
Number of Live Market-Sized Oysters per square meter	26.7 ± 9.6	69.3 ± 15.4	58.5 ± 15.6
Live Oyster Biomass (g Dry Weight per Bushel)	ND	ND	ND
Observed Mortality (%)	18 ± 5	12 ± 1	17 ± 3
Cultch (Bushels per 100 ft Towed)	2.2 ± 1.1	1 ± 0.2	1 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

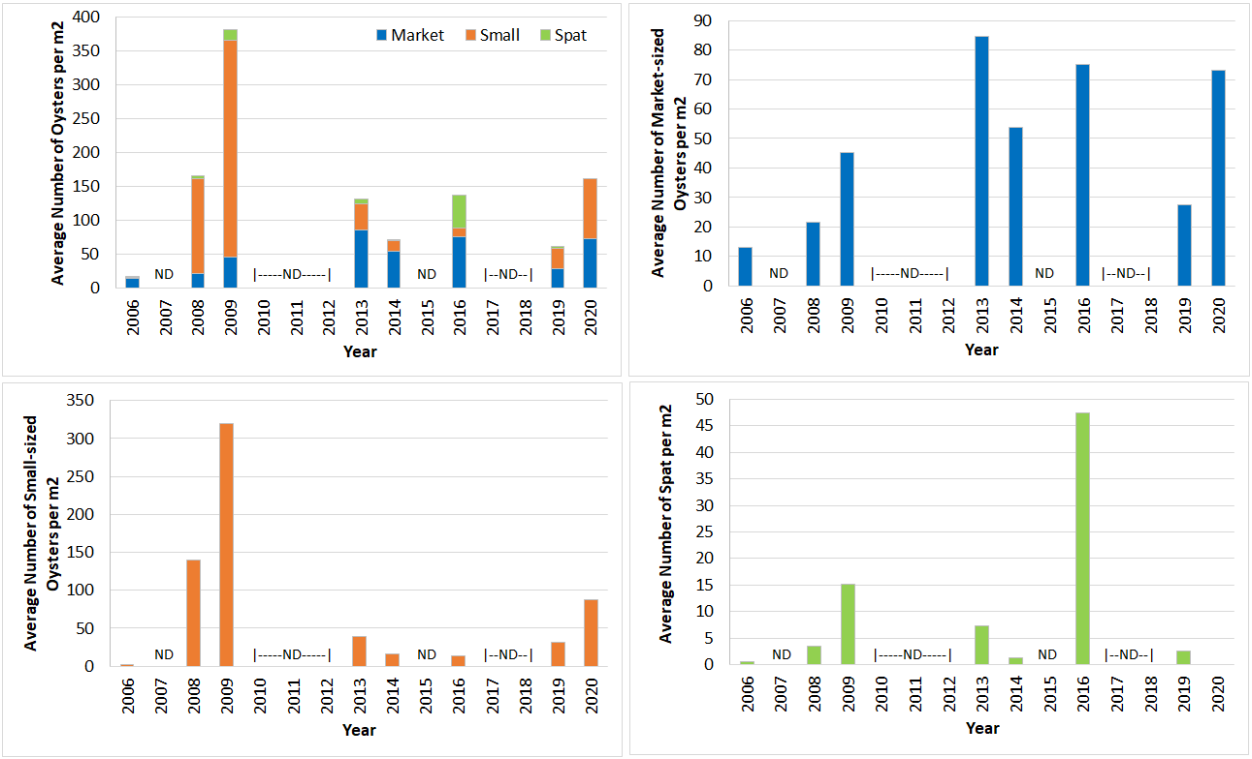

Figure A.28-3. Average number of live oysters per square meter by size class in the Neal Addition Sanctuary. Black line indicates the date the sanctuary was established. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND = No Data.

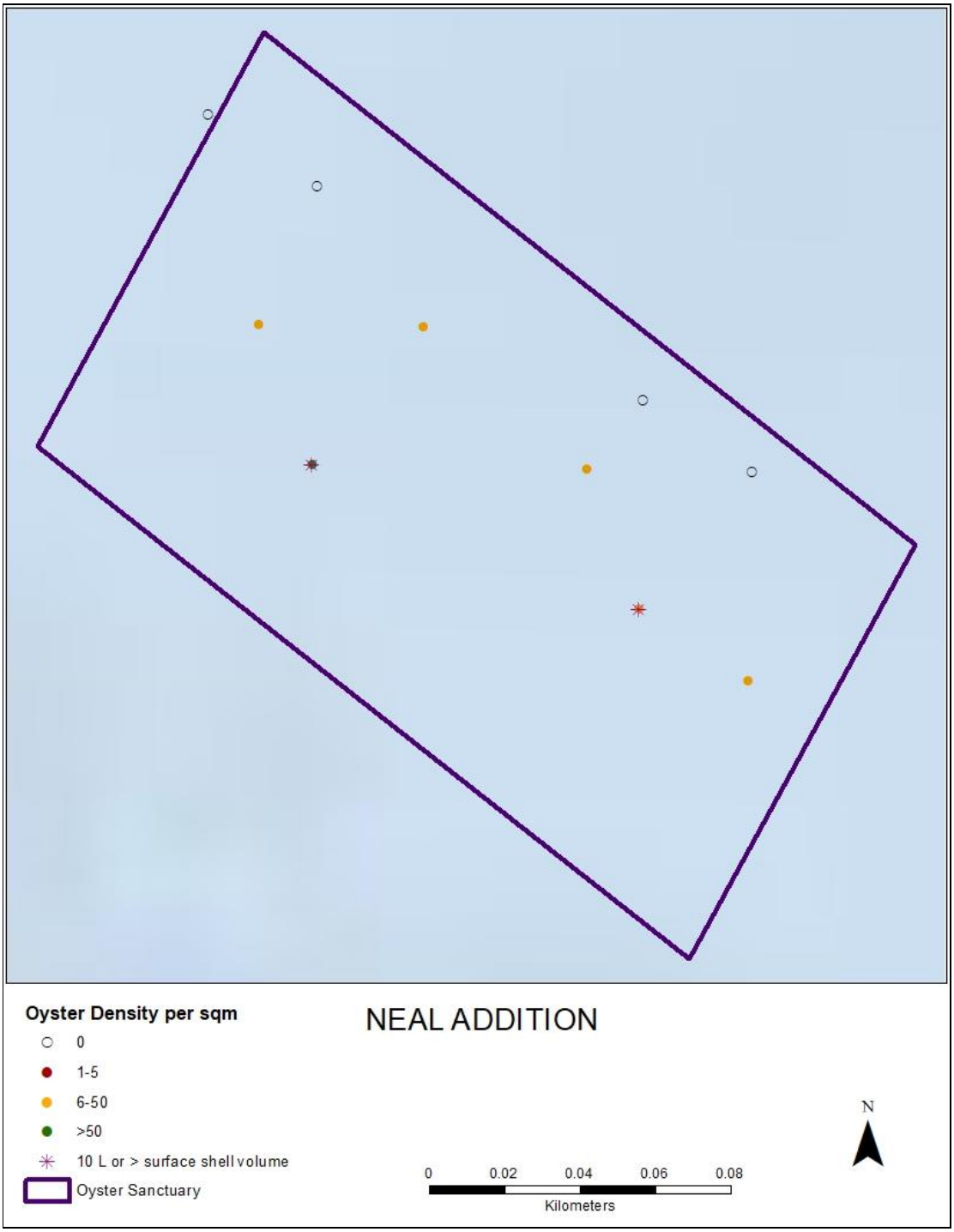

Figure A.28-4. Map of 2018 oyster density in the Neal Addition Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

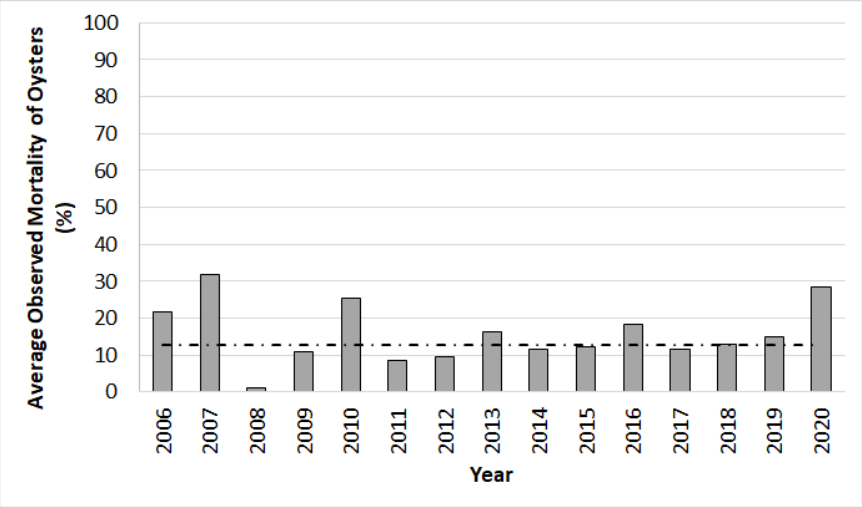

Figure A.28-5. Average annual observed mortality of market-sized and small-sized oysters in Neal Addition Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality.

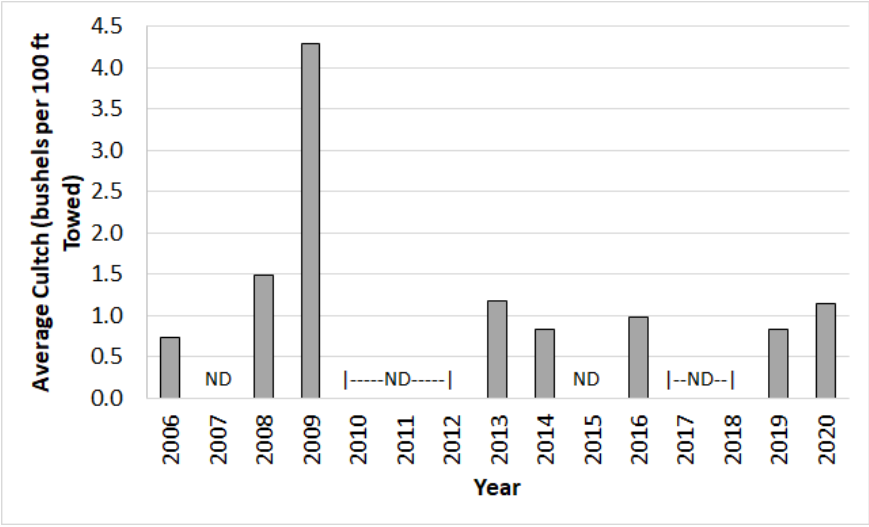

Figure A.28-6. Average cultch (live and dead oysters and loose shell) in the Neal Addition Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. ND = No Data.

Section A.29: Oxford Lab Sanctuary

The Oxford Lab Sanctuary is located in the Tred Avon River, a low-salinity (Zone 1) region within NOAA Code 637. The sanctuary was created in 1961 and encompasses 36 acres of which 3 (7%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar within the sanctuary. This was Maryland's first oyster sanctuary and was created to support the Cooperative Oxford Research Laboratory's oyster research needs.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.29-1)
- Bottom types map (Figure A.29-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. No patent tong population survey has occurred since 2006 by the department. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary. The sanctuary has not received any replenishment or restoration efforts since 2006 with the exception of Marylanders Grow Oysters. Marylanders Grow Oysters, a public outreach program, has planted oysters annually in the sanctuary since 2008.

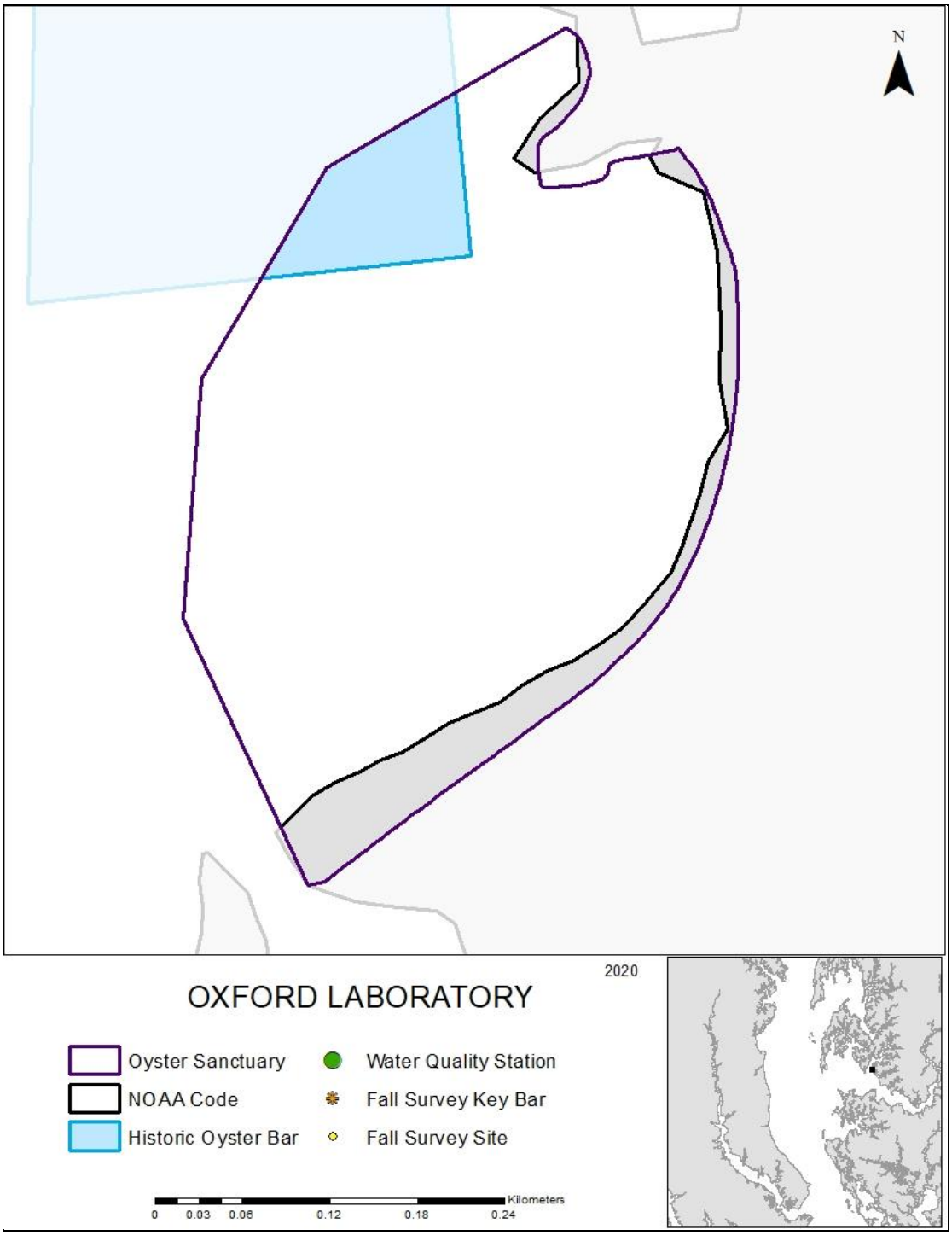

Figure A.29-1. Oxford Lab Sanctuary.

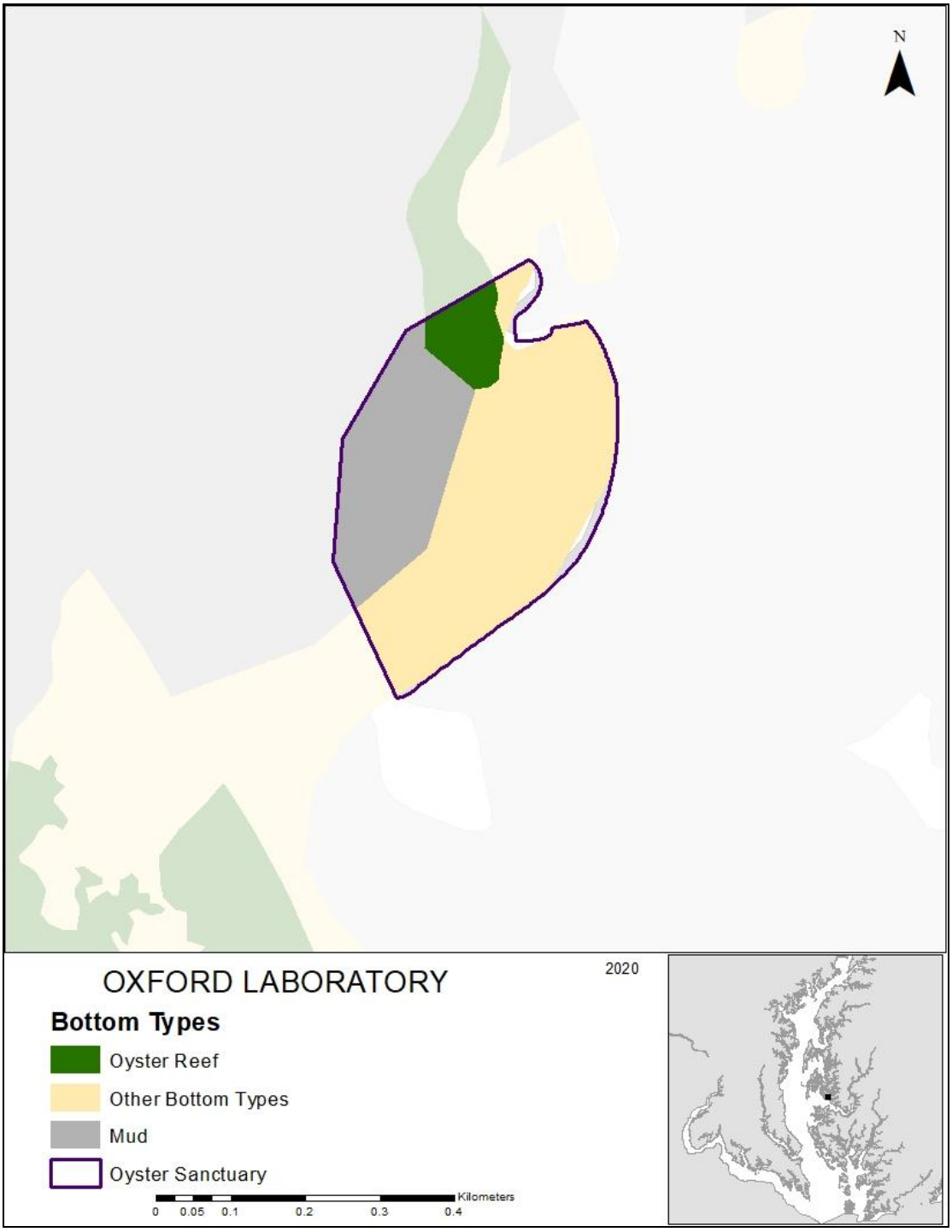

Figure A.29 -2. Oxford Lab Sanctuary bottom types. Data from NOAA Chesapeake Bay Office in 2010.

Section A.30: Piney Point Sanctuary

The Piney Point Sanctuary is located in St. George Creek, a low-salinity (Zone 1) tributary of the lower Potomac River. The sanctuary was created in 1986 to support the Piney Point Aquaculture Center's logistical and research needs and encompasses 13 acres in which there is no historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments).

Information available for this sanctuary includes:

- Sanctuary map (Figure A.30-1)
- Bottom types map (Figure A.30-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. No patent tong population survey has occurred since 2006 by the department. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

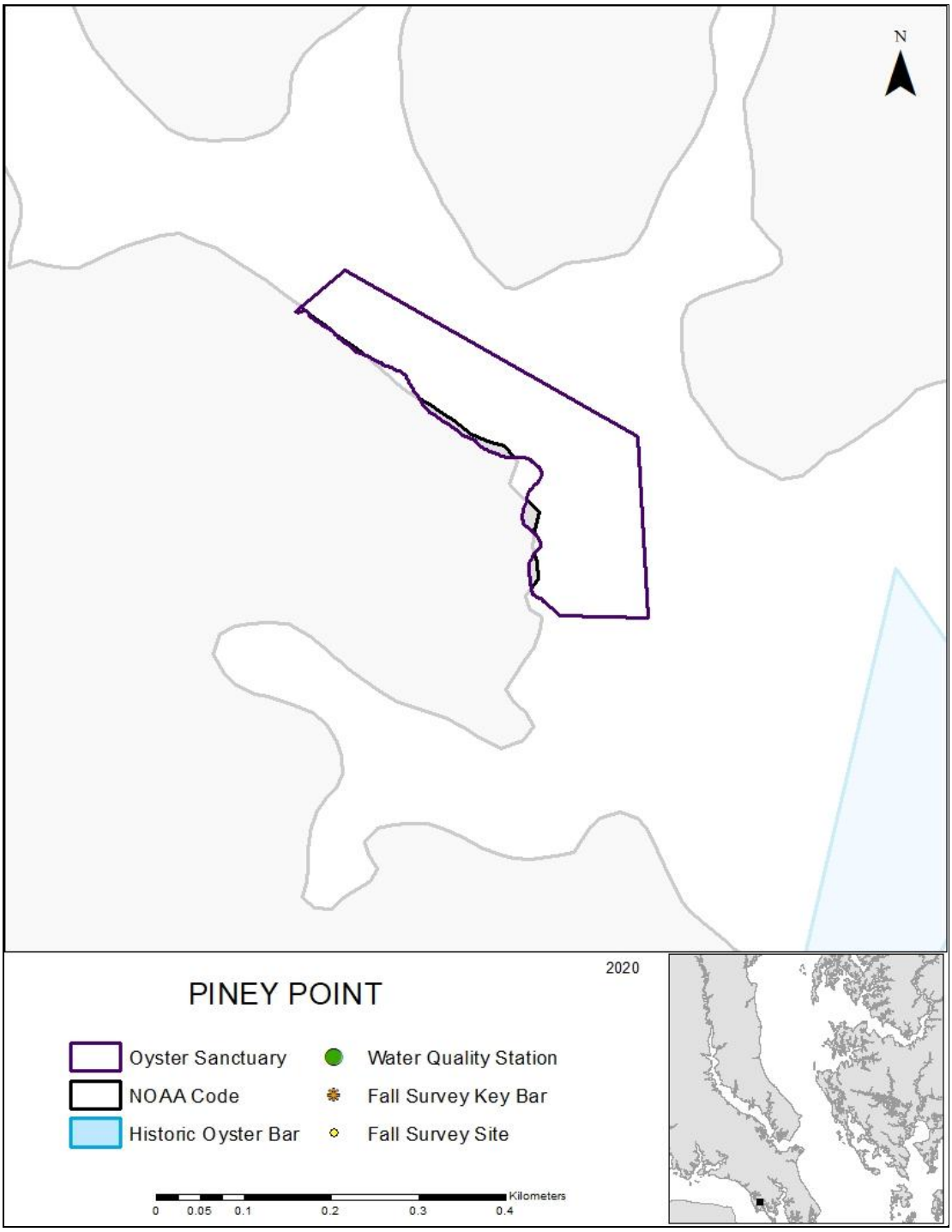

Figure A.30-1. Piney Point Sanctuary.

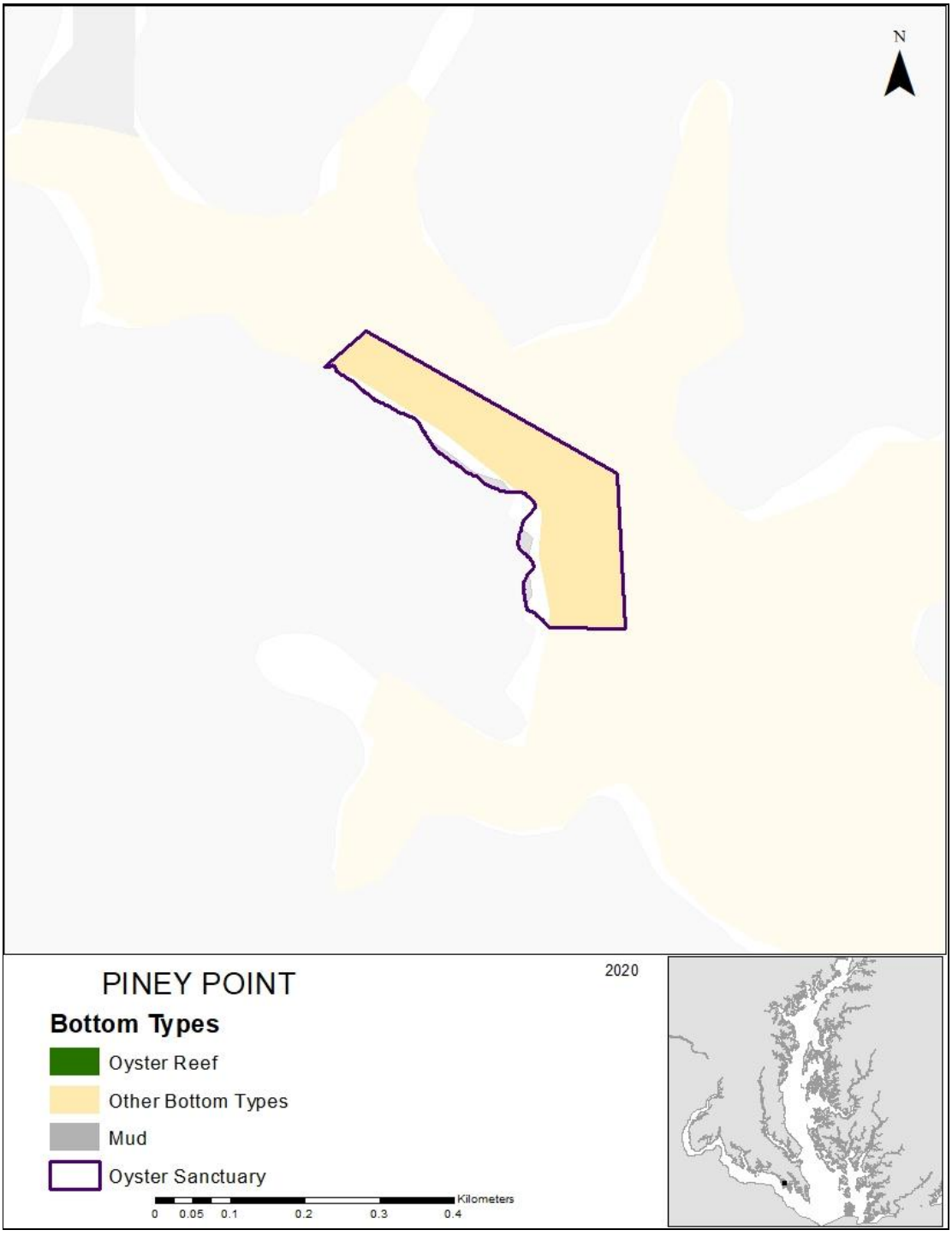

Figure A.30-2. Piney Point Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

Section A.31: Plum Point Sanctuary

The Plum Point Sanctuary is located in the middle-western portion of Maryland's Chesapeake Bay along the Calvert County shore in a medium-salinity (Zone 2) region within NOAA Code 027. The sanctuary was created in 1999 and encompasses 6,209 acres of which 4,405 (71%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Six historic oyster bars are within the sanctuary[61]. The sanctuary was one of four sanctuaries created in 1999 when legislation was passed opening up new areas to power dredging of oysters.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.31-1)
- Bottom types map (Figure A.31-2)
- Water Quality (Figure A.31-3)

The Fall Survey has not sampled any oyster bars within this area since 2006. No patent tong population surveys have occurred since 2006 by the department. The sanctuary has not received any replenishment or restoration efforts since 2006, though it has received artificial reef materials under the Maryland Artificial Reef Initiative program.

Continuous water quality monitoring has occurred at station CB4.2W (38.64354; -76.5022). During the 2006-2020 timeline, surface salinity ranged from 2.6 ppt to 17.7 ppt, with the lowest salinity being during the freshet of 2018-2019 and during the high rainfall year of 2011.

[61] See chart 17 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

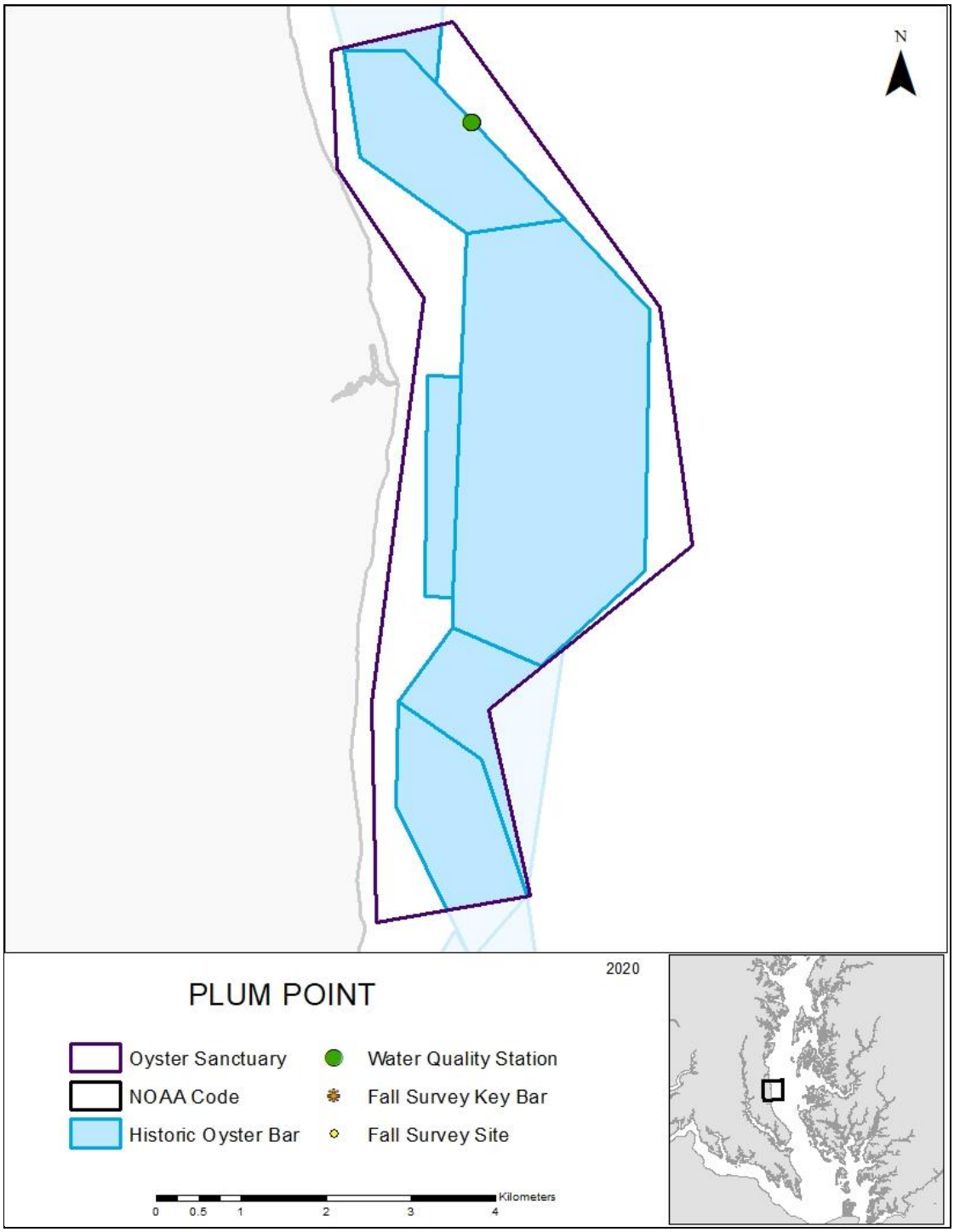

Figure A.31-1. Plum Point Sanctuary.

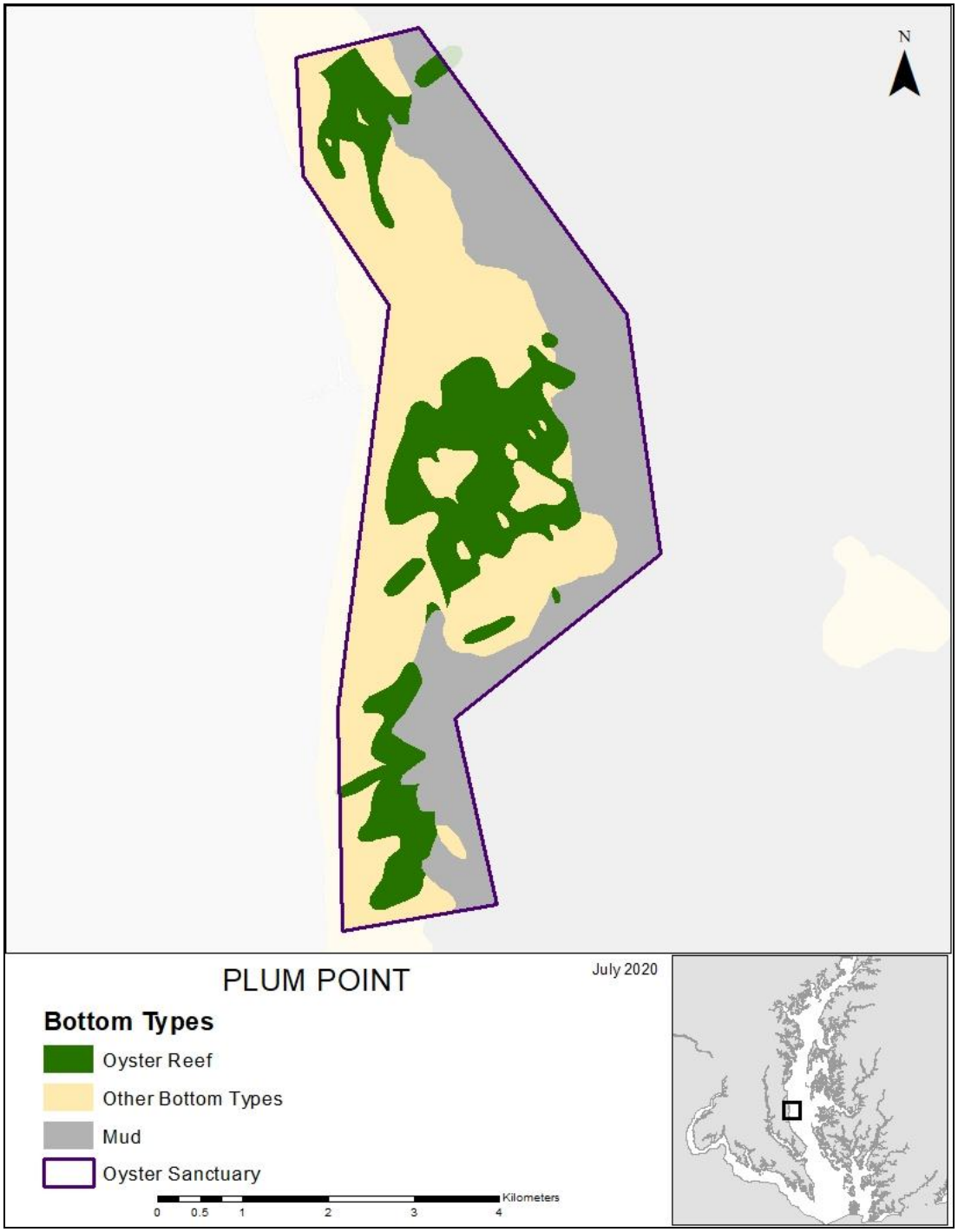

Figure A.31-2. Plum Point Sanctuary bottom types. Data from Maryland Bay Bottom Survey of 1974-1983.

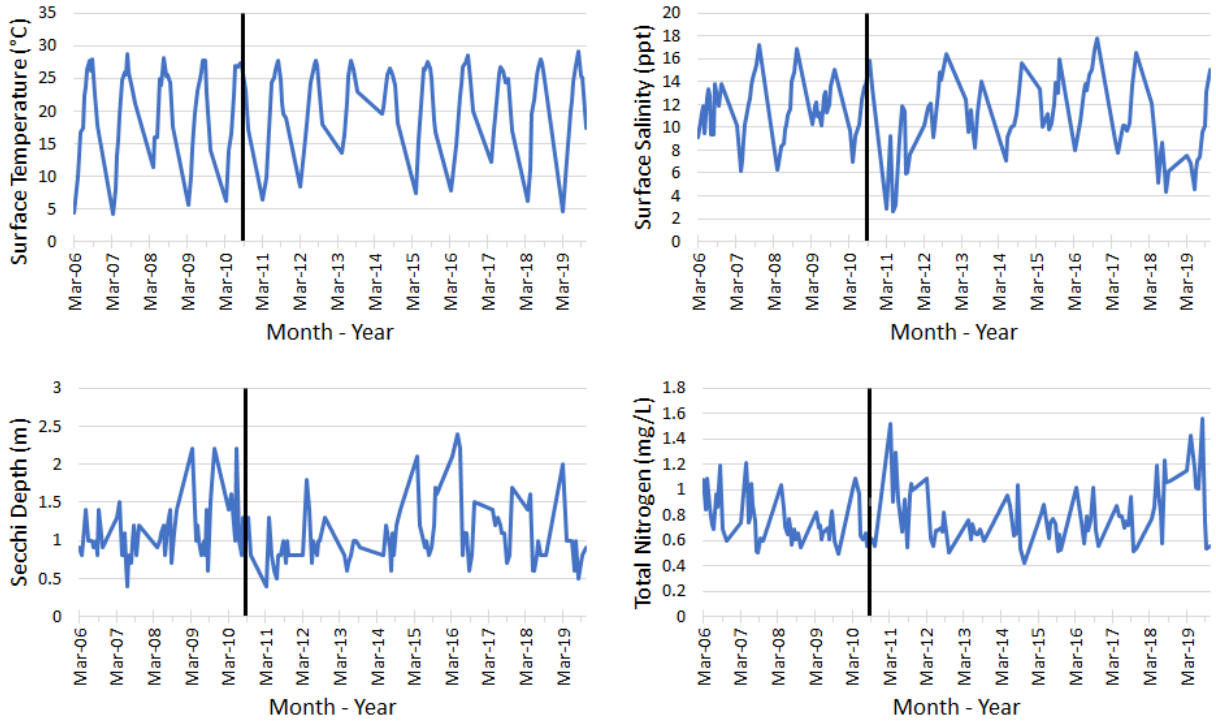

Figure A.31-3. Water quality data collected at Station CB4.2W in Plum Point Sanctuary. Data from Chesapeake Bay Program Data Hub.

Section A.32: Point Lookout Sanctuary

The Point Lookout Sanctuary is located in the lower western portion of Maryland's Chesapeake Bay at the mouth of the Potomac River, a medium-salinity (Zone 2) region within NOAA Code 229. The original sanctuary was 104 acres but was expanded to 399 acres in 2010, of which 396 acres (99%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Thus, the total surface area is 503 acres and the total historic bottom is 500 acres. There are two historic oyster bars within the sanctuary[62]. The sanctuary was one of four sanctuaries created in 1999 when legislation was passed opening up new areas to power dredging of oysters

Information available for this sanctuary includes:

- Sanctuary map (Figure A.32-1)
- Bottom types map (Figure A.32-2)
- Summary statistics (Table A.32-1)
- Abundance per year (Figure A.32-3)
- Density Survey (Figure A.32-4)
- Shell height frequencies (Figure A.32-5)
- Biomass per year (Figure A.32-6)
- Observed mortality (Figure A.32-7)
- Dermo and MSX per year (Figure A.32-8)
- Cultch per year (Figure A.32-9)

The Fall Survey sampled one or two sites in this sanctuary annually. The density of spat, small and market oysters increased in 2016-2020. Biomass also increased, while observed mortality declined but remained above the long-term baywide average. Cultch remained unchanged. The mean size for 2016-2020 was 63 mm. A population patent tong survey was conducted by the department in 2014[63] and 2020. Results indicate an increase in population from the 2014 survey with an average density of 5.3 per square meter, with more small-sized oysters than market-sized oysters (3.1 per square meter and 1.5 per square meter respectively). Of the 148 samples taken, 78 had no oysters and 63 had no surface shell volume.

No restoration planting activities have occurred in this sanctuary since 2006. We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[62] See chart 40 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[63] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

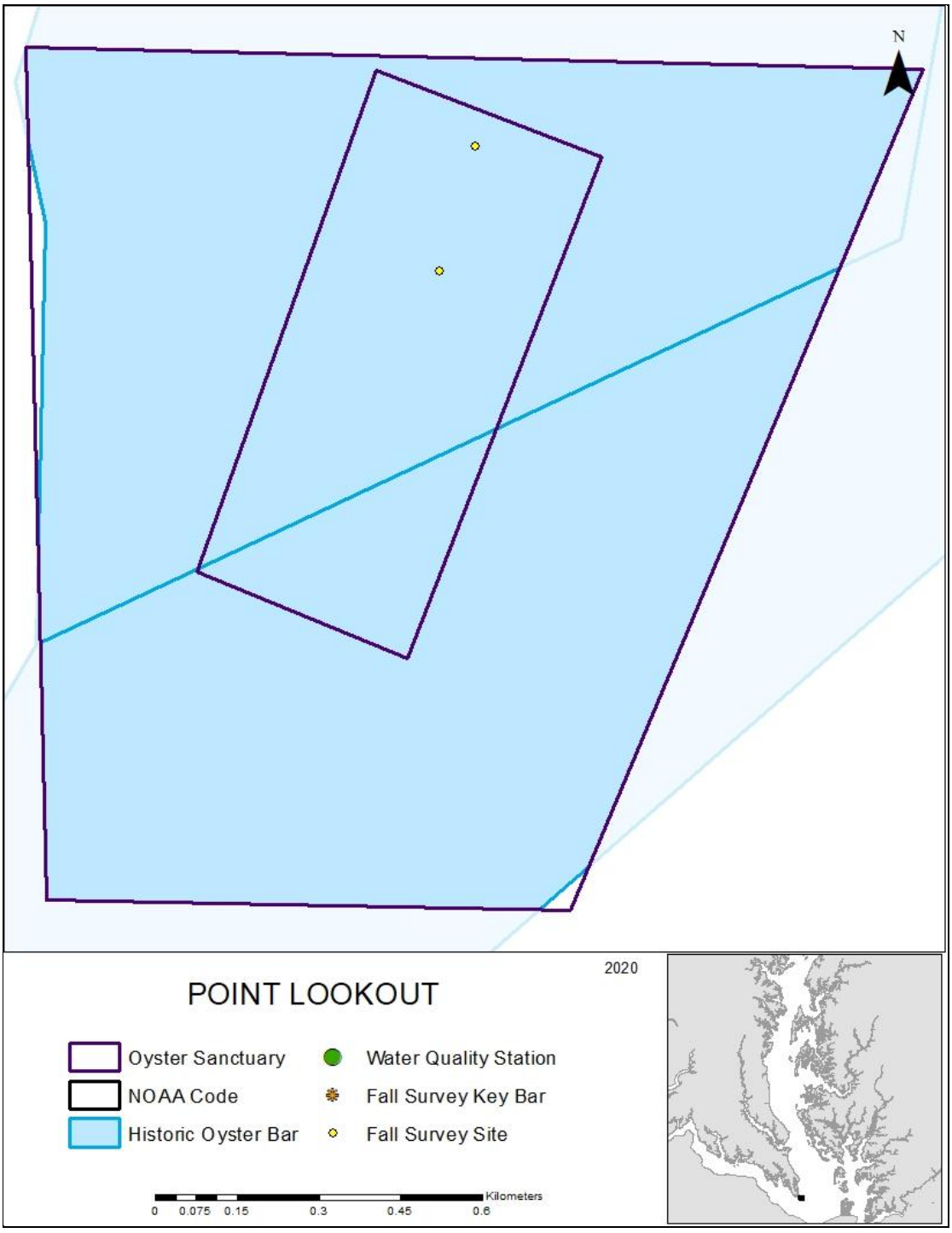

Figure A.32-1. Point Lookout Sanctuary. Fall Survey sites may not be sampled every year.

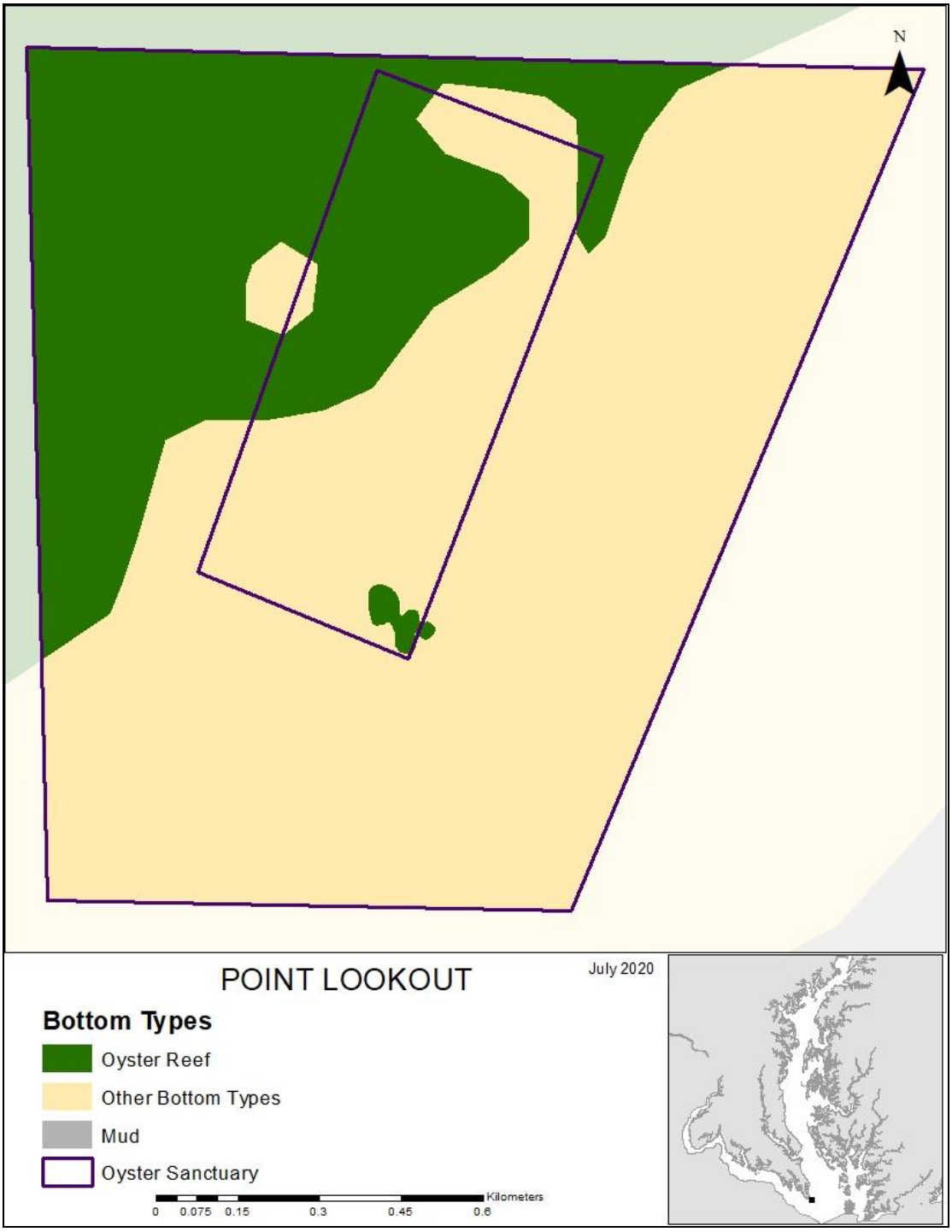

Figure A.32-2. Point Lookout Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Table A.32-1. Oyster population characteristics based on the Fall Survey in the Point Lookout Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 6	5 / 5
Number of Live Spat Oysters per square meter	4.8 ± 2	31.6 ± 15.6	40.6 ± 19.5
Number of Live Small-Sized Oysters per square meter	13.1 ± 3	24.6 ± 5.8	60.7 ± 11.9
Number of Live Market-Sized Oysters per square meter	17.1 ± 2.6	41.6 ± 8.7	61.8 ± 15.8
Live Oyster Biomass (g Dry Weight per Bushel)	207 ± 5	215 ± 36	342 ± 21
Observed Mortality (%)	23 ± 2	17 ± 2	15 ± 3
Cultch (Bushels per 100 ft Towed)	0.5 ± 0.1	0.8 ± 0.2	0.7 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

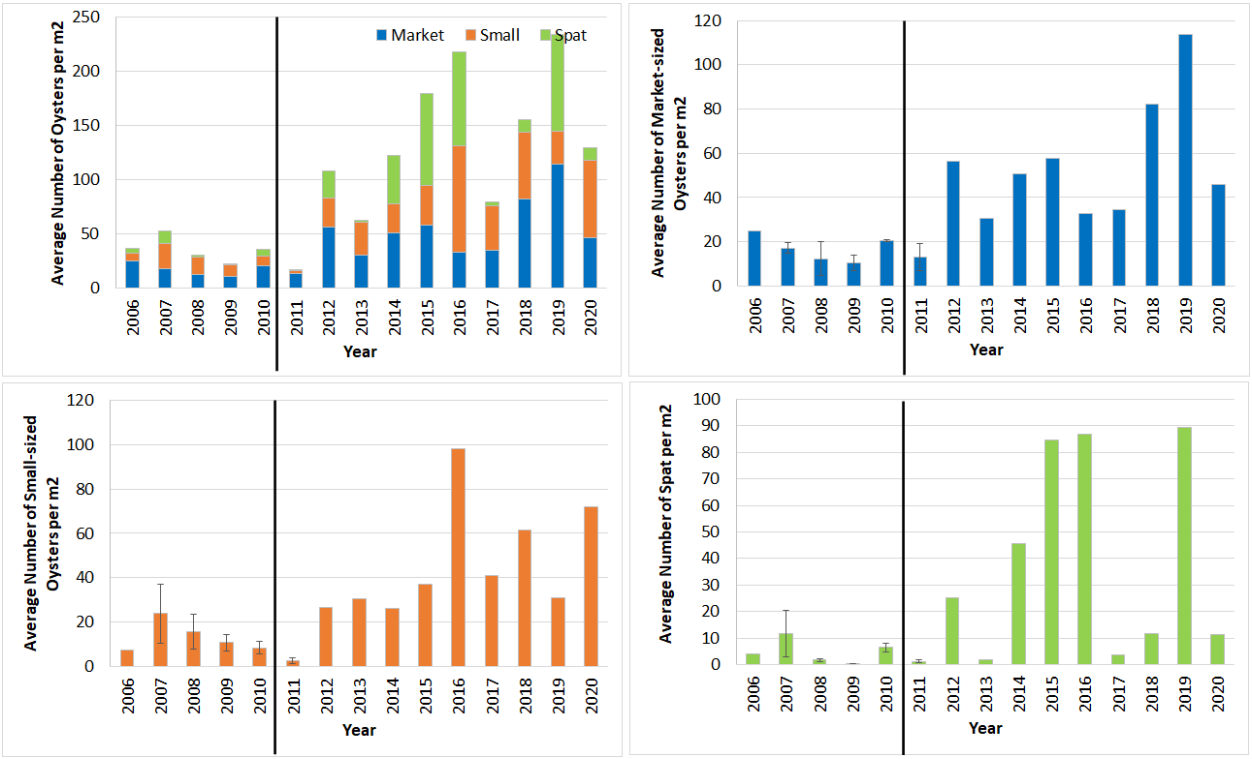

Figure A.32-3. Average number of live oysters per square meter by size class in the Point Lookout Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

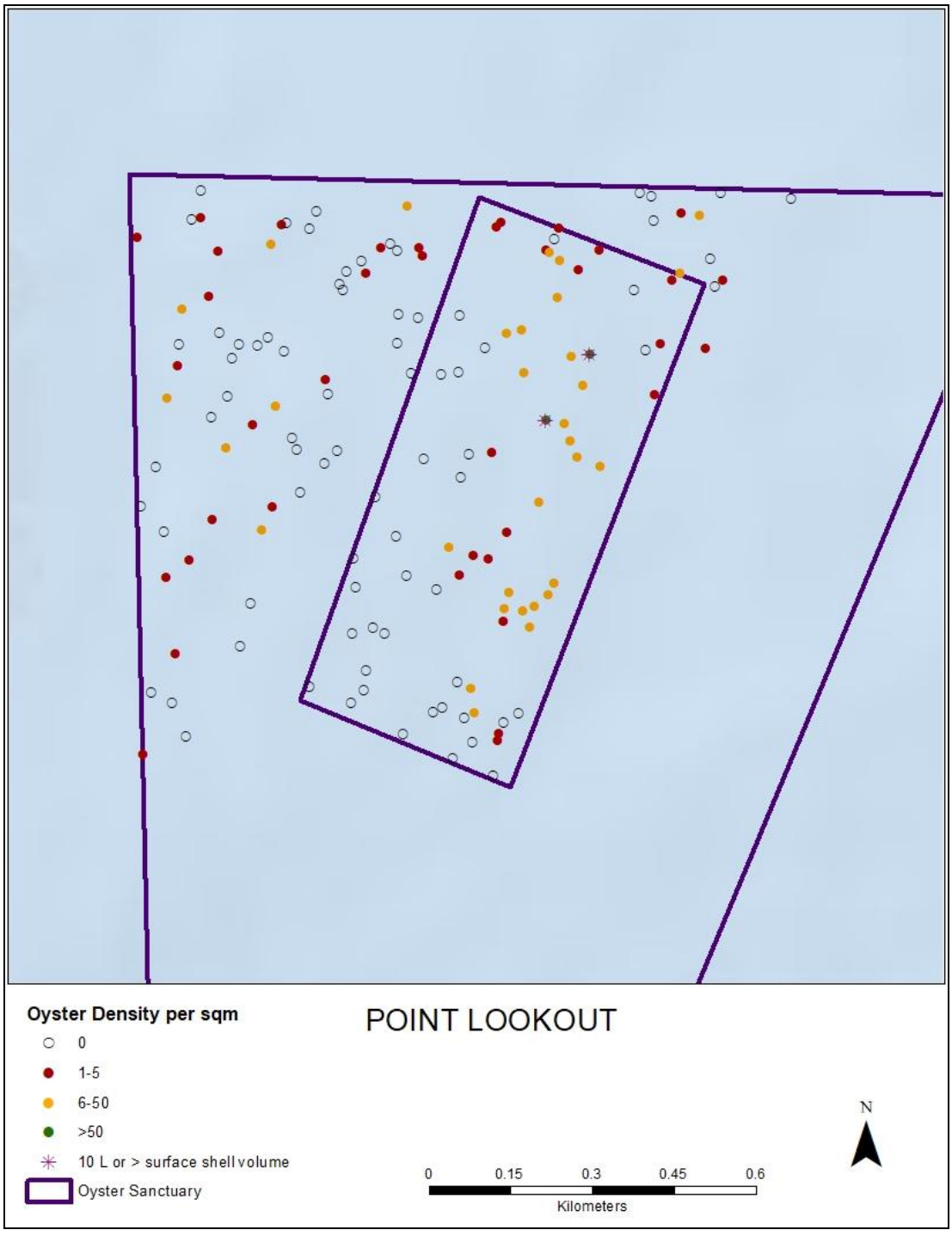

Figure A.32-4. Map of 2020 oyster density in the Point Lookout Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

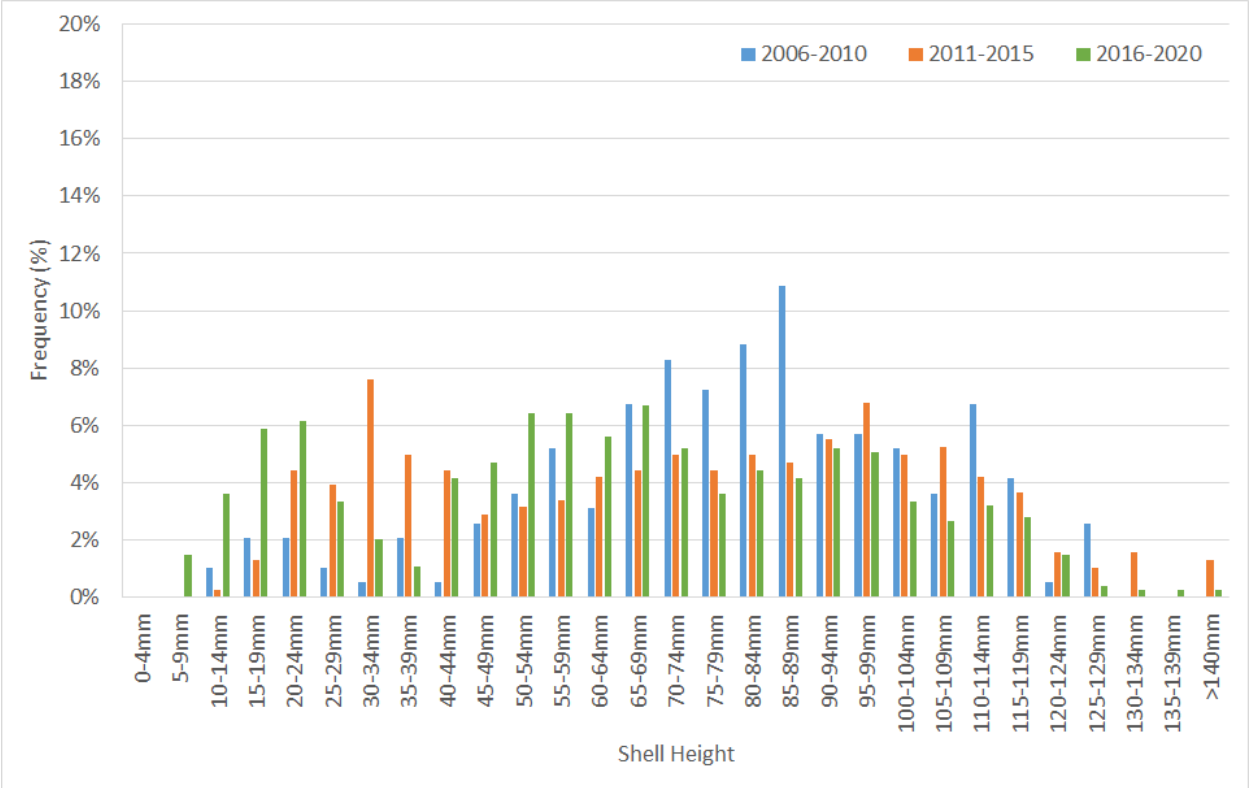

Figure A.32-5. Shell height frequencies of live oysters per bushel of material in the Point Lookout Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Point Lookout bar. No data was collected in 2006, 2008, and 2009.

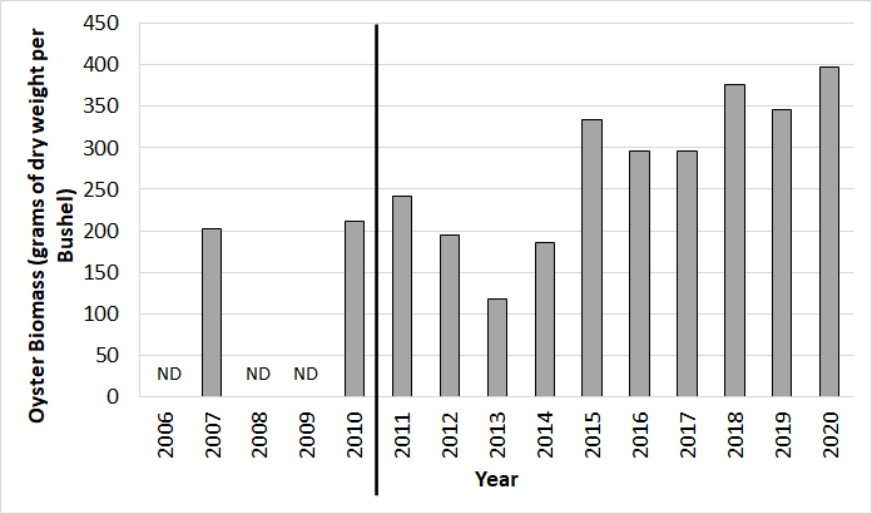

Figure A.32-6. Oyster biomass (grams of dry weight per bushel of material) in the Point Lookout Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Point Lookout bar. Black line indicates the date the sanctuary was established. ND = No Data.

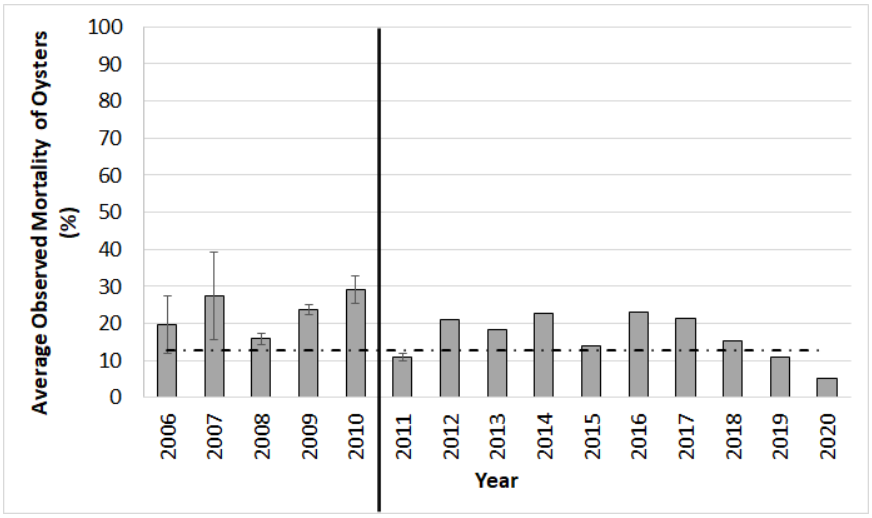

Figure A.32-7. Average annual observed mortality of market-sized and small-sized oysters in Point Lookout Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

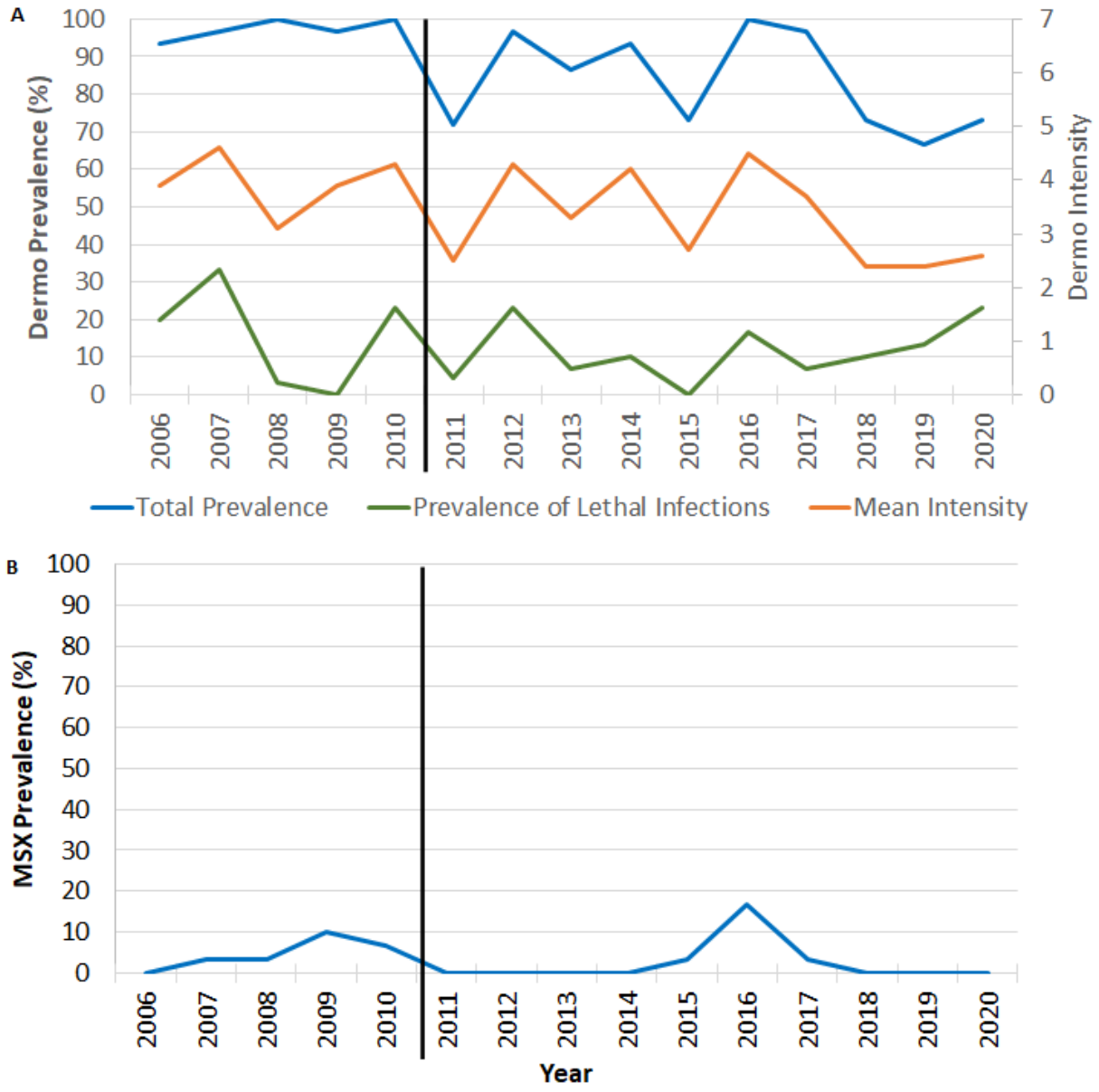

Figure A.32-8. Oyster disease prevalence and intensity in the Point Lookout Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Point Lookout bar. Black line denotes the date the sanctuary was established.

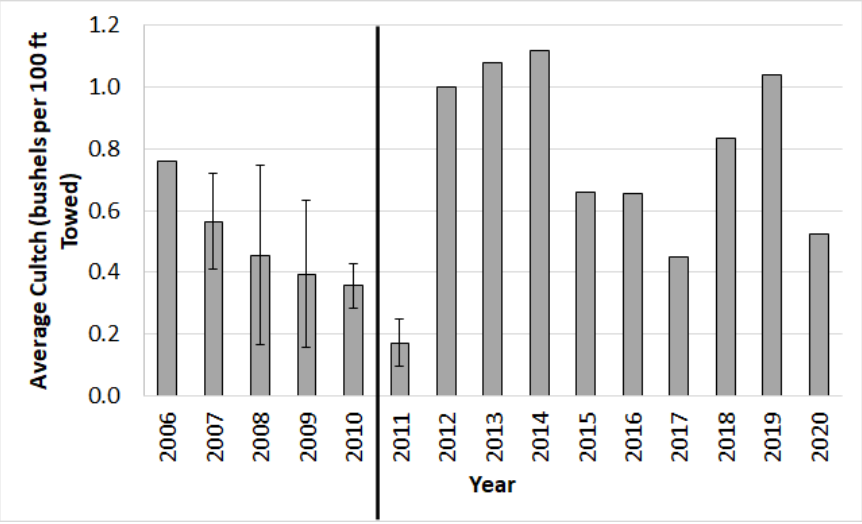

Figure A.32-9. Average cultch (live and dead oysters and loose shell) in the Point Lookout Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.33: Poplar Island Sanctuary

The Poplar Island Sanctuary is located in the central portion of Maryland's Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Code 027. The sanctuary was created in 2003 and encompasses seven acres all of which is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). The sanctuary is located in the southwest corner of the historic Poplar Island bar.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.33-1)
- Bottom types map (Figure A.33-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. No patent tong population survey has occurred since 2006 by the department. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

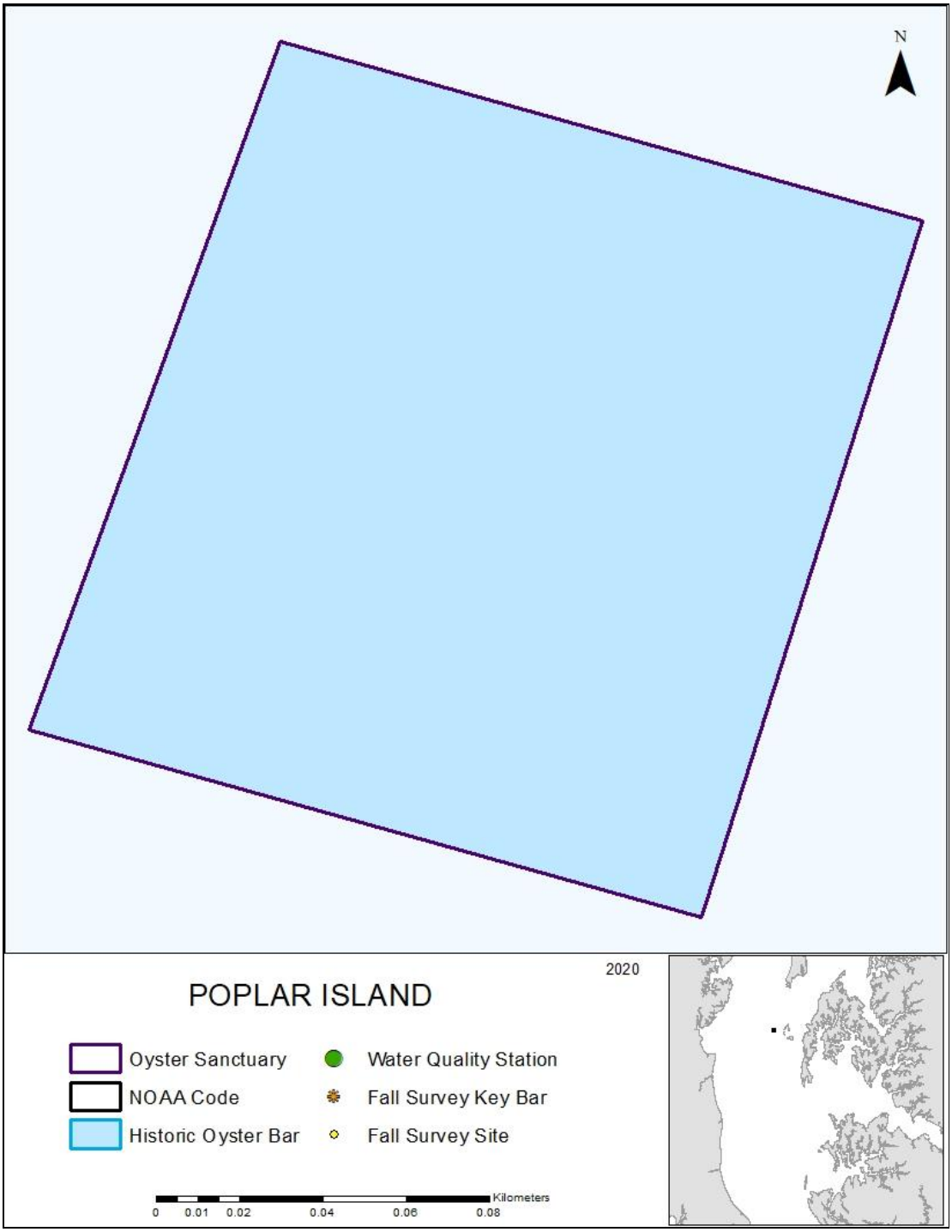

Figure A.33 -1. Poplar Island Sanctuary.

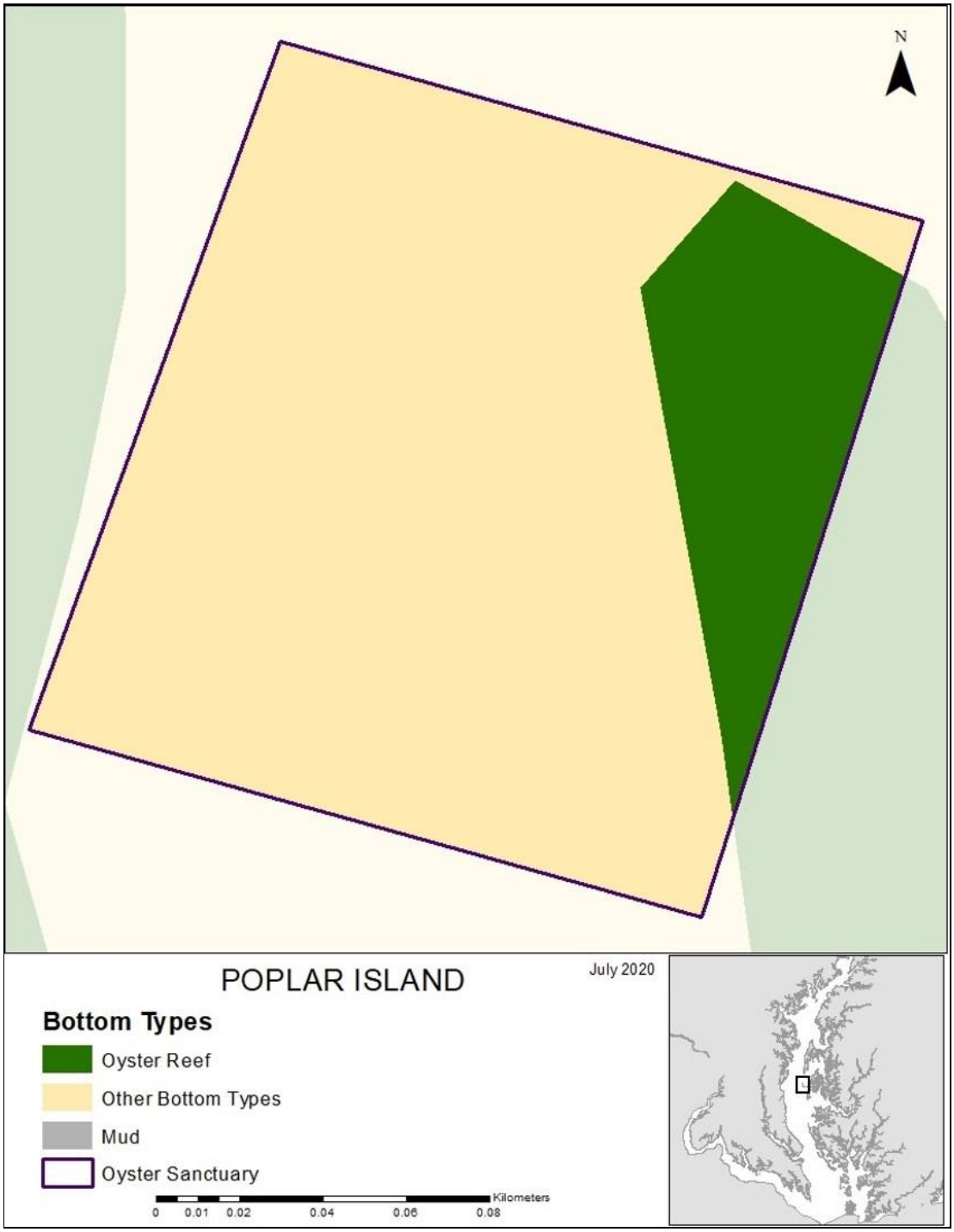

Figure A.33 -2. Poplar Island Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Section A.34: Prospect Bay Sanctuary

The Prospect Bay Sanctuary is located in Eastern Bay, a medium-salinity (Zone 2) region within NOAA Code 039. The sanctuary was created in 2010 and encompasses 1,478 acres of which 1,061 (72%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are three historic oyster bars within the sanctuary[64].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.34-1)
- Bottom types map (Figure A.34-2)
- Density Survey (Figure A.34-3)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in sanctuary in 2013[65] and in 2020. The 2020 patent tong survey found an average of 0.5 per square meter with a larger number of market-sized oysters than small-sized oysters (0.42 per square meter and 0.06 per square meter respectively). This was slightly lower than the average density of 0.95 per square meter in 2013. Of the 105 samples taken, 92 had no oysters and 39 had no surface shell volume.

The area has not received any replenishment plantings from 2006 to 2010. The area has received one restoration planting in 2011 where eight million hatchery spat-on-shell were planted on 21 acres. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[64] See chart 11 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[65] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

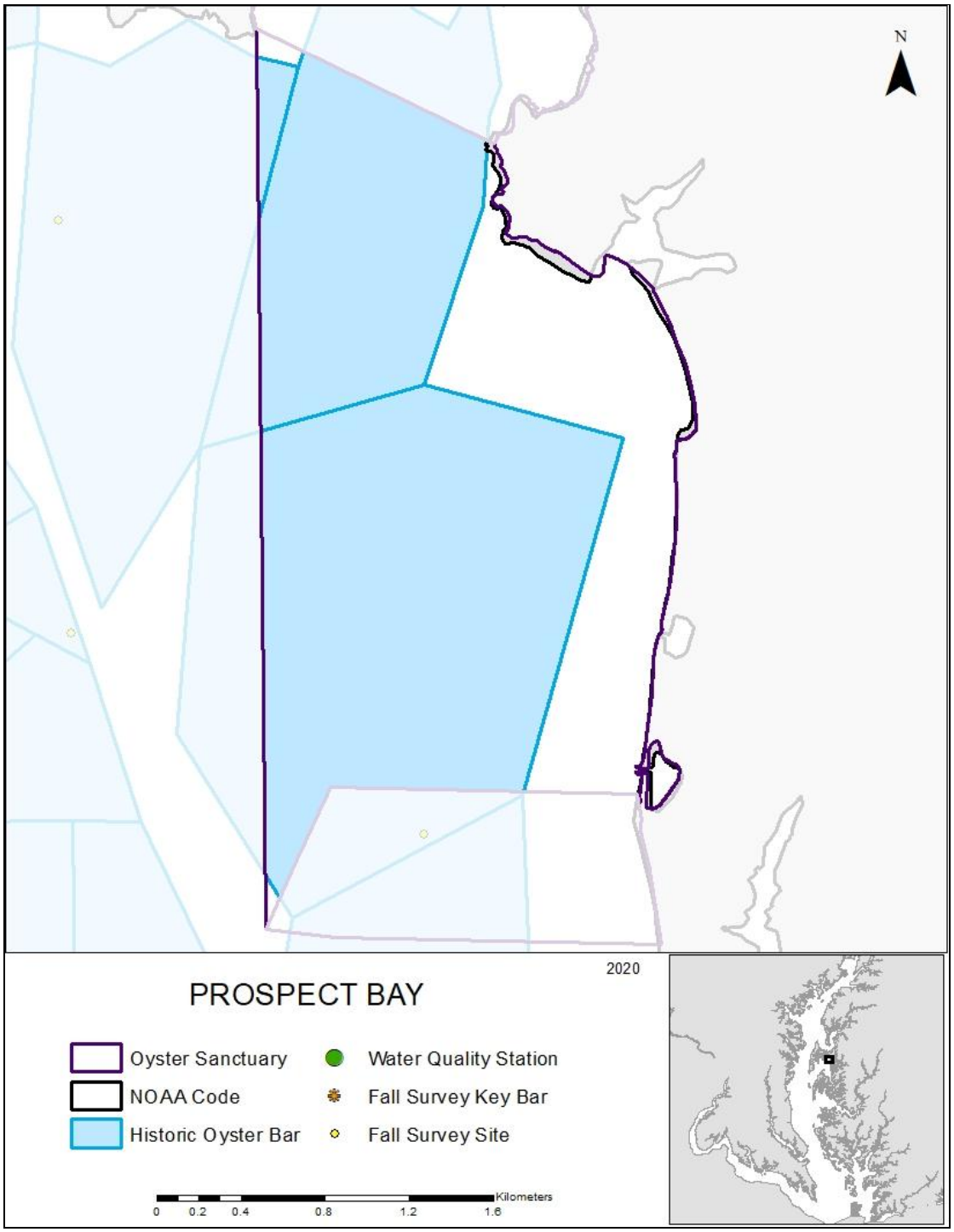

Figure A.34 -1. Prospect Bay Sanctuary.

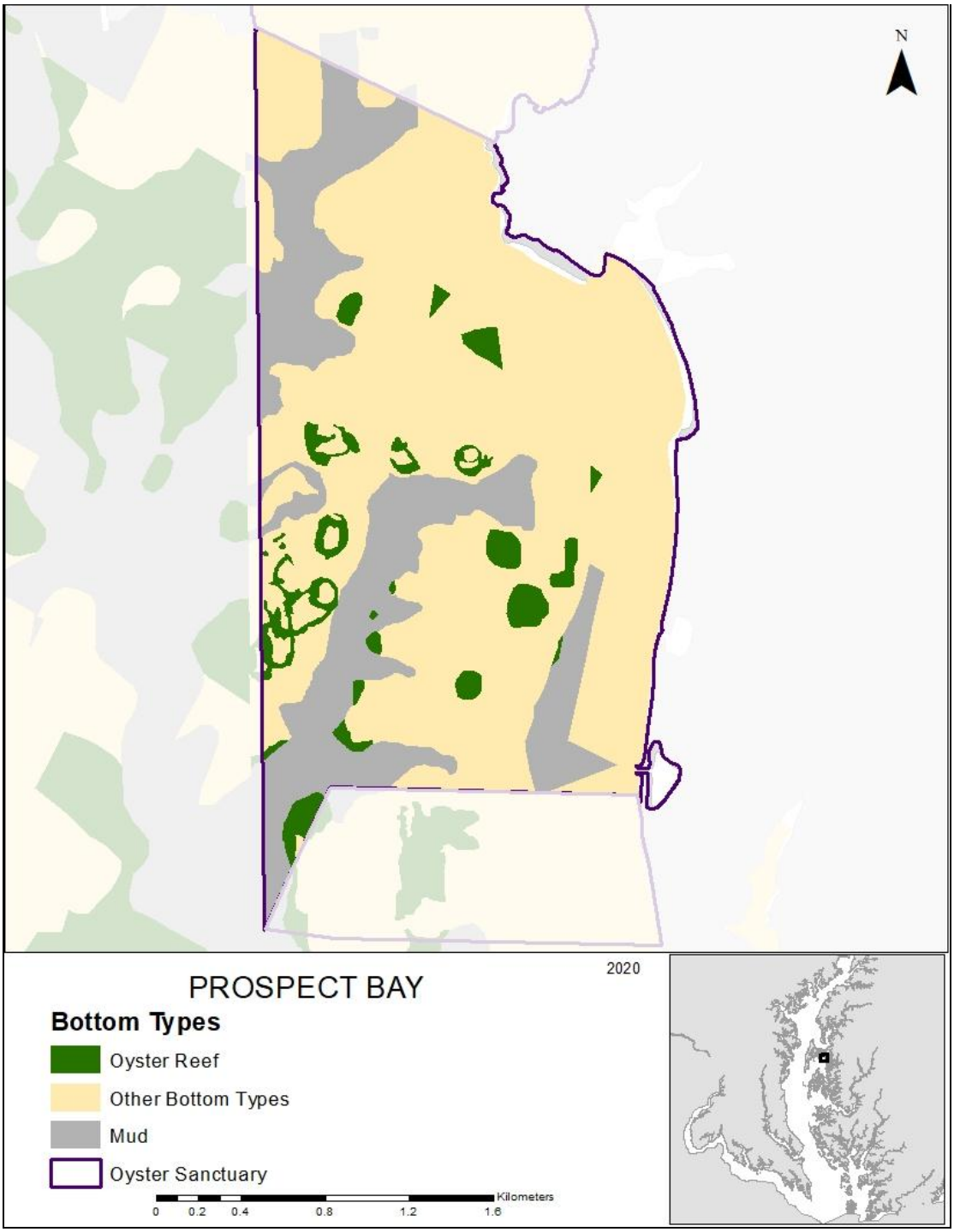

Figure A.34 -2. Prospect Bay Sanctuary bottom types. NOAA Chesapeake Bay Office in 2012.

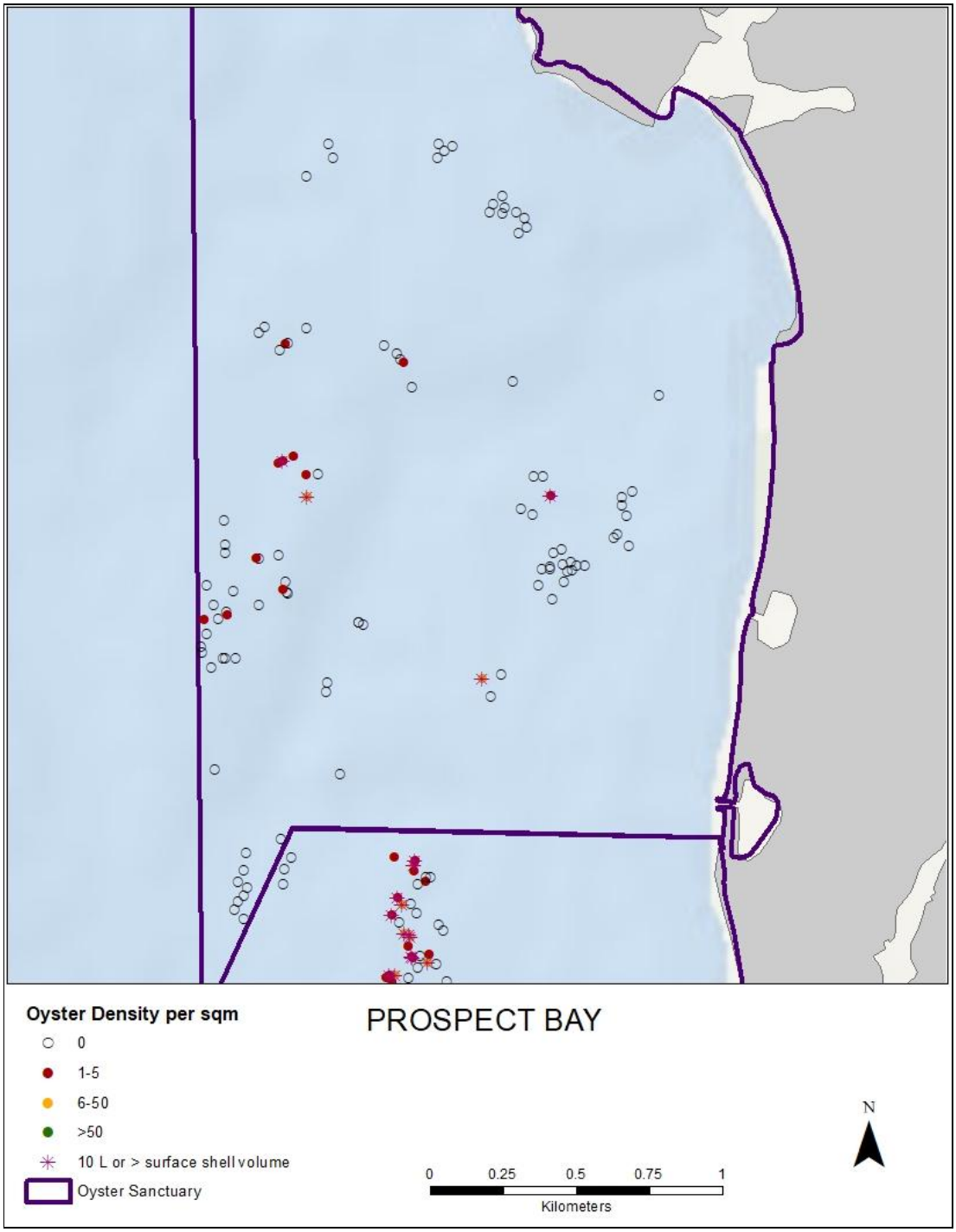

Figure A.34-3. Map of 2020 oyster density in the Prospect Bay Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.35: Prospect Bay Cabin Creek Sanctuary

The Prospect Bay Cabin Creek Sanctuary is located in Eastern Bay, a low-salinity (Zone 1) region within NOAA Code 039. The sanctuary was created in 2005 for restoration work by the Chesapeake Bay Environmental Center, which was designated by the state as a site for testing and developing comprehensive restoration techniques that might have bay-wide application for enhancing oyster stocks. The sanctuary encompasses 298 acres of which 128 (43%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar (Cabin Creek bar) within the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.35-1)
- Bottom types map (Figure A.35-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. The department has not conducted a population patent tong survey. The sanctuary received restoration plantings between 2006 and 2012 where 6.5 million hatchery spat-on-shell were planted and 160 reef balls were deployed. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary since 2006. Although the area that is now the sanctuary may have been surveyed during the Bay Bottom Survey (1974 to 1983), the chart covering this area has been lost[66]. There have not been any recent bottom surveys using side scan sonar in this area.

[66] Smith, G.F., K.N. Greenhawk, D.G. Bruce, E.B. Roach, and S.J. Jordan. 2001. A digital presentation of the Maryland oyster habitat and associated bottom types in the Chesapeake Bay (1974–1983). Journal of Shellfish Research 20:192–206.

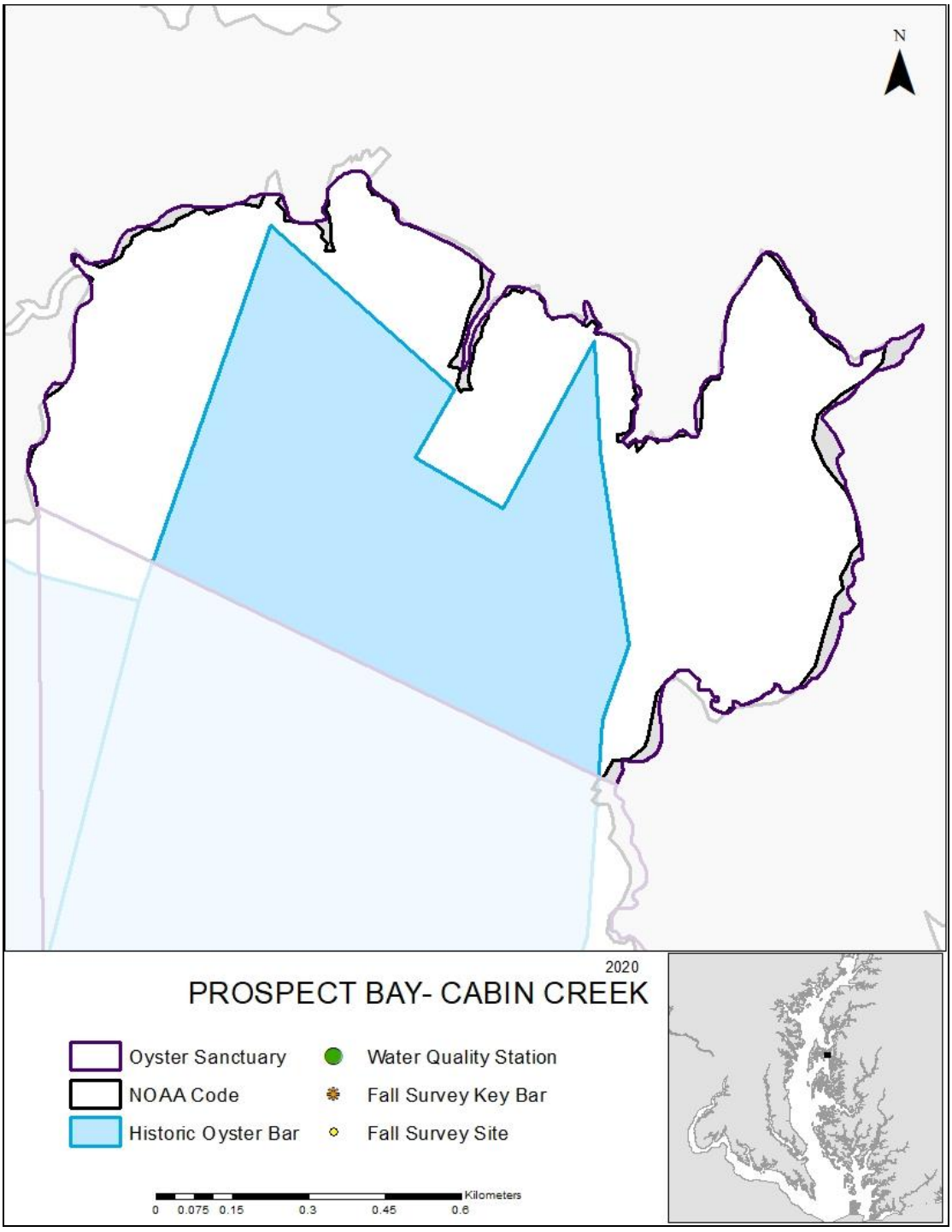

Figure A.35-1. Prospect Bay Cabin Creek Sanctuary.

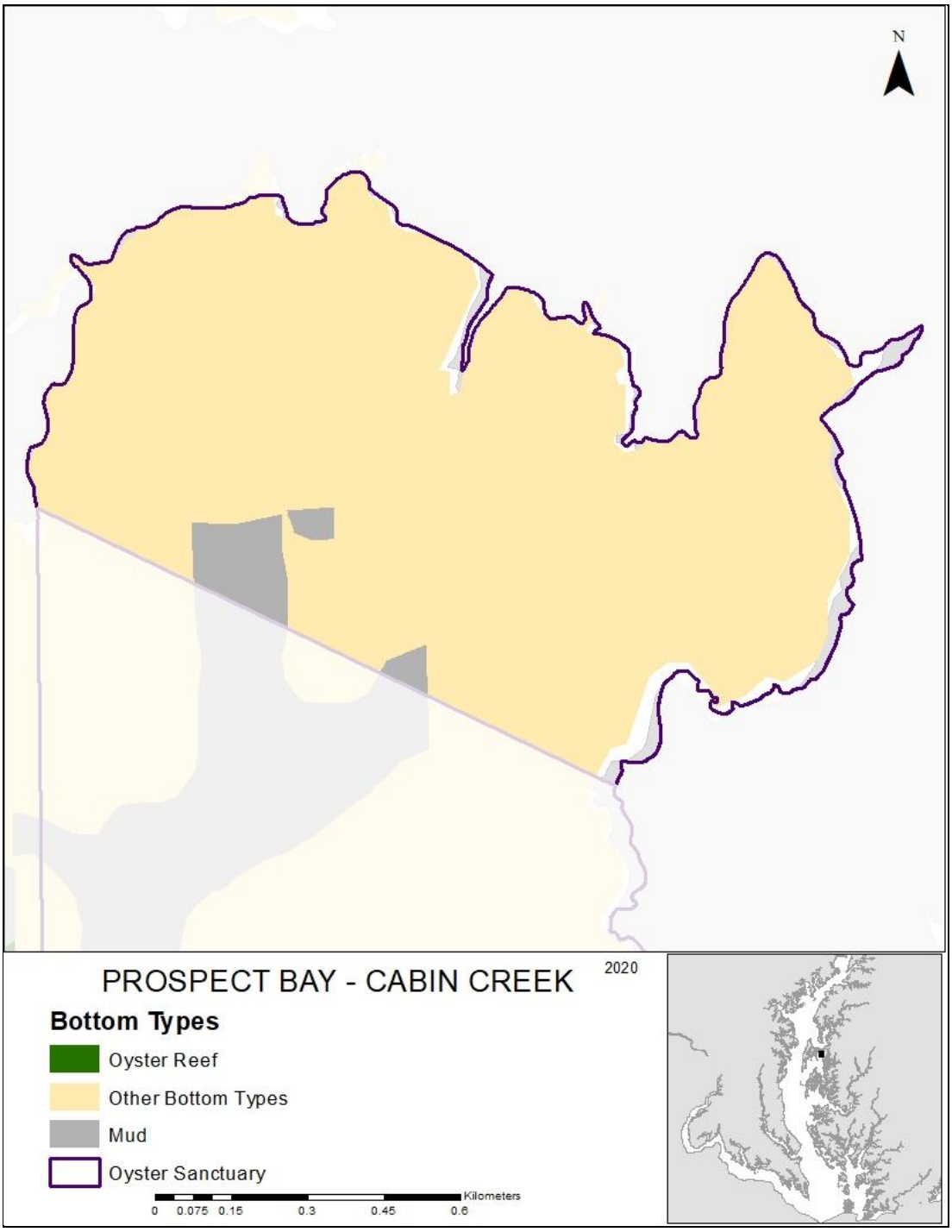

Figure A.35 -2. Prospect Bay Cabin Creek bottom types. NOAA Chesapeake Bay Office in 2012.

Section A.36: Ringgold Sanctuary

The Ringgold Sanctuary is located in the upper Chester River, a low-salinity (Zone 1) region within NOAA Code 231. The sanctuary was created in 2001 and encompasses 120 acres of which 63 (52%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar (Bay Bush Point bar) within the sanctuary. The sanctuary was created for a project by the U.S. Army Corps of Engineers designed to examine differences in oyster growth, mortality and disease prevalence between hatchery spat-on-shell and natural seed between bars constructed with a minimum of 150 cm relief above the bottom and "flat" bars, with no more than 15 cm relief above the bottom[67].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.36-1)
- Bottom types map (Figure A.36-2)
- Density Survey (Figure A.36-3)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in the sanctuary in 2020 and found four market-sized oysters from 100 samples taken with an average density of 0.04 per square meter. Of the samples taken, 96 had no oysters and 84 had no surface shell volume.

This area has not received any active restoration or replenishment efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[67] Paynter, K. T., 2007. A 10-Year Review of Maryland's Hatchery-based Oyster Restoration Program: 1997-2006. A Summary of Monitoring and Research Conducted by the Paynter Laboratory at the University of Maryland.

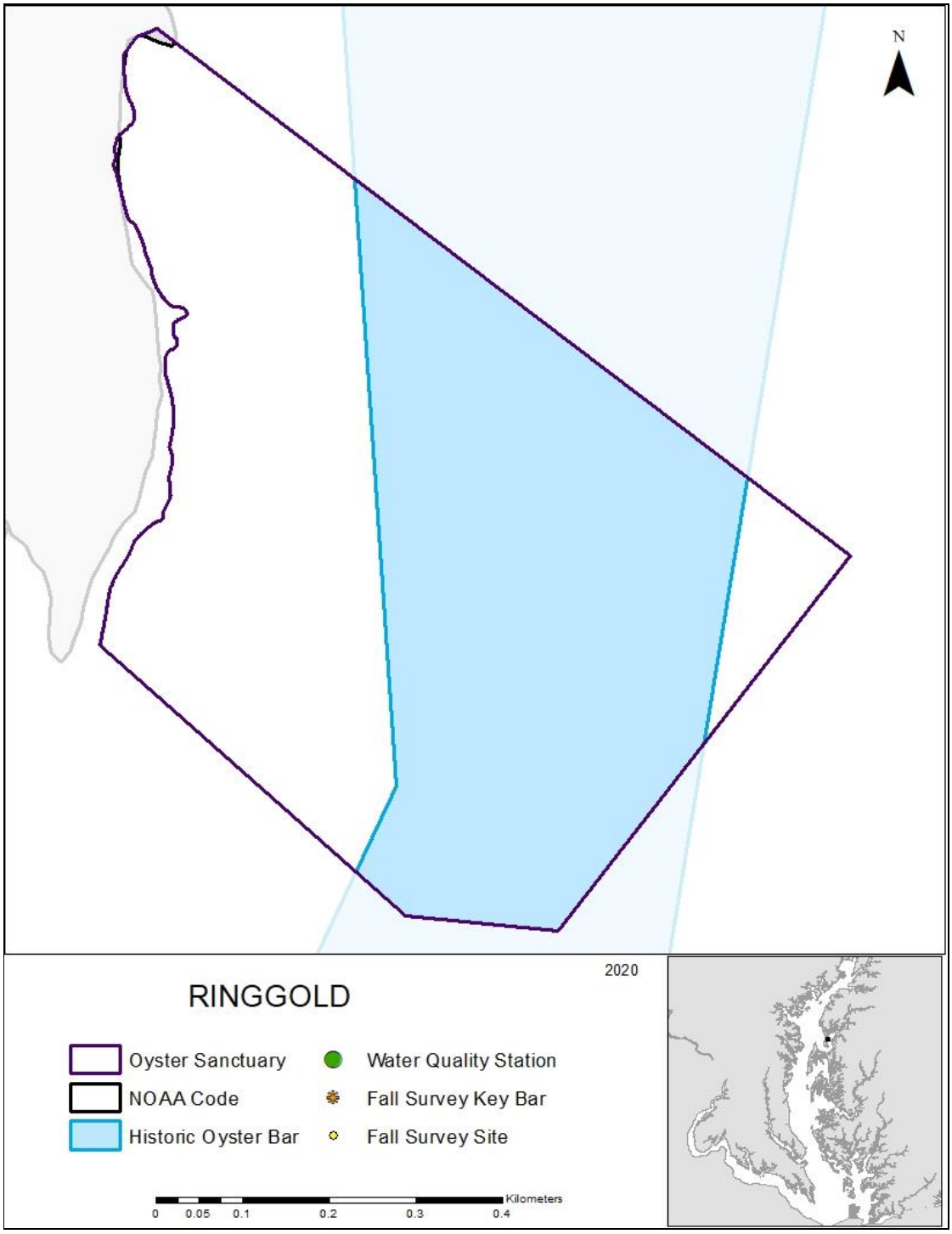

Figure A.36-1. Ringgold Sanctuary.

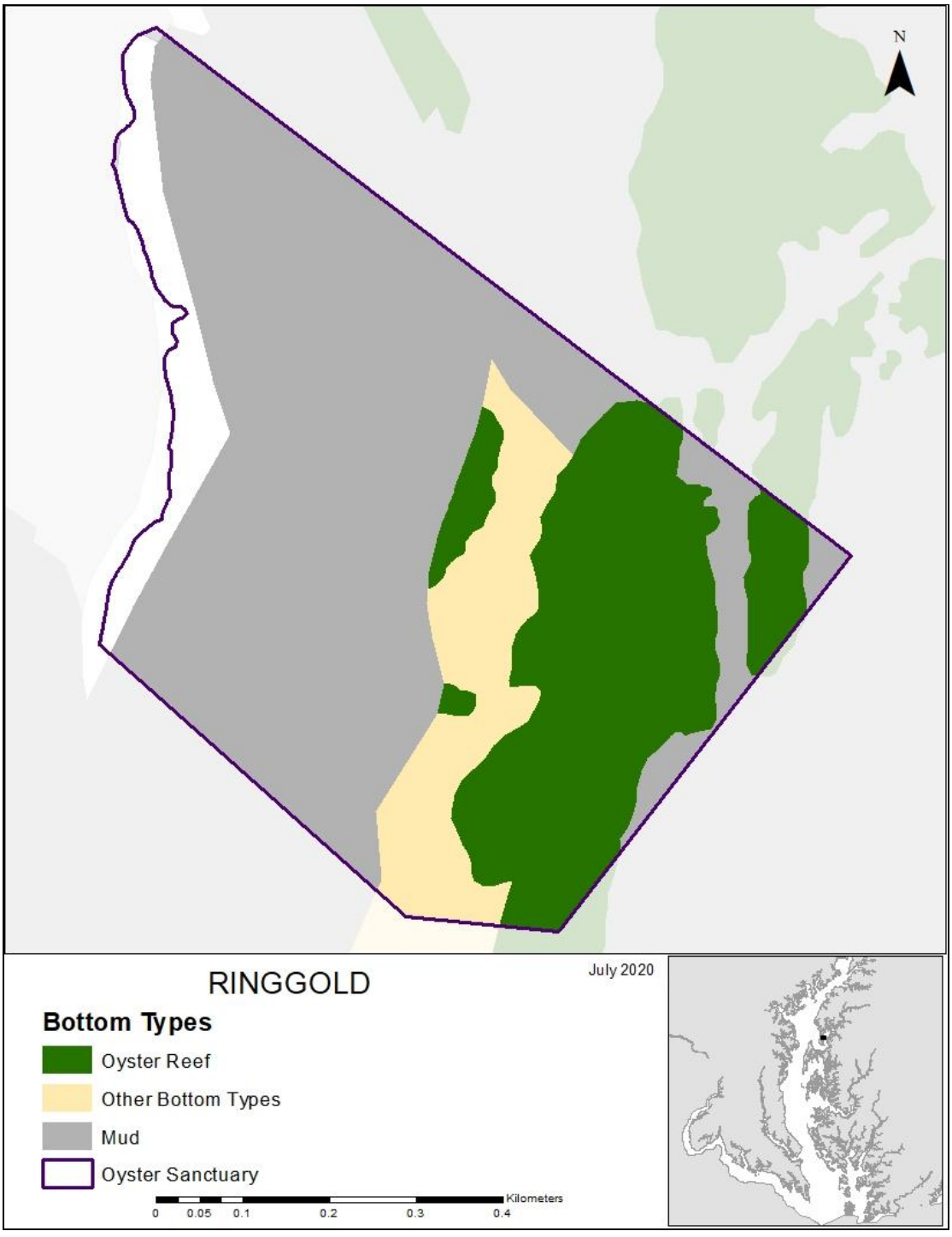

Figure A.36 -2. Ringgold Sanctuary bottom types. Data from NOAA Chesapeake Bay Office from 2003-2007.

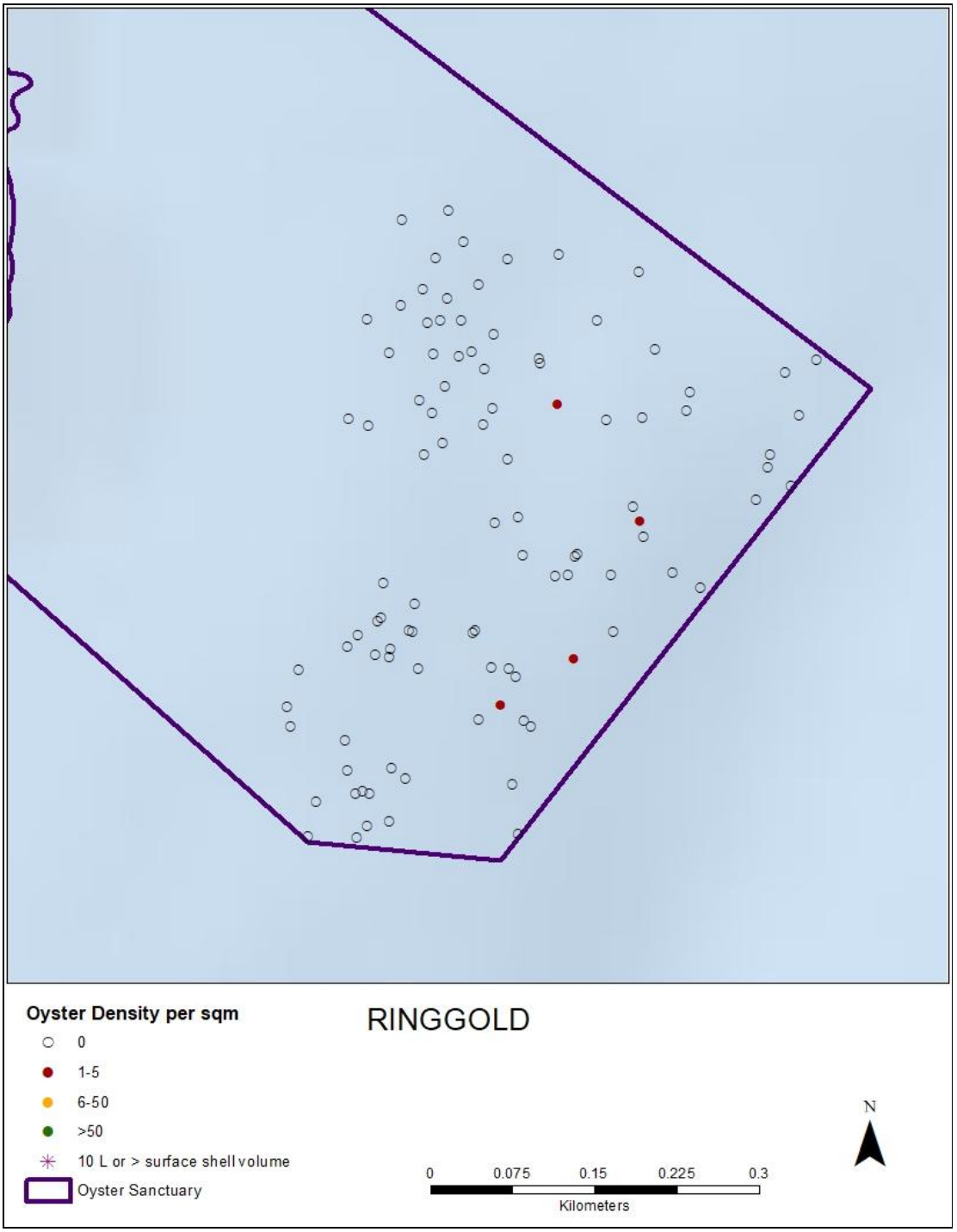

Figure A.36-3. Map of 2020 oyster density in the Ringgold Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.37: Roaring Point Sanctuary

The Roaring Point Sanctuary is located at the mouth of the Nanticoke River, a medium-salinity (Zone 2) region within NOAA Code 062. The sanctuary was created in 2004 and encompasses 10 acres of which none is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Roaring Point Sanctuary was created from an old oyster lease for oyster restoration work by the Chesapeake Bay Foundation.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.37-1)
- Density Survey (Figure A.37-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in the sanctuary in 2018 and found no live oysters from the four samples.

This area has not received any active restoration or replenishment efforts since 2006 with the exception of Marylanders Grow Oysters. Marylanders Grow Oysters, a public outreach program, has planted oysters annually in the sanctuary since 2009.

We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary. This area was not mapped by the Bay Bottom Survey, nor have any more recent surveys using side scan sonar been performed.

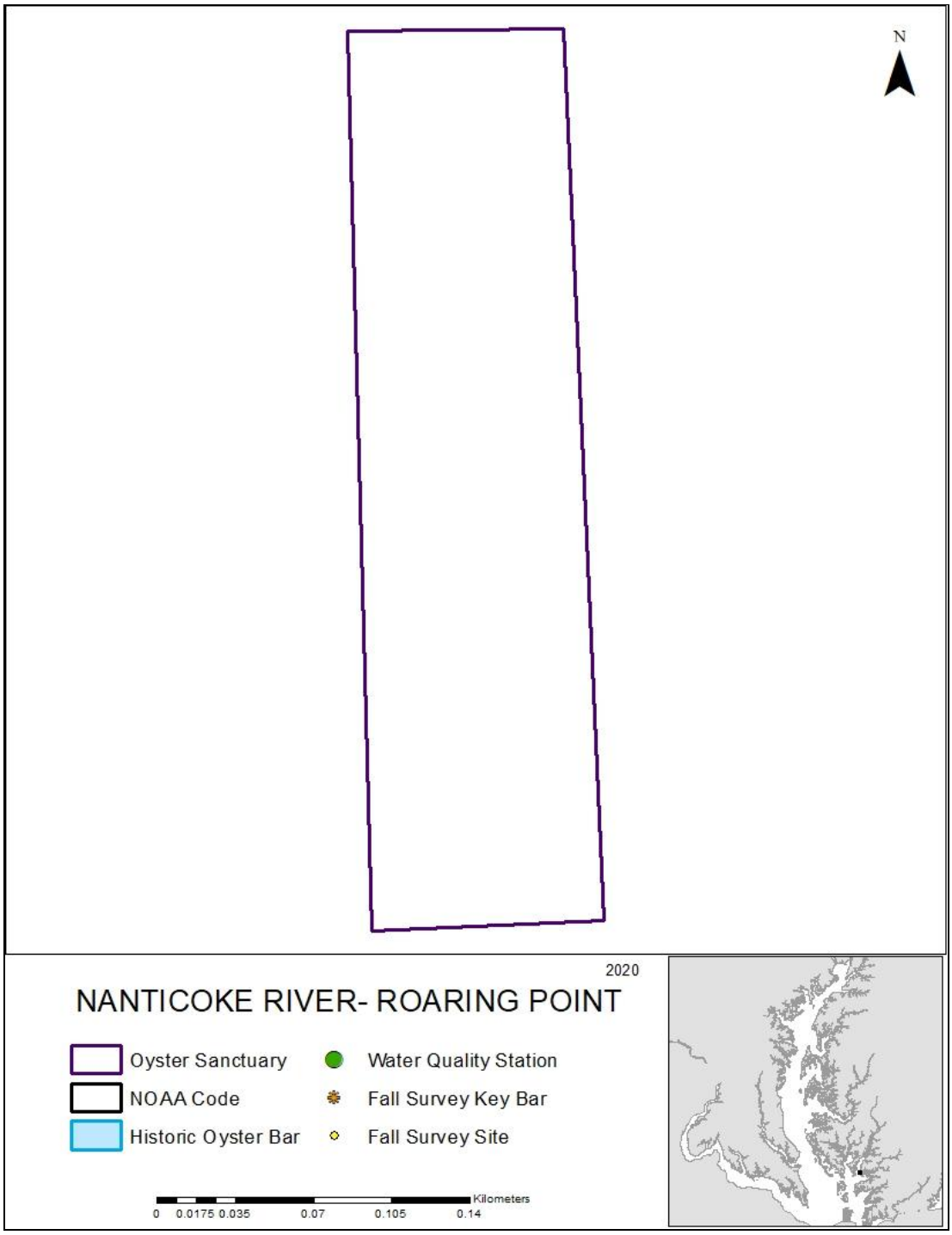

Figure A.37-1. Roaring Point Sanctuary.

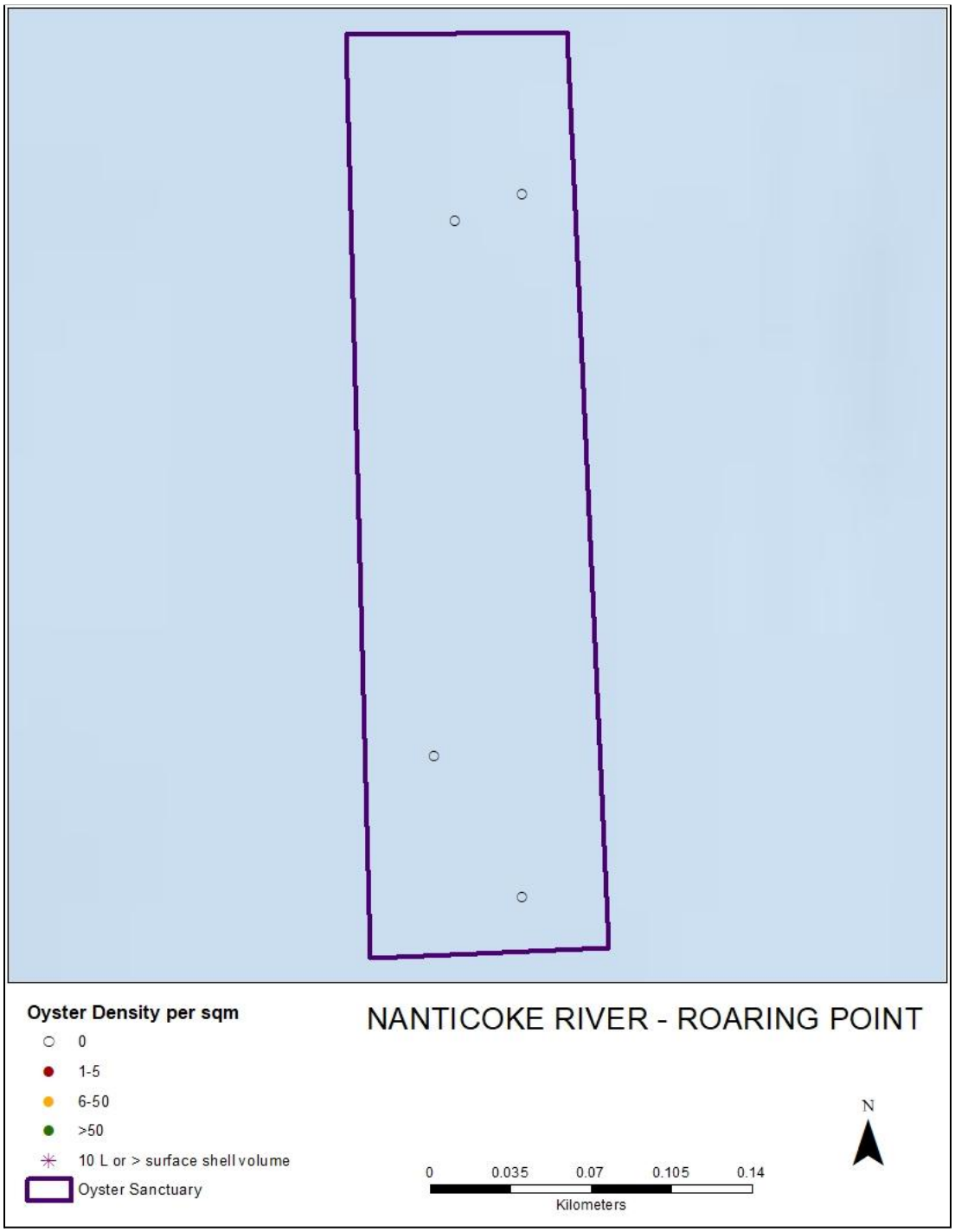

Figure A.37-2. Map of 2018 oyster density in the Roaring Point Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

Section A.38: Sandy Hill Sanctuary

The Sandy Hill Sanctuary is located in the middle Choptank River, a low-salinity (Zone 1) region of Maryland within NOAA Code 237. This sanctuary connects the Lower and Upper Choptank River sanctuaries on the southern shore of the river, creating a large contiguous sanctuary area. The sanctuary was created in 2009 and encompasses 1,947 acres of which 1,308 (67%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Sandy Hill Sanctuary emcompasses one older sanctuary, University of Maryland's Horn Point, which has 10 surface acres, all of which is historic oyster bottom. Thus, the total surface area is 1,957 acres and total historic oyster bottom is 1,318 acres. There are 11 historic oyster bars within the sanctuary[68]. This sanctuary was created based on recommendations from the Oyster Advisory Commission to establish larger oyster sanctuaries in a range of salinities.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.38-1)
- Bottom types map (Figure A.38-2)
- Summary statistics (Table A.38-1)
- Abundance per year (Figure A.38-3)
- Shell height frequencies (Figure A.38-4)
- Biomass per year (Figure A.38-5)
- Observed mortality (Figure A.38-6)
- Dermo and MSX per year (Figure A.38-7)
- Cultch per year (Figure A.38-8)

The Fall Survey sampled one bar in this sanctuary. Density and biomass remained stable in 2016-2020 compared to 2011-2015 but was still higher than 2006-2010. Observed mortality was consistent with the long-term baywide average. The amount of cultch was slightly higher in 2016-2020. The average size of oysters in this sanctuary was 100 mm and 61% of all oysters were over 100 mm in 2016-2020. The last patent tong population survey conducted by the department occurred in 2015[69].

Between 2006 and 2009, before the sanctuary was established, no planting activities occurred to enhance the commercial fishery. After the sanctuary was established, approximately 93 million hatchery spat-on-shell were planted for restoration purposes.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[68] See chart 20 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[69] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

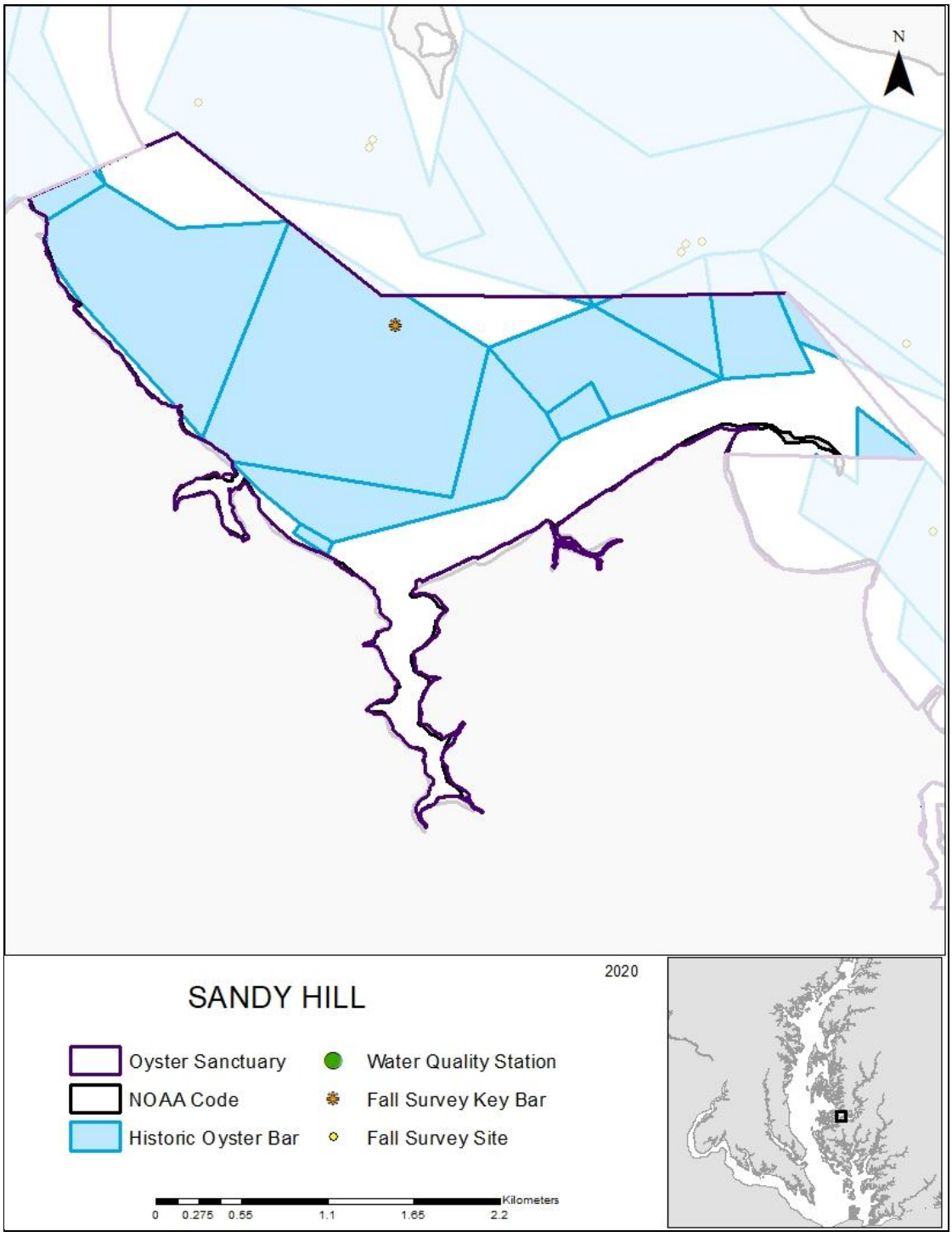

Figure A.38-1. Sandy Hill Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

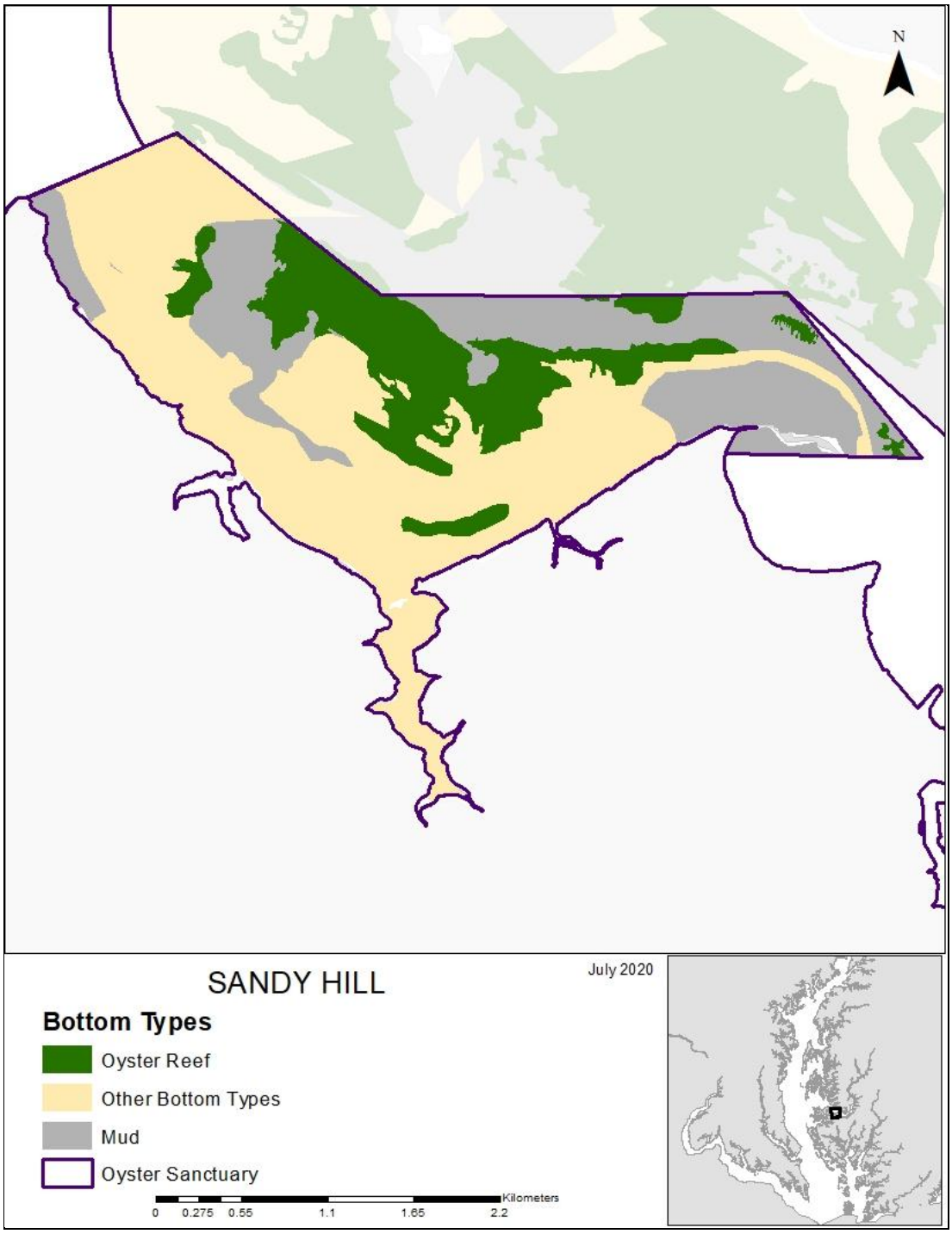

Figure A.38-2. Sandy Hill Sanctuary bottom types. Data from NOAA Chesapeake Bay Office from 2010.

Table A.38-1. Oyster population characteristics based on the Fall Survey in the Sandy Hill Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 5	5 / 5	5 / 5
Number of Live Spat Oysters per square meter	0.8 ± 0.3	0.5 ± 0.4	0.7 ± 0.4
Number of Live Small-Sized Oysters per square meter	0.7 ± 0.2	3.3 ± 1.2	2.5 ± 0.8
Number of Live Market-Sized Oysters per square meter	3.6 ± 0.3	15.1 ± 2.9	17.1 ± 2.1
Live Oyster Biomass (g Dry Weight per Bushel)	60 ± 10	200 ± 43	193 ± 13
Observed Mortality (%)	8 ± 4	8 ± 2	11 ± 2
Cultch (Bushels per 100 ft Towed)	0.5 ± 0.1	0.6 ± 0.1	0.7 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

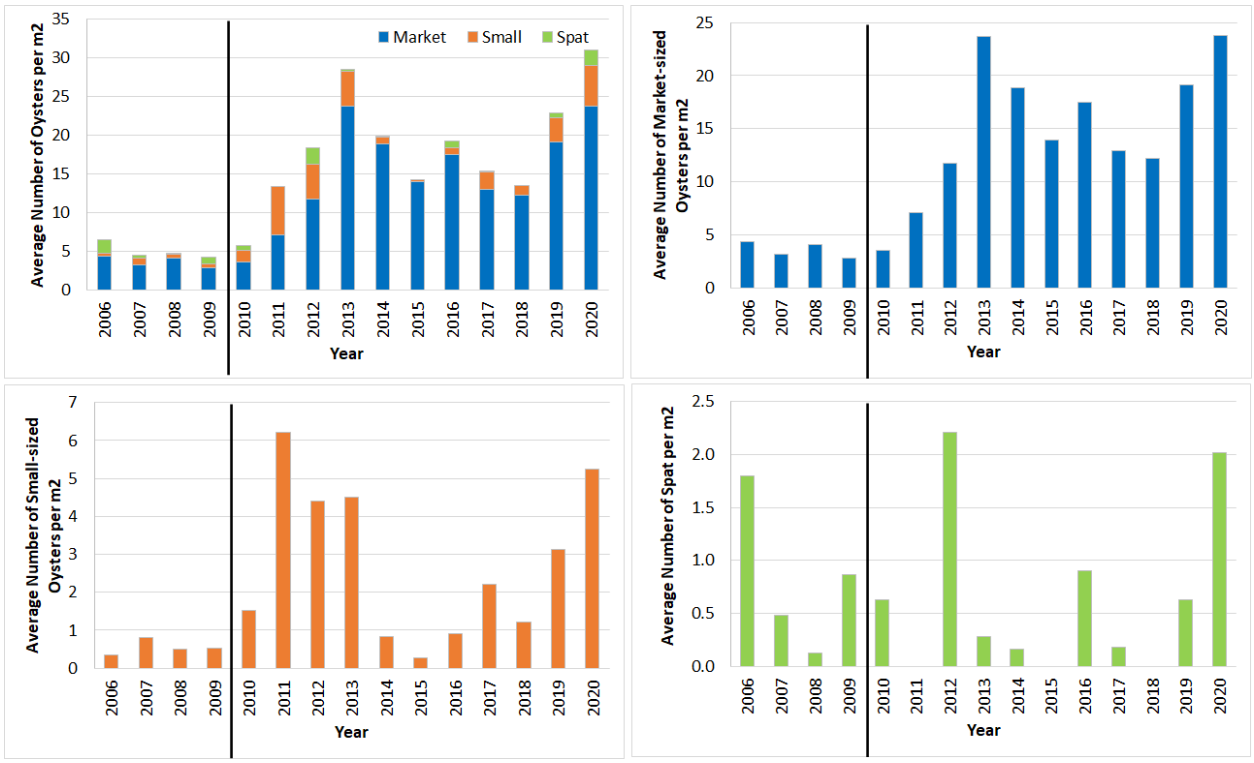

Figure A.38-3. Average number of live oysters per square meter by size class in the Sandy Hill Sanctuary. Black line indicates the date the sanctuary was established. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

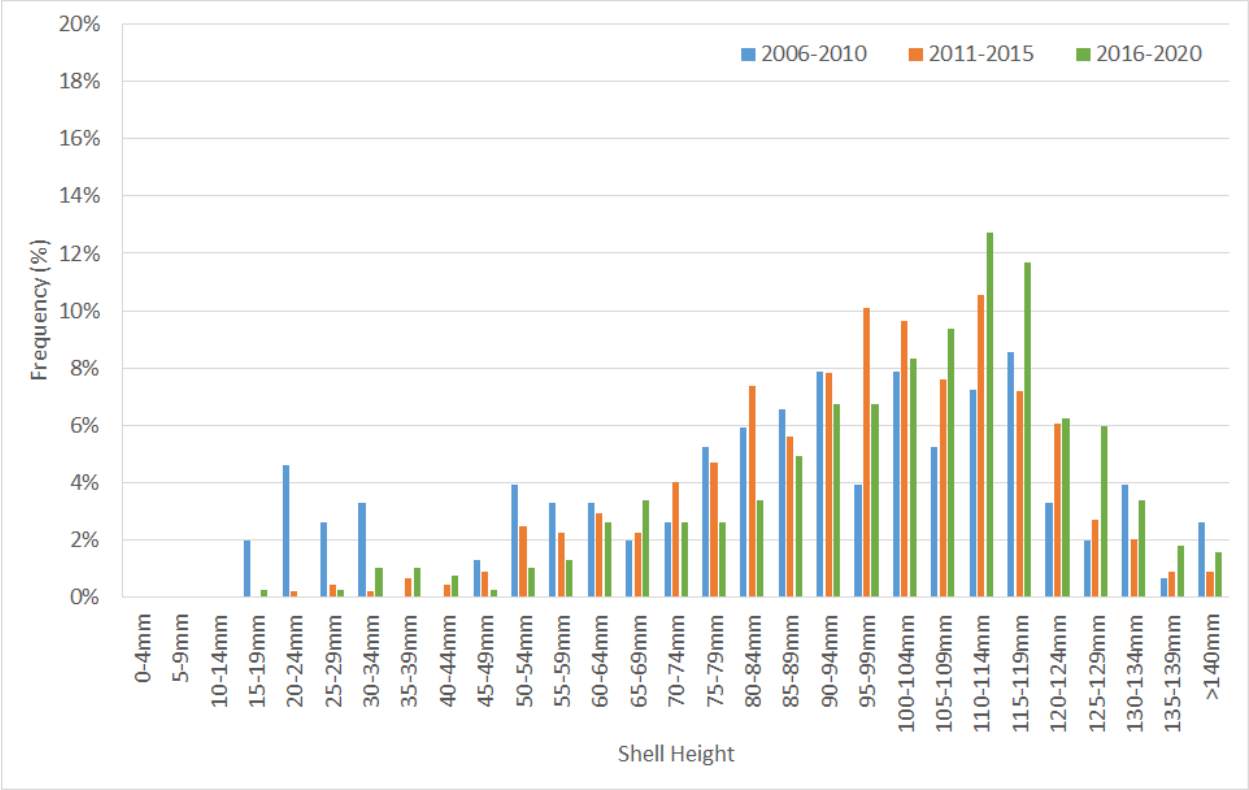

Figure A.38-4. Shell height frequencies of live oysters per bushel of material in the Sandy Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Sandy Hill bar.

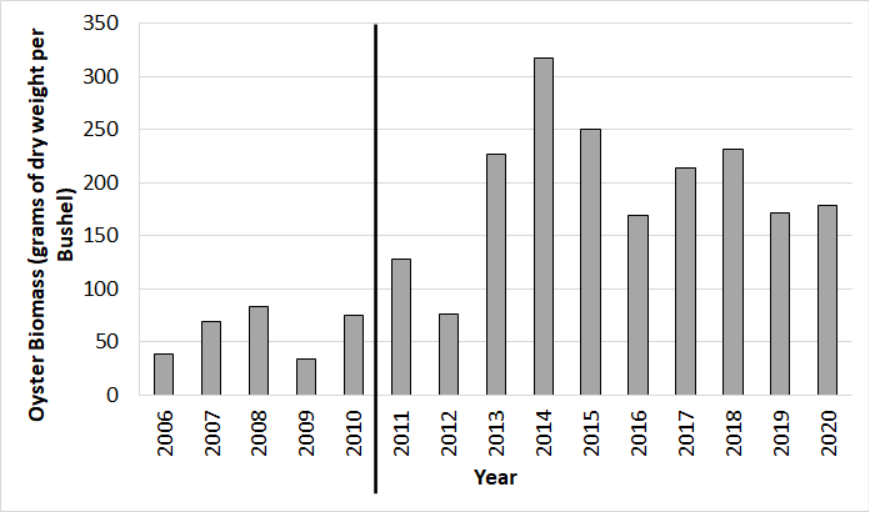

Figure A.38-5. Oyster biomass (grams of dry weight per bushel of material) in the Sandy Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Sandy Hill bar. Black line indicates the date the sanctuary was established.

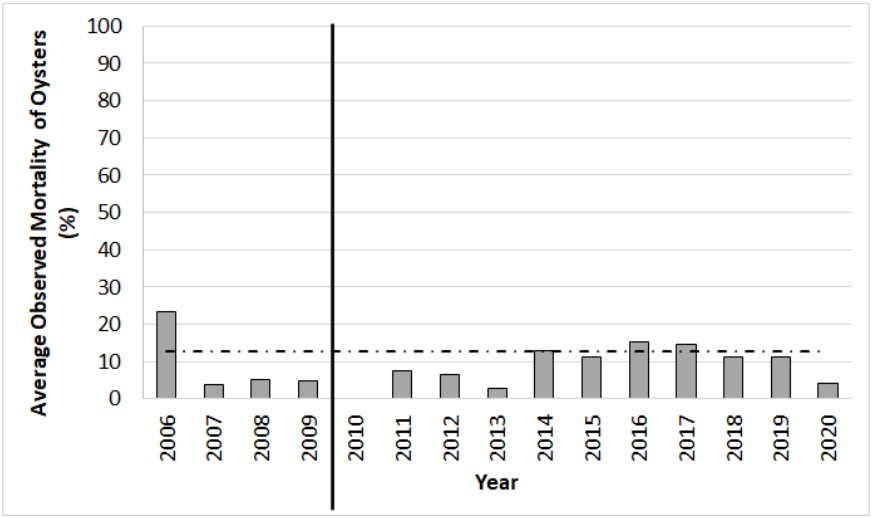

Figure A.38-6. Average annual observed mortality of market-sized and small-sized oysters in Sandy Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality.

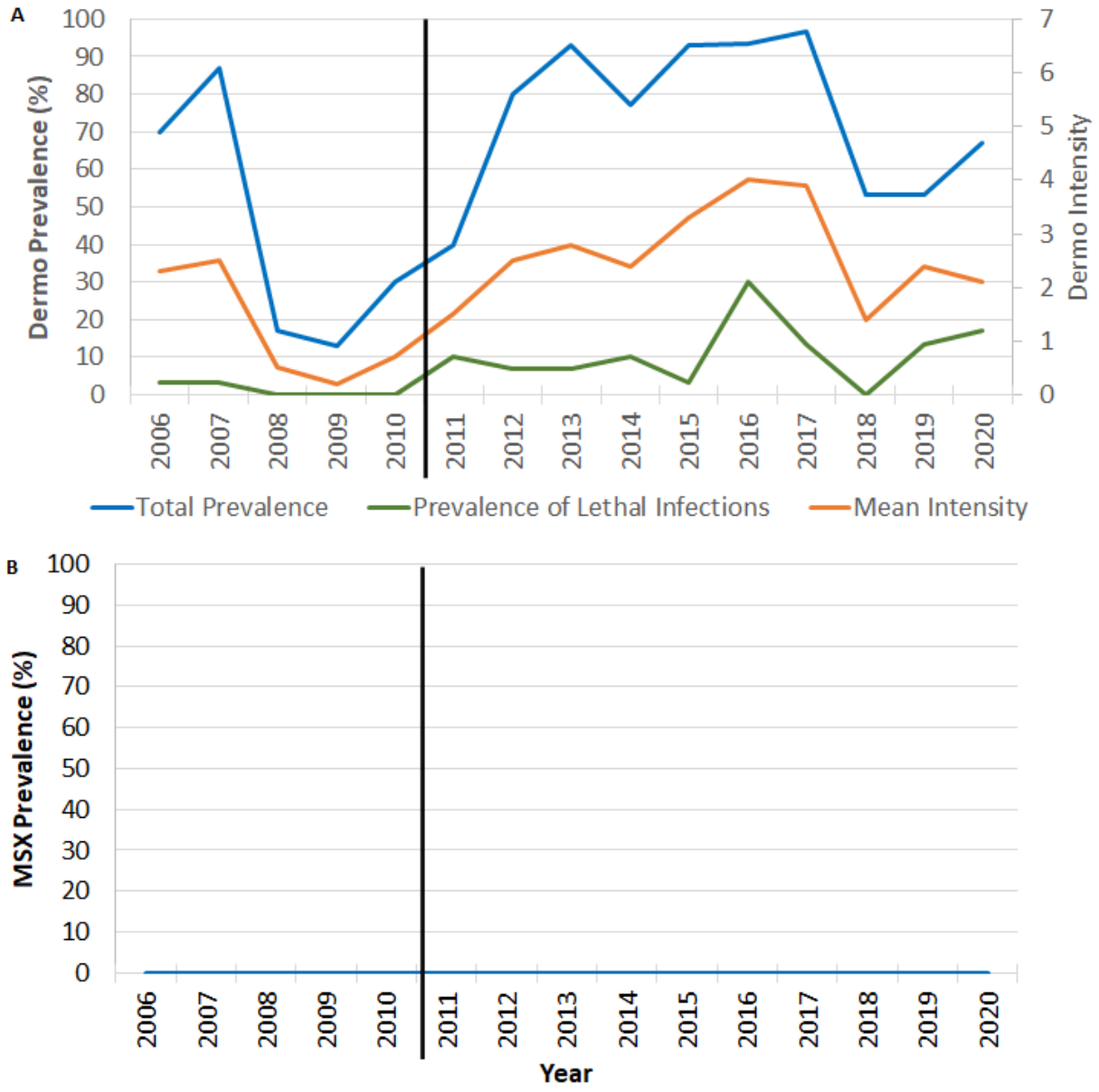

Figure A.38-7. Oyster disease prevalence and intensity in the Sandy Hill Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Sandy Hill bar. Black line denotes the date the sanctuary was established.

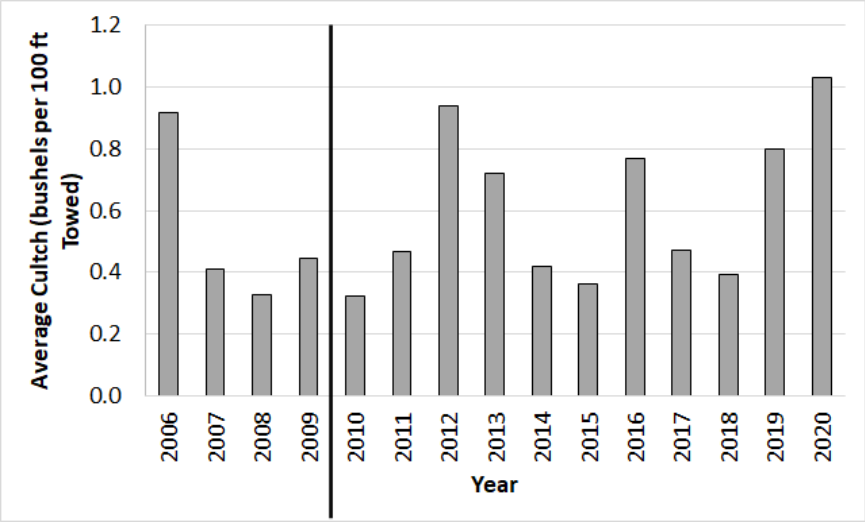

Figure A.38-8. Average cultch (live and dead oysters and loose shell) in the Sandy Hill Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established.

Section A.39: Severn River Sanctuary

The Severn River Sanctuary encompasses the entire Severn River, a tributary of the upper western Chesapeake Bay within NOAA Codes 082 and 127, in a low-salinity (Zone 1) region. In 1998, 6,719 acres were designated by Maryland Department of the Environment (MDE) as restricted from harvest due to potential contamination of shellfish by fecal coliform and other bacteria. This restricted area constituted most of the river and essentially made the area a sanctuary since no harvest was allowed. In 2010, 7,804 acres were designated as a sanctuary. Within the sanctuary, 1,376 (18%) acres are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 27 historic oyster bars within the sanctuary[70].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.39-1)
- Bottom types map (Figure A.39-2)
- Summary statistics (Table A.39-1)
- Abundance per year (Figure A.39-3)
- Shell height frequencies (Figure A.39-4)
- Biomass per year (Figure A.39-5)
- Observed mortality (Figure A.39-6)
- Cultch per year (Figure A.39-7)
- Water Quality (Figure A.39-8)

The Fall Survey sampled one bar in this sanctuary. No natural spat were found during the 2016-2020 time period. There were two spat-on-shell plantings in 2007 and 2008 that likely influenced spat, small and market oyster densities in the first five-year time period. Average density of small and market oysters in 2016-2020 declined from the 2011-2015. Biomass and cultch were similar to the previous five-year average. Average mortality increased to 18% during the 2016-2020 time period, driven mostly by much higher total mortality in 2017-2019. The last patent tong population survey conducted by the department occurred in 2012[71].

From 2006 to 2020, approximately 268 million spat were planted for restoration purposes. Marylanders Grow Oysters has been active and planting oysters in the Severn River annually since 2009. Maryland's Eyes on the Bay Program monitors monthly water quality at station WT7.1 (39.00764, -76.5035) in this area. Water quality was generally suitable for oysters except for brief periods of low salinity. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[70] See chart 9 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[71] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

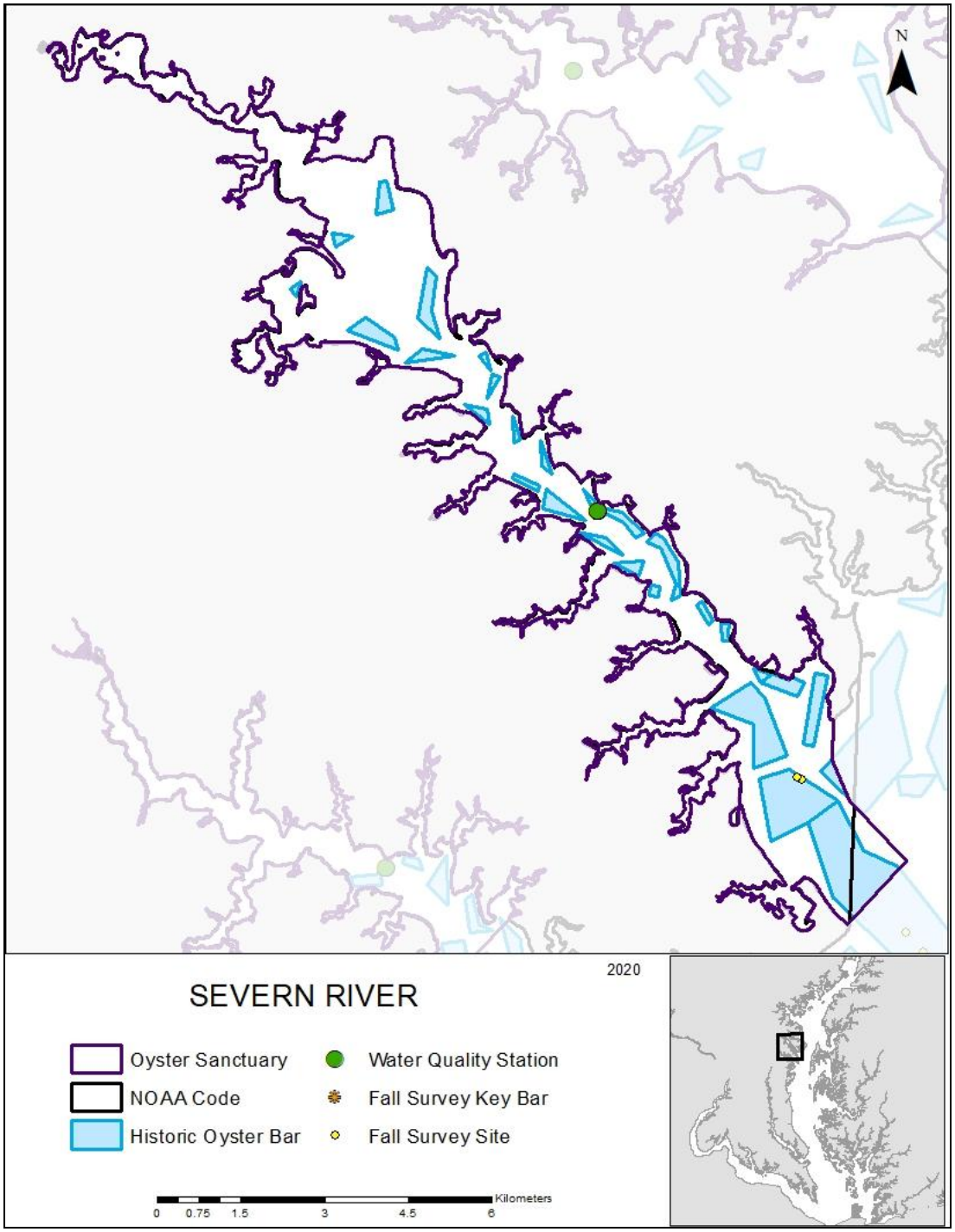

Figure A.39-1. Severn River Sanctuary. Fall Survey sites may not be sampled every year.

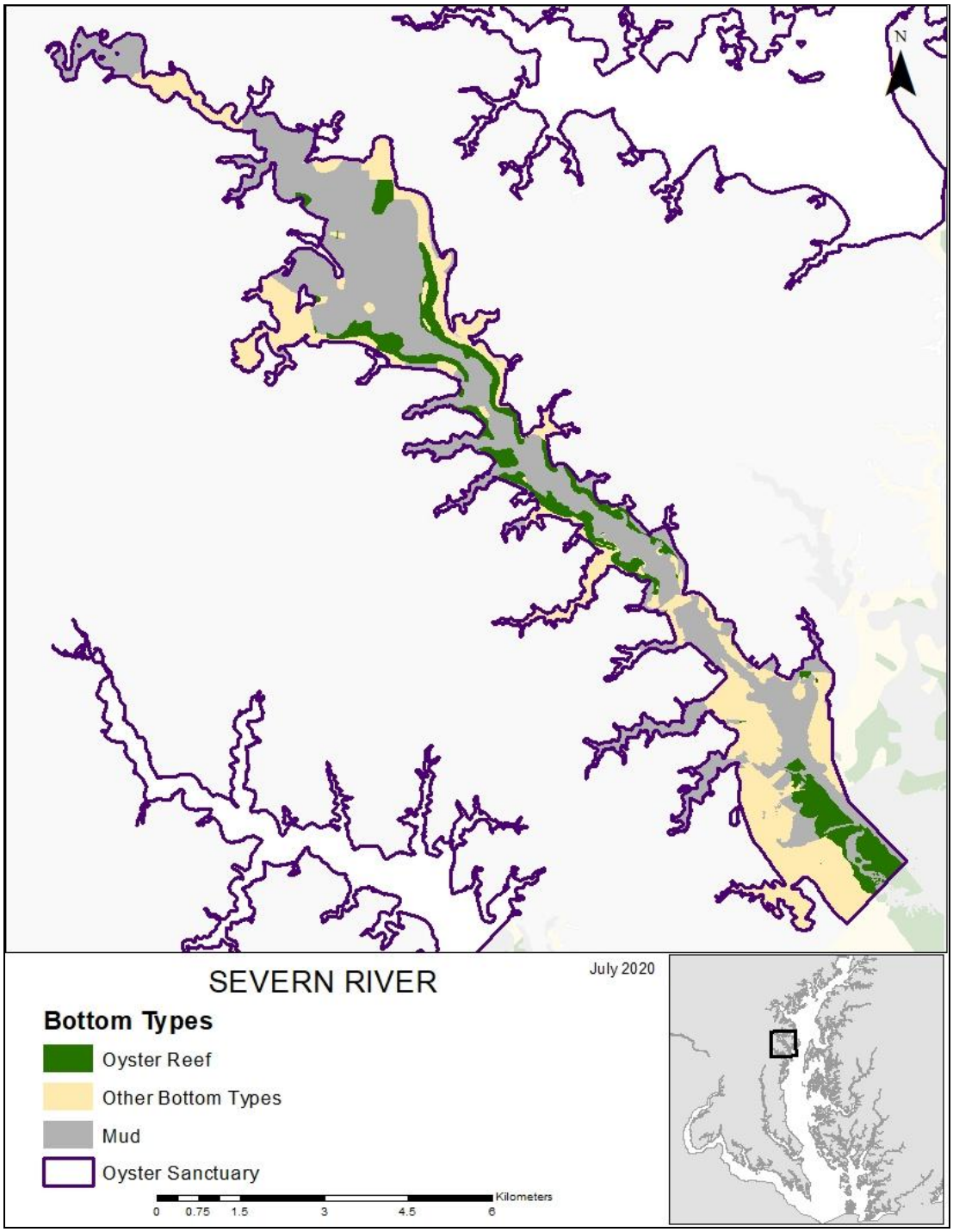

Figure A.39-2. Severn River Sanctuary bottom types. Data from Maryland Geological Survey in 2009.

Table A.39-1. Oyster population characteristics based on the Fall Survey in the Severn River Sanctuary. ND = No Data. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 10
Number of Live Spat Oysters per square meter	6.8 ± 6.8	0 ± 0	0 ± 0
Number of Live Small-Sized Oysters per square meter	18 ± 17.6	5.2 ± 1.5	1 ± 0.4
Number of Live Market-Sized Oysters per square meter	32.3 ± 21.4	65.3 ± 24.2	29.2 ± 8
Live Oyster Biomass (g Dry Weight per Bushel)	ND	88 ± 30	86 ± 7
Observed Mortality (%)	8 ± 4	6 ± 2	18 ± 5
Cultch (Bushels per 100 ft Towed)	1.3 ± 0.4	1.9 ± 0.2	1.5 ± 0.2
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

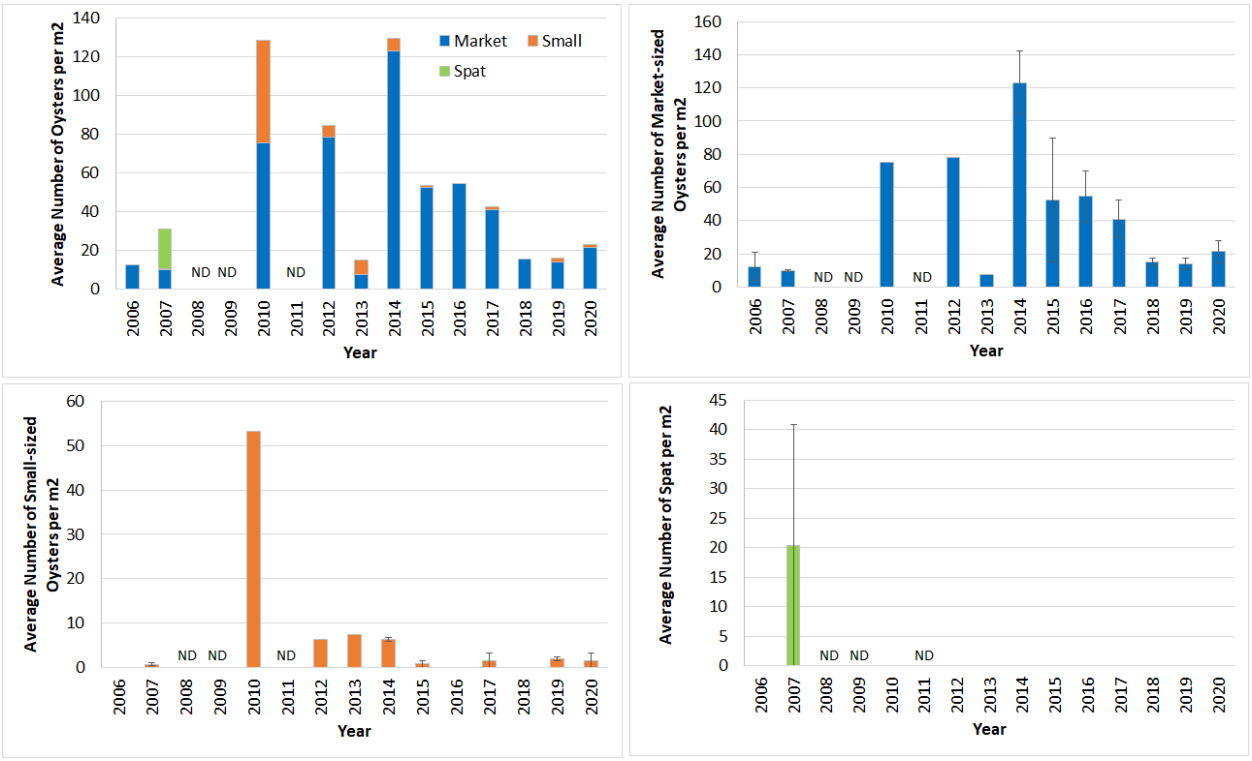

Figure A.39-3. Average number of live oysters per square meter by size class in the Severn River Sanctuary. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales. ND= No Data.

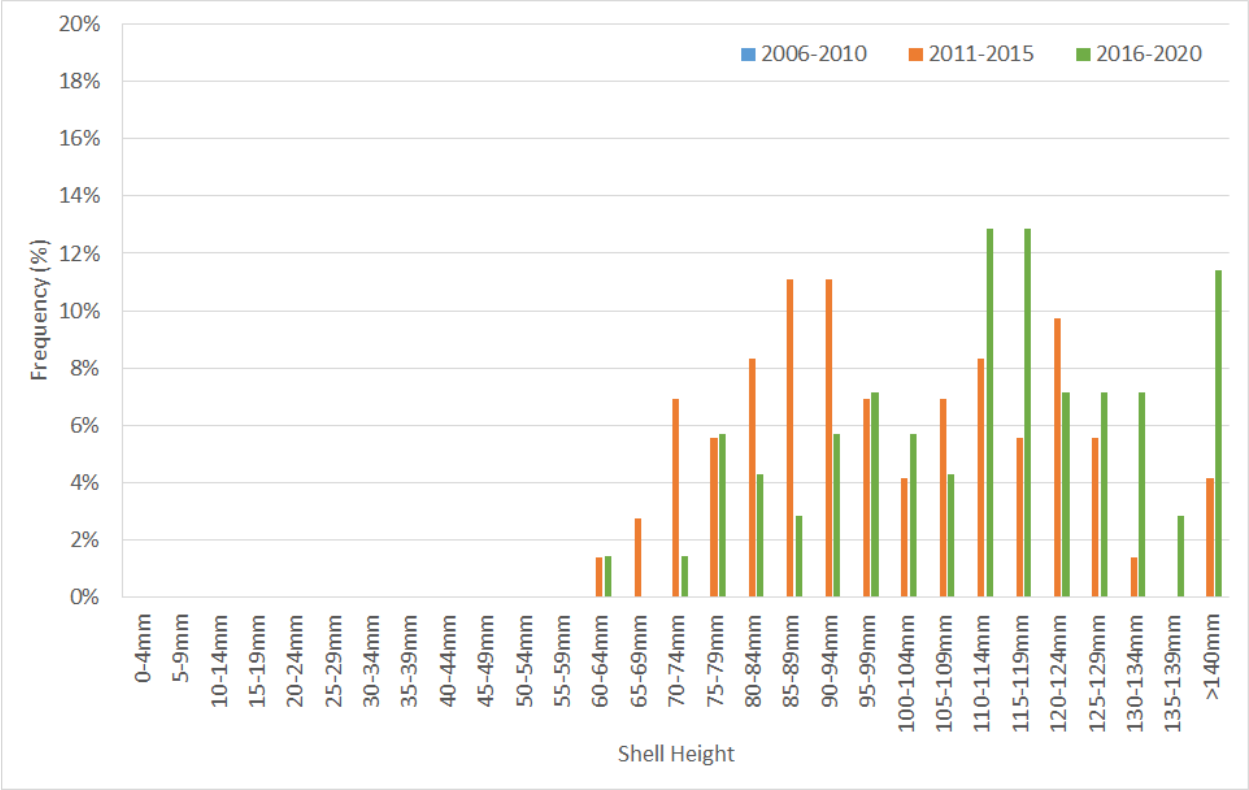

Figure A.39-4. Shell height frequencies of live oysters per bushel of material in the Severn River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Chinks Point bar. No data was collected from 2006 to 2010 and 2014.

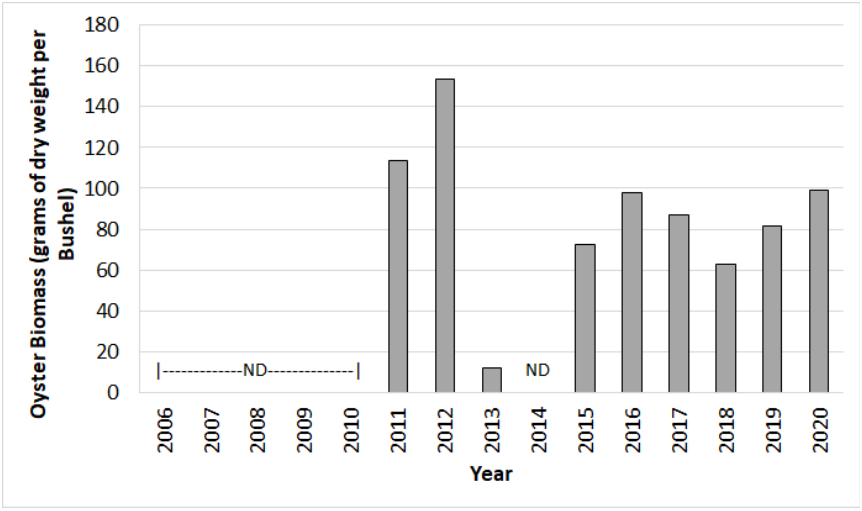

Figure A.39-5. Oyster biomass (grams of dry weight per bushel of material) in the Severn River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Chinks Point bar. No data was collected from 2006 to 2010 and 2014.

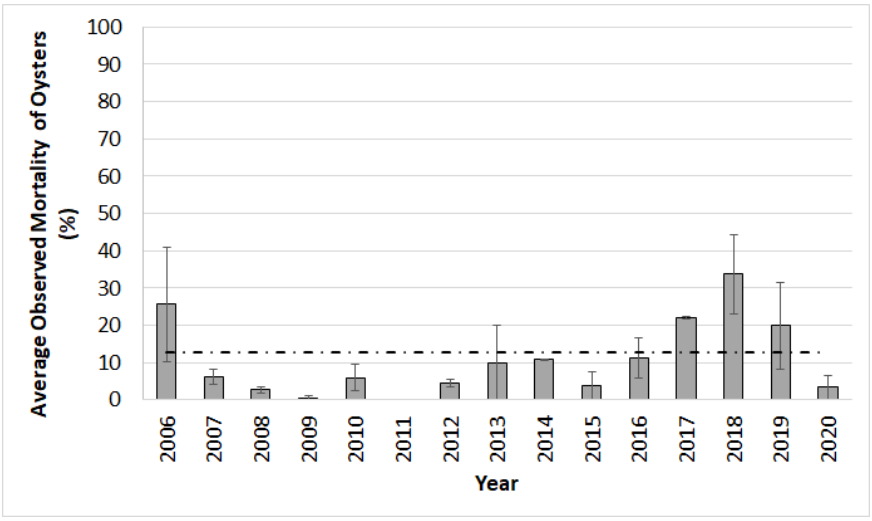

Figure A.39-6. Average annual observed mortality of market-sized and small-sized oysters in Severn River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

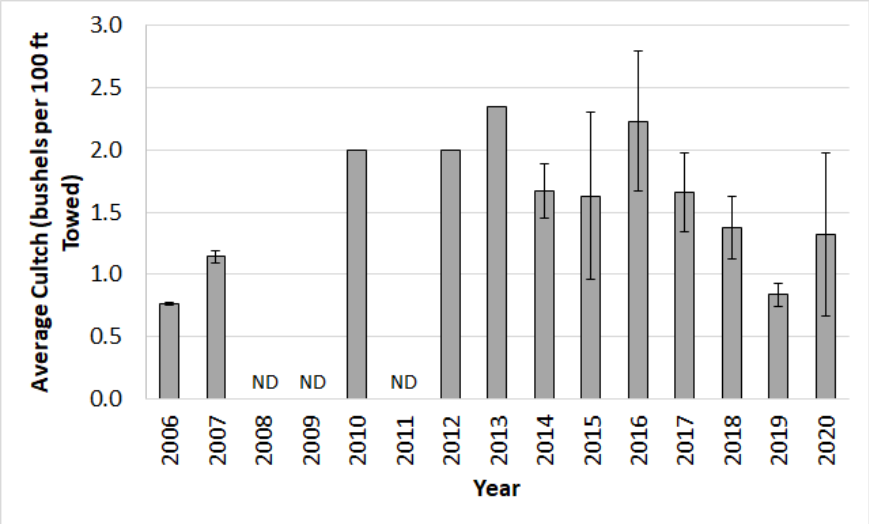

Figure A.39-7. Average cultch (live and dead oysters and loose shell) in the Severn River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Error bars represent ± 1 standard error. ND = No Data.

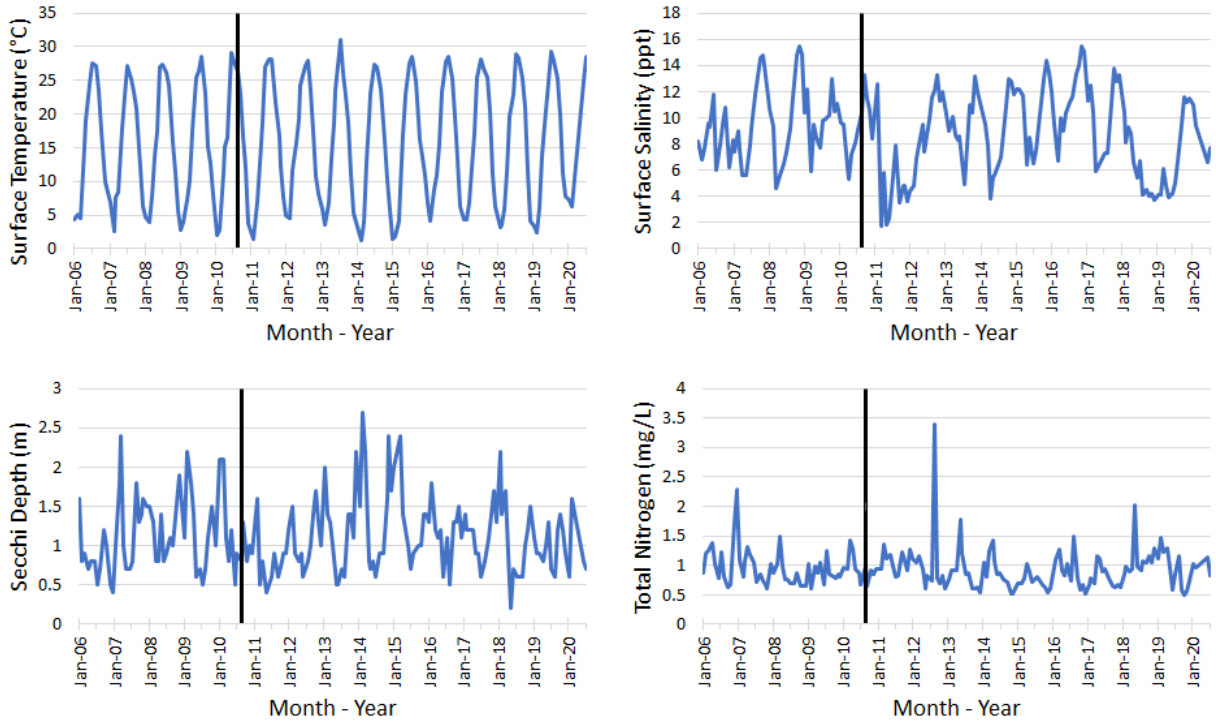

Figure A.39-8. Water quality data collected at Station WT7.1 in Severn River. Black line denotes the date the sanctuary was established. Data from Chesapeake Bay Program Data Hub.

Section A.40: Solomons Creeks Sanctuary

The Solomons Creeks Sanctuary is located in the lower Patuxent River, a medium-salinity (Zone 2) region within NOAA Code 168. The sanctuary was created in 2010 to accommodate oysters produced by the Southern Maryland Oyster Cultivation Society, a citizen-sponsored restoration group. It encompasses 617 acres of which only five acres (0.8%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). The sanctuary contains all of the Shell Pile historic oyster bar and a portion of the Cherry Tree bar.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.40-1)

The Fall Survey has not sampled any oyster bars within this area since 2006 nor have any patent tong population surveys occurred since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary. No bottom mapping has been conducted in this area since 2006.

This area has not received any replenishment plantings between 2006 and 2010. Chesapeake Bay Foundation, Coastal Conservation Association, and Southern Maryland Oyster Cultivation Society planted 7.2 million oysters in the sanctuary from 2008-2012. This planting program has been officially discontinued, but individuals continue to plant cage-reared oysters in the creek through Marylanders Grow Oysters. Marylanders Grow Oysters, a public outreach program, has planted oysters annually in the sanctuary since 2009.

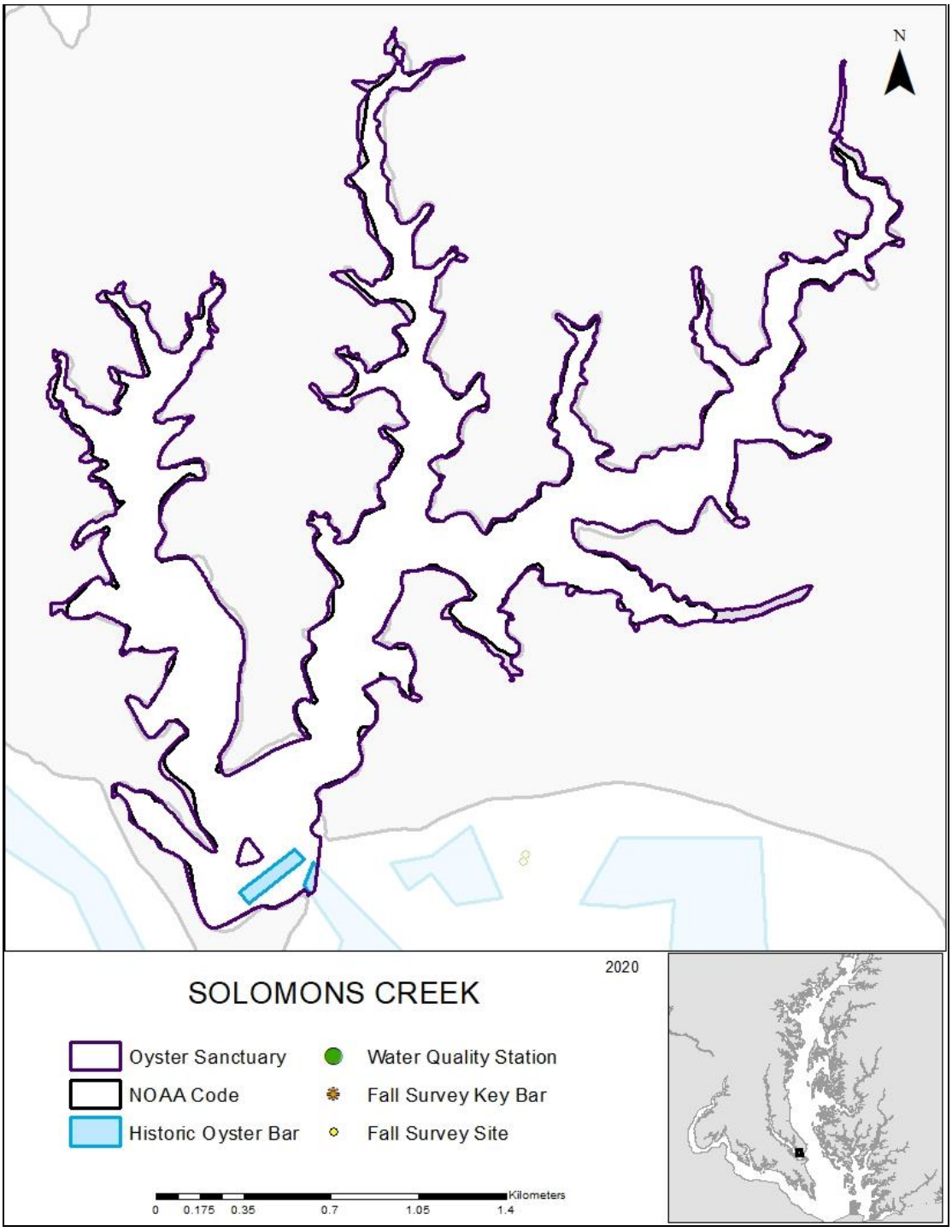

Figure A.40-1. Solomons Creeks Sanctuary.

Section A.41: Somerset Sanctuary

The Somerset Sanctuary is located in Tangier Sound, a high-salinity (Zone 3) region within NOAA Code 192. The sanctuary was created in 1999 and encompasses 101 acres of which six acres (6%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There is one historic oyster bar (Piney Island East Addition) within the sanctuary. The sanctuary was one of four sanctuaries created in 1999 when legislation was passed opening up new areas to power dredging of oysters.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.41-1)
- Bottom types map (Figure A.41-2)
- Summary statistics (Table A.41-1)
- Abundance per year (Figure A.41-3)
- Density Survey (Figure A.41-4)
- Shell height frequencies (Figure A.41-5)
- Biomass per year (Figure A.41-6)
- Observed mortality (Figure A.41-7)
- Dermo and MSX per year (Figure A.41-8)
- Cultch per year (Figure A.41-9)

The Fall Survey samples three locations in this sanctuary. Average spat density increased for 2016-2020, while small and market oyster density decreased. While mean biomass declined from the previous period, it was substantially higher in 2020 than in the previous four years. Although mean observed mortality was higher than the previous five-year average, largely due to high mortalities in 2016-2018, it was very low for both 2019 and 2020 (less than 5%). Cultch remained stable. The mean size was 37 mm, driven by the increase in spat from 2018-2020. A population patent tong survey was conducted by the department in 2015[72] and 2020. Results indicate an increase in oyster density from the last survey with an average of 50.3 oysters per square meter in the 2020 survey. The average density of spat was greater than the average density of small-sized or market-sized oysters (25.0 per square meter, 21.8 per square meter, and 3.5 per square meter respectively). Of the 70 samples taken, 8 had no oysters and 7 had no surface shell volume.

Marylanders Grow Oysters, a public outreach program, grew oysters at Janes Island State Park and planted oysters at one site in the sanctuary. Oysters were planted through this program between 2013 and 2017.

We are unaware of any studies explicitly examining oyster ecosystem services and continual water quality monitoring in this area.

[72] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

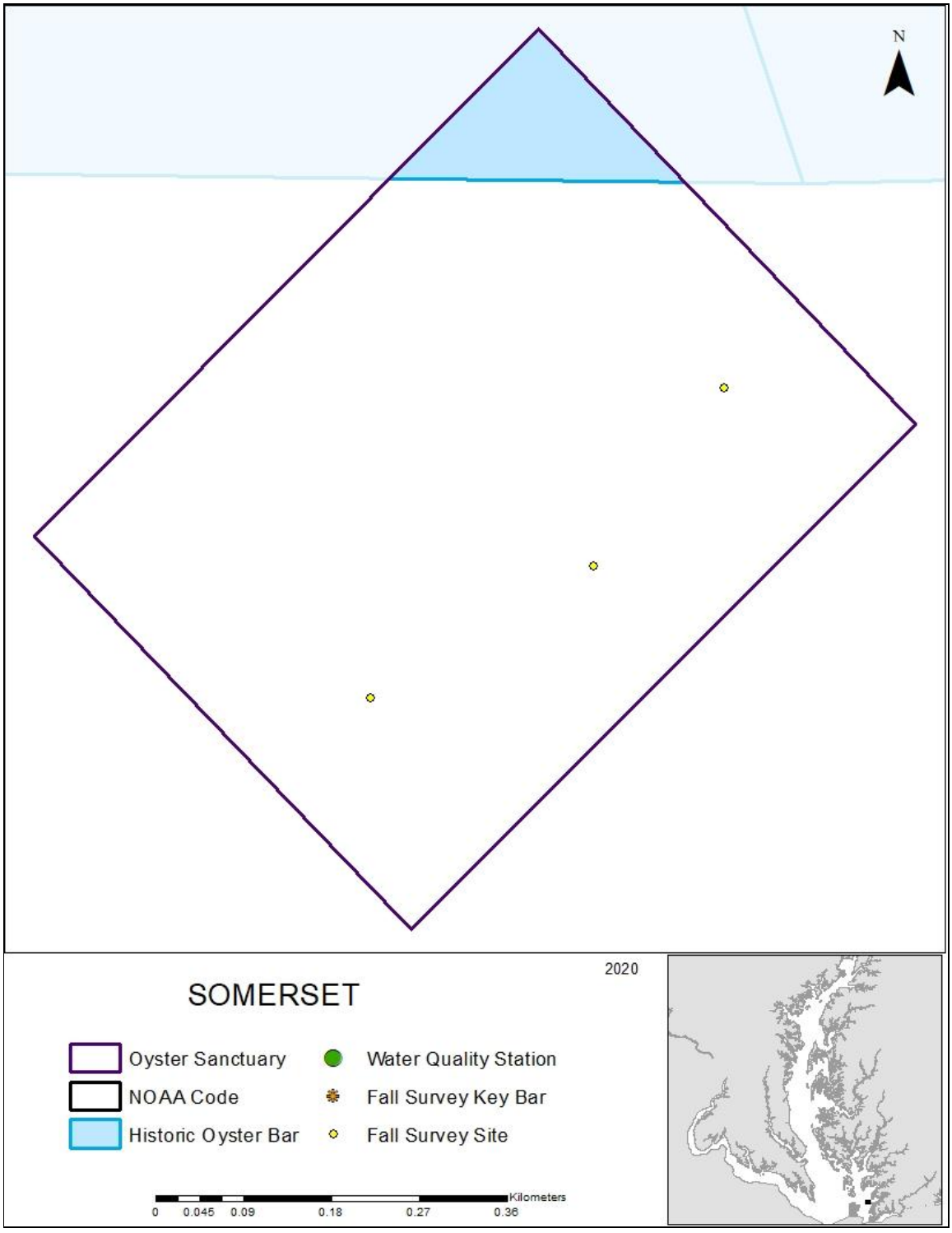

Figure A.41-1. Somerset Sanctuary. Fall Survey sites may not be sampled every year.

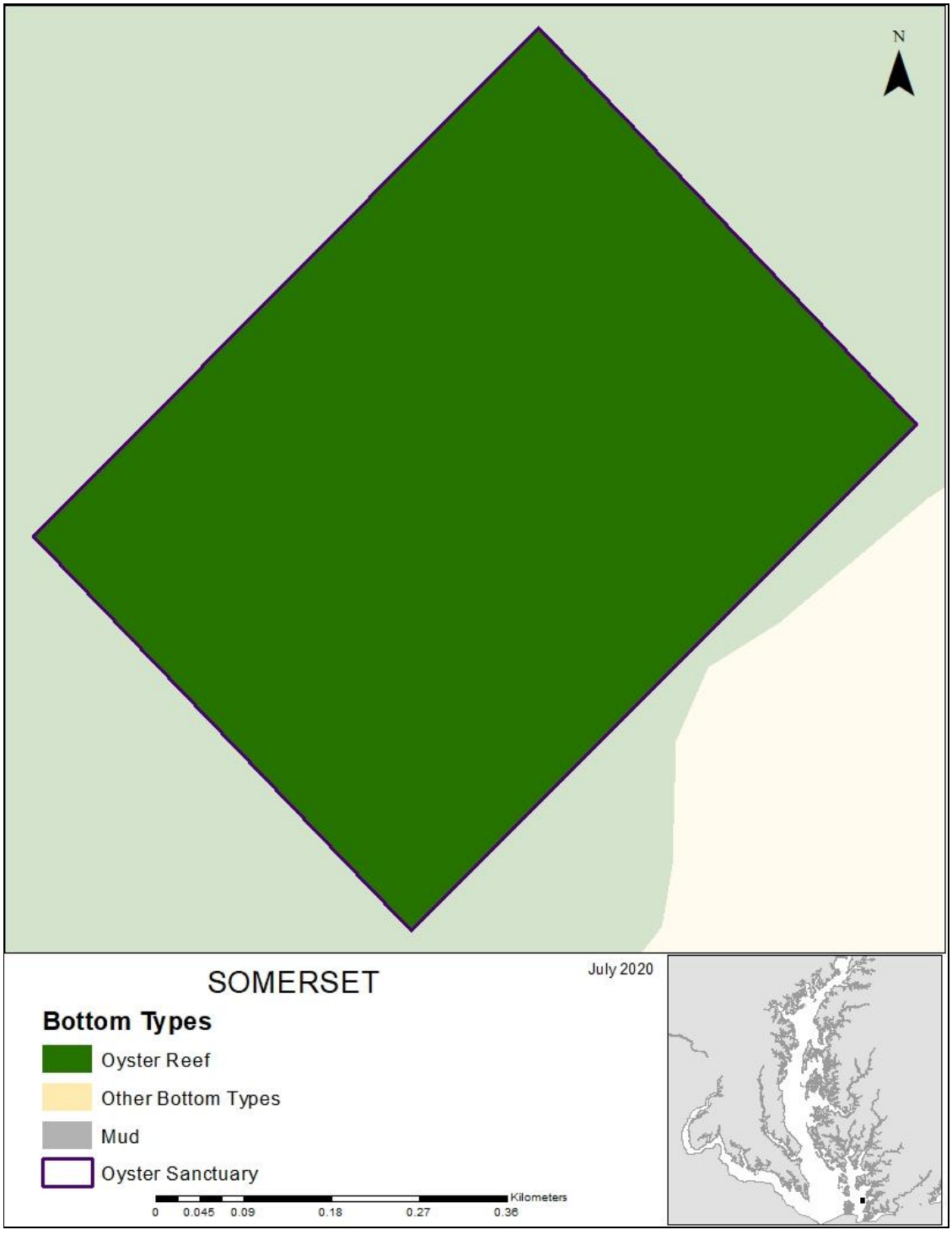

Figure A.41-2. Somerset Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Table A.41-1. Oyster population characteristics based on the Fall Survey in the Somerset Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 15	5 / 15	5 / 15
Number of Live Spat Oysters per square meter	69.6 ± 48.7	31.6 ± 9.3	70.6 ± 31.8
Number of Live Small-Sized Oysters per square meter	54.8 ± 24.6	42.8 ± 12.7	26.8 ± 11.7
Number of Live Market-Sized Oysters per square meter	14.8 ± 5.1	29.9 ± 5.2	10.8 ± 1.9
Live Oyster Biomass (g Dry Weight per Bushel)	176	283 ± 24	106 ± 61
Observed Mortality (%)	19 ± 2	14 ± 1	17 ± 6
Cultch (Bushels per 100 ft Towed)	1.2 ± 0.2	1 ± 0.1	1 ± 0.2
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

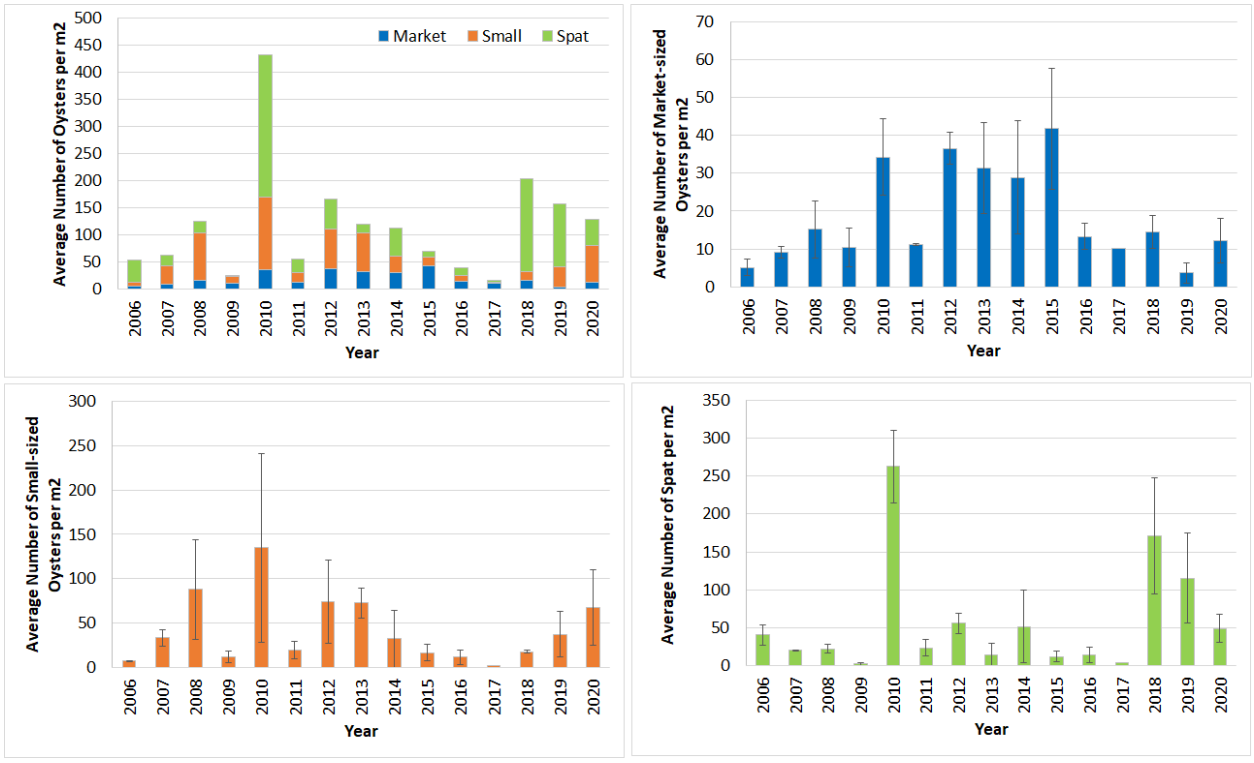

Figure A.41-3. Average number of live oysters per square meter by size class in the Somerset Sanctuary. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

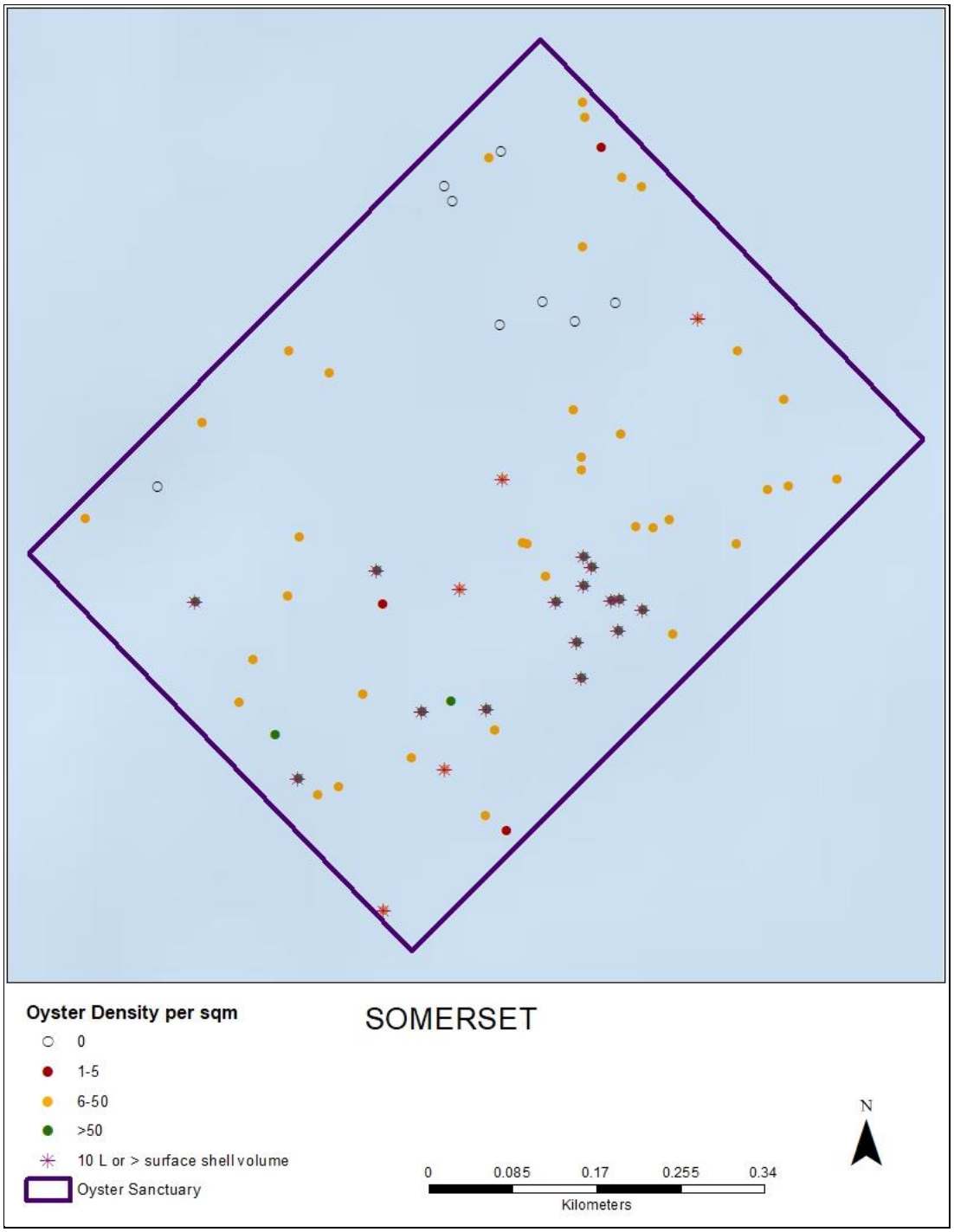

Figure A.41-4. Map of 2020 oyster density in the Somerset Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

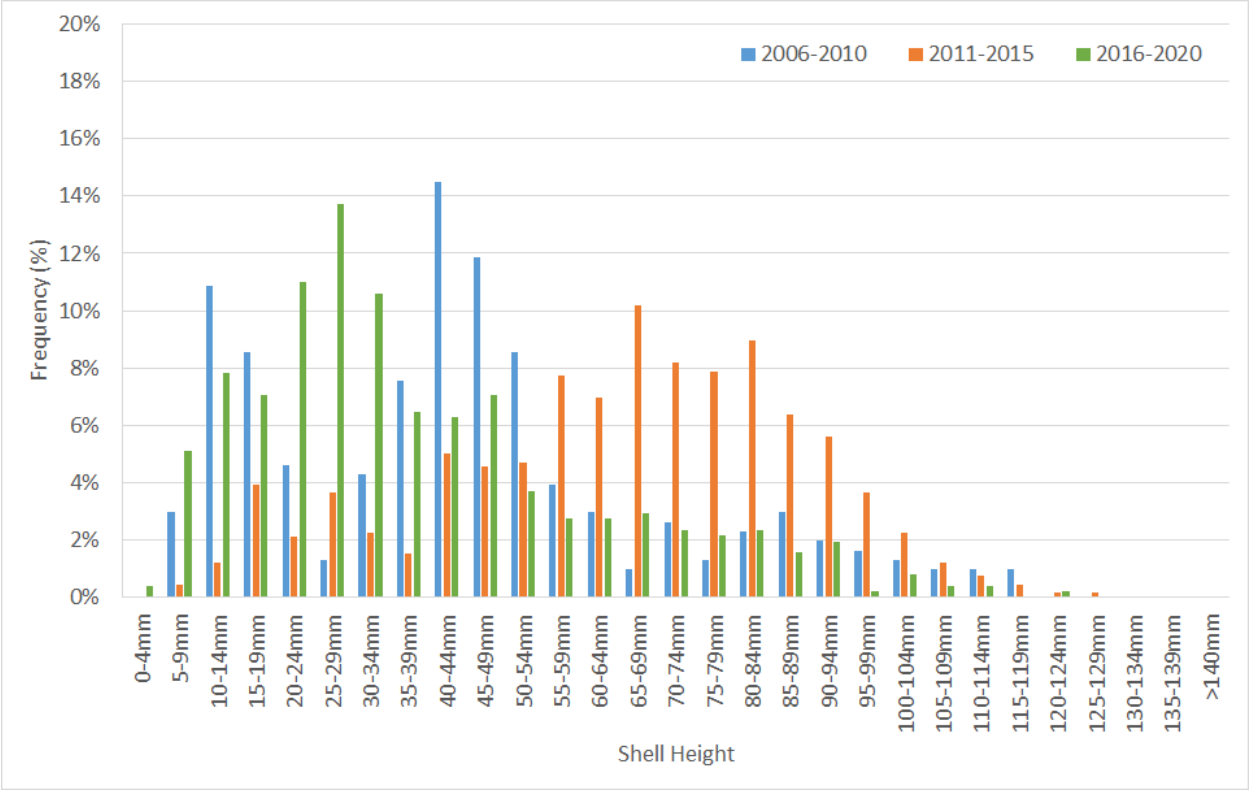

Figure A.41-5. Shell height frequencies of live oysters per bushel of material in the Somerset Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Piney Island East Addition 1 bar. Data was not collected in 2006 and 2008 to 2010.

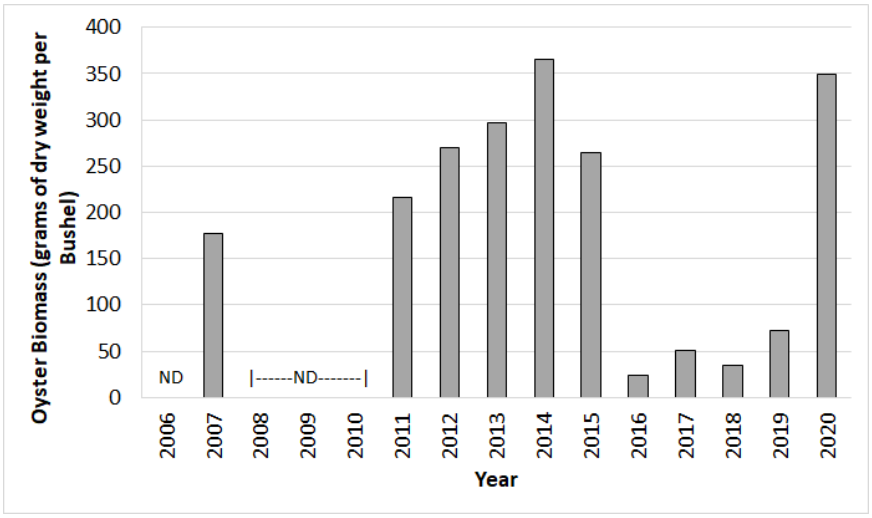

Figure A.41-6. Oyster biomass (grams of dry weight per bushel of material) in the Somerset Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Piney Island East Addition 1 bar. ND = No Data.

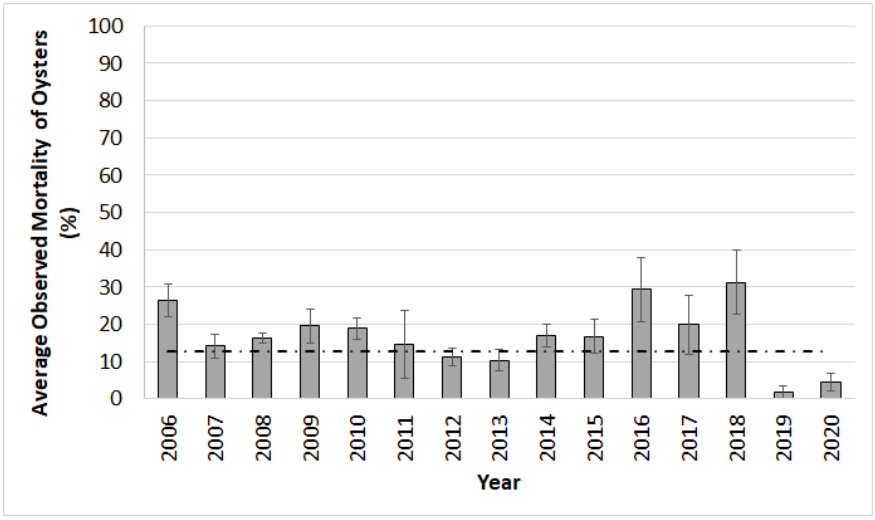

Figure A.41-7. Average annual observed mortality of market-sized and small-sized oysters in Somerset Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. The dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

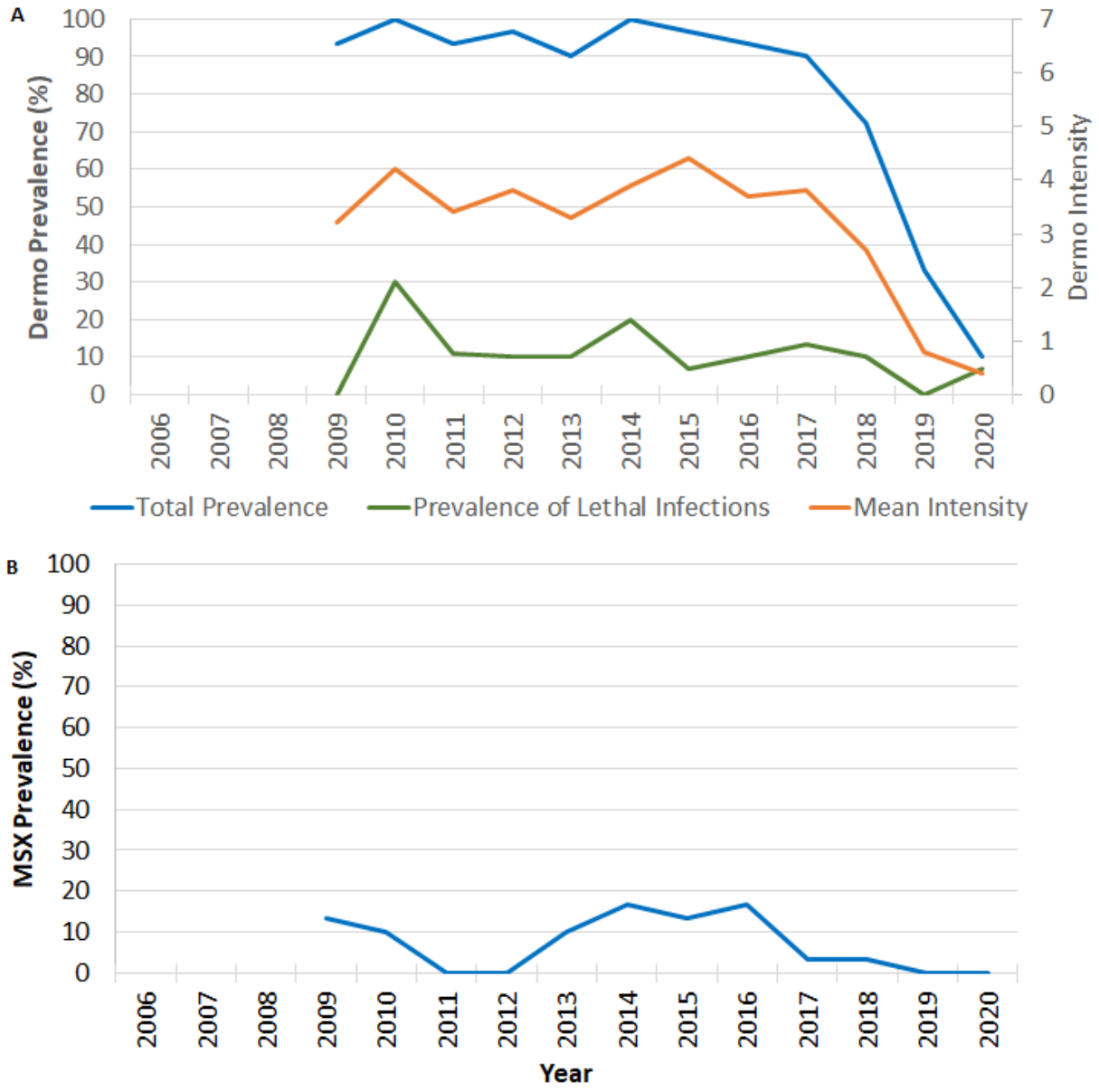

Figure A.41-8. Oyster disease prevalence and intensity in the Somerset Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Piney Island East Addition 1 bar. No data was collected from 2006 to 2008.

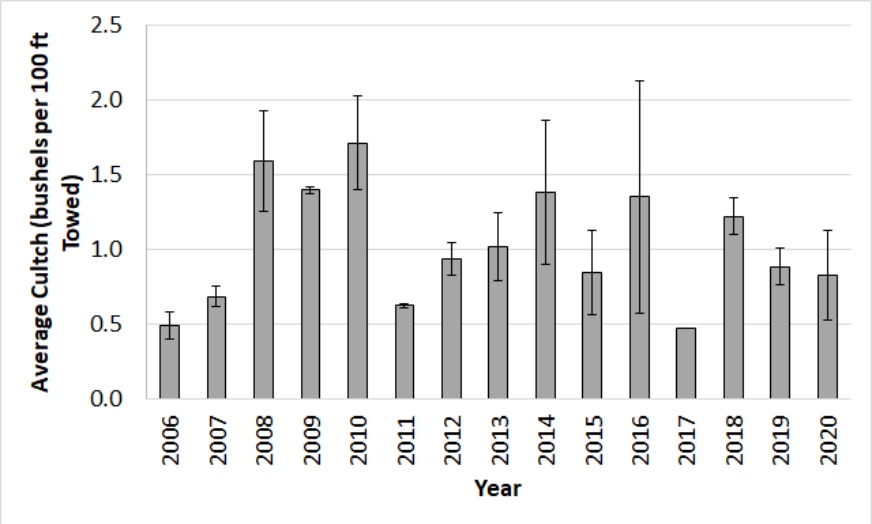

Figure A.41-9. Average cultch (live and dead oysters and loose shell) in the Somerset Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Error bars represent ± 1 standard error. ND = No Data.

Section A.42: South River Sanctuary

The South River Sanctuary is located in the upstream part of the South River, a tributary of the upper western shore of Chesapeake Bay within NOAA Code 088. The sanctuary is in a low-salinity (Zone 1) region. The South River Sanctuary was created in 2000 and encompasses 2,327 acres of which 141 (6%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are seven historic oyster bars within the sanctuary[73].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.42-1)
- Bottom types map (Figure A.42-2)
- Water Quality (Figure A.42-3)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in the sanctuary in 2014[74] and no new surveys have occurred since then.

Maryland's Eyes on the Bay Program monitors monthly water quality at station WT8.1 (38.9496, -76.5461) in this area. Water quality was favorable for oysters except for brief periods of low salinity. We are unaware of any studies explicitly examining oyster ecosystem services in the sanctuary.

The sanctuary has received restoration plantings since 2006 (four million hatchery spat-on-shell). Marylanders Grow Oysters, a public outreach program, plants oysters at one site in the sanctuary. Oysters have been planted through this program since 2009.

[73] See chart 9 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[74] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

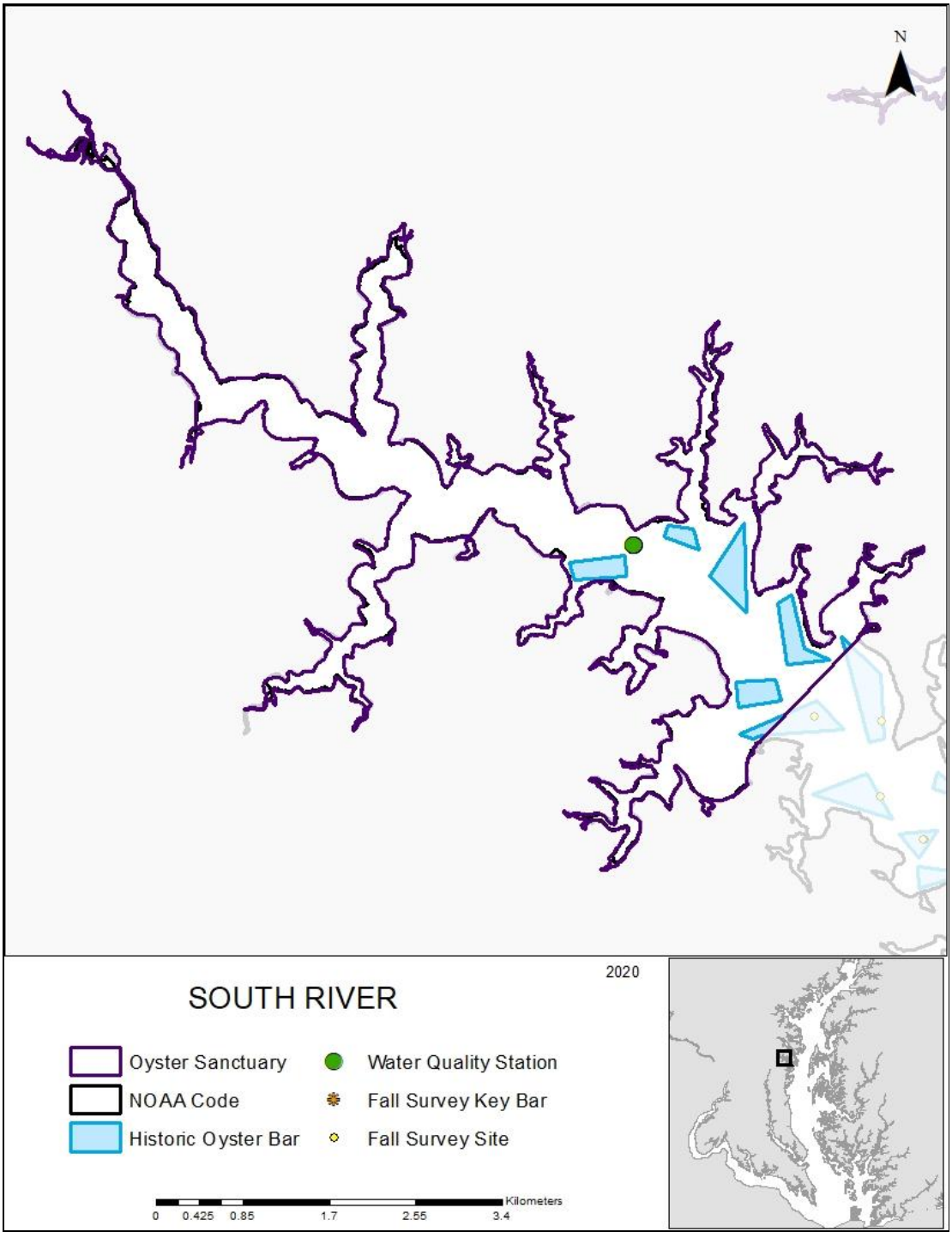

Figure A.42-1. South River Sanctuary.

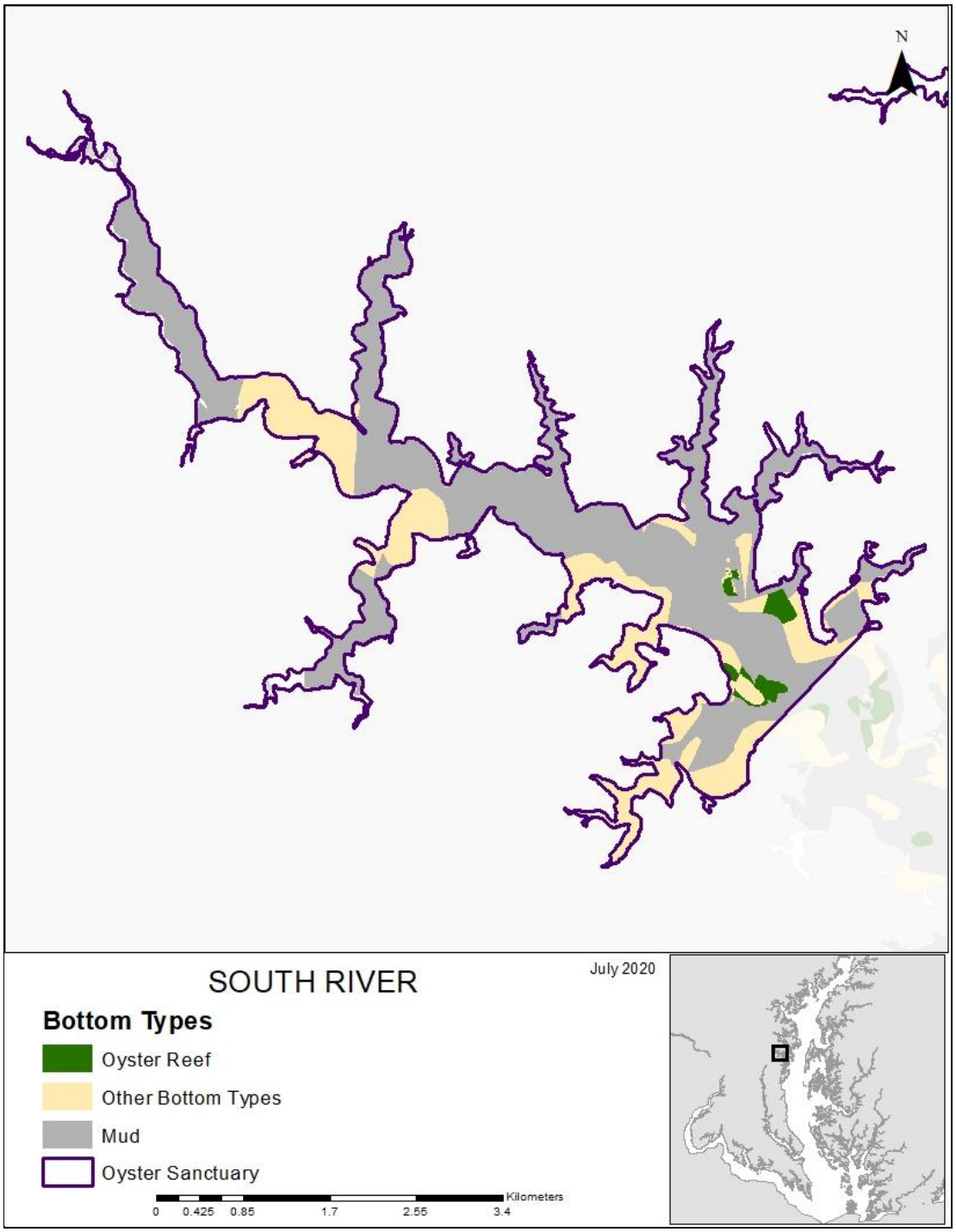

Figure A.42-2. South River Sanctuary bottom types. Data from NOAA Chesapeake Bay from 2006.

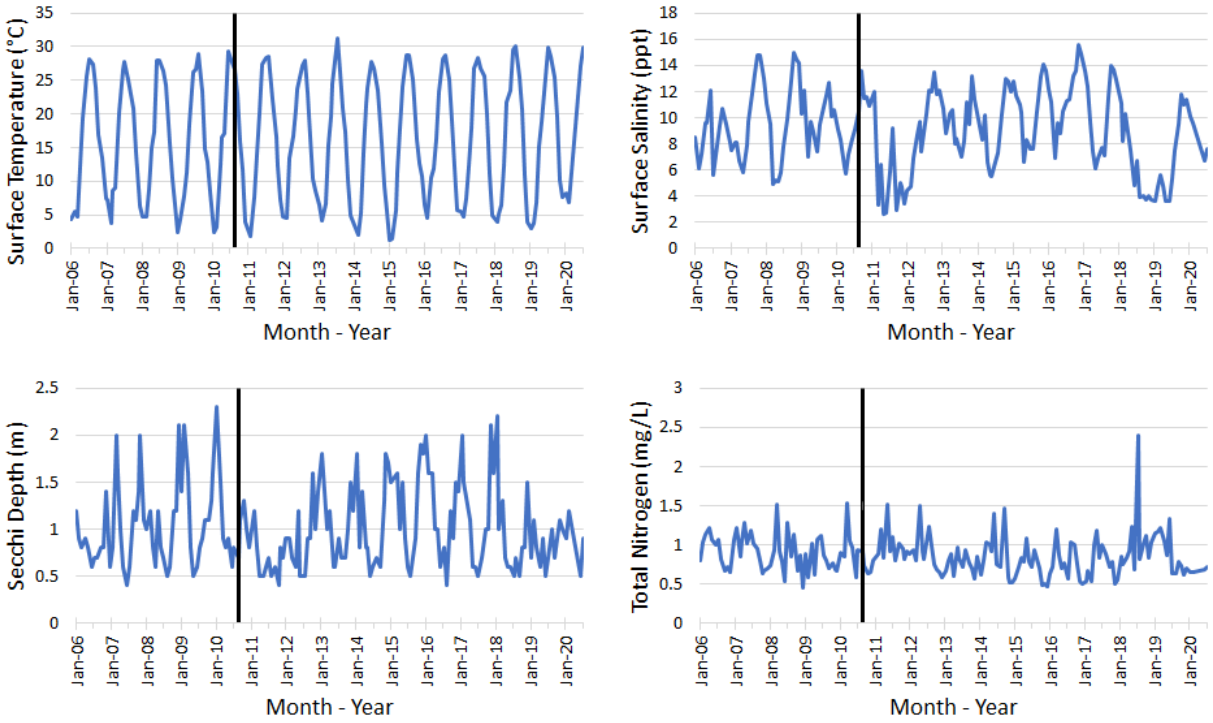

Figure A.42-3. Water quality data collected at Station WT8.1 in South River. Black line denotes the date the sanctuary was established.

Section A.43: St Marys River Sanctuary

The St Marys River Sanctuary is located in the upstream portion of the St. Marys River, a medium-salinity (Zone 2) region within NOAA Code 078. The mouth of the river empties into the Potomac River. The sanctuary was created in 2010 and encompasses 1,304 acres of which 89 (9%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are nine historic oyster bars within the sanctuary[75]. In 2018, the St. Marys River Sanctuary was selected to be the fourth large-scale restoration area in Maryland towards meeting the 2014 Chesapeake Bay Watershed Agreement[76].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.43-1)
- Bottom types map (Figure A.43-2)
- Summary statistics (Table A.43-1)
- Abundance per year (Figure A.43-3)
- Density Survey (Figure A.43-4)
- Shell height frequencies (Figure A.43-5)
- Biomass per year (Figure A.43-6)
- Observed mortality (Figure A.43-7)
- Dermo and MSX per year (Figure A.43-8)
- Cultch per year (Figure A.43-9)

The Fall Survey sampled two bars in this sanctuary. Average market and small densities have remained stable in 2016-2020 as compared to 2011-2015. Average spat density decreased in 2016-2020 as compared to 2011-2015. Oyster biomass increased over time, due to the increase in number of market oysters since 2006. Oyster shell height frequencies shifted over time whereas oysters larger than 100 mm comprised 0% of those measured before 2011, compared to 8% of those measured between 2016 and 2020. Trends in oyster dermo disease have varied over time and have decreased since 2016. Average cultch, a relative measure of oyster habitat defined as the amount of oysters (live and dead) and loose shell, has varied over time with no clear trend. Average mortality doubled during the 2016-2020 time period and was well above the long-term baywide average. This is driven by observed mortality being 96% on one bar in 2020. The cause is currently unknown but is thought to be from an algal bloom.

In 2018, a patent tong survey was conducted by Oyster Recovery Partnership and Versar, Inc[77]. This oyster reef preconstruction site assessment survey was conducted to identify benthic habitat suitable for oyster population growth in the St. Marys River Sanctuary and to determine the type of restoration construction needed. The survey also determined if any areas within the sanctuary already met the criteria to be considered restored.

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[75] See chart 38 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[76] Maryland Interagency Oyster Restoration Workgroup of the Sustainable Fisheries Goal Implementation Team. 2020. Upper St. Mary's River Oyster Restoration Tributary Plan. https://dnr.maryland.gov/fisheries/Documents/Reg_Changes/St.%20Mary%27s%20Blueprint%20final.pdf

[77] Maryland Interagency Restoration Workgroup. 2020. Upper St. Marys River Oyster Restoration Tributary Plan - Appendix B. 49 pgs. https://dnr.maryland.gov/fisheries/Documents/Reg_Changes/St.%20Mary%27s%20Blueprint%20final.pdf

On the 64 acres surveyed, the average oyster density was 18.16 oysters per square meter. Of the 583 samples, 32% had zero oysters, 12.5% had 1-5 oysters per square meter, 48.5% had 6-50 oysters per square meter and 6.9% of the samples had >50 oysters per square meter. The average shell volume density was 9.8 liters per square meter.

Water quality information was collected from 1999 to 2009[78]. We are not aware of any new water quality information collected since 2015. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

No replenishment plantings occurred between 2006 and 2009. After the sanctuary was established, the St. Mary's Watershed Association applied for and was granted a permit to construct an oyster reef in the sanctuary. The association has planted 603 reef balls, 185 tons of concrete rubble, 27,000 bushels of shell in piles, 27 million and spat-on-shell. Marylanders Grow Oysters, a public outreach program, has planted oysters in the sanctuary since 2009. Saint Mary's College also plants spat in the sanctuary annually as part of their orientation program for incoming students.. In 2021 The Nature Conservancy planted approximately 109,142 aquaculture oysters in this sanctuary of which 47% were diploid as part of a nationwide program to help aquaculture farmers impacted by Covid19. Large-scale restoration planting activities are slated to begin in 2021.

[78] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

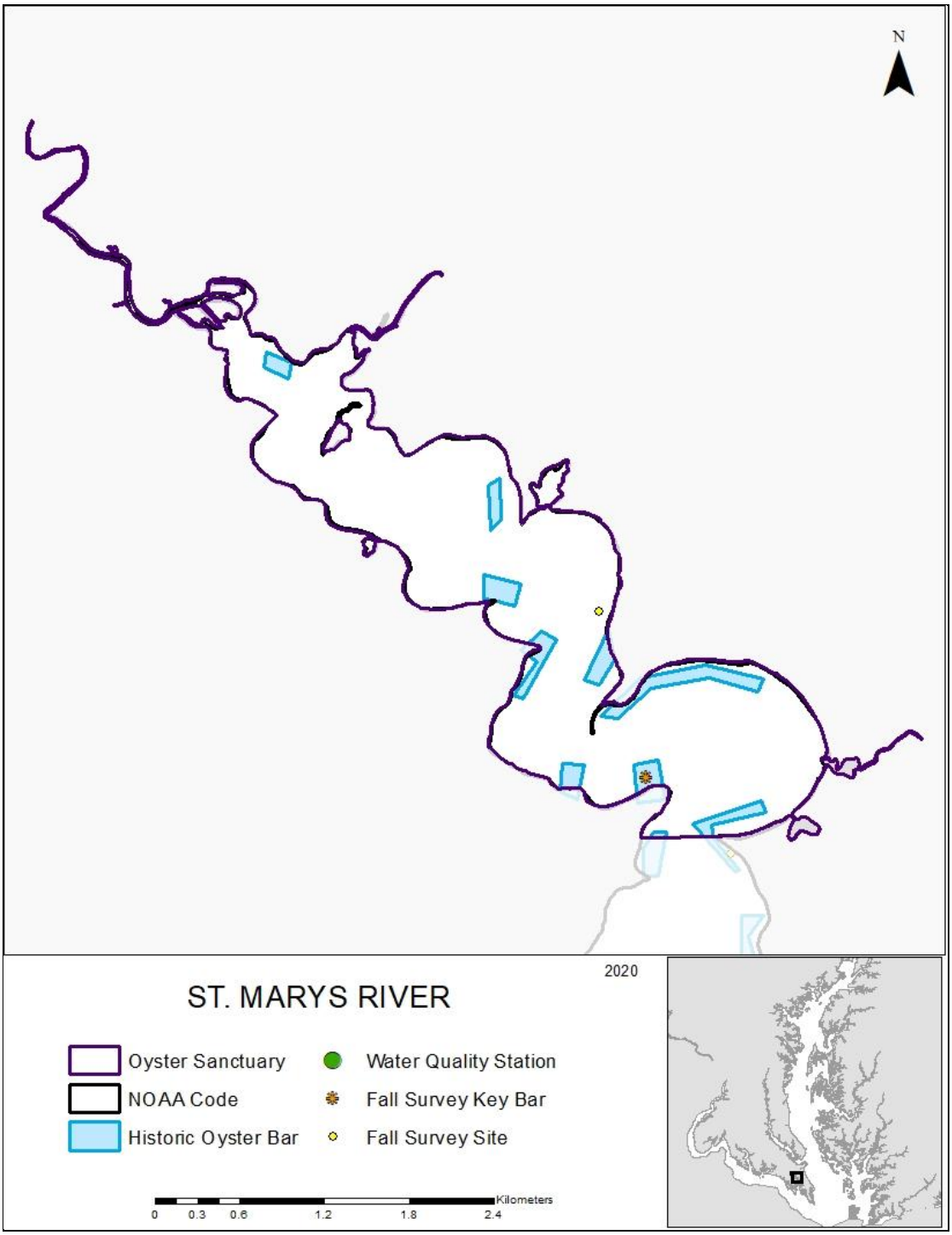

Figure A.43-1. St Marys River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

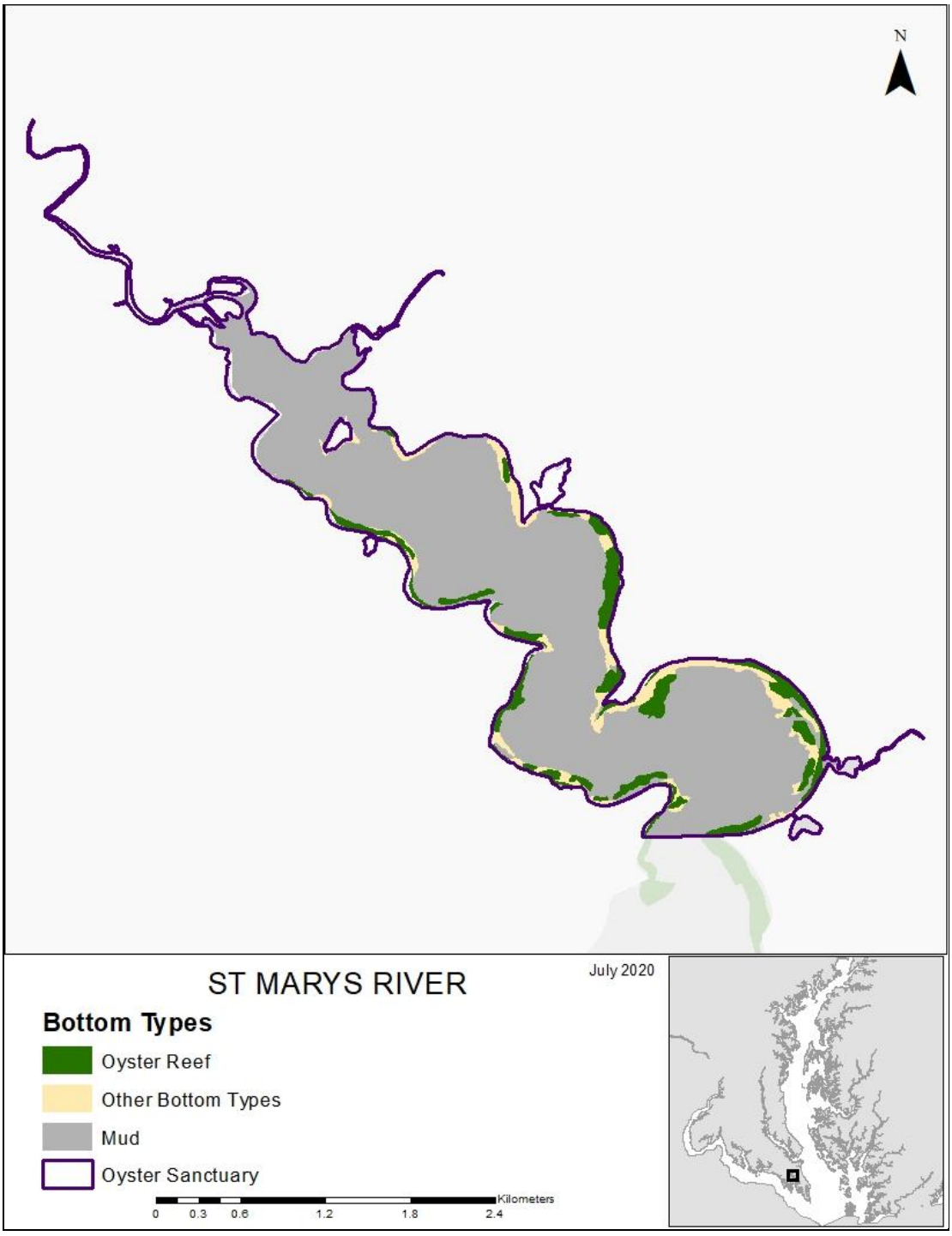

Figure A.43-2. St. Marys River Sanctuary bottom types. Data from Maryland Geological Survey (MGS) in 2010 and 2018.

Table A.43-1. Oyster population characteristics based on the Fall Survey in the St. Marys River Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 10	5 / 10	5 / 10
Number of Live Spat Oysters per square meter	332.1 ± 140.1	127.6 ± 55.9	52.4 ± 30.9
Number of Live Small-Sized Oysters per square meter	391 ± 185.2	234.3 ± 36	213.3 ± 73.7
Number of Live Market-Sized Oysters per square meter	29.5 ± 12.3	79.4 ± 20	93.3 ± 24.8
Live Oyster Biomass (g Dry Weight per Bushel)	206 ± 45	347 ± 53	399 ± 56
Observed Mortality (%)	12 ± 2	11 ± 3	22 ± 13
Cultch (Bushels per 100 ft Towed)	2.4 ± 0.4	2 ± 0.2	2 ± 0.2
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

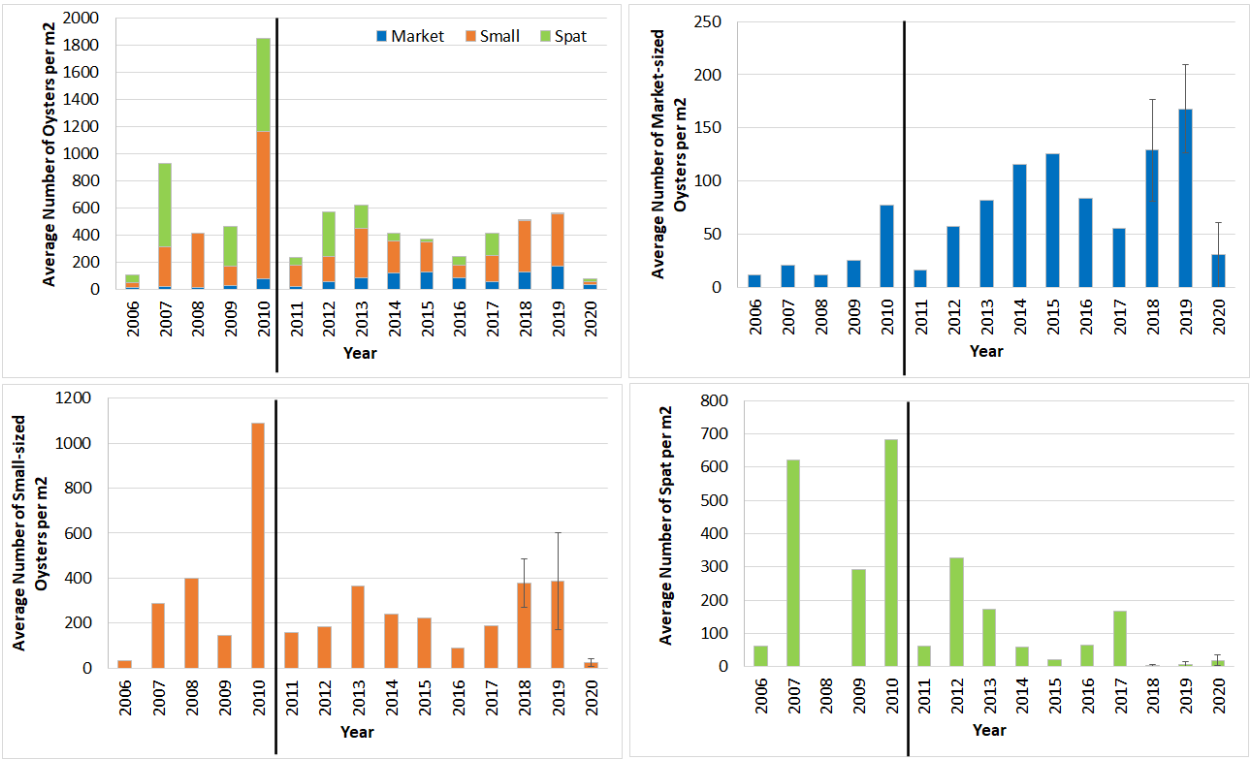

Figure A.43-3. Average number of live oysters per square meter by size class in the St Marys River Sanctuary. The black line denotes the year the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

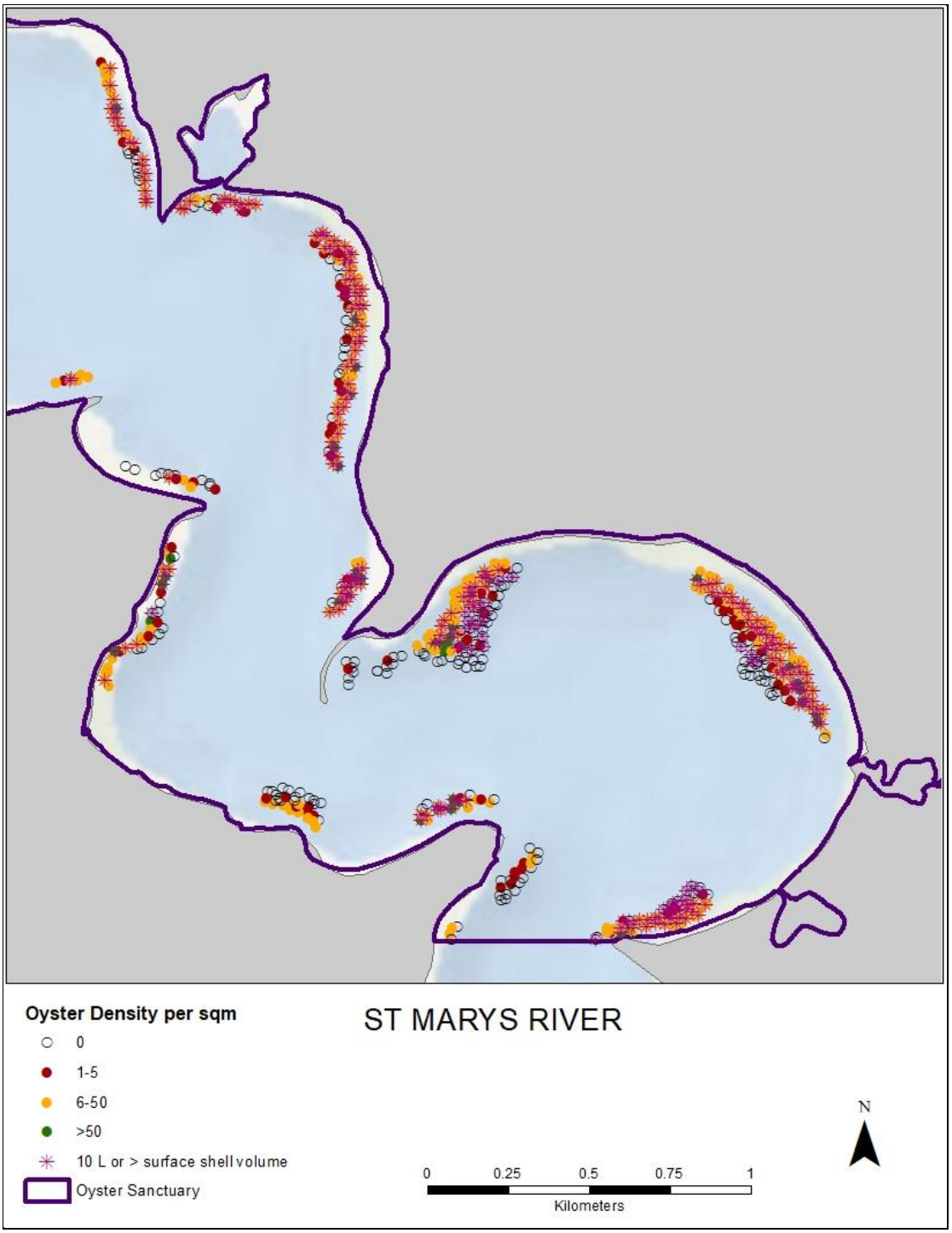

Figure A.43-4. Map of 2018 oyster density in the St Marys Sanctuary. Data from Oyster Recovery Partnership Patent Tong Groundtruth Survey.

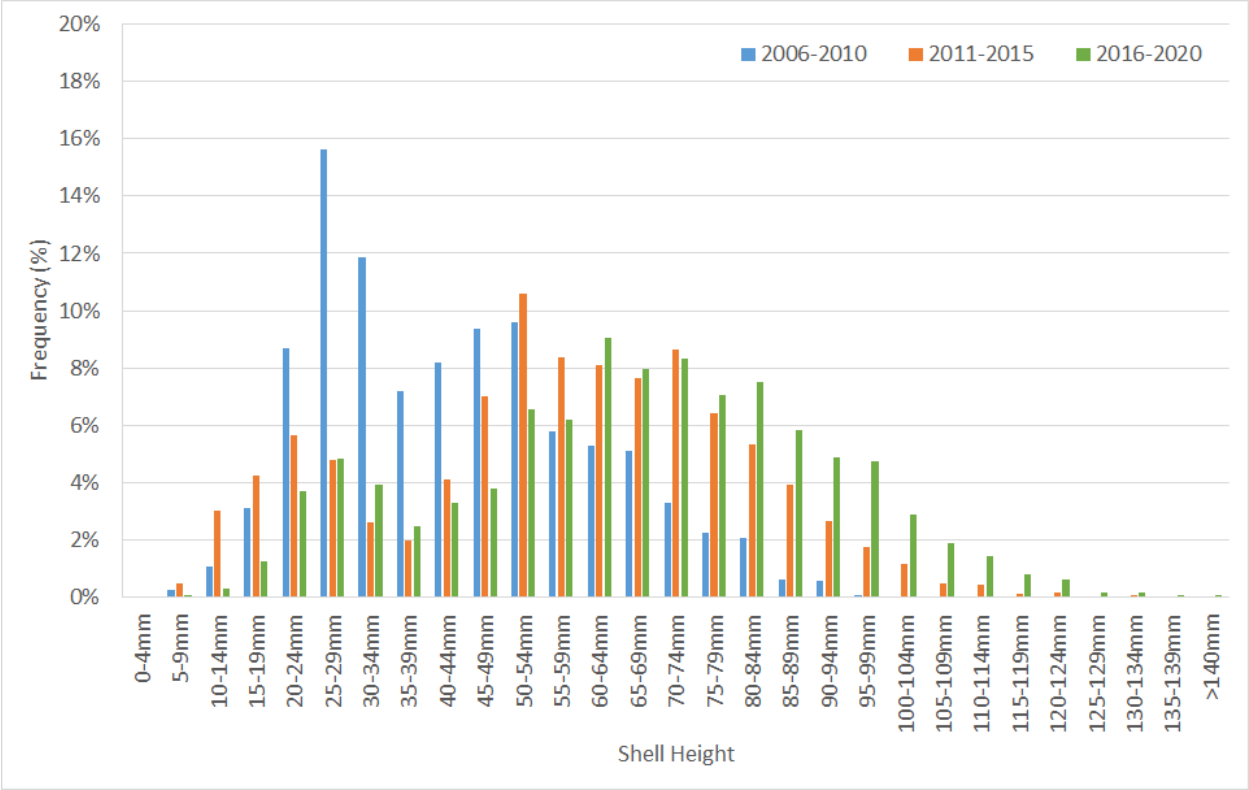

Figure A.43-5. Shell height frequencies of live oysters per bushel of material in the St Marys River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Pagan bar.

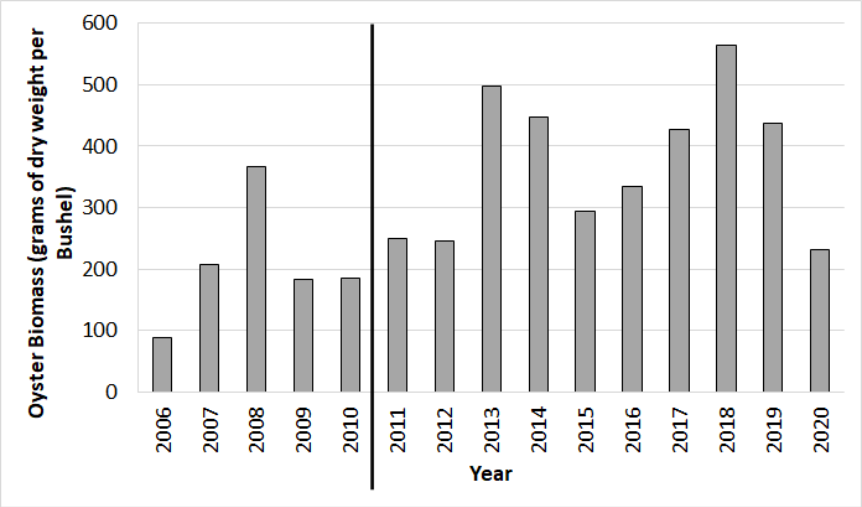

Figure A.43-6. Oyster biomass (grams of dry weight per bushel of material) in the St Marys River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Pagan bar. Black line indicates the date the sanctuary was established.

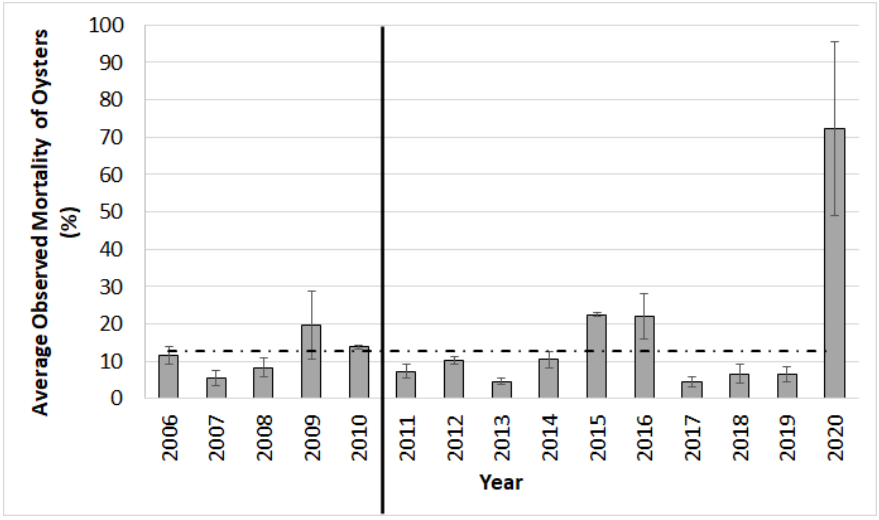

Figure A.43-7. Average observed mortality of market-sized and small-sized oysters in St Marys River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006 to 2020 baywide average observed mortality. Error bars represent ± 1 standard error.

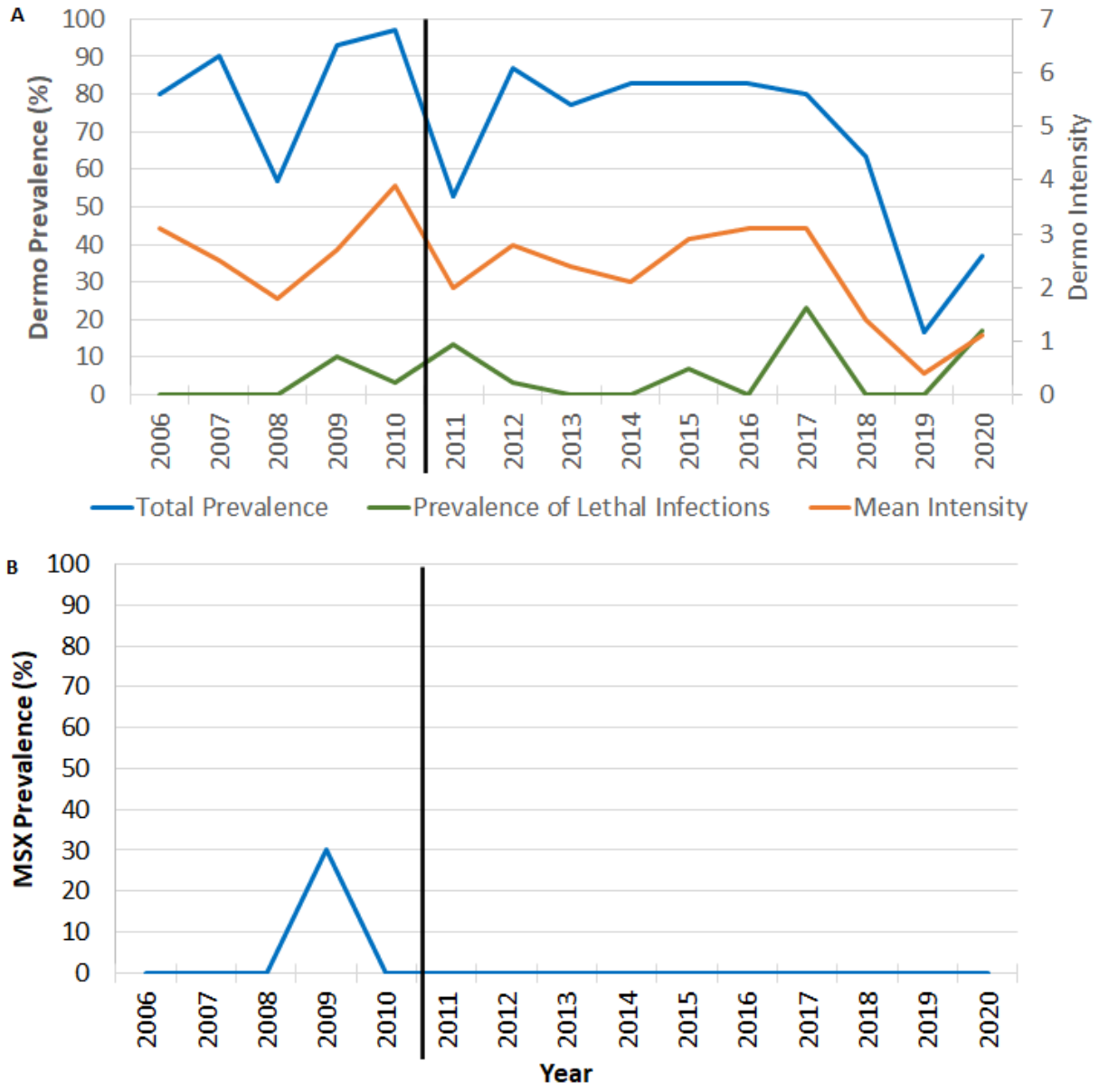

Figure A.43-8. Oyster disease prevalence and intensity in the St Marys River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Pagan bar. Black line denotes the date the sanctuary was established.

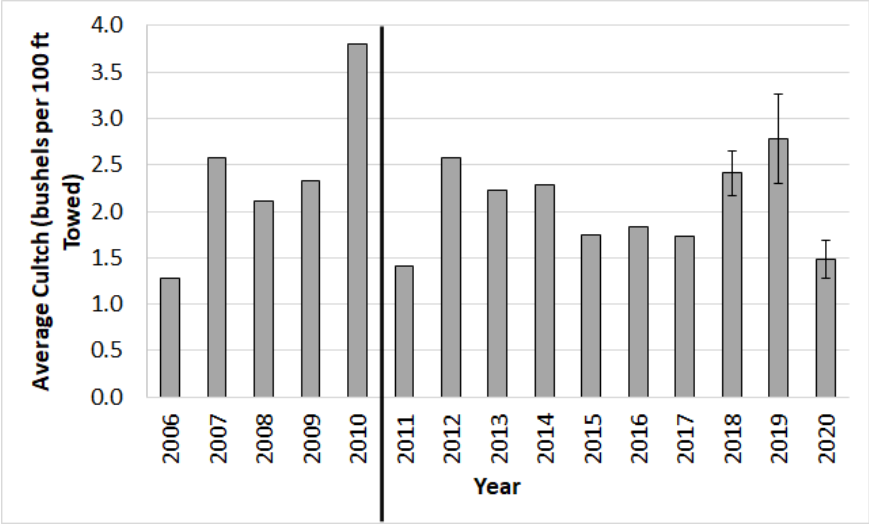

Figure A.43-9. Average cultch (live and dead oysters and loose shell) in the St Marys River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error. ND = No Data.

Section A.44: Tilghman Island Sanctuary

The Tilghman Island Sanctuary is located in the middle eastern portion of Maryland's Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Code 027. The sanctuary was created in 2010 and encompasses 2,534 acres of which 1,345 acres (53%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are two historic oyster bars (Bay Hundred and Pone bars) within the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.44-1)
- Bottom types map (Figure A.44-2)

The Fall Survey has not sampled any oyster bars within this area since 2006. A patent tong population survey was conducted in sanctuary in 2015[79] and no new surveys have occurred since then. The sanctuary has not received any replenishment or restoration efforts since 2006. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

[79] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

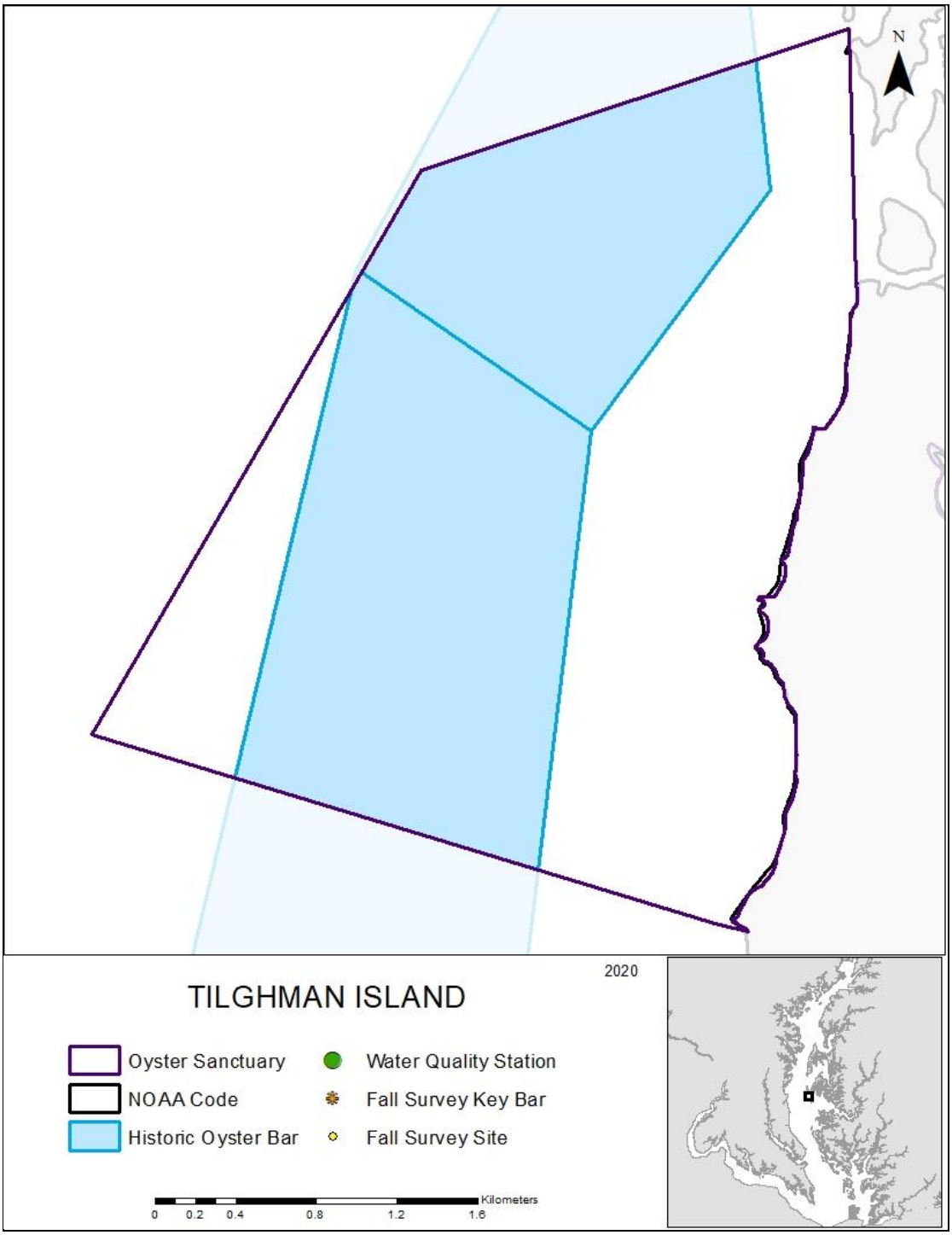

Figure A.44-1. Tilghman Island Sanctuary.

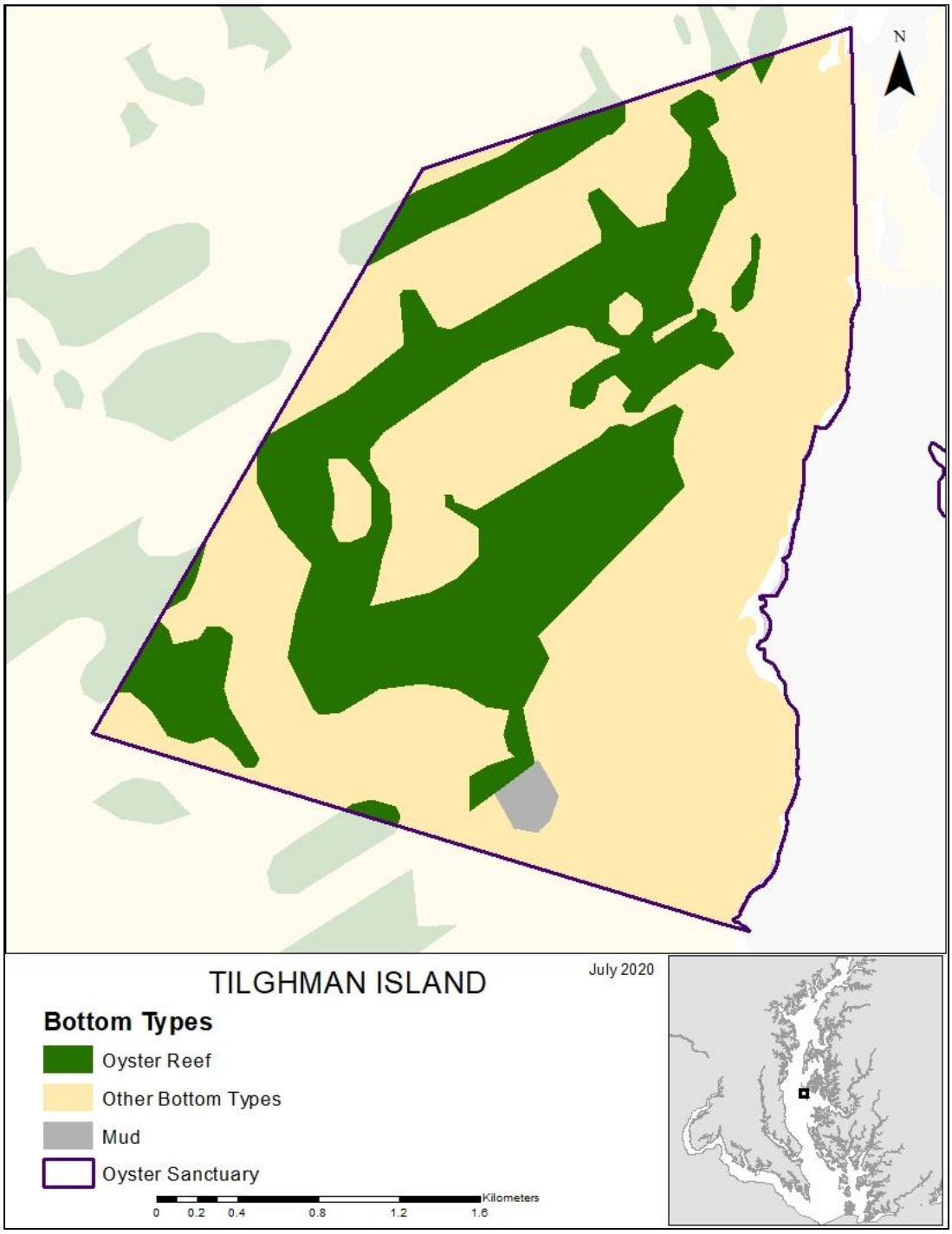

Figure A.44-2. Tilghman Island Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Section A.45: Tred Avon River Sanctuary

The Tred Avon River Sanctuary, created in 2010, is located in the upper reaches of the Tred Avon River, a tributary of the Choptank River within NOAA Code 637. The sanctuary is in a low-salinity (Zone 1) region and encompasses 4,149 acres of which 1,152 (28%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 27 historic oyster bars within the sanctuary[80]. The Tred Avon River Sanctuary is one of the sanctuaries chosen for large-scale oyster restoration under the Chesapeake Watershed Agreement.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.45-1)
- Bottom types map (Figure A.45-2)
- Summary statistics (Table A.45-1)
- Abundance per year (Figure A.45-3)
- Shell height frequencies (Figure A.45-4)
- Biomass per year (Figure A.45-5)
- Observed mortality (Figure A.45-6)
- Dermo and MSX per year (Figure A.45-7)
- Cultch per year (Figure A.45-8)

The Fall Survey sampled five bars in the sanctuary. The density of spat, small and market oysters increased in 2016-2020. While there was an increase in natural spat for 2020, much of the large increase in spat density may be due to a sample taken on a 2020 hatchery spat-on-shell planting. Average 2016-2020 spat density without the one sample in 2020 taken on a hatchery spat-on-shell planting was 20 oysters per square meter. There is an increasing trend in biomass over time. Observed mortality increased slightly but remained below the long-term baywide average. The amount of cultch declined slightly from the previous five-year average. The mean size of oysters in this area has remained relatively consistent.

The department conducted a population patent tong survey in 2012 and 2013[81]. Other organizations have been monitoring the restoration areas using patent tong and diver surveys. Results from these surveys indicate that three years after initial restoration 80% of the reefs monitored met the minimum threshold restoration criteria of 15 oysters per square meter and 15 grams of dry weight (biomass) per square meter[82].

Between 2006 and 2010, approximately 14 million hatchery spat-on-shell were planted to enhance the public oyster fishery. After the creation of the sanctuary areas in 2010, Tred Avon River has received substrate and hatchery spat-on-shell restoration plantings. Due to a shortage of oyster shell, reefs were restored using stone, clam shell, and mixed shell (clam and whelk).

[80] See chart 16 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[81] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

[82] National Oceanic and Atmospheric Administration. 2020. 2019 Oyster Reef Monitoring Report Analysis of Data from Large-Scale Sanctuary Oyster Restoration Projects in Maryland Collected from Fall 2019 through Summer 2020. https://www.chesapeakebay.net/documents/2019_MD_Oyster_Monitoring_Report_FINAL.pdf

Over 460.4 million hatchery spat-on-shell were placed in the sanctuary from 2015-2020 on 92.45 acres of restored oyster bottom. Several organizations participated in the restoration work including MDNR, U.S. Army Corps of Engineers, NOAA, Oyster Recovery Partnership, National Fish and Wildlife Foundation, and Chesapeake Bay Foundation. Marylanders Grow Oysters, a public outreach program, has planted oysters since 2008 at four sites in the sanctuary.

Many studies took place evaluating ecosystem services provided by large-scale oyster restoration, including, a study from May 2014 through September 2017 to assess how fish communities and abundance vary on restored and unrestored reefs: a study evaluating the impacts of reef restoration on finfish; a study of fish trap encounter, capture efficiency rates, and trap-independent finfish and crab abundance on restoration sites; a qualitative index of oyster reef habitat quality developed using images from restored and unrestored reefs, including those from the Tred Avon sanctuary; and as a study estimating the ecological benefits and socioeconomic impacts from oyster restoration.[83] We are unaware of any continual water quality monitoring in this area.

[83] Bruce, D. G., J. C. Cornwell, L. Harris, T. F. Ihde, M. L. Kellogg, S. Knoche, R. N. Lipcius, D. N. McCulloch-Prosser, S. P. McIninch, M. B. Ogburn, R. D. Seitz, J. Testa, S. R. Westby, and B. Vogt. 2021. A Synopsis of Research on the Ecosystem Services Provided by Large-Scale Oyster Restoration in the Chesapeake Bay. NOAA Tech. Memo. NMFS-OHC-8, 52 p.

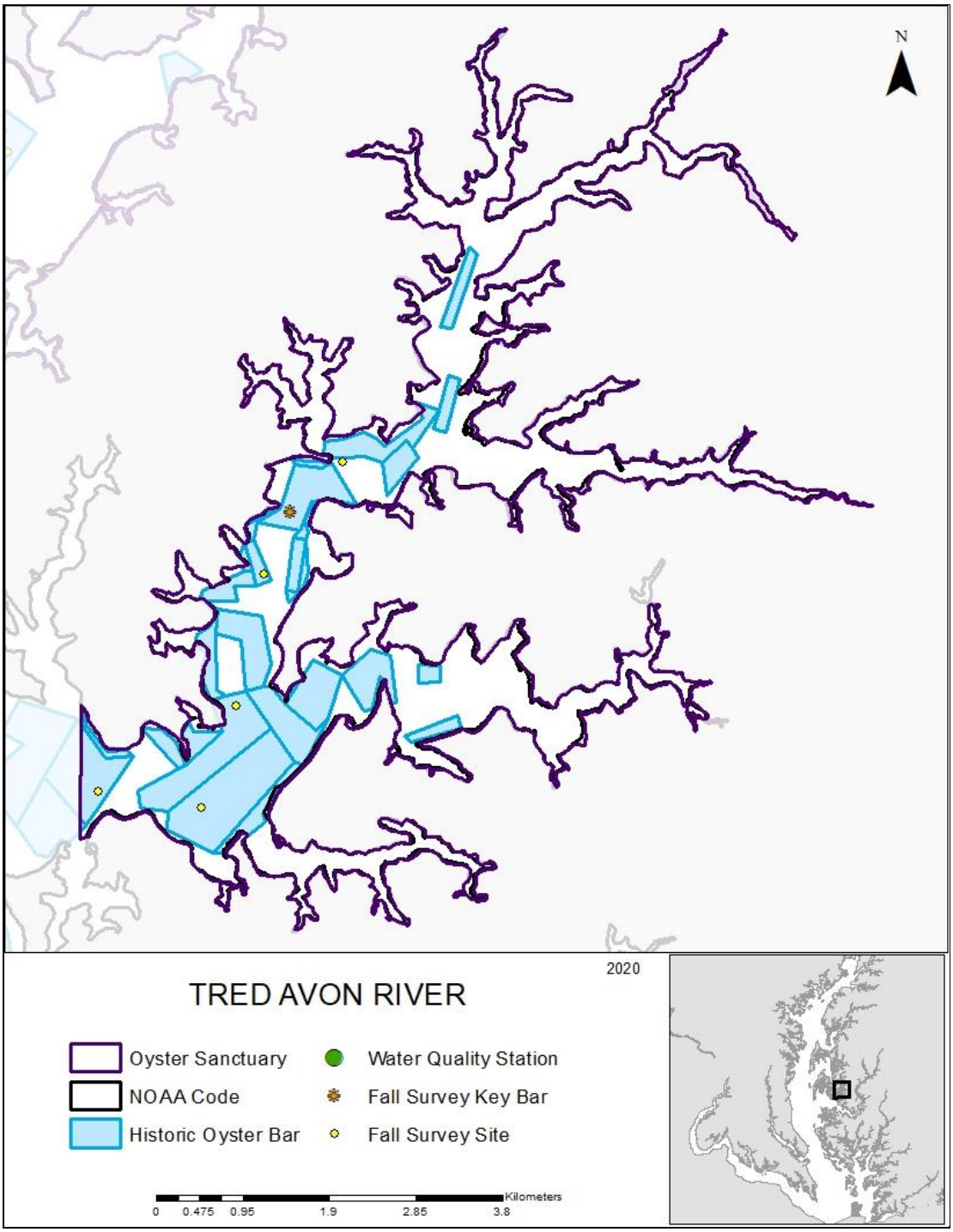

Figure A.45-1. Tred Avon River Sanctuary. Fall Survey sites may not be sampled every year.

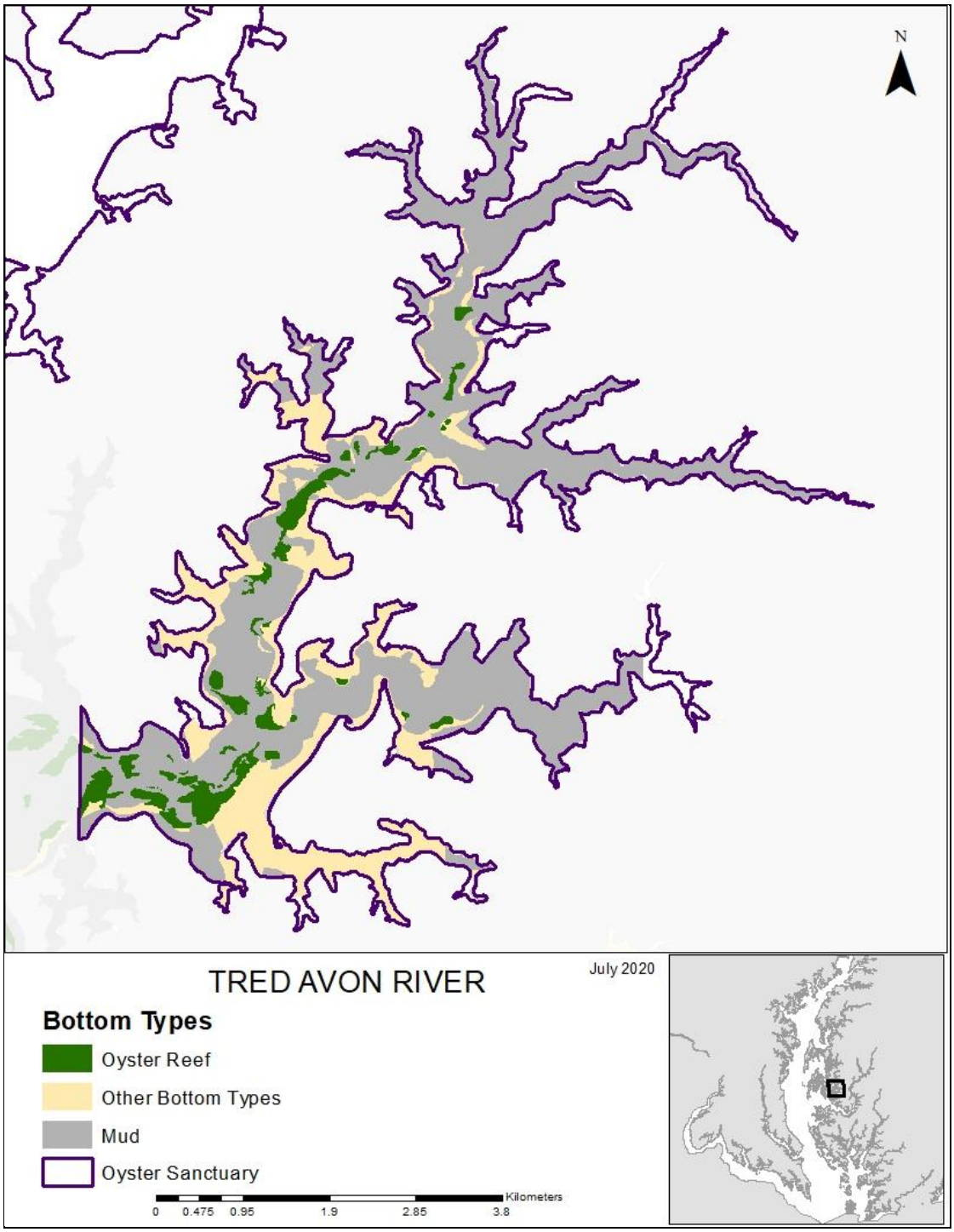

Figure A.45-2. Tred Avon River Sanctuary bottom types. Data from Maryland Geological Survey in 2008, The Nature Conservancy, and NOAA's Chesapeake Bay Office from 2015 and 2016.

Table A.45-1. Oyster population characteristics based on the Fall Survey in the Tred Avon River Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 30	5 / 30	5 / 30
Number of Live Spat Oysters per square meter	5 ± 2.2	3.5 ± 2.9	64.6 ± 61.5
Number of Live Small-Sized Oysters per square meter	19.9 ± 9.9	21.8 ± 7	48.6 ± 22.9
Number of Live Market-Sized Oysters per square meter	29 ± 3	107.9 ± 17	113.5 ± 14.9
Live Oyster Biomass (g Dry Weight per Bushel)	103 ± 13	175 ± 22	265 ± 17
Observed Mortality (%)	8 ± 2	8 ± 2	11 ± 2
Cultch (Bushels per 100 ft Towed)	1.6 ± 0.2	2.5 ± 0.4	1.9 ± 0.1
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

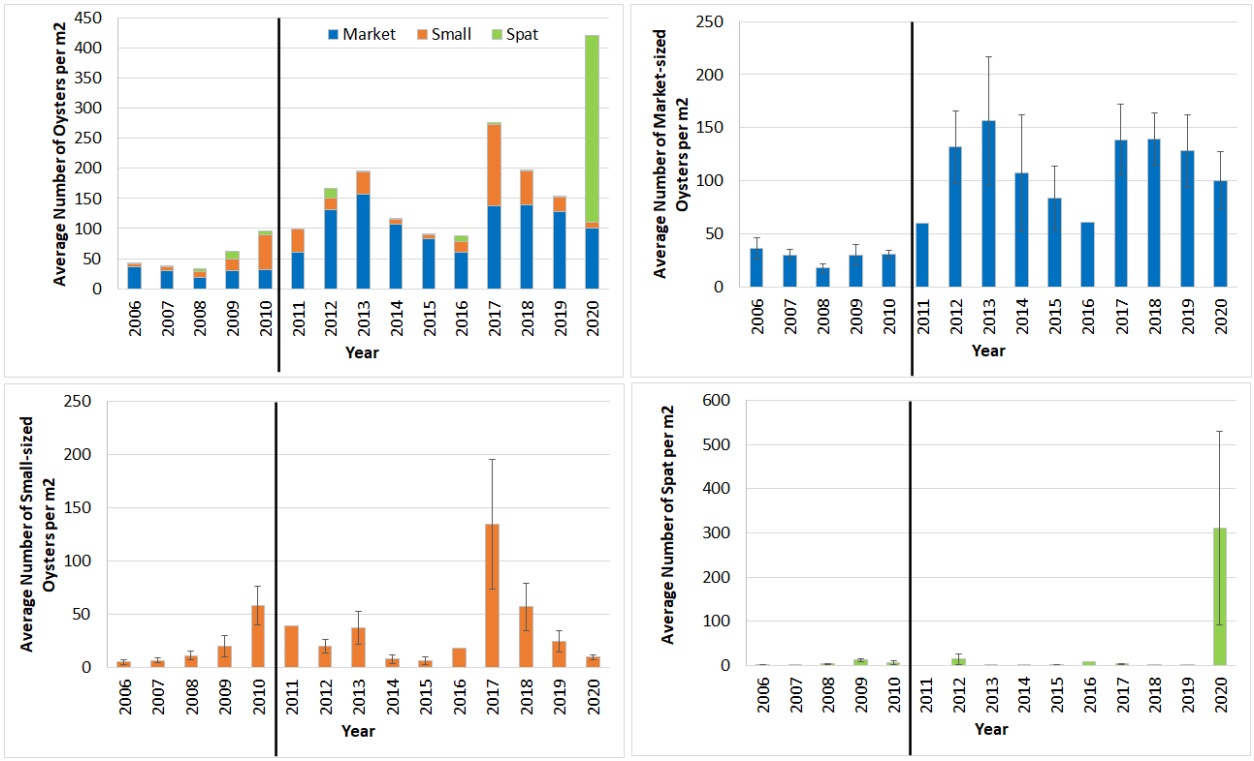

Figure A.45-3. Average number of live oysters per square meter by size class in the Tred Avon River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

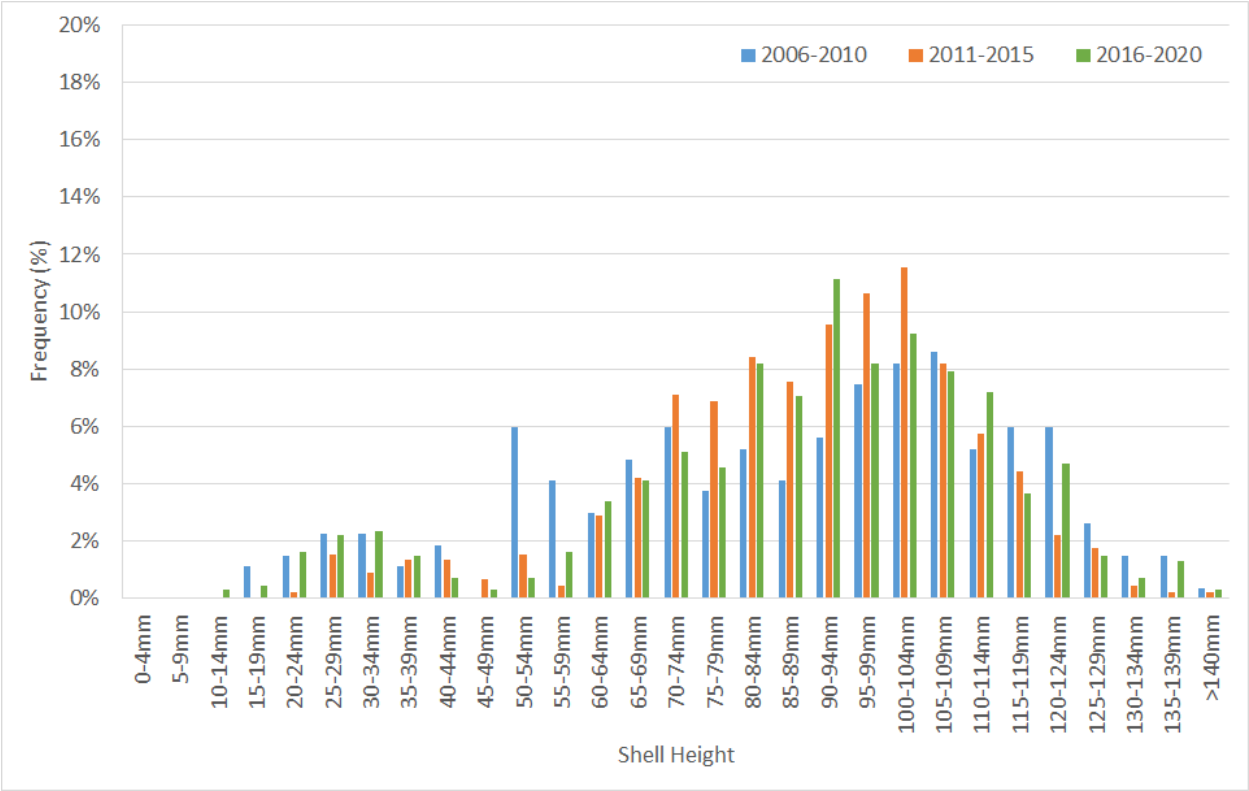

Figure A.45-4. Shell height frequencies of live oysters per bushel of material in the Tred Avon River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Double Mills bar.

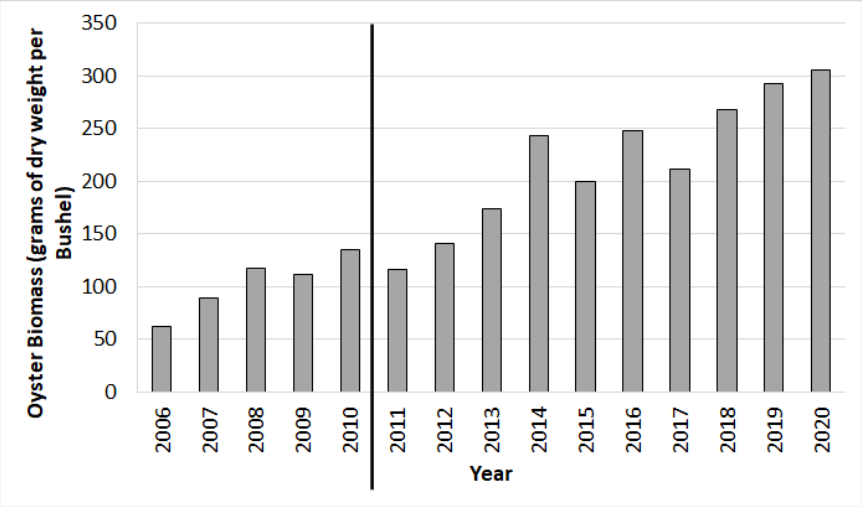

Figure A.45-5. Oyster biomass (grams of dry weight per bushel of material) in the Tred Avon River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Double Mills bar. Black line indicates the date the sanctuary was established.

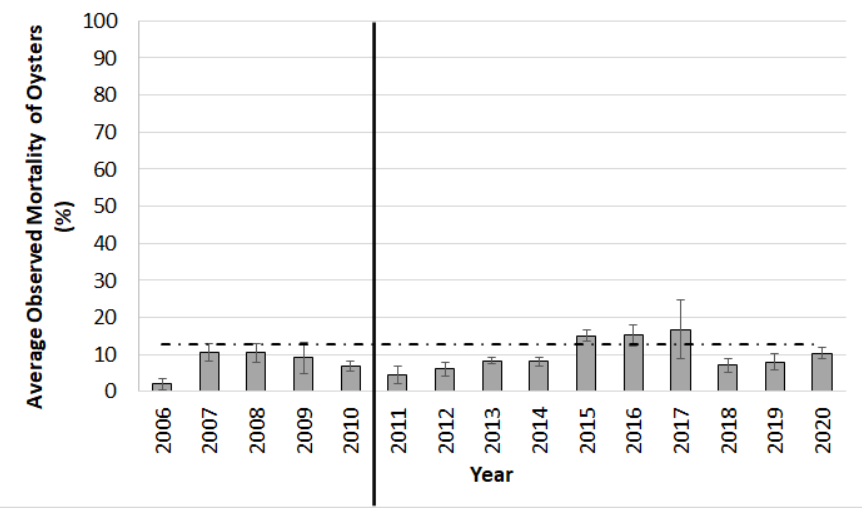

Figure A.45-6. Average annual observed mortality of market-sized and small-sized oysters in Tred Avon River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

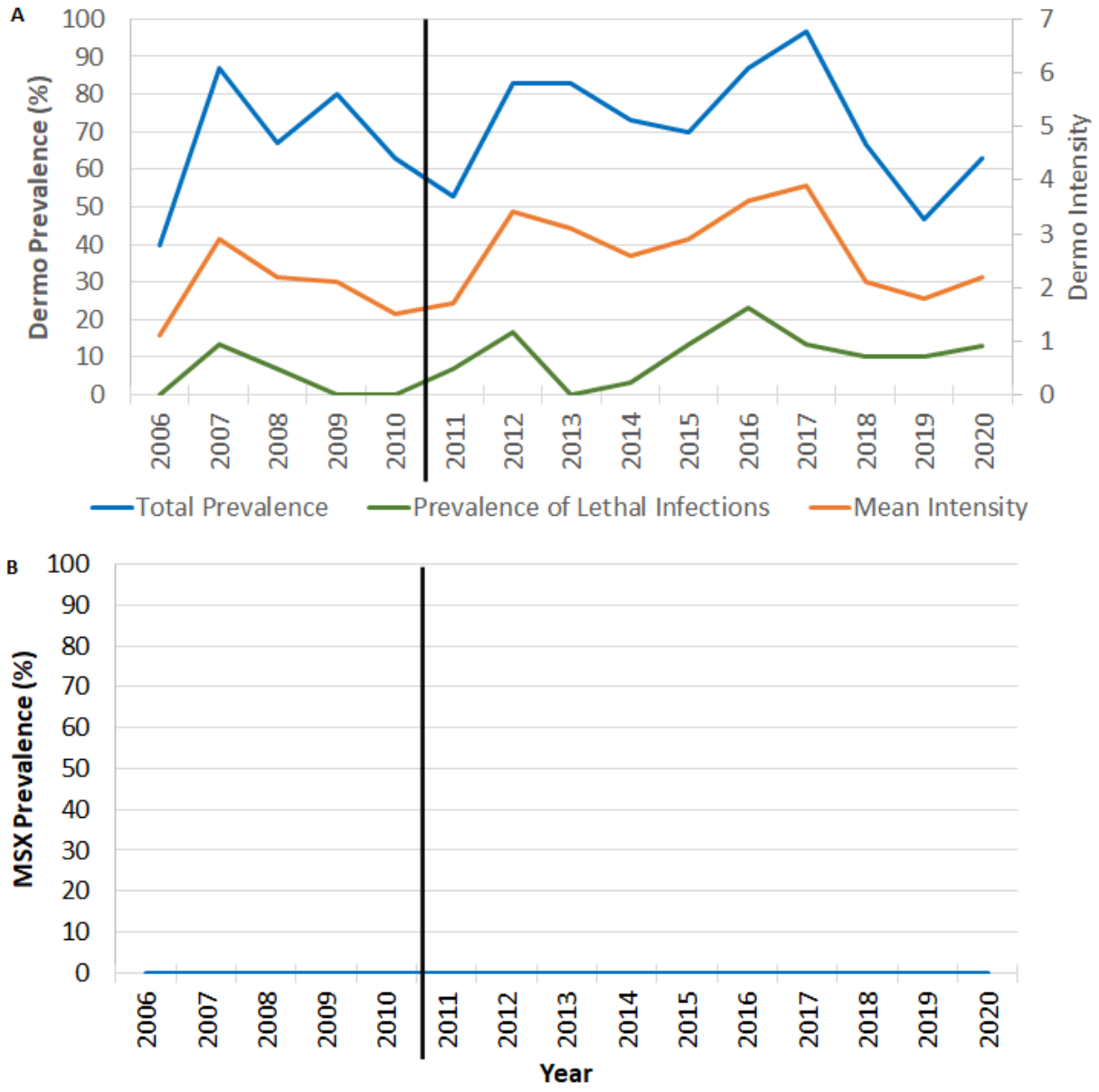

Figure A.45-7. Oyster disease prevalence and intensity in the Tred Avon River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Double Mills bar. Black line denotes the date the sanctuary was established.

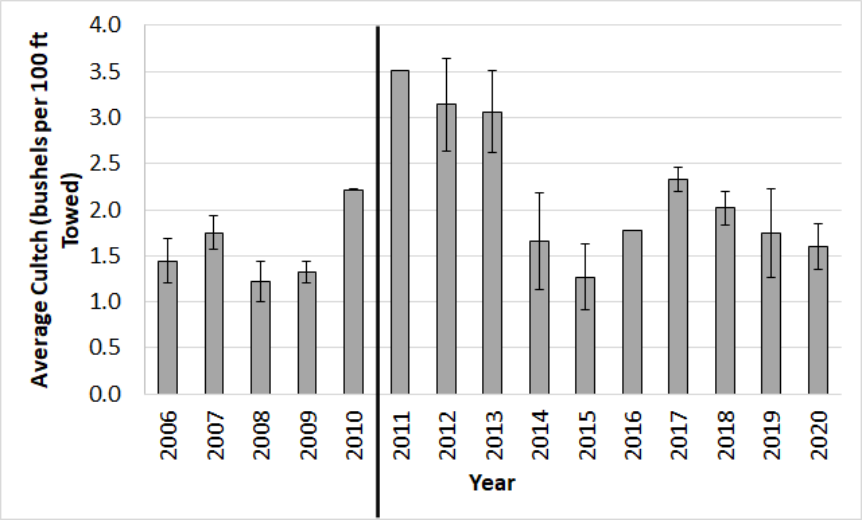

Figure A.45-8. Average cultch (live and dead oysters and loose shell) in the Tred Avon River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.46: Upper Chester River Sanctuary

The Upper Chester River Sanctuary is located in the Chester River adjacent to the Chester ORA A Sanctuary, creating a large contiguous protected area. The sanctuary is located in a low-salinity (Zone 1) region within NOAA Codes 231 and 331. The sanctuary was created in 2010 and has an area of 9,033 acres of which 2,365 (26%) are historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Two smaller sanctuaries created in 2007 are encompassed in this sanctuary: Emory Wharf (65 acres) and Possum Point (11 acres). Thus, the total surface area is 9,109 acres and the total historic oyster bottom is 2,389 acres. There are 31 historic bars within the sanctuary[84].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.46-1)
- Bottom types map (Figure A.46-2)
- Summary statistics (Table A.46-1)
- Abundance per year (Figure A.46-3)
- Shell height frequencies (Figure A.46-4)
- Biomass per year (Figure A.46-5)
- Observed mortality (Figure A.46-6)
- Dermo and MSX per year (Figure A.46-7)
- Cultch per year (Figure A.46-8)

The Fall Survey sampled six bars in this sanctuary. No naturally recruited spat or small oysters were found in the 2016-2020 time period. The density of market oysters and biomass declined over the previous five-year average. Mortality increased and was higher than the long-term baywide average. The amount of cultch remained the same. The average size of oysters increased to 124 mm. The last patent tong population survey conducted by the department occurred in 2012[85].

Before the sanctuary was established, approximately 150 million hatchery spat-on-shell were planted to enhance the commercial public fishery. After the sanctuary was established, approximately 35 million hatchery spat-on-shell were planted for restoration purposes. Marylanders Grow Oysters, a public outreach program has been planting oysters in the Sanctuary annually since 2010.

We are unaware of any studies explicitly examining continuous water quality or oyster ecosystem services in this area.

[84] See chart 8 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[85] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

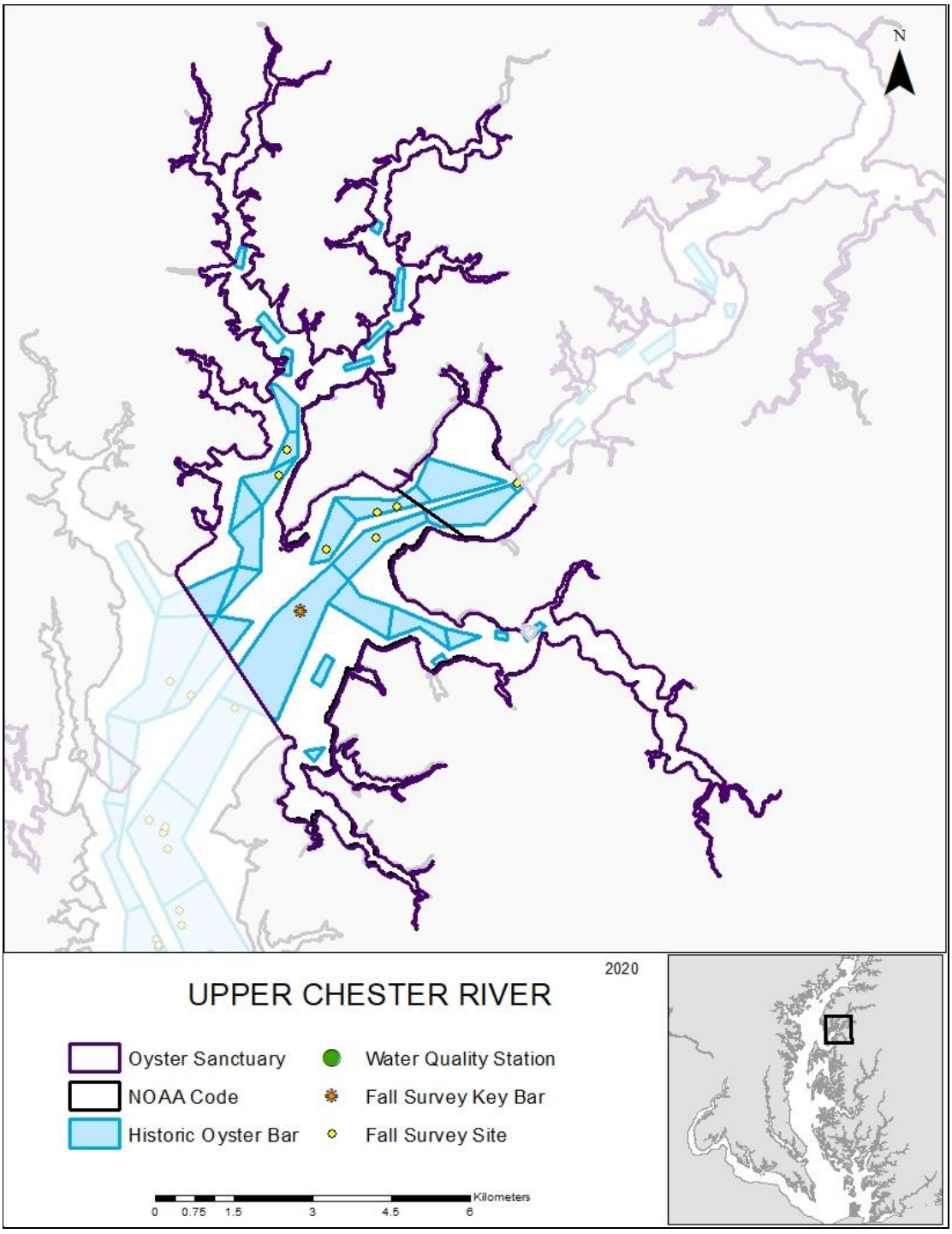

Figure A.46-1. Upper Chester River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

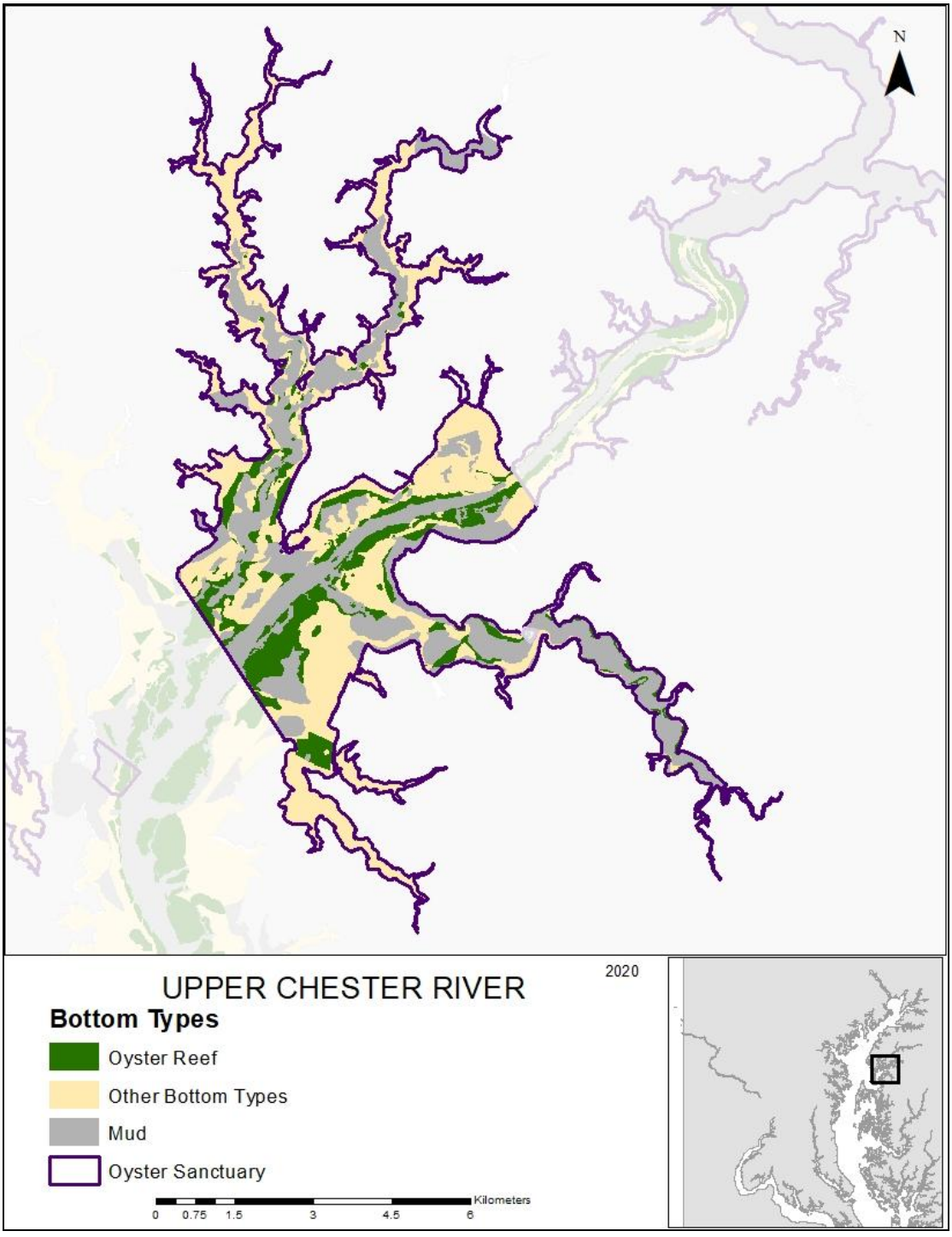

Figure A.46-2. Upper Chester River Sanctuary bottom types. Data from NOAA Chesapeake Bay Office in 2003-2007 and 2012.

Table A.46-1. Oyster population characteristics based on the Fall Survey in the Upper Chester River Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 37	5 / 35	5 / 35
Number of Live Spat Oysters per square meter	0.1 ± 0.1	0.2 ± 0.2	0 ± 0
Number of Live Small-Sized Oysters per square meter	4 ± 2.2	6.1 ± 4.4	0 ± 0
Number of Live Market-Sized Oysters per square meter	16.6 ± 4	14.3 ± 1.2	10.4 ± 2.5
Live Oyster Biomass (g Dry Weight per Bushel)	92 ± 22	68 ± 12	38 ± 9
Observed Mortality (%)	14 ± 3	7 ± 1	18 ± 3
Cultch (Bushels per 100 ft Towed)	1 ± 0.1	1 ± 0.2	1 ± 0
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

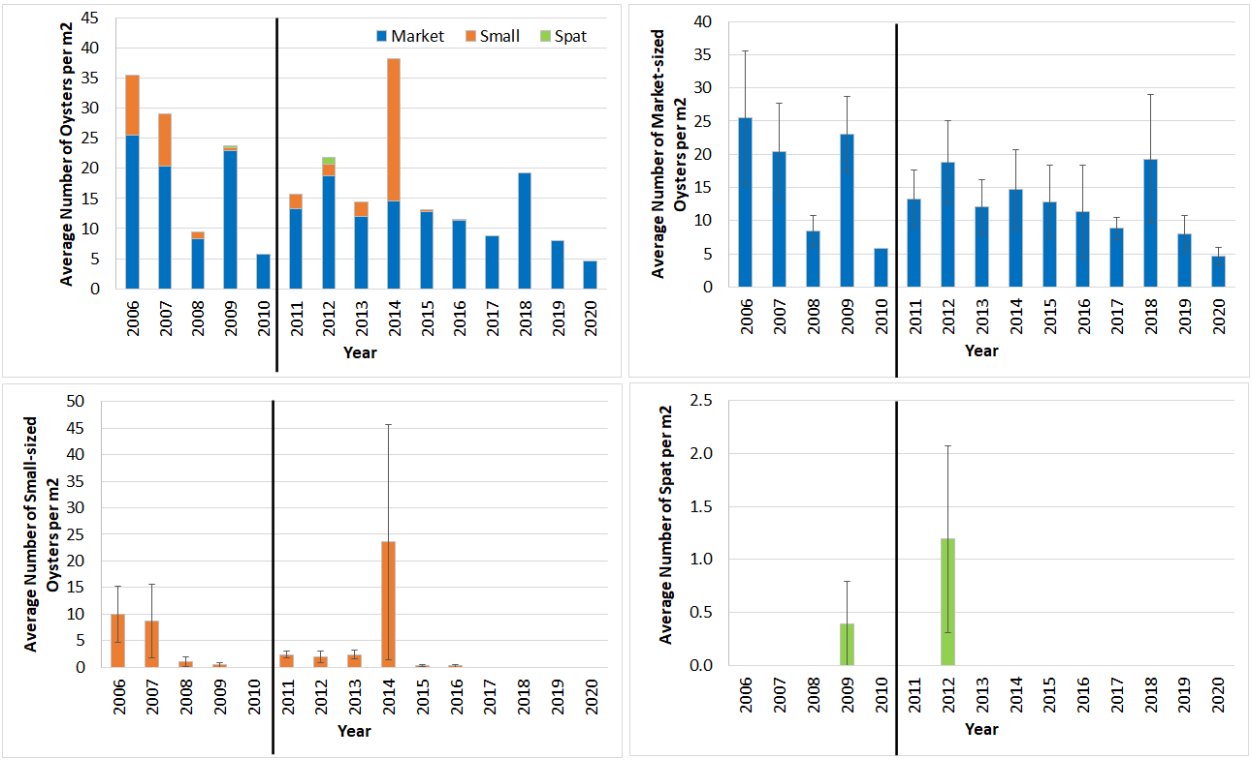

Figure A.46-3. Average number of live oysters per square meter by size class in the Upper Chester River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

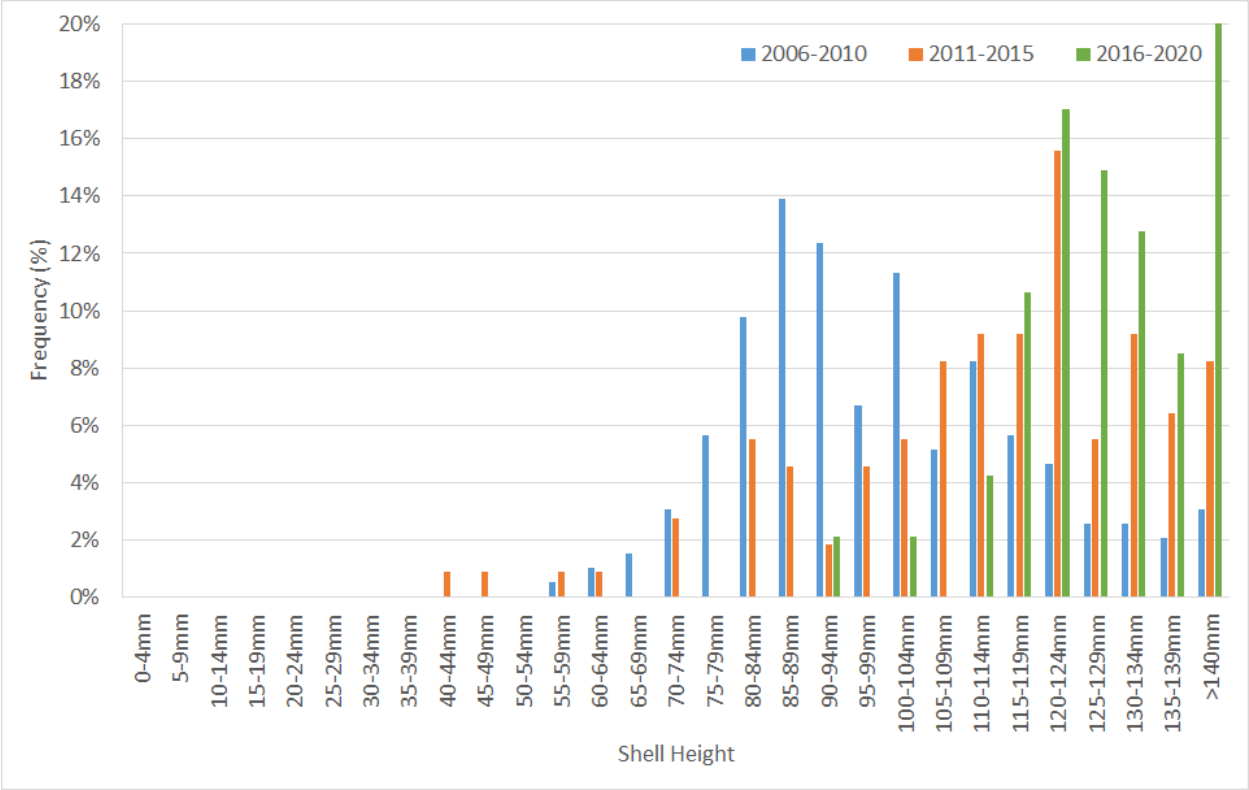

Figure A.46-4. Shell height frequencies of live oysters per bushel of material in the Upper Chester River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Old Field bar.

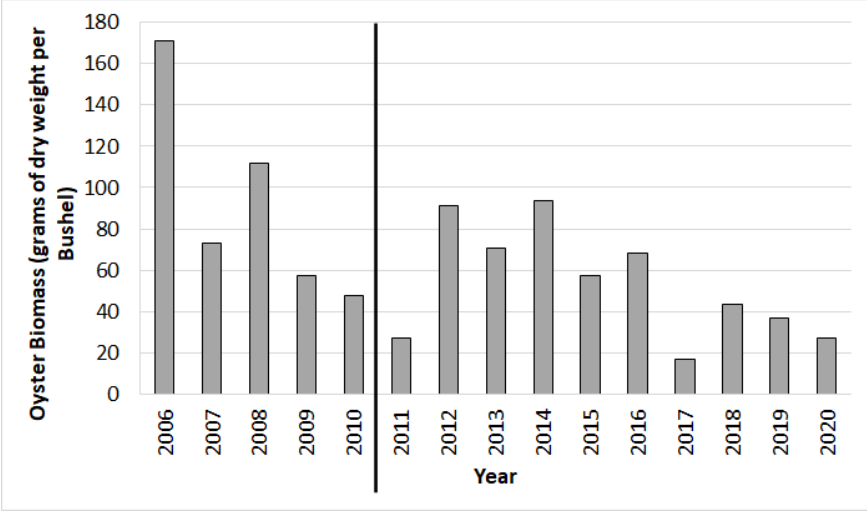

Figure A.46-5. Oyster biomass (grams of dry weight per bushel of material) in the Upper Chester River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Old Field bar. Black line indicates the date the sanctuary was established.

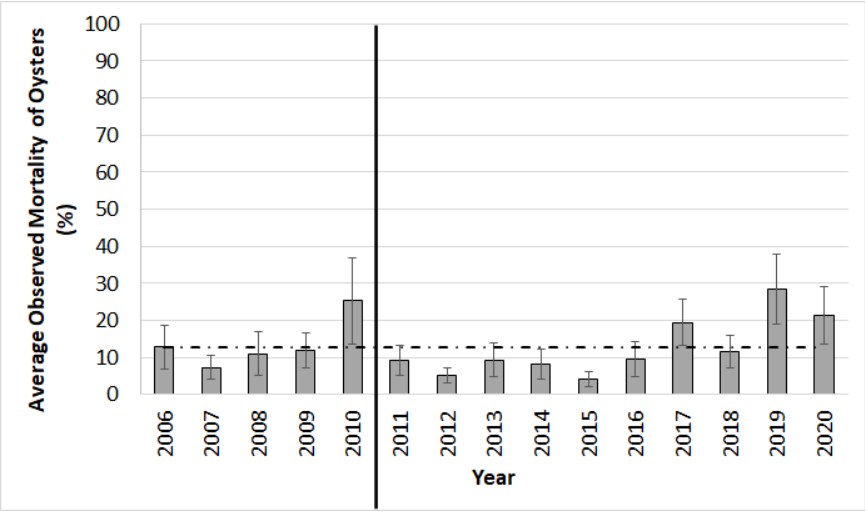

Figure A.46-6 Average annual observed mortality of market-sized and small-sized oysters in Upper Chester River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

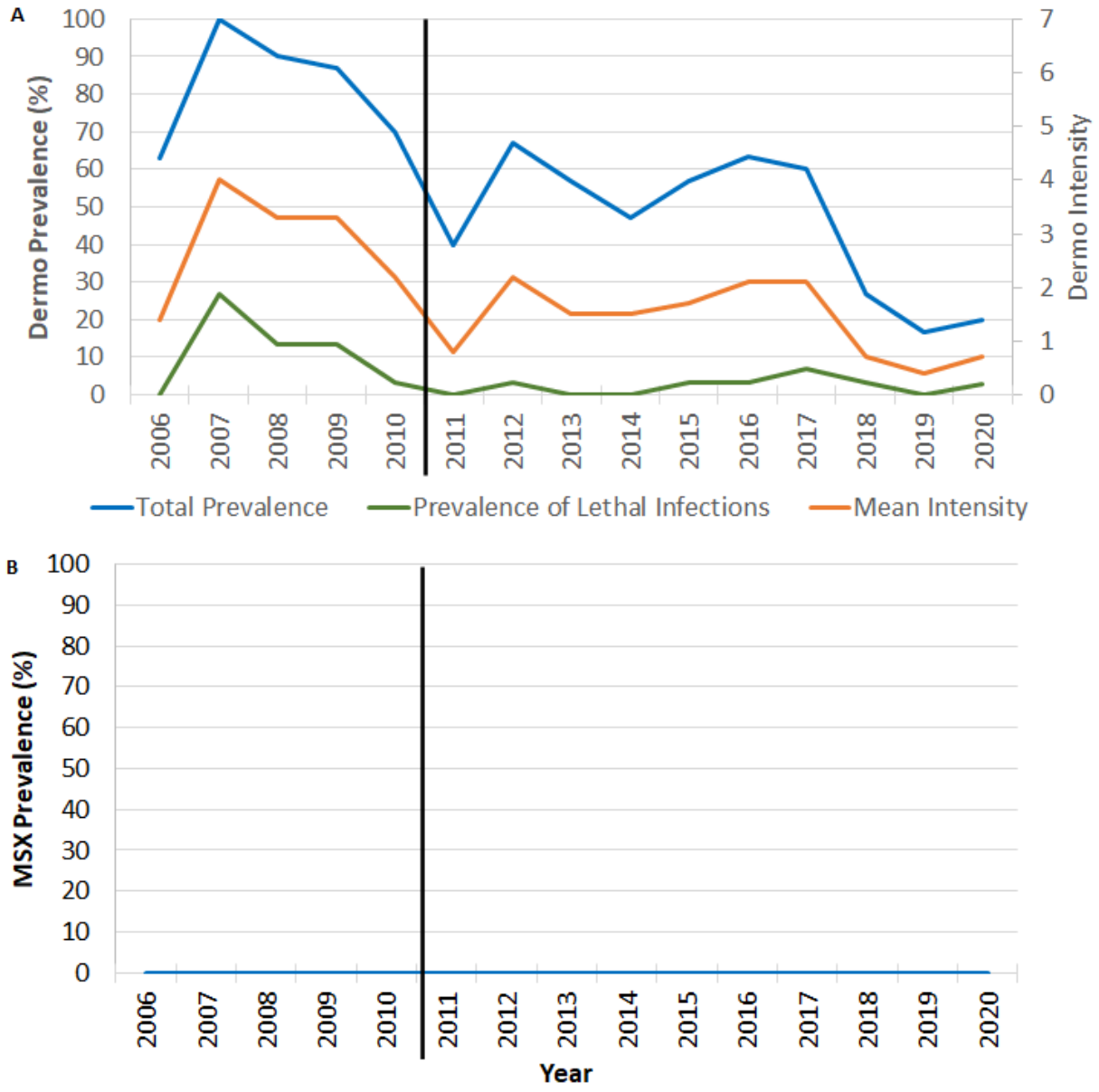

Figure A.46-7. Oyster disease prevalence and intensity in the Upper Chester River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Old Field bar. Black line denotes the date the sanctuary was established.

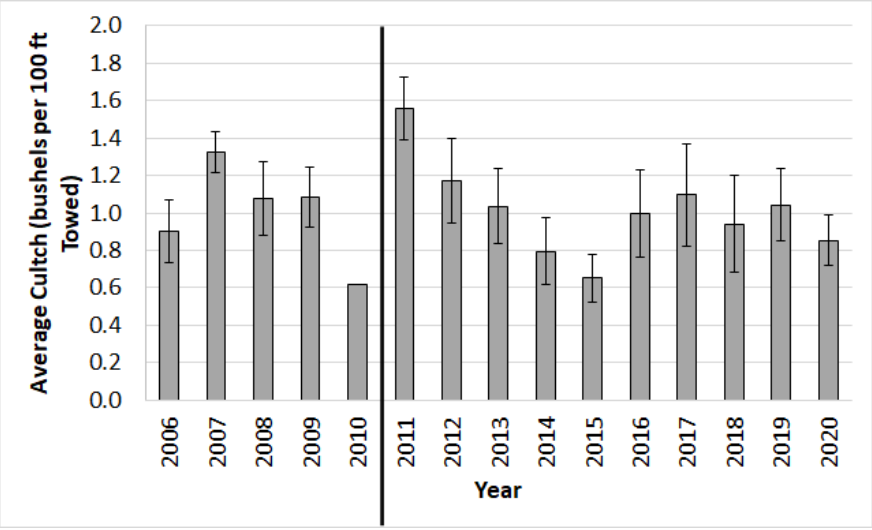

Figure A.46-8. Average cultch (live and dead oysters and loose shell) in the Upper Chester River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

Section A.47: Upper Choptank River Sanctuary

The Upper Choptank River Sanctuary is located along the southern shore of the Choptank River, a low-salinity (Zone 1) region within NOAA Codes 237 and 337. The sanctuary was created in 2010 and has 5,898 acres of which 1,675 (28.4%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). States Bank Sanctuary (82 acres), established in 2005, is now encompassed by the Upper Choptank River Sanctuary. Thus, the total surface area is 5,980 and the total historic oyster bottom is 1,687 acres. There are nine historic oyster bars within the sanctuary[86].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.47-1)
- Bottom types map (Figure A.47-2)
- Summary statistics (Table A.47-1)
- Abundance per year (Figure A.47-3)
- Shell height frequencies (Figure A.47-4)
- Biomass per year (Figure A.47-5)
- Observed mortality (Figure A.47-6)
- Dermo and MSX per year (Figure A.47-7)
- Cultch per year (Figure A.47-8)
- Water Quality (Figure A.47-9)

The Fall Survey sampled seven bars in this sanctuary. Average densities of all sizes of oysters and biomass declined in the 2016-2020 time period as compared to 2011-2015. Observed mortality increased and was above the long-term baywide average. The amount of cultch increased slightly from the previous five-year average. The average size of oysters was 107 mm. Relatively few small oysters were measured. The last patent tong population survey conducted by the department occurred in 2015[87].

Between 2006 and 2010, approximately 335 million hatchery spat-on-shell were planted to enhance the commercial public fishery. In 2010, approximately 88 million hatchery spat-on-shell were planted for restoration purposes.

Maryland's Eyes on the Bay Program monitors monthly water quality at station ET5.2 (38.5807, -76.0587) in this area. Water quality was generally suitable for oysters except for occasional periods of low salinity. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[86] See chart 21 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[87] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

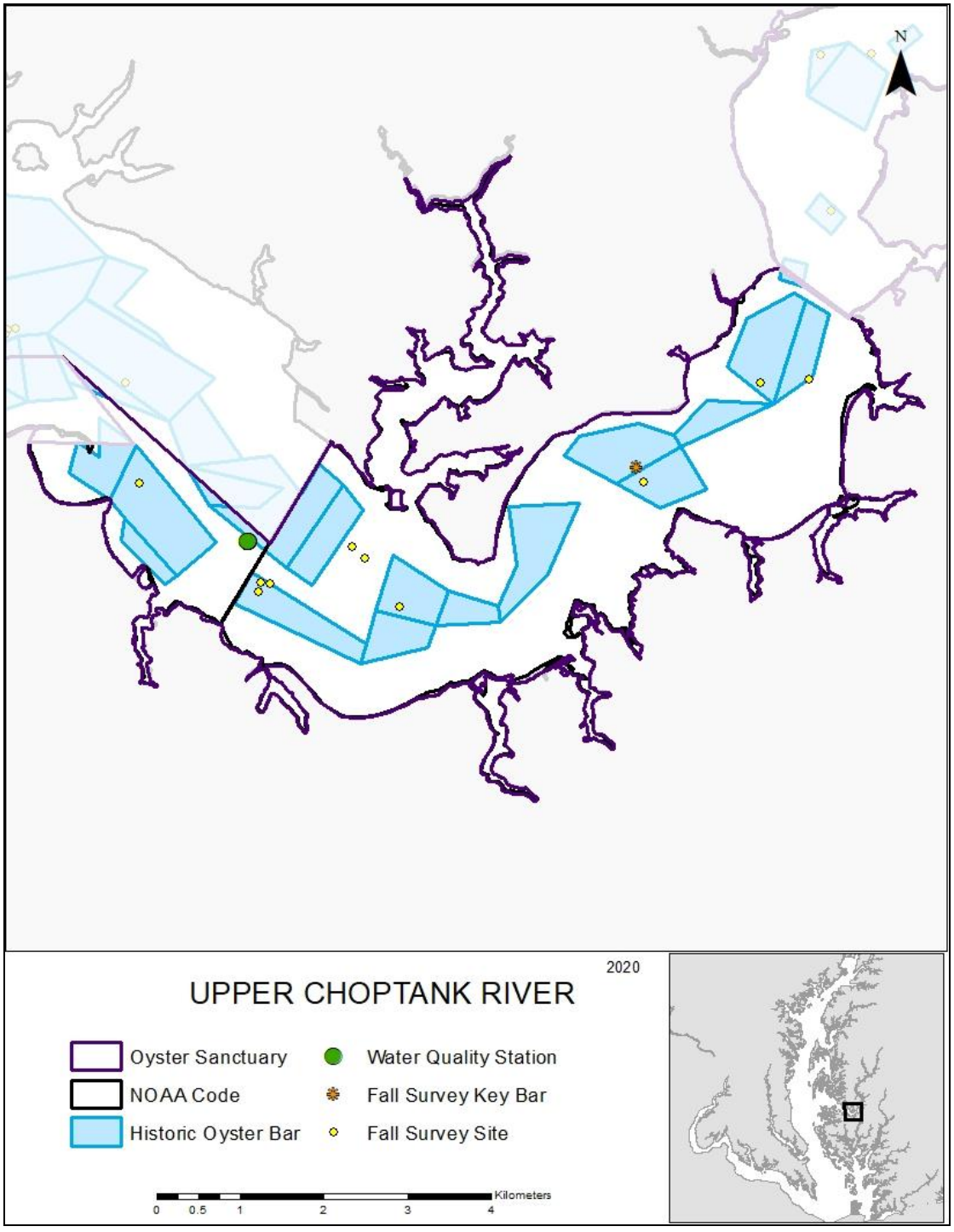

Figure A.47-1. Upper Choptank River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

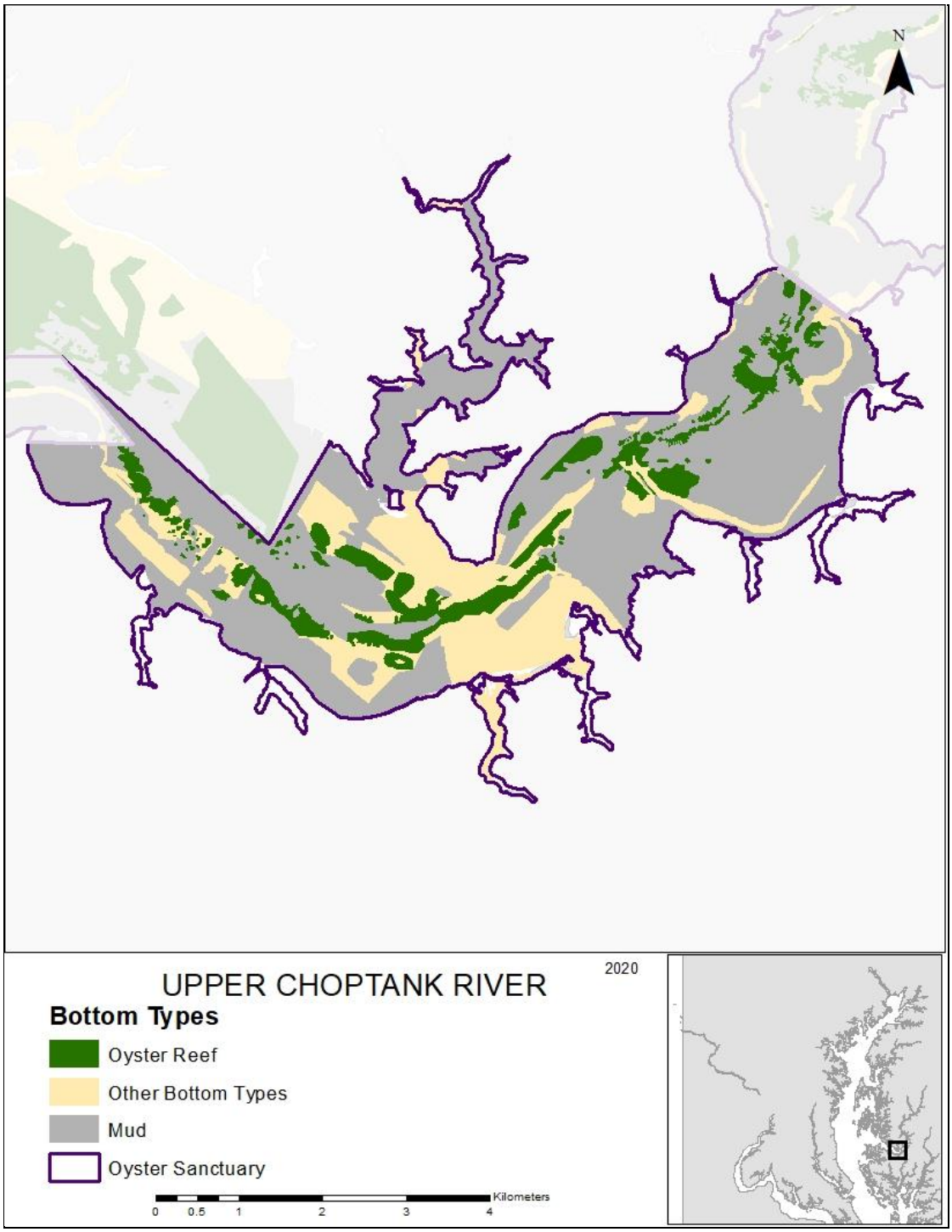

Figure A.47-2. Upper Choptank River Sanctuary bottom types. Data from Maryland Geological Survey and NOAA Chesapeake Bay Office in 2007-2010.

Table A.47-1. Oyster population characteristics based on the Fall Survey in the Upper Choptank River Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 50	5 / 42	5 / 40
Number of Live Spat Oysters per square meter	3.6 ± 1.3	1.3 ± 0.6	0.3 ± 0.1
Number of Live Small-Sized Oysters per square meter	16.2 ± 3.9	25.4 ± 8.5	7.3 ± 1.5
Number of Live Market-Sized Oysters per square meter	20.3 ± 4.6	81 ± 14.5	69 ± 8.9
Live Oyster Biomass (g Dry Weight per Bushel)	106 ± 24	181 ± 26	176 ± 16
Observed Mortality (%)	6 ± 1	7 ± 1	16 ± 2
Cultch (Bushels per 100 ft Towed)	1.2 ± 0.1	2 ± 0.3	2.1 ± 0.2
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

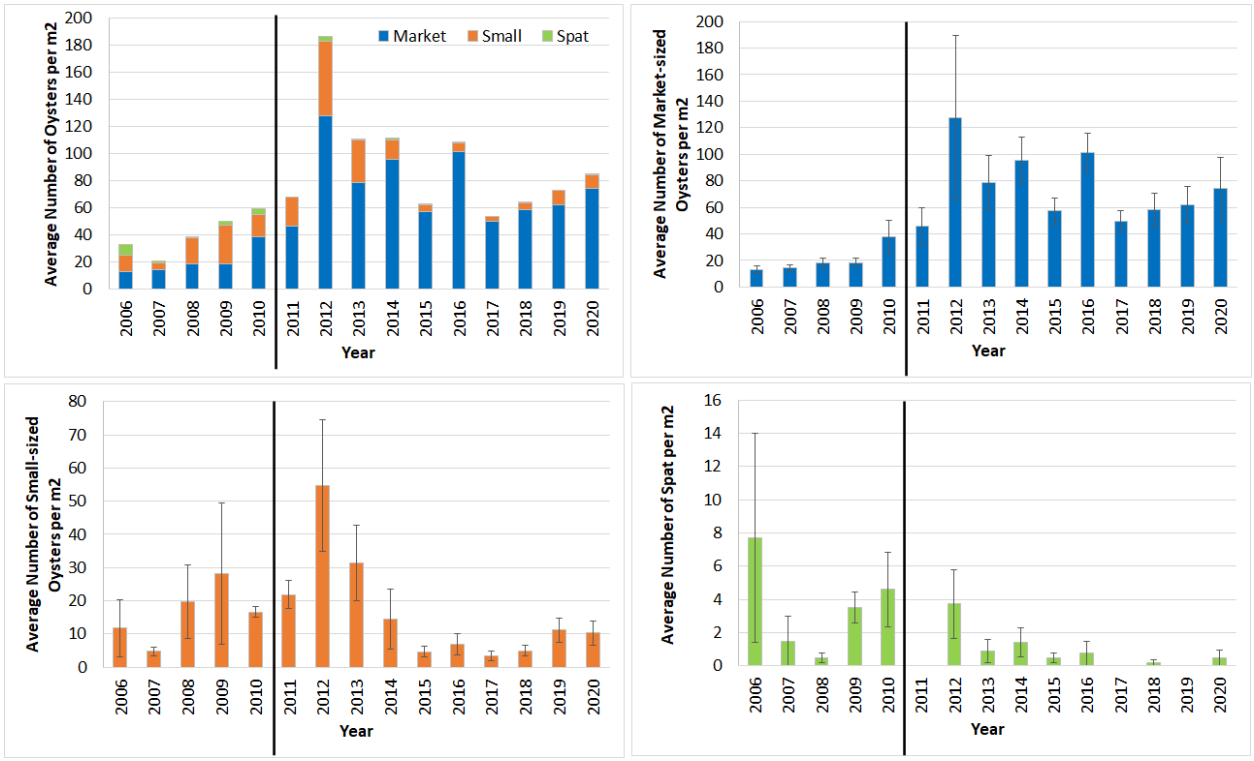

Figure A.47-3. Average number of live oysters per square meter by size class in the Upper Choptank River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

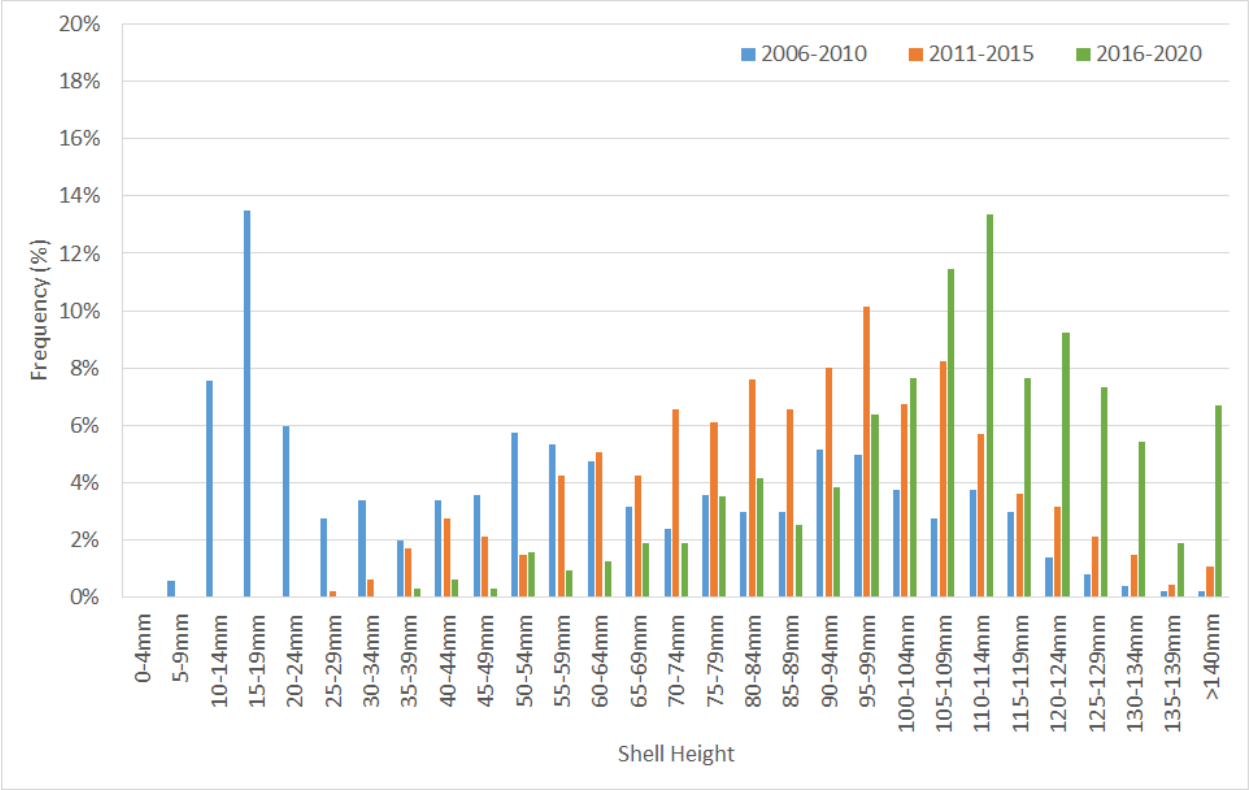

Figure A.47-4. Shell height frequencies of live oysters per bushel of material in the Upper Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Oyster Shell Point bar.

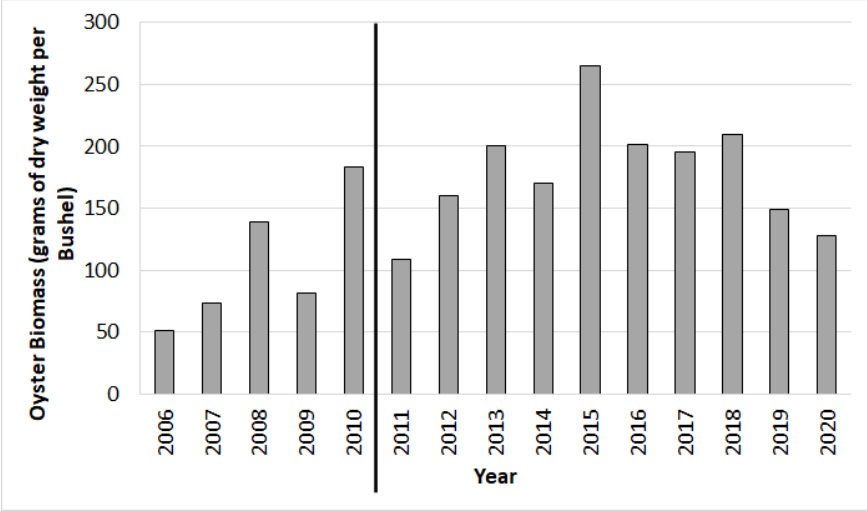

Figure A.47-5. Oyster biomass (grams of dry weight per bushel of material) in the Upper Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Oyster Shell Point bar. Black line indicates the date the sanctuary was established.

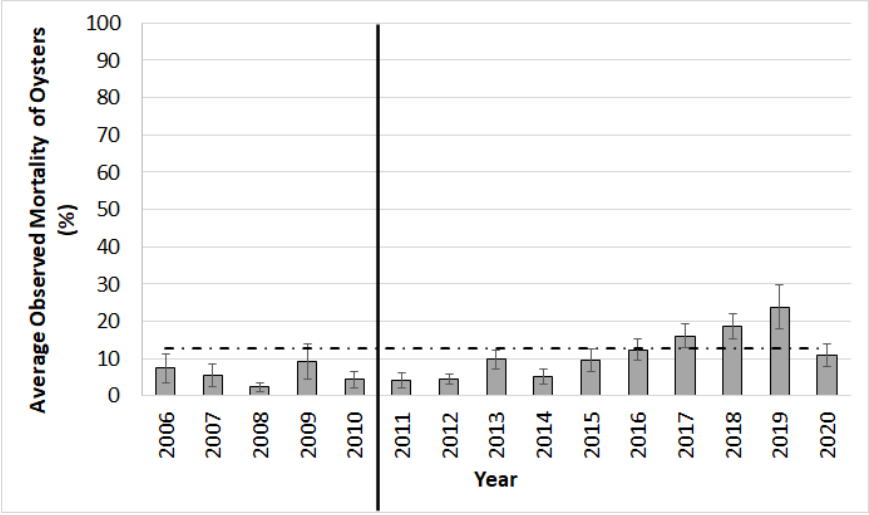

Figure A.47-6. Average annual observed mortality of market-sized and small-sized oysters in Upper Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

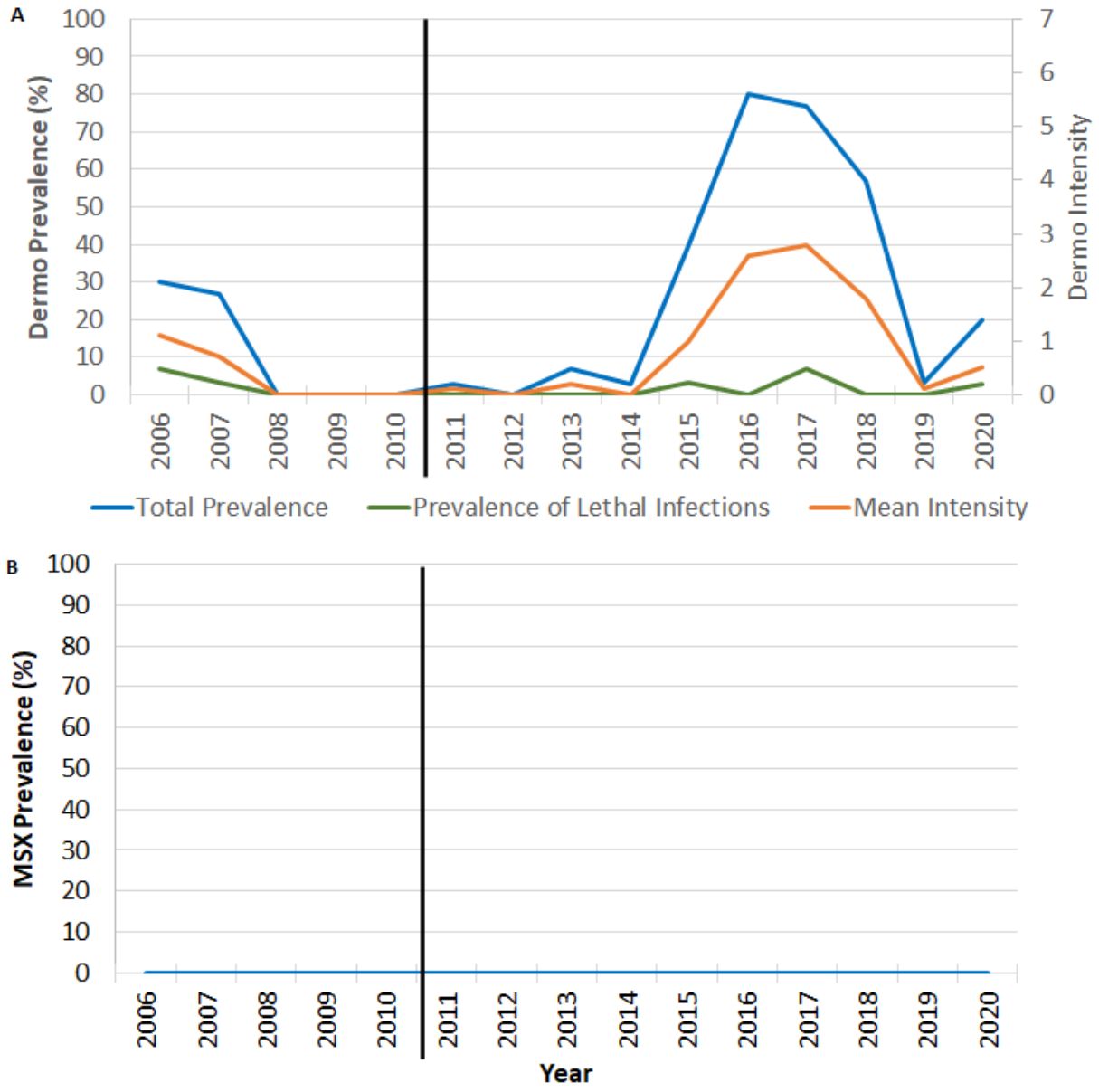

Figure A.47-7. Oyster disease prevalence and intensity in the Upper Choptank River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Oyster Shell Point bar. Black line denotes the date the sanctuary was established.

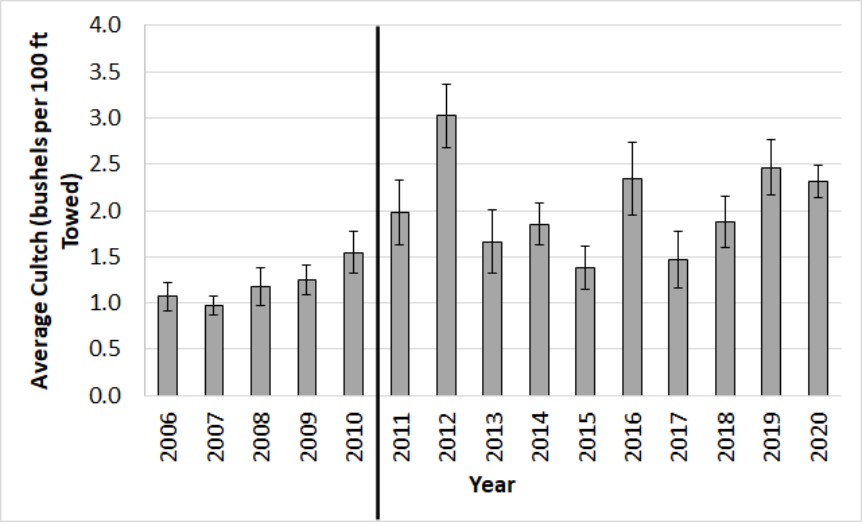

Figure A.47-8. Average cultch (live and dead oysters and loose shell) in the Upper Choptank River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

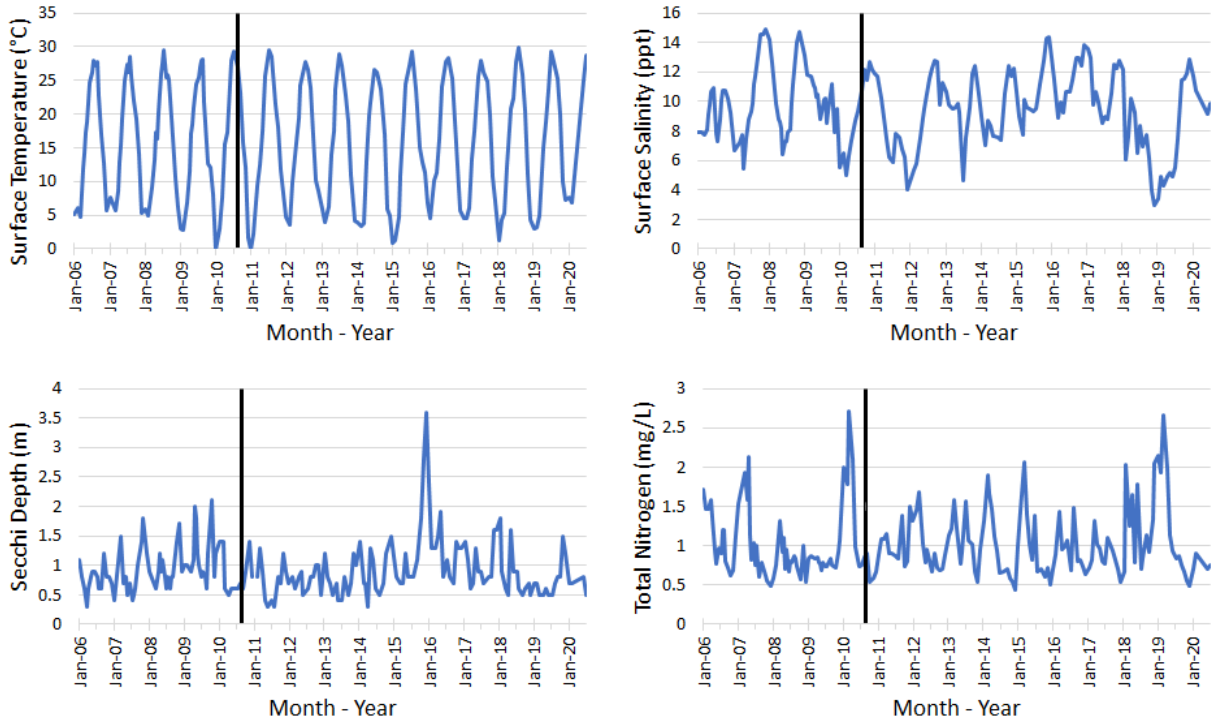

Figure A.47-9. Water quality data collected at ET5.2 (38.5807, -76.0587) in Upper Choptank River. Black line denotes the date the sanctuary was established. Data from Chesapeake Bay Program Data Hub.

Section A.48: Upper Patuxent River Sanctuary

The Upper Patuxent River Sanctuary is located in the Patuxent River, a low-salinity (Zone 1) region within NOAA Code 368. The sanctuary was created in 2010 and has 14,461 acres of which 2,228 (15%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). Originally there was a small sanctuary in the area (Trent Hall, 9 acres, created 2003). Thus, the total surface acres is 14,470 acres and the total historic bottom is 2,229 acres. There are 29 historic oyster bars within the sanctuary[88]. After the sanctuary was established, harvest was allowed in two areas within the sanctuary during the 2010-2011 oyster harvest season. These were the Broad Neck (224 acres, established 2001) and Holland Point (33 acres, established 2008) harvest reserves. After the 2010-2011 harvest season, these two reserves were eliminated and re-classified as part of the sanctuary.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.48-1)
- Bottom types map (Figure A.48-2)
- Summary statistics (Table A.48-1)
- Abundance per year (Figure A.48-3)
- Shell height frequencies (Figure A.48-4)
- Biomass per year (Figure A.48-5)
- Observed mortality (Figure A.48-6)
- Dermo and MSX per year (Figure A.48-7)
- Cultch per year (Figure A.48-8)
- Water Quality (Figure A.48-9)

The Fall Survey sampled five bars in this sanctuary. Average densities of spat, small and market oysters remained stable in 2016-2020 as compared to 2011-2015. Biomass declined slightly and observed mortality remained below the long-term baywide average. Although the mean biomass was lower for 2016-2020, it was also highly variable throughout both time periods, with very similar patterns: higher biomass in the first years, followed by a decline. Cultch increased slightly from the previous five-year average. The average size was similar to the previous time periods, but the percentage of oysters over 100 mm increased slightly. The last patent tong population survey conducted by the department occurred in 2012[89].

Between 2006 and 2010, approximately 71 million hatchery spat-on-shell were planted to enhance the commercial public fishery. After the sanctuary was established, approximately 27 million hatchery spat-on-shell were planted for restoration purposes.

Maryland's Eyes on the Bay Program monitors monthly water quality at station RET1.1 (38.13794, -75.81411) in this area. Water quality was suitable for oysters except for occasional

[88] See chart 22 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[89] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

periods of low salinity. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

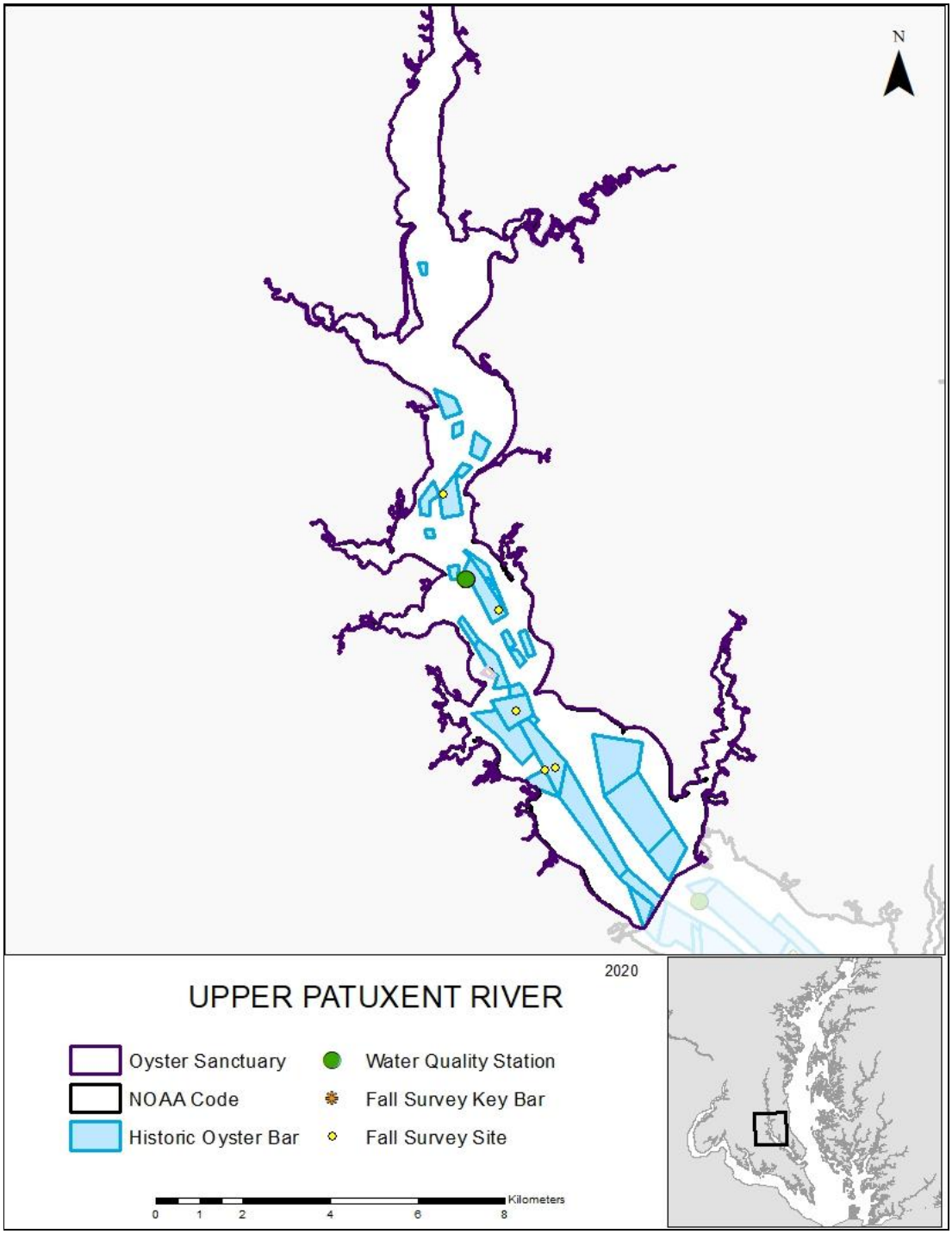

Figure A.48-1. Upper Patuxent River Sanctuary. Fall Survey sites may not be sampled every year.

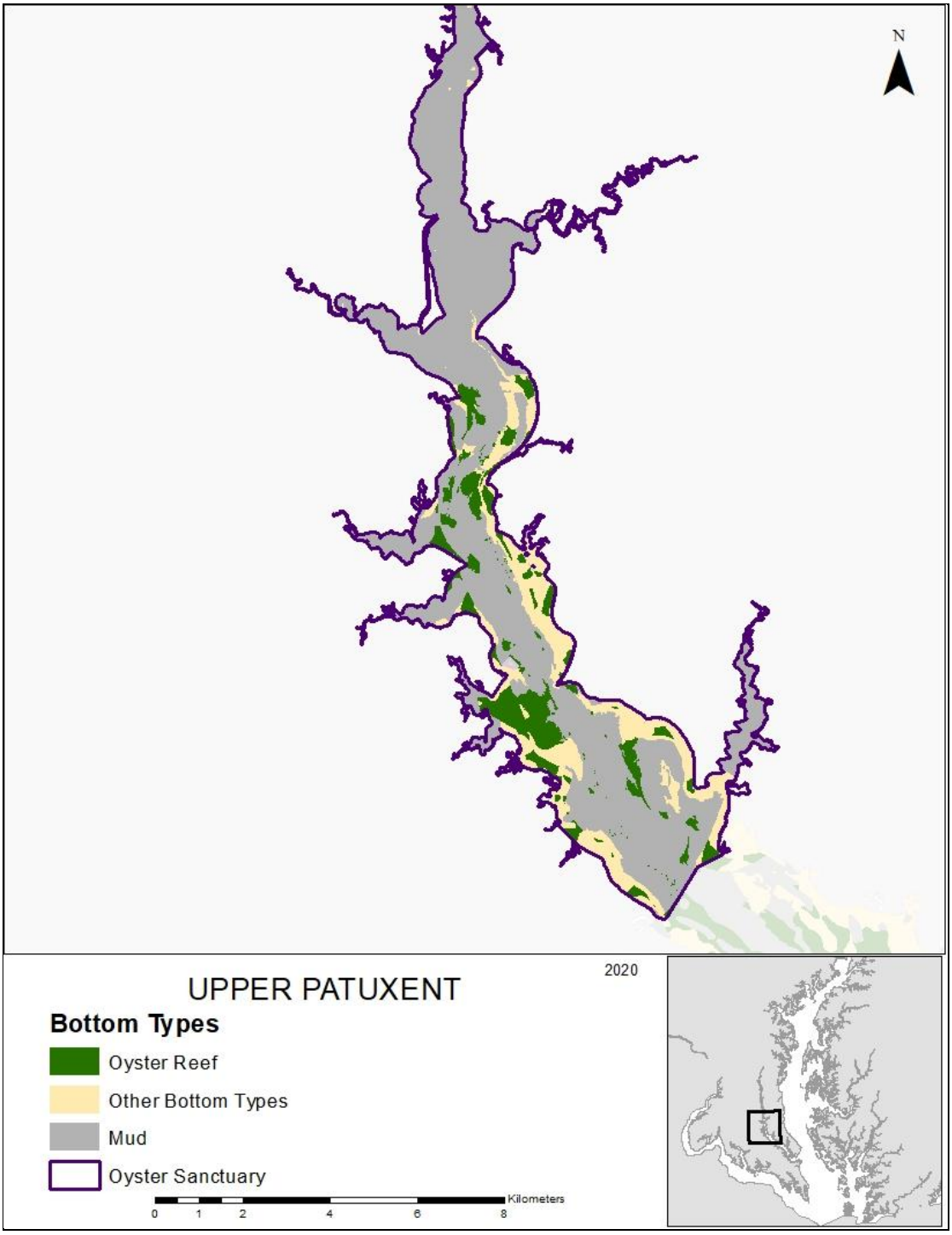

Figure A.48-2. Upper Patuxent River Sanctuary bottom types. Data from Maryland Geological Survey in 2011.

Table A.48-1. Oyster population characteristics based on the Fall Survey in the Upper Patuxent River Sanctuary. Values are given as an annual mean ± standard error.

	2006-10	2011-15	2016-20
Number of Years Sampled / Number of Samples	5 / 27	5 / 25	5 / 25
Number of Live Spat Oysters per square meter	12.5 ± 11	0.7 ± 0.6	0.9 ± 0.3
Number of Live Small-Sized Oysters per square meter	81.9 ± 53.3	27.8 ± 7.1	32.9 ± 9.4
Number of Live Market-Sized Oysters per square meter	21.5 ± 3.2	58.7 ± 13.5	66.7 ± 6.2
Live Oyster Biomass (g Dry Weight per Bushel)	125	154 ± 54	105 ± 34
Observed Mortality (%)	11 ± 3	8 ± 1	9 ± 2
Cultch (Bushels per 100 ft Towed)	1.6 ± 0.2	1.6 ± 0.1	1.7 ± 0.1

Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.

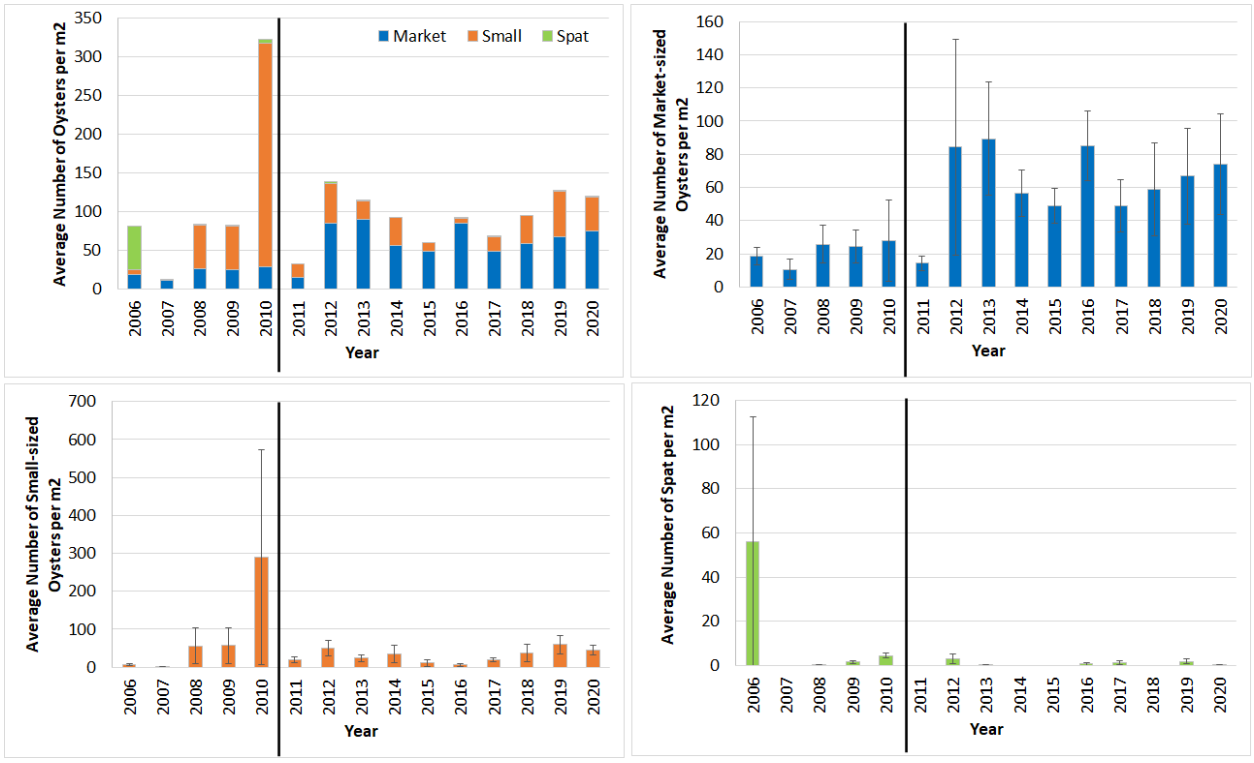

Figure A.48-3A. Average number of live oysters per square meter by size class in the Upper Patuxent River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

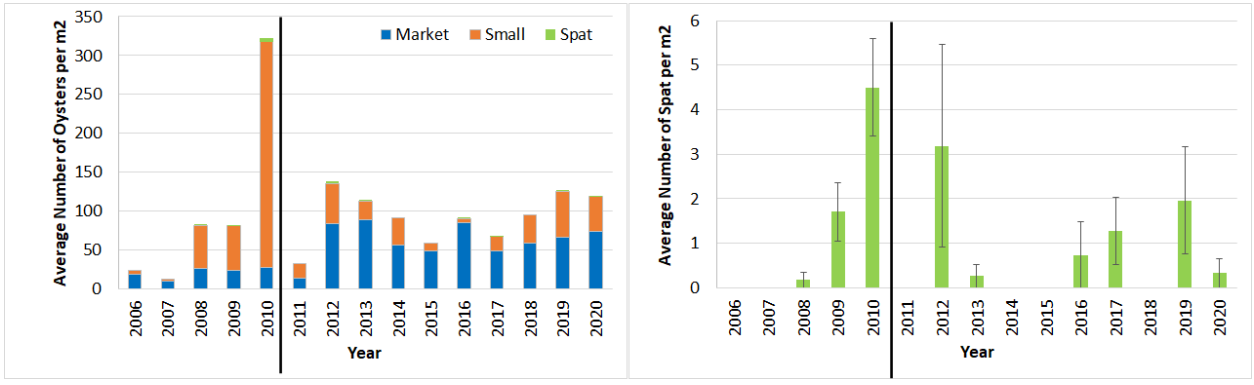

Figure A.48-3B. Average number of live oysters per square meter by size class in the Upper Patuxent River Sanctuary excluding the sample taken in 2006 on the hatchery spat-on-shell planting. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

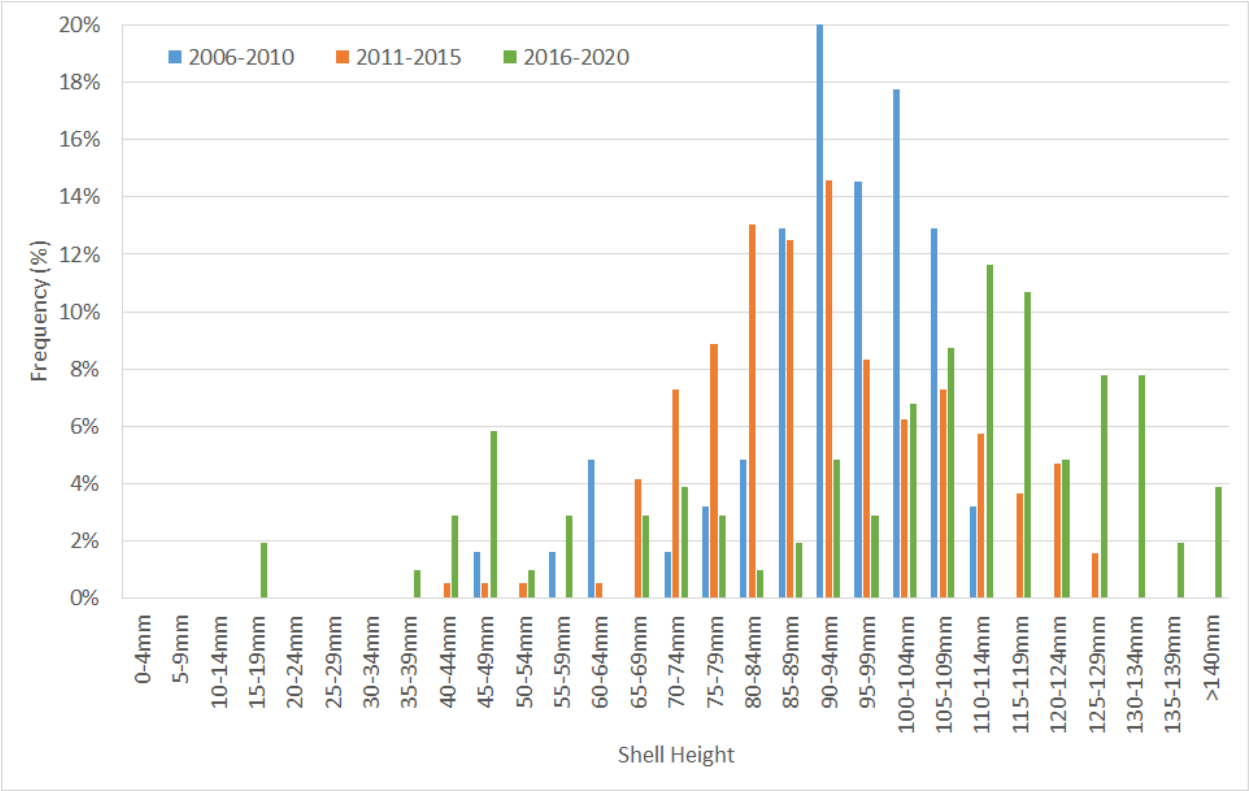

Figure A.48-4. Shell height frequencies of live oysters per bushel of material in the Upper Patuxent River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Trent Hall bar. No data was collected in 2006 and 2008 to 2010.

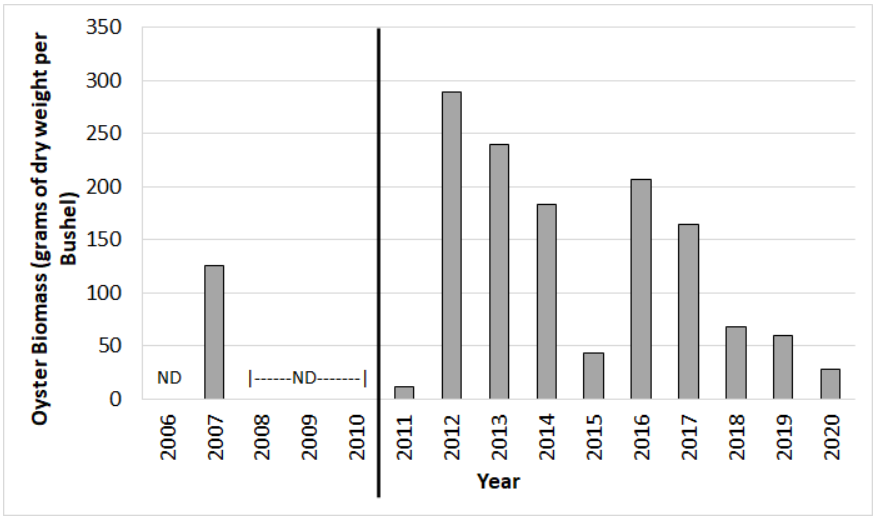

Figure A.48-5. Oyster biomass (grams of dry weight per bushel of material) in the Upper Patuxent River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Trent Hall bar. Black line indicates the date the sanctuary was established. ND = No data.

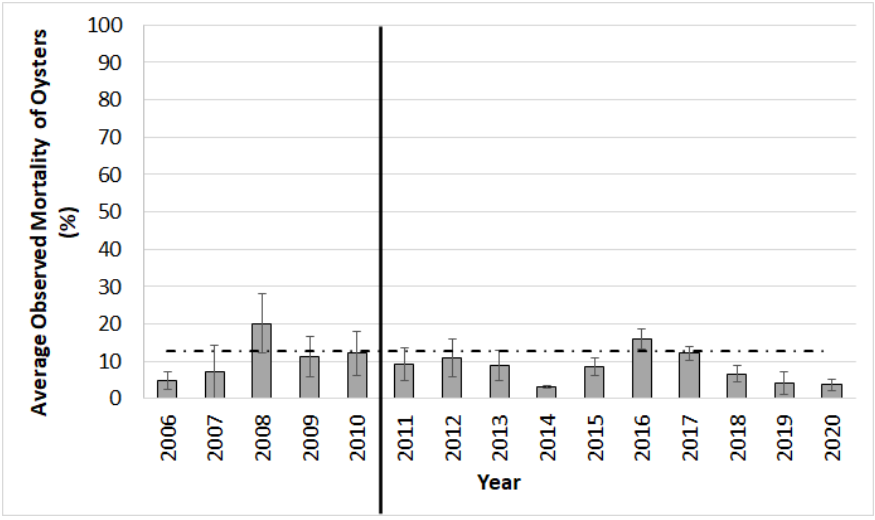

Figure A.48-6. Average annual observed mortality of market-sized and small-sized oysters in Upper Patuxent River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

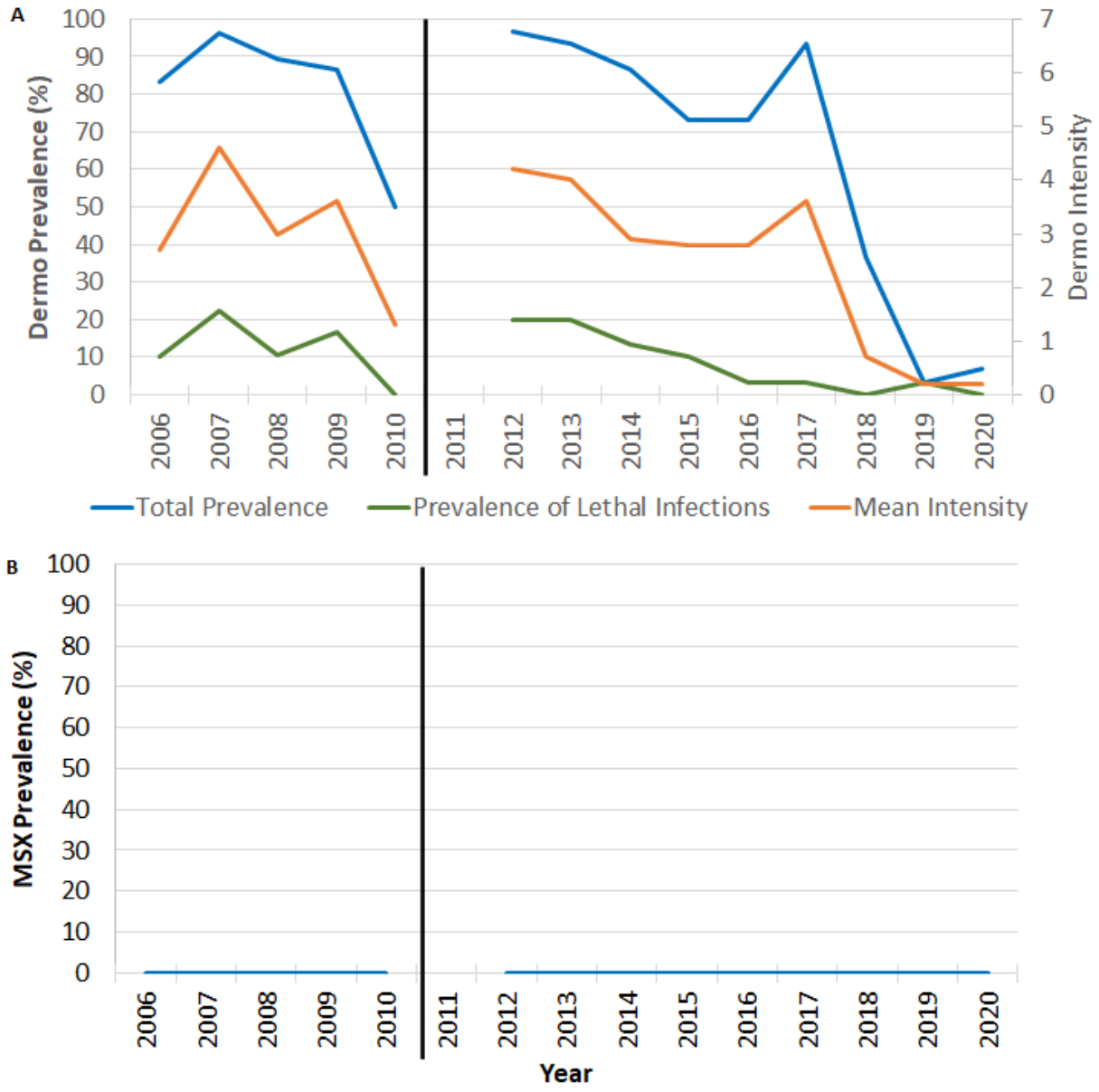

Figure A.48-7. Oyster disease prevalence and intensity in the Upper Patuxent River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Trent Hall bar. Black line denotes the date the sanctuary was established. No data was collected in 2011.

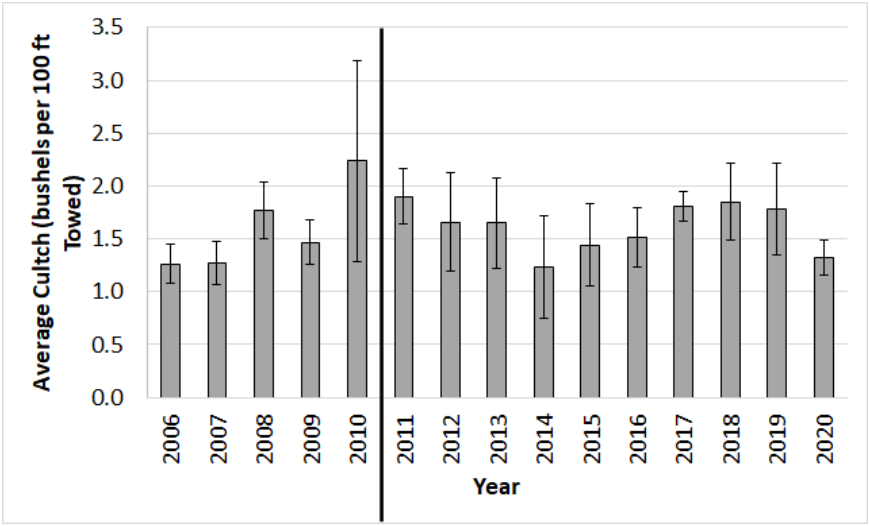

Figure A.48-8. Average cultch (live and dead oysters and loose shell) in the Upper Patuxent River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.

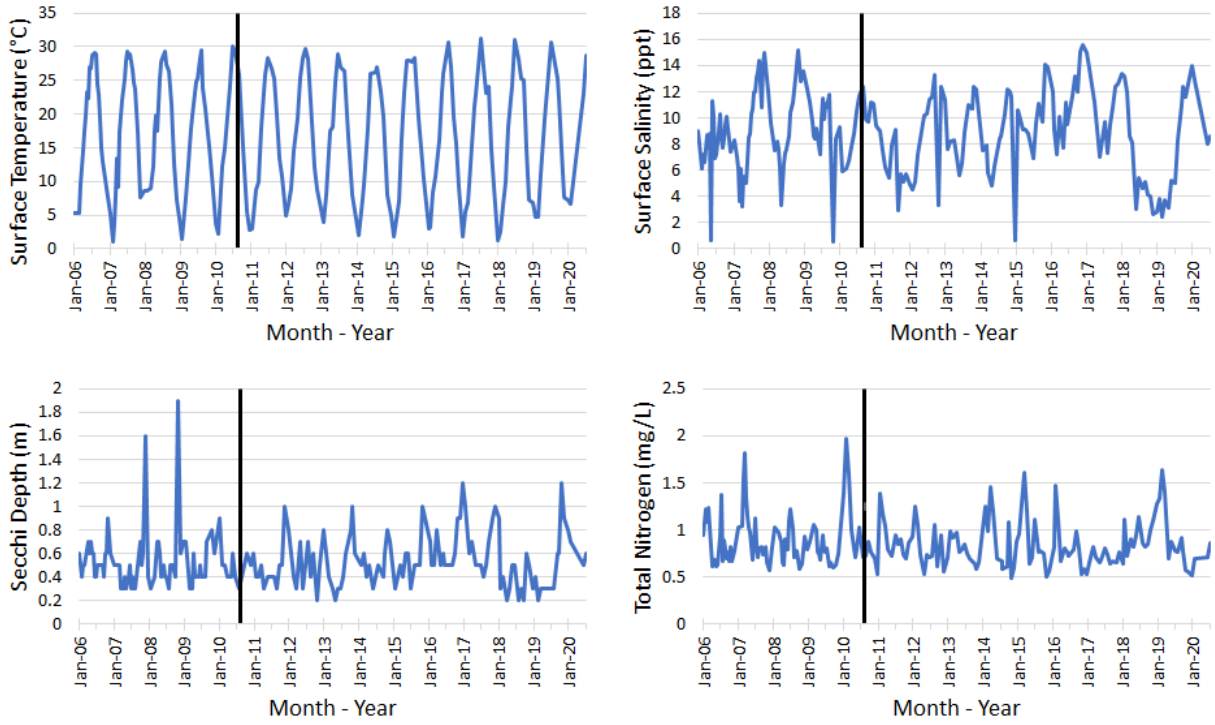

Figure A.48-9. Water quality data collected at Station RET1.1 in Upper Patuxent River. Black line denotes the date the sanctuary was established. Data from Chesapeake Bay Program Data Hub.

Section A.49: Webster Sanctuary

The Webster Sanctuary is located in the lower eastern portion of Maryland's Chesapeake Bay, a medium-salinity (Zone 2) region within NOAA Code 098. The sanctuary is located at the mouth of the Wicomico River. It was created in 1997 and encompasses 554 acres, none of which is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). The sanctuary was an old aquaculture lease that is located adjacent to the Monie Bay National Estuarine Research Reserve and the Deal Island Facility Wildlife Management Area.

Information available for this sanctuary includes:

- Sanctuary map (Figure A.49-1)
- Bottom types map (Figure A.49-2)

The Fall Survey has not sampled any oyster bars within this area since 2006, nor has a patent tong survey been conducted there by the department. The department considered conducting a patent tong survey in 2020 but determined that the area that would support oyster growth and that was in deep enough water to survey was mostly encompassed by leases, therefore, no patent tong survey was conducted. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

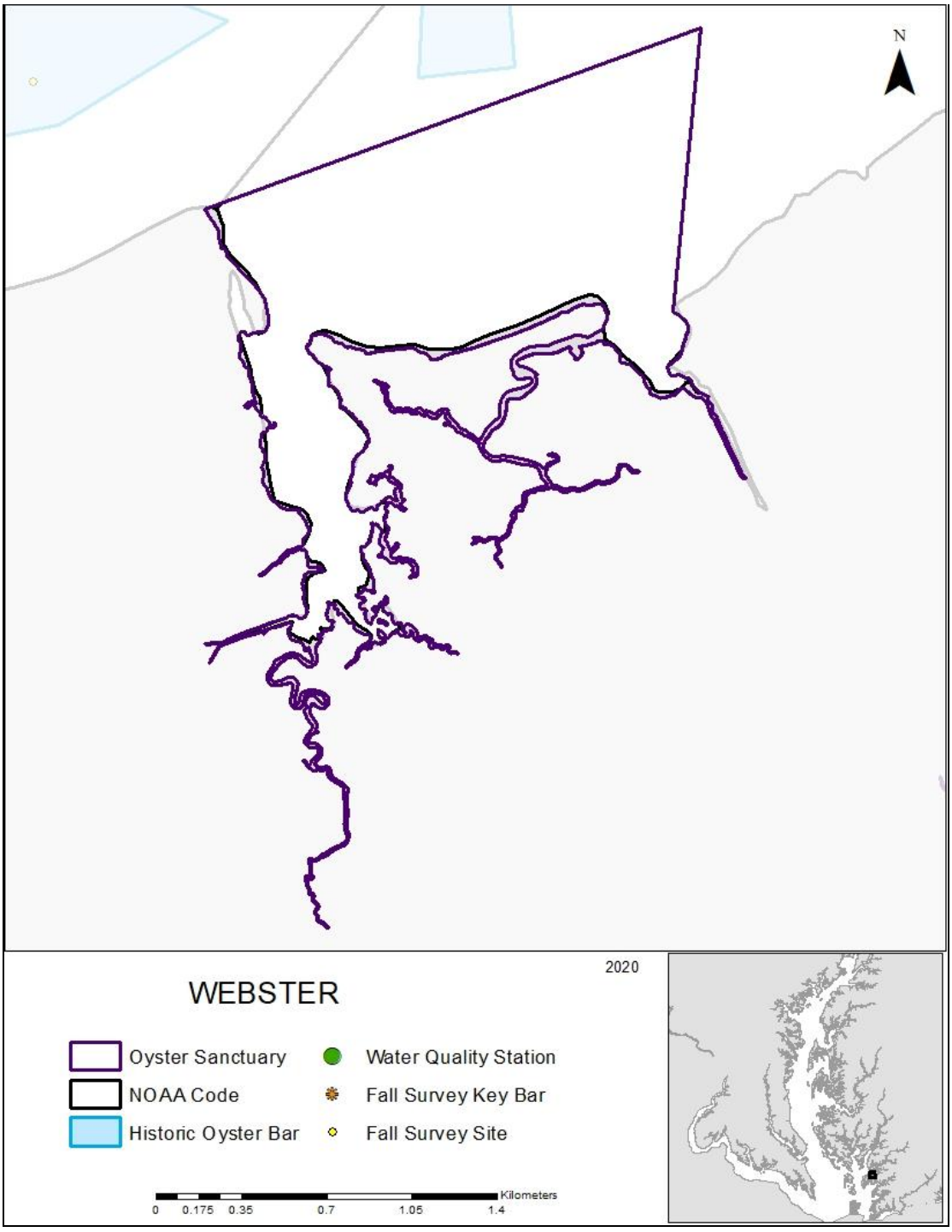

Figure A.49-1. Webster Sanctuary.

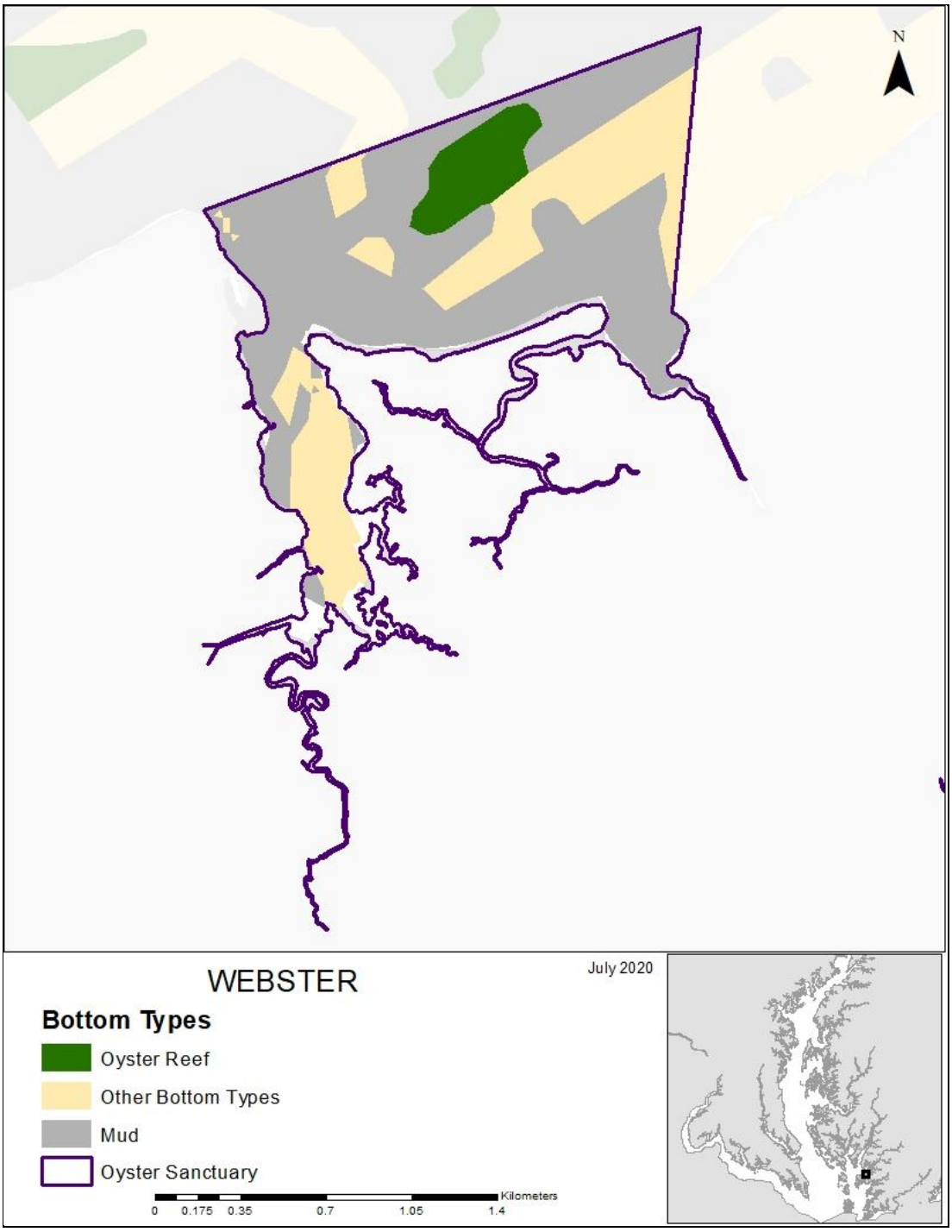

Figure A.49-2. Webster Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983.

Section A.50: Wicomico River Sanctuary

The Wicomico River Sanctuary is located on Maryland's western shore, a low-salinity (Zone 1) region, and near the Potomac River within NOAA Code 274. The sanctuary was created in 2010 and encompasses 450 acres of which 272 (61%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are portions of three historic oyster bars within the sanctuary. Blackstone bar is located almost entirely within the sanctuary (96%), but two others are only partially within the sanctuary (Bluff Point, 35%; White Point, 7%).

Information available for this sanctuary includes:

- Sanctuary map (Figure A.50-1)
- Bottom types map (Figure A.50-2)

The Fall Survey collected one sample in this area in 2015. No live or dead oysters were found in the sample. No patent tong population surveys by the Department have been conducted in the sanctuary. We are unaware of any studies explicitly examining environmental conditions (e.g. continual water quality monitoring) or oyster ecosystem services in the sanctuary.

The sanctuary has not received any replenishment or restoration efforts since 2006 with the exception of Marylanders Grow Oysters. Marylanders Grow Oysters, a public outreach program, has planted oysters annually in the sanctuary since 2009.

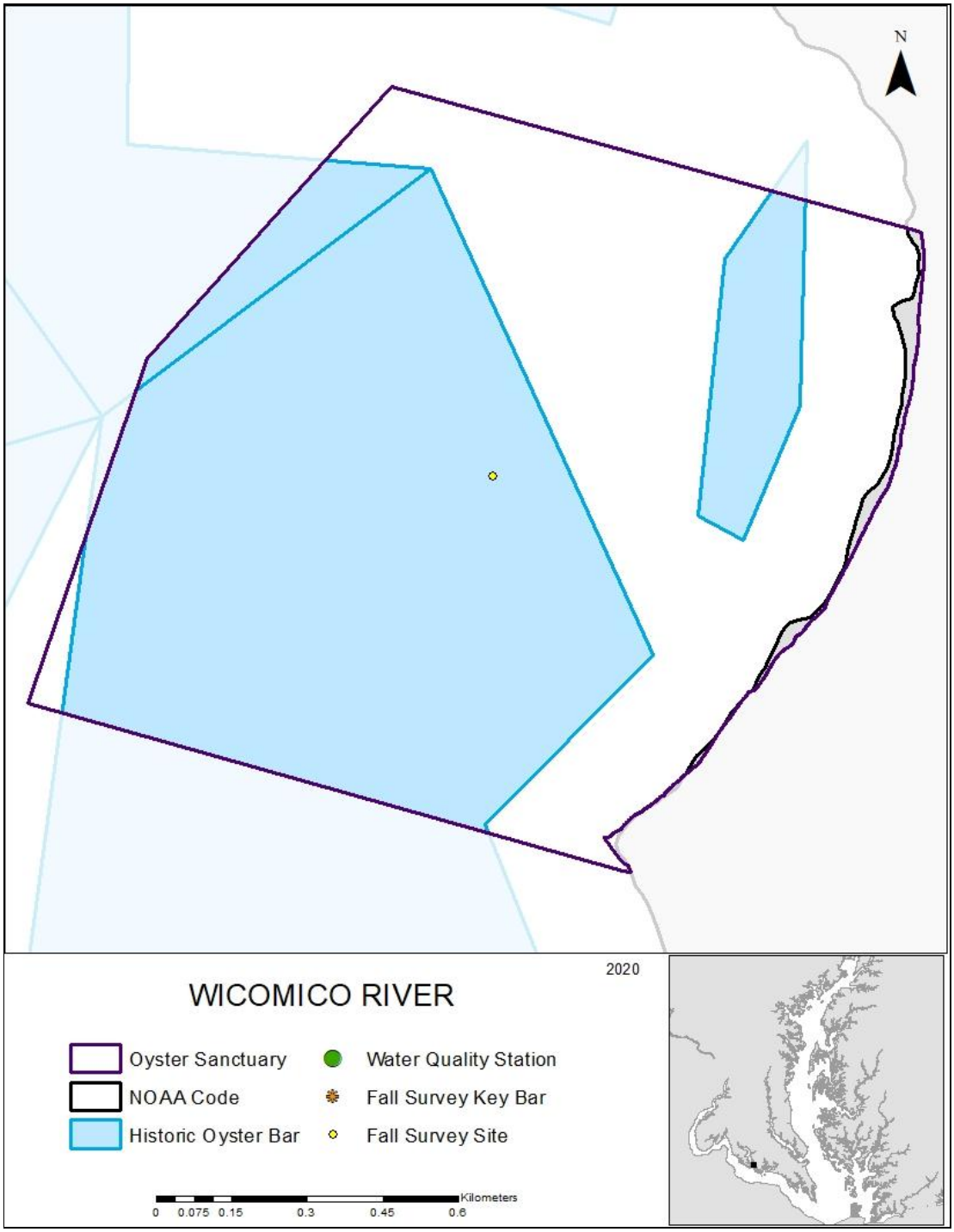

Figure A.50-1. Wicomico River. Fall Survey sites may not be sampled every year.

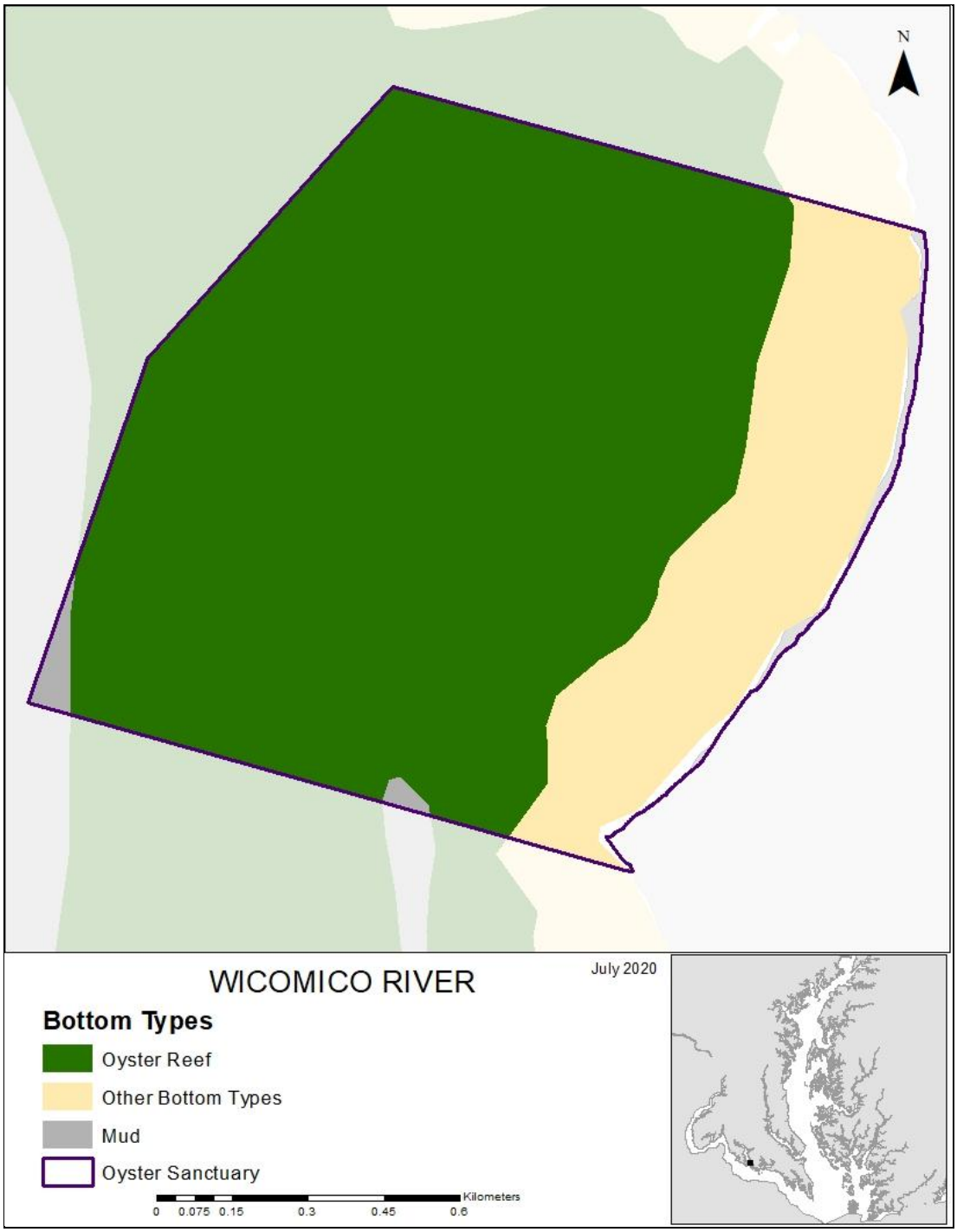

Figure A.50-2. Wicomico River Sanctuary bottom types. Data from Maryland Bay Bottom Survey from 1974-1983 and the Nature Conservancy from 1842-2000.

Section A.51: Wye River Sanctuary

The Wye River Sanctuary is located in Eastern Bay, a medium-salinity (Zone 2) region within NOAA Code 099. The sanctuary was created in 2010 and encompasses 3,510 acres of which 1,100 (31%) is historic oyster bottom (as charted in the Yates Oyster Survey from 1906 to 1912 plus its amendments). There are 23 historic oyster bars within the sanctuary[90].

Information available for this sanctuary includes:

- Sanctuary map (Figure A.51-1)
- Bottom types map (Figure A.51-2)
- Summary statistics (Table A.51-1)
- Abundance per year (Figure A.51-3)
- Density Survey (Figure A.51-4)
- Shell height frequencies (Figure A.51-5)
- Biomass per year (Figure A.51-6)
- Observed mortality (Figure A.51-7)
- Dermo and MSX per year (Figure A.51-8)
- Cultch per year (Figure A.51-9)

The Fall Survey sampled five bars in this sanctuary. Oyster abundance in the Wye River Sanctuary increased through the first six years after establishment of the sanctuary. However, abundance declined recently most likely due to lack of spatfall and an upward trend in observed mortality. Oyster biomass followed the same trend as abundance. The average size of oysters increased to 118 mm, due to the relative lack of small oysters and spat measured. Oyster Dermo disease trends have varied over time with a period of low disease prevalence and intensity during 2012 to 2014. MSX was only found in one year (2016). Average cultch, a relative measure of oyster habitat defined as the amount of oysters (live and dead) and loose shell, has varied over time with no clear trend. A patent tong population survey was conducted in 2014[91]. In 2020, the patent tong population survey was repeated and found the average density of live oysters was 0.5 oysters per square meter, with a greater density of market-sized oysters than small-sized oysters. This was lower than the 2.3 oysters per square meter found in the 2014 survey. Of the 146 samples taken, 103 had no oysters and 27 had no surface shell volume.

No replenishment plantings occurred between 2006 and 2009. Marylanders Grow Oysters, a public outreach program, has planted oysters annually in the sanctuary since 2010. We are not aware of any continual water quality information collected since 2006. We are unaware of any studies explicitly examining oyster ecosystem services in this area.

[90] See chart 12 for bar names and locations in the State of Maryland Shellfish Closure Areas Book http://dnr.maryland.gov/fisheries/Pages/oysters/index.aspx

[91] Maryland Department of Natural Resources. 2016. Oyster Management Review: 2010-2015 - Appendix A. July 2016. 490pgs. https://dnr.maryland.gov/fisheries/Documents/Appendix%20A%20-%20DRAFT%2020160727.pdf

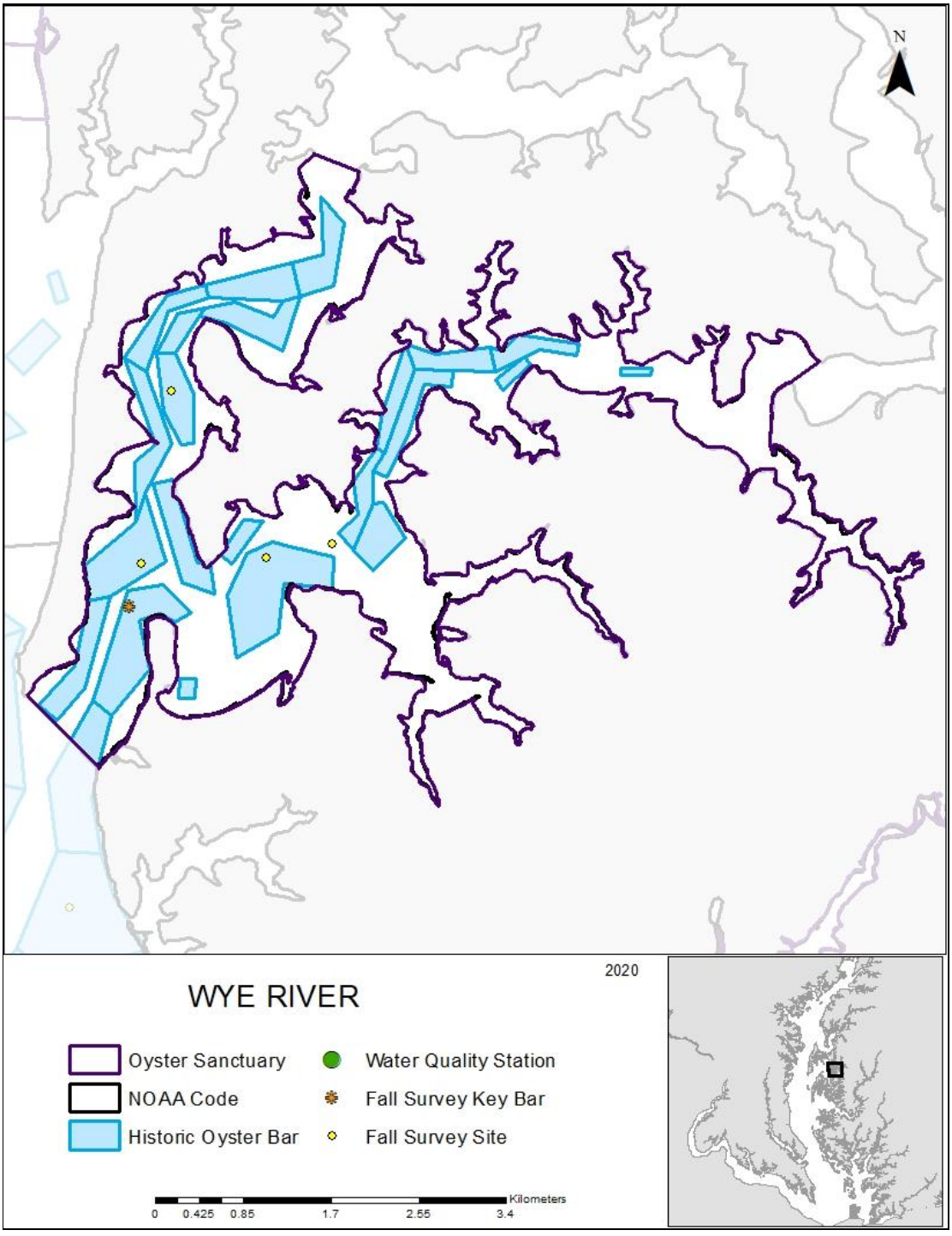

Figure A.51-1. Wye River Sanctuary. Fall Survey sites may not be sampled every year. Fall Survey key bars may consist of a key bar, disease bar or both.

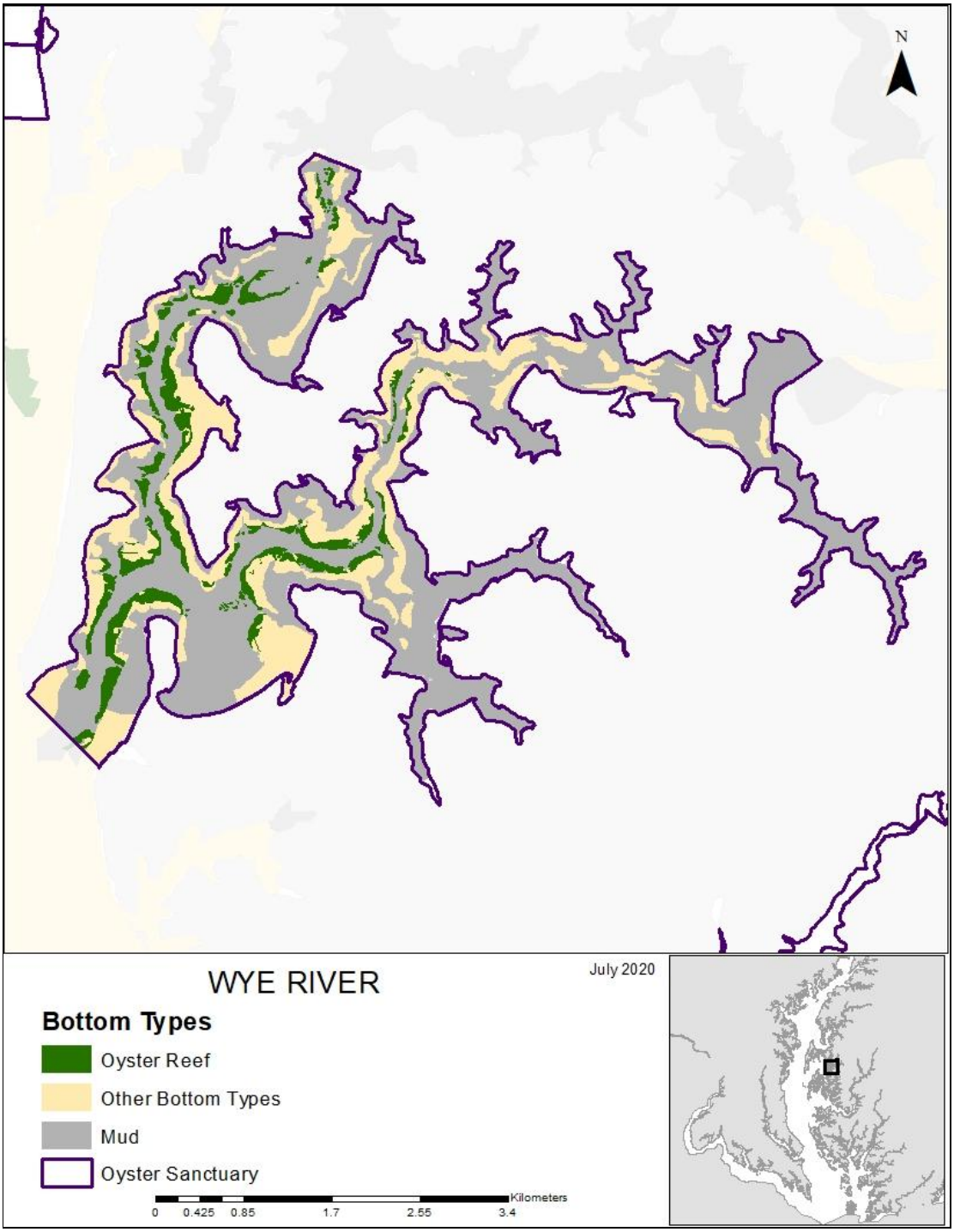

Figure A.51-2. Wye River Sanctuary bottom types. Data from NOAA Chesapeake Bay Office in 2011.

Table A.51-1. Oyster population characteristics based on the Fall Survey in the Wye River Sanctuary. Values are given as an annual mean ± standard error.			
	2006-10	**2011-15**	**2016-20**
Number of Years Sampled / Number of Samples	5 / 25	5 / 25	5 / 25
Number of Live Spat Oysters per square meter	0.5 ± 0.3	4.2 ± 3.9	0.1 ± 0.1
Number of Live Small-Sized Oysters per square meter	1.8 ± 0.7	9.9 ± 4.1	0.4 ± 0.1
Number of Live Market-Sized Oysters per square meter	10.3 ± 2.9	16.2 ± 3.5	19.6 ± 4.1
Live Oyster Biomass (g Dry Weight per Bushel)	67 ± 32	129 ± 56	124 ± 23
Observed Mortality (%)	21 ± 3	5 ± 1	23 ± 2
Cultch (Bushels per 100 ft Towed)	0.9 ± 0.1	1 ± 0.1	0.8 ± 0.2
Note: The number of samples is based on the number of samples having a value for observed mortality. There may be fewer samples per year for density, biomass, and cultch.			

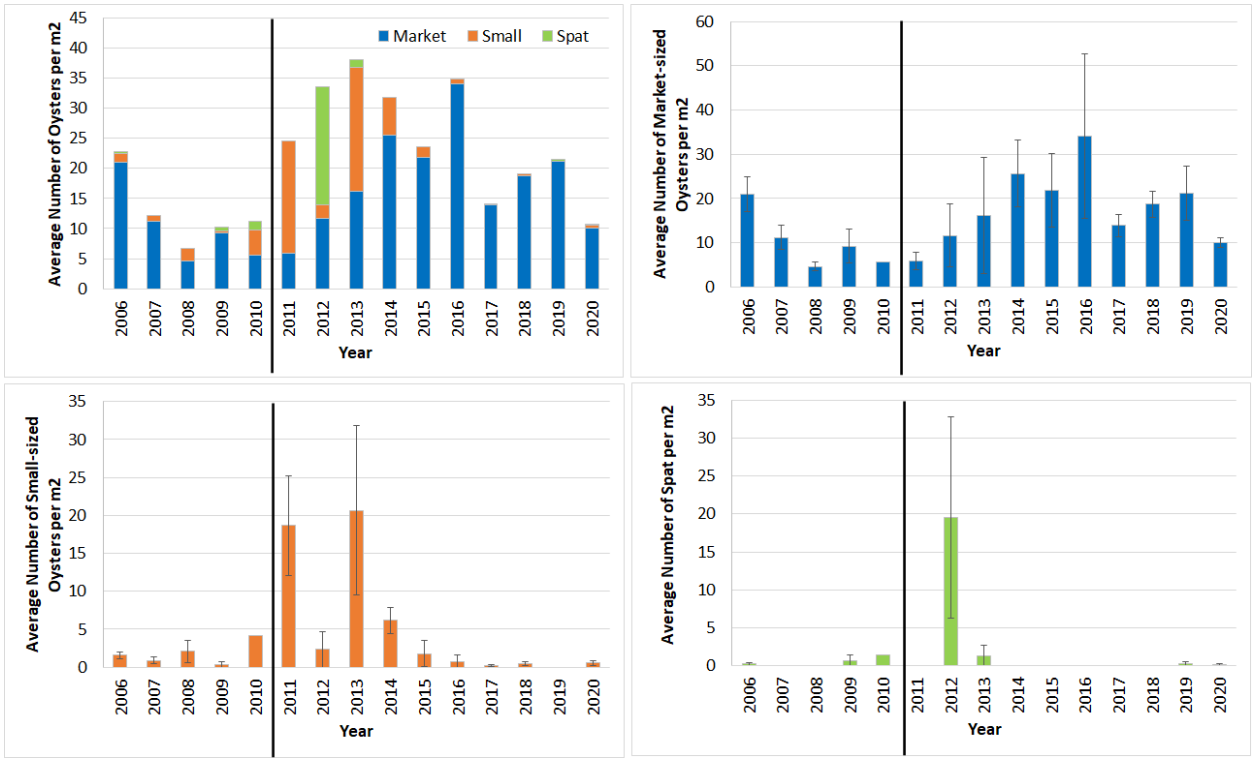

Figure A.51-3. Average number of live oysters per square meter by size class in the Wye River Sanctuary. Black line indicates the date the sanctuary was established. Error bars represent ± 1 standard error. Data from Maryland's Annual Fall Oyster Dredge Survey. Note differing Y-axis scales.

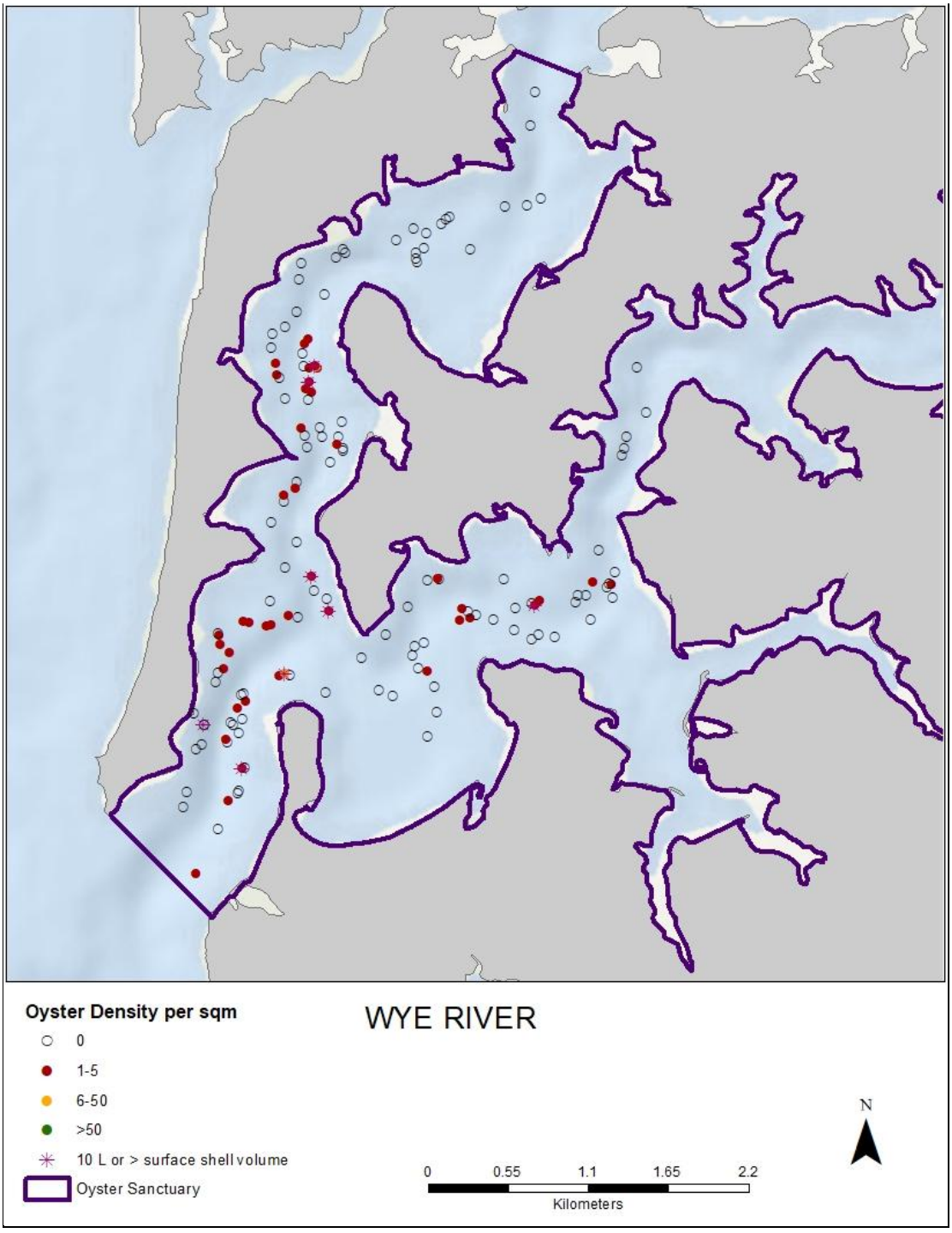

Figure A.51-4. Map of 2020 oyster density in the Wye River Sanctuary. Data from Maryland Department of Natural Resources Patent Tong Population Survey.

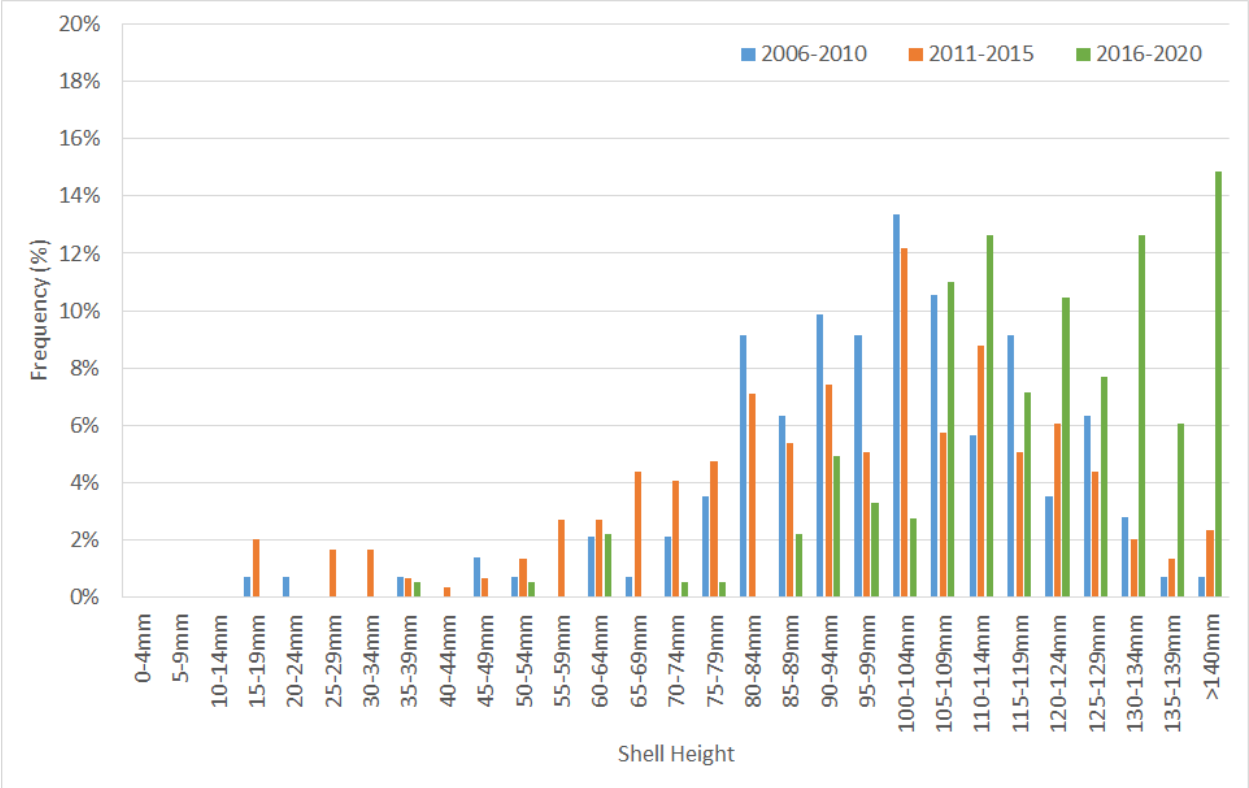

Figure A.51-5. Shell height frequencies of live oysters per bushel of material in the Wye River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Bruff Island bar.

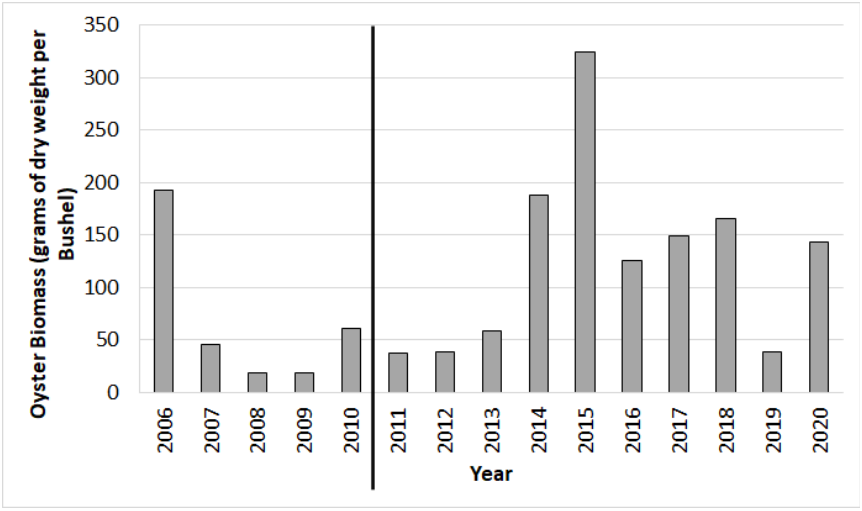

Figure A.51-6. Oyster biomass (grams of dry weight per bushel of material) in the Wye River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey on Bruff Island bar. Black line indicates the date the sanctuary was established.

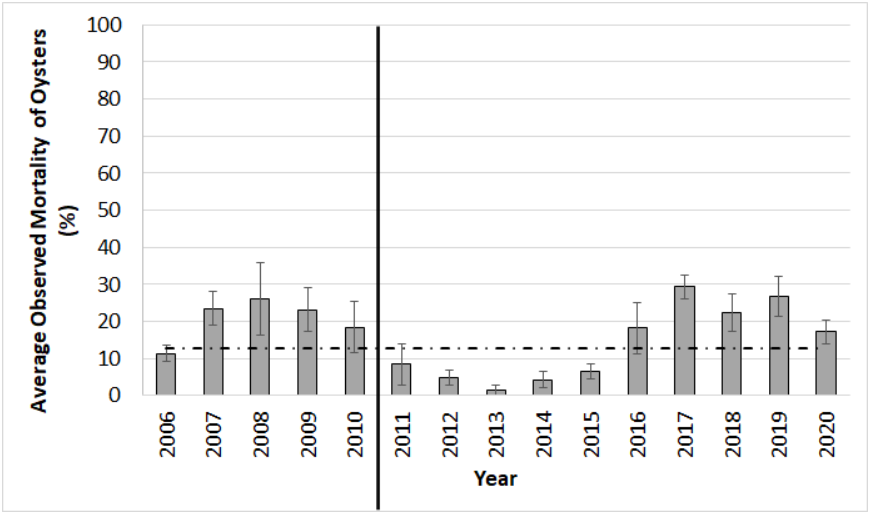

Figure A.51-7. Average annual observed mortality of market-sized and small-sized oysters in the Wye River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established and the dashed line represents the 2006-2020 baywide average observed mortality. Error bars represent ± 1 standard error.

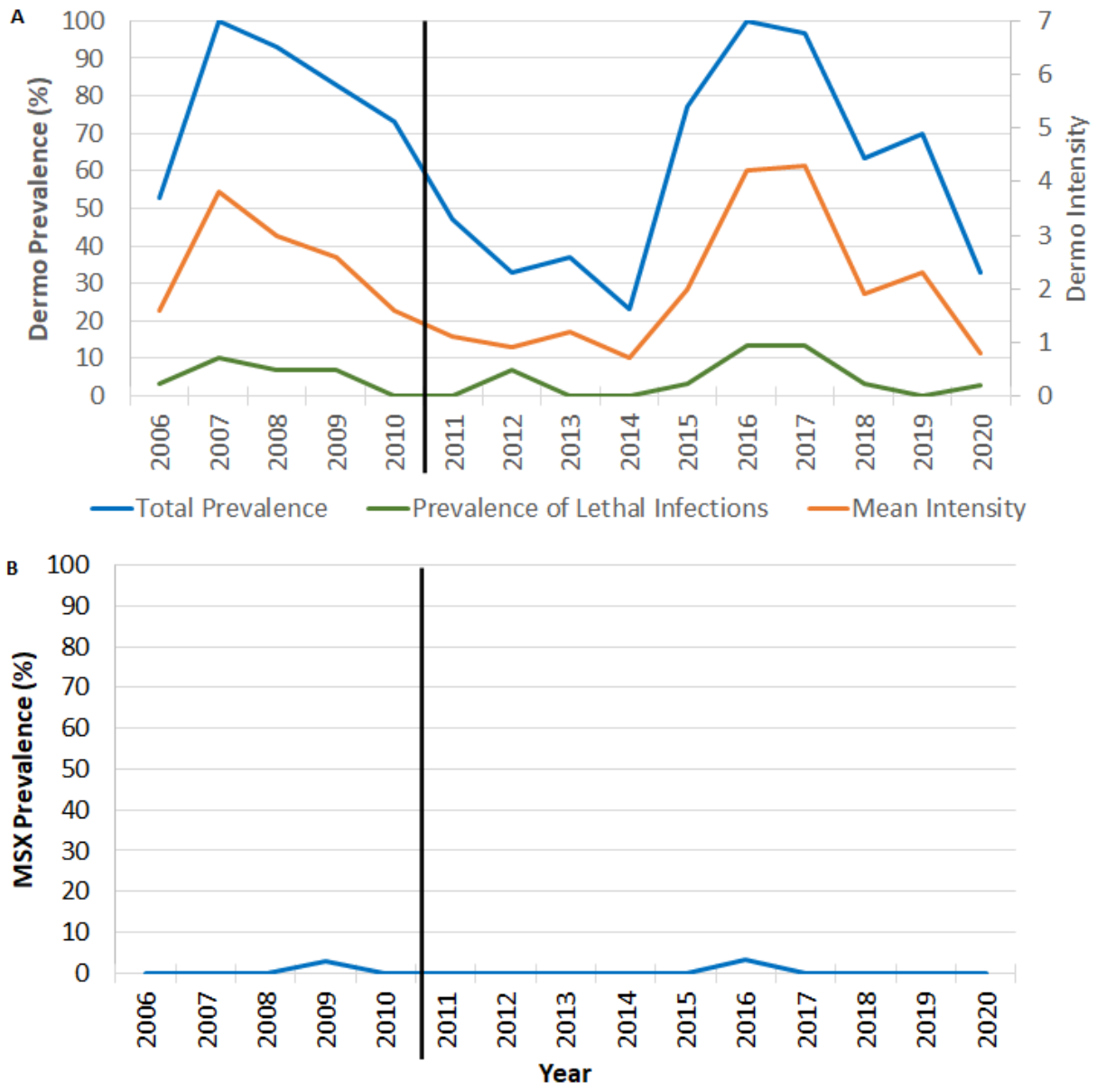

Figure A.51-8. Oyster disease prevalence and intensity in the Wye River Sanctuary. (A) Dermo prevalence and mean intensity (B) MSX prevalence (intensity is not examined). Data from Maryland's Annual Fall Oyster Dredge Survey on Bruff Island bar. Black line denotes the date the sanctuary was established.

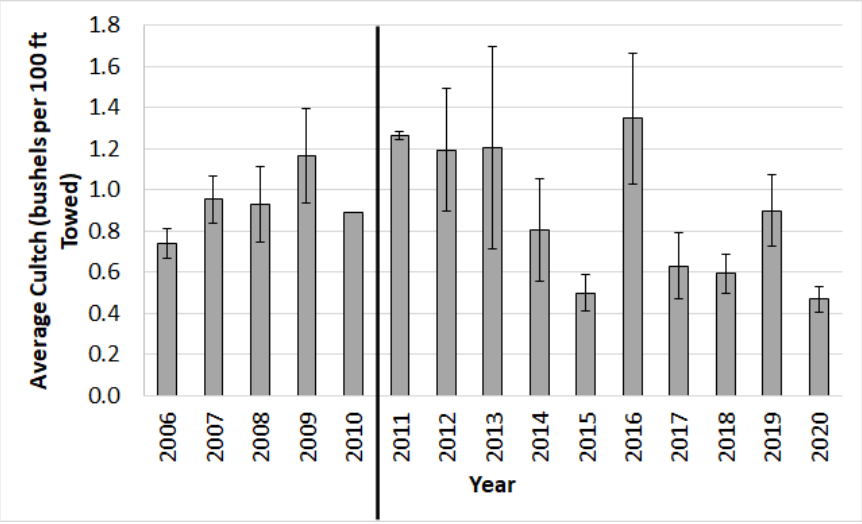

Figure A.51-9. Average cultch (live and dead oysters and loose shell) in the Wye River Sanctuary. Data from Maryland's Annual Fall Oyster Dredge Survey. Black line denotes the date the sanctuary was established. Error bars represent ± 1 standard error.