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Full Report of the

2020 Update Stock Assessment of the Eastern Oyster, *Crassostrea virginica*, in the Maryland waters of Chesapeake Bay

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Maryland Department of Natural Resources Fishing and Boating Services

in consultation with

The University of Maryland Center for Environmental Science

Executive Summary

Introduction

In 2020, the Maryland General Assembly passed a bill entitled Natural Resources - Fishery Management Plans - Oysters (Senate Bill 808, HB 911). This legislation requires the Maryland Department of Natural Resources to review the status of the oyster stock every 2 years relative to the biological reference points established in the 2018 Maryland Oyster Stock Assessment (Maryland Department of Natural Resources, 2018). This report fulfills that mandate, summarizing the results of the first update of the 2018 Maryland Oyster Stock Assessment. An assessment update generally involves applying the methods of the previously peer-reviewed stock assessment to updated time series of data to include information from the most recent years. For the 2020 Maryland Oyster Stock Assessment Update, the stage-structured model and reference point model from the 2018 Maryland Oyster Stock Assessment were reapplied to the updated time series of data through the end of the 2019-2020 harvest season. This resulted in updated estimates of abundance, harvest fractions, and biological reference points.

Spatial Scale and Time Span of Assessment

The stock assessment update was conducted on the spatial scale of "NOAA Codes", which are regional units of the Maryland portion of Chesapeake Bay to which commercial harvest is attributed (Executive Summary Figure 1). The stage-structured model from the 2018 Maryland Oyster Stock Assessment was updated with data from the most recent two years for 36 individual NOAA Codes allowing the assessment results to reflect varying rates of reproduction, growth and mortality within the Maryland Bay. NOAA Code-specific results are combined for Maryland-wide estimates. Available survey and harvest data supported a 21-year assessment period beginning in 1999 and ending in 2019 (years indicate the beginning of the fishing seasons on October 1).

Stock Assessment Model Estimates of Oyster Abundance

Maryland-wide, the estimated abundance of market oysters (three inches and larger) varied between 214 million and 684 million oysters. Estimated market abundance was highest in 1999 at 684 million, the initial year of the time series, decreased to 214 million in 2003, and generally remained below 284 million until 2010. After 2010 abundance increased to the third highest value in the time series in 2014 (500 million) before declining and then increasing again in the final year to 453 million, the fifth highest in the time series. In 1999, estimated market abundance was highest in the Choptank River and Eastern Bay Regions, but after 2007 abundance was generally highest in the Choptank River and Tangier Regions. **Abundance estimates in the Choptank River and Tangier Sound regions in 2019 are the 2nd and 4th highest, respectively, of the time series.**

Stock Assessment Model Estimates of Harvest Fraction

The harvest fraction for each NOAA Code is calculated as the percentage of market-size oysters removed from the population by commercial harvest. This varied over time and among NOAA Codes, ranging from 0 to 88%. Harvest fraction often tracked abundance in the NOAA Codes so that when abundance increased over time and there were no large sanctuaries, the percentage of oysters harvested generally increased. On average, the harvest fraction was highest among NOAA Codes in the southern part of Maryland. In NOAA Codes with no trend or a declining trend in abundance, harvest fraction tended to be low, but showed some variability.

Biological Reference Points

NOAA Code-specific biological reference points were developed for the Maryland oyster resource including a minimum safe level (lower limit) of abundance. If oyster abundance declines below this level, the population in that NOAA Code would be classified as 'depleted' or 'overfished'. Both of these terms are convention in fisheries management when a population declines below an identified lower limit abundance. For the purposes of this report, the term 'depleted' will be used since the oyster population can decline for many reasons (e.g. disease, habitat loss) that are independent of fishing. NOAA Code-specific target harvest fractions and maximum safe (upper limit) harvest fractions above which fishing is deemed unsustainable were also estimated.

The Lower Limit Abundance Reference Point

For each NOAA Code, the lower limit abundance reference point is the minimum estimated number of market-size oysters during 1999 through 2017 as estimated by the assessment model. The choice of the lowest value of the time-series as a lower limit abundance reference point is based on the fact that oysters in most NOAA Codes have been able to increase in abundance from their lowest observed levels, but it is unknown whether populations would be able to persist below those levels. If abundance falls below the lower limit, the oyster population within that NOAA Code would be considered depleted.

Estimated market abundance in three NOAA Codes (82, 131, 331) was below the lower limit abundance reference point. In NOAA Codes 131 and 331, estimated market abundance was at the minimum value in the last year of the 2018 Maryland Oyster Stock Assessment and has declined since then.

Target and Limit Harvest Fraction Reference Points

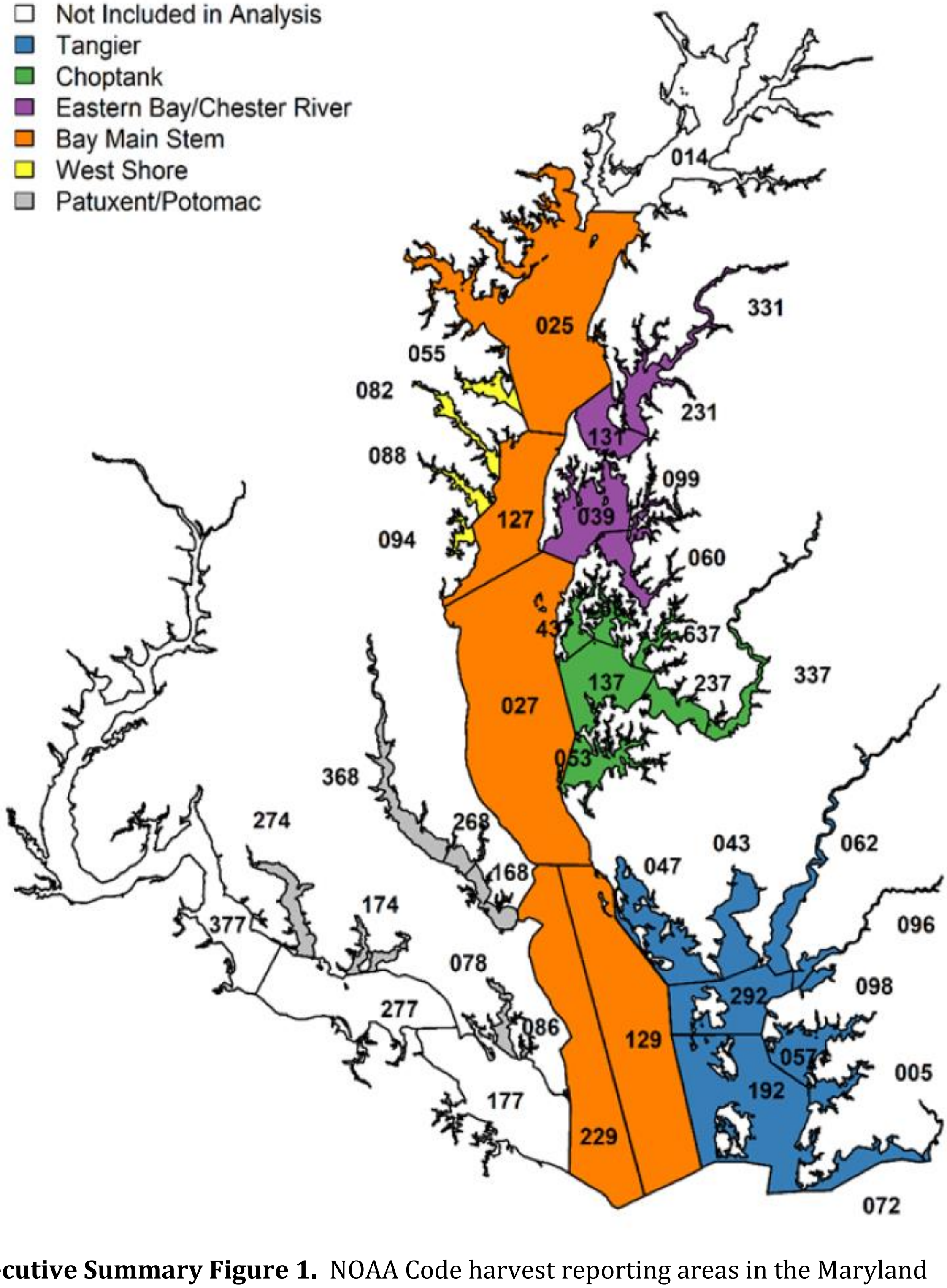
The target harvest fraction (fishing level) is an estimate of the harvest fraction (U) which provides maximum sustainable yield (MSY). If U_{MSY} is achieved annually, it is expected to yield a maximum harvest over time, while resulting in a stable or increasing oyster population (given current abundances of oysters in Maryland). The

upper limit reference point U_{limit} represents the absolute maximum harvest fraction that would allow sustainable harvest. If U_{limit} is exceeded over time it will result in eventual disappearance of the population. The limiting rate for oyster population growth is likely the ability of oysters to produce shell. Therefore, shell production is an important process to include in sustainable harvest reference point calculations for oysters. The target (U_{MSY}) and limit (U_{limit}) reference points were estimated separately for each NOAA Code using a reference point model that describes linkages between population growth and habitat. The amount of habitat depends on habitat production from living oysters, habitat loss, and shell and alternate substrate plantings.

Annual estimates of harvest fraction from the assessment model can be compared to the target and upper limit reference points in order to determine if harvest is at sustainable levels. It should be noted that, for each NOAA Code, the correct estimate of harvest fraction for comparison to the reference points depends on the management objective for oysters planted in the area. If oysters were planted with an objective of supplementing the fishery, then the harvest fraction that accounts for planted oysters should be the most appropriate for comparison with the reference points. If, however, the oysters were planted as part of restoration efforts to increase population size, then the harvest fraction that does not include planted oysters should be used. For the purposes of this report, all estimates of harvest fraction are corrected for the number of planted oysters. However, both methods are presented in tables in the body of the report.

Estimates of the upper limit reference point, U_{limit}, vary over NOAA Codes and range from 0 to 0.55 (55 percent) per year. Estimates of the target, U_{MSY}, ranged from 0 to 0.28 (28 percent) per year. Estimated target and upper limit reference points were highest, on average, in the southernmost NOAA Codes, Tangier Sound and the Potomac Tributaries, and were lower for the more northerly regions.

There was little variability among NOAA Codes and regions in their status relative to the harvest fraction reference points in the most recent year. **In the most recent fishing season (2019-2020), five NOAA Codes had harvest fractions above the upper limit reference point (U_{limit}), six were between the target and upper limit reference points, and 25 were at or below the target reference point.**



Executive Summary Figure 1. NOAA Code harvest reporting areas in the Maryland portion of Chesapeake Bay

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1 Introduction

1.1 Life history and Biology

The eastern oyster, *Crassostrea virginica*, is native to coastal waters from the Gulf of St. Lawrence in Canada to the Atlantic coast of Argentina (Carriker and Gaffney, 1996). It is common in estuaries and coastal areas of reduced salinity and can occur as extensive reefs or 'bars' on hard to firm bottoms in both the intertidal and subtidal zones (Carriker and Gaffney, 1996). As is typical of animals that have evolved to inhabit the environmentally variable estuarine environment, eastern oysters can tolerate a broad range of both temperatures and salinities (Shumway, 1996). In Maryland, sub-freezing temperatures and ice scouring restrict oyster bars to the subtidal zone (Galtsoff, 1964).

In the Maryland portion of Chesapeake Bay variable salinity and temperature regimes are primary environmental determinants of oyster population dynamics, given their influence on reproduction, growth, and mortality (Shumway, 1996). Mortality rates are interrelated with temperature and salinity because of the presence of two oyster protozoan parasites, *Perkinsus marinus* (Dermo disease) and *Haplosporidium nelsoni* (MSX). Dermo disease was identified in Chesapeake Bay oysters in 1949 but did not become a major problem until the mid-1980s (Ford and Tripp, 1996). MSX appeared in the Bay in 1959 and by the 1970s had dramatically reduced oyster densities in Virginia's high salinity oyster grounds (National Research Council, 2004). MSX is active at temperatures above 10°C although it is intolerant of salinities below 10 parts per thousand (ppt) (Ford and Tripp, 1996). Dermo disease proliferates most rapidly at temperatures between 25° and 30°C and salinities greater than 15 ppt, but survives at much lower temperatures and salinities (Ford and Tripp, 1996). During the latter part of the 20th century, these diseases had a devastating impact on oyster populations in Chesapeake Bay, although they acted on a population that was already compromised by poor water quality, fishing, and habitat loss (National Research Council, 2004). In any case, the presence of these two pathogens adds complexity to oyster population dynamics in Chesapeake Bay because mortality rates may vary substantially among years and also spatially within the same year.

All oyster bars in Maryland are located in mesohaline salinities (5-18 ppt). Within this salinity range, Maryland oyster bars are further classified into three zones whose boundaries, especially in the mid ranges, shift with varying climatic conditions. Zone one has an average salinity between five and < 12 ppt, Zone two has an average salinity between 12 and 14 ppt and Zone three salinities are greater than 14 ppt (Maryland Department of Natural Resources, 2005). In general, disease pressure intensifies during dry years as a result of the northward intrusion of the salt wedge and the resulting elevated salinities. In these years, Zone one can serve as a refuge from disease so that oysters in these areas may have lower mortality rates relative to the other zones. However, the influx of oyster larvae is intermittent and settlement rates are low in these less saline areas. Oysters in Zone one can also be subject to episodic freshets that result in substantial mortality (Maryland Department of Natural Resources, 2005). Zone two represents a transition area and oysters in these areas may have fluctuating rates of reproduction, growth and mortality based on the salinity variation between wet and dry years (Maryland Department of Natural Resources, 2005). In the Maryland portion of Chesapeake Bay, Zone three salinities are equal to or above 14 ppt and generally fall within what is thought to be the optimal salinity range (14 - 28 ppt) for eastern oysters (Shumway, 1996). Although disease pressure can be persistent and mortality rates high in Zone three, reproductive capability is maximized so that there is likely to be consistent recruitment of new oysters.

Gametogenesis and spawning in oysters are directly correlated with water temperature (Shumway, 1996). In the Chesapeake Bay, oysters begin gametogenesis in the spring and spawning can occur from late May to late September and generally peaks in late June or early July (Shumway, 1996; Thompson et al., 1996). The larval stage lasts for about 2 to 3 weeks, depending on food availability and temperature. Larval growth rates increase rapidly with increasing temperature; the fastest rates occur near 30°C. Larvae appear to migrate vertically, particularly at later stages, tending to concentrate near the bottom during the outgoing tide and rising in the water column during the incoming tide, thus increasing their chance of being retained in the estuary (Kennedy, 1996; Shumway, 1996).

C. virginica are either male or female (the reported incidence of simultaneous hermaphroditism is less than 0.5%) but may change sex over the winter when they are reproductively inactive. Generally, *C. virginica* function as males when they first mature, which can happen as early as 6 weeks post settlement (Thompson et al., 1996). As the individuals grow, the proportion of functional females in each size class increases, with an excess of females occurring among larger (and presumably older) animals (Galtsoff, 1964).

The assessment team could find no definitive study of the longevity of *C. virginica*. Several ages have been proposed, the most common being 20 years (Sieling, 1972; Buroker, 1983; Mann et al., 2009; NOAA-CBO, 2018), but the statements are either unsupported or make questionable inferences from other sources. Sieling (1972) comments "Oysters may live as long as 20 years, at least if undisturbed, as records of oysters kept in laboratories for that long are well known", but with no supporting references. Powell and Cummins (1985) are cited in two papers for *C. virginica* lifespans of 10 to 15 years and 10 to 20 years, even though this species is never mentioned by them. Likewise, Lavoie and Bryan (1981) are cited for a longevity estimate of at least 15 years, although the only suggestion of longevity in their paper is a von Bertalanffy curve that extends to 14 years but with observed data only up to age eight. The longest estimate, 30 years, was made by Lockwood (1882). He based it on very old-appearing oysters that were supposedly planted 30 years earlier. He supported this assertion by counting 30 bands in the hinge area of both the upper and lower valves of a single oyster, a technique that subsequently has not gained widespread acceptance. *C. virginica* from plantings in Maryland have been reported to survive at least 9 years (assuming no natural reproduction in these areas; Paynter et al., 2010).

1.2 The Importance of Substrate

Larvae of eastern oysters require a firm, sediment-free surface upon which to settle and metamorphose (Kennedy, 1996), and this substrate is typically provided by oyster shell. The larvae's gregarious settlement response produces dense aggregations of oysters coexisting in communities, often called bars, reefs, or rocks (Smith et al., 2005). Oysters are unique in that they create the habitat they require for population growth. In the absence of fishing and other anthropogenic effects, the rate of shell accretion through recruitment, growth and mortality exceeds by some small amount the rate of shell loss (Mann and Powell, 2007). Fishing not only removes adult animals but also potentially decreases productivity of the population by altering and diminishing necessary habitat (Lenihan and Peterson, 1998). Reefs with higher profiles above the seafloor appear to promote enhanced oyster productivity. Low-profile reefs are subject to sediment deposition on the reef surface (DeAlteris, 1988; Seliger and Boggs, 1988). Increased sedimentation reduces the nutritional value of material that oysters ingest, leading to reduced growth and reproduction and heightened physiological stress from clogging of the oyster's filtering mechanism (MacKenzie, 1983). Siltation on reefs also impairs habitat quantity and quality for settling larvae and attached juveniles (Bahr, 1976). Smith et al. (2005) concluded that, regardless of the cause, high rates of oyster mortality in the Maryland portion of Chesapeake Bay have reduced the ability of natural oyster bottom to accrete more shell, thereby rendering the remaining shell more susceptible to being covered by sediment.

1.3 Description and History of Fisheries

At the peak of its production in the late 1800s, the Chesapeake Bay was the greatest oyster-producing region of the world, with an oyster harvest twice that of the rest of the (non-US) world (Kennedy and Breisch, 1983). However, commercial landings in Maryland plummeted in the last part of the 19th century, with annual harvests decreasing by more than half between the late 1800s and the 1930s (Table 1). Over the following 50 years, harvests remained fairly stable, fluctuating around 2 million bushels annually until another decline occurred in the late 1980s primarily due to the oyster diseases MSX and Dermo (Maryland Department of Natural Resources, 1987). Since that time, commercial yields have remained at less than 420,000 bushels with a low of 19,028 bushels occurring in the 2003-2004 oyster season due to drought conditions and resulting elevated disease-related mortality (Maryland Department of Natural Resources, 2016). Although the Maryland Department of Natural Resources (hereafter, the department) has harvest records back to the latter part of the 19th century, this stock assessment update is conducted on the most recent 21 years beginning with the 1999-2000 harvest season. This represents the period when the most comprehensive and consistent harvest reports are available along with corresponding survey indices.

Maryland's commercial oyster fishery remains an important cultural and economic driver within Bay-side communities. During the 1999-2000 to the 2019-2020 harvest seasons, the average annual ex-vessel value of the Maryland oyster fishery was estimated to be $6 million.

Oyster bars throughout the Maryland portion of Chesapeake Bay vary widely in their habitat quality and level of productivity. The patchiness of oyster habitat combined with the regional management of the harvest gears and the activities of the County Oyster Committees results in an oyster population and fishery that is spatially complex. During the time series covered by this assessment update (1999-2000 through 2019-2020 seasons), the bulk (75 percent) of the harvest was generated by a small percentage of harvest reporting areas, known as NOAA Codes and the fishery is most active in the lower Eastern regions of the Maryland portion of the Chesapeake Bay.

1.4 Management

The Maryland oyster fishery is currently managed using a variety of laws and regulations that are mainly targeted at controlling effort:

Recreational harvest: Maryland residents may harvest oysters recreationally without a license or permit. As of 2019, a Maryland resident may take up 100 oysters per day Tuesday, Friday, and Saturday during the public fishery oyster season (previously this was 1 bushel per day per person Monday to Saturday). All of the oysters harvested must meet the minimum size requirement of 3 inches. Oysters can be recreationally harvested only by hand, rake, shaft tong or diving with or without scuba equipment. Recreational harvest of oysters can only occur in areas that are open to commercial harvest and where the harvest gear is allowed. While recreational harvest of oysters is not as popular as blue crabs, it does occur. The department does not have any data on effort or catch from recreational harvest. Anecdotal information suggests most recreational harvest occurs in the Wicomico (west) and Choptank rivers. Due to lack of information, recreational harvest information is not included in the assessment model.

Commercial licensing and limited entry: Maryland regulation limits the number of commercial licenses for the harvest of oysters to 737. In addition to their annual license renewal fee, these licensees must pay an annual surcharge of $300(US) in order to activate their license to harvest oysters prior to each season. Maryland also has a cap of 2,091 commercial fishing licenses which enable the licensee to participate in a wide variety of fisheries including oysters. Individuals possessing this 'umbrella' license must also pay the annual surcharge to harvest oysters, which allows the department to identify the subset of these licensees that are active in an oyster season. As such, there are 2,828 individuals who have the potential to harvest oysters in any given year (Code of Maryland Regulations [COMAR] 08.02.01.05, Natural Resources Article §4-10). From the 1999-2000 through the 2019-2020 oyster season, an average of 776 individuals paid the annual surcharge for oyster harvest. However, this number can fluctuate dramatically with changes in oyster abundance. For example, the number of surcharges rose from 599 in the 2011-2012 season to 1,134 in the 2014-2015 season, likely fueled by above average spat sets occurring in 2010 and 2012 and relatively low natural mortality, which increased the availability of oysters for harvest.

Commercial gear: There is a variety of permissible gears for the commercial harvest of oysters. Gears are restricted both in terms of when and where they can be used as well as in their dimensions (Code of Maryland Regulations [COMAR] 08.02.04, Natural Resources Article §4-10). The primary gears are hand tongs, patent tongs, diver, power dredge, and sail dredge. Hand tongs are typically constructed of two wooden shafts ranging from 16 to 30 feet with rakes at the ends to harvest oysters. Patent tongs are similar to hand tongs, except the patent tongs are suspended from a cable, are larger and heavier, and are opened and closed with hydraulic power. Divers use a surface-supply air hose or, in some cases, SCUBA to collect oysters, cull them, and then send them to the surface. A power dredge is a chain-mesh bag attached to a frame that is lowered to the bottom using a winch. The dredge is pulled along the bottom using a motorized vessel to collect oysters and then retrieved. A sail dredge, operated from a sailboat or skipjack, is typically a chain-mesh bag attached to a frame and pulled across the bottom using a boat under sail power. Sail dredges are allowed to use an auxiliary yawl boat to push the skipjack two days per week, which renders them similar to power dredges.

Commercial season and time limits: The harvest of wild oysters in Maryland is restricted to the months of October through March (power dredging and sail dredging is conducted November-March). The department has the authority to extend the season into April in the event of significant weather events such as icing that impede harvest during the normal season. Up until the 2019-2020 fishing season, harvesting was allowed Monday through Friday from sunrise to 3 p.m., and the hours are extended to sunset in November and December. Harvesting on Wednesdays was not allowed during the 2019-2020 fishing season. Because oyster harvest seasons straddle the calendar year, this report refers to 'seasons' rather than years. In cases where a year is used, it refers to the beginning year of the season (e.g., 2019 refers to the 2019-2020 harvest season).

Commercial bushel limits: Daily catch limits were basically unchanged since the 1980s until the 2019-2020 fishing season and depended on gear types. Until the 2019-2020 fishing season, all gear types except power and sail dredge were allowed 15 bushels/license/day, not to exceed 30 bushels/vessel. Power dredges were allowed 12 bushels/license/day, not to exceed 24 bushels/vessel. Sail dredges were allowed 150 bushels/vessel/day. These bushel limits were changed for the 2019-2020 season so that all gear types except power and sail dredge were allowed 12 bushels/license/day, not to exceed 24 bushels/vessel. Power dredges were allowed 10 bushels/license/day, not to exceed 20 bushels/vessel. Sail dredges were allowed 100 bushels/vessel/day.

Size limits: In 1927 the minimum size limit for oysters harvested from public grounds was increased from 2.5 to 3 inches, and this size limit remains in place to the present day (Kennedy and Breisch, 1983).

In addition to the traditional use of effort and size limit controls described above, the Maryland wild oyster fishery has historically been managed on a fine spatial scale (bar level) in cooperation with the oystermen of the State. In 1947 legislation created county oyster committees whose charge is to interact with management and to advise on closing and opening bars; and on shell and seed planting activities (Kennedy and Breisch, 1983). The county oyster committees remain in place to the present day and are closely involved in the management of harvest bars (Natural Resources Article §4-1106). Funding for county efforts to improve certain bars through the planting of hatchery spat on shell, wild spat on shell, or just cultch (shell) is generated from the $300 license surcharge paid by each oysterman, by a $1 tax levied on each bushel of oysters harvested, an oyster export tax (Natural Resources Article §4-1020, §4-701), and since 1996, by a grant from the Maryland Department of Transportation, Port Authority.

The active management of the wild oyster fishery has historically focused on bolstering the productivity of individual bars through the placement of shell and oysters in order to maintain some level of harvest, rather than on population level parameters related to overall stock sustainability.

In 2010, the department amended its management plan for oysters to include a 10-point plan for the restoration of the oyster population and fishery in the Maryland portion of Chesapeake Bay (Maryland Department of Natural Resources, 2010). To implement the amended plan, the department overhauled its regulations for managing oysters; expanding the scale of oyster sanctuaries, creating new opportunities for oyster aquaculture, and designating areas to be maintained for the public fishery. Several objectives were laid out within the preamble to the regulations including to “Implement a more targeted and scientifically managed wild oyster fishery” (Maryland Register, 2010).

The first stock assessment for oysters in Maryland was completed in December, 2018 (Maryland Department of Natural Resources, 2018). This assessment was conducted as a means toward achieving the goal of a more scientifically managed fishery and was mandated by the Maryland General Assembly as part of the Sustainable Oyster Population and Fishery Act of 2016 (Senate Bill 937, Natural Resources Article §4–215, revised in 2017, HB 924, Chapter 27). The 2018 Maryland Oyster Stock Assessment provided biological reference points for the management of the oyster population. An independent peer review of the 2018 Maryland Oyster Stock Assessment indicated that it was sufficiently sound for use in management.

In 2019, the department modified the bushel and day of the week restrictions for the 2019-2020 fishing season as described above. All areas above the bay bridge were closed to harvest except public fishery areas that had been planted with seed between three and six years ago. These modifications were prompted by results from the 2018 Maryland Oyster Stock Assessment.

1.5 Call for a Stock Assessment Update

In 2020, the Maryland General Assembly passed a bill entitled Natural Resources - Fishery Management Plans - Oysters (Per Natural Resources Article § 4-215(e)(5)(iii)1, Annotated Code of Maryland, SB 808, Chapter 598 and HB 911, Chapter 597, MSAR 12769). This legislation requires the department to review the status of the oyster stock every 2 years relative to the biological reference points developed in the 2018 Maryland Oyster Stock Assessment. This report fulfills that mandate, summarizing the results of the first update of the 2018 Maryland Oyster Stock Assessment. An assessment update generally involves applying the methods that were peer reviewed to update the time series of data to include information from the most recent years. For the 2020 Maryland Oyster Stock Assessment Update, the stage-structured model and reference point model from the 2018 Maryland Oyster Stock Assessment were reapplied to the updated time series of data through the end of the 2019-2020 harvest season. This resulted in updated estimates of abundance, harvest fractions, biological reference points, and stock status.

2 Data

2.1 Fishery Dependent Data

2.1.1 Harvest Data

Two sources of commercial harvest and effort data are collected by the department: seafood dealer buy tickets (buy tickets) and individual harvester reports (harvest reports). Buy tickets were used in the 2018 assessment and we have continued to use this data source with updated data for the 2018-2019 and 2019-2020 seasons. Every dealer registered to buy oysters in Maryland completes a buy ticket report for every purchase made from a licensed commercial harvester. These reports are then submitted to the department. Because oysters are almost always harvested and sold to seafood dealers on the same day, buy tickets represent a record of daily oyster harvest.

This assessment is conducted on the scale of NOAA Codes. Harvest location is reported by the name of the oyster bar and by NOAA Code (Maryland Department of Natural Resources, 2016). Individual oyster bars were delineated in surveys conducted between 1906 and 1912 (Yates, 1913) and these delineations were amended until the 1980s. There are 1,105 Yates bars and amendments with areas ranging from 1.2 to 4,988 acres with a mean size of 299 acres. NOAA Codes are statistical reporting areas that were created for the purpose of reporting fishery harvest. There are currently 47 NOAA Codes used by the department for shellfish harvest reporting and as with the 2018 assessment we only use a subset of 36 of these NOAA Codes in this update.

Buy tickets include useful information for estimating effort and harvest as they include trip-level data on total bushels harvested, gear used, location of harvest, hours spent harvesting, number of licensees aboard a vessel (1 or 2). For this update we have continued to use the catch-per-unit-effort (CPUE) metric of bushels per license per day. CPUE metrics were used to calculate instantaneous fishing mortality rates that were used as input to the stage-structured population model. We used the method presented by Leslie and Davis modified to account for daily harvest limits (Mace and Wilberg, 2020).

A mistake in the computer code from the Maryland 2018 Oyster Stock Assessment used to calculate harvest within each NOAA Code was corrected. The previous code inadvertently excluded some records (e.g. double patent tong, rake, and scrape), which caused an under count of harvest in some NOAA Codes for some years. Fixing the code did not qualitatively change the results for the assessment except for NOAA Codes 57 and 27. NOAA Code 27 is now estimated to be below the target harvest rate in the 2017-2018 season whereas it was estimated to be between the target and limit harvest rate in the 2018 Maryland Oyster

Stock Assessment in the 2017-2018 season. NOAA Code 57 is now estimated to be between the target and upper limit harvest rate reference points in the 2017-2018 season whereas it was estimated to be above the upper limit harvest reference point in the 2018 Maryland Oyster Stock Assessment.

2.2 Fishery Independent Data

2.2.1 Fall Dredge Survey

Since 1939, the department and its predecessor agencies have conducted surveys to monitor the oyster population in the Maryland portion of Chesapeake Bay. Samples are collected on natural oyster bars, seed and shell plantings and in sanctuaries from mid-October through late November (Tarnowski, 2017). This survey was designed to look at long-term trends in aspects of the oyster population (spat density, disease, biomass and mortality) rather than to estimate abundance. Since 1975, 53 sites have been designated as "key bars" and are used to provide an annual index of spat settlement intensity at fixed locations. A subset of 43 bars, 31 of which are also key bars, are used to collect information on oyster parasite prevalence and intensity. From 1999-2019, the number of samples taken during the survey ranged from 310 to 385 (mean = 346) and the number of oyster bars sampled ranged from 255 to 272 (mean = 262).

The survey uses a 32-inch-wide (.81 meter) oyster dredge to obtain samples. Beginning in 2005, the distance for each tow has been recorded using a hand-held GPS unit. The total volume of dredged material is recorded prior to the sample being removed. A full dredge is 2.1 Maryland bushels (Maryland bushel = 2008.9 cubic inches or 45 liters). On key bar and disease bar sites, two one-half bushel samples are collected from replicate dredge tows, while at most other stations, a single half-bushel sample is taken. Water quality data (salinity and temperature) are collected on each bar. For each sample, live oysters are sorted into spat (recently settled oysters), smalls (≥ one year old and <76 mm), and markets (≥ one year old and ≥ 76 mm). Small and market boxes (dead oysters with hinges articulated) are also counted and the relative age of the boxes is assessed. For disease bars, key bars, and selected other samples, all live oysters and boxes are measured to the nearest millimeter. For the remainder, a range of oyster shell heights and an estimate of the mean are taken. Samples of live oysters are retained for disease testing at the 43 disease sites and selected other locations in the bay.

This assessment update incorporated data from the fall dredge survey for the years 1999 through 2019 for all NOAA Codes except for the Potomac River, West and Rhode rivers, the Magothy River and Monie Bay. Potomac River samples were excluded because bars in that area are managed by the Potomac River Fisheries Commission. The other NOAA Codes had no fall dredge survey samples for the time series.

In this assessment update, standardized counts of live oysters and boxes were used as data to which the assessment model was fitted to estimate abundance and natural mortality. See Section 2.4.1 in the 2018 Maryland Oyster Stock Assessment (Maryland Department of Natural Resources, 2018) for a complete description of the model and standardization procedure.

2.2.2 Patent Tong Surveys

The department regularly conducts patent (hydraulic) tong surveys for a variety of purposes: 1) to evaluate the effects of power dredging, 2) to assess the effects of waterway dredging or construction on oyster populations and 3) to assess potential aquaculture lease sites. When Maryland expanded the oyster sanctuary program in 2010, the department began a study to evaluate oyster populations within sanctuaries. Most sanctuaries have been sampled at least once (Maryland Department of Natural Resources, 2016).

These surveys use a stratified random sampling design, with the strata based on substrate type. The number of sampling points varies based on the estimated amount of potential oyster habitat within the sanctuary but ranges generally from 50 to 300. The patent tongs used in these surveys sample an area of 1 square meter. Any oysters in the sample are sorted into categories as described above for the fall survey. Live oysters and boxes are counted and measured. The amount of total material in a sample is measured to the nearest 0.5 liter and the amount of surface material is estimated. Depth and bottom type are also recorded.

Because patent tongs sample a fixed area of the bottom, oyster density can be calculated. The average density of oysters based on all samples collected within a sanctuary was used to derive the overall density of oysters within the sanctuary.

2.2.3 Bay Bottom Surveys

Several attempts have been made to estimate the amount of oyster habitat in Chesapeake Bay. The first was the Yates survey from 1906 to 1912. The purpose of this survey was to identify the boundaries of “Natural Oyster Bars” within Maryland’s portion of the bay, so that areas outside of oyster bars could be used for oyster aquaculture leases. The original Yates survey and subsequent surveys identified approximately 1,100 oyster bars and over 300,000 acres of oyster habitat. Later studies have estimated that only 36,000 acres are currently viable oyster habitat (U.S. Army Corps of Engineers, 2009).

The Bay Bottom Survey was conducted from 1975-1983, generating maps that updated the Yates bars. This survey used a dragged acoustical device, patent tongs and sonar, to produce bottom classifications that included sand, mud, cultch (oyster shells) and hard-bottom. Cultch and mixed-cultch categories are substrate types that provide habitat for oyster spat. These surveys (and other, more recent, side-scan sonar surveys conducted in sanctuaries) can be used to estimate the amount of habitat available for oysters.

2.2.4 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 were intended to enhance the public fishery for economic benefit and occurred prior to the establishment of sanctuaries. Restoration efforts were those activities occurring after the establishment of a sanctuary with the 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 1999 were used in the assessment. All replenishment and restoration planting data are stored in an Arc GIS file. Information recorded includes planting year, planting type, planting location, and planting amount. Both the planting center point latitude and longitude is recorded along with the corner coordinates.

Since 2010, planting data have been recorded using GPS trackers and exact tracklines are provided to the department. Prior to 2010 there are issues within the data concerning both precision and completeness of records, and care must be used when trying to infer total planting volume within a given area.

3 Assessment Model Description and Results

3.1 Model Description

Stage-structured assessment models were developed for each of 36 NOAA Codes to estimate time series of abundance, harvest fraction (fishing levels) and natural mortality rates of oysters (modified from Wilberg et al. (2011) and Damiano and Wilberg (2019)). The five stages used in the models are those described in the fall dredge survey: spat (recently settled oysters), small (≥ one year old and <3 inches), market (≥ 3 inches), small box, and market box. The model year began October 1 which is the beginning of the oyster season for all gears except power dredge which begins November 1. The beginning of the model year (October 1) is about the same time as the fall dredge survey. The processes being modeled 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 (harvest fraction or fishing levels), changes to habitat over time, effects of planting substrate and oysters, and the disarticulation of small and market boxes. The full details of the stage-structured assessment model can be found in the 2018 stock assessment report (Maryland Department of Natural Resources, 2018).

3.2 Model Results

Model Fit and Diagnostics
Similar to the 2018 Maryland Oyster Stock Assessment, fits of the individual NOAA code-specific models to all data sources were acceptable overall with the fishery-dependent data generally fitting less well than the fishery-independent data (Appendix 1).

Market Abundance

Maryland-wide, the estimated abundance of market oysters (three inches and larger) varied between 214 million and 684 million oysters (Figure 1). Estimated market abundance was highest in 1999 at 684 million, the initial year of the time series, and decreased to 214 million in 2003 and generally remained below 284 million until 2010. After 2010 abundance increased to the third highest value in the time series in 2014 (500 million) before declining and then increasing again in the final year to 453 million, the fifth highest in the time series. In 1999, estimated market abundance was highest in the Choptank River and Eastern Bay Regions, but after 2007 abundance was generally highest in the Choptank River and Tangier Regions. Abundance in the Choptank River and Tangier Sound regions in 2019 were the 2nd and 4th highest, respectively, of the time series. Estimated market abundance also varied among NOAA Codes within each region (Figure 2-Figure 37).

Small Abundance

Maryland-wide, the estimated abundance of small oysters (older than one year, but less than three inches) varied between 247 million to 1,038 million oysters (Figure 38). Estimated abundance of small oysters was highest in 2000, the second year of the time series, and then decreased to 224 million in 2002. After 2002 estimated small abundance fluctuated over time with no strong trend. Peaks occurred in 2003, 2007, 2011, 2013, and 2017 when estimated small abundance ranged from 456 million to 668 million. Estimated small abundance in the most recent year was 433 million, which is slightly below the long-term mean of 480 million. Estimated small abundance was relatively high (> 150 million) in the Choptank River, Tangier Sound, Eastern Bay, and Mainstem regions at the beginning of the time series, but after 2010 estimated small abundance was highest in the Choptank River and Tangier Sound regions. Estimated small abundance also varied among NOAA Codes within each region (Figure 2-Figure 37).

Spat Abundance

Maryland-wide, the estimated abundance of spat varied between 128 million to 1,266 million oysters (Figure 39). Estimated spat abundance was highest in 1999, the initial year of the time series, and decreased to 394 million in 2000. After 2000, estimated spat abundance fluctuated over time with no strong trend. After 1999, peaks occurred in 2002, 2006, 2010, 2012, and 2016 when estimated spat abundance ranged from 582 million to 1,007 million. Estimated spat abundance in the most recent year was the 6th lowest in the time series. Estimated spat abundance was generally highest at the beginning of the time series in all regions, but only the Choptank River and Tangier Sound regions have consistently had relatively high (> 100 million) estimated spat abundance after 1999. Estimated spat abundance also varied among NOAA Codes within each region (Figure 2-Figure 37).

Total Abundance

Maryland-wide, estimated total abundance (spat, smalls, and markets combined) varied between 0.8 billion and 2.79 billion oysters (Figure 40). Estimated abundance of all oysters was highest in 1999, the initial year of the time series, and decreased to 0.8 billion in 2005, which is the year with the lowest estimated total abundance in the time series. After 2005, estimated total abundance generally stayed around 1 billion oysters except for peaks in 2010 and 2012 when abundance reached 1.6 and 1.9 billion, respectively. Estimated total abundance in the most recent year was 1.2 billion, which is slightly below the long-term mean of 1.3 billion. Estimated total abundance was highest in 1999 for all regions except the Tangier Sound region. After 1999, estimated total abundance was generally below 200 million for the Mainstem, Severn/South Rivers, Patuxent/Potomac Rivers, and Eastern Bay regions. However, estimated total abundance for the Choptank River and Tangier Sound regions was above 200 million for almost all years in the time series. Estimated total abundance also varied among NOAA Codes within each region (Figure 2-Figure 37).

Natural Mortality

Across NOAA Codes, estimated natural mortality was generally higher and more variable in the beginning of the time series than in more recent years (Figure 2-Figure 37). Despite similar temporal patterns, the year in which natural mortality first began to be lower and less variable varied among the regions of the bay. For example, among NOAA Codes in the

Tangier Sound region, natural mortality became lower and less variable later than among most NOAA Codes in the Choptank region. In general, average natural mortality was lower in both the northern part of the bay and farther upstream in the tributaries, except in the most recent year. In the most recent year (2019) natural mortality increased in NOAA Codes in the northern part of the bay (e.g., NOAA Code 25, 131, 231) and farther upstream in tributaries (e.g., NOAA Codes 331 and 337). Department biologists indicate this increased mortality was due to the freshet in 2018 and 2019.

Harvest Fraction

Harvest fraction is calculated as the percentage of market oysters removed from each NOAA Code by harvest. The harvest fractions varied over time and among NOAA Codes, ranging from zero to about 88% per year (Figure 2-Figure 37). Harvest fraction often tracked market abundance in the NOAA Codes. In NOAA Codes where abundance was increasing over time and there were no large sanctuaries, the harvest fraction generally increased over time during the period from 2008 through 2016. On average, the harvest fraction was highest in the Tangier Sound region and neighboring NOAA Codes. In NOAA Codes with no trend or a declining trend in abundance, harvest fraction tended to be low, but showed some variability.

Other Parameters

Other parameters directly estimated by the model were probability of transition from small to market stage, habitat decay rate, and catchabilities for each NOAA Code (Table 2).

Changes in Harvest Fraction and Market Abundance Since Last Assessment

In 75% of NOAA Codes the harvest fraction decreased between 2017 and 2019 (Table 3). Most NOAA Codes where the harvest fraction increased were still negative (i.e., the estimated number of market oysters from plantings was higher than the number of market oysters harvested). NOAA Codes 137, 192, and 229 were the only NOAA Codes where harvest fraction was positive and increased from 2017 compared to 2019. Most (72%) NOAA Codes experienced an increase in market abundance since 2017, the final year in the 2018 Maryland Oyster Stock Assessment (Table 3). Estimated market abundance decreased from 2017 to 2019 in NOAA Codes 5, 25, 60, 82, 99, 131, 174, 192, 331, and 337.

4 Biological Reference Points and Stock Status

Maryland law requires that fishery management plans contain the best available estimates of sustainable harvest rates and minimum abundance levels (biological reference points, Natural Resources Article §4-215). Specifically, statute requires the development of target and upper limit (threshold) reference points for harvest fraction (fishing levels) and a lower limit (threshold) reference point for abundance. Additionally, there must be objective and measurable means to determine if the oyster fishery is operating within the reference points. To fulfill this requirement, harvest fraction and abundance biological reference points were developed as part of the 2018 Maryland Oyster Stock Assessment and these reference points were incorporated into the Maryland Chesapeake Bay Oyster Management Plan (Maryland Department of Natural Resources, 2019).

The lower limit abundance reference point developed in the 2018 Maryland Oyster Stock Assessment is the minimum estimated number of market oysters during the period 1999-2017 for each NOAA code. The choice of the time-series minimum as an abundance lower limit reference point is based on the observation that oysters in most NOAA Codes have been able to increase in abundance from their lowest observed levels, but it is unknown whether populations would be able to persist below those levels. Additionally, minimum abundance during the period from 1999 through 2017 is likely the minimum during the last several hundred years. Market-size oysters were chosen because they are the targeted size group of the fishery and they also produce more eggs per individual than small oysters. This reference point is proposed as an operational definition for depleted status, similar to the previously used abundance reference points for blue crabs in Chesapeake Bay.

Estimated market abundance in three NOAA Codes (82, 131, and 331) was below the lower limit abundance reference point (Figure 41; Table 4). Estimated market abundance in NOAA Codes 131 and 331 was at the minimum value in the last year of the 2018 Maryland Oyster Stock Assessment and has declined since then. Department biologists indicate the declines in these areas are due to environmental causes and not harvest since these areas include sanctuaries (69%, 98% and 100% of NOAA Codes 131, 082 and 331, respectively, are sanctuary areas) and were not estimated to be experiencing overfishing in the most recent two years.

In determining appropriate target and upper limit harvest fractions to propose for Maryland's oyster resource in the 2018 Maryland Oyster Stock Assessment, there was consideration of Natural Resources Article §4-215 which states that conservation and management measures adopted under a fishery management plan, to the extent possible: Shall prevent overfishing while attempting to achieve the best and most efficient utilization of the State's fishery resources. Therefore, the adopted target exploitation rate (U) is that which provides maximum sustainable yield (MSY). If U_{MSY} is achieved annually, it is expected to result in a maximum harvest over time, while resulting in a stable or increasing oyster population (given current abundances of oysters in Maryland).

In order to prevent overfishing, the adopted upper limit is equivalent to the estimate of U_{limit}, which represents the absolute maximum harvest fraction that would allow sustainable harvest. If U_{limit} is exceeded over time, it will result in eventual disappearance of the population. As noted above, the limiting rate for oyster population growth is likely their ability to produce shell. Therefore, shell production is an important process to include in sustainable harvest reference point calculations for oysters.

The target (U_{MSY}) and limit (U_{limit}) reference points were estimated separately for each NOAA code using a harvest fraction reference point model that was modified from the model presented in Wilberg et al. (2013). This model describes population growth as a logistic function of abundance with carrying capacity determined by the amount of habitat (Maryland Department of Natural Resources, 2018). The amount of habitat depends on habitat production from living oysters, habitat loss, habitat plantings, and a maximum amount of potential oyster habitat in the system. Additionally, the model includes planted oysters and shell or other substrate. Several of the original parameters in the Wilberg et al. (2013) model were not estimable, so they were fixed at values from the literature as described in the 2018 Maryland Oyster Stock Assessment (Maryland Department of Natural Resources, 2018). Lastly, the model required a parameter to convert from habitat in units of oysters to habitat in units of area. A discrete time version of the model was fitted with linked habitat dynamics to estimates of market-sized oyster abundance and area of habitat from the stage-structured assessment models for each NOAA code.

For each NOAA code, the correct harvest fraction to use for comparison to the reference points depends on the management objective for the planted oysters. If oysters were planted with an objective of supplementing the fishery, then the harvest fraction that accounts for planted oysters should be the most appropriate for comparison with the reference points. If, however, the oysters were planted as part of restoration efforts to increase population size, then the harvest fraction that does not include planted oysters should be used. Annual estimates of harvest fraction from the assessment model can be compared to the reference points. For the purposes of comparisons with the harvest fraction reference points in this report, all estimates of harvest fraction are adjusted for the number of planted oysters. However, annual estimates of harvest fraction estimated using both methods are presented in Table 5 and Table 6.

In the 2019-2020 fishing season, five NOAA Codes had harvest fractions above the upper limit reference point (U_{limit}), six were between the target and upper limit reference points, and 25 were at or below the target reference point (Figure 42). The NOAA Codes above the upper limit reference point were 96, 137, 192, 292, and 537. The NOAA Codes between the target and upper limit reference point were 43, 72, 78, 86, 168, and 229. Showing progress from the prior assessment, the number of NOAA Codes above the upper limit reference point declined from 18 in the last year of the 2018 Maryland Oyster Stock Assessment to 5 in the last year of the 2020 Maryland Oyster Stock Assessment Update, while the number of NOAA Codes at or below the target increased from 15 to 25 (Table 6).

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Table 1. Oyster harvest from the Maryland portion of Chesapeake Bay beginning with the 1889-1890 season through the 2019-2020 season based on Maryland dealer buy tickets.

Season	Bushels Harvested	Season	Bushels Harvested	Season	Bushels Harvested
1889-90	10,450,087	1945-46	2,322,185	1983-84	1,076,884
1890-91	9,945,058	1946-47	2,157,838	1984-85	1,142,493
1891-92	11,632,730	1947-48	2,027,381	1985-86	1,557,091
1892-93	10,142,500	1948-49	2,702,814	1986-87	976,162
1897-98	7,254,934	1949-50	2,495,787	1987-88	363,259
1900-01	5,685,561	1950-51	2,170,556	1988-89	397,180
1904-05	4,500,000	1951-52	2,339,976	1989-90	413,113
1906-07	6,232,000	1952-53	2,642,147	1990-91	416,720
1910-11	3,500,000	1953-54	2,129,115	1991-92	318,128
1916-17	4,120,819	1954-55	2,878,755	1992-93	123,618
1917-18	2,461,603	1955-56	2,799,788	1993-94	78,817
1918-19	3,743,638	1956-57	2,259,882	1994-95	164,673
1919-20	4,592,001	1957-58	2,190,074	1995-96	193,629
1920-21	4,959,962	1958-59	1,968,894	1996-97	171,630
1921-22	4,435,186	1959-60	2,114,899	1997-98	278,292
1922-23	3,687,489	1960-61	1,635,123	1998-99	413,010
1923-24	3,440,810	1961-62	1,495,235	1999-00	345,850
1924-25	2,787,047	1962-63	1,243,498	2000-01	316,630
1925-26	2,367,122	1963-64	1,383,617	2001-02	109,175
1926-27	2,571,540	1964-65	1,340,177	2002-03	47,141
1927-28	2,260,898	1965-66	1,645,144	2003-04	19,028
1928-29	1,993,591	1966-67	3,014,670	2004-05	57,558
1929-30	1,839,772	1967-68	3,000,272	2005-06	130,323
1930-31	1,775,738	1968-69	2,509,701	2006-07	154,236
1931-32	2,041,043	1969-70	2,533,275	2007-08	66,807
1932-33	1,626,214	1970-71	2,395,528	2008-09	87,358
1933-34	1,835,364	1971-72	2,900,547	2009-10	114,236
1934-35	2,100,233	1972-73	2,925,236	2010-11	103,608
1935-36	2,407,693	1973-74	2,845,924	2011-12	101,398
1936-37	3,081,063	1974-75	2,559,112	2012-13	330,064
1937-38	3,245,816	1975-76	2,449,440	2013-14	417,784
1938-39	3,403,549	1976-77	1,891,614	2014-15	375,244
1939-40	3,129,403	1977-78	2,311,434	2015-16	380,163
1940-41	3,430,269	1978-79	2,197,457	2016-17	213,397
1941-42	2,792,069	1979-80	2,111,080	2017-18	179,779
1942-43	2,328,541	1980-81	2,532,321	2018-19	145,849
1943-44	2,413,349	1981-82	2,308,619	2019-20	270,011

Table 2. Estimates of the probability of transition from the small to market stage (G), rate of disarticulation for small (d_{sm}) and market (d_{mk}) boxes, spat catchability (q_{sp}), live small and market catchability (q_{live}), small and market box catchability (q_{box}), and rate of habitat decay (d).

NOAA Code	G	d_{sm}	d_{mk}	q_{sp}	q_{live}	q_{box}	d
5	0.67 (0.31)	0.73 (0.59)	0.43 (0.76)	20.99 (0.51)	7.16 (0.46)	3.12 (0.53)	0.03 (0.45)
25	0.64 (0.35)	2.6 (0.52)	1.71 (0.45)	14.76 (0.57)	18.83 (0.46)	3.34 (0.46)	0.03 (0.46)
27	0.62 (0.32)	1.42 (0.5)	0.8 (0.43)	19.8 (0.53)	56.25 (0.42)	25.46 (0.47)	0.02 (0.44)
39	0.57 (0.24)	2.1 (0.46)	0.92 (0.32)	2.08 (0.39)	8.11 (0.29)	5.96 (0.36)	0.01 (0.41)
43	0.45 (0.3)	1.15 (0.45)	0.9 (0.36)	3.34 (0.56)	4.59 (0.56)	2.32 (0.6)	0.04 (0.5)
47	0.36 (0.35)	1.57 (0.42)	0.97 (0.4)	6.37 (0.61)	8.24 (0.61)	3 (0.64)	0.04 (0.51)
53	0.38 (0.25)	2.42 (0.29)	1.37 (0.25)	1.27 (0.35)	5.26 (0.3)	3.59 (0.34)	0.02 (0.41)
57	0.33 (0.32)	1.46 (0.41)	0.97 (0.4)	8.9 (0.36)	9.76 (0.29)	3.4 (0.38)	0.05 (0.37)
60	0.65 (0.26)	1.46 (0.43)	0.99 (0.36)	2.82 (0.5)	10.87 (0.45)	7.41 (0.5)	0.02 (0.45)
62	0.55 (0.24)	1.96 (0.48)	0.67 (0.35)	1.54 (0.4)	3.59 (0.31)	1.46 (0.38)	0.02 (0.41)
72	0.36 (0.33)	2.63 (0.48)	1.97 (0.49)	4.09 (0.61)	5.84 (0.61)	2.34 (0.64)	0.04 (0.51)
78	0.35 (0.33)	1.28 (0.38)	0.91 (0.43)	1.85 (0.42)	3.58 (0.33)	1.34 (0.41)	0.03 (0.38)
82	0.67 (0.31)	0.94 (0.51)	1.58 (0.53)	6.38 (0.6)	7.83 (0.4)	3.44 (0.46)	0.02 (0.44)
86	0.44 (0.34)	1.6 (0.5)	0.64 (0.5)	1.9 (0.48)	5.19 (0.43)	2.81 (0.49)	0.02 (0.44)
88	0.63 (0.32)	1.93 (0.51)	0.98 (0.42)	4.48 (0.56)	6.19 (0.38)	1.5 (0.41)	0.02 (0.43)
96	0.73 (0.29)	1.17 (0.59)	0.78 (0.42)	1.71 (0.52)	3.79 (0.38)	2.02 (0.47)	0.02 (0.43)
99	0.75 (0.22)	1.26 (0.48)	0.8 (0.4)	4.27 (0.48)	13.34 (0.37)	6.93 (0.44)	0.03 (0.46)
127	0.56 (0.31)	2.03 (0.48)	1.46 (0.48)	1.6 (0.54)	7.42 (0.44)	2.07 (0.45)	0.02 (0.45)
129	0.36 (0.48)	0.5 (0.45)	0.46 (0.52)	13.71 (0.56)	14.59 (0.48)	6.59 (0.56)	0.07 (0.37)
131	0.72 (0.29)	1.71 (0.47)	0.96 (0.49)	8.24 (0.57)	10.57 (0.39)	3.37 (0.44)	0.02 (0.44)
137	0.5 (0.28)	1.97 (0.39)	1.06 (0.33)	10.18 (0.52)	32.97 (0.53)	16.95 (0.59)	0.03 (0.48)
168	0.37 (0.27)	1.05 (0.38)	0.92 (0.33)	2.03 (0.44)	4.45 (0.35)	2.66 (0.41)	0.02 (0.42)
174	0.69 (0.31)	0.8 (0.48)	1.06 (0.48)	46.85 (0.87)	84.19 (0.83)	50.24 (0.85)	0.04 (0.5)
192	0.36 (0.29)	2.39 (0.45)	1.05 (0.38)	18.22 (0.44)	13.93 (0.43)	6.69 (0.46)	0.04 (0.41)
229	0.48 (0.31)	0.98 (0.46)	0.87 (0.41)	7.43 (0.59)	22.33 (0.57)	9.06 (0.6)	0.04 (0.47)
231	0.8 (0.23)	1.8 (0.47)	0.96 (0.38)	6.28 (0.56)	8.03 (0.37)	2.09 (0.43)	0.02 (0.43)
237	0.71 (0.25)	1.59 (0.47)	0.69 (0.36)	4.66 (0.45)	13.78 (0.36)	5.32 (0.41)	0.02 (0.41)
268	0.58 (0.33)	1.27 (0.52)	0.89 (0.53)	3.9 (0.53)	17.59 (0.48)	9.65 (0.55)	0.03 (0.46)
274	0.58 (0.33)	1.91 (0.54)	1.25 (0.45)	3.18 (0.56)	8.48 (0.41)	2.69 (0.46)	0.03 (0.43)
292	0.45 (0.32)	1.39 (0.48)	0.82 (0.39)	1.53 (0.62)	2.95 (0.61)	1.54 (0.65)	0.04 (0.53)
331	0.65 (0.34)	1.13 (0.61)	1.03 (0.57)	7.57 (0.82)	8.54 (0.75)	3.47 (0.76)	0.04 (0.51)
337	0.51 (0.35)	2.41 (0.51)	1.16 (0.42)	1.01 (0.46)	4.39 (0.3)	1.44 (0.37)	0.01 (0.41)
368	0.52 (0.32)	1.37 (0.47)	0.85 (0.42)	7.68 (0.6)	24.22 (0.46)	10.81 (0.5)	0.03 (0.46)
437	0.55 (0.29)	1.91 (0.38)	0.96 (0.35)	0.9 (0.43)	2.99 (0.38)	0.55 (0.41)	0.05 (0.35)
537	0.27 (0.3)	1.95 (0.42)	1.25 (0.35)	1.42 (0.5)	2.55 (0.48)	0.85 (0.51)	0.03 (0.47)
637	0.66 (0.26)	1.85 (0.45)	0.85 (0.33)	0.71 (0.37)	5.22 (0.31)	2.79 (0.39)	0.01 (0.4)

Table 3. Comparison of estimated harvest fraction (adjusted for plantings) and market abundance within each NOAA Code between 2017 (the last year of the 2018 Maryland Oyster Assessment) and 2019 (the last year of the 2020 Maryland Oyster Assessment).

	Harvest Fraction			Market Abundance		
NOAA Code	2017	2019	Change	2017	2019	Change
5	0.05	0.02	down	0.44	0.32	down
25	-0.92	-0.75	up	16.43	15.61	down
27	0.03	-0.04	down	5.41	6.99	up
39	0.10	-0.27	down	20.67	24.86	up
43	0.57	0.44	down	2.95	11.06	up
47	0.20	0.13	down	2.47	4.92	up
53	-0.12	-0.69	down	29.83	82.09	up
57	0.17	0.03	down	2.66	3.22	up
60	0.03	-0.07	down	4.88	3.94	down
62	0.05	-0.13	down	19.13	19.41	up
72	0.44	0.16	down	2.79	2.90	up
78	0.87	0.34	down	4.72	6.69	up
82	-4.98	-1.55	up	2.57	1.56	down
86	0.52	0.21	down	0.52	0.60	up
88	-3.16	-3.11	up	1.53	1.53	up
96	0.25	0.07	down	0.99	1.32	up
99	0.01	0.00	down	0.92	0.60	down
127	-0.47	-1.19	down	13.69	14.85	up
129	0.42	0.11	down	2.00	3.50	up
131	-1.24	-1.71	down	4.91	2.96	down
137	0.50	0.52	up	2.92	5.92	up
168	0.19	0.10	down	4.98	13.75	up
174	0.09	0.00	down	0.06	0.04	down
192	0.28	0.32	up	5.40	5.14	down
229	0.04	0.09	up	5.35	11.20	up
231	-0.29	-0.63	down	6.24	9.33	up
237	-0.38	-0.28	up	10.19	13.89	up
268	0.16	-0.06	down	1.29	2.31	up
274	-0.20	-0.44	down	6.66	7.69	up
292	0.49	0.47	down	15.10	40.89	up
331	0.00	0.00	down	0.70	0.53	down
337	-1.59	-1.17	up	21.07	9.49	down
368	0.15	-0.59	down	2.43	4.51	up
437	-5.23	-2.36	up	24.10	34.51	up
537	0.33	0.22	down	22.49	39.75	up
637	-0.04	-2.31	down	14.91	45.30	up

Table 4. Estimated market abundance in millions (1999 – 2019) in each NOAA Code relative to the threshold abundance reference point (N_{ref}). Green indicates estimates above and red below the threshold. The threshold reference point is indicated by gold shading and is the lowest estimated abundance during 1999-2017. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

NOAA Code	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	N_{ref}
5	0.31	0.27	0.48	0.43	0.68	1.38	0.81	0.47	0.57	1.43	1.04	0.8	0.5	0.82	0.69	0.38	1.17	0.44	0.44	0.39	0.32	0.27
25	48.1	39.41	38.34	28.42	20.6	26.41	55.01	35	25.88	33.54	39.79	30.78	10.03	11.32	8.63	12.25	12.21	13.27	16.43	21.33	15.61	8.63
27	10.52	7.06	4.01	2.81	3.15	5.07	7.75	5.39	2.4	2.75	4.52	4.38	4.12	6.25	5.44	10.7	9.43	5.82	5.41	6.65	6.99	2.4
39	67.24	60.89	30.48	17.04	20.67	40.42	45.62	26.92	11.22	9.71	4.51	9.62	13.49	20.37	22.73	26.78	26.33	20.2	20.67	26.02	24.86	4.51
43	9.19	6.9	4.47	2.83	1.42	1.28	0.36	0.36	0.43	5.43	6.53	7.3	7.64	20.99	17.4	11.62	7.32	4	2.95	6.24	11.06	0.36
47	8.61	4.9	5.83	2.63	6.37	5.37	1.85	1.91	2.28	10.72	8.71	6.27	8.73	16.18	10.92	9.58	7.71	3.62	2.47	2.62	4.92	1.85
53	57.49	48.89	24.33	1.06	2.19	11.32	16.9	19.17	16.37	26.01	22.67	21.12	39.06	60.79	59.87	70.36	66.7	39.51	29.83	53.82	82.09	1.06
57	1.57	1.08	2.51	1.19	2.1	3.45	1.1	0.56	0.51	1.42	1.47	1.07	1.63	3.52	3.64	4.18	3.67	2.59	2.66	2.65	3.22	0.51
60	20.41	16.28	9.8	4.37	6.86	7.68	12.91	9.34	5.52	4.4	3.04	3.32	3.89	5.6	6.13	6.06	6.7	5.85	4.88	4.7	3.94	3.04
62	13.84	11.24	8.1	2.39	1.98	5.31	6.75	5.33	4.19	6.26	7.75	9.42	9.99	12.89	13.89	20.13	20.37	18.11	19.13	16.83	19.41	1.98
72	6.05	6.8	5.84	6.06	5.12	7.41	2.23	2.07	3.28	3.71	3.61	3.56	4.89	14.77	12.15	8.93	5.09	3.5	2.79	1.91	2.9	2.07
78	4.34	3.35	3.3	0.19	0.6	1.91	2.63	2.2	1.47	2.7	3.82	2.08	2.47	5.23	5.28	11.83	8.01	2.7	4.72	4.56	6.69	0.19
82	13.25	23.84	22.85	11.81	7.44	4.93	3.55	2.26	1.68	1.84	2.92	4.59	1.64	3.51	3.52	3.24	4.45	4.01	2.57	1.85	1.56	1.64
86	0.3	0.23	0.19	0.13	0.24	0.42	0.5	0.44	0.54	0.41	0.37	0.31	0.31	0.86	0.86	0.92	0.58	0.34	0.52	0.74	0.6	0.13
88	5.05	5.54	2.12	2.96	2.36	2.52	3.67	2.63	0.88	1.67	1.48	1.31	1.1	2.15	1.26	2.83	2.83	1.96	1.53	1.22	1.53	0.88
96	2.51	2.05	0.69	0.72	0.6	0.62	0.44	0.32	0.34	0.35	0.37	0.47	1.22	1.87	3.14	4.65	3.73	1.78	0.99	1.18	1.32	0.32
99	6.66	5.08	1.55	0.69	1.07	1.21	1.15	1.12	0.86	0.57	0.48	0.36	0.37	0.53	0.54	1.51	1.62	1.29	0.92	0.75	0.6	0.36
127	64.05	66.59	61.38	33.43	23.56	30.8	53.98	32.88	28.63	33.15	20.59	14.65	14.69	17.96	17.81	17.38	18.13	16.18	13.69	13.64	14.85	13.69
129	6.14	4.03	1.7	1.61	3.18	9.38	12.36	10.88	3.51	3.3	5.2	4.91	5.12	5.98	4.06	2.31	1.16	1.08	2	3.04	3.49	1.08
131	25.28	17.8	16.53	8.28	7.09	6.65	8.34	7.78	10.91	10.16	6.21	6.32	10.05	10.33	9.78	8.15	6.69	5.33	4.91	3.12	2.96	4.91
137	14.21	11.64	7.66	0.52	0.73	1.62	2	2.48	1.89	2.35	2.4	2.57	4.92	10.13	12.67	14.77	9.87	4.33	2.92	5.42	5.92	0.52
168	5.45	3.85	3.28	2.48	5.11	12.33	13.15	7.79	5.29	7.62	8.47	8.52	9.72	13.99	12.86	21.38	16.38	6.93	4.98	10.11	13.75	2.48
174	0.39	0.34	0.32	0.08	0.06	0.05	0.04	0.04	0.03	0.12	0.1	0.11	0.11	0.08	0.08	0.15	0.14	0.08	0.06	0.05	0.04	0.03
192	13.24	8.05	17.22	6.91	16.34	18.68	10.15	8.04	8.6	22.08	19.95	17.59	15.14	23.75	20.13	15.55	10.31	4.98	5.4	3.34	5.14	4.98
229	3.96	3.42	3.29	2.93	6.24	10.34	10.78	8.52	4.96	5.42	5.33	3.94	3.78	5.25	5.09	7.71	7.47	4.87	5.34	9.42	11.2	2.93
231	84.72	79.23	40.88	24.62	17.15	34.91	18.22	17.16	12.19	9.39	10.29	9.61	8.24	8.32	11.26	9.37	9.9	8.55	6.24	10.22	9.33	6.24
237	19.08	16.41	13.63	4.53	2.31	7.67	9.03	8.52	6.88	9.26	10.51	10.78	14.7	16.27	18.85	19.31	17.43	12.91	10.19	13.56	13.89	2.31
268	4.9	5.63	5.61	0.4	0.49	3.41	4.07	1.46	1.04	1	2.47	3.29	3.64	4.59	5.23	5.05	4.24	2.35	1.29	2.2	2.31	0.4
274	14.9	12.96	15.75	7.15	6.73	10.23	16.01	13.67	4.2	5.9	6.61	5.47	6.44	6.66	4.92	3.69	8.31	6.5	6.66	5.04	7.69	3.69
292	19.57	13.51	19.19	9.08	8.57	17.16	6.15	5.18	6.05	13.56	12.57	14.14	14.5	34.94	29.69	26.17	18.17	9.85	15.1	25.1	40.89	5.18
331	5.08	4.69	4.45	3.79	3.65	2.75	2.64	2.56	2.07	2.08	1.47	0.75	0.9	0.9	0.82	0.71	0.93	0.83	0.7	1.09	0.53	0.7
337	30.28	25.77	33.38	15.67	12.28	8.82	9.85	8.68	9.41	12.19	13.71	16.61	21.23	23.97	23.5	25.07	26.05	24.59	21.07	18.86	9.49	8.68
368	8.97	6.89	2.92	2.74	2.52	3.78	4.72	4.52	2.66	3.4	3.54	3.52	4.69	4.75	4.6	6.71	6.16	3.7	2.42	3.41	4.51	2.42
437	38.41	30.76	26.52	3.36	2.89	5.3	7.99	10.78	6.11	7.99	5.17	3.86	5.28	16.47	31.18	47.5	38.47	21.15	24.1	25.43	34.51	2.89
537	31.16	27.82	23.35	5.85	5.51	13.23	17.78	26.88	15.69	13.4	10.97	19.46	29.92	44.54	33.06	42.37	35.81	22.38	22.49	28.19	39.75	5.51
637	18.9	16.45	13.67	4.41	5.72	7.54	8.42	9.83	9.1	9.07	7.16	7.72	12.18	15.33	14.79	20.74	19.01	14.86	14.9	29.61	45.3	4.41

Table 5. Estimated harvest fraction (adjusted for plantings) for market oysters during 1999-2019 in each NOAA Code relative to the upper limit (U_{limit}) and target (U_{MSY}) harvest fraction reference points. Green indicates estimates at or below the target, gold indicates estimates above the target but equal to or below the upper limit, and red indicates estimates above the upper limit reference point. These estimates would be used in areas where the management objective for plantings is to supplement the fishery. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

NOAA Code	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	U_{limit}	U_{MSY}
5	0.15	0	0.07	0	0	0	0.04	0.01	0	0	0	0	0.12	0.02	0.25	0.35	0.81	0.25	0.05	0.04	0.02	0.12	0.06
25	0.14	0.18	-0.24	-0.69	-1.49	-4.52	-9.44	-4.13	-6.01	-11.71	-13.85	-7.3	-4.95	-3.19	-0.82	-1.55	-1.44	-0.93	-0.92	-0.74	-0.75	0	0
27	0.32	0.17	0.07	0.17	0.04	0.02	0.3	0.5	0.31	-1.46	-4.42	-3.86	-2.38	-0.56	-0.02	0.15	0.32	0.22	0.03	-0.13	-0.04	0.15	0.07
39	0.25	0.46	0.23	0.05	0.06	0.09	0.25	0.32	0.16	0.02	-0.19	-1.96	-2.5	-1.02	-0.53	-0.22	-0.05	0.14	0.1	-0.25	-0.27	0.04	0.02
43	0	0	0	-0.21	-0.27	-0.16	-0.11	-0.06	0.01	0.15	0.4	0.39	0.53	0.57	0.83	0.79	0.64	0.77	0.57	0.2	0.44	0.55	0.28
47	0	0	0	0.05	0.01	0.12	-0.15	-0.18	-0.05	0.39	0.54	0.26	0.12	0.27	0.53	0.53	0.4	0.72	0.2	0.08	0.13	0.32	0.16
53	0.13	0.13	0.01	0.01	0.07	0	0.04	0.05	0.02	0.01	0	0	0.01	0	-0.01	0	0	-0.02	-0.12	-0.58	-0.69	0.06	0.03
57	0.02	0.04	0.37	0.19	0.17	0.19	0.17	0.06	0.17	0.03	0.1	0.02	-0.16	-0.06	0.09	0.17	0.09	0.1	0.17	0.09	0.03	0.18	0.09
60	0.4	0.29	0.09	-0.02	-0.01	0	0.07	0.03	0	0.05	0	-0.15	-0.15	-0.1	-0.06	0.02	0.12	0.07	0.03	-0.05	-0.07	0	0
62	0.12	0.01	0.08	-0.36	-1.14	-2.27	-3.38	-3.61	-3.54	-2.59	-2.64	-1.26	-0.8	-0.19	0	0.17	0.08	0.05	0.05	-0.07	-0.13	0	0
72	0	0	-0.03	-0.02	-0.01	0.08	0.11	0.03	0.07	0.05	0.04	0.06	0.16	0.55	0.64	0.48	0.47	0.41	0.44	0.26	0.16	0.23	0.12
78	0.2	0.43	0.12	0	0	0.01	0.13	0.21	0.19	0.14	0.18	0.14	0.09	0.47	0.33	0.21	0.28	0.61	0.87	0.55	0.34	0.38	0.19
82	0	0	-0.01	-0.01	-0.02	-0.03	-0.03	-0.02	-0.02	-0.22	-0.15	-0.87	-1.86	-6.3	-6.12	-6.28	-9.22	-8.5	-4.98	-3.8	-1.55	0	0
86	0.52	0	0	0	0	0	0.09	0.03	0.01	0.04	0.01	0.01	0.01	0.19	0.24	0.37	0.41	0.55	0.52	0.36	0.21	0.23	0.11
88	0.03	0.01	-0.21	-0.1	-0.12	-0.56	-0.86	-0.51	-0.23	-2.65	-3.14	-4.46	-4	-6.36	-2.17	-9.62	-7.27	-5.61	-3.16	-2.73	-3.11	0	0
96	0.05	0.01	0.01	-1.05	-1.2	-0.72	-0.63	-0.51	-0.32	-0.13	0	0.15	-1.62	-0.19	-1.38	-0.31	0.52	0.61	0.25	-0.16	0.07	0.04	0.02
99	0.34	0.53	0.29	0.02	0	0.03	0.02	0	0	0	0.11	0	0	0.04	0	0.01	0	0	0.01	0	0	0	0
127	0.06	0.03	-0.28	-0.55	-0.72	-1.05	-2.5	-2.81	-4.33	-6.87	-7.96	-7.79	-4.3	-1.33	-1.01	-0.8	-0.62	-0.51	-0.47	-0.85	-1.19	0	0
129	0.13	0.12	0	0	0.01	0.02	0	0.01	0.13	0.36	0.43	0.09	0.03	0.25	0.52	0.86	0.35	0.12	0.42	0.22	0.11	0.28	0.14
131	0.3	0.05	-0.11	-0.26	-0.28	-0.32	-0.79	-0.66	-1.61	-1.82	-1.94	-2.94	-6.34	-9.26	-12.09	-10.14	-3.88	-2.14	-1.24	-1.04	-1.71	0	0
137	0.14	0.01	0.04	-0.06	-0.05	0.02	0.14	0.29	0.25	0.25	0.16	0.27	0.07	0.15	-0.02	0.37	0.55	0.57	0.5	0.51	0.52	0.26	0.13
168	0	0	-0.2	-0.58	-0.51	-0.48	-0.34	-0.09	-0.12	-0.64	-1.1	-1.07	-0.64	-0.01	0.29	0.36	0.54	0.56	0.19	-0.12	0.1	0.16	0.08
174	0.09	0	0	0	0	0	0.15	0	0	0.22	0.05	0	0.09	0.06	0	0	0	0.15	0.09	0	0	0	0
192	0.05	0.04	0.1	0.2	0.05	0.21	0.14	0.12	0.24	0.21	0.5	-0.01	0.21	0.34	0.51	0.37	0.63	0.37	0.28	0.18	0.32	0.31	0.15
229	0.01	0	0.02	0	0	0.02	0	0.01	0	0.02	0.09	0.11	0.07	0.08	0.2	-0.42	-0.7	-0.44	0.04	0.02	0.09	0.1	0.05
231	0.1	0.05	-0.16	-0.59	-1.33	-5.98	-6.3	-2.72	-2.15	-3.44	-2.23	-3.59	-4.15	-2.41	-0.77	-0.58	-0.4	-0.37	-0.29	-0.34	-0.63	0	0
237	0.02	0.12	-0.16	-0.13	-0.1	-2.07	-1.97	-1.68	-1.57	-0.67	-0.45	-0.58	-1.35	-1.73	-2.29	-1.39	-1.07	-0.67	-0.38	-0.19	-0.28	0	0
268	0.04	0	0	-0.01	-0.04	0	0.67	0.07	0.04	0.09	0.03	0.01	-0.01	0	0.07	0.16	0.26	0.22	0.16	-0.12	-0.06	0.1	0.05
274	0.13	0.04	-0.42	-0.51	-1.03	-3.94	-7.34	-7.83	-5.16	-7.4	-8.54	-2.5	-1.39	-0.87	-0.27	-0.11	0.03	0	-0.2	-0.34	-0.44	0	0
292	0.02	0	0.06	0.09	0.13	0.19	0.11	0.09	0.18	0.18	0.27	-0.06	0.19	0.25	0.45	0.48	0.82	0.82	0.49	0.2	0.47	0.41	0.21
331	0.09	0	0	0.09	-0.05	-0.07	-0.07	-0.13	-0.14	-0.59	-0.63	0.09	-0.09	-0.09	-0.08	-0.06	-0.03	-0.03	0	0	0	0	0
337	0.05	0.01	-0.16	-0.38	-0.4	-0.51	-0.93	-1.2	-1.7	-2.79	-3.48	-4.94	-6.83	-8.24	-7.49	-3.96	-2.83	-1.92	-1.59	-1.34	-1.17	0	0
368	0.03	0	-0.21	-0.26	-0.41	-1.16	-2.03	-2.57	-2.61	-3.39	-3.32	-3.68	-4.56	-2.78	-1.59	-0.37	-0.01	0.22	0.15	-0.62	-0.59	0	0
437	0.11	0.19	0.01	-0.06	-0.1	-0.05	-0.26	-0.07	0.05	-0.22	-0.28	-0.11	0.03	0.04	-0.05	-0.48	-1.37	-2.66	-5.23	-1.81	-2.36	0.02	0.01
537	0.13	0.31	0.03	-0.02	-0.03	0	0.17	0.46	0.3	0.1	-0.1	-0.64	-0.52	0.15	0.51	0.32	0.43	0.32	0.33	0.26	0.22	0.22	0.11
637	0.04	0.13	0.01	-0.41	-0.64	-0.45	-0.36	-0.27	-0.24	-0.19	-0.17	-0.12	-0.13	-0.08	-0.04	0.01	0.05	0.04	-0.04	-1.05	-2.31	0.02	0.01

Table 6. Estimated harvest fraction (U, unadjusted) for plantings for market oysters during 1999-2019 in each NOAA Code relative to the upper limit (U_{limit}) and target (U_{MSY}) reference points. Green indicates estimates at or below the target, gold indicates estimates above the target but equal to or below the upper limit, and red indicates estimates above the upper limit reference point. These estimates would be used for areas where the management objective for plantings is restoration. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

NOAA Code	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	U_{limit}	U_{MSY}
5	0.15	0	0.07	0	0	0	0.04	0.01	0	0	0	0	0.12	0.02	0.25	0.35	0.81	0.25	0.05	0.04	0.02	0.12	0.06
25	0.14	0.18	0.1	0.16	0.03	0.01	0.07	0.1	0.08	0.04	0.02	0.04	0	0	0	0.01	0.07	0.08	0.04	0.01	0	0	0
27	0.32	0.17	0.07	0.17	0.04	0.02	0.3	0.5	0.31	0.16	0.12	0.09	0.02	0.1	0.28	0.16	0.32	0.23	0.11	0.08	0.12	0.15	0.07
39	0.25	0.46	0.26	0.06	0.06	0.1	0.25	0.32	0.16	0.18	0.12	0.04	0	0.06	0.17	0.08	0.12	0.18	0.11	0.08	0.09	0.04	0.02
43	0	0	0	0.03	0	0.02	0.02	0	0.05	0.15	0.4	0.39	0.53	0.57	0.83	0.79	0.64	0.79	0.6	0.21	0.48	0.55	0.28
47	0	0	0	0.05	0.01	0.12	0.03	0.02	0.07	0.4	0.54	0.26	0.25	0.29	0.54	0.54	0.4	0.72	0.2	0.08	0.13	0.32	0.16
53	0.13	0.13	0.02	0.04	0.12	0	0.05	0.05	0.02	0.01	0	0	0.01	0	0.01	0.02	0.01	0.01	0	0	0.03	0.06	0.03
57	0.02	0.04	0.37	0.19	0.17	0.19	0.17	0.06	0.17	0.03	0.1	0.02	0	0.01	0.13	0.18	0.09	0.1	0.17	0.09	0.03	0.18	0.09
60	0.4	0.29	0.16	0	0	0.01	0.07	0.03	0	0.05	0	0	0	0	0.03	0.07	0.12	0.07	0.03	0.05	0.01	0	0
62	0.12	0.01	0.08	0.05	0.01	0.04	0.01	0	0.01	0	0.07	0.04	0.06	0.15	0.11	0.17	0.08	0.1	0.1	0.06	0.1	0	0
72	0	0	0	0	0.01	0.09	0.11	0.03	0.07	0.05	0.04	0.06	0.16	0.55	0.64	0.48	0.47	0.41	0.44	0.26	0.16	0.23	0.12
78	0.2	0.43	0.12	0	0	0.01	0.15	0.22	0.19	0.14	0.18	0.19	0.1	0.47	0.33	0.21	0.28	0.62	0.88	0.57	0.38	0.38	0.19
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.04	0	0	0	0	0	0	0
86	0.52	0	0	0	0	0	0.09	0.03	0.01	0.04	0.01	0.01	0.01	0.19	0.24	0.37	0.41	0.55	0.52	0.36	0.21	0.23	0.11
88	0.03	0.01	0.03	0.01	0	0.01	0.01	0.11	0.11	0.08	0.17	0.07	0.07	0.17	0.49	0.07	0.2	0.22	0.18	0.04	0.11	0	0
96	0.05	0.01	0.01	0	0	0	0	0.02	0.01	0.08	0.08	0.15	0.14	0.28	0.2	0.14	0.61	0.61	0.25	0.18	0.19	0.04	0.02
99	0.34	0.53	0.29	0.02	0	0.03	0.02	0	0	0	0.11	0	0	0.04	0	0.01	0	0	0.01	0	0	0	0
127	0.06	0.03	0.01	0	0	0	0.03	0.04	0.01	0	0.02	0.01	0	0	0	0	0.01	0.05	0.04	0.01	0.02	0	0
129	0.13	0.12	0	0.01	0.01	0.02	0	0.01	0.13	0.36	0.43	0.09	0.03	0.25	0.52	0.86	0.35	0.12	0.42	0.22	0.11	0.28	0.14
131	0.3	0.05	0.05	0.03	0.01	0.08	0.01	0.08	0.05	0.06	0.02	0.03	0	0	0.01	0.05	0.04	0.02	0.12	0.01	0.01	0	0
137	0.14	0.01	0.04	0.02	0	0.04	0.14	0.29	0.25	0.25	0.16	0.27	0.07	0.26	0.27	0.44	0.58	0.59	0.51	0.51	0.52	0.26	0.13
168	0	0	0	0	0	0.01	0.11	0.2	0.01	0.02	0.04	0.07	0.17	0.22	0.31	0.43	0.58	0.59	0.35	0.2	0.37	0.16	0.08
174	0.09	0	0	0	0	0	0.15	0	0	0.22	0.05	0	0.09	0.06	0	0	0	0.15	0.09	0	0	0	0
192	0.05	0.04	0.11	0.2	0.05	0.21	0.14	0.12	0.24	0.21	0.53	0.35	0.36	0.39	0.53	0.38	0.64	0.44	0.32	0.2	0.33	0.31	0.15
229	0.01	0	0.02	0	0	0.02	0	0.01	0	0.02	0.09	0.11	0.07	0.08	0.2	0.13	0.08	0.18	0.24	0.2	0.24	0.1	0.05
231	0.1	0.05	0.09	0.09	0	0.01	0.05	0.06	0.05	0.05	0.03	0.07	0	0	0	0.04	0.01	0.01	0.1	0.01	0.02	0	0
237	0.02	0.12	0.06	0.03	0	0	0.02	0.07	0.02	0.02	0.01	0.02	0.01	0.02	0.06	0.07	0.13	0.1	0.15	0.07	0.07	0	0
268	0.04	0	0	0	0	0	0.67	0.07	0.04	0.09	0.03	0.1	0.02	0.01	0.08	0.16	0.26	0.22	0.16	0.06	0.06	0.1	0.05
274	0.13	0.04	0.01	0.01	0	0	0.02	0	0.04	0.03	0.02	0.04	0.02	0.15	0.3	0.25	0.16	0.12	0.03	0.05	0.01	0	0
292	0.02	0	0.06	0.09	0.13	0.19	0.11	0.09	0.18	0.21	0.34	0.31	0.32	0.27	0.47	0.49	0.83	0.84	0.52	0.2	0.47	0.41	0.21
331	0.09	0	0	0.09	0	0.01	0	0	0	0	0.02	0.65	0	0	0	0.01	0	0	0.02	0	0	0	0
337	0.05	0.01	0.04	0	0	0	0.01	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0	0	0
368	0.03	0	0	0	0	0	0.02	0.02	0.03	0.02	0	0.04	0.01	0.02	0.05	0.16	0.22	0.23	0.15	0	0.02	0	0
437	0.11	0.19	0.01	0	0	0	0.13	0.12	0.12	0.06	0.01	0.07	0.08	0.04	0.03	0.04	0.04	0.03	0.04	0.05	0.04	0.02	0.01
537	0.13	0.31	0.03	0.03	0.04	0.02	0.18	0.47	0.3	0.11	0.05	0.08	0.09	0.38	0.54	0.34	0.44	0.33	0.34	0.27	0.23	0.22	0.11
637	0.04	0.13	0.01	0	0	0	0	0	0	0	0	0	0	0.02	0.03	0.03	0.05	0.04	0.01	0.02	0	0.02	0.01

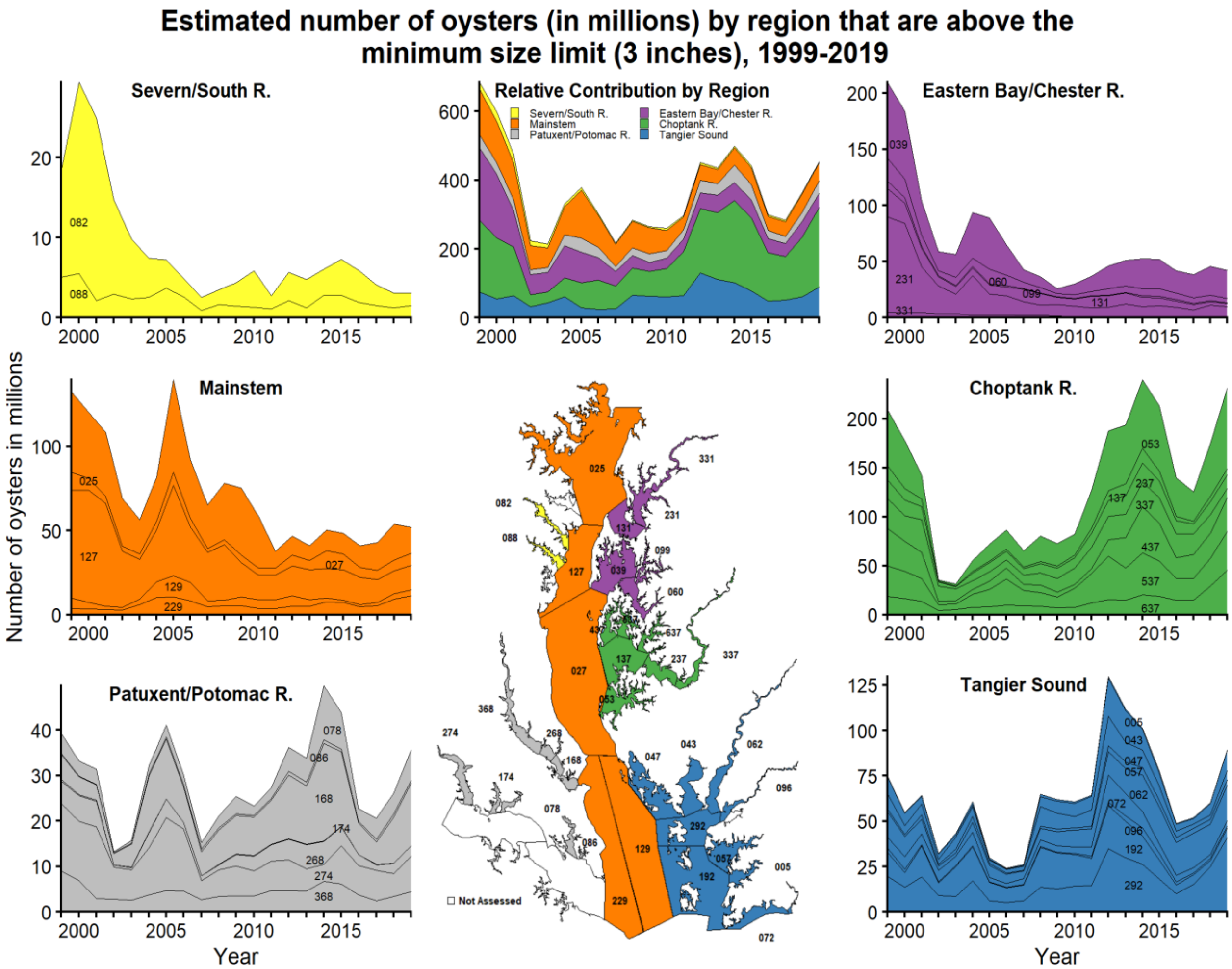

Figure 1. Estimated number of market size oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

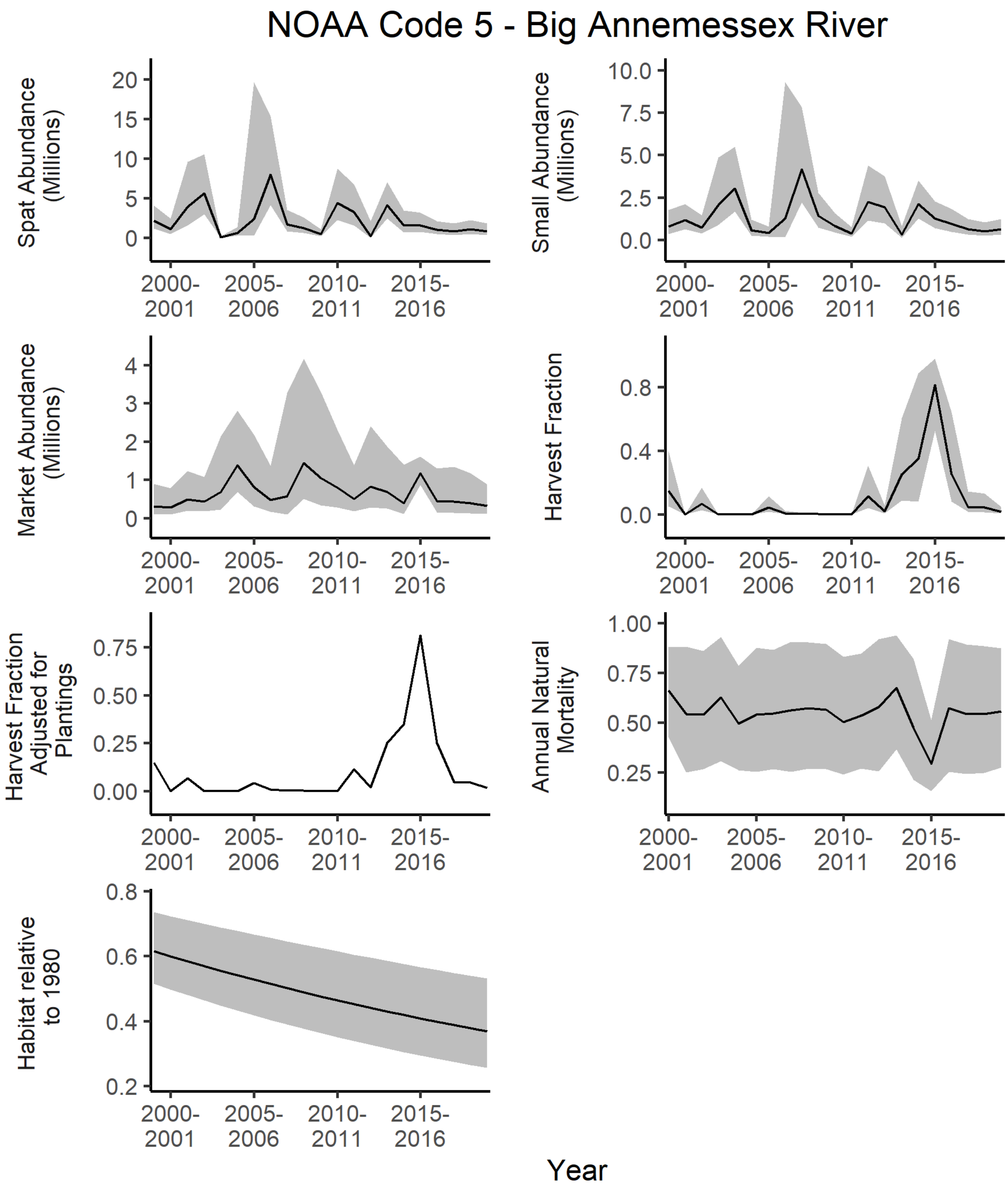

Figure 2. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Big Annemessex River - NOAA Code 5.

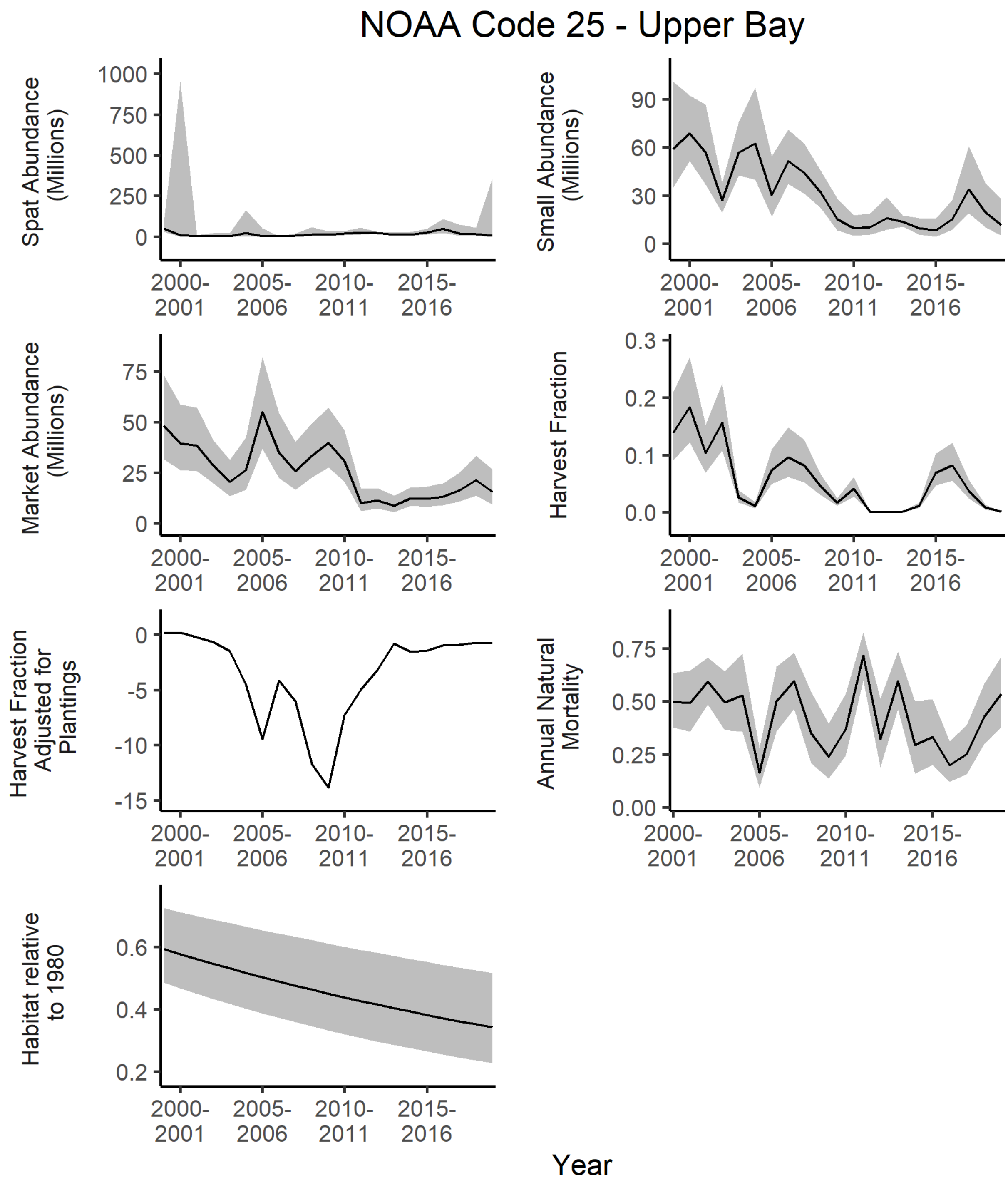

Figure 3. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Upper Bay - NOAA Code 25.

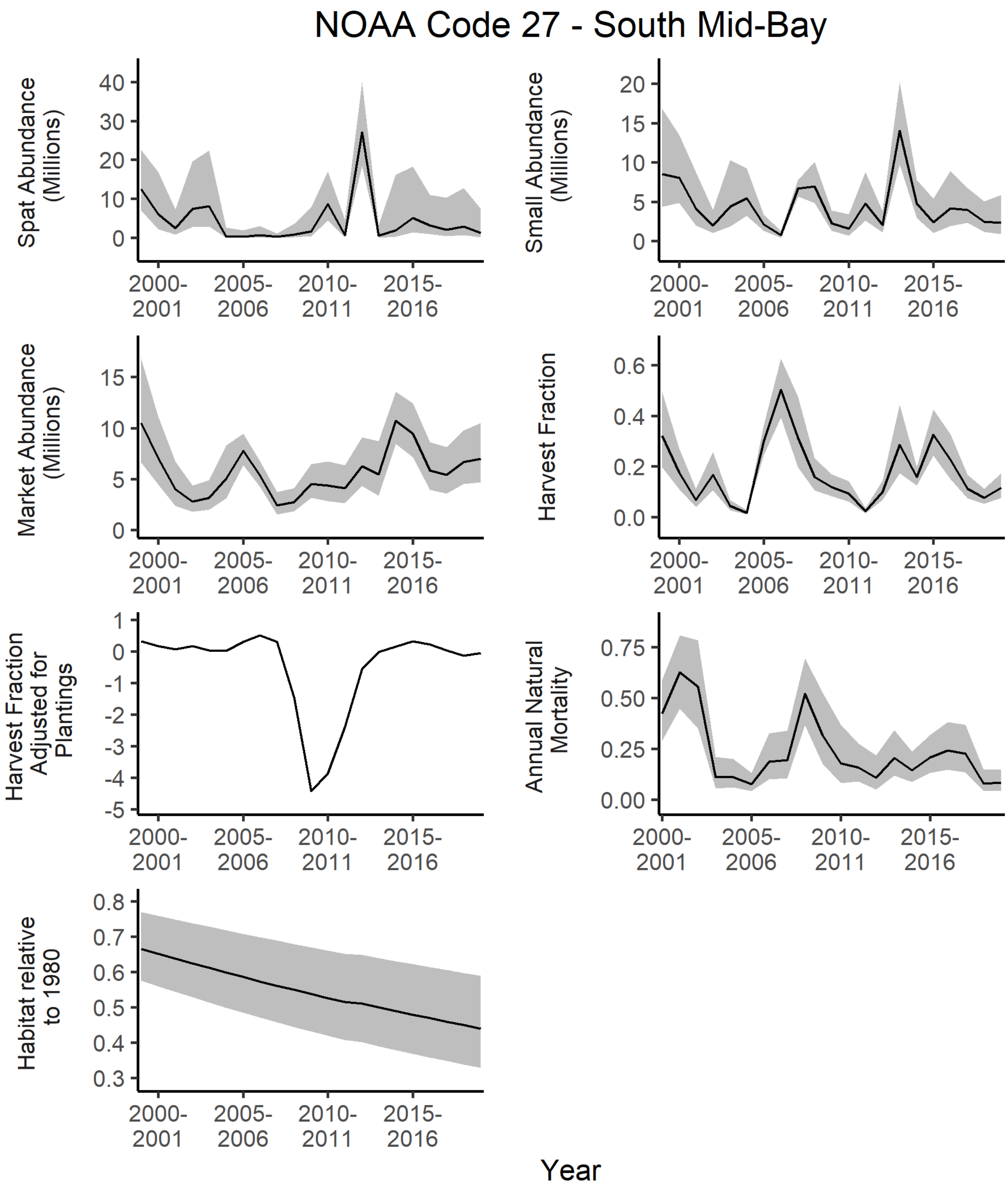

Figure 4. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in South Mid-Bay - NOAA Code 27.

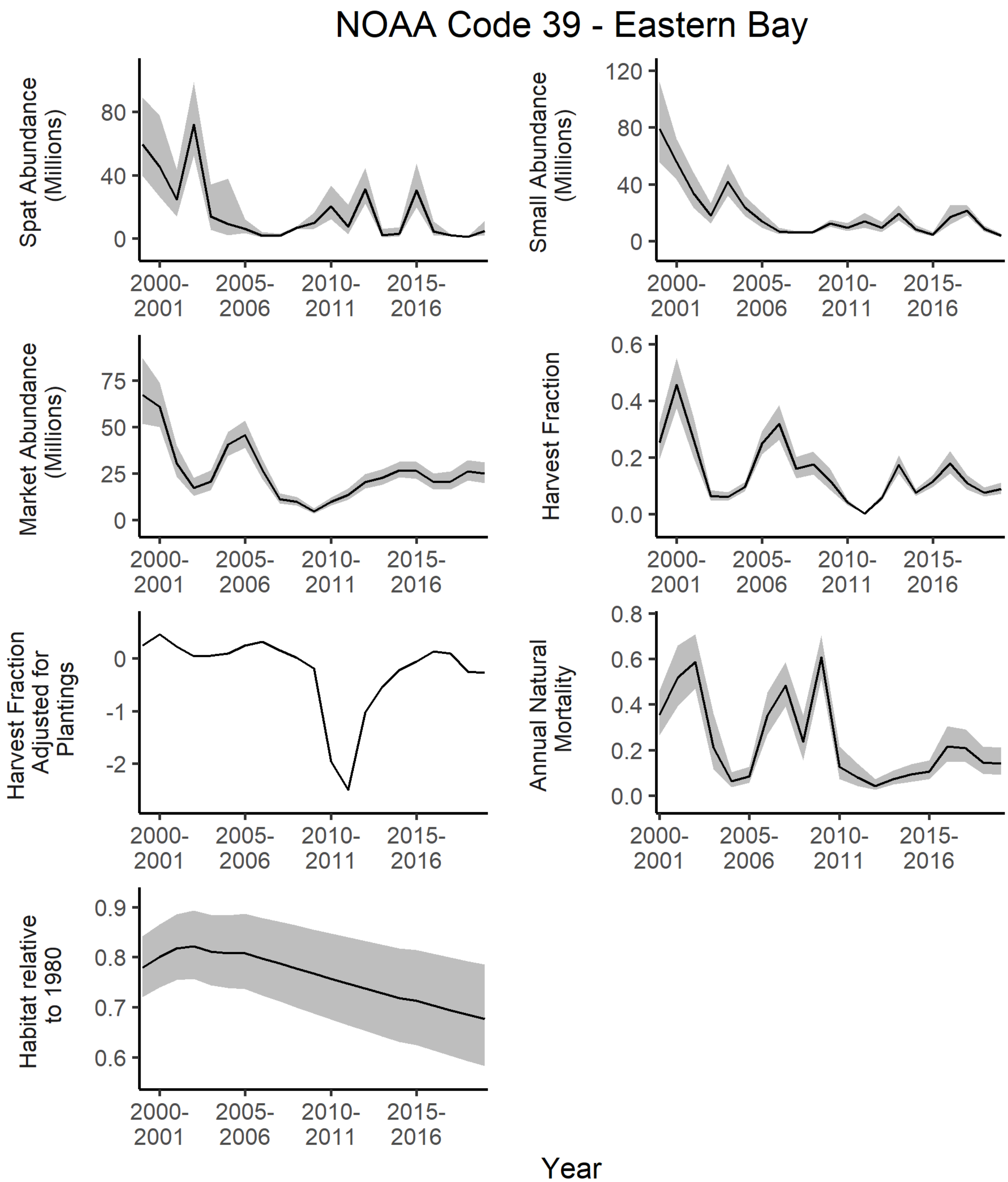

Figure 5. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Eastern Bay - NOAA Code 39.

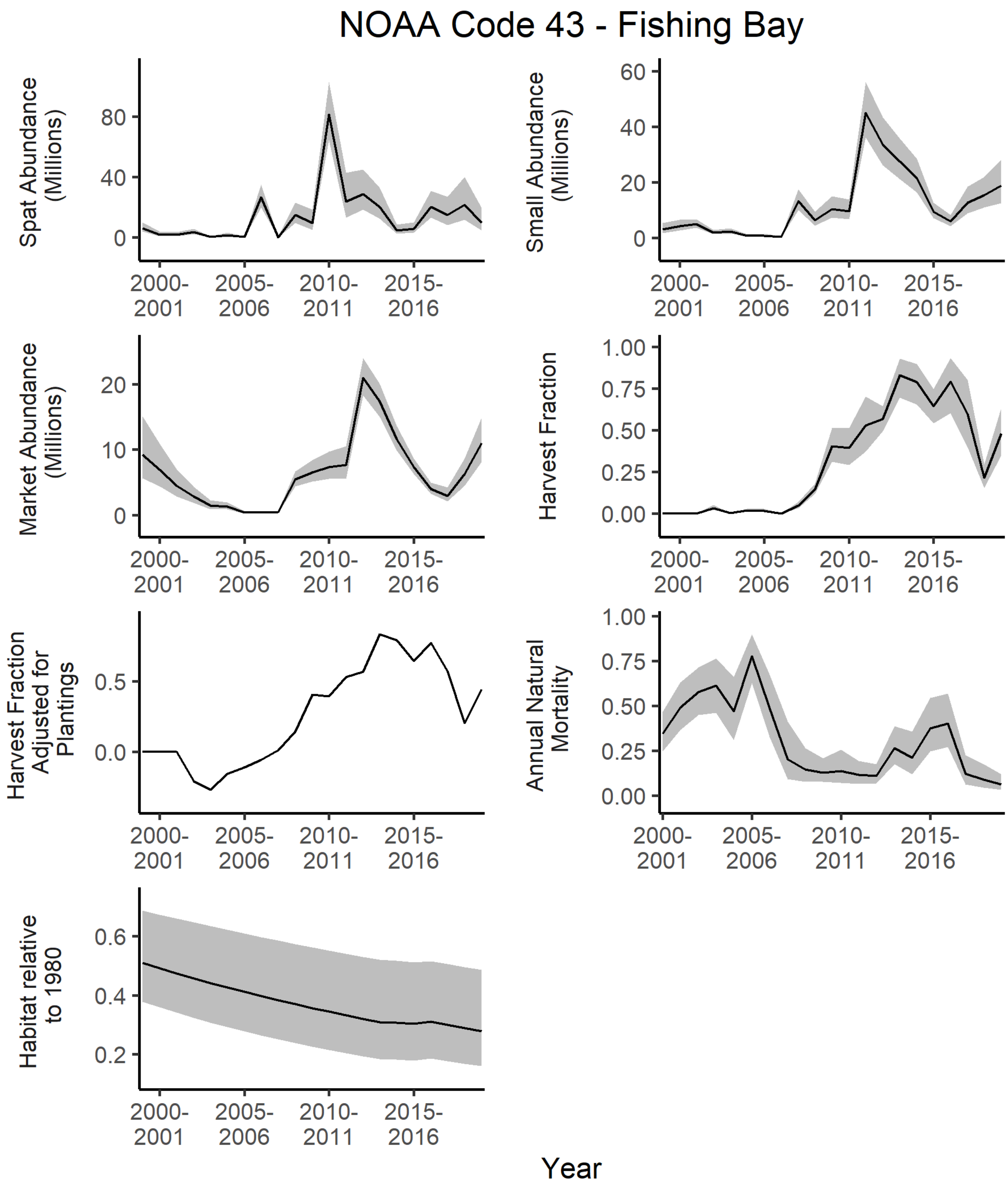

Figure 6. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Fishing Bay - NOAA Code 43.

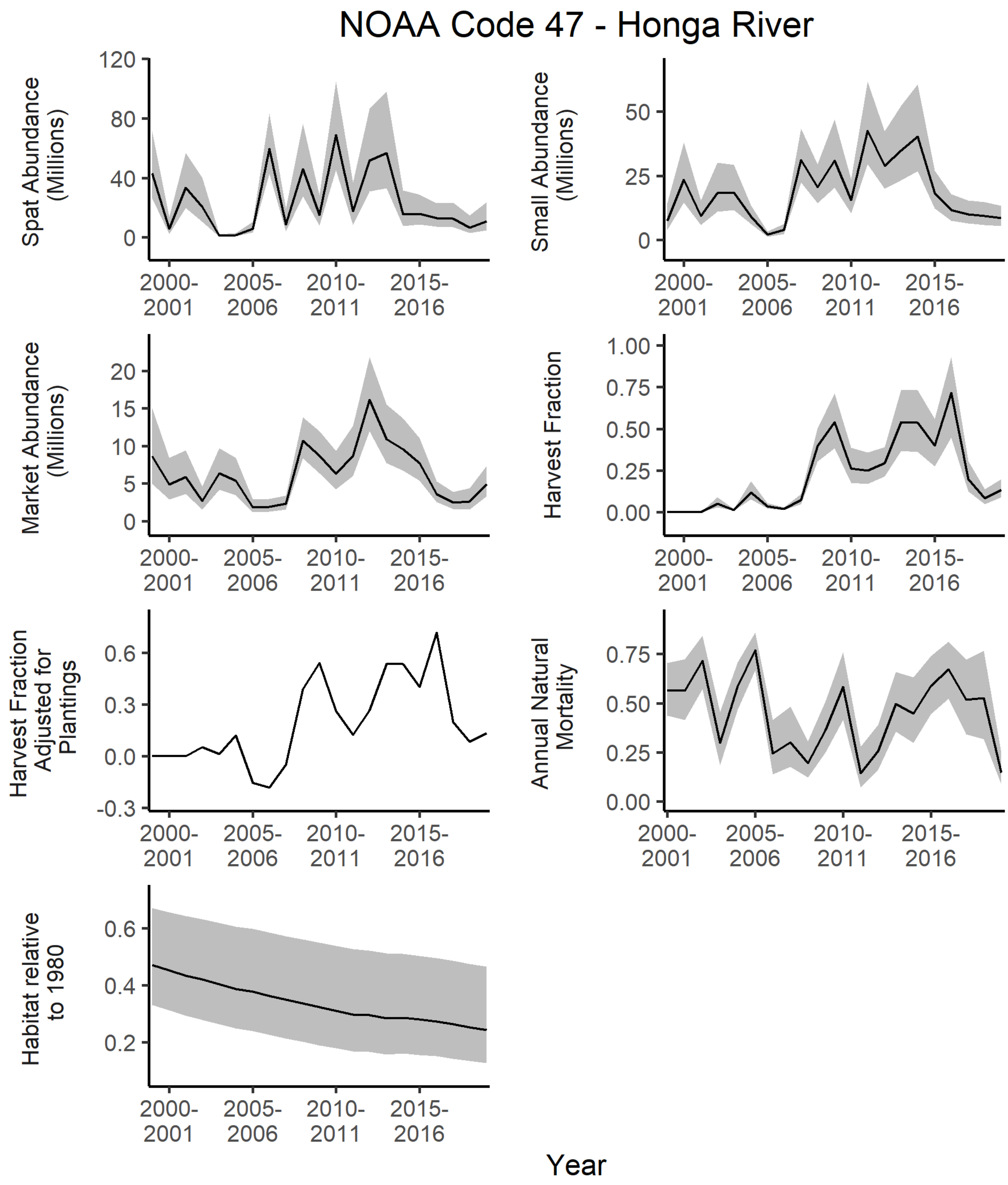

Figure 7. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Honga River - NOAA Code 47.

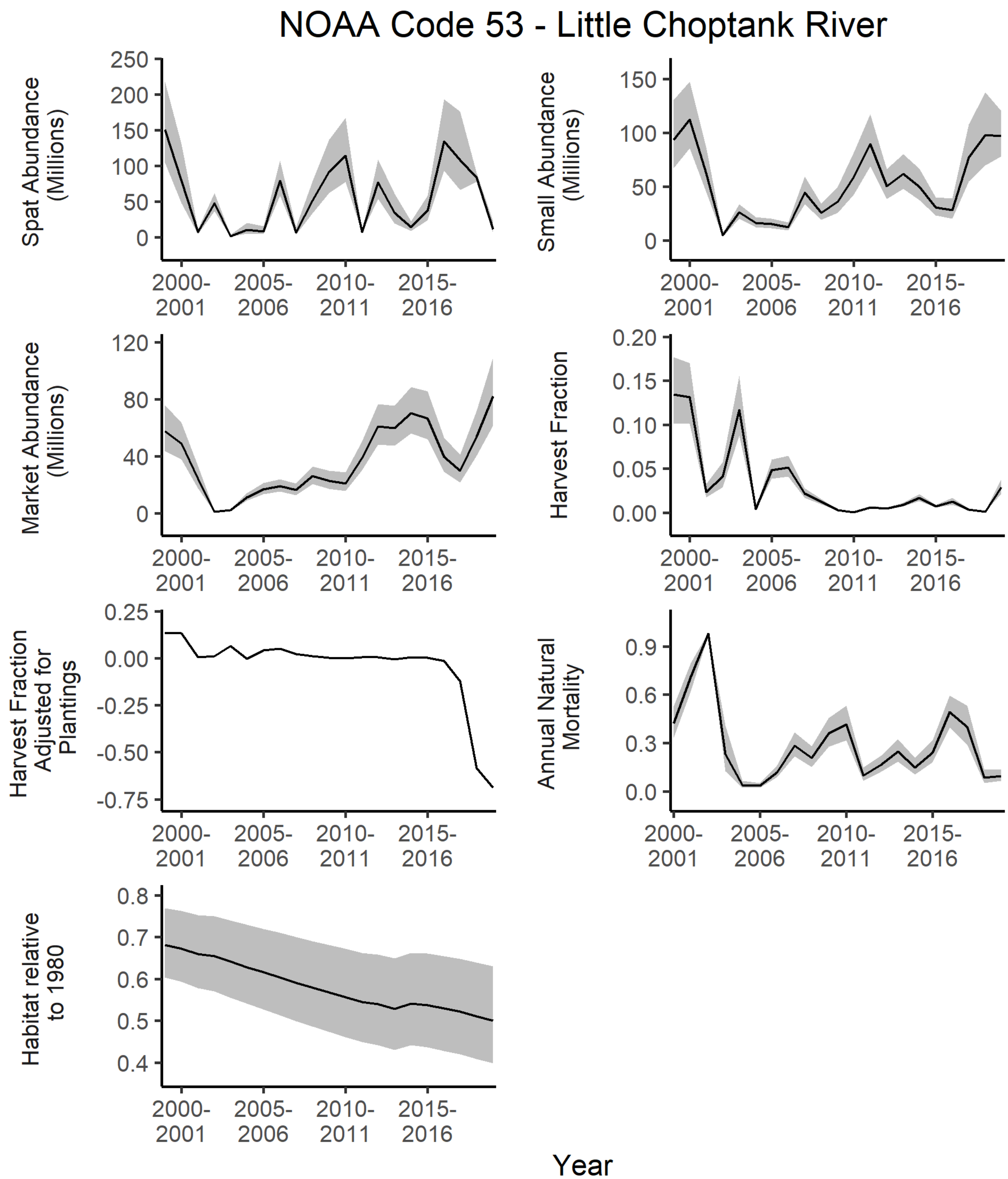

Figure 8. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Little Choptank River - NOAA Code 53.

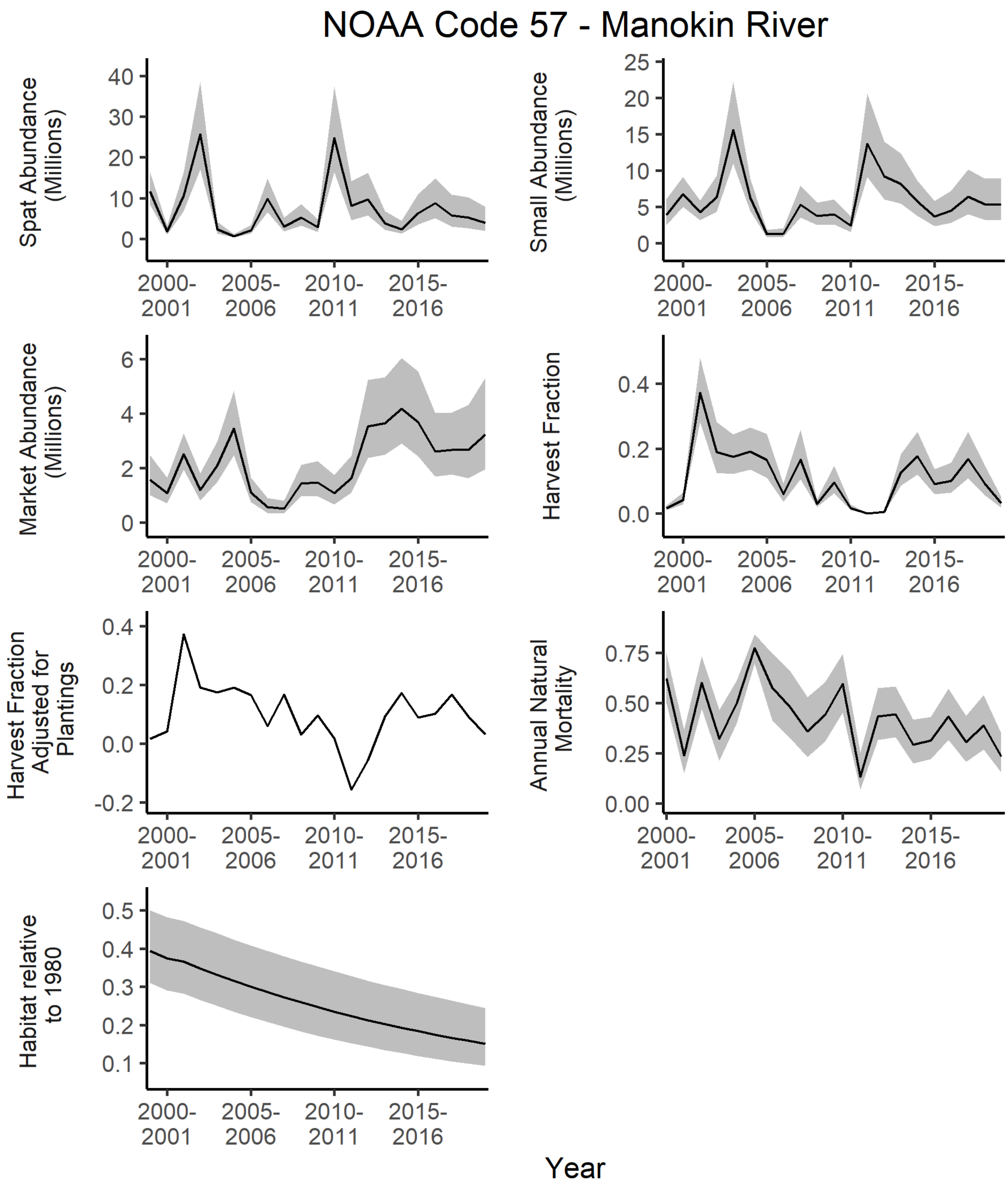

Figure 9. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Manokin River - NOAA Code 57.

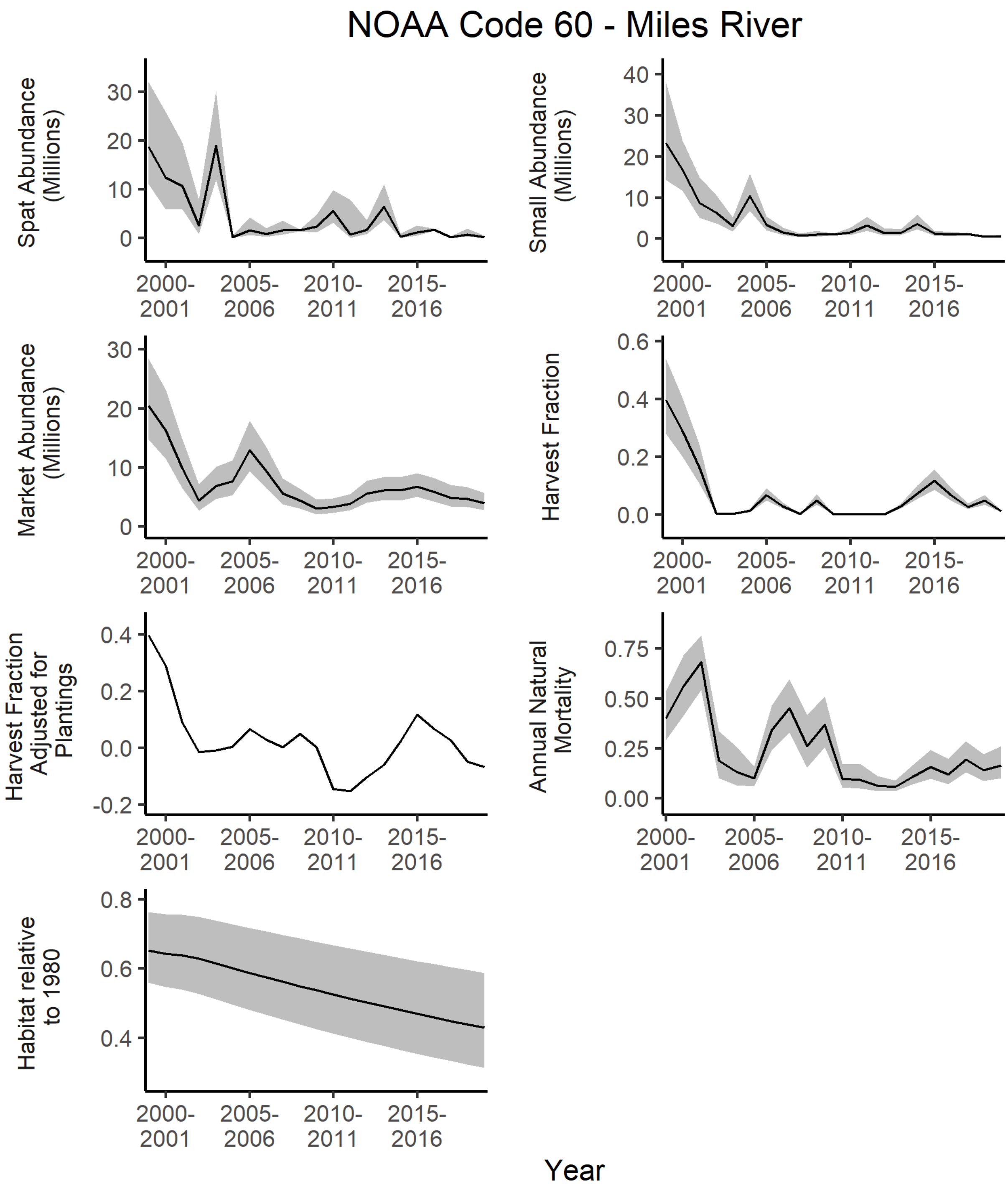

Figure 10. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Miles River - NOAA Code 60.

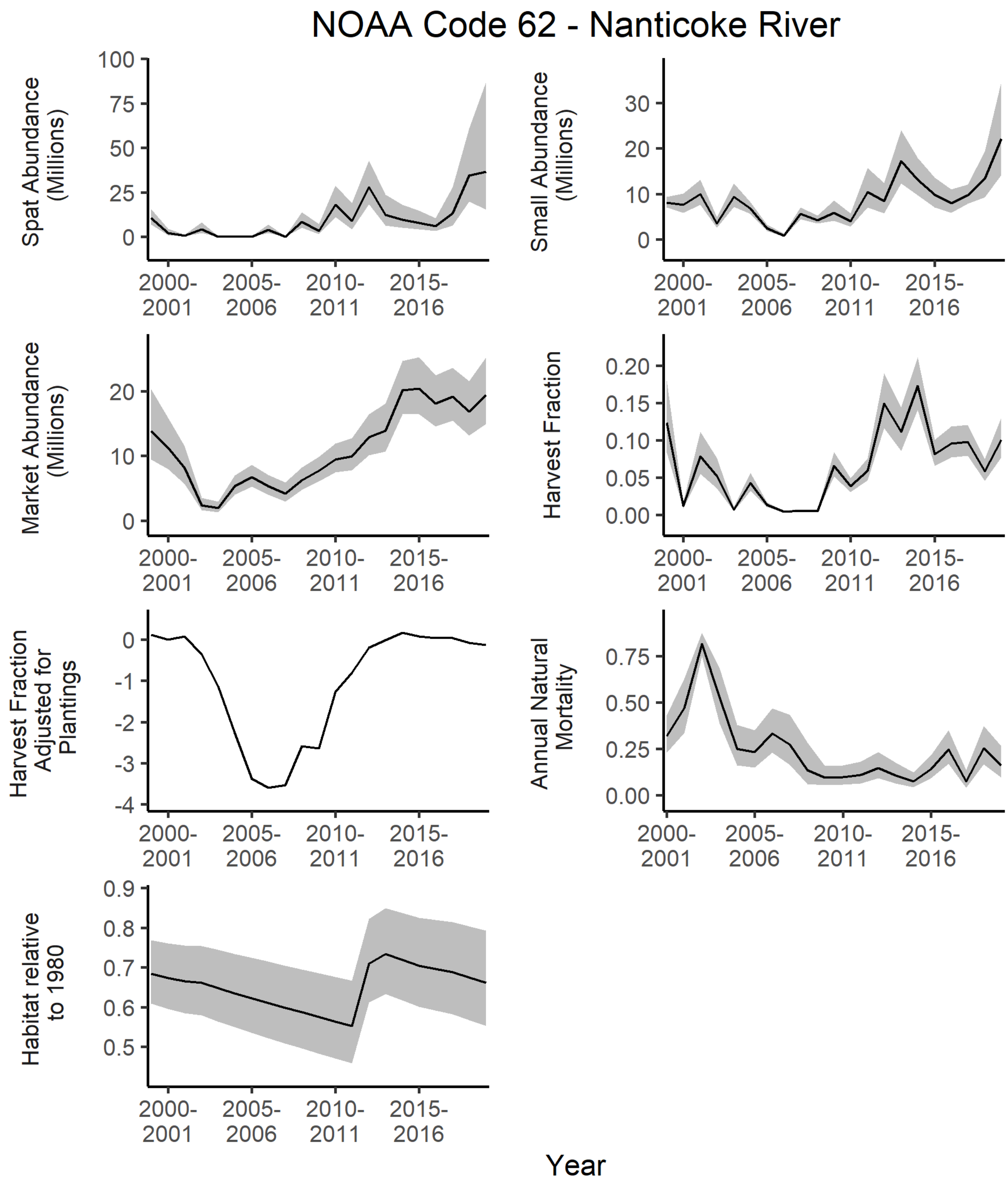

Figure 11. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Nanticoke River - NOAA Code 62.

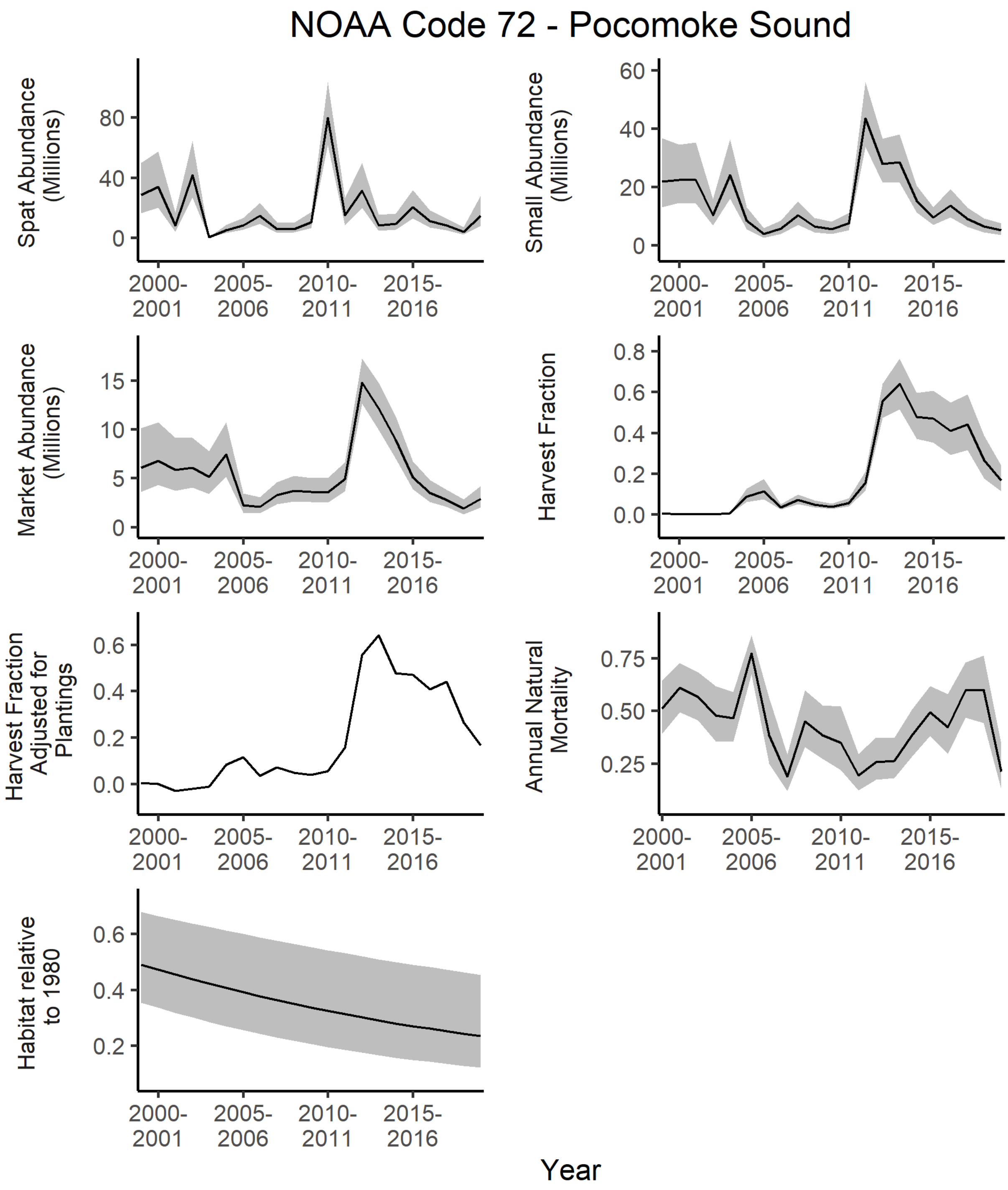

Figure 12. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Pocomoke Sound - NOAA Code 72.

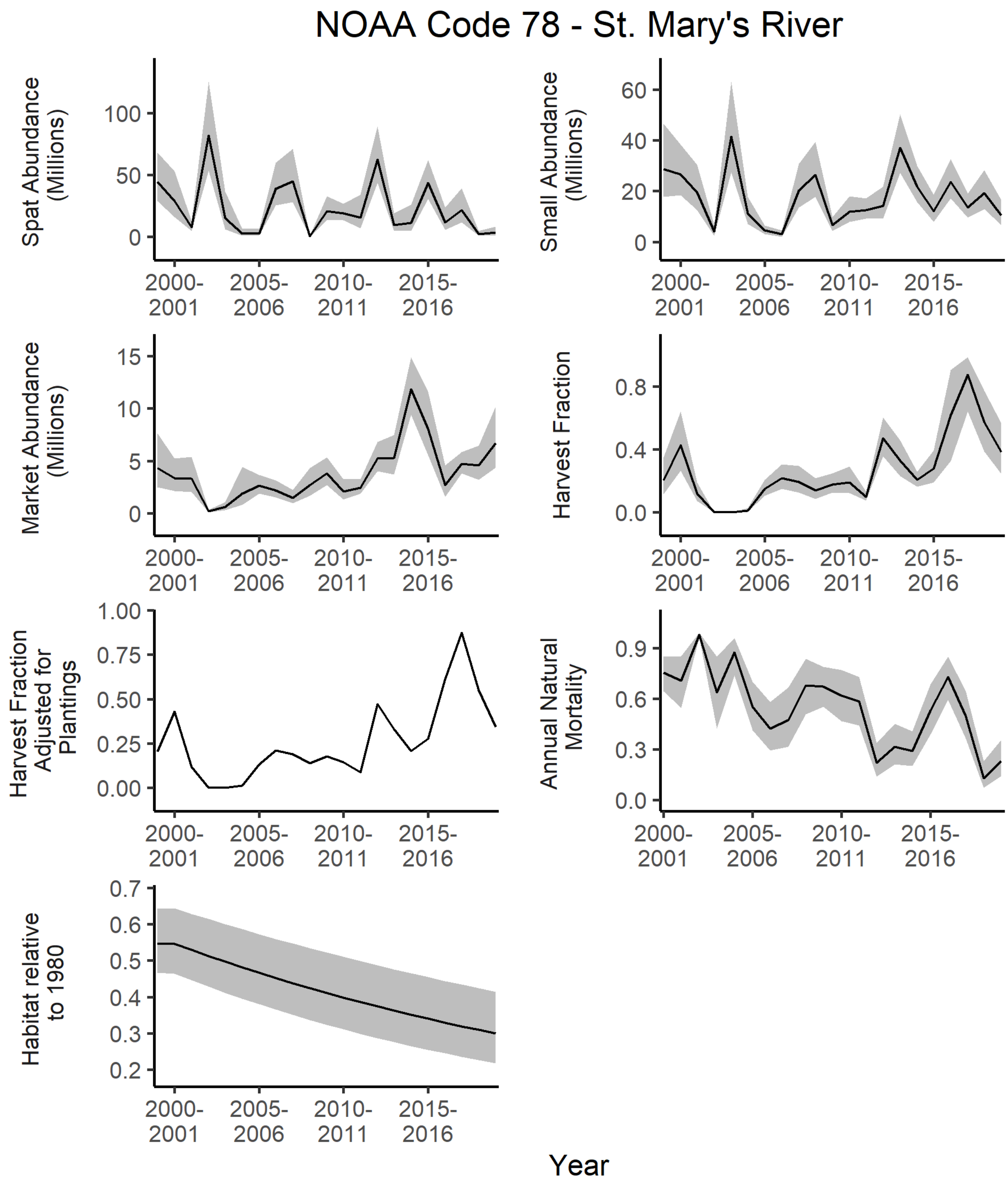

Figure 13. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in St. Mary's River - NOAA Code 78.

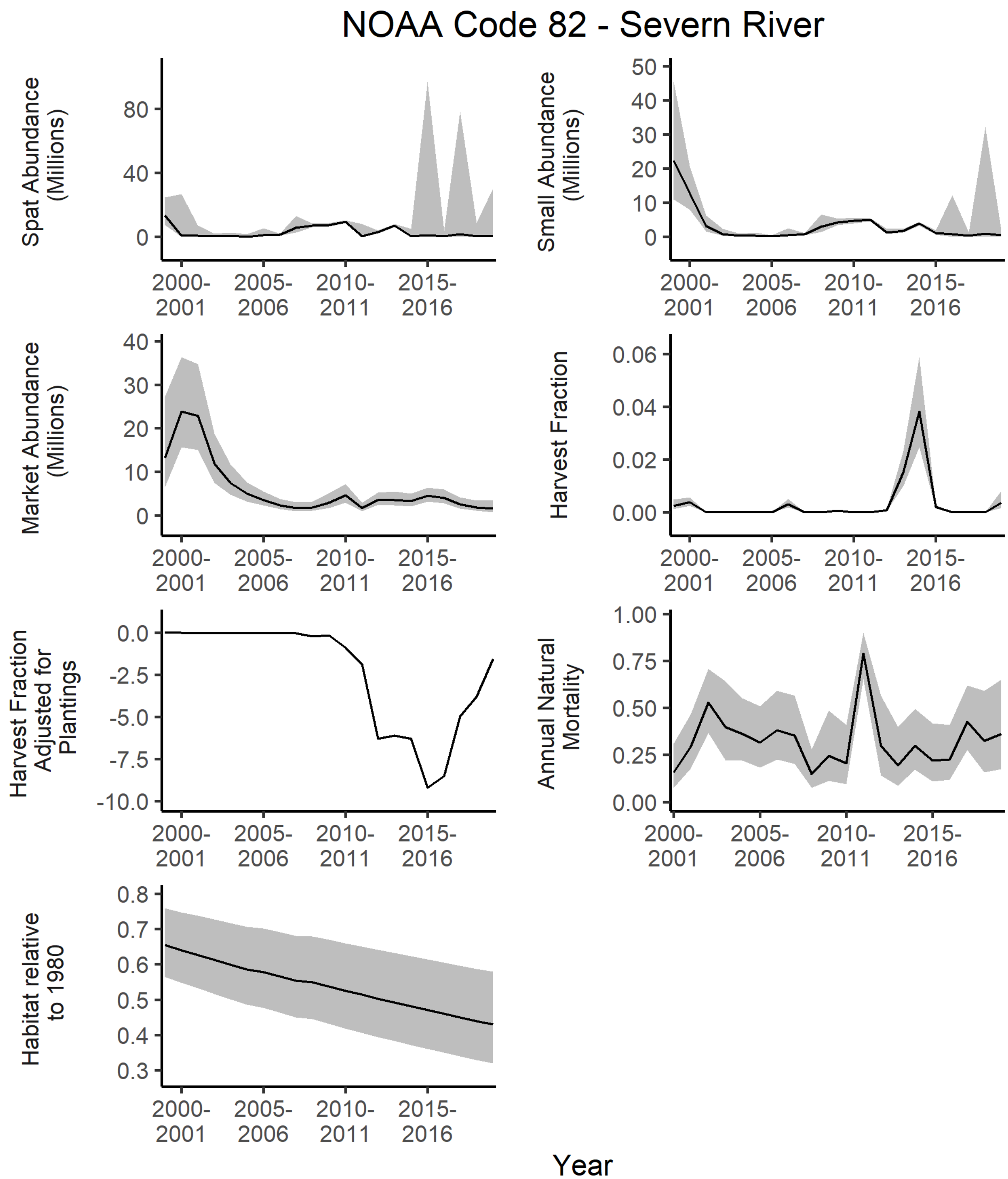

Figure 14. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Severn River - NOAA Code 82.

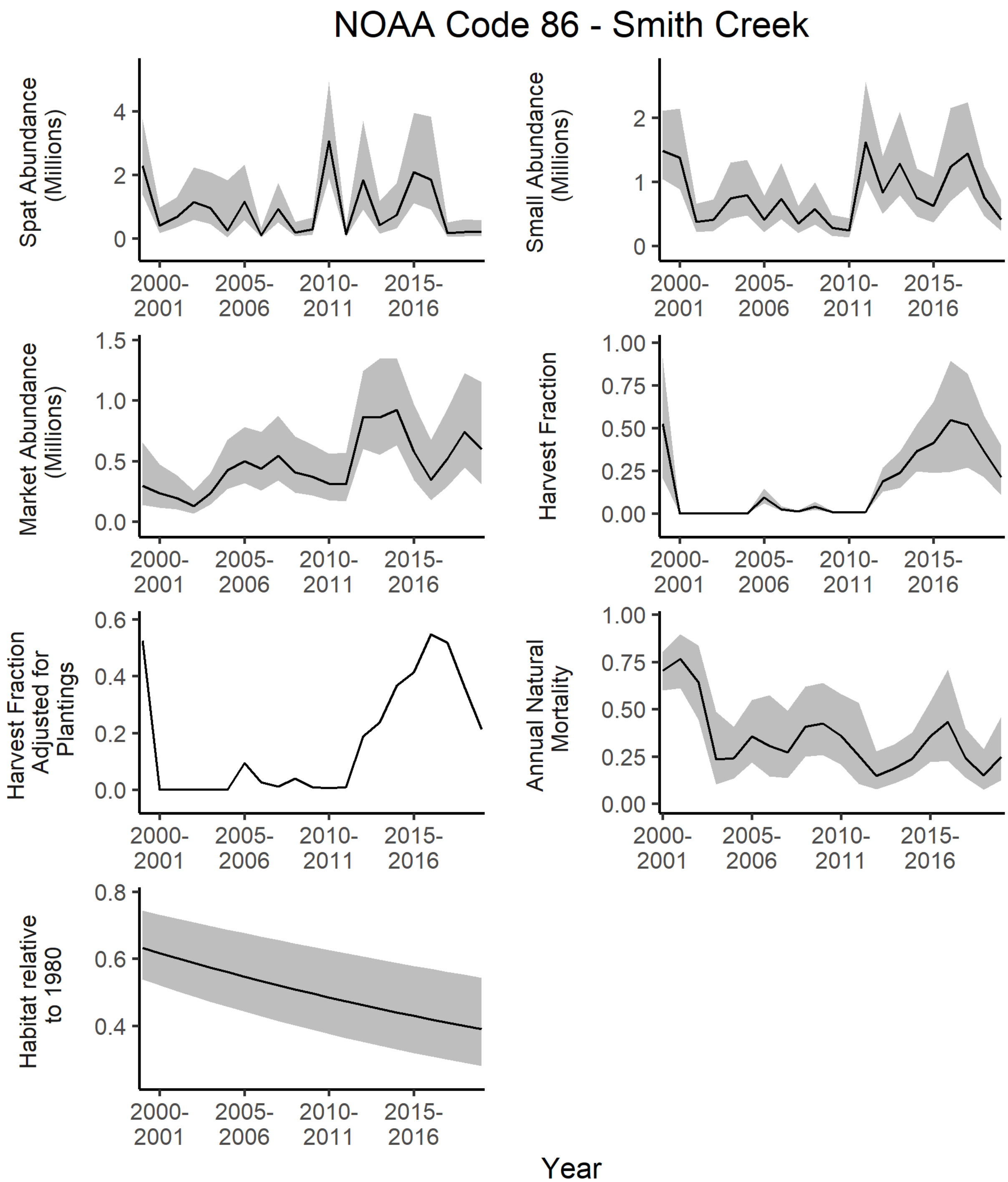

Figure 15. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Smith Creek - NOAA Code 86.

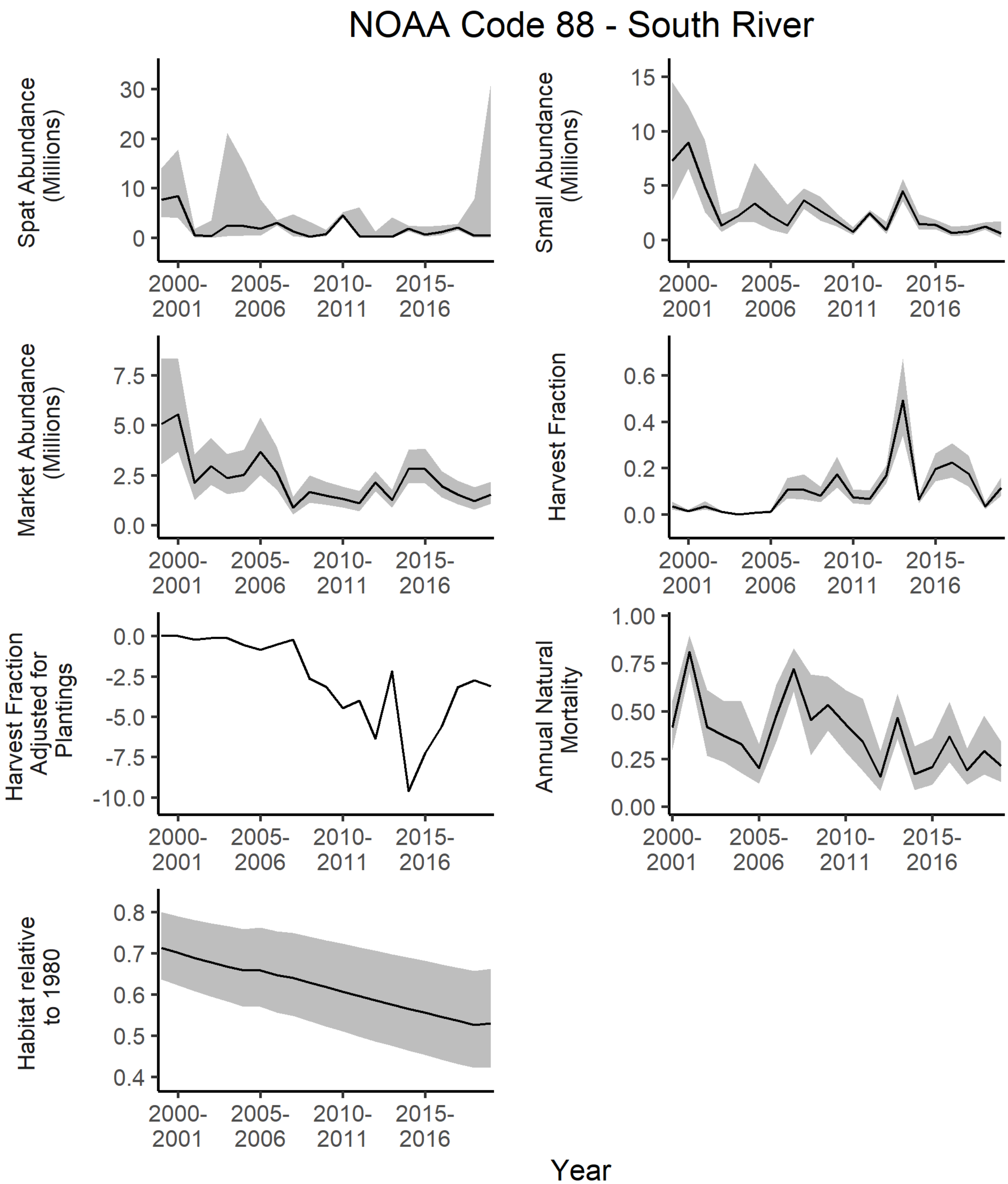

Figure 16. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in South River - NOAA Code 88.

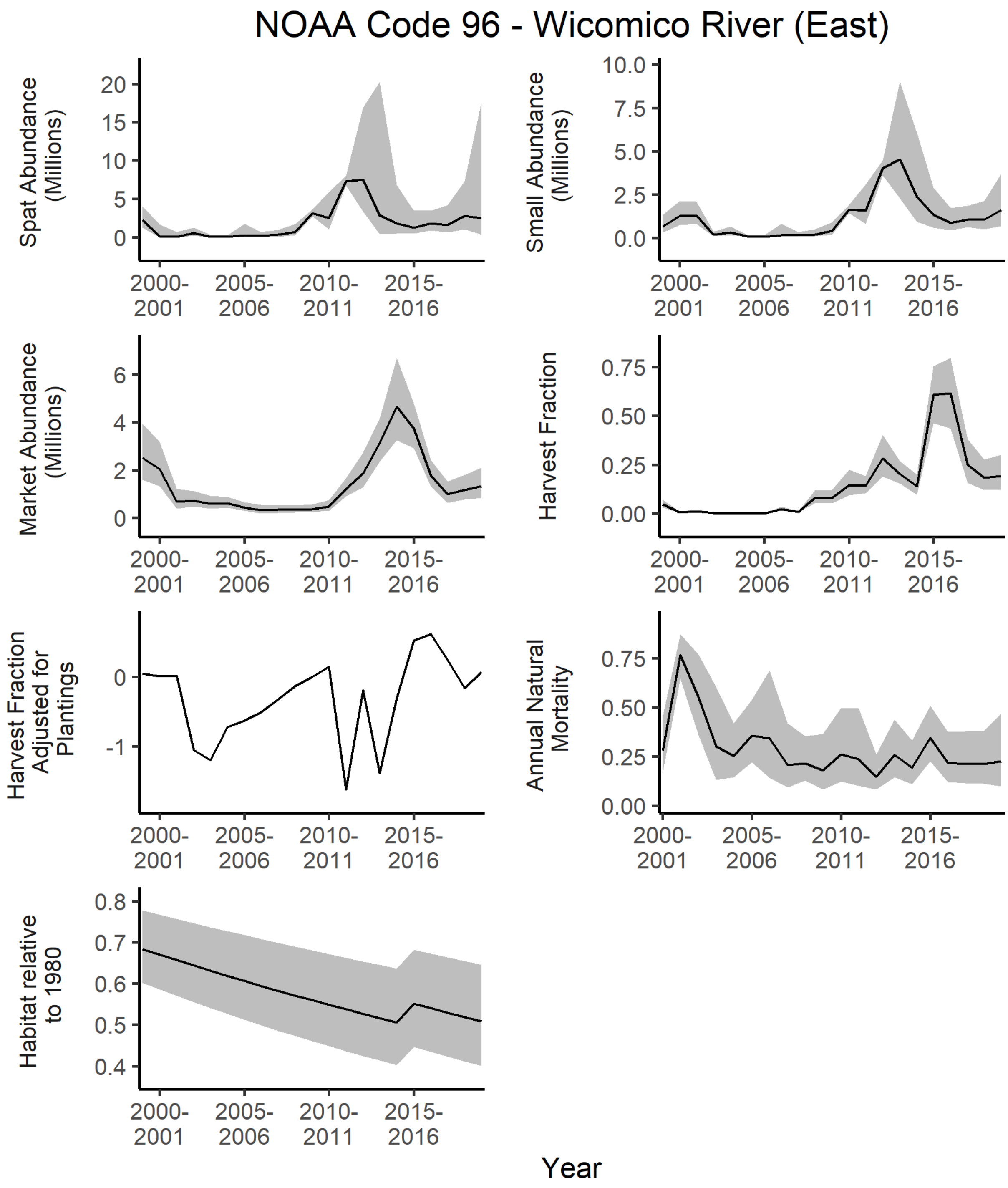

Figure 17. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Wicomico River (East) - NOAA Code 96.

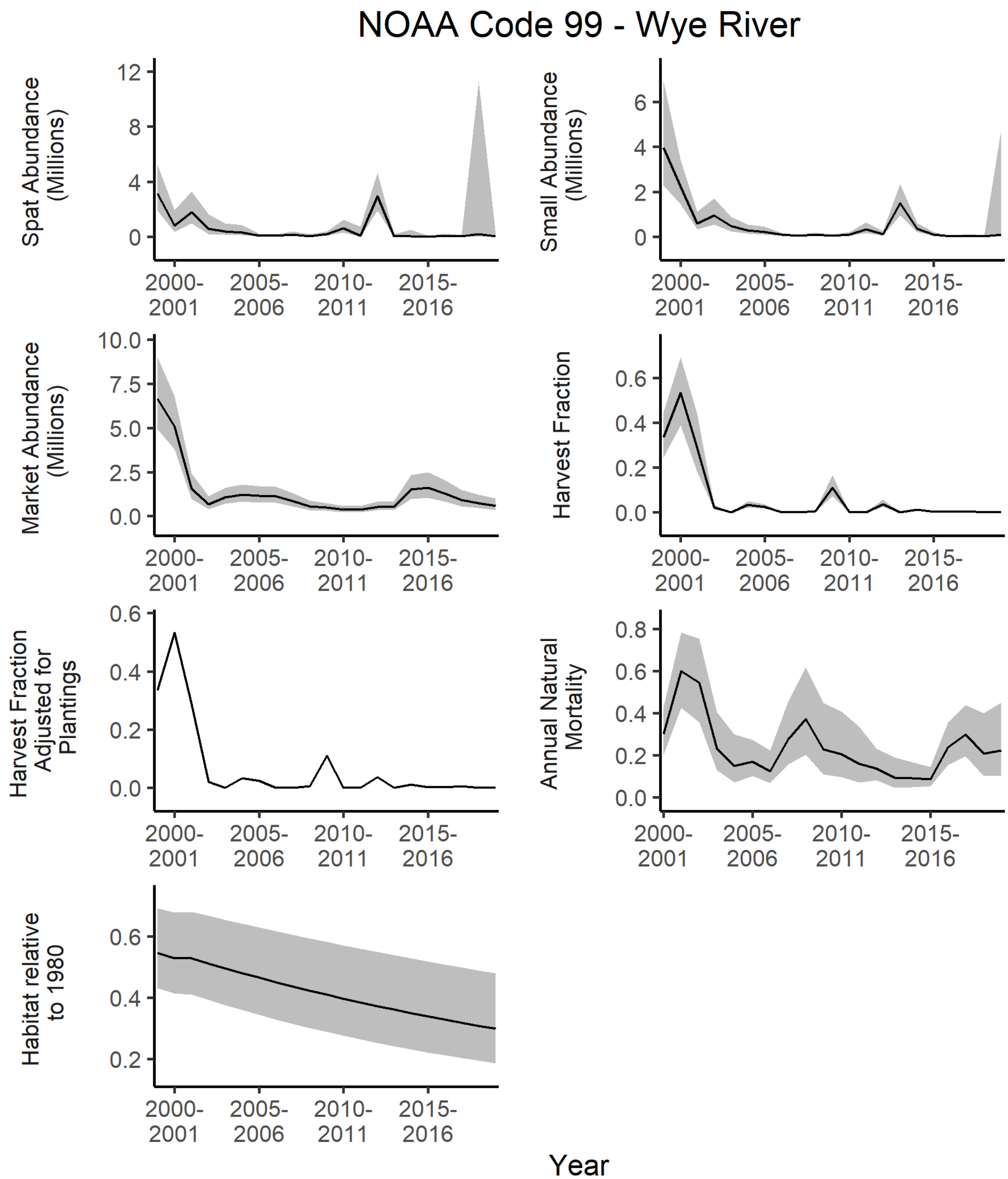

Figure 18. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Wye River - NOAA Code 99.

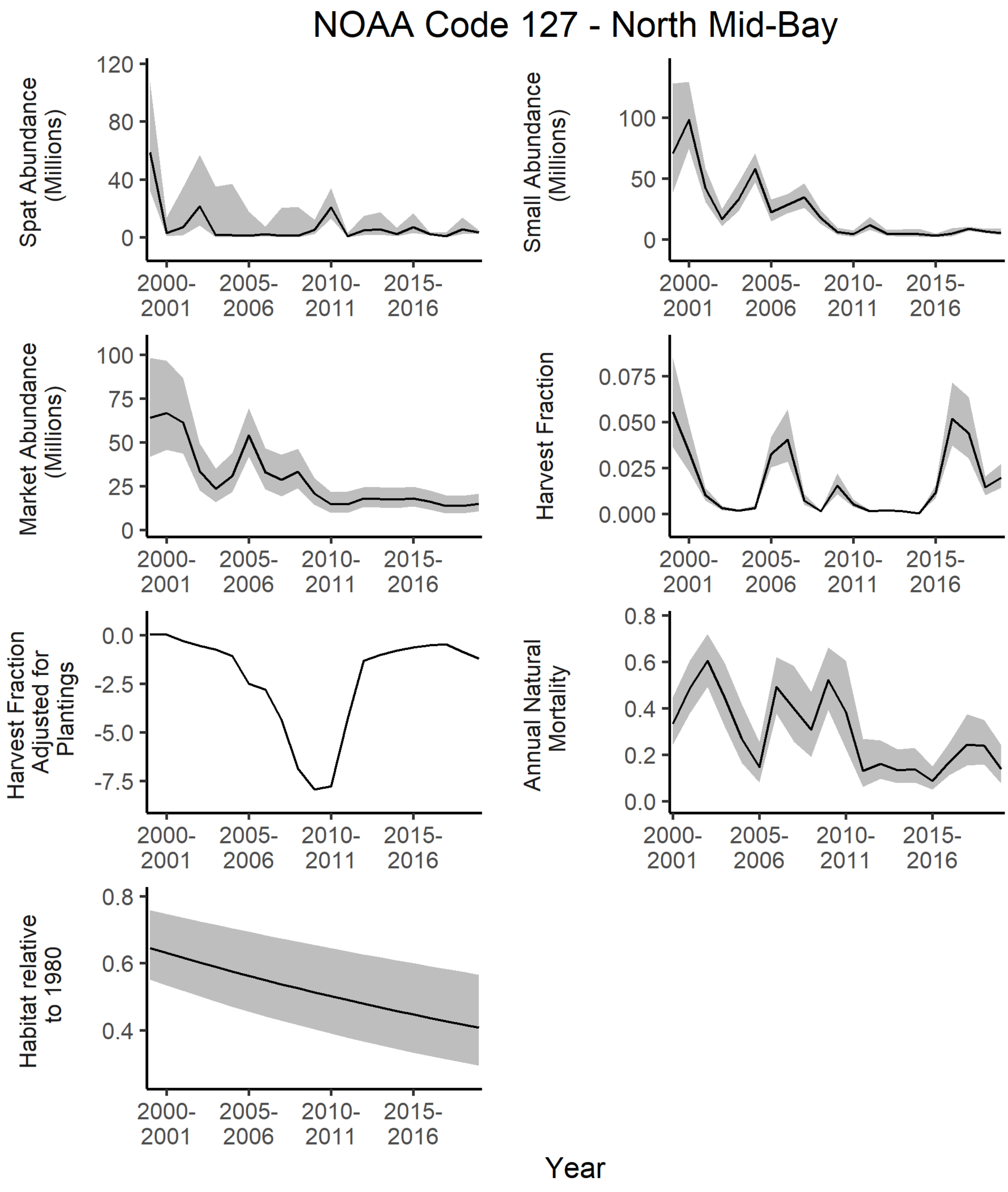

Figure 19. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in North Mid-Bay - NOAA Code 127.

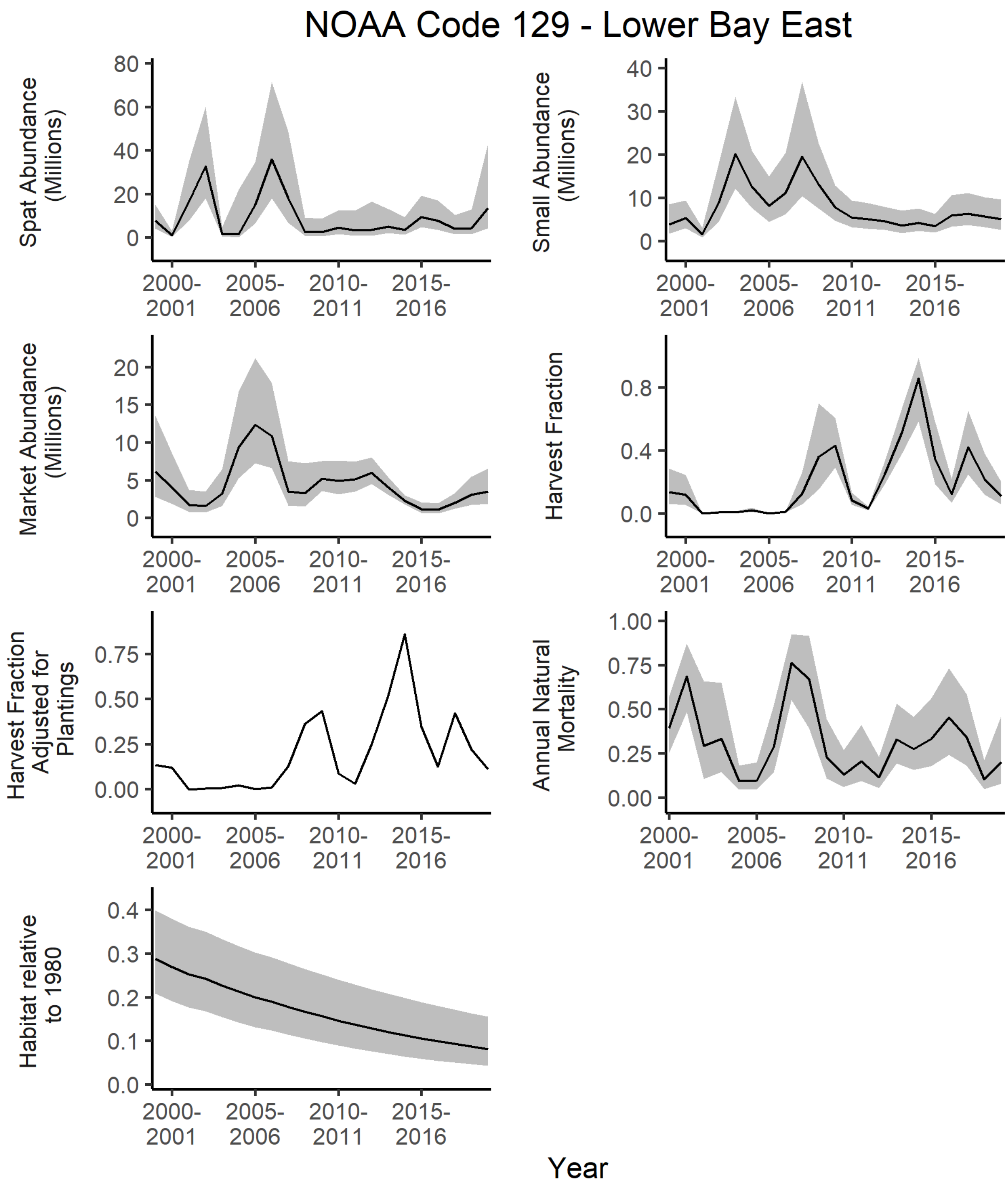

Figure 20. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Lower Bay East - NOAA Code 129.

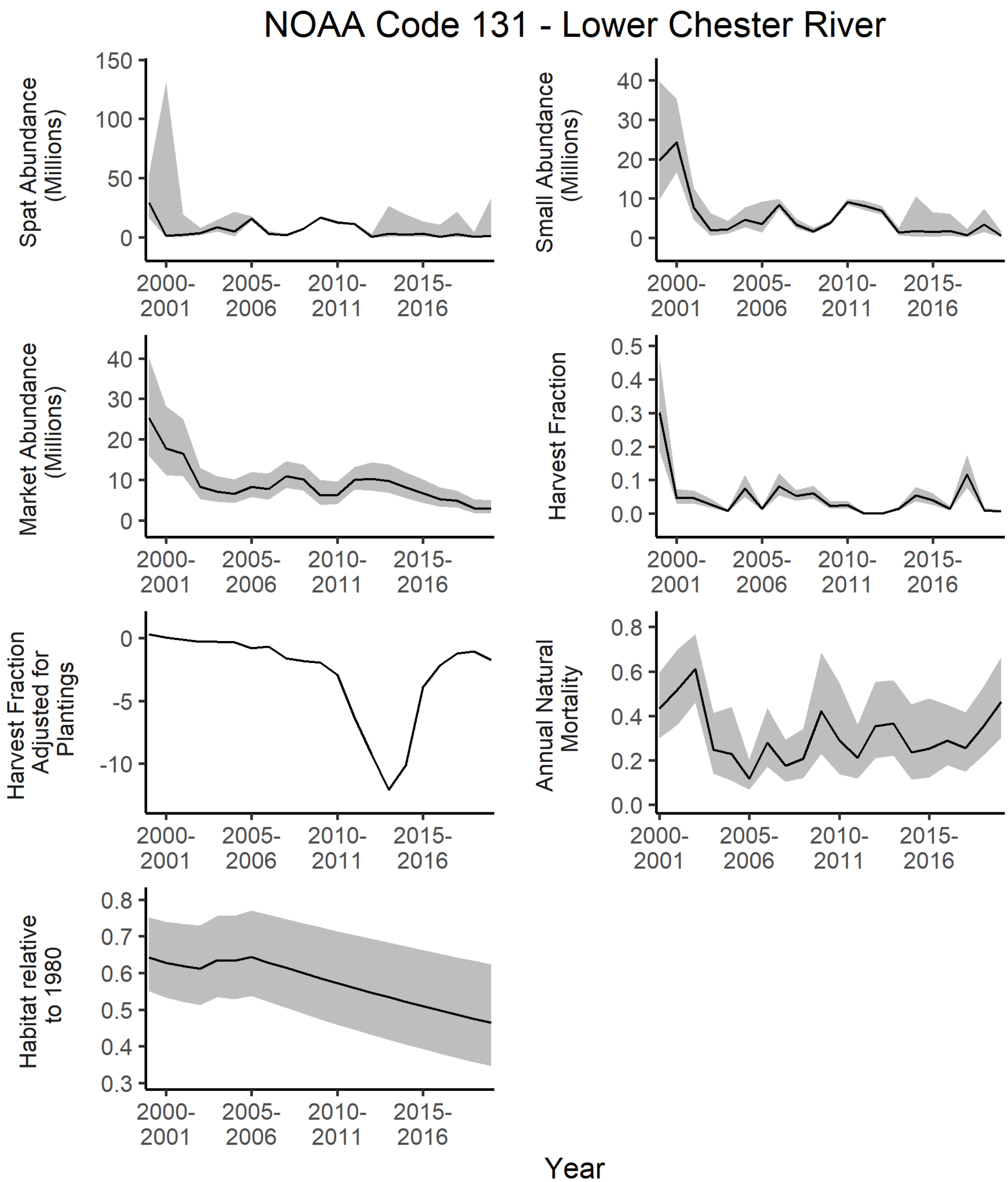

Figure 21. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Lower Chester River - NOAA Code 131.

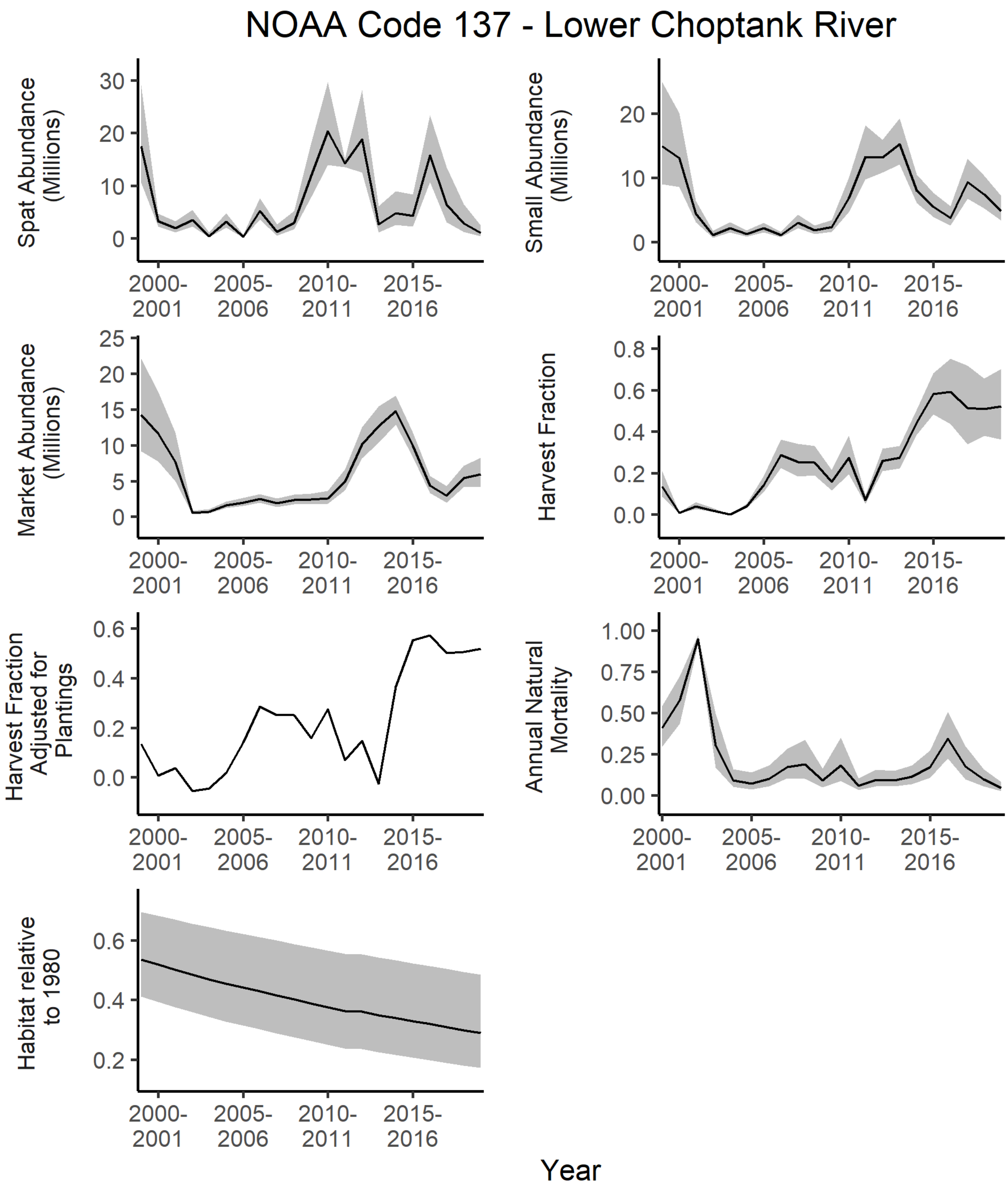

Figure 22. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Lower Choptank River - NOAA Code 137.

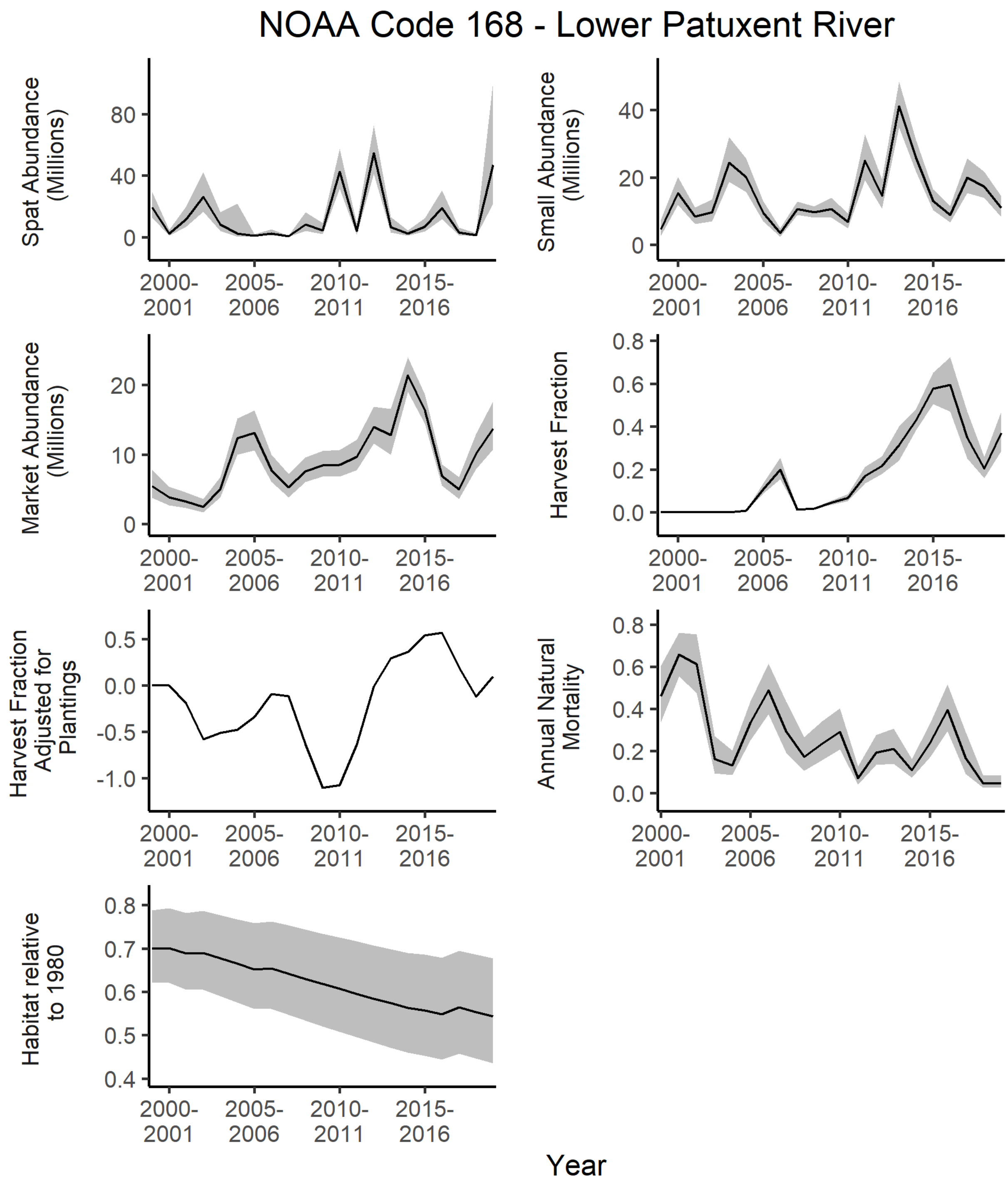

Figure 23. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Lower Patuxent River - NOAA Code 168.

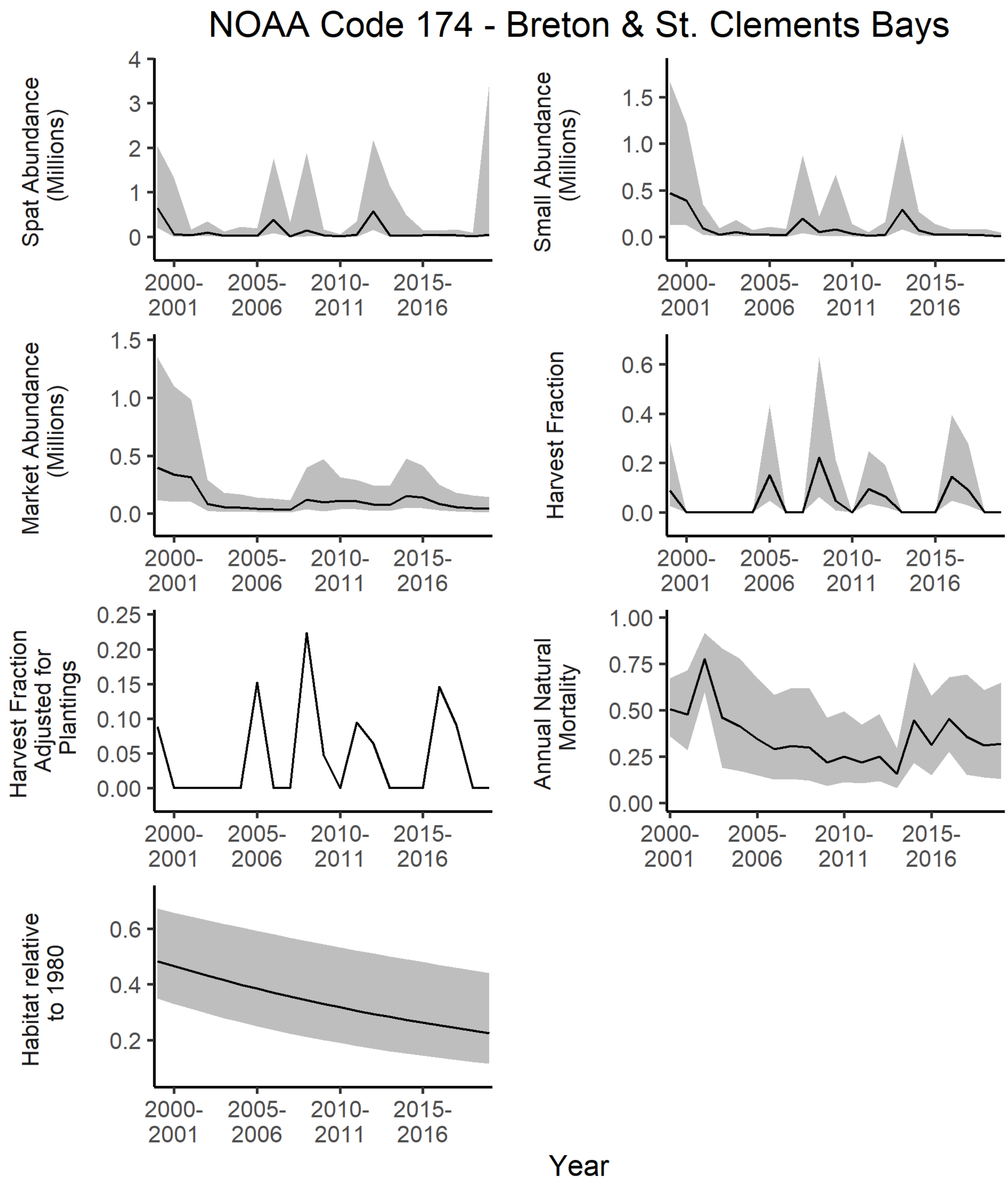

Figure 24*.* Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Breton & St. Clements Bays - NOAA Code *174.*

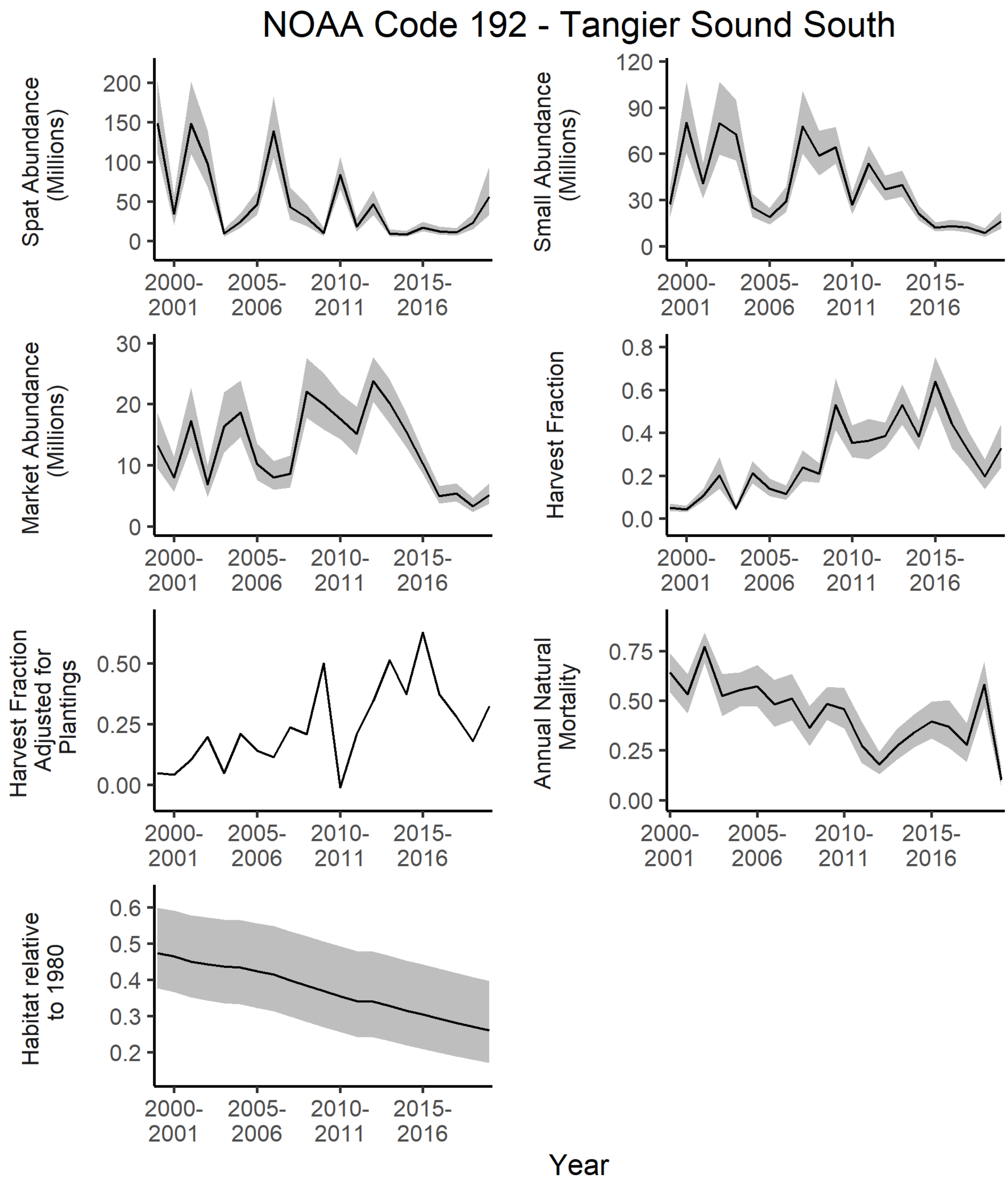

Figure 25. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Tangier Sound South - NOAA Code 192.

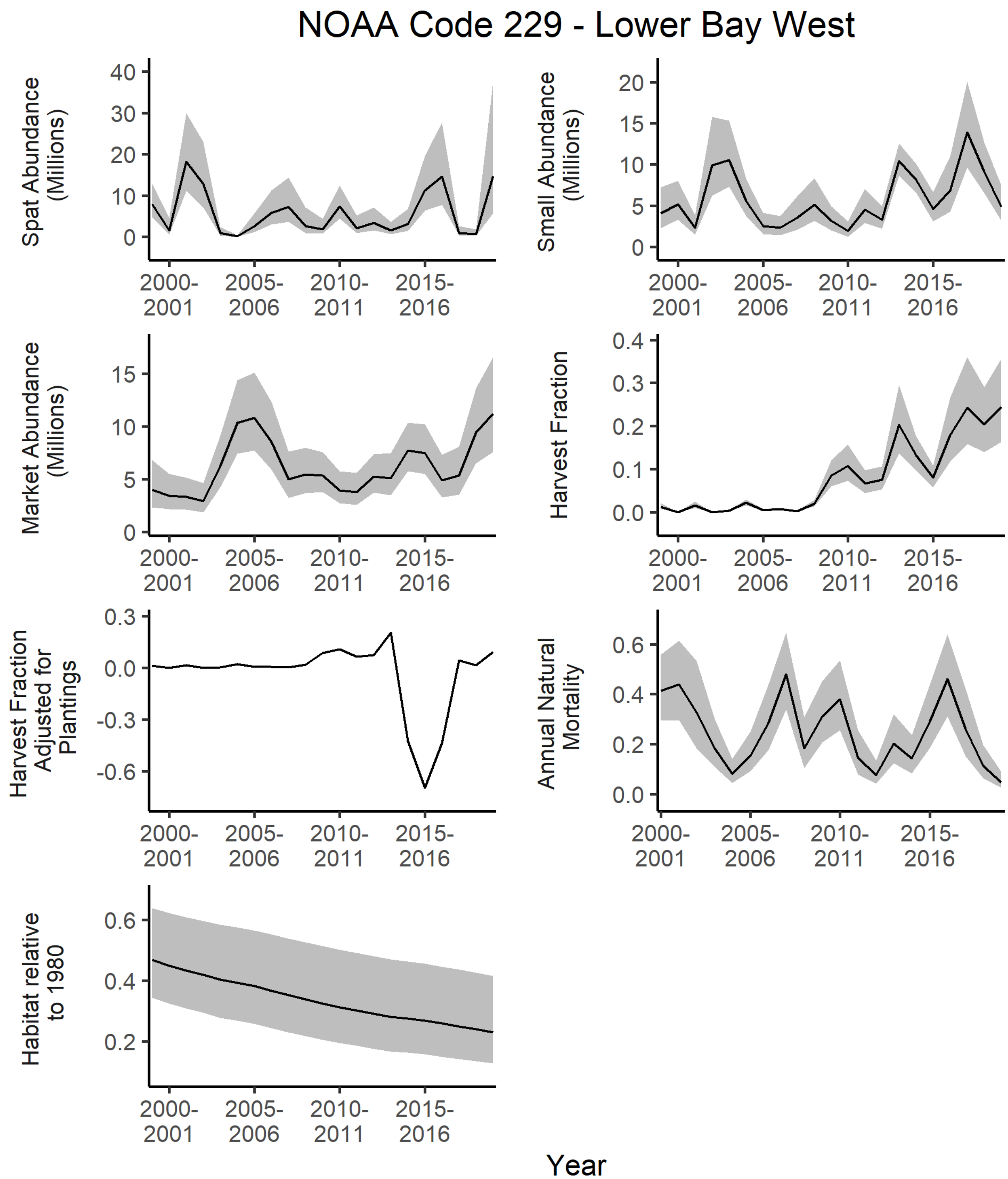

Figure 26. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Lower Bay West - NOAA Code 229.

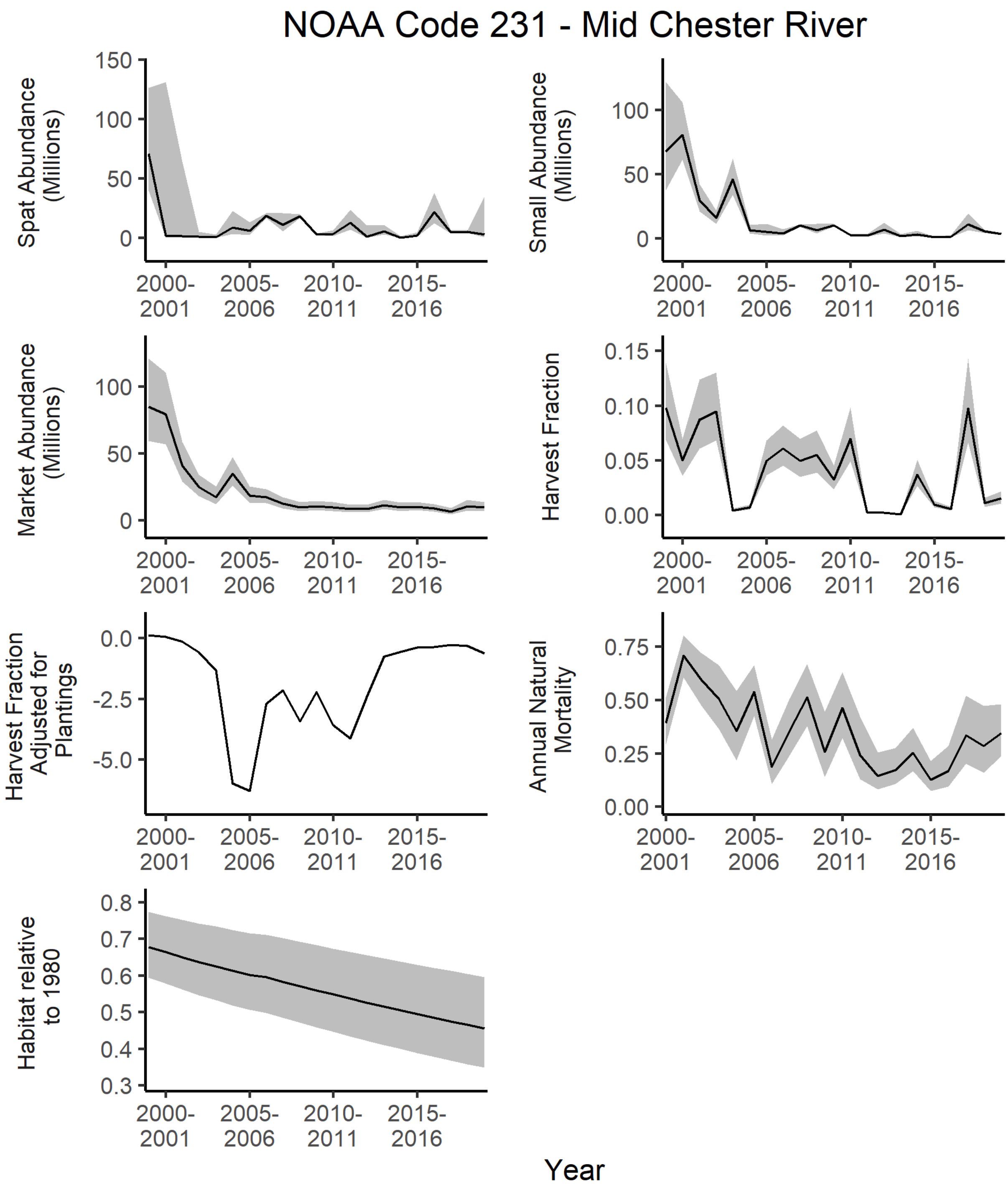

Figure 27. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Mid Chester River - NOAA Code 231.

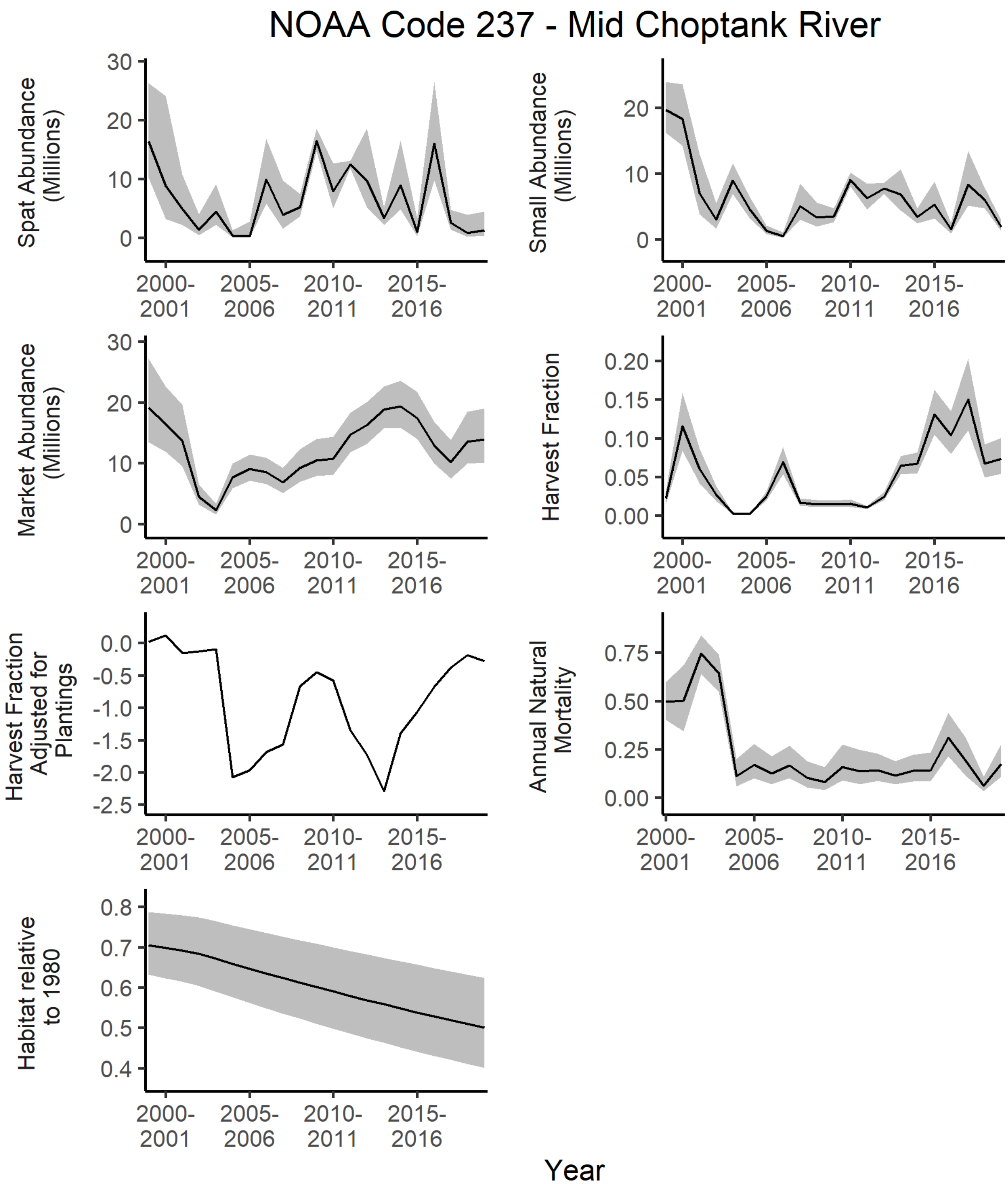

Figure 28. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Mid Choptank River - NOAA Code 237.

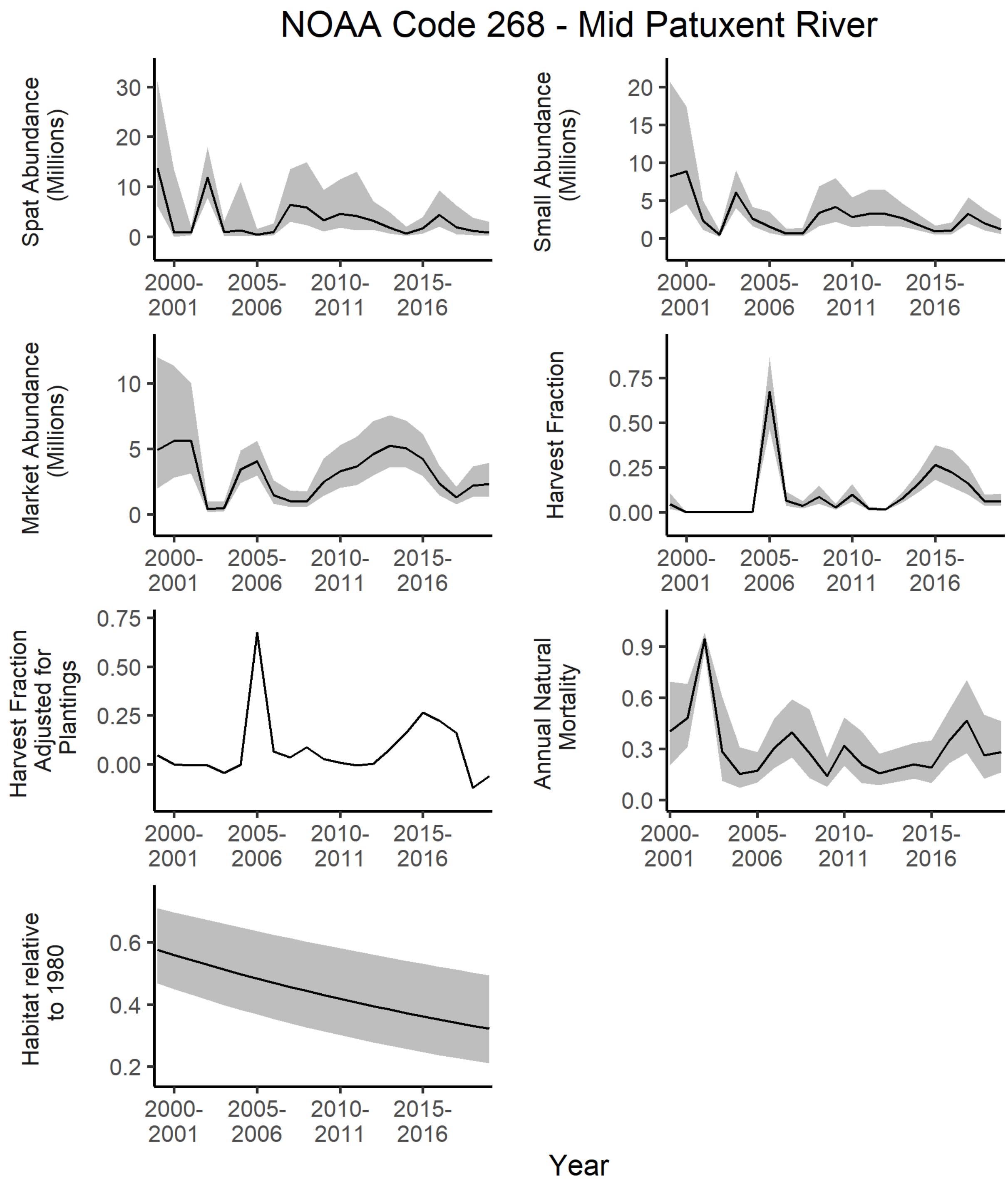

Figure 29. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Mid Patuxent River - NOAA Code 268.

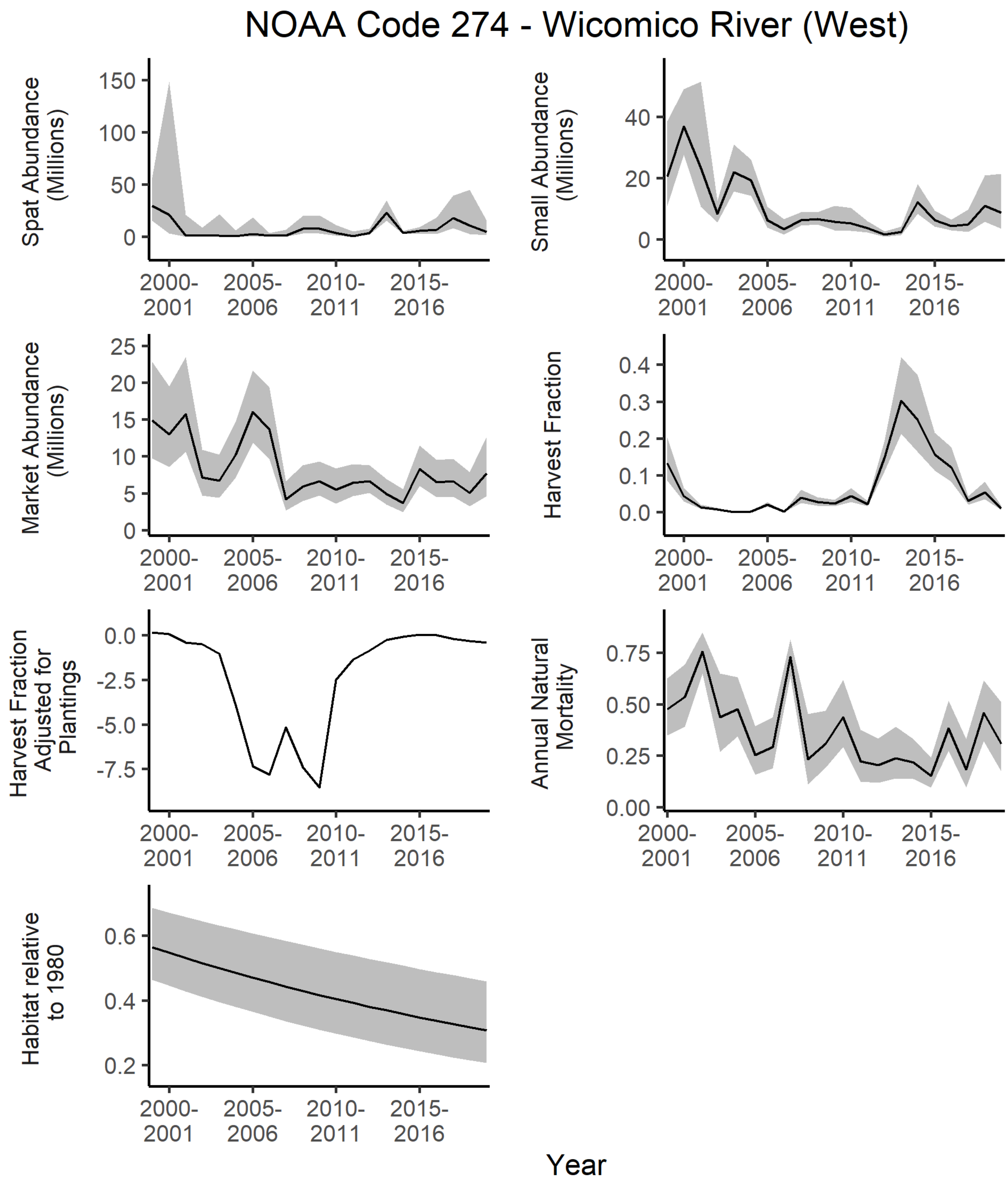

Figure 30. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Wicomico River (West) - NOAA Code 274.

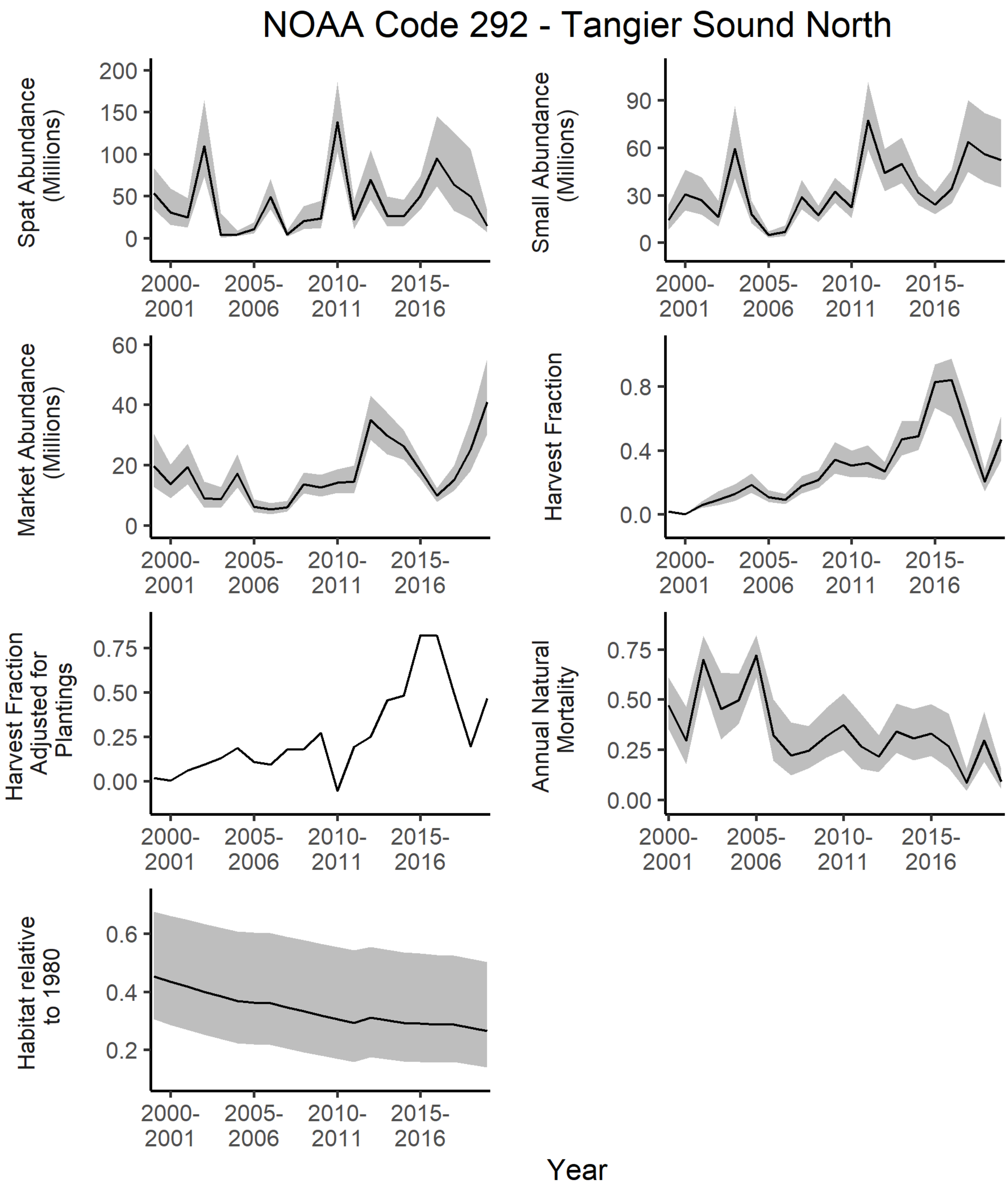

Figure 31*.* Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Tangier Sound North - NOAA Code 292.

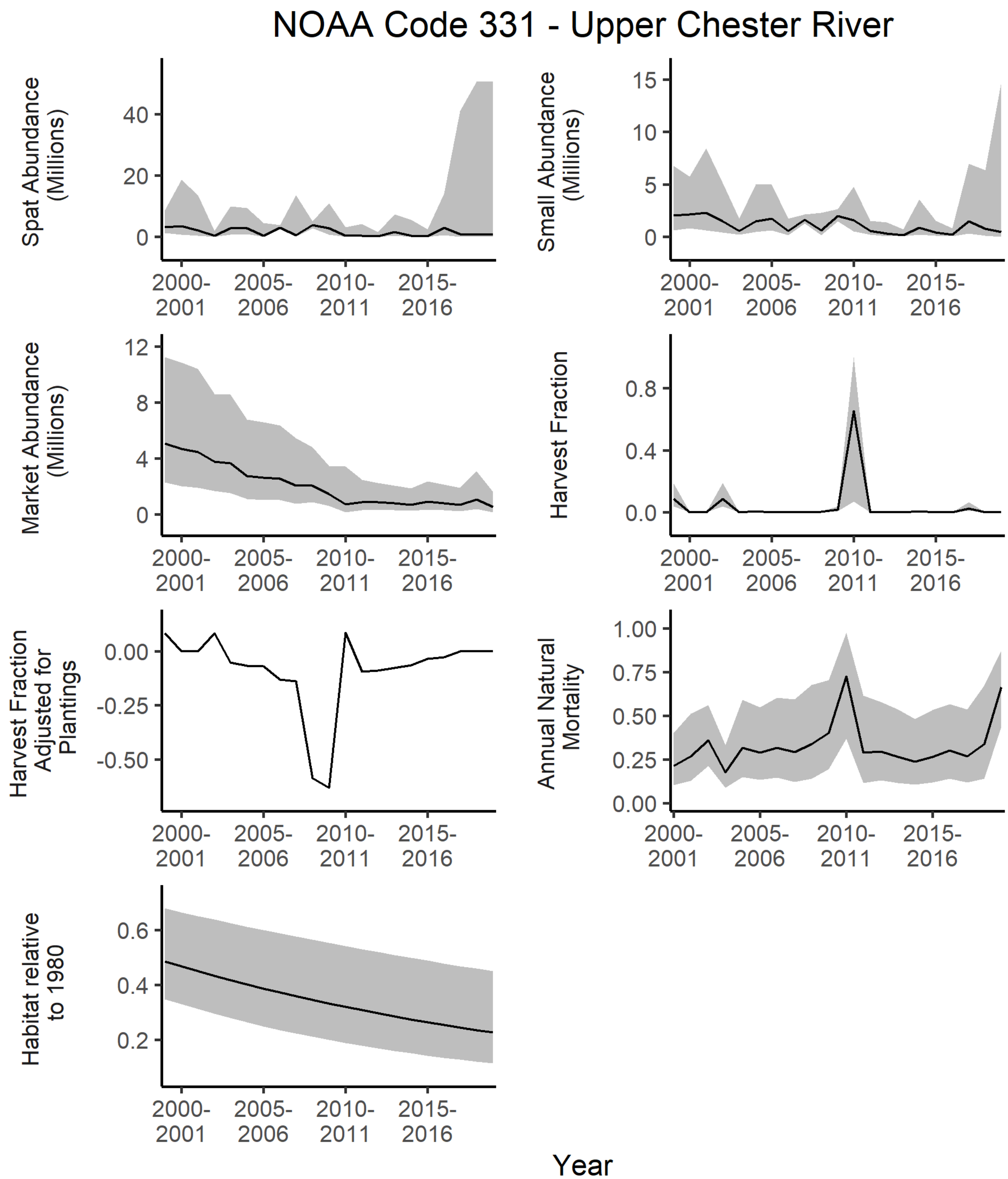

Figure 32. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Upper Chester River - NOAA Code 331.

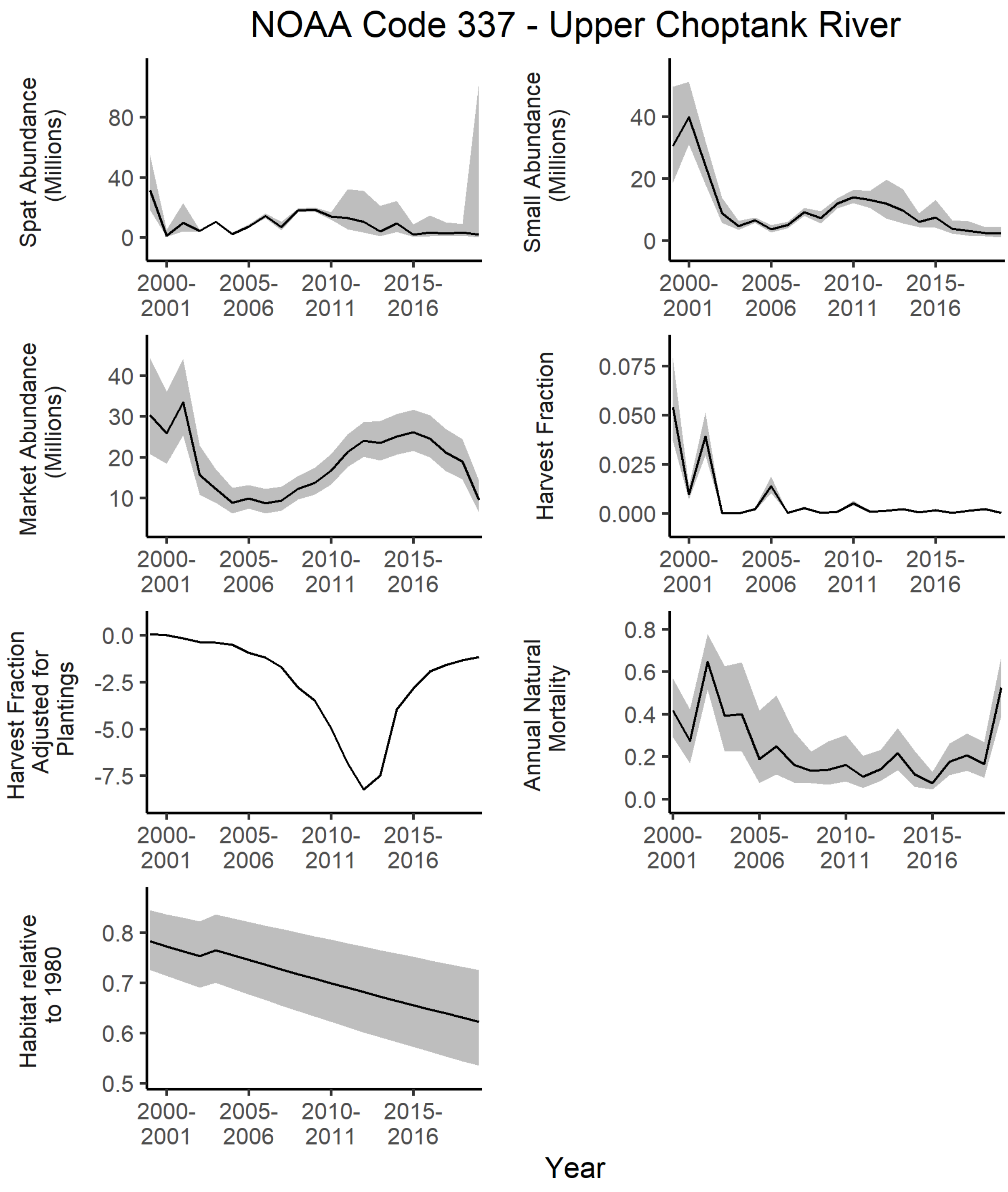

Figure 33. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Upper Choptank River - NOAA Code 337.

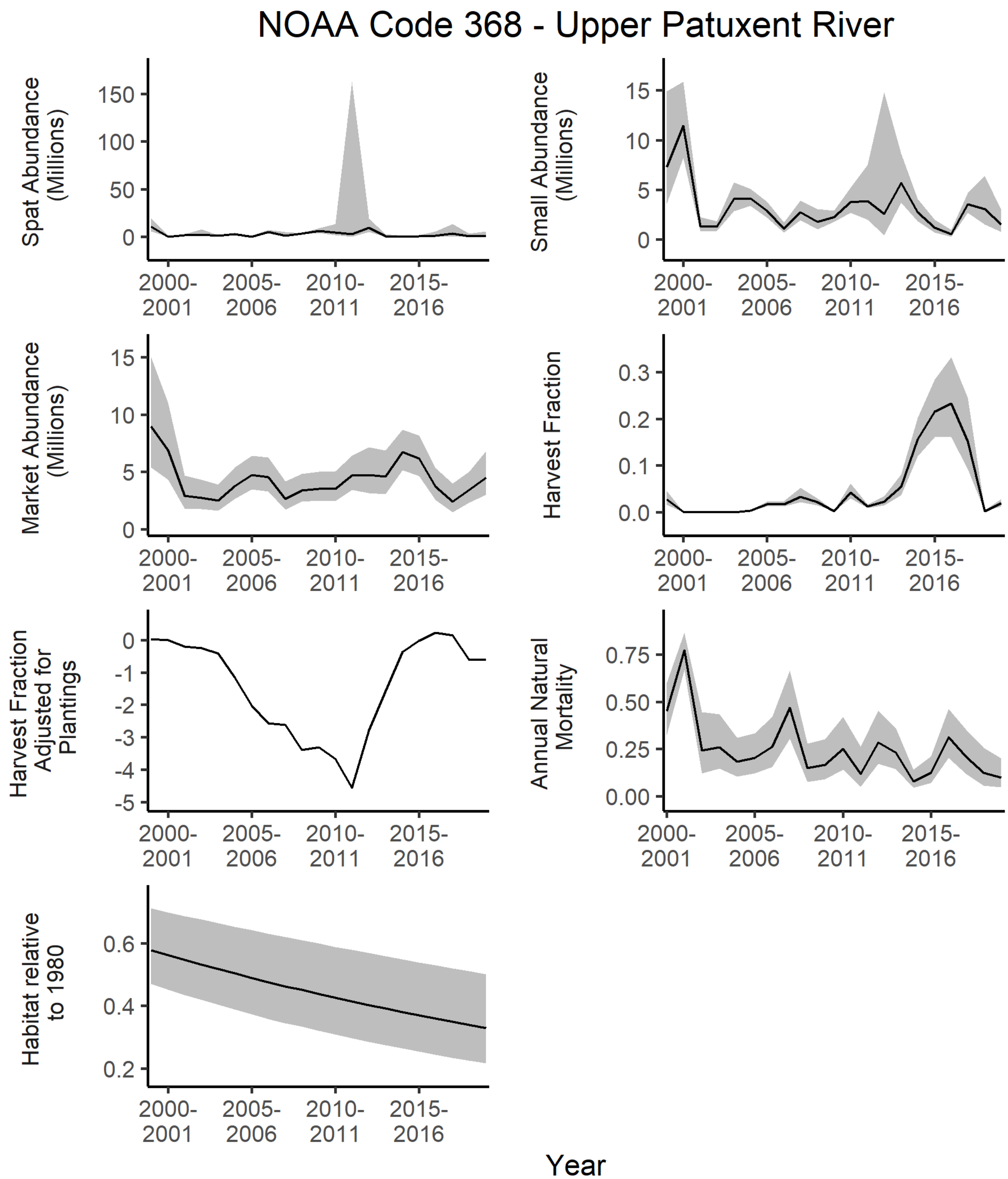

Figure 34. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Upper Patuxent River - NOAA Code 368.

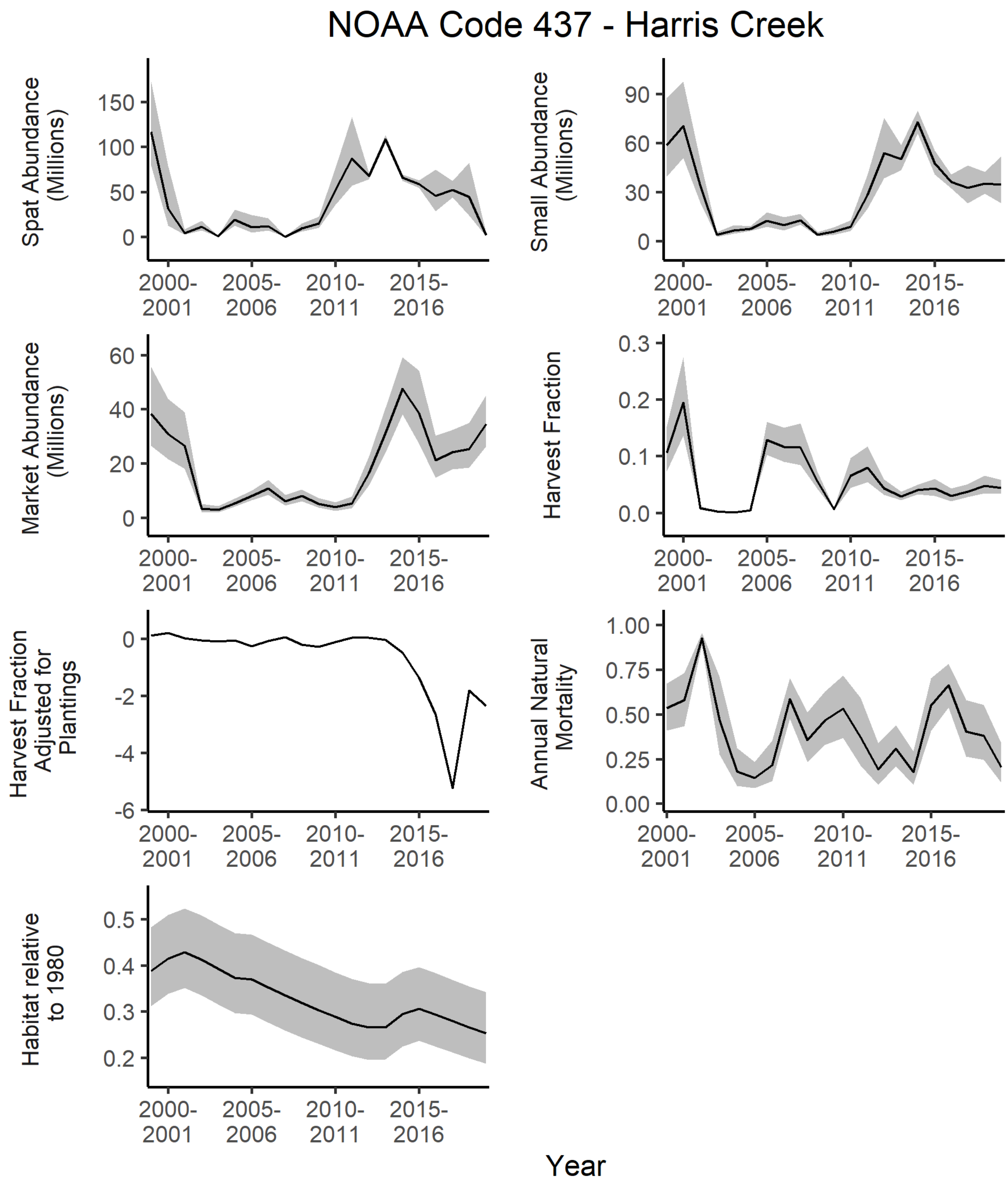

Figure 35. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Harris Creek - NOAA Code 437.

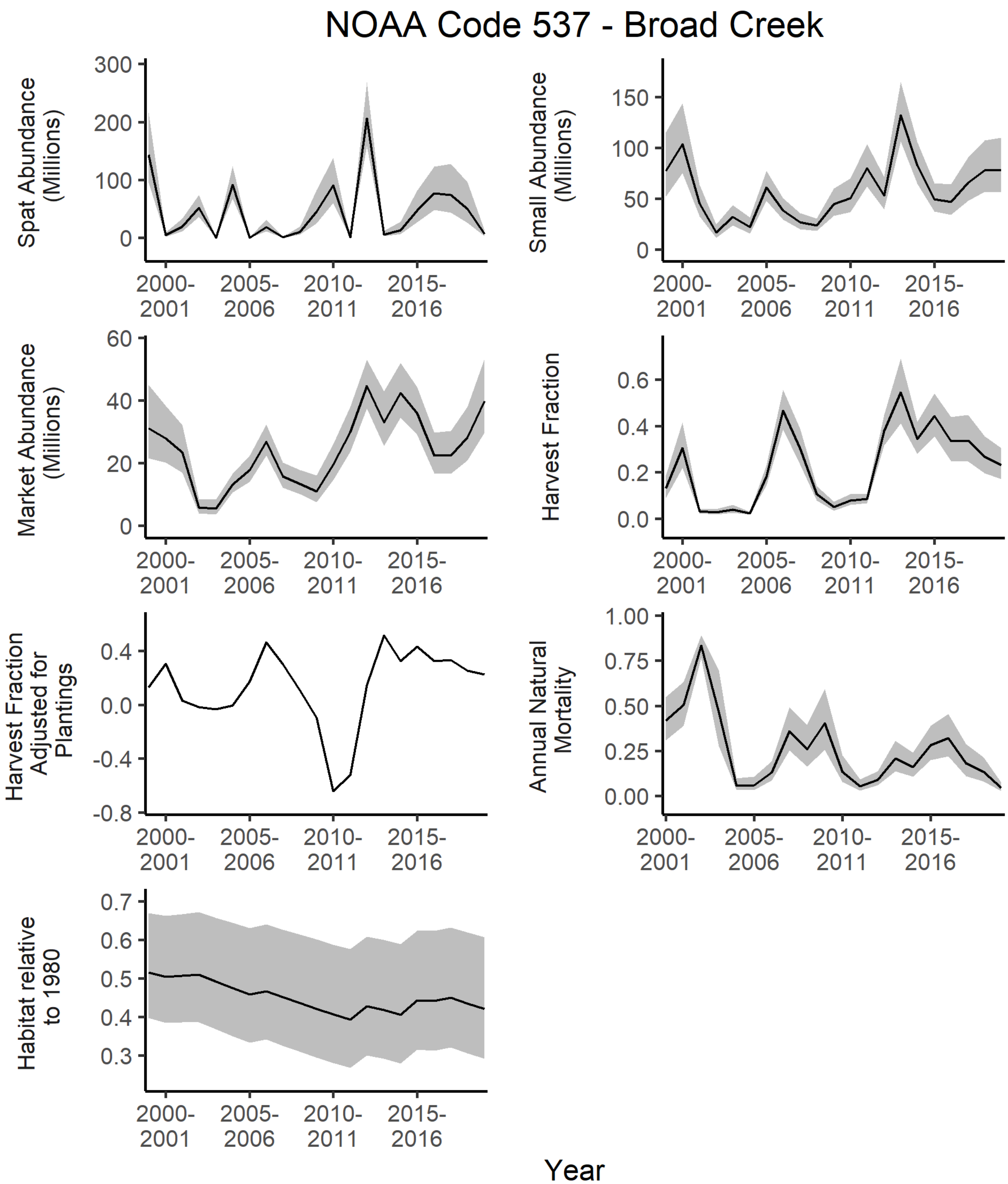

Figure 36. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Broad Creek - NOAA Code 537.

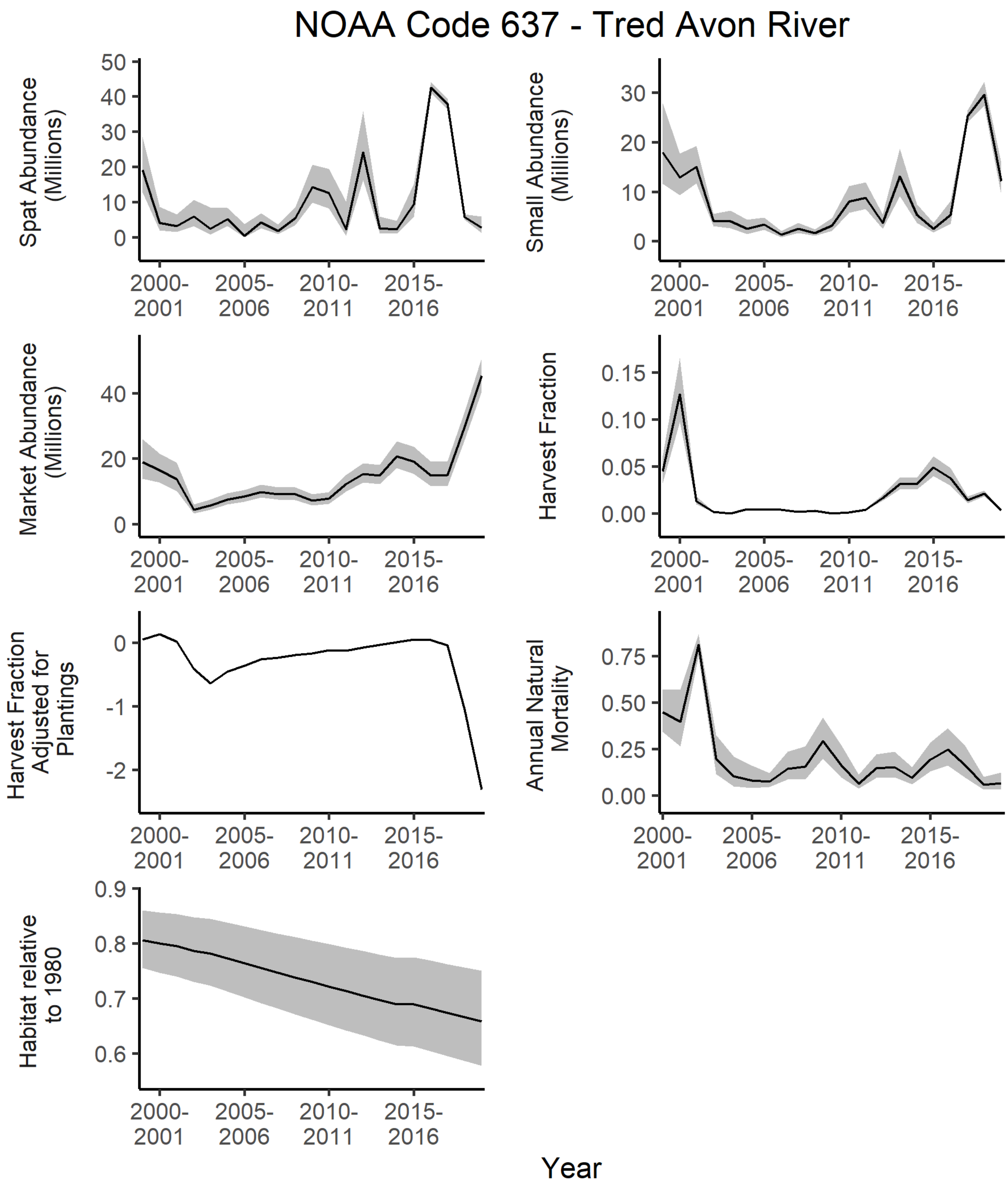

Figure 37. Estimated abundance of spat, small, and market oysters, harvest fraction (proportion/year), harvest fraction adjusted for plantings, natural mortality rate (proportion/year), and change in habitat relative to 1980 during the 1999-2000 through 2019-2020 seasons in Tred Avon River - NOAA Code 637.

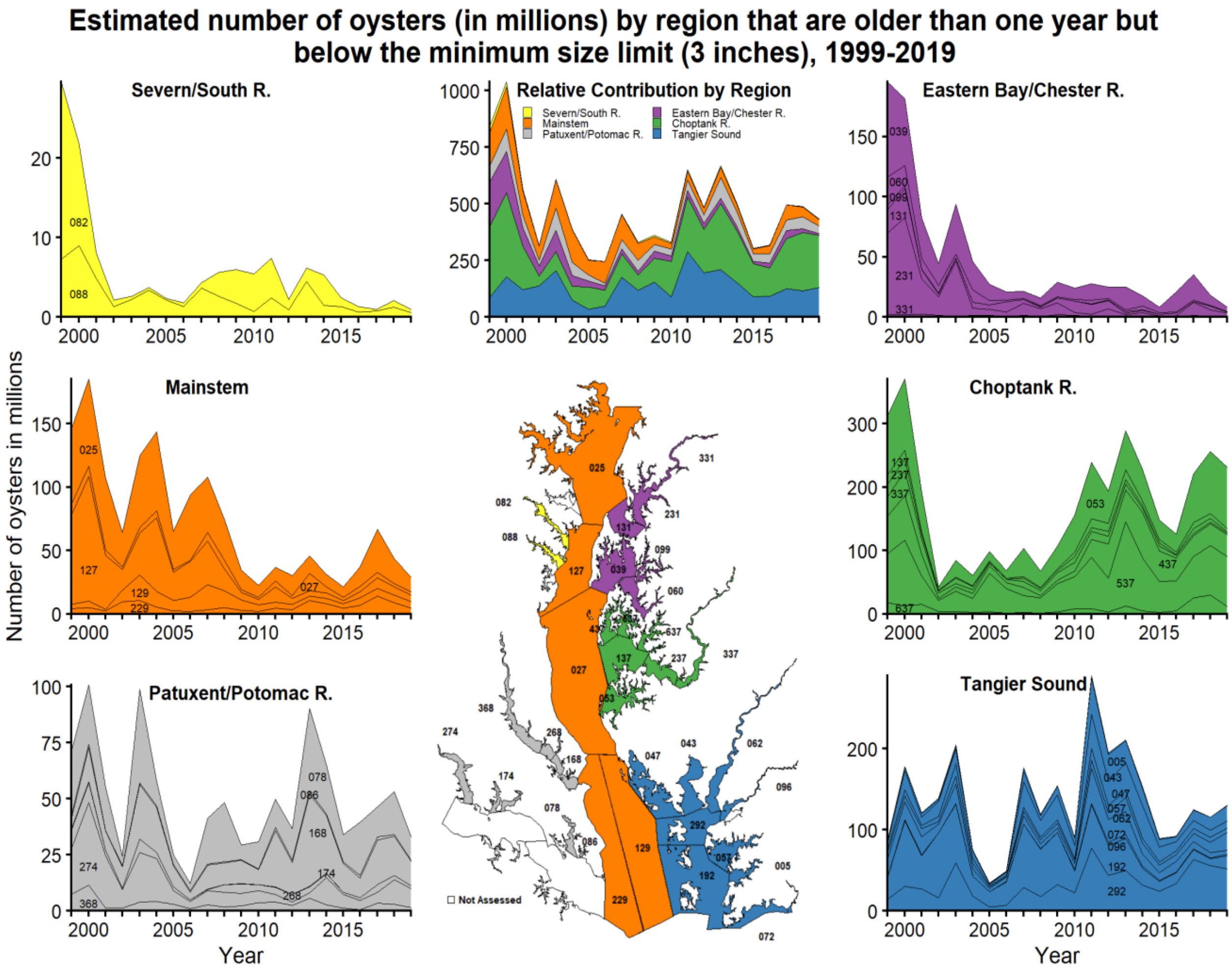

Figure 38. Estimated number of small oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

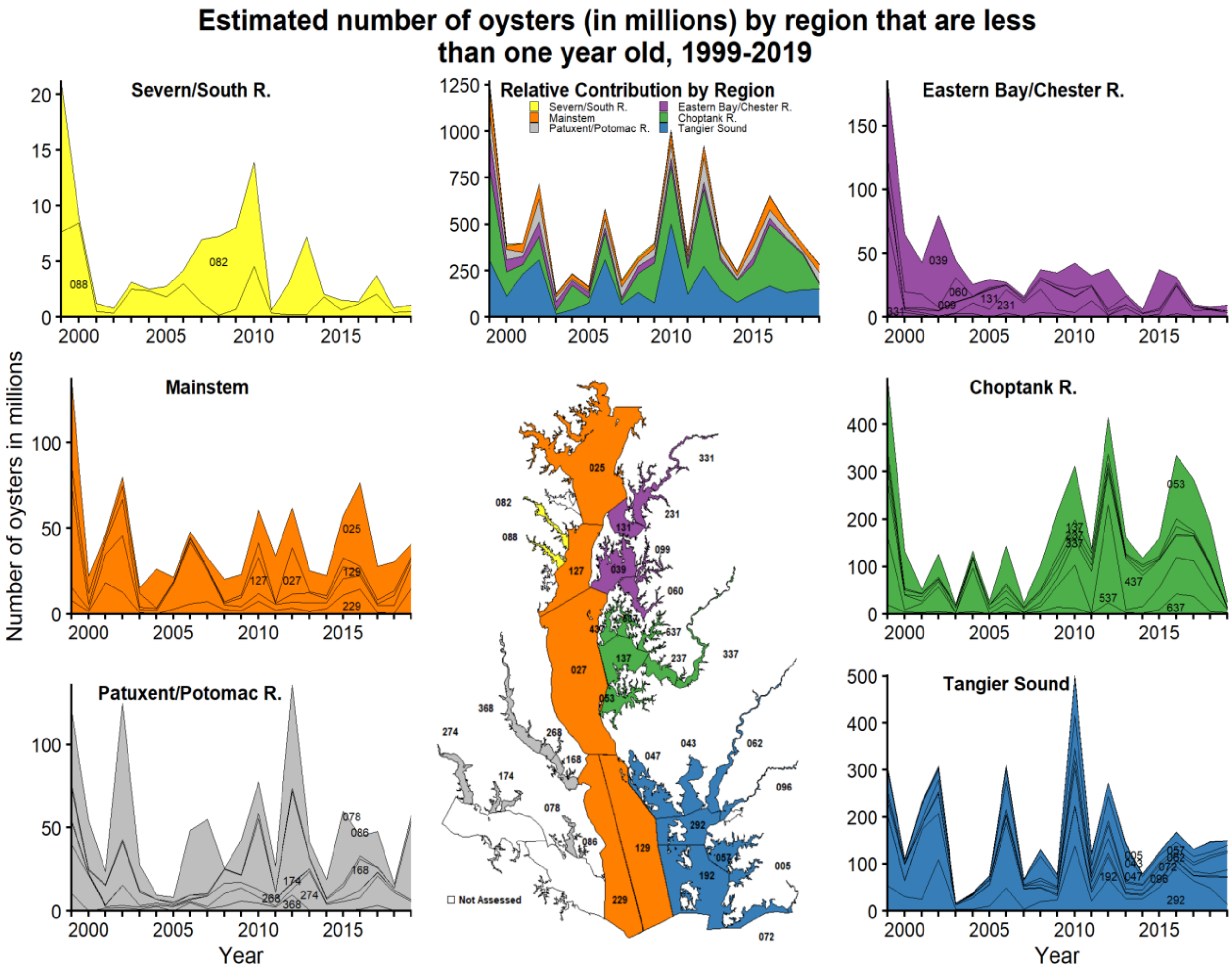

Figure 39. Estimated number of oyster spat (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

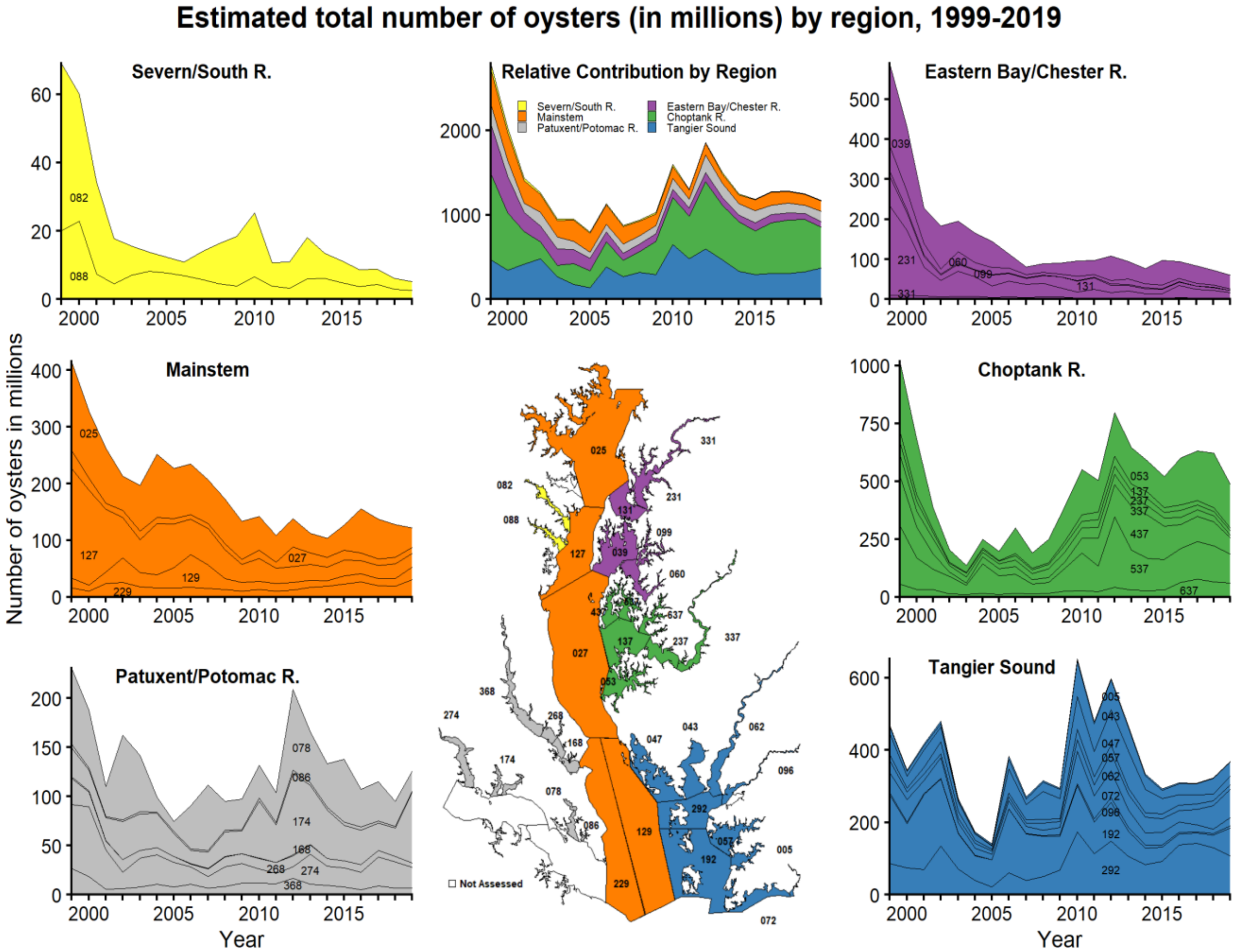

Figure 40. Estimated total (spat, small, and market) abundance of oysters (in millions) by region, during 1999-2019. Trends in abundance are presented by NOAA Code within six regions. The regions are displayed on the map as well as the NOAA Code locations. Note that years indicate the beginning of the fishing season (2019 refers to the 2019-2020 season).

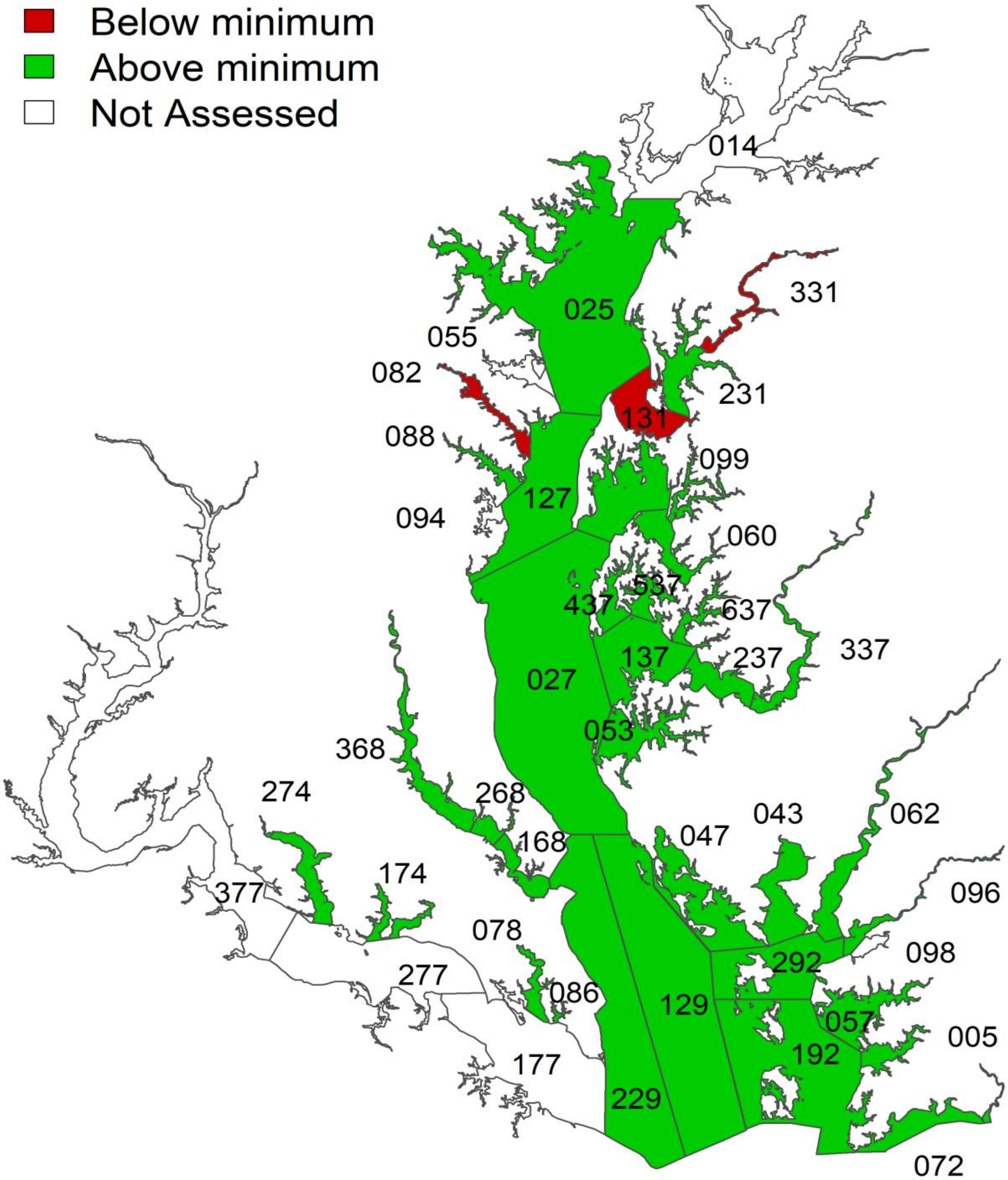

Figure 41*.* Status of market oyster abundance in the last year of the assessment (2019) relative to the lower limit reference point, which is the lowest estimated abundance during 1999-2017 for each NOAA Code. Note that years indicate the beginning of the fishing season (2017 refers to the 2017-2018 season).

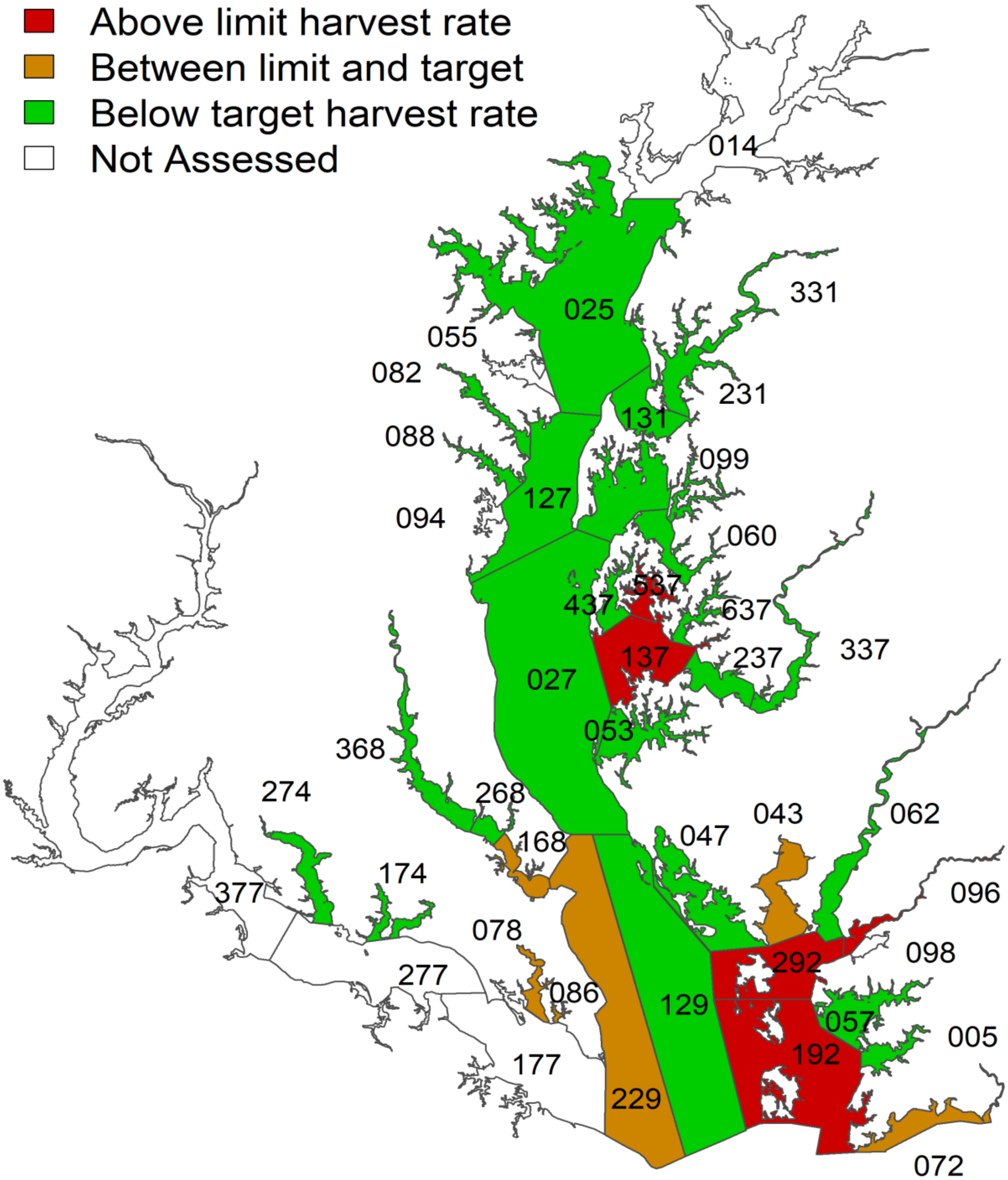

Figure 42. Estimated harvest fractions compared to target (U_{MSY}) and upper limit (U_{limit}) reference points for the 2019-2020 season by NOAA Code. The estimates of harvest fraction have been adjusted for planted spat.