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New Jersey Agricultural Experiment Station

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Final Report

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Abbreviations Used in this Report

Dermo	A parasitic oyster disease caused by the protozoan, *Perkinsus marinus*
HM	High Mortality region
HSRL	Haskin Shellfish Research Laboratory
LM	Low Mortality region
LPUE	Landings per unit effort
MMM	Medium Mortality Market region
MMT	Medium Mortality Transplant region
MSX	A parasitic oyster disease caused by the protozoan, *Haplosporidium nelsoni*
NJDEP	New Jersey Department of Environmental Protection
SARC	Stock Assessment Review Committee
SAW	Stock Assessment Workshop
SR	Shell Rock region
VLM	Very Low Mortality region
WP	Weighted prevalence, a measurement of the intensity of dermo

I. HISTORICAL OVERVIEW

The Population

The natural oyster beds of the New Jersey portion of Delaware Bay, managed to support the oyster fishery, stretch for about 28 miles from Artificial Island at the upper end of the Bay to Egg Island midway down the Bay, and cover approximately 16,000 acres (Figures 1 and 2). From upbay to downbay, oysters on these beds experience increasingly higher salinity that generally corresponds to higher rates of growth, predation, and disease. The standing stock has fluctuated between 1 and 10 billion animals since 1953 with two outlier years exceeding 30 billion animals in 1973 and 1974.

The long-term dynamics of the surveyed population can be divided into several periods of high or low relative mortality, generally corresponding to periods of high or low levels of disease intensity (Figure 3a). MSX disease, caused by the parasite *Haplosporidium nelsoni* became a significant periodic source of mortality in 1957 (Ford and Haskin 1982) but has been of little consequence following a widespread epizootic in 1986 and subsequent spread of resistance through much of the stock thereafter (Ford and Bushek 2012). From 1969-1985, MSX and mortality were low, and oyster abundance was high. Around 1990, dermo disease, caused by the parasite *Perkinsus marinus* became prevalent in the Delaware Bay and effectively doubled natural mortality rates (Powell et al. 2008b). It has been a major control on the oyster population in the Delaware Bay since 1990 although mortality began declining after 2012 and has since remained lower (Figure 3a).

Throughout the time series, fishing has usually taken a small fraction of the stock compared to natural mortality (Figures 3a, b). Indeed, the whole-stock fishing mortality rate has fluctuated little since the inception of the Direct Market Fishery in 1996, hovering around 2% (Figure 3b).

In addition to disease and fishing, habitat has played a key role in driving the historical population dynamics. Oysters create their own habitat and shell, whether as natural reef or planted, is critical to oyster population stability and growth (Abbe 1988, Powell et al. 2006). Moreover, oyster shell is not a permanent resource (Mann and Powell 2007). Chemical, physical, and biological processes degrade shell over time (Powell et al. 2006). The circular nature of the relationship between oysters and the habitat they create makes monitoring and enhancement of the shell resource critical to sustainable management (Powell and Klinck 2007; Powell et al. 2012b). For this reason, shellplanting has been employed throughout the time series when funding is available to enhance recruitment (Figures 4a, b). Shellplanting is an important management activity that adds clean substrate to oyster beds. In the Delaware Bay, it has been practiced with varying regularity and intensity throughout the Assessment Survey time series with the volumes of shell planted usually dependent on available funds (Figure 4a). Earlier programs planted large volumes of oyster or clamshell on NJ oyster beds, particularly in the 1960s and 70s. Efforts since 2003 have primarily used clamshell (quahog and surf clam), a by-product of local clam processing plants.

The Fishery

From the 19th century to 1996, the natural oyster beds of New Jersey were used as a source of young oysters (seed) that were transplanted to private leases each spring; a practice called 'Bay Season' (Ford 1997). Bay Season occurred over a period of months in the earliest days but over time, it was shortened to weeks to prevent overharvesting. From about 1953 to 1996, this transplant fishery was nominally managed by a loosely applied reference point called the "40% rule" that closed beds when the percentage by volume of oysters in a dredge haul went down to 40% (Ford, 1997). Other factors such as spat set and economics were also considered in making management decisions (Fegley et al. 2003). There were years of Bay Season closures due to MSX and dermo mortality in the 1950's, 60's, 80's, and early 90's (Figure 5).

In response to the increased number of Bay Season closures and the persistent high mortality of oysters transplanted to leased grounds, a Direct Market Fishery was created for the natural oyster beds in 1996. Studies indicated that the impact of dermo decreased as salinity decreased and the twenty-three beds were grouped into six Management Regions that follow the estuarine salinity gradient of the Delaware Bay. Each region was named to reflect its mortality rates and industry use of the oyster resource (Figure 1). The upper 3 regions (VLM, LM, MMT) are Transplant Regions and contain oysters that are often too small for market or of insufficient quality to market directly. These are used for a management activity termed "intermediate transplant" to enhance abundance on the lower three regions (MMM, SR, HM) called the Direct Market Regions. On these lower regions, market-size oysters may be taken directly to market without first being transplanted to leased grounds as previously required although the harvesters may choose to replant them on leases. A regional quota-based system designed to sustain the abundance of oysters on each of the six regions is now in use. Once moved, the larger oysters from the Transplant Regions quickly attain market quality and enhance the quota in the receiving region while smaller oysters supplement recruitment to the recipient bed. This system of area management was instituted to make use of the whole resource and to avoid overfishing of any one region (see HSRL SAW reports 2001 to 2005[1]).

From 1996-2000, direct market harvest generally occurred in two phases, each lasting 7 to 15 weeks during April-June and September-December. Since 2001, the harvest generally begins in

[1] HSRL SAW reports are archived at https://hsrl.rutgers.edu/documents/

early April and runs through late November. The intermediate transplant that moves seed from the Transplant Regions to the Direct Market Regions generally occurs in late April or early May.

The total direct market harvest quota is divided equally among 80 licenses. Through 2009, each license was tied to a separate harvesting boat with a limit of one license per vessel. In 2010, rules were changed to allow a single boat to fish on up to 3 licenses. In 2014, this was changed again to allow up to 6 licenses per harvesting boat. Further consolidation in 2023 allowed a single harvest boat to carry up to 10 licenses. This consolidation benefited harvesters because they no longer needed to maintain and work all boats during the season. It has also helped manage the resource by keeping large boats maintained and working – vessels that are also needed to effectively operate the intermediate transplant program and other management activities.

The Assessment Survey

The oyster beds on the New Jersey side of Delaware Bay have been surveyed regularly since 1953, initially in response to industry observations of low oyster abundance (Fegley et al. 2003). The Assessment Survey methodology has changed over time as summarized herein, including the number of beds surveyed and their groupings (Table 1).

Survey timing and sampling gear. From 1953 through 1988, the annual oyster Assessment Survey was conducted from a small Rutgers research vessel using a small dredge and occurred over several months in the fall, winter, and spring. In 1989, sampling was switched to a large traditional oyster boat, the *F/V Howard W. Sockwell,* using a 1.27m commercial dredge and sampling was completed in a few days. Annual sampling now occupies up to five days between mid-October and mid-November.

Size definitions for oyster and spat. Prior to 1990, oysters were not measured but were categorized as “spat”, “yearling”, and “oyster” based on morphology. After 1990, yearlings and oysters were measured to allow biomass estimates. Spat were still classified based on morphology[2] and were not measured. In 1998, size frequency estimates included all individuals ≥ 20 mm regardless of morphology but abundance estimates continued to be based on morphological categories until 2002. From 2003 on, spat were defined as any individual < 20 mm, such that total “oyster” abundance estimates include all individuals ≥ 20 mm. The “oyster” category is further sub-divided into “markets” and “sub-markets” based on the minimum legal harvest size of 63.5 mm (2.5 inches).

[2] Spat have a thin flat morphology whereas yearlings show inflation between the valves.

Capture efficiency and catchability coefficients. Measurement of survey swept area and experiments to determine gear efficiency began in 1998 to allow estimates of oyster density on each sampled grid (Powell et al. 2002, 2007). To estimate dredge efficiency, divers sampled quadrats placed alongside a dredge path removing everything within the quadrat. Catchability coefficients calculated from these experiments began being applied to correct for dredge capture efficiency and calculate density in 1998 (Table 2). Work from 1999 to 2003 to establish catchability coefficients for the oyster beds in Delaware Bay is described in Powell et al. (2002, 2007). Analyses revealed a differential in dredge efficiency between the upper (above Shell Rock) and lower oyster beds. Additionally, on average, the dredge caught oysters with greater efficiency than boxes, and boxes with greater efficiency than cultch. Concerns about the effect that natural benthic changes over time might have on dredge efficiency led to the application of different sets of catchability coefficients being applied to different parts of the Assessment Survey time series (Table 3 in Ashton-Alcox et al. 2016). In September 2013, dredge efficiency experiments were repeated using the F/V Howard W. Sockwell and a commercial dredge, but instead of divers for the 100% efficiency numbers, patent tongs on the R/V Baylor were used (Morson et al. 2018). Spatial and temporal analyses compared the 2013 patent tong experiments to the 1999, 2000, and 2003 dredge-diver experiments (Morson et al. 2018). These updated analyses showed no statistically significant temporal trend in gear efficiency. Thus, the 2016 SARC advised that data from all experiment years be averaged together within bed groups and applied to the entire time series (Ashton-Alcox et al. 2016). The 2016 SARC also advised adoption of updated bed groupings (Table 2). Finally, in addition to the influence of region, data collected during the three separate experiments suggested that capture efficiency was density-dependent (Morson et al. 2018; Figure 6). Therefore, the continued recommendation of the SARC since 2016 is to re-evaluate capture efficiency when possible, including whether other forms of sampling (e.g., patent tongs) could be used in tandem with the survey dredge during the Assessment Survey to estimate capture efficiency each year.

<u>Science Advice:</u> Evaluate whether it is feasible to collect dredge efficiency estimates during the Assessment Survey

> *Dredge efficiency experiments were conducted in tandem with the 2025 Assessment Survey. The amount of time required to collect tong samples relative to dredge samples as well as weather delays prevented all tong samples from being collected on the same day as dredge samples for a given site. A total of 20 sites were sampled using a commercial dredge aboard the F/V Howard W. Sockwell and patent tongs aboard the R/V James Joseph. Three dredge tows were taken per site, and ten tong grabs were collected parallel to the path of each tow. Effort was focused on beds in each of the Direct Market regions: Ship John in the MMM region, Shell Rock in the SR region, and Nantuxent, Bennies Sand, and Bennies in the HM region. Data collected for both dredge and tong samples included*

sample composition (volumes of oysters, boxes, and cultch), counts and size frequencies of oysters and boxes, position data, and area sampled. Data analyses are in progress.

***Retrospective reconstruction of the time series*.** In 2005, by request of the 6th SARC, the Assessment Survey time series from 1953 to 1997 was retrospectively reconstructed. For a complete explanation of the time series reconstruction, see Powell et al. (2008b). In brief, survey samples were divided into volumes of oysters and cultch, and oysters per bushel[3] were calculated throughout the time series. The survey was quantified in 1998 using measured tows and dredge efficiency corrections, permitting estimates of oysters and cultch per m^2. Using the assumption that cultch density is relatively stable over time, oysters per m^2 for each survey sample can be estimated using the relationship between oysters per bushel and cultch per bushel in a sample and the relationship between the cultch per bushel and the average cultch density for each bed (see equation 3 in Powell et al. 2008b). Cultch varies with input rate from natural mortality, and the temporal dynamics of this variation are unknown for the 1953-1997 timeframe. An understanding of the shell dynamics on Delaware Bay oyster beds, however, indicates that shell is the most stable component of the survey sample supporting the assumption that a two-fold error is unlikely to be exceeded.

Survey sampling domain and strata definitions. Prior to 2005, each bed was divided into three strata based on oyster abundances. Grids of 0.2-min latitude x 0.2-min longitude were created for the primary beds and approximately 10% of them were sampled based on a stratified random sampling design (Fegley et al. 2003). On each bed, grids with “commercial” abundances of oysters ≥ 75% of the time were called “high”; grids with marginal or highly variable “commercial” densities of oysters 25-75% of the time were called “medium”; grids with abundances well below commercial densities were called “low” (HSRL personnel; Fegley et al. 1994). Non-gridded areas between beds were never included in surveys. Information from oystermen in the early 2000s indicated that harvesting between beds was not uncommon. Therefore, from 2005 to 2008, the grid overlay was increased to cover all areas from the central shipping channel to the New Jersey Delaware Bay shoreline with every grid assigned to an existing bed. In 2007, an HSRL survey investigated the upbay extent of the New Jersey oyster resource based on bottom sediment mapping conducted by the Delaware Department of Natural Resources and Environmental Control and provided by B. Wilson (2007, personal communication). This survey resulted in the addition of three more beds termed the Very Low Mortality region (VLM) into the stock assessment (Figure 1). Earlier data for the VLM are not present in the survey database; therefore, reconstruction of its 1953-2006 time series is not possible.

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[3] The NJ bushel volume is the same as a US or DE bushel: 35 L; MD and VA bushels are larger (46 and 49 L respectively)

From 2005-2008, all oyster beds were resurveyed except Ledge and Egg Island which have low oyster abundance with survey averages < 0.5 oysters per m^2. This resulted in a change of strata definition and survey design from that used historically (Kraeuter et al. 2006). The restratification kept the three strata system within beds and used oyster densities to determine High, Medium, and Low strata. Since 2002, a fourth "Enhanced" stratum exists to temporarily identify grids that receive shellplants or transplants. A rotating schedule restratifies each bed approximately once per decade (Table 3, Appendix A). Analysis of many survey simulations suggested that a random survey based on High and Medium quality strata is sufficient for stock assessment (Kraeuter et al. 2006).

Through 2004, the Assessment Survey sampled most beds yearly although a selection of beds was sampled every other year. Since then, all beds have been sampled each year, except Egg Island and Ledge, which are sampled every other year. As of 2007, there are 23 surveyed beds grouped into six regions designated by their relative oyster mortality and the current management scheme (Figure 7). Prior to 2007, the three beds at the upbay limit of the oyster resource (VLM region) were not included in the survey, thus the first 12 years of the Direct Market time series and all of the retrospective analyses exclude them.

The Assessment

Management of the NJ Delaware Bay oyster fishery and the annual stock assessments for the oyster resource since 1999 include the participation of scientists from Rutgers University (HSRL), the NJDEP's Bureau of Marine Habitat and Shellfisheries, members of the oyster industry, external academics, and resource managers (Table 4). The SARC is made up of nine members as follows: one member of the Delaware Bay section of the NJ Shellfisheries Council (Shellfisheries Council); one from the NJ oyster industry; two NJDEP members; one from the Delaware Department of Natural Resources & Environmental Control (DNREC); two outside academics; one outside resource management representative; and one non-HSRL Rutgers University representative. Appendix B lists SARC participants since the first SAW in 1999. The SAW is held annually over 1-2 days in the first half of February at HSRL following the October-November Assessment Survey and subsequent sample processing and data analyses.

Information available to the SARC to make recommendations includes reporting on the status and trends of the stock, an estimate of current abundance relative to biological reference point targets/thresholds for each region, regional summaries, and a stoplight diagram representing the overall condition by region. The latter includes abundance, mortality, an index of recruitment, and trends in oyster disease (specifically dermo) which has been a leading cause of oyster mortality since 1990. Control rules (management guidelines) that had been implicitly used at every SAW were articulated at the 18th SAW in 2016 (Table 5).

Discussion of stock status and recommendations from the SARC regarding the assessment, resource management, and quota allocation are reported to the Shellfisheries Council on the first Tuesday in March. The Shellfisheries Council then makes decisions about the direct market quota and any transplant and/or shellplant activities, the cost of which is borne by the industry via their self-imposed "bushel tax" supplemented, when possible, with State, Federal or other external support that may be available. Decisions are finalized by the NJDEP, including those made about harvest dates and area management schedule.

II. CURRENT METHODOLOGY

Bed Stratification and Resurveys

Beds are stratified by mortality region as described above and then grids within a bed are stratified by relative density within each bed (Figure 7). Each bed that makes up the assessed population is completely surveyed for restratification on a rotating schedule at least once per decade (Table 3, Appendix A). The current stratification method is based on ordering grids within beds by oyster abundance. Grids with the lowest oyster densities that cumulatively contain 2% of a bed's stock are relegated to the "Low Quality" stratum. This includes grids with no oysters. Those that cumulatively account for the middle 48% of a bed's stock are designated "Medium Quality" and the rest that cumulatively account for the upper 50% make up the "High Quality" stratum. The Enhanced stratum includes transplant- or shellplant-receiving grids specifically sampled for a few years after which the grid returns to its original stratum until it is restratified.

Assessment Survey Design

The complete extent of the natural oyster resource extends across 23 traditionally named beds, each of which is divided into grids of approximately 10 hectares (25 acres) defined by 0.2-min lines of latitude and longitude (Figure 7). During the annual Assessment Survey, a random subset of grids is sampled from the high and medium quality strata on each bed to estimate abundance (e.g., Figure 15). Resources limit sampling to about 250 grids. Oyster density varies along the salinity gradient, within beds, and within strata, therefore, sampling effort is allocated statistically to maximize the accuracy of abundance estimates. Prior to 2021, simulations using the most recent resurvey data estimated the strata variance (for a given number of sampled grids) to determine how many grids to sample within a given stratum on each bed. The number of grids was set by determining when increasing the number of sampled grids no longer appreciably reduced the variance around the estimate. However, at the 2019 SARC, a Science

Recommendation was made to evaluate whether alternatives for allocating survey effort might provide a better estimate of abundance by reducing overall survey error. After alternative methods were presented to the 2020 and 2021 SARCs, the 2021 SARC recommended adopting the Neyman optimal allocation formula for allocating survey effort going forward with the stipulation that a minimum of two grids be sampled within each stratum (high or medium) on each bed (Kimura and Somerton 2006; Morson et al. 2021). This method is applied to each stratum on each bed and concentrates effort toward higher density grids. In addition, grids that receive transplant or shellplant enhancements are sampled consecutively for two or three years respectively following the enhancement activity.

The survey dredge is a standard 1.27-m commercial oyster dredge towed from either port or starboard. The on-bottom distance for each one-minute dredge tow is measured using a GPS that records positions every 1 to 3 seconds. A one-minute tow covers about 100 m^2 and usually prevents the dredge from filling completely thus avoiding the "bulldozer" effect. The entire haul volume is recorded. If the haul is 7 bushels or larger (a full dredge), the haul is not counted, and the tow is redone at a duration of 45 seconds. Three tows are taken for each sampled grid, and a $^{1}/_{3}$-bushel subsample is taken from each haul to create a composite 37-quart bushel[4].

Each composite bushel sample is processed to quantify the following: volume of live oysters, boxes, cultch, and debris; number of spat, oysters and boxes; and sizes of oysters[5]. Separate oyster samples are collected from each sampled grid and processed for condition index, the intensity of dermo and MSX infections. As was described in the Historical Overview section, the term oyster refers to individuals ≥ 20 mm (> ¾ in) in longest dimension while the term spat refers to those < 20 mm. Market-size oysters are defined as those ≥ 63.5 mm (≥ 2.5 inches). Using total counts per bushel, total bushels per tow, and swept area per tow, the raw density of spat, sub-market size oysters, market size oysters, and boxes are estimated for each sampled grid.

Estimating Abundance of Oysters, Boxes, and Spat

To obtain the annual estimates of abundance for each region, the randomly chosen grids from the high and medium quality strata from each bed in the region are sampled as described above to generate a relative estimate of the numbers per m^2 (or density) on each grid of spat, oysters, and boxes. Catchability coefficients (Table 2), estimated by dredge efficiency experiments (see "Capture efficiency and catchability coefficients" section above), are applied to the relative density estimates to calculate corrected density estimates for each grid. The corrected-density estimates for all sampled grids within a stratum on a given bed are then averaged to generate

[4] The New Jersey standard bushel is 37 quarts (~35 liters).
[5] Box measurements were only collected from 1998 until 2019.

stratum-specific density estimates for each bed. These estimates are then multiplied by the area of each stratum to generate the total abundance per stratum on each bed. Strata-specific abundances are summed across beds and beds are summed across regions to generate the annual estimate of abundance in a region. The quantitative point estimates of abundance in this report include the High quality, Medium-quality, and Enhanced strata only. Low-quality areas are excluded as described earlier.

Estimating Survey Error

Two potential sources of error associated with the annual abundance estimates for each region are accounted for by estimating the uncertainty using bootstrap simulations. The first source of error is variability in oyster density within each stratum, the survey error. The second is variability in the estimate of the catchability coefficient being applied to the relative oyster density measured on each grid, the dredge efficiency error. Uncertainty around the survey point estimate is calculated by conducting 1,000 simulated surveys, each with a selection of samples from each stratum on each bed and each corrected for dredge efficiency by a randomly chosen value from all efficiency estimates available within a bed's dredge efficiency group. Samples are selected from sites sampled for the Assessment Survey in the last ten years. For each simulation run, sites and efficiency estimates are resampled with replacement. Error in this report is expressed as the 10^{th} and 90^{th} percentiles of these simulated distributions.

Exploitation Rate Calculations and Reference Points

Exploitation, or the fraction of the stock removed in a year by fishing, is calculated for each region on both total and market-sized oyster abundances for each year. The calculation of exploitation on total oysters in Transplant Regions is done in five steps:

1. Calculate the average number of total oysters (>20mm) per bushel (from the spring transplant monitoring program) moved from each donor bed in the current year.
2. Determine the total removals from a given donor bed by multiplying the average number of total oysters per bushel on that bed by the total bushels moved from it.
3. Calculate total removals by region by summing all removals from donor beds in each region.
4. Subtract the total number of oysters transplanted to each region in the current year from this total number of removals to get total net removals by region.
5. Divide the total number of oysters removed for a given region by the total abundance in that region from the previous year's Assessment Survey.

These steps are repeated for exploitation on market oysters (panel "f" of Figures 18-20) using the average number of market sized oysters per bushel (Step 1) to calculate removals (Steps 2-3) and the previous year's market abundance to calculate the removal rate (Step 4).

The calculation for exploitation of market size oysters on Direct Market Regions is more complicated than it is on Transplant Regions because (1) an adjustment needs to be made for any region that received oysters during the transplant program, and (2) the calculation is based on market size oysters instead of all oysters. For the Direct Market Regions, market size exploitation rate is calculated in seven steps:

1. Calculate the average number of market sized oysters per harvested bushel (estimated from the Dock Monitoring Program and includes attached and smalls) from each direct market regions in the current year.
2. Multiply this average by the total catch in bushels in each market region to get total catch by region.
3. Calculate the proportion of oysters in each 0.5-inch size bin for each region from the size frequency data collected during the Dock Monitoring Program.
4. Distribute the total catch in numbers across the size frequency by region to get total numbers of oysters caught in each size bin by region.
5. Sum the numbers of oysters from all size bins 2.5 inches and above to get total numbers of markets removed by fishing in each region.
6. Subtract the total number of market sized oysters transplanted to each region in the current year from this total number of removals to get total net removals by region.
7. Divide this number by the total market size abundance in each region from the previous year's Assessment Survey.

These steps are repeated for exploitation on total oysters (panel "f" of Figures 21-23) using the average number of total oysters per bushel (Step 1) to calculate removals (Steps 2-5), the total number of oysters transplanted (Step 6), and the previous year's total abundance to calculate the removal rate (Step 7).

The process described above was used to calculate the exploitation history of the fishery since the inception of the Direct Market and in 2006, the SARC advised adoption of a quota system with exploitation rates based on the 1996-2005 section of this history (later extended to 2006). These rates, herein referred to as **Exploitation Reference Points**, were thought to be from a period of conservative fishery management during a time of persistent, high disease pressure and were therefore deemed likely to provide conservative management goals. Initially, the 2006 SARC suggested reference points based on each Management Region's median (50^{th} percentile) exploitation rate. To provide flexibility in management, the SARC recommended using the 50^{th} percentile of exploitation as a base but to allow increasing exploitation to the 60^{th} percentile rate when the population was expanding or to reduce it to the 40^{th} percentile rate if the population was decreasing or appeared unstable.

Fishing activity during the 1996-2006 base time series was concentrated on the more downbay regions of the stock with limited data for the Transplant regions (MMT and LM) and none at all for the VLM since it did not enter the assessment until 2007. Data were so sparse for the Transplant Regions that it was decided they should share the same set of exploitation rates. Because the exploitation percentiles were based on only eleven years of fishing data, they did not always transition linearly. Therefore, the 2009 SARC made an adjustment to the original set of Exploitation Reference Points for the Transplant Regions in order to smooth a temporally biased change in exploitation rates at the 50th percentile that separated as high and low. The 50th and 60th percentile values from the original data were averaged. That average was used as the 50th percentile and the previous 50th percentile was then used as the 40th. Transitions between exploitation rates for the Direct Market Regions were similarly irregular. For example, in the HM, the change from the 40th to 50th percentile spanned a much larger range of exploitation rates than that of its 25th to 40th percentiles whereas SR's 40th and 50th percentiles were nearly identical. Consequently, if market-size oyster abundance was low on SR and other parameters were not promising, the choice for conservative exploitation was constrained to fishing below the 40th percentile.

The 2015 SARC specified a desire to have more regular changes between exploitation rates within each region. The 2016 SARC examined realized fishing exploitation rates since the adoption of the 1996-2006 baseline time period (i.e., 2007-2015) and concluded that the median of the realized exploitation rates from 2007-2015 should be used as an exploitation target for each region going forward and that the target rate should be bounded by the range of realized rates from that period. This change from the previous Exploitation Reference Points to the new Exploitation Rate Reference Points is visualized in Figure 8. Further, the 2016 SARC agreed to allow percentage changes in either direction from no harvest up to the 2007-2015 maximum exploitation rate depending on stock status for each region.

SARC Exploitation Recommendations and Quota Projections

Each year the SARC makes a recommendation for a maximum allowable exploitation rate at or below the maximum of the 2007-2015 rates as described above for each of the six Management Regions. This recommendation is presented to the Shellfisheries Council which then selects the exploitation rate to be applied on each region for the upcoming season. The Shellfisheries Council selection is then sent as a recommendation to the Commissioner of NJDEP. The total allowable quota is then the sum of the calculated bushels resulting from the exploitation rate chosen for each Direct Market Region (plus any additional quota as a result of transplants from the Transplant Regions to the Direct Market Regions). This total allowable quota is then equally allocated across 80 commercial oyster licenses. To estimate the total allowable quota from the SARC recommended exploitation rates, oysters in numbers are converted to projected catch in bushels using a grand mean of the average total oysters per landed bushel per year and the average market oysters per landed bushel per year from the Dockside Monitoring program time series (2004 to present). The SARC expressed interest in exploring region-specific conversions for comparison (see Section VI. Science Advice). The rationale for using the grand mean is that the number of attached small oysters will vary between years depending on recruitment dynamics.

III. 2025 STATUS AND TRENDS

2025 Dockside Monitoring Program and Trends in Catch Composition

The Dockside Monitoring program counts and measures oysters at dockside from boats unloading direct market harvest. The results are used in the assessment to determine size frequency of the catch and harvested numbers per bushel so that beds can be appropriately debited, and exploitation rates can be determined (see section on "Exploitation Rate Calculations and Reference Points"). The overall average number of oysters per landed bushel in 2025 was 307 and the average number of market sized oysters per landed bushel was 246 (Figure 9). The grand mean for all years, used to convert targeted removals in oysters to projected quota in bushels (see section on "SARC Exploitation Recommendations and Quota Projections") was 271 oysters in both 2024 and in 2025.

Landings per unit effort (LPUE) represent the number of bushels landed per hour of fishing. The number of hours worked, beds fished, and bushels landed are calculated from the compilation of daily and weekly captain reports as well as dealer records. Although data reported were effectively the same, prior to 2016 LPUE was erroneously labelled CPUE (see explanation in the 2017 SAW report) and assumed an eight-hour day. In this report, LPUE is reported separately for single and dual dredge boats using actual hours of fishing time. Dual dredge LPUE increased by approximately 11% in 2025 to 30 bushels landed per hour (Figure 10). Only one single dredge vessel operated in 2025 so single dredge LPUE is not reported. The number of harvest vessels decreased in 2023 due to license consolidation and has remained constant at 11 vessels with one new dual dredge vessel replacing a single dredge vessel in 2025 (Figure 10). License consolidation is just one factor that may influence changes in LPUE on the direct market beds. Other factors include changes in market-sized or total oyster abundance, seasonal limits on harvest time dictated by *Vibrio* control rules, shifts in population size structure, and even changes in vessel captains with more or less experience or skill. It is difficult to determine the influence of these factors on catch rates, and it is most likely a changing combination of them that drives trends in LPUE from year to year and over time.

The size frequency landed by the fishery is more or less representative of the size frequency of the surveyed population (Figure 11). The frequency of oysters just below market size (1.5-2.5-

inches) within the population increased in 2024 and to a lesser degree in 2025. These smaller size classes appear in fishery landings as small oysters attached to market-sized oysters (Figures 9, 11). Larger oysters (≥ 3.5 inches) represented 23% of all market-sized oysters landed in 2025, similar to 2024 (24%). Within the population, these larger individuals made up 28% of all market-sized oysters (Figure 12).

2025 Catch Statistics and Fishery Exploitation

Table 6a describes the 2025 SARC recommendations, the Shellfisheries Council decisions, and the achieved exploitation rates of market-sized oysters from the Direct Market Regions. To be harvested at their maximum rates, all regions (MMM, SR, HM) required a transplant and each region received a transplant as described below in "2025 Enhancement Efforts". Achieved exploitation rates on all three market regions were lower than those approved by the Shellfisheries Council.

The 2025 direct market harvest occurred from April 7 to November 28 and included a period of curtailed harvest hours from June 1 to August 31 to comply with New Jersey's FDA-approved *Vibrio parahaemolyticus* Control Plan.[6] One single- and ten dual-dredge boats fished ten of the 14 beds comprising the Direct Market Region during the 2025 season (Table 6b). The total direct market harvest in 2025 was 72,799 bushels, a 9.5% increase from 2024 (Table 6a). Both the 2024 and 2025 harvests fell below the long-term Direct Market Fishery average (84,219 bushels) and were similar to harvests that occurred before 2007 (Figure 13). Harvest from the three Direct Market Regions broke down as follows: 51% from the HM; 27% from SR; and 22% from the MMM (Table 6b). Within the HM and MMM regions, harvests were unevenly distributed across beds. Bennies Sand accounted for 30% of the total harvest and ~60% of the HM harvest (Table 6b) while 82% of the MMM harvest came from Ship John. Harvest on the HM region was distributed across more beds in 2025 than in 2024 (Table 6b) which represents a management initiative to spread the harvest out across beds that have not been routinely worked in recent years (e.g. New Beds, Hog Shoal, Ledge).

Across all regions excluding the VLM, fishing harvest was 1.20% relative to total oyster abundance and 3.90% relative to market-sized (≥ 2.5") oyster abundance (Figure 14). These rates are consistent with the exploitation rates achieved since the inception of the direct market fishery in 1996 and remain low relative to natural mortality that has ranged from about 7 to more than 30% during the Direct Market Fishery era (Figure 3a, 1996 onward). Bed-level exploitation rates can be found in Appendix J.

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[6] See New Jersey's FDA-approved *Vibrio* Control Plan here:
[NJDEP and NJ DOH 2025 Vibrio Control Plan]

2025 Enhancement Efforts

Intermediate Transplant. Table 7 describes the 2025 SARC recommendations and the Shellfisheries Council decisions for Transplant Region exploitation rates as well as the estimated and realized number of oysters moved based on the chosen rates. A transplant occurred in late April and early May 2025 from Upper Arnolds and Arnolds in the LM region to Bennies in the HM region and to the SR region and from Middle in the MMT region to Cohansey in the MMM region and to the SR region (Table 8). A transplant from the VLM region to Sea Breeze in the MMT region also took place. A transplant to the MMT region was required in order to transplant oysters off the region at the maximum exploitation rate (Table 7a).

The LM transplant moved 37,650 bushels, resulting in an achieved exploitation rate of 5.22% that slightly exceeded the 5.00% limit (Tables 7 and 8). The 2025 SARC recommended that the LM region could be fished at a rate of up to 5.00% which exceeds the maximum rate established by previous SARCs for sustainability. This flexibility is permitted by Control Rule 5 which states "*strong justification is required for movement above these bounds since they have proven sustainable for the fishery*". Increasing the exploitation rate above the established maximum was a one-time singular decision and does not represent a new maximum exploitation rate (see Sections IV and V of the 27th SAW Report for full details). The MMT transplant moved 11,275 bushels, resulting in an achieved exploitation of 2.66% that was also slightly above the 2.46% limit (Tables 7 and 8). The 2025 VLM transplant moved 8,875 bushels and resulted in an achieved exploitation rate of 3.31% (Tables 7 and 8) exceeding the approved rate of 2.26%. Overall, the 2025 transplant added 9,925 market-equivalent bushels to the quota (Table 6a), representing 13.6% of the final quota. Appendix C provides a detailed history of transplant activities.

<u>Science Advice</u> Closely monitor the proposed removals and observed benefits of the LM transplant

> *Upper Arnolds and Arnolds in the LM region were resurveyed in mid-June 2025 approximately six weeks following the completion of a transplant from these beds at the elevated rate of 5.22%. Resurvey results indicated no immediate negative impacts to grid density on the beds. Bed-level data from the Assessment Survey in November 2025 indicated increases in point estimates of total and sub-market abundance on both Upper Arnolds and Arnolds (Appendices E and G). The point estimate of market abundance increased on Arnolds and remained relatively unchanged on Upper Arnolds (Appendix F).*
>
> *Approximately 30 million oysters were transplanted from Upper Arnolds and Arnolds in the LM region to two grids on Bennies in the HM region (Table 8). Despite the significant number of oysters transplanted to the bed, subsequent increases in point estimates of total, market, and sub-market abundance were not observed during the Assessment Survey (Appendices E-G). An initial theory regarding the apparent discrepancy between*

transplant effort and abundance estimates from the Assessment Survey may relate to dredge efficiency. Past dredge efficiency experiments showed that dredge efficiency is density dependent ("Capture efficiency and catchability coefficients" section and Morson et al. 2018). The addition of 30 million, mostly sub-market (Table 8), oysters to two grids on Bennies may have increased the density on these grids such that dredge efficiency on these grids may differ from the efficiency on the rest of the bed. Although previous experiments showed no size-selectivity of the dredge (Morson et al. 2018), the addition of that many sub-market oysters to a concentrated area of Bennies may still have affected dredge efficiency and subsequent abundance estimates on the enhanced grids. Weather-related changes in reef consolidation may also have had an effect on dredge efficiency. Discussions during the 2026 SAW indicated that weather conditions (i.e. high winds, decreasing temperatures) prior to sampling in mid-November 2025 may have hardened the bottom. Industry members confirmed that this bed is particularly sensitive to hardening during these conditions. Further close monitoring of the 2025 transplant sites on Bennies is required to fully evaluate the performance of the LM transplant on this bed.

Shellplanting. In 2025, there were three shell plants on NJ's Delaware Bay oyster beds funded by the NJ oyster industry through its self-imposed "bushel tax" and a resource enhancement allocation by NJDEP. A total of 120,584 bushels of crushed, unspatted clamshell were distributed to beds in three of the direct market regions (Appendix D). In the HM region, Bennies Sand received 38,779 bushels to enhance it following several years low recruitment (Appendix I). Ship John in the MMM region received 40,344 bushels and the Shell Rock region received 41,461 bushels. A formal evaluation of the increase in productivity that results from enhancement efforts (shellplanting and transplanting) was made in 2018 by comparing the change in oyster density on enhanced grids on Shell Rock to adjacent, non-enhanced grids on the same reef. Results from that analysis are in the 2019 SAW Report (Morson et al. 2019) and suggest that oyster density is, on average, 25 oysters per square meter higher on enhanced grids relative to adjacent, non-enhanced grids.

2025 Stock Status

At the 8th SAW in 2006, the SARC established target and threshold abundance reference points based on the 1989-2005 time series for total abundance and the 1990-2005 time series for market abundance for each region (Table 9). This period represented a range of oyster population dynamics under the climate and disease regime present in the Bay since the establishment of dermo disease in 1990. Targets for each region were therefore calculated as the median values of total and market-size oyster abundance and the threshold was calculated as half the target.

The only exception to this was on the VLM region where the time series begins in 2007. The 2017 SARC designated targets and thresholds for the VLM as the 75th and 50th percentiles respectively of its 2007-2016 time series (Table 9) but recommended these reference points be re-evaluated periodically. Following this recommendation, a workshop was convened in 2022 by the Oyster Industry Scientific Steering Committee (OISSC) to assess whether the abundance reference points designated for the VLM region in 2017 were still appropriate. The OISSC is made up of staff from NJDEP, HSRL, and members of the Oyster Industry and the Shellfisheries Council (Table 4). The OISSC unanimously supported retaining the current VLM abundance reference points (75th percentile as the target and 50th percentile as the threshold of its 2007-2016 time series). For the full workshop discussion, refer to Appendix J of the 25th SAW Report (Morson et al. 2023).

A total of 245 grids were sampled to estimate the status of the stock in 2025 (Figure 15). Total stock data do not include the VLM due to its shorter time series. Total population abundance has been steadily increasing since 2021, and at 2.2 billion, is now just below the target reference point of 2.3 billion (Table 9, Figures 16a, 17). Market-sized oyster abundance rose above the target in 2025 after falling below it in 2023 (Table 9, Figures 16b, 17). Spat decreased in abundance between 2024 and 2025 (Figure 16c) in all regions (panel e in Figures 18-23). Natural mortality increased slightly in 2025 (Figure 16d) but remains low relative to the current decade and the "dermo era" that began in 1990 (Figures 3a, 16d).

Transplant Region trends (point estimates). Figures 18-20 summarize the Direct Market era trends of the stock in transplant regions (VLM from 2007, LM and MMT from 1997). Bed-level abundances and mortality estimates can be found in Appendices E-I.

The uppermost region, VLM, reached the highest total abundance since it was first surveyed in 2007 and at 284 million oysters now sits at nearly twice the total abundance target (Table 10, Figure 18a). VLM total abundance has increased steadily and considerably in the years following massive die-offs due to prolonged influxes of fresh water in 2018 and 2019 (Figures 18a, 18d). Low disease and natural mortality, coupled with large recruitment events in 2022 and 2024, likely contributed to increases in both total and sub-market abundance in 2025 (Figures 18a-e). As in previous years, dermo remains nearly undetectable in this region (Table 10, Figure 18b) and outside of major freshets, natural mortality rates are low (Figure 18d). The slow growth rate in this region, however, keeps market abundance below targets and thresholds (Figures 18c, 24) that, as described earlier, were established with considerable uncertainty. A transplant from the VLM region at an exploitation rate of 3.31% did not appear to impact the trajectory of total abundance (Table 7a, Figure 18f).

Consecutive years of increasing sub-market abundance on the LM region along with continued low natural mortality have continued to increase total abundance on this region (Figure 19a, c, d). Total abundance at 750 million remained well above its target reference point of 392 million for a third year (Table 10, Figure 24). Similar to recruitment on the VLM, spat abundance on the LM region decreased in 2025 (Figure 19e). Dermo levels increased from 2024 but remain insignificant and well below levels that affect overall mortality of the population (Table 10, Figure 19b). The 2025 LM transplant resulted in a total exploitation rate of 5.22% for the region, more than double the rate from 2024 and above the 5.00% experimental rate approved during the 27th SAW (Table 7a, Figure 19f). Despite that, there was a 12% increase in sub-market oysters. A 3% increase in market sized oysters kept market abundance above its target value (Table 10, Figures 19c, 24).

Total abundance on the MMT increased by 49% to almost 350 million in 2025, closer to the target of 414.6 million (Table 10, Figure 20a). Both sub-market and market abundance increased in 2025, with market abundance moving definitively above its target reference point (Table 10, Figures 20c, 24). Spat abundance, however, was low following the bay-wide trend (Figure 20e). Dermo levels decreased in 2025 to fall back below the 1.5 threshold above which dermo begins to increase natural levels of mortality (Figure 20b). Although natural mortality increased on the MMT in 2025, it remains low relative to the Direct Market time series (Figure 20d). This region both donated and received transplanted oysters in 2025 (Tables 7b and 8). This resulted in a negative exploitation rate of -0.90% relative to total abundance (Table 7b, Figure 20f) as more oysters were added than removed from the region.

Direct Market Region Trends (point estimates). Figures 21-23 summarize of the stock in these regions for the Direct Market era (1997 to present). Bed-level abundance and mortality estimates for the Direct Market Regions can be found in Appendices E-I.

Total abundance on the MMM region increased by about 26% from 2024 to approximately 630 million as a result of increased sub-market abundance but remains below the target of 747 million (Table 10, Figures 21a, 21c, 24). Market abundance on the region increased by 35% to 150 million and is approaching its target reference point 175 million (Figures 21c, 24). The increase in sub-market abundance on the region is likely the result of a recruitment event in 2024. Increases in market and sub-market abundance may also partially be the result of a transplant to the region in 2025 (Table 8). Spat abundance decreased in 2025 to levels comparable to those observed in 2023 (Table 10, Figure 21e). While natural mortality was relatively unchanged from 2024, remaining below 10% (Figure 21d), dermo levels decreased below the 1.5 threshold and were similar to levels observed from 2020 to 2023 (Table 10, Figure 21b). In 2025, total fishing mortality decreased to 0.4% while market-size fishing mortality was 3.0%, similar to rates in previous years (Figure 21f).

A 15% increase in total oyster abundance on the SR region to 328 million, moved it above its target reference point of 313.6 million for the first time since 2020 (Table 10, Figures 22a, 24). Market abundance increased by about 20% in 2025 to well above the target (Table 10, Figures 22c, 24). Although spat abundance decreased on the SR region, sub-market abundance benefitted from a good recruitment event in 2024 increasing by 11% in 2025 (Figures 22c, e). This region has received annual transplants since 2021 and consistent shellplants since 2005 (Appendix D). Dermo levels on the SR region increased slightly from 2024 and remained above the 1.5 threshold (Table 10, Figure 22b). Natural mortality also increased on the region in 2025 (Figure 22d). Fishing exploitation relative to total abundance was -0.7% as a result of the transplants, and 4.39% relative to market abundance in 2025 (Figure 22f).

Unlike the other management regions, total oyster abundance on the HM region decreased from 2024 by about 24% to 118 million and remains below the threshold of 219 million as it has in most years since 2001 (Table 10, Figures 23a, 24). Abundance decreased in both sub-market and market sizes although market abundance remains above its target reference point (Table 10, Figures 23c, 24). As in all other regions, spat abundance decreased on the HM region in 2025 (Figures 23c, e). For the last decade, market abundance has exceeded submarket abundance on this region which was rare in prior years (Figure 23c). Dermo levels decreased from 2024 but remained just above the 1.5 threshold (Table 10, Figure 23b). Natural mortality was relatively unchanged in 2025, maintaining an overall long-term decline (Figure 23d). A significant transplant added over 30 million oysters to the HM region, resulting in a fishing mortality rate of -12% relative to total abundance (Table 8, Figure 23f). About 5% of the oysters transplanted to the region were market-size. Fishing exploitation relative to market abundance remained nearly unchanged between 2024 (9.3%) and 2025 (9.5%) (Figure 23f).

IV. SARC EXPLOITATION RATE AND AREA MANAGEMENT RECOMMENDATIONS

Upon review of the status of the stock, the 2026 SARC made the recommendations listed below and summarized in Table 11 for each management region. With total abundance on the VLM region in a strong position relative to its target reference point, the SARC recommended that it could be transplanted from at the maximum exploitation rate. There was general agreement that the LM region remains in good condition relative to its reference points and that it could sustain a transplant rate of 5.00% again this year, exceeding the region’s maximum rate of 2.26%. Total abundance on the MMT region sits between its target and threshold reference points while market abundance remains above its target. After some discussion, it was agreed that, despite its position relative to its reference points, the MMT region could be transplanted from at a rate of 3.5% with no requirement for a transplant to the region. A 3.5% transplant rate exceeds the MMT region's maximum rate of 2.46%. This change results in a potential removal of an additional 3.6 million oysters, a 42% increase in total removals, and an additional 2,400 estimated quota bushels.

Control Rule 5 permits flexibility in exploitation rates and states *"strong justification is required for movement above these bounds since they have proven sustainable for the fishery"*. Justification for exceeding the maximum transplant rate on the MMT region is as follows:

1. All Direct Market Beds are in need of enhancement to increase total abundance toward their target levels and to increase sub-market abundance.
2. Enhancement efforts are funded by the industry's self-imposed bushel tax and are therefore directly tied to the amount of total allowable catch. Increasing transplant rates beyond the maximum recommended rates supports an elevated harvest, and the SARC believes this elevated rate and harvest is likely to be sustainable, though cautioned careful monitoring is important to validate the belief. In turn, an elevated harvest would support more robust enhancement efforts on the Direct Market regions, leading to an increased ability to fund enhancement activities in the future. The opposite is also true – a reduction in harvest reduces funds collected to use for future enhancement efforts This conundrum highlights the need to explore augmented or alternative funding strategies.
3. This recommendation to exceed the maximum rates on the LM and MMT regions does not represent new maximum exploitation rates and must be monitored for impact to donor beds and performance on recipient beds. It was agreed that conditions are sufficient on the MMT to enhance abundance on HM where increases in overall abundance (and submarket abundance in particular) are crucially needed to support future productivity.

On the Direct Market Regions, the SARC recommended the median exploitation rate on each region if no enhancement occurs, but the maximum exploitation rate could be used on any region following successful enhancement, whether through shellplanting or transplanting. General consensus was to recommend that enhancement occur on all three Direct Market Regions. It was generally agreed that transplants should be focused on the HM region but there was little discussion as to what specific enhancement efforts should be directed to each Direct Market Region.

In summary:

- A transplant up to the maximum exploitation rate of 2.26% can be moved from the Very Low Mortality region. This transplant could potentially target the Shell Rock region.
- A transplant up to 5.00% exploitation rate can be moved from the Low Mortality region with the SARC acknowledging that this exceeds the maximum exploitation rate for the region and is only considered because abundances are well above target levels and there is a strong need to enhance abundance on market beds.
- The Medium Mortality Transplant region can be fished up to a 3.5% exploitation rate with no requirement for a transplant with the SARC acknowledging that this exceeds the maximum exploitation rate for the region and is a singular decision following the justification provided above.
- The Medium Mortality Market region can be fished up to its median exploitation rate (3.03%) with no requirement for enhancement. With enhancement, the exploitation rate could be increased to the maximum rate of 3.70%.
- The Shell Rock region can be fished up to its median exploitation rate (3.70%) with no requirement for enhancement. With enhancement, the exploitation rate could be increased to the maximum rate of 4.88%.
- The High Mortality region can be fished up to its median exploitation rate (7.49%) with no requirement for enhancement. With enhancement, the exploitation rate could be increased to the maximum rate of 9.82%.

V. STATEMENT OF SUSTAINABILITY

There has been general consensus by the SARC since 2017 that the New Jersey Delaware Bay oyster fishery is being managed sustainably although it does not fit the definition of sustainability used in the Magnuson-Stevens Act for federal fisheries which depends on population models and theory in the absence of strong empirical data on abundance and mortality. The Delaware Bay, NJ oyster stock assessment contains robust measures of abundance, natural mortality, and fishing mortality. Upon review of the oyster stock abundance, the exploitation time series, and management practices from 1996 to present, the 2026 SARC recommended continued acceptance of the following statement for the New Jersey Delaware Bay oyster fishery initially crafted by the 2017 SARC:

> The New Jersey Delaware Bay oyster fishery is likely to remain sustainable under current fishery management strategies and prescribed exploitation rates.

The sustainability statement was modified slightly with the addition of the phrase "likely to remain" in 2025 in response to the experimentally elevated exploitation rate for the Low Mortality region. The modification remains applicable based on the recommendations to uphold the elevated exploitation rate on the Low Mortality region and to increase the exploitation rate on the Medium Mortality Transplant region in 2026. The increased exploitation rates were based upon stock condition (Table 10 in this report and in Bushek and Gius 2025), an expectation that the elevated exploitation rates were likely to be sustainable under present conditions, and the need to increase abundance of oysters on harvest beds to both improve those beds via enhancement activities and to help sustain a viable quota for the economic needs of the industry. Reductions in the quota reduce funds generated from the industry-imposed bushel tax. This will reduce the flexibility of managers to respond to future resource conditions through enhancement efforts like intermediate transplanting via this source of funding, therefore stakeholders should pursue augmented and/or alternative funding to ameliorate funding reductions from the harvest-dependent bushel tax.

VI. SARC SCIENCE ADVICE

In addition to continuing the core assessment and monitoring programs, including the Assessment Survey, the Resurvey/Restratification Program, the Dock Monitoring Program, the Dermo
Monitoring Program, and the Shellplant and Transplant Monitoring Program, the 2026 SARC recommended the following list of science advice (not ordered by priority):

<u>2026 SARC Science Advice</u>

- Develop oyster per bushel numbers by bed or region. Current number per bushel is derived for entire harvest by dockside monitoring, but it typically varies such that there are fewer oysters per bushel in the lower bay beds.
- Look for impact signal (e.g. change in abundance) from the transplants on receiver areas. Attempt to evaluate this item broadly (e.g., all years, all regions, all beds). What is the delay in transplanted oysters reaching market size?
- Sample the Bennies 2025 transplant sites (grids 100 and 101) as soon as possible in the spring to verify transplant performance. Consider using a lined dredge to see if small single transplants were missed.
    - Determine pre-transplant density for future recipient transplant grids.
    - Sample the Bennies 2025 transplant sites with patent tongs in the early spring, mid-summer, and fall to better understand the success rate of enhancement efforts on this bed.

- Consider revisiting the feasibility of tow-specific dredge efficiency estimates.
- Reassess target and threshold reference points for all regions and reference point time periods for all regions (possibly with the exception of the VLM was thoroughly reevaluated in 2022). This might also provide some insight into the possible effects of “moving baselines” vs substantive changes in the bay due to climate change. Consider an analysis based on:
    - Use of different time periods (10,15, 20, 25 years)
    - Use of a different starting basis (1990-2006, 1991-2007, 1992-2008, 1993-2009 etc.)
- Develop a document on survey sampling methods that includes quality assurance components and site selection methods.
- Develop a methodology to determine the importance of sediment/oyster substrate hardness in sampling efficiency.
- It is apparent that there needs to be some sampling of spat set or a better measurement of spat set and recruitment into submarket and market size classes, particularly in the lower part of the seed beds. Consider adjusting definition of spat using previous analysis on spat size across season and size at shift from spat to adult morphology.
- Conduct a lab experiment investigating the survivorship of oysters transplanted from low to higher salinity at temperatures that mirror those during the season when the transplant takes place. Consider both a “short term” (a few weeks) and a “long term” (months) analysis.

<u>Prior SARC Science Advice to be addressed:</u>

- Establish a mass balance model of oyster population dynamics with existing empirical data (in progress).
- Track the costs of transplanting at higher rates and move towards the development of a bioeconomic model to help inform decisions.
- Review long-term transplant monitoring data to evaluate the relative success rates of transplants at different distances between donor and receiver regions.
- Characterize suspected yield of recruit per bushel transplanted between donor and recipient sites.
- Use size composition of transplants to estimate additional yield in the first year as well as the expected yield of the remaining individuals over time.
- Determine the expected dollar value of the transplant, taking into consideration the sale price, costs of transplanting from the donor region, cost of eventual harvest from the receiver region, etc.

- Compute a Markov transition matrix to evaluate whether unsampled low-quality grids change strata between resurveys.
- Develop a Gini Index for each bed to monitor changes in spatial concentration of the oyster resource.

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Table 1. Timeline of surveys and monitoring programs that comprise the data presented in this report. For a detailed explanation of survey design changes see "The Assessment Survey" in the "Historical Overview" section of this report.

Annual Stock Assessment Survey – Timeline and Changes

1953 – 1988	Small boat/dredge used for the survey; no size data collected; no sampling of VLM region; no swept area data collected; not all high/medium quality strata sampled
1989 – 1998	Changes: Commercial boat/dredge used for the survey; began collecting size data; remaining methods the same as above
1999 – 2007	Changes: Began collecting swept area; remaining methods the same as above
2008 – present	Changes: Restratified the beds; all high/medium quality strata now sampled; VLM region now sampled

Other Annual Programs	
2009 – Present	Resurvey/Restratification Program
1990 – Present	Dermo Monitoring Program
2004 – Present	Port Sampling Program

Harvest Methods	
Pre-1996	Bay Season Fishery
1996 - Present	Direct Market Fishery

Table 2. Catchability coefficients for oysters, boxes, and cultch by region. The entire time series since 1953 was reconstituted using these catchability coefficients as of 2016 SAW.

	Catchability Coefficient		
Region	**Oyster**	**Box**	**Cultch**
Very Low Mortality	2.41	6.82	9.11
Low Mortality - *Round Island*	2.41	6.82	9.11
Upper Arnolds, Arnolds	8.26	12.69	25.79
Medium Mortality Transplant	8.26	12.69	25.79
Medium Mortality Market	8.26	12.69	25.79
Shell Rock	8.26	12.69	25.79
High Mortality	2.82	5.10	8.46

Table 3. Restratification survey (resurvey) schedule. Upper Arnolds, Arnolds, and Strawberry were resurveyed in 2025. Liston Range, Shell Rock, and Hog Shoal are scheduled for resurvey in 2026. Grids are 0.2’ latitude by longitude.

Region	Bed	# Grids	# Full Resurveys	Latest Resurvey	10-Year Schedule
VLM	Hope Creek	97	2	2017	2027
	Fishing Creek	67	2	2022	2032
	Liston Range	**32**	**2**	**2016**	**2026**
LM	Round Island	73	2	2018	2028
	Upper Arnolds	29	2	2025	2035
	Arnolds	99	2	2025	2035
MMT	Upper Middle	84	2	2020	2030
	Middle	51	2	2021	2031
	Sea Breeze	48	2	2022	2032
MMM	Cohansey	83	2	2019	2029
	Ship John	68	2	2020	2030
SR	**Shell Rock**	**93**	**3**	**2016**	**2026**
HM	Bennies Sand	49	3	2019	2029
	Nantuxent	68	3	2018	2028
	Bennies	171	2	2024	2034
	Hog Shoal	**23**	**2**	**2016**	**2026**
	Strawberry	29	2	2025	2035
	Hawk's Nest	28	2	2017	2027
	New Beds	112	3	2023	2033
	Beadons	38	3	2021	2031
	Vexton	47	3	2021	2031
	Egg Island	125	1	2022	2032
	Ledge	53	1	2021	2031

Table 4. Groups and responsibilities for managing the oyster fishery of Delaware Bay, NJ.

Group	Members	Duties
Rutgers Haskin Shellfish Research Laboratory	HSRL faculty and staff	Design/analyze stock assessment. Execute surveys with industry and NJDEP assistance. Address science needs. Host and facilitate SAW. Prepare SAW report.
Oyster Industry Science Steering Committee	HSRL Shellfish Council NJDEP	Prioritize science agenda and mgmt. strategies. Nominate SARC membership.
Stock Assessment Review Committee	Academics: RU & other Managers: NJDEP & other Industry	Peer review of assessment. Recommend harvest rates & area mgmt. by region. Provide science advice.
Shellfish Council	Industry	Select harvest rate & area mgmt. activities from SARC recommendations. Plan/approve disbursement of industry-imposed harvest taxes.
New Jersey Department of Environmental Protection	Biologists Managers Statisticians Enforcement Administrators	Approve decisions impacting public oyster resource. Lead/coordinate mgmt. activities. Monitor harvest and enforce regulations. Collect, maintain & disperse industry-imposed harvest taxes.

Table 5. Control Rules and Management Program. Control Rules were formally adopted at the 2016 SAW and contain updates from the 2017 SAW. They articulate the basic process used to manage the New Jersey Delaware Bay Oyster Fishery.

1. *Area Management*: Harvest and transplant activities are set by region (3 harvest and 3 transplant regions) to help ensure that no area receives more harvest pressure than it can sustain and enhancement efforts are appropriately directed.

2. *Baseline Abundance Targets*: The 2006 SARC set the target and threshold total abundances for each region as the median and ½ the median for the time series 1989-2005, inclusive. Those for market-size oyster (>2.5") abundances are set the same way using 1990-2005 because length measurements for oysters began in 1990. Both time series represent the beginning of the current Dermo era to the year prior to the institution of the reference points. Both periods include highs and lows of recruitment, growth, disease and mortality. For the VLM, the 2017 SARC advised use of the 75th percentile of its 2007-2016 time series as a target and the 50th percentile as the threshold for total and market-size abundance with the proviso that this be re-evaluated in three to five years. VLM reference points were reevaluated in 2022 by the OISSC which unanimously supported the continued use of the 75th percentile as the target and the 50th percentile as the threshold of the region's 2007-2016 abundance time series.

3. *Additional Population Indicators*: Trends in abundance, recruitment, disease, mortality and other factors are examined and summarized (regional panels and stoplight table) to develop expectations of population change in the coming year(s) and to inform harvest and management decisions.

4. *Exploitation Targets*: The 2006 SARC set regional exploitation rate targets as the medians of the realized exploitation rates from the beginning of the Direct Market in 1996 to 2005 (later 2006). The 2016 SARC updated the targets as the median exploitation rate realized from 2007-2015.

5. *Exploitation rate flexibility*: The 2006 SARC set flexibility around the regional median exploitation rates (1996-2006) generally as the 40th and 60th percentiles. The 2016 SARC set flexibility between the bounds of the 2007 – 2015 max and min realized exploitation rates. Movement away from the median requires justification based upon the status of the stock, its position relative to targets and thresholds, anticipated changes to the stock, or management activities. Movement away from the median should be in percentage points, generally increments of 10% for simplicity. Strong justification is required for movement above these bounds since they have proven sustainable for the fishery.

6. *Enhancement Tools*: Shellplanting and transplanting are enhancement tools used to facilitate sustainable management. Shellplanting places non-spatted or spatted shell in areas where additional cultch can enhance recruitment. Transplanting relocates culled

oysters from non-harvestable regions to Direct Market regions via the Intermediate Transplant Program.

7a. *Transplant Recipient Exploitation*: For any market region, the SARC may recommend two exploitation rates. The first would be the maximum recommended rate without a transplant. The second would be a higher rate allowed if a transplant occurs. Harvest in the region may begin at the lower rate and move to the higher rate only after a transplant has occurred. Market-size oysters that are transplanted to the region are added to the region's quota.

7b. *Transplant Donor Exploitation*: Annual exploitation rate recommendations for transplant regions are made by the SARC. Resource managers will direct transplant harvests to minimize the cultch fraction transplanted, ideally to < 25%, directing transplant vessels to new sites in the region as necessary.

Table 6. Direct Market harvest summary and 2025 exploitation rates. (a) Council-chosen and fishery-achieved exploitation rates for 2025. Direct market exploitation rates include market-size (≥ 2.5”) oysters only. (b) Direct market bushels harvested, including those replanted to leases. Beds arranged upbay to downbay and color-coded by region.

a. Chosen and achieved exploitation rates

Region	Highest SARC Exploit. Option	Council Choice	Achieved Expl. Rate	Chosen Market Bushels	Additional Quota Bushels	Achieved Total Bushels
MMM	Max 3.70% *transplant req'd.*	3.70%	2.96%	15,213	1,607	15,890
SR	Max 4.88% *transplant req'd.*	4.88%	4.39%	17,518	2,511	19,891
HM	Max 9.82% *transplant req'd.*	9.82%	9.53%	30,245	5,807	37,018
			Totals	62,976	9,925	72,799

Estimated Quota	**Unharvested Bushels**
72,901	102

b. Harvested bushels

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cohansey	12,475	20,687	8,709	7,253	12,238	3,760	242	11,964	2,053	2,941
Ship John	19,938	16,331	22,021	25,037	2,751	23,611	24,685	16,379	13,931	12,949
Shell Rock	31,794	38,189	31,872	28,761	46,765	42,033	25,707	25,468	17,862	19,891
Bennies Sand		22,339	23,395	13,911	6,014	8,145	3,311	507	8,310	21,833
Bennies	29,293	23,071	21,626	7,126	60	8,223	37,459	39,919	17,414	7,682
Nantuxent	2,101	628	11,347	17,575	26,461	28,254	12,860	528	6,901	4,755
Hog Shoal		1,756	283	9,445	2,201	758		556		189
New Beds	4,494	1,143	89			1,410		340		2,530
Ledge										24
Strawberry										5
Total	**100,095**	**124,144**	**119,342**	**109,108**	**96,490**	**116,194**	**104,264**	**95,661**	**66,471**	**72,799**

Table 7. Transplant bushel summary and 2025 exploitation rates. (a) Council-chosen and fishery-achieved exploitation rates for 2025. Transplant exploitation rates include all sizes of oysters. Small oysters and shell are culled during both transplant and harvest. (b) Bushels of culled material removed. Beds without removals were omitted. A transplant did not take place in 2020.

a. Chosen and achieved exploitation rates

Region	Highest SARC Exploit. Option	Council Choice	Achieved Expl. Rate	Chosen Oysters Moved	Achieved Oysters Moved	Under/Over
VLM	Max 2.26%	2.26%	3.31%	5,669,284	8,292,309	2,623,025
LM	5.00%	5.00%	5.22%	33,868,034	35,354,722	1,486,688
MMT	Max 2.46% *transplant req'd.*	2.46%	2.66%	5,733,654	6,208,672	475,018

b. Bushel removals

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Hope Creek							2,700	2,700	3,800	4,775
Fishing Creek										1,200
Liston Range										2,900
Upper Arnolds							2,500	5,400	3,725	5,325
Arnolds	4,800			7,200	0	5,400	5,400	10,800	8,150	32,325
Upper Middle		3,200	4,750		0	2,650	2,700	2,050	0	
Middle	8,150	21,350	27,500	25,000	0	13,400	5,400	6,050	11,700	11,275
Sea Breeze	2,400	4,700	7,700	8,800	0	2,700	10,800	10,750	16,375	
Total	**15,350**	**29,250**	**39,950**	**41,000**	**0**	**24,150**	**29,500**	**37,750**	**43,750**	**57,800**

Table 8. Summary of the 2025 intermediate transplant program. A detailed history of transplant efforts since 2007 can be found in Appendix C.

Region	Donor Bed	Receiver Bed	Bushels Moved	Total # Oysters	Fraction Oysters < 2.5"	Number Oysters ≥ 2.5"	Added Quota Allocation	Fraction Cultch	Chosen Expl. Rate	Achieved Expl. Rate	# Oysters at Chosen (all sizes)	# Oysters at Achieved (all sizes)
VLM	Hope Creek	Sea Breeze	4,775	4,109,105	0.973	111,869	413	0.453	2.26%	3.31%	5,669,284	8,292,309
	Fishing Creek	Sea Breeze	1,200	900,946	0.937	57,052	211	0.446				
	Liston Range	Sea Breeze	2,900	3,282,258	0.983	56,160	207	0.309				
LM	Upper Arnolds	Bennies	3,950	3,873,756	0.954	178,599	659	0.341	5.00%	5.22%	33,868,034	35,354,722
	Upper Arnolds-Arnolds	Bennies	1,375	1,191,528	0.967	38,749	143	0.359				
	Arnolds	Shell Rock	5,475	4,928,530	0.943	279,362	1,031	0.379				
	Arnolds	Bennies	26,850	25,360,908	0.947	1,356,320	5,005	0.325				
MMT	Middle	Cohansey	5,675	3,089,928	0.859	435,446	1,607	0.294	2.46%	2.66%	5,733,654	6,208,672
	Middle	Shell Rock	5,600	3,118,744	0.871	401,154	1,480	0.354				

Table 9. Whole stock and region-specific performance targets and thresholds. The targets are the median of total abundance for 1989–2005 and the median of market-size (≥ 2.5") abundance for 1990–2005. The threshold is taken as half of each target value. VLM values here represent 2017 SARC Science Advice to use the 75th percentiles of the 2007-2016 total and market-size abundance time series as targets and the 50th percentiles as thresholds with the proviso that they be re-evaluated in three to five years. After a thorough reassessment in 2022, the OISSC unanimously supported retaining these abundance reference points for the VLM.

	Whole Stock	Very Low Mortality	Low Mortality	Medium Mortality Transplant	Medium Mortality Market	Shell Rock	High Mortality
Abundance							
Target	2,305,660,128	150,632,432	391,877,696	414,560,096	747,234,944	313,595,904	438,391,488
Threshold	1,152,830,064	120,130,688	195,938,848	207,280,048	373,617,472	156,797,952	219,195,744
≥ 2.5" Abund.							
Target	401,049,116	32,061,787	42,075,297	46,566,027	175,051,502	72,910,219	64,446,071
Threshold	200,524,558	16,872,067	21,037,649	23,283,014	87,525,751	36,455,110	32,223,036

Table 10. Color coded summary status of the stock by region in 2025. See key at the bottom for definitions of what each color represents for each metric.

2025 Metrics	*Transplant* Very Low Mortality	*Transplant* Low Mortality	*Transplant* Medium Mortality	*Market* Medium Mortality	*Market* Shell Rock	*Market* High Mortality
Total Abundance						
2025 Percentile (1990-2025)	1.000	0.942	0.628	0.600	0.571	0.114
2025 vs. Target-Threshold						
Market Abundance						
2025 Percentile (1990-2025)	0.111	0.428	0.428	0.342	0.600	0.428
2025 vs. Target-Threshold						
Sub-Market Abundance (< 2.5")						
2025 Percentile (1990-2025)	1.000	0.971	0.800	0.657	0.628	0.057
Spatfall						
2025 Percentile (1990-2025)	0.555	0.571	0.228	0.314	0.285	0.057
Mortality						
2025 Percentile (1990-2025)	0.333	0.057	0.171	0.114	0.285	0.171
Dermo WP						
2025 vs. Category	0.00	0.342	1.367	1.325	2.050	1.661

	Green	**Yellow**	**Orange**
2025 Percentile (1990-2025)	Above the 60th	40th - 60th	Below the 40th
2025 vs. Target/Threshold	Above Target	b/w Target and Threshold	Below Threshold
2025 Dermo Levels	Low (<1.5)	Medium (1.5-2)	High (>2)

Table 11. 2026 SARC recommended exploitation rates for each region and projected quota associated with each recommendation. See text for justification of recommended LM and MMT exploitation rates above maximum control rule rates (rates labeled as "Max+").

Transplant Regions

Region	Label	Removal Rate of All Sizes	Total Abundance	Removals	Oysters/ Bushel[1]	Deck Bushels	Proportion Market	Estimated Quota Bushels[2]
VLM	Max	0.0226	283,675,420	6,411,064	612	10,476	2.3%	244
LM	*Max+*	0.0500	753,890,519	37,694,526	570	66,131	7.9%	5,195
MMT	*Max+*	0.0350	347,385,649	12,158,498	315	38,598	21.1%	8,129

Direct Market Regions

Region	Label	Removal Rate of Market Sizes	Market Abundance	Removals	Oysters/ Market Bushel[1]	Quota Bushels	Enhancement Required?
MMM	Median	0.0303	150,006,370	4,545,193	271	16,772	No
MMM[3]	Max	0.0370	150,006,370	5,550,236	271	20,481	Yes
SR	Median	0.0370	117,782,973	4,357,970	271	16,081	No
SR[3]	Max	0.0488	117,782,973	5,747,809	271	21,210	Yes
HM	Median	0.0749	67,962,405	5,090,384	271	18,784	No
HM[3]	Max	0.0982	67,962,405	6,673,908	271	24,627	Yes

[1]For transplant regions, oysters per bushel is an average from all previous transplants in that region. For market regions, the dock monitoring program calculates an average total number and an average market number per market bushel annually; a grand average is then calculated using all annual averages.

[2]The estimated potential quota bushels from the transplant will always be low relative to what is achieved because the deckloads are culled (removing some of the smaller oysters) before being transplanted to the recipient region.

[3]Higher exploitation rates require enhancement before they can be applied.

Figure 1. The natural oyster beds of Delaware Bay, NJ that comprise the managed fishery grouped by regional designations. The six regions are named based on long-term disease mortality patterns and management categories that follow the estuarine salinity gradient. From upbay to downbay: Very Low Mortality (dark green), Low Mortality (red), Medium Mortality Transplant (light green), Medium Mortality Market (light blue), Shell Rock (orange), High Mortality (dark blue). Black outlines indicate the complete footprint of each bed.

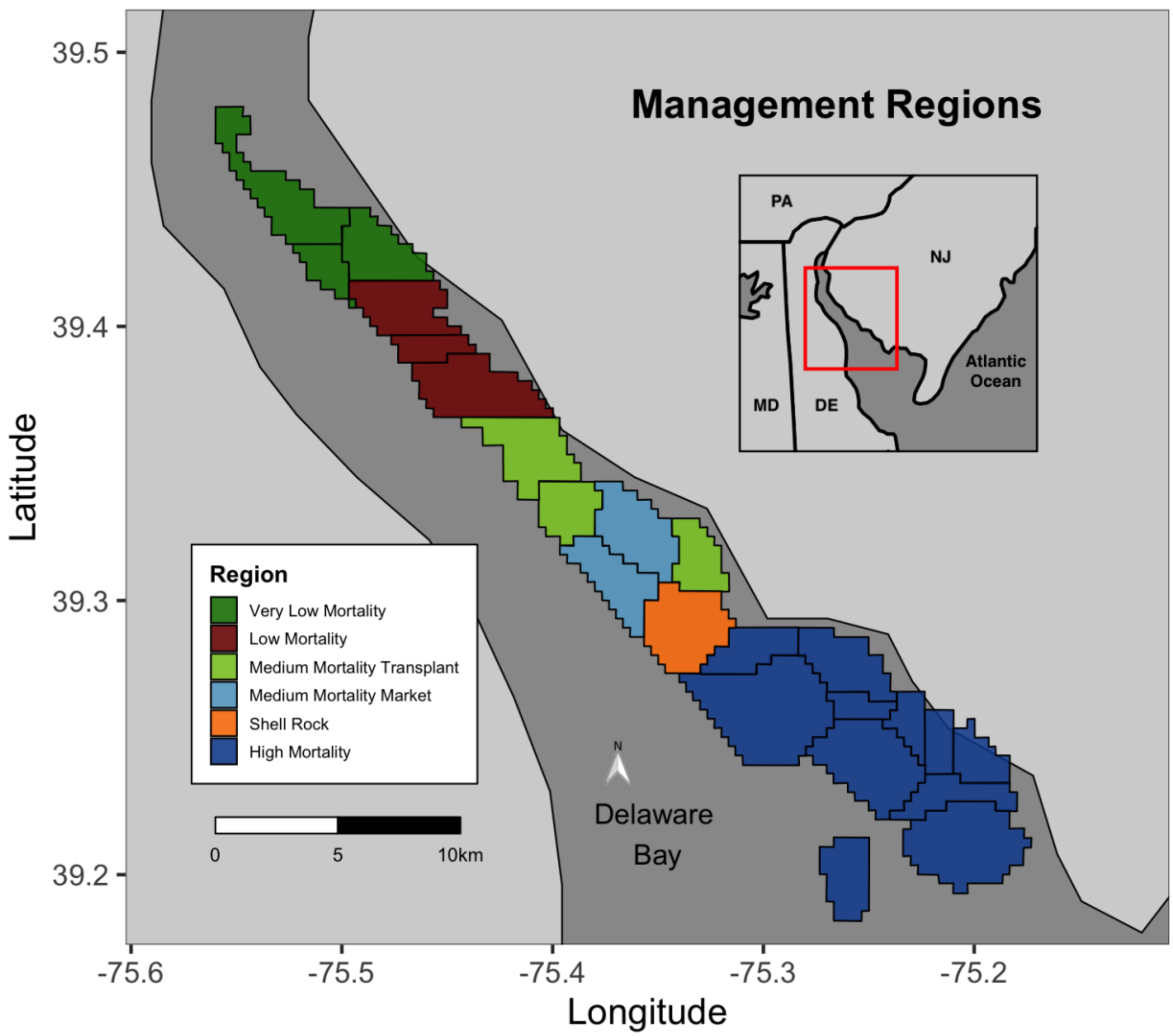


Figure 2. Regional acreage of the assessed NJ Delaware Bay oyster resource, excluding low quality grids. Regions are listed upbay to downbay from left to right. The VLM, LM, and MMT contain three beds each and comprise the Transplant region. The Direct Market region includes the MMM made up of two beds, SR (one bed), and HM with eleven beds. Resource density, population characteristics and population dynamics vary among regions as described elsewhere in this document.

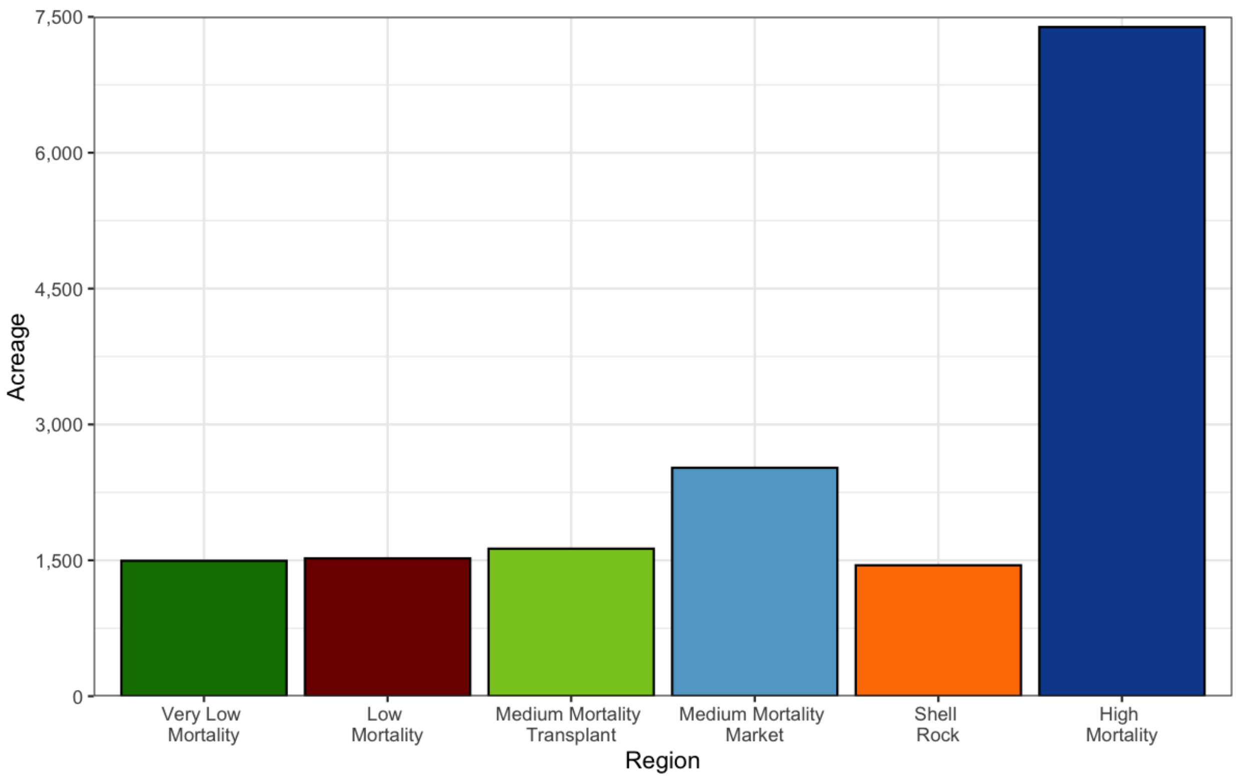
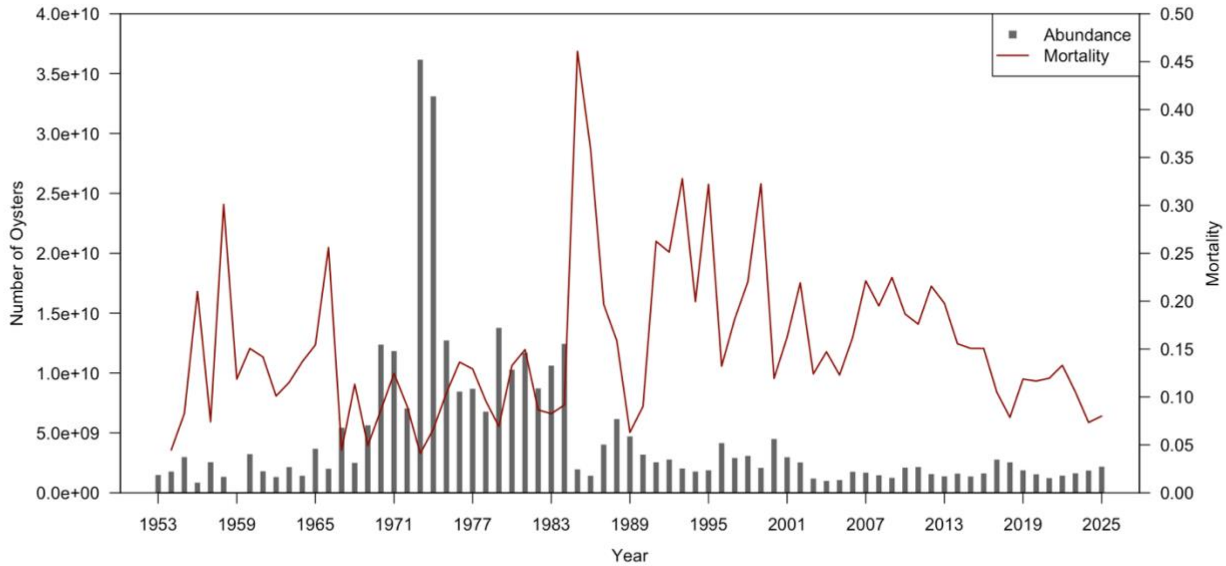


Figure 3. Time series of total oyster abundance (left axes) compared to natural mortality rate (a, right axis) and fishing mortality (b, right axis). Both figures exclude the VLM which was not quantitively surveyed until 2007.

a.



b.

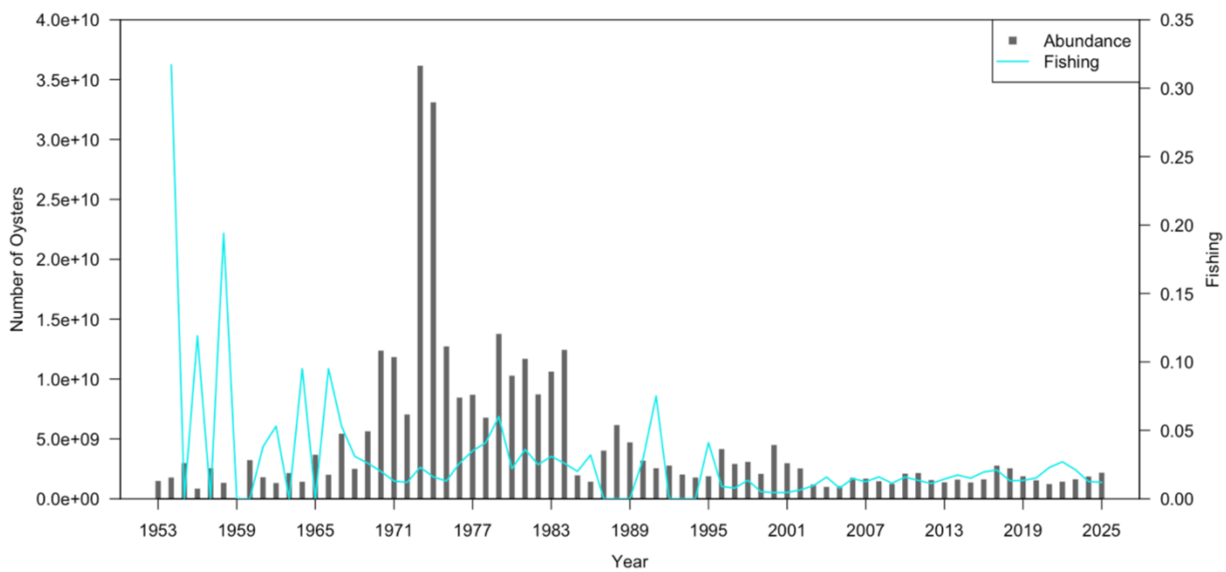
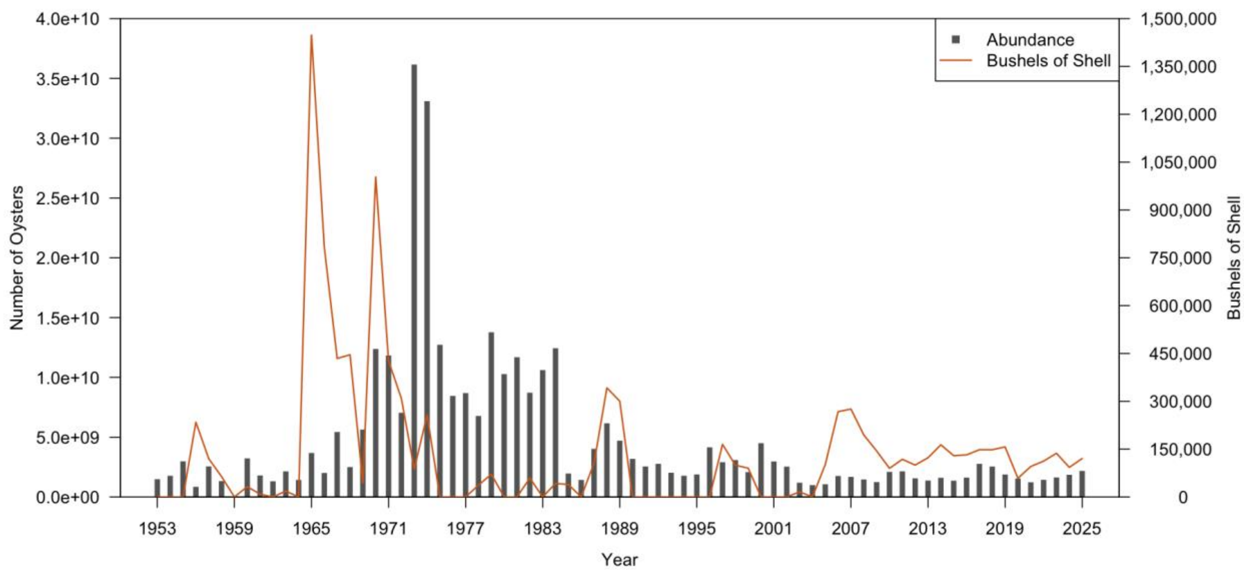


Figure 4. Time series of total oyster abundance (left axes) compared to bushels of shell planted (a, right axis) and total spat abundance from the stock assessment time series (b, right axis). Both figures exclude the VLM which was not quantitively surveyed until 2007.

a.



b.

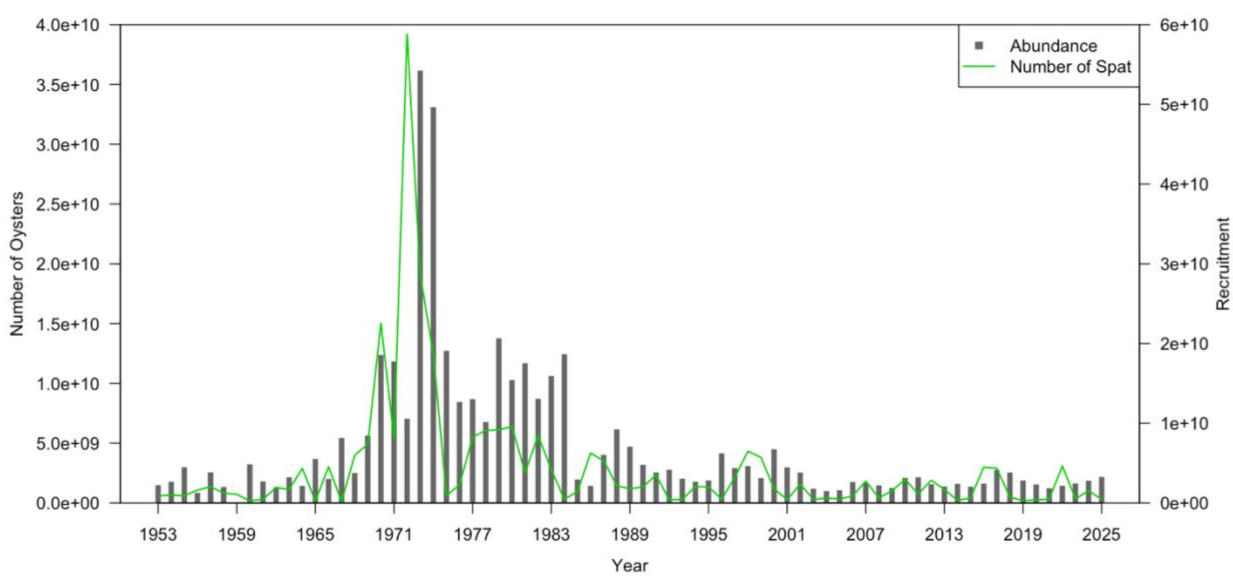


Figure 5. Number of oysters harvested from the natural oyster beds of Delaware Bay, NJ from 1953 to present. Prior to 1996, the bay-season fishery permitted removing oysters of all sizes from the natural beds but required transplanting them downbay to leased grounds for subsequent harvest. Since 1996, the direct market fishery has restricted harvest to market-size oysters which are generally landed but may be planted on leased grounds. Zeros represent years of fishery closure.

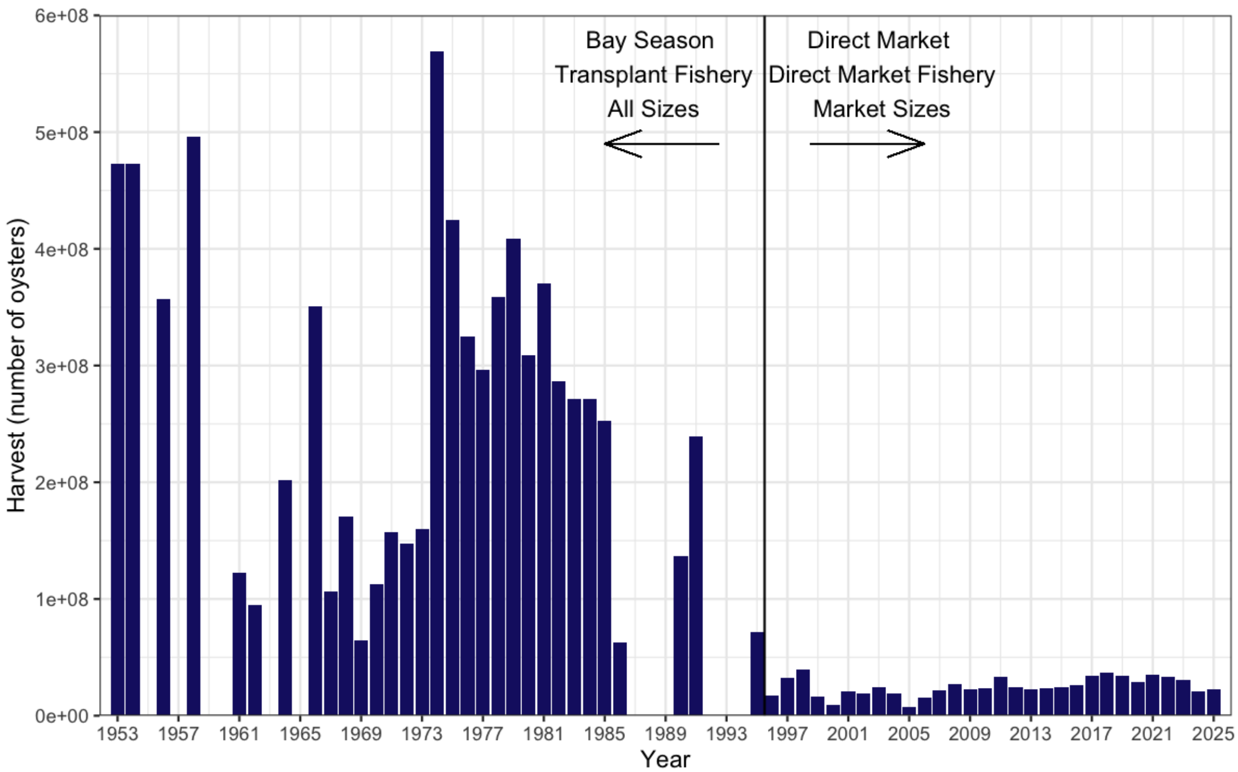


Figure 6. Survey gear capture efficiency as a function of true oyster density. Error bars represent the standard deviation from 1,000 bootstrap simulations. Line indicates the best fit power model estimated by weighted nonlinear least squares. *Adapted from Morson et al. (2018)*

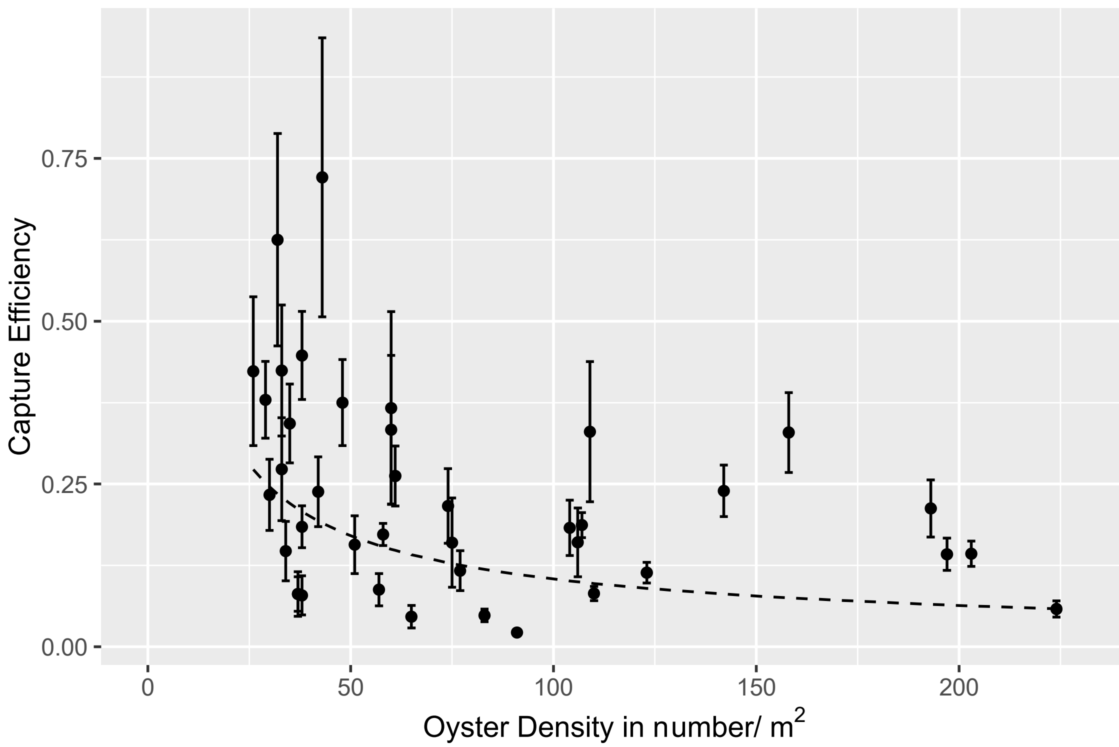


Figure 7. The assessed oyster beds of Delaware Bay, NJ color coded by region (see legend) with the 2025 strata designations. Strata designations are calculated within-bed not within-region. White outlines indicate the complete boundary of each bed with the high and medium quality strata grids in dark and light colors, respectively. Gray areas in each bed indicate low quality strata. Annual assessments include samples from high and medium quality strata only within each bed. Each grid is 0.2” latitude x 0.2” longitude, approximately 25 acres (10.1 hectares).

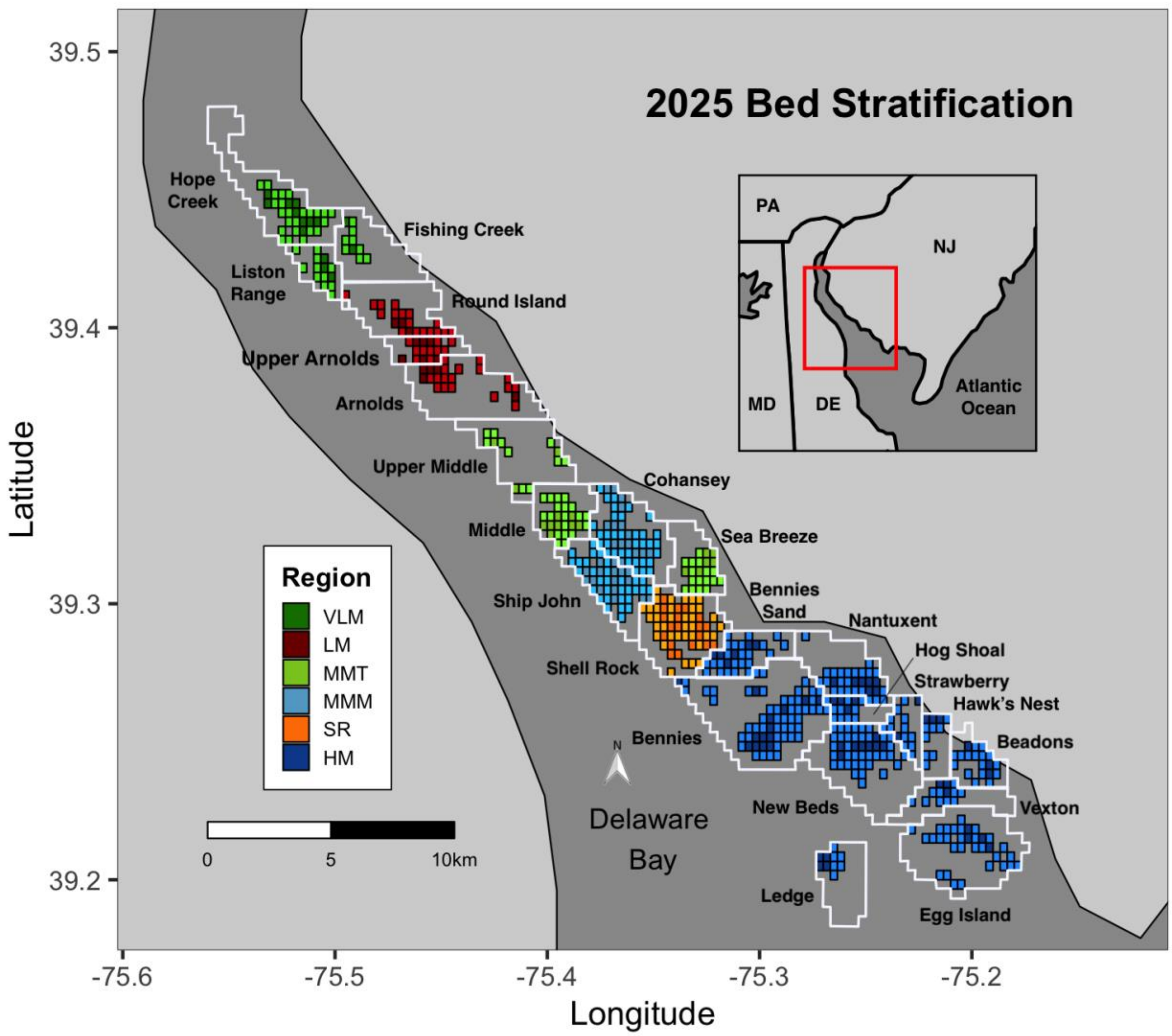


Figure 8a. Realized exploitation fractions of the whole oyster stock, excluding spat, on the Transplant regions in Delaware Bay NJ for two time periods: 1996-2006 and 2007-2015. The 2007-2015 median (dotted line) is based on the realized exploitation for each region with shading indicating the range. The VLM abundance time series began in 2007, and the region has only 3 years of exploitation. Due to sparse data in the earlier time series, the LM and MMT share the same set of data.

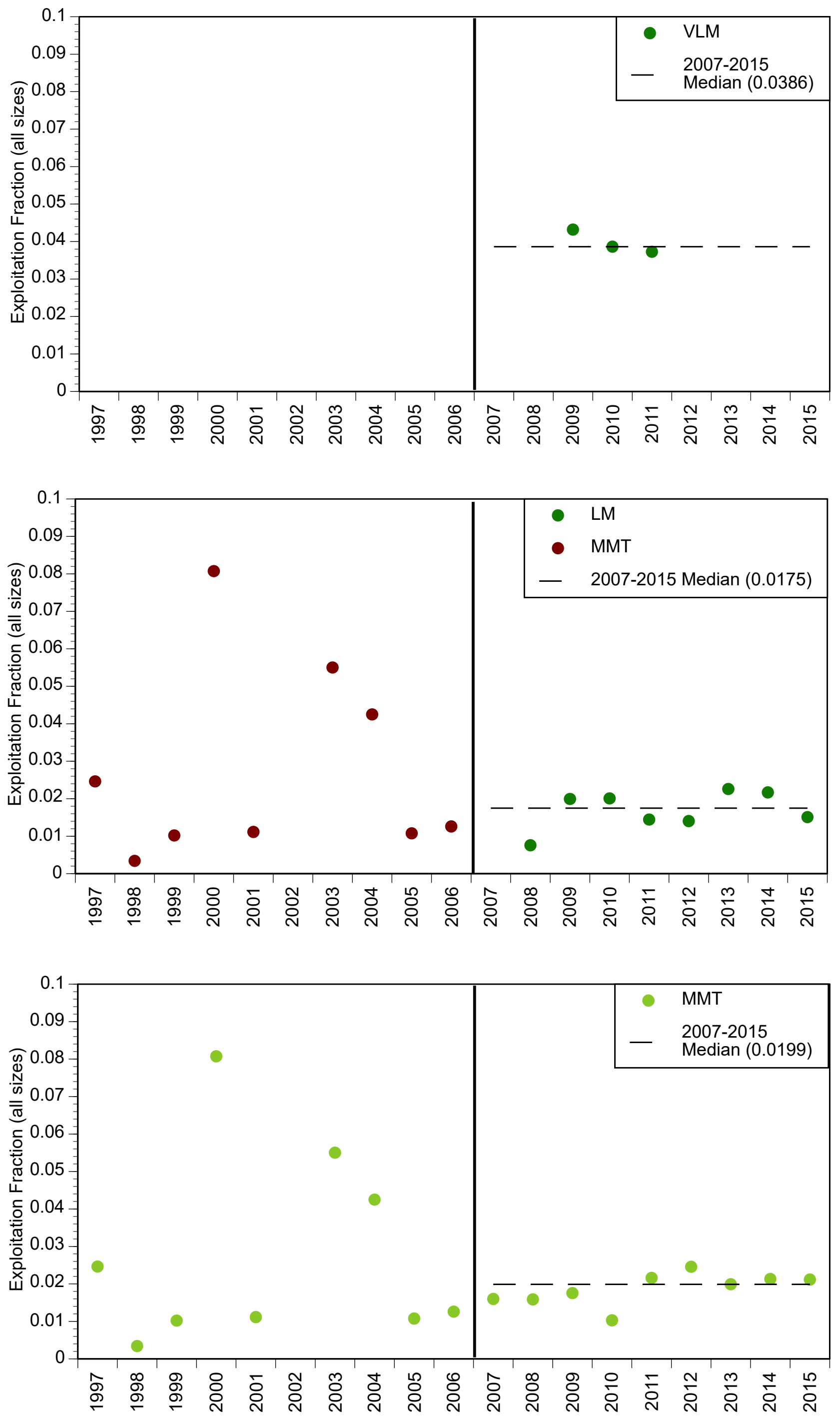


Figure 8b. Realized exploitation fractions of the >2.5" oyster stock on the Direct Market regions in Delaware Bay NJ for two time periods: 1996-2006 and 2007-2015. The 2007-2015 median (dotted line) is based on the realized exploitation values with shading indicating the range. Negative values reflect oysters added through intermediate transplanting.

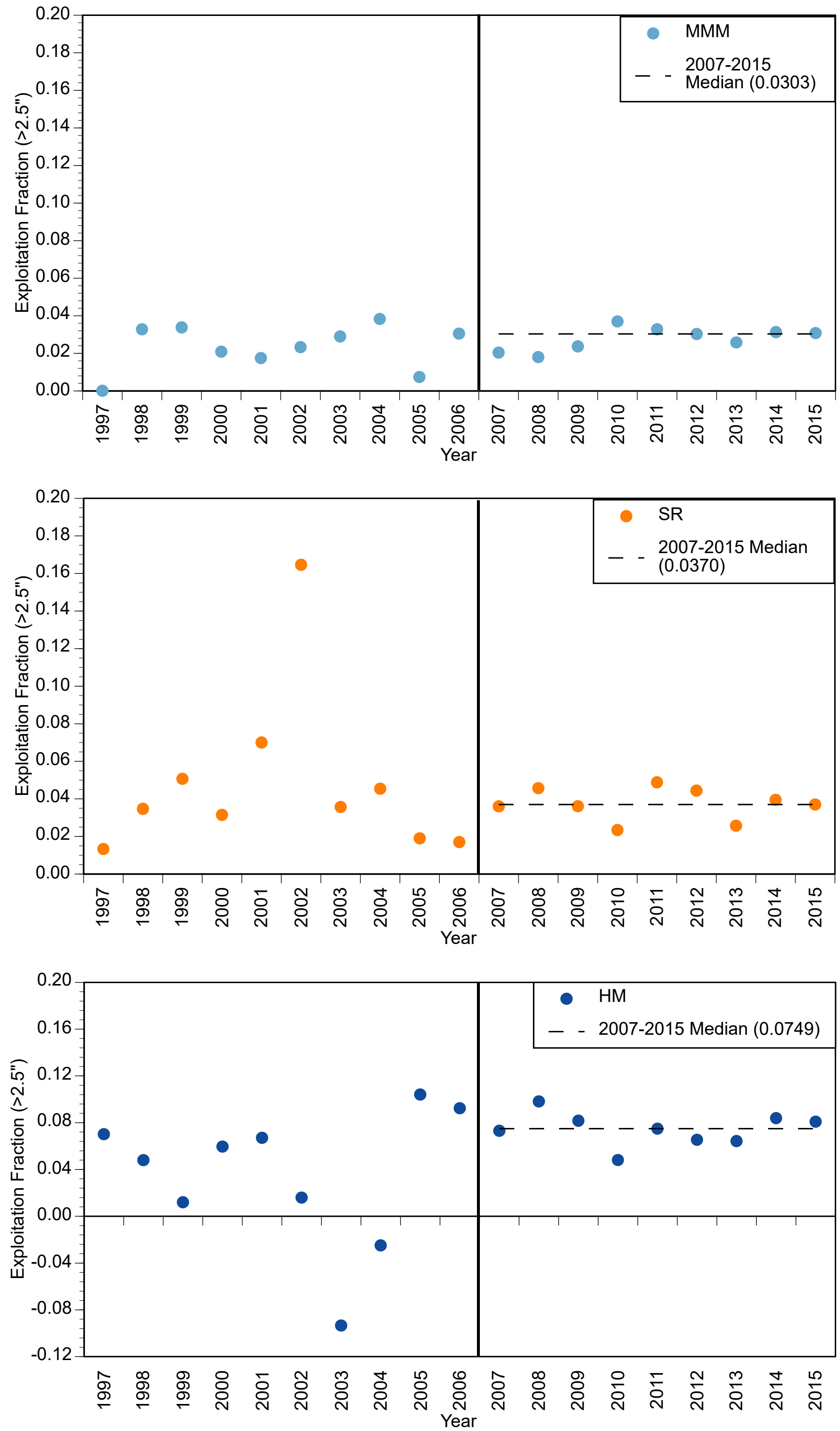


Figure 9. Landed oysters per bushel in three groups: market-size (≥ 2.5”), smaller attached oysters, and smaller unattached oysters. The number of market-size oysters per landed bushel in 2025 averaged 246, while the total oysters per landed bushel averaged 307. The long-term mean of all oysters and market oysters per landed bushel (271) is shown as an orange line.

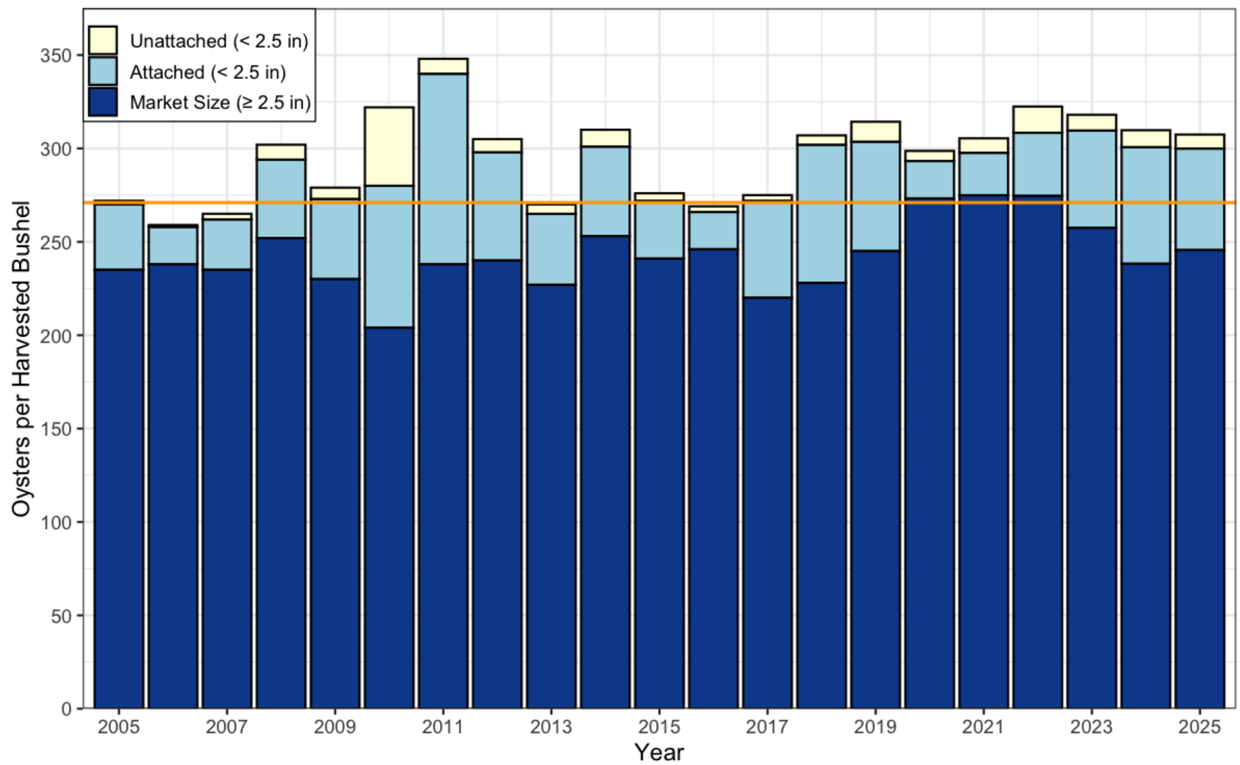


Figure 10. Numbers of single and dual dredge boats (stacked bars) participating in the NJ Delaware Bay oyster harvest overlaid with LPUE (total number of harvested bushels/total hours worked) for each dredge type.

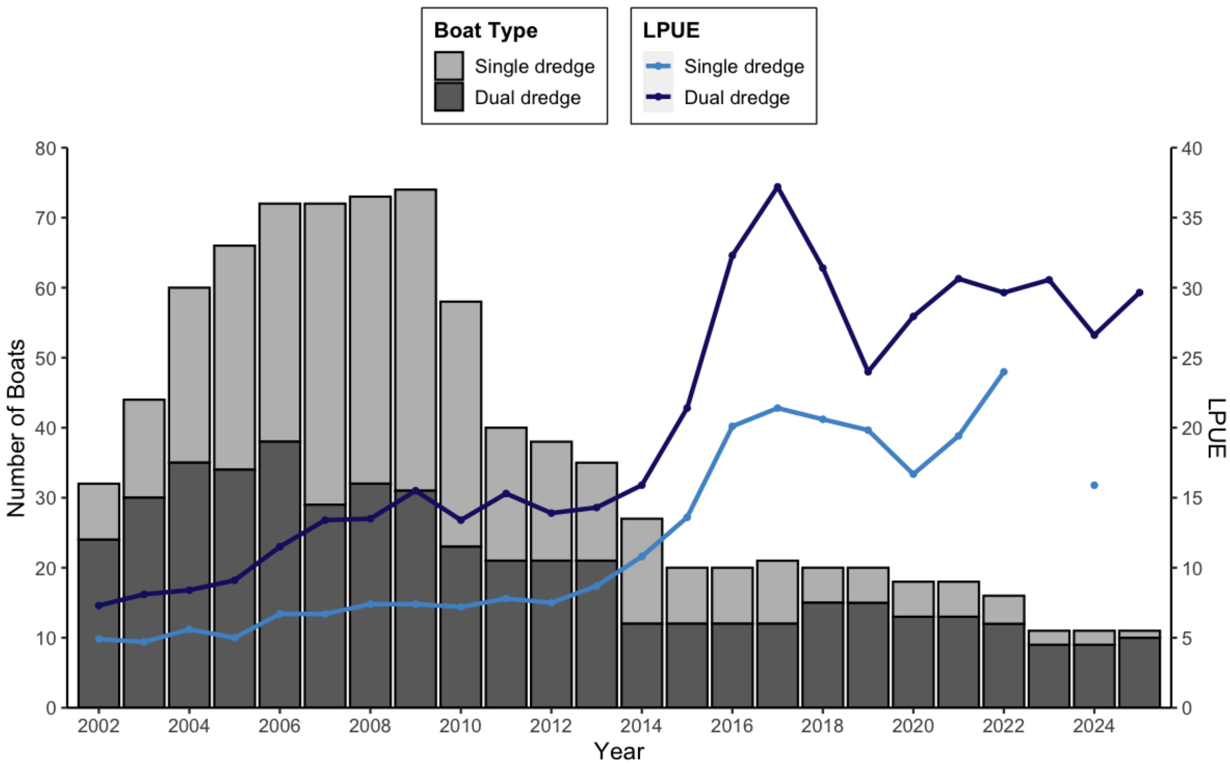


Figure 11. Size frequency of oysters landed by the fishery in direct market regions (top panel) and within the direct market regions of the surveyed population (bottom panel). Vertical line indicates the market-size cutoff (≥ 2.5 inches).

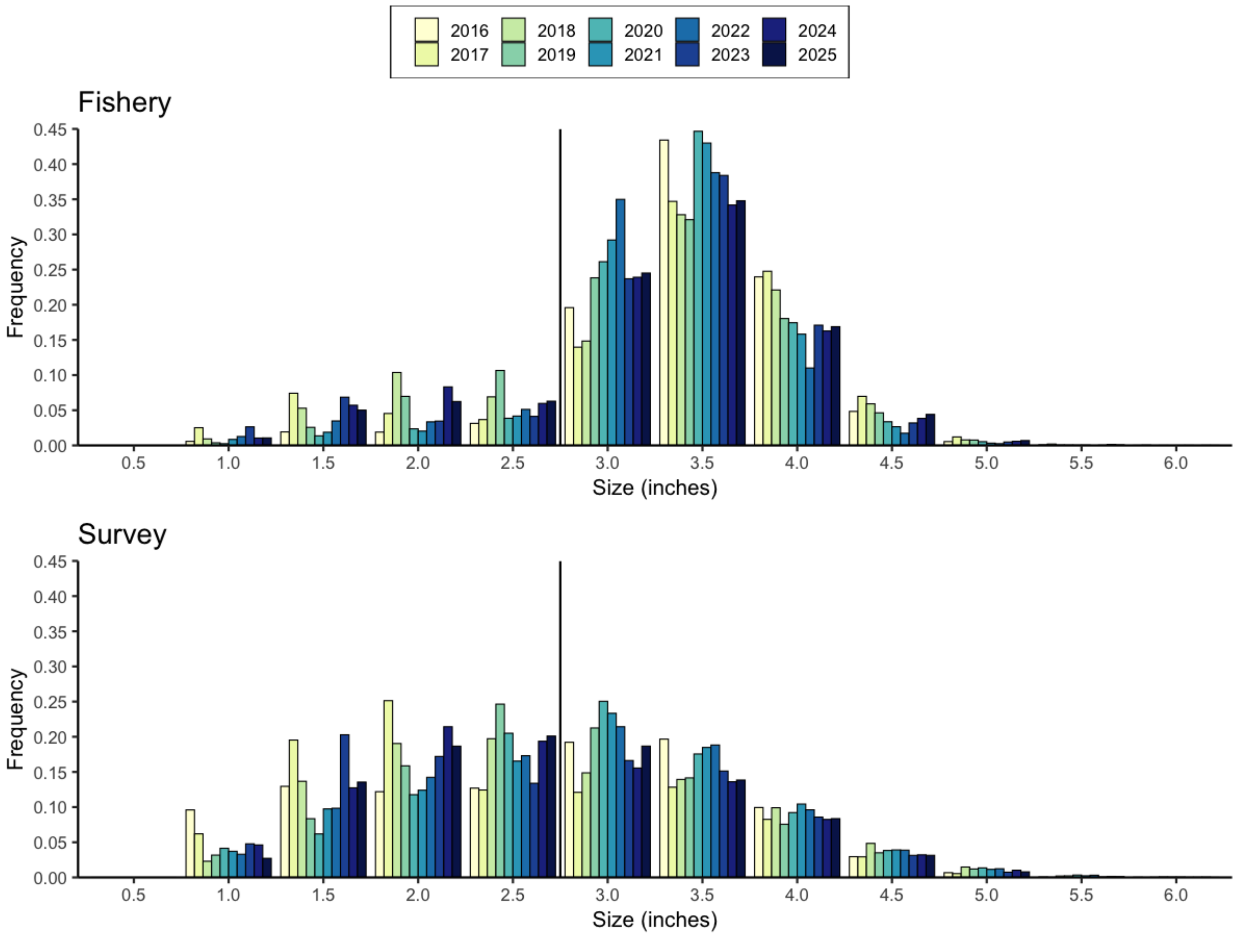


Figure 12. Frequencies of large (≥ 3.5 inches) oysters landed by the fishery in Direct Market Regions (top panel) and within the Direct Market Regions of the surveyed population (bottom panel). Frequencies represent the fraction of large oysters within market-sized individuals.

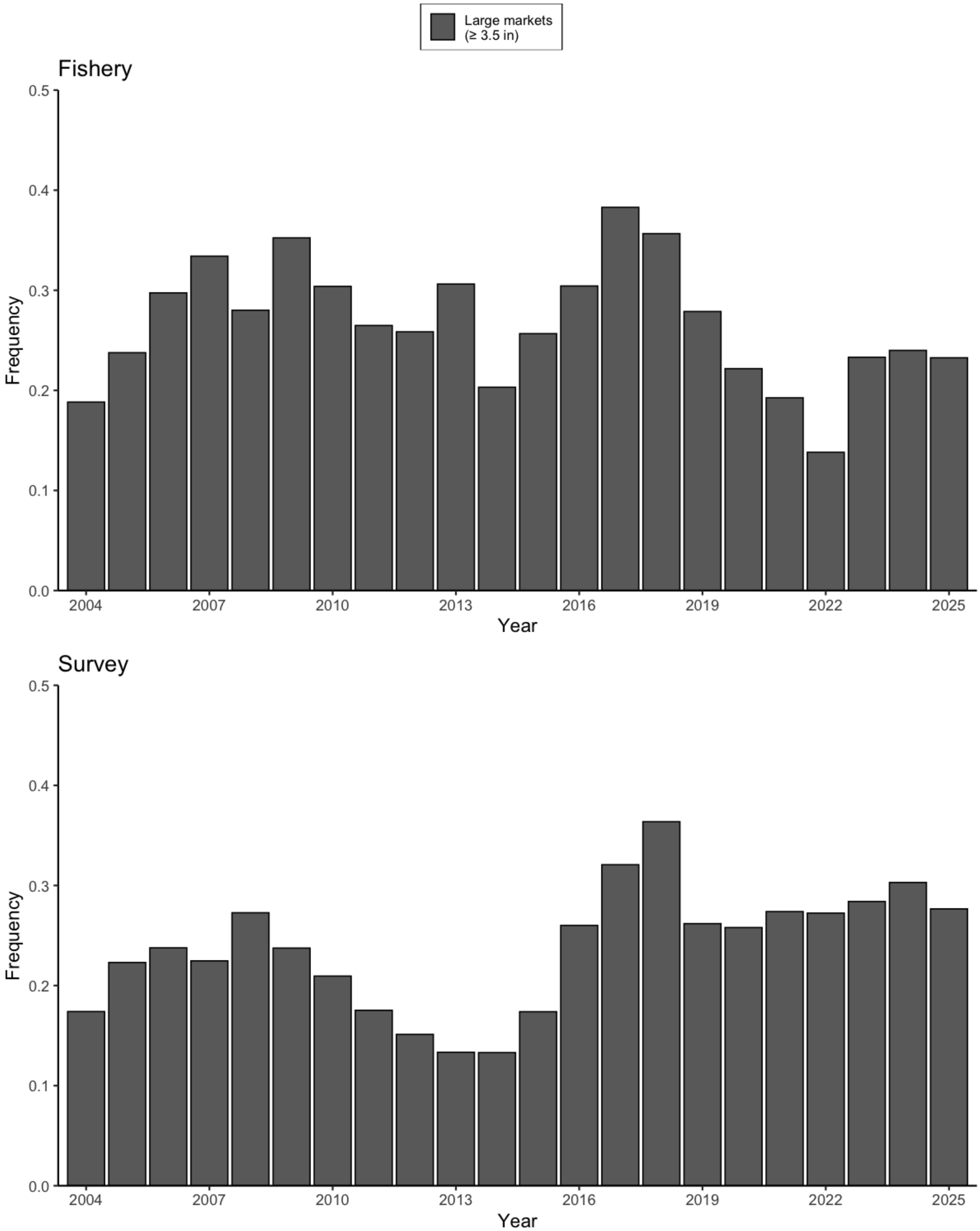


Figure 13. Number of bushels harvested from the natural oyster beds of Delaware Bay since the inception of the direct-market program in 1996. The long-term average harvest is 84,219 bushels (orange line). The vertical line shows the beginning of the current exploitation and management strategy in 2007.

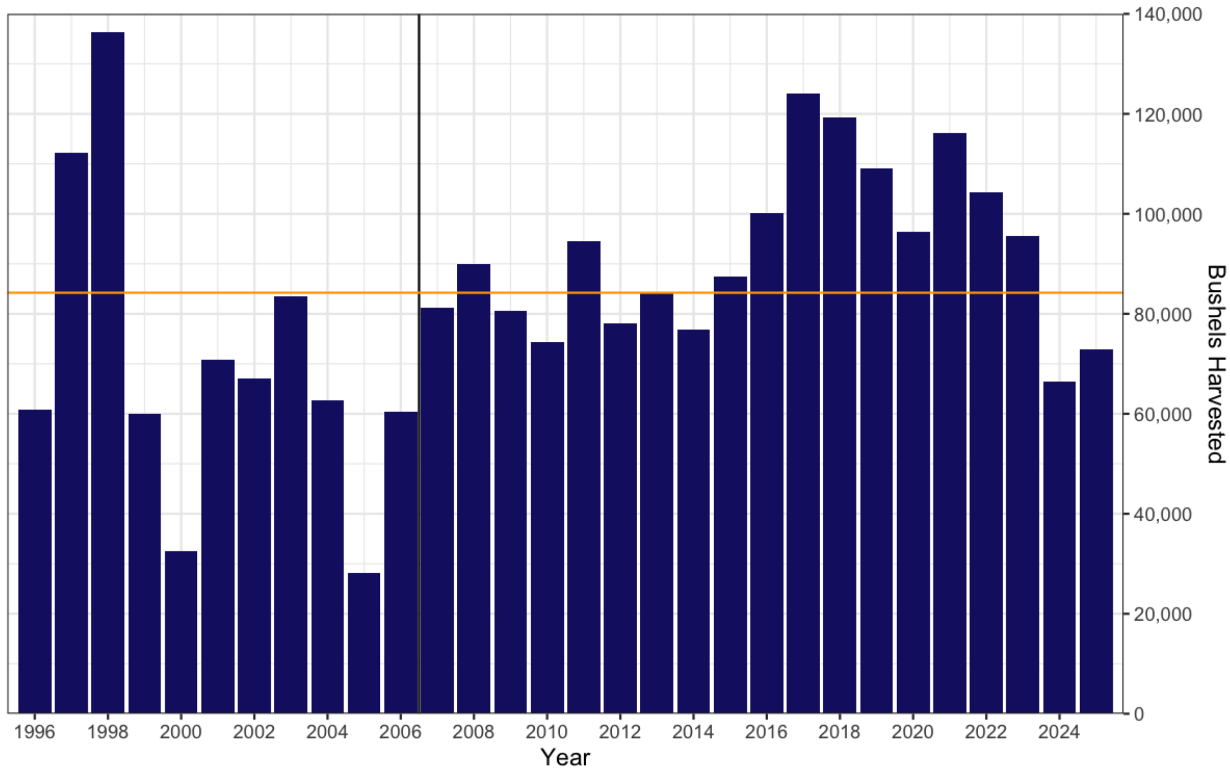
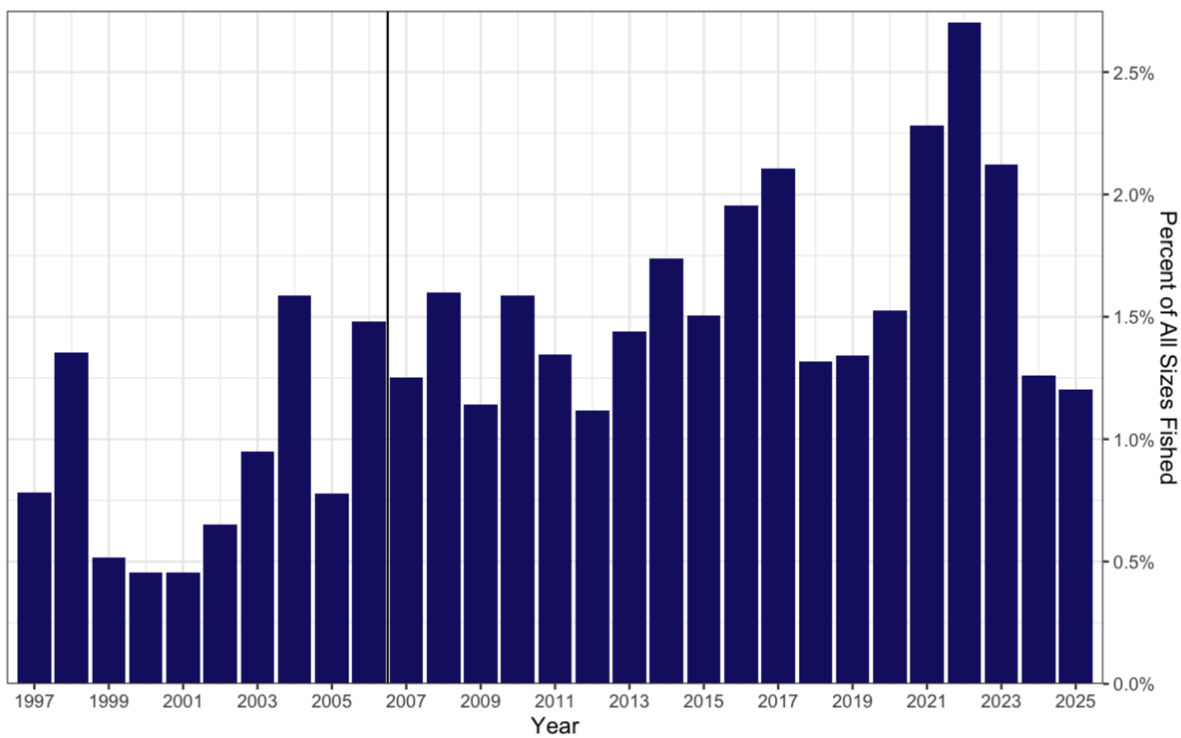


Figure 14. Fishing mortality as a percentage of (a) total oyster abundance and (b) the market-sized oyster abundance (≥2.5”) over all regions excluding the VLM. Regional abundance-based quotas began in 2007 (vertical line).

a.



b.

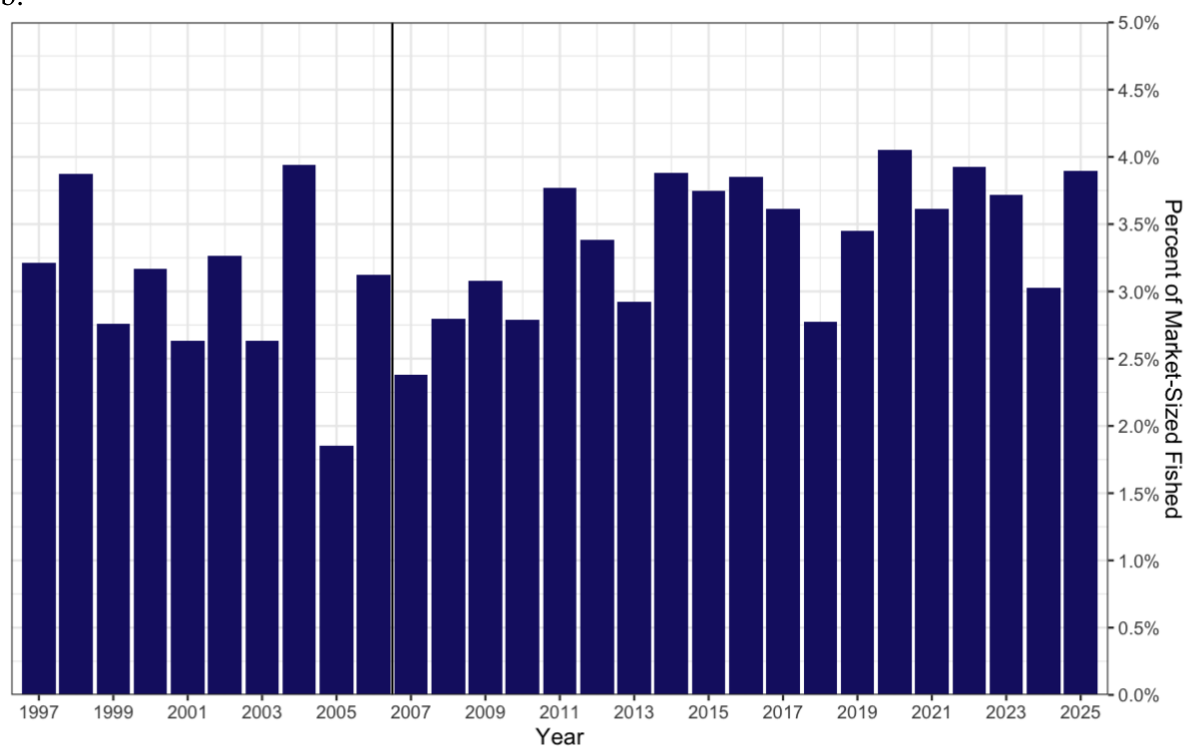


Figure 15. Map of the 2025 oyster stock assessment sample sites. Black dots are sites from high quality stratum on each bed and white dots are sites from medium quality stratum on each bed. X's indicate transplant enhancement sites and triangles indicate shellplant enhancement sites.

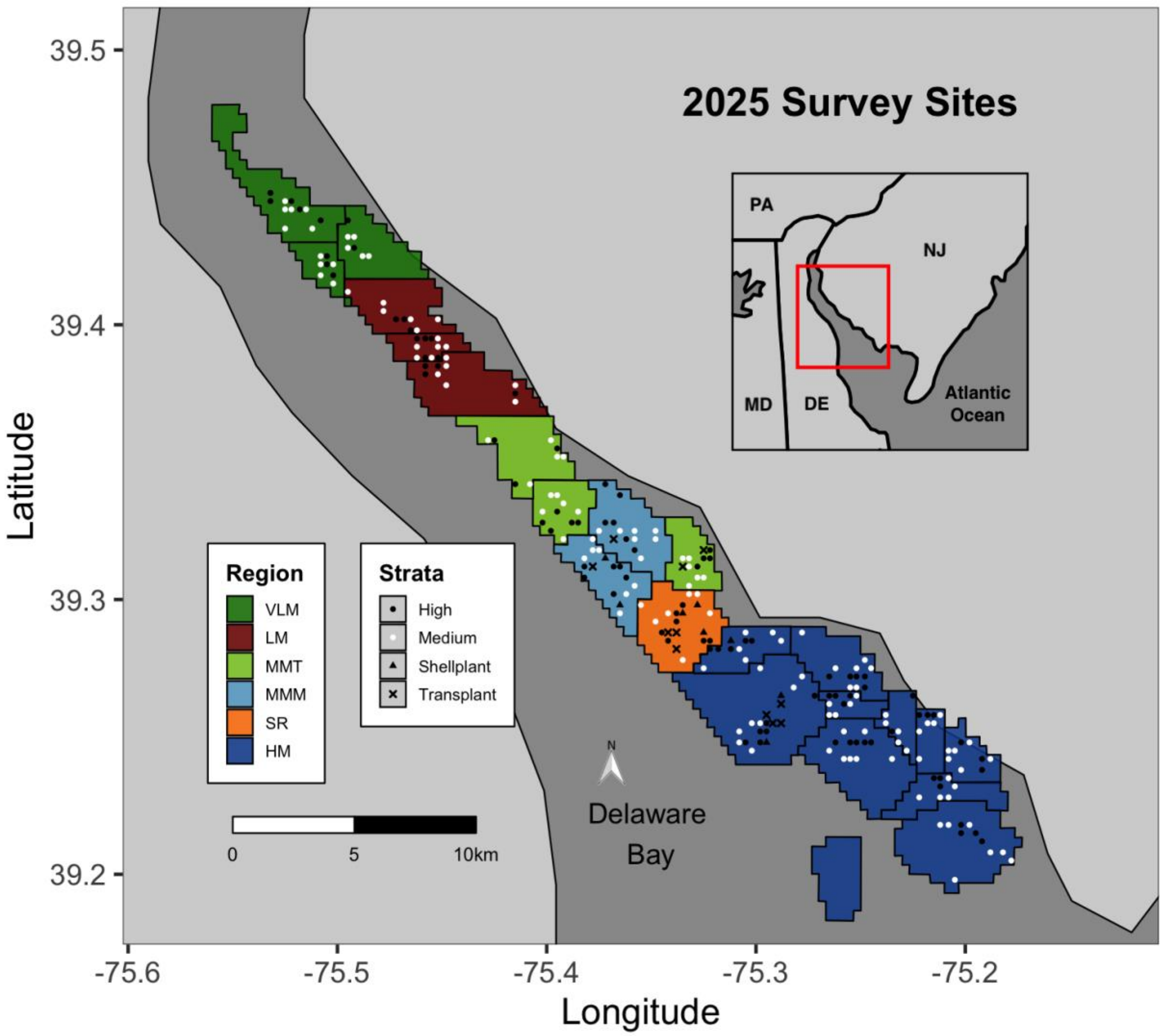


Figure 16. Direct Market time series summary for the population, excluding the VLM. (a) total oyster abundance (≥ 20 mm). (b) abundance of market (≥ 63.5 mm) and submarket (< 63.5 mm, but ≥ 20 mm) oysters. (c) spat abundance (< 20 mm). (d) mortality rate. Dashed horizontal lines represent the threshold and solid horizontal lines represent the target for abundance in panel (a) and for market abundance in panel (b).

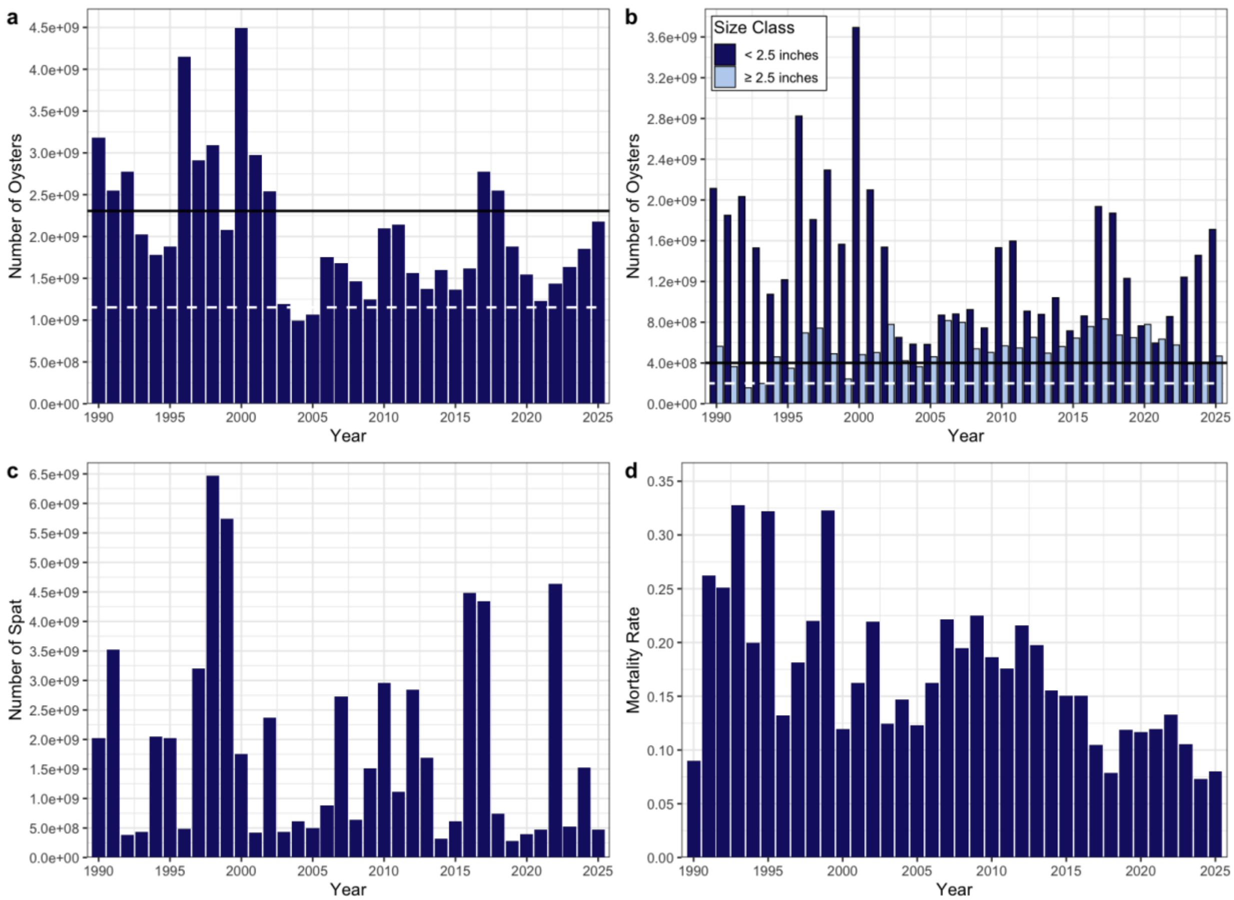
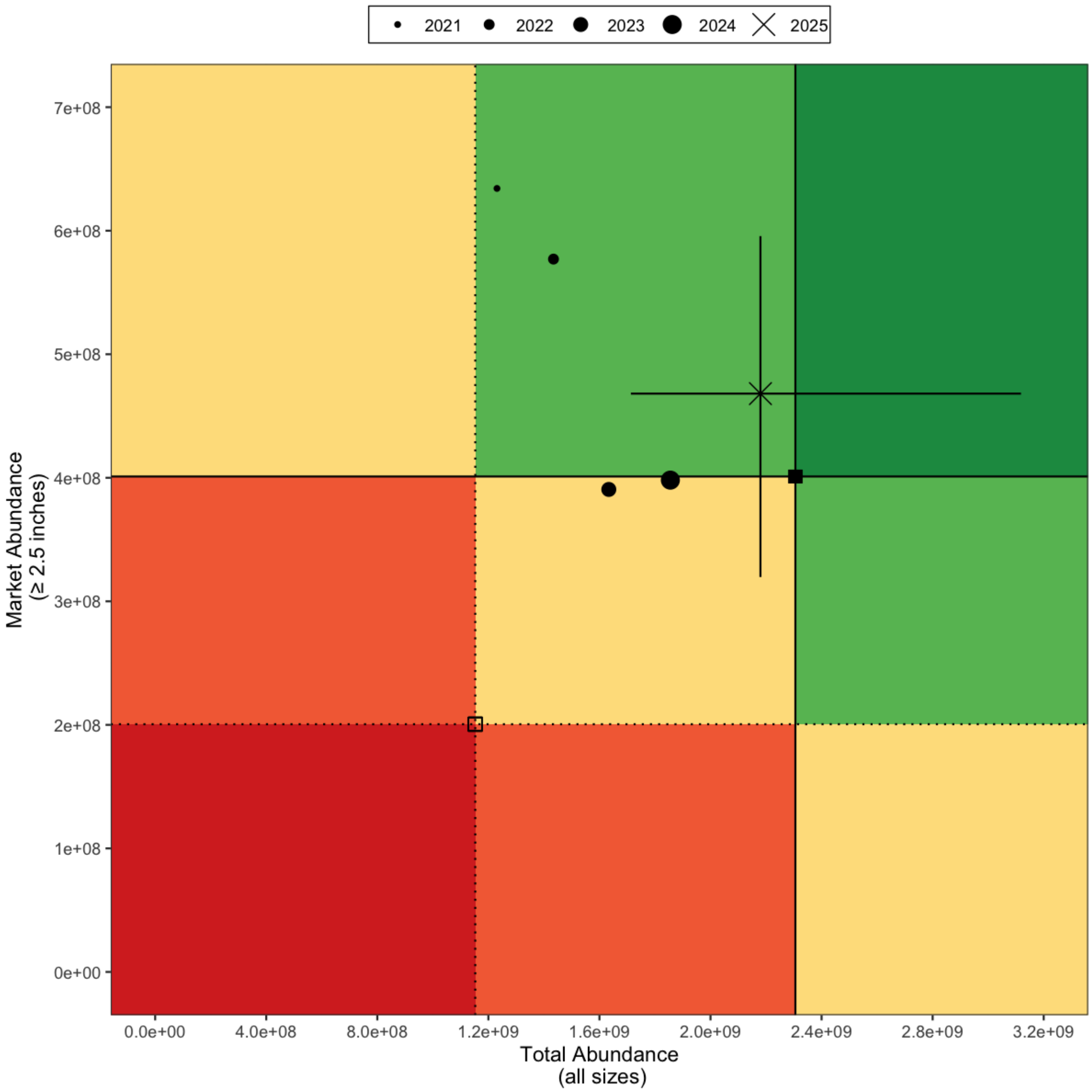


Figure 17. Position of the oyster stock from 2021-2025 with respect to abundance and market abundance (≥ 2.5") targets and thresholds, excluding the VLM. Targets and thresholds are defined in Table 9. Error bars on the 2025 values are the 10th and 90th percentiles of 1,000 simulations of estimates incorporating both survey error and gear efficiency error. *Shading: Green, above all 4 cutoffs*; *Light green, above 3 cutoffs*; *Yellow, above 2 cutoffs*; *Orange, above 1 cutoff*; *Red, below all 4 cutoffs.*



Figures 18 – 23. Direct Market time series (1997 to present; 2007 to present for VLM only) summaries by region Left panels: a) total abundance (≥ 20 mm), c) size class abundances (≥ 20 mm), and e) spat abundance (< 20 mm). Spat abundance does not include spat recruited to planted clamshell. Solid and dashed horizontal lines indicate target and threshold abundances, respectively (a, c). Target and threshold lines on size class abundance plots (c) refer to market-sized oysters only. Right panels: b) dermo levels, d) box-count mortality rate and f) fishing mortality rate relative to both total (≥ 20 mm) and market-size (≥2.5”) abundance. Horizontal line on dermo plot (b) indicates threshold above which natural mortality begins to increase due to dermo.

Figure 18. Direct Market time series summary for the VLM. Targets are the 75th percentiles and the thresholds are the 50th percentiles of the 2007-2016 total and market abundance time series.

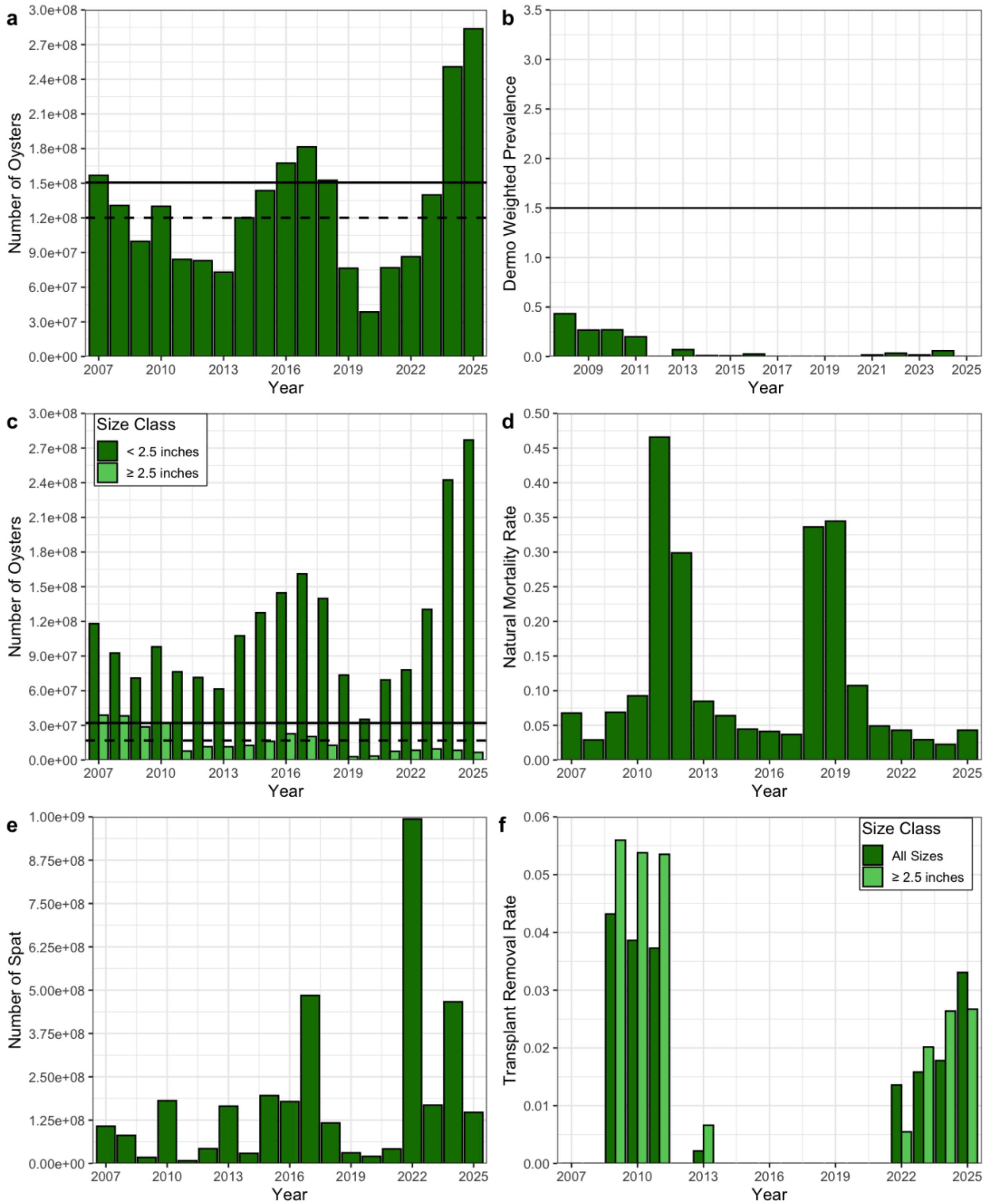


Figure 19. Direct Market time series summary for the LM. Targets are the median of the total abundance for 1989-2005 and the median of market-size (≥ 2.5") abundance for 1990-2005. Thresholds are half the target value.

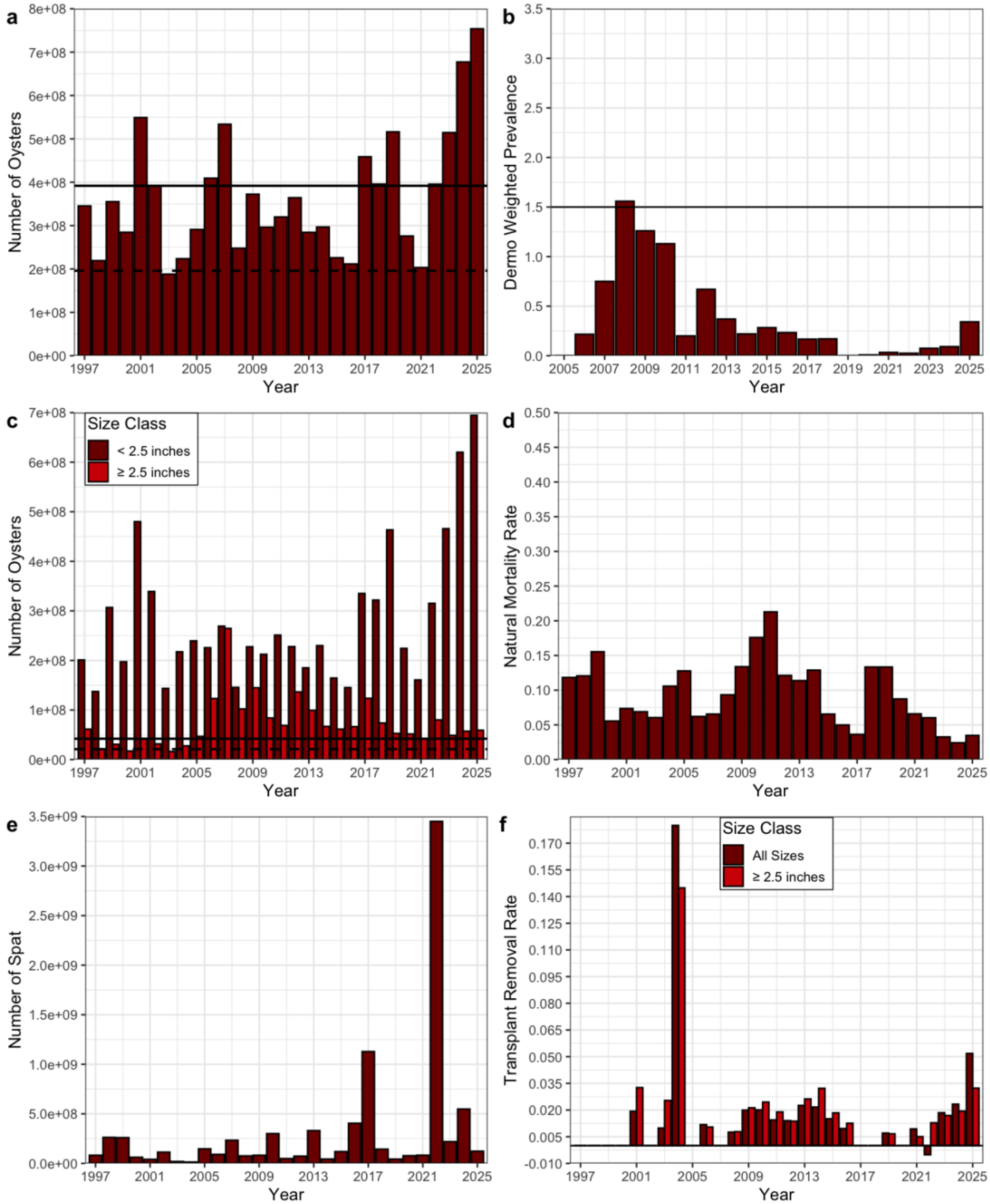


Figure 20. Direct Market time series summary for the MMT. Targets are the median of the total abundance for 1989-2005 and the median of market-size (≥ 2.5”) abundance for 1990-2005. Thresholds are half the target value.

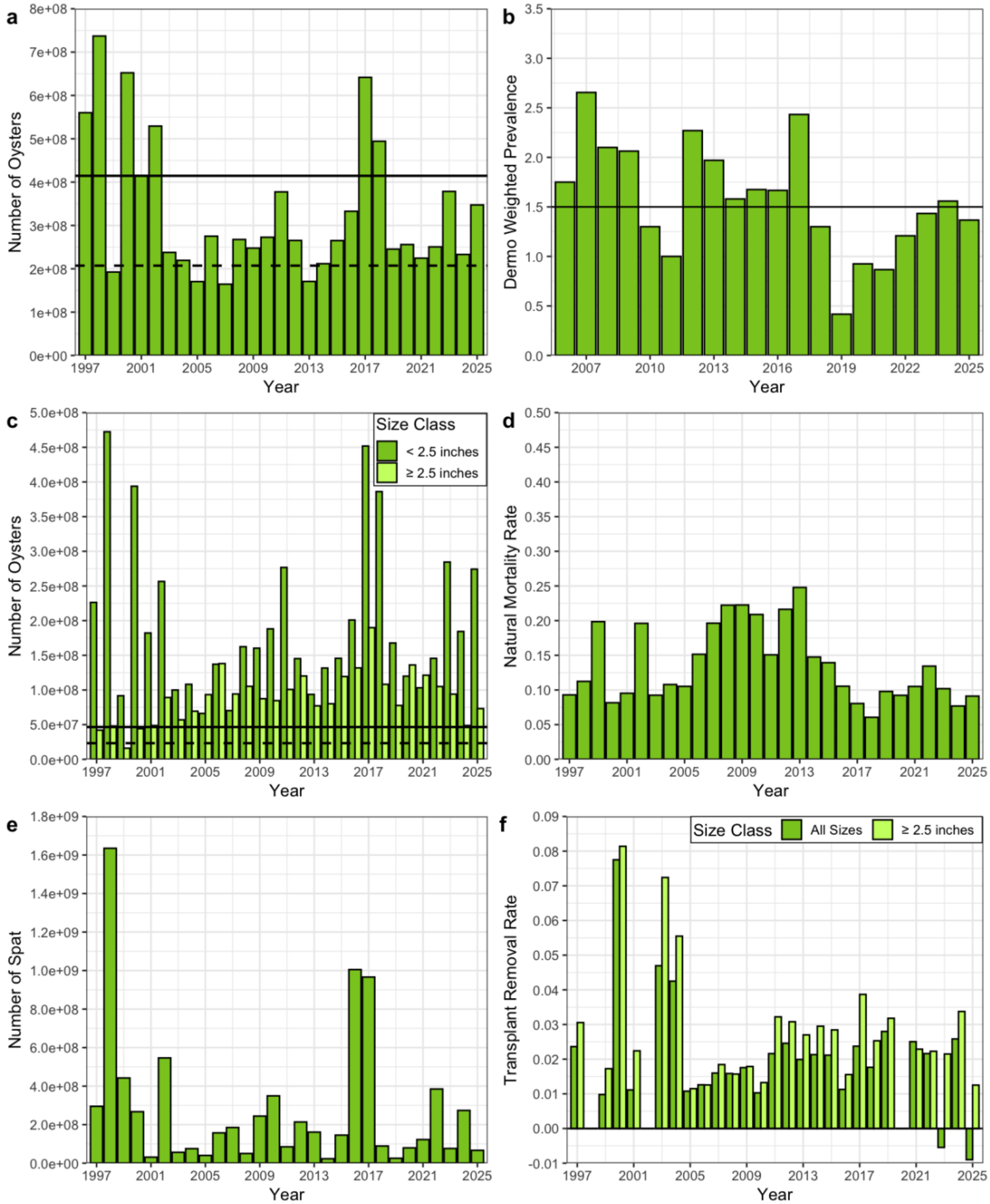


Figure 21. Direct Market time series summary for the MMM. Targets are the median of the total abundance for 1989-2005 and the median of market-size (≥ 2.5”) abundance for 1990-2005. Thresholds are half the target value.

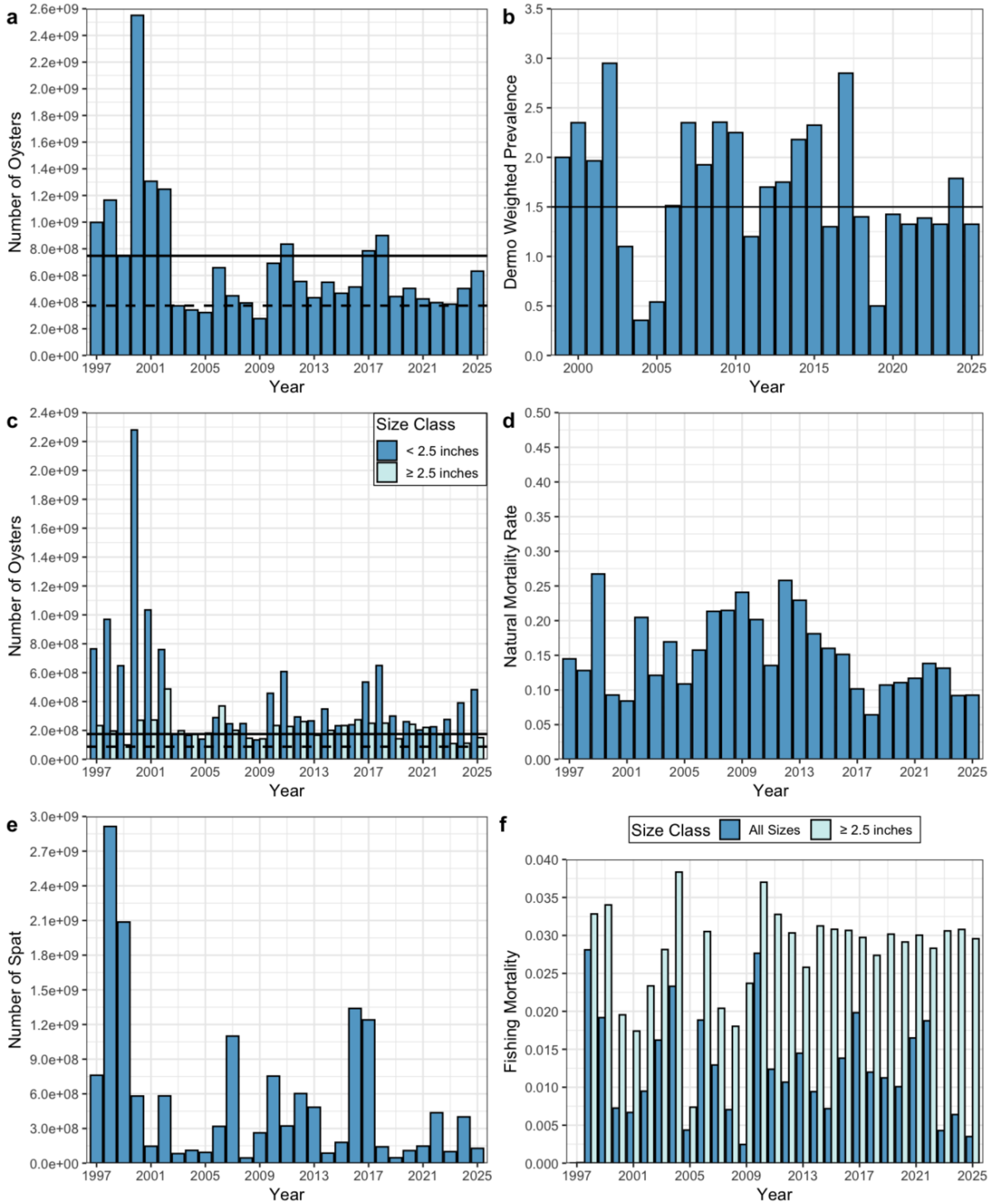


Figure 22. Direct Market time series summary for the SR. Targets are the median of the total abundance for 1989-2005 and the median of market-size (≥ 2.5”) abundance for 1990-2005. Thresholds are half the target value.

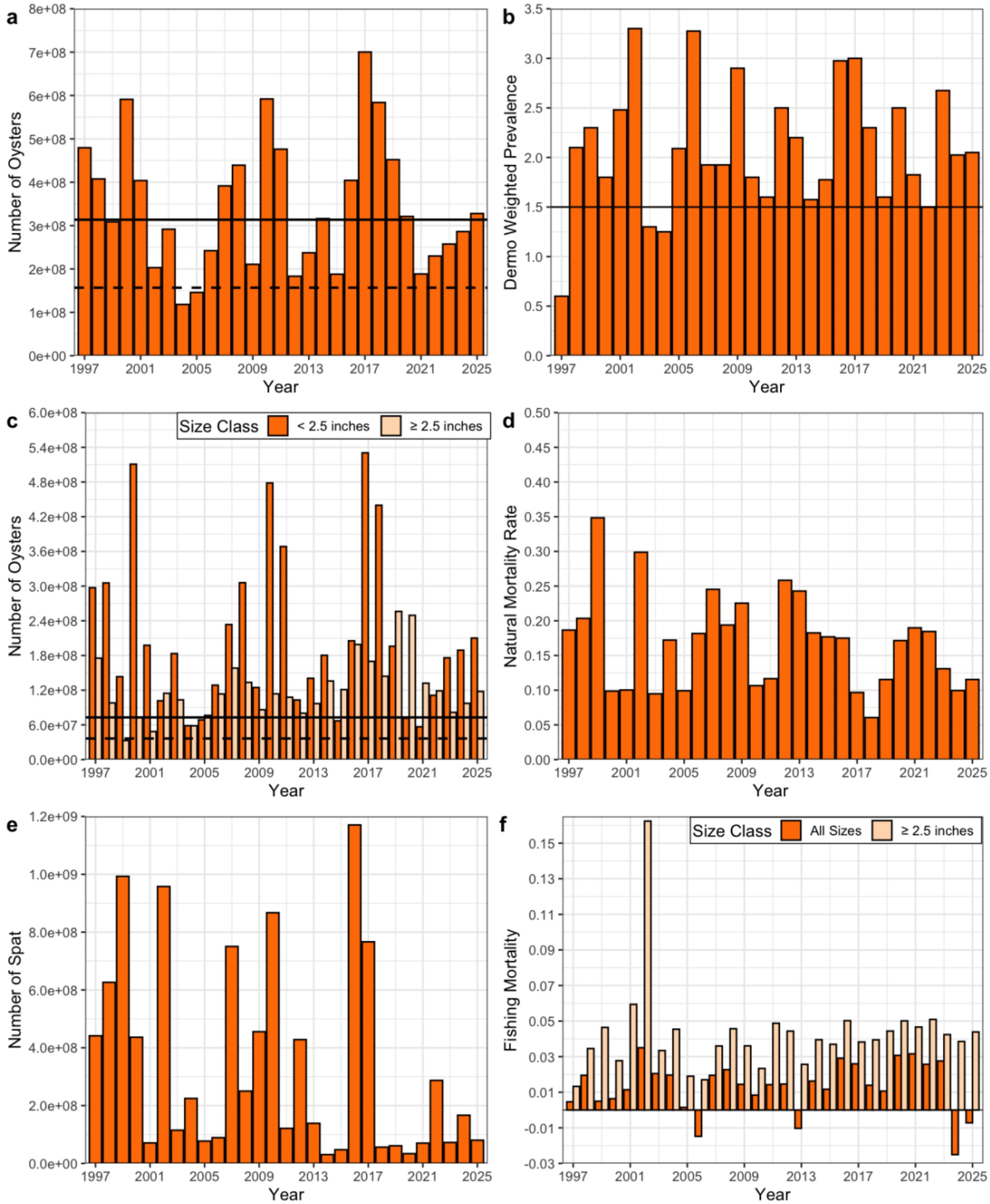


Figure 23. Direct Market time series summary for the HM. Targets are the median of the total abundance for 1989-2005 and the median of market-size (≥ 2.5") abundance for 1990-2005. Thresholds are half the target value.

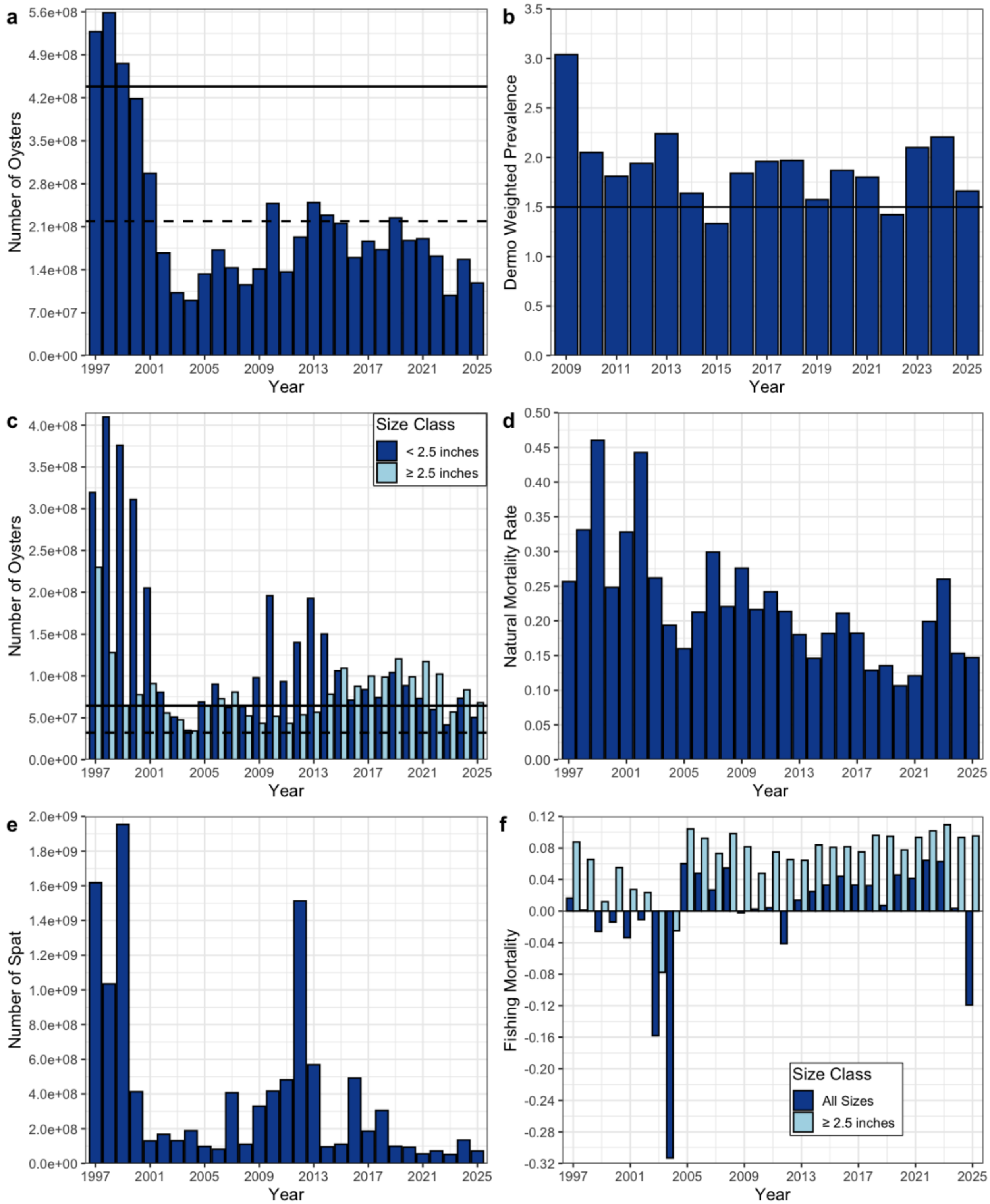
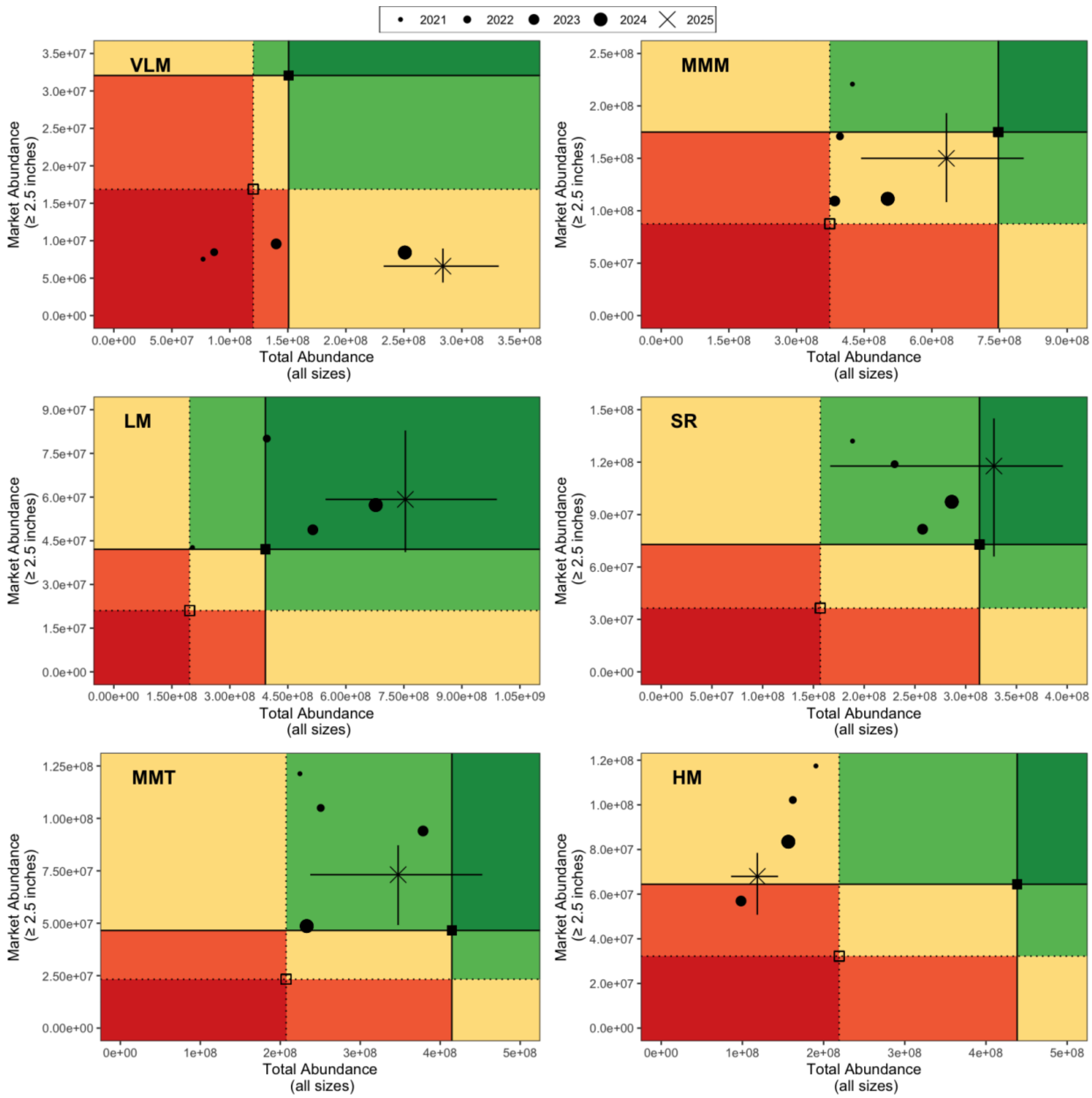


Figure 24. Position of the oyster stock from 2021-2025 with respect to abundance and market abundance (≥ 2.5") targets and thresholds for each region. Targets (solid lines) and thresholds (dashed lines) are defined in text. Error bars on the 2025 values are the 10th and 90th percentiles of 1,000 simulations of estimates incorporating both survey error and gear efficiency error. *Shading: Green, above all 4 cutoffs*; *Light green, above 3 cutoffs*; *Yellow, above 2 cutoffs*; *Orange, above 1 cutoff*; *Red, below all 4 cutoffs.*



Appendix A. History of resurveys for all beds, grouped by region, since the current 10-year resurvey schedule was implemented in 2009. “X” indicates the year(s) in which a bed was resurveyed.

Region	Bed	# Grids	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	'24	'25
VLM	Hope Creek	97									X								
VLM	Fishing Creek	67														X			
VLM	Liston Range	32								X									
LM	Round Island	73										X							
LM	Upper Arnolds	29					X												X
LM	Arnolds	99							X										X
MMT	Upper Middle	84												X					
MMT	Middle	51			X										X				
MMT	Sea Breeze	48				X										X			
MMM	Cohansey	83	X										X						
MMM	Ship John	68		X										X					
SR	Shell Rock	93				X				X									
HM	Bennies Sand	49	X										X						
HM	Nantuxent	68		X								X							
HM	Bennies	171						X										X	
HM	Hog Shoal	23								X									
HM	Strawberry	29							X										X
HM	Hawk's Nest	28									X								
HM	New Beds	112					X										X		
HM	Beadons	38			X										X				
HM	Vexton	47			X										X				
HM	Egg Island	125														X			
HM	Ledge	53													X				

Appendix B. SARC members listed by affiliation. SAW year refers to when the February workshop was held to discuss the previous year's data. Names in parentheses indicate that the appointed member did not attend the meeting.

SAW Year	Council	Industry	NJDEP	NJDEP	Academic	Academic	Management	Rutgers (non-HSRL)	DNREC
1999			Don Byrne	Jim Joseph	Eleanor Bochenek	Judy Grassle	Paul Rago	Joe Dobarro	
2000			Paul Scarlett	Jim Joseph	Steve Jordan		Paul Rago	Joe Dobarro	
2001	Scott Bailey		Bruce Halgren	Jim Joseph	Steve Jordan	Roger Mann	Jim Weinberg	Joe Dobarro	
2002	Scott Bailey	Steve Fleetwood	Bruce Halgren	Jim Joseph	Tom Soniat	Roger Mann	Larry Jacobsen	Joe Dobarro	
2003	Scott Bailey	Scott Sheppard	Tom McCloy	Jim Joseph	Tom Soniat	Joe DeAlteris		John Quinlan	Desmond Kahn
2004	Scott Bailey	Scott Sheppard	Russ Babb	Jim Joseph	Ken Paynter	Joe DeAlteris		John Quinlan	Desmond Kahn
2005	Scott Bailey	Steve Fleetwood	Russ Babb	Brandon Muffley	Ken Paynter	Joe DeAlteris	Jim Weinberg	John Quinlan	Desmond Kahn
2006	Scott Bailey	Steve Fleetwood	Russ Babb	Brandon Muffley	(Ken Paynter)	Roger Mann	Larry Jacobsen	Joe Dobarro	Desmond Kahn
2007	Barney Hollinger	Steve Fleetwood	Russ Babb	Mike Celestino	Steve Jordan	Roger Mann	Tom Landry	Joe Dobarro	Rich Wong
2008	Barney Hollinger	Steve Fleetwood	Russ Babb	Mike Celestino	Steve Jordan	Roger Mann	Tom Landry	Gef Flimlin	
2009	Scott Bailey	Steve Fleetwood	Russ Babb	Mike Celestino	Steve Jordan	Ken Paynter	Tom Landry	Francisco Werner	
2010	Barney Hollinger	Steve Fleetwood	Russ Babb	Mike Celestino	Ken Paynter	(Roger Mann)	Tom Landry	Francisco Werner	Rich Wong
2011	Barney Hollinger	Bill Riggin	Russ Babb	Mike Celestino	Danielle Kreeger	Roger Mann	Patrick Banks	Olaf Jensen	Rich Wong
2012	Barney Hollinger	Bill Riggin	Jason Hearon	Mike Celestino	Steve Fegley	Roger Mann	Patrick Banks	Olaf Jensen	Rich Wong
2013	Barney Hollinger	Bill Riggin	Jason Hearon	Mike Celestino	Steve Fegley	Juli Harding	Patrick Banks	Olaf Jensen	Rich Wong
2014	Barney Hollinger	Scott Bailey	Jason Hearon	Mike Celestino	(Steve Fegley)	(Juli Harding)	Mitch Tarnowski	John Wiedenmann	Rich Wong
2015	Steve Fleetwood	Scott Bailey	Jason Hearon	Mike Celestino	Pat Sullivan	Juli Harding	Mitch Tarnowski	John Wiedenmann	Rich Wong
2016	Steve Fleetwood	Scott Bailey	Jason Hearon	Mike Celestino	Pat Sullivan	(Jerry Kauffman)	Mitch Tarnowski	John Wiedenmann	Rich Wong
2017	Steve Fleetwood	Barney Hollinger	Craig Tomlin	Mike Celestino	Pat Sullivan	Jerry Kauffman	Missy Southworth	John Wiedenmann	Rich Wong
2018	Barney Hollinger	Scott Sheppard	Craig Tomlin	Mike Celestino	Mike Wilberg	Jerry Kauffman	Missy Southworth	John Wiedenmann	Rich Wong
2019	Barney Hollinger	Scott Sheppard	Craig Tomlin	Mike Celestino	Mike Wilberg	Matthew Hare	Missy Southworth	John Wiedenmann	Rich Wong
2020	Steve Fleetwood	Scott Sheppard	Craig Tomlin	Mike Celestino	Mike Wilberg	Matthew Hare	Carolina Bourque	John Wiedenmann	Rich Wong
2021	Steve Fleetwood	Tim Reeves	Craig Tomlin	Mike Celestino	Daniel Hennen	Matthew Hare	Carolina Bourque	John Wiedenmann	Rich Wong
2022	Barney Hollinger	Tim Reeves	Craig Tomlin	Mike Celestino	Daniel Hennen	Dave Eggleston	Carolina Bourque	John Wiedenmann	Rich Wong
2023	Barney Hollinger	Tim Reeves	Craig Tomlin	Mike Celestino	Daniel Hennen	Daniel Bowling	Christine Jensen	John Wiedenmann	Rich Wong
2024	Scott Sheppard	Steve Fleetwood, Jr.	Craig Tomlin	Mike Celestino	Paul Rago	Daniel Bowling	Christine Jensen	John Wiedenmann	Rich Wong
2025	Scott Sheppard	Steve Fleetwood, Jr.	Craig Tomlin	Mike Celestino	Paul Rago	---	Christine Jensen	John Wiedenmann	Ben Wasserman
2026	Scott Sheppard	Steve Fleetwood, Jr.	Craig Tomlin	Mike Celestino	John Kraeuter	Kathy Alcox	Mitch Tarnowski	John Wiedenmann	Ben Wasserman

Appendix C. Detailed history of transplant efforts since 2007. A transplant was initially planned for 2020, but due to the COVID-19 pandemic and associated impacts on the market the transplant was canceled. ND = No Data.

Year	Region	Donor Bed	Receiver Bed	Bushels Moved	Total # Oysters	Fraction Oysters < 2.5"	Number Oysters ≥ 2.5"	Added Quota Allocation	Fraction Cultch	Chosen Expl. Rate	Achieved Expl. Rate	# Oysters at Chosen (all sizes)	# Oysters at Achieved (all sizes)
2025	VLM	Hope Creek	Sea Breeze	4,775	4,109,105	0.973	111,869	413	0.453	2.26%	3.31%	5,669,284	8,292,309
		Fishing Creek	Sea Breeze	1,200	900,946	0.937	57,052	211	0.446				
		Liston Range	Sea Breeze	2,900	3,282,258	0.983	56,160	207	0.309				
	LM	Upper Arnolds	Bennies	3,950	3,873,756	0.954	178,599	659	0.341	5.00%	5.22%	33,868,034	35,354,722
		Upper Arnolds-Arnolds	Bennies	1,375	1,191,528	0.967	38,749	143	0.359				
		Arnolds	Shell Rock	5,475	4,928,530	0.943	279,362	1,031	0.379				
		Arnolds	Bennies	26,850	25,360,908	0.947	1,356,320	5,005	0.325				
	MMT	Middle	Cohansey	5,675	3,089,928	0.859	435,446	1,607	0.294	2.46%	2.66%	5,733,654	6,208,672
		Middle	Shell Rock	5,600	3,118,744	0.871	401,154	1,480	0.354				
2024	VLM	Hope Creek	Ship John	3,800	2,541,268	0.901	252,611	936	0.418	2.26%	1.82%	3,162,332	2,541,268
	LM	Upper Arnolds	Shell Rock	3,725	3,242,461	0.903	312,916	1,159	0.374	2.26%	2.34%	11,628,715	12,016,124
		Arnolds	Shell Rock	8,150	8,773,663	0.928	633,531	2,346	0.332				
	MMT	Middle	Bennies	11,700	6,425,048	0.809	1,227,929	4,548	0.299	2.46%	2.58%	9,311,775	9,773,403
		Sea Breeze	Bennies	16,375	3,348,355	0.419	1,944,355	7,201	0.339				
2023	VLM	Hope Creek	Upper Middle	2,700	1,367,553	0.875	170,737	635	0.397	1.49%	1.58%	1,288,464	1,367,553
	LM	Upper Arnolds	Ship John	5,400	2,738,633	0.839	439,711	1,635	0.406	2.26%	1.86%	8,937,844	7,353,603
		Arnolds	Ship John	10,800	4,614,970	0.801	916,186	3,406	0.426				
	MMT	Upper Middle	Nantuxent	2,050	478,829	0.786	102,423	381	0.659	2.46%	1.95%	6,164,686	4,889,477
		Middle	Nantuxent	6,050	2,086,892	0.685	658,321	2,447	0.397				
		Sea Breeze	Nantuxent	2,650	632,171	0.355	408,022	1,517	0.241				
		Sea Breeze	Shell Rock	8,100	1,691,585	0.357	1,087,348	4,042	0.338				
2022	VLM	Hope Creek	Upper Arnolds	2,700	1,046,387	0.960	41,339	154	0.597	1.93%	1.36%	1,484,417	1,046,387
	LM	Upper Arnolds	Shell Rock	2,500	1,386,018	0.826	241,547	901	0.322	1.49%	1.66%	3,030,154	3,366,124
		Arnolds	Shell Rock	5,400	1,980,106	0.845	306,252	1,143	0.538				
	MMT	Upper Middle	Bennies Sand	2,700	544,825	0.744	139,260	520	0.650	2.46%	2.15%	5,524,254	4,837,920
		Middle	Bennies Sand	5,400	1,481,666	0.564	645,894	2,410	0.491				
		Sea Breeze	Bennies Sand	10,800	2,811,429	0.318	1,916,946	7,153	0.292				

Appendix C (cont.). Detailed history of transplant efforts since 2007. A transplant was initially planned for 2020, but due to the COVID-19 pandemic and associated impacts on the market the transplant was canceled. ND = No Data.

Year	Region	Donor Bed	Receiver Bed	Bushels Moved	Total # Oysters	Fraction Oysters < 2.5"	Number Oysters $\geq$ 2.5"	Added Quota Allocation	Fraction Cultch	Chosen Expl. Rate	Achieved Expl. Rate	# Oysters at Chosen (all sizes)	# Oysters at Achieved (all sizes)
2021	LM	Arnolds	Shell Rock	5,400	2,601,798	0.900	260,180	974	0.472	0.76%	0.94%	2,097,973	2,601,798
	MMT	Upper Middle	Bennies	2,650	659,794	0.733	176,218	660	0.573	2.46%	2.50%	6,297,118	6,401,396
		Middle	Bennies	2,700	997,139	0.481	517,274	1,937	0.199				
		Middle	Nantuxent	10,700	3,935,479	0.535	1,829,275	6,851	0.263				
		Sea Breeze	Bennies	2,700	808,984	0.279	583,363	2,185	0.206				
2020	*NO TRANSPLANT CONDUCTED*												
2019	LM	Arnolds	Shell Rock	7,200	2,837,705	0.828	489,430	1,861	0.449	2.26%	0.70%	8,941,378	2,837,705
	MMT	Middle	Bennies Sand	25,000	9,890,349	0.748	2,496,843	9,494	0.288	2.46%	2.79%	12,158,274	13,956,501
		Sea Breeze	Bennies Sand	8,800	4,066,152	0.768	941,483	3,580	0.206				
2018	MMT	Upper Middle	Bennies	4,750	973,690	0.527	460,846	1,752	0.566	2.46%	1.76%	15,785,722	12,310,312
		Middle	Bennies	27,500	8,230,069	0.507	4,054,033	15,415	0.329				
		Sea Breeze	Bennies	7,700	3,106,553	0.759	749,703	2,851	0.290				
2017	MMT	Upper Middle	Bennies	3,200	948,685	0.365	602,546	2,282	0.408	2.46%	2.37%	8,184,564	7,887,414
		Middle	Bennies	21,350	5,625,257	0.312	3,868,205	14,652	0.299				
		Sea Breeze	Bennies	4,700	1,313,472	0.515	636,920	2,412	0.219				
2016	LM	Arnolds	Cohansey	4,800	2,168,012	0.637	787,816	2,972	0.290	0.76%	0.96%	1,712,353	2,168,012
	MMT	Middle	Shell Rock	8,150	2,556,215	0.386	1,569,932	5,925	0.280	1.49%	0.97%	3,958,253	2,979,901
		Sea Breeze	Shell Rock	2,400	426,443	0.319	290,458	1,096	0.440				
2015	LM	Upper Arnolds	Ship John	10,200	4,474,515	0.721	1,247,128	4,688	0.330	1.30%	1.30 - 1.90%	3,598,514	4,474,515
	MMT	Middle	Shell Rock	5,550	1,726,335	0.604	682,813	2,567	0.310	2.30%	> 2.30%	4,360,643	4,475,247
		Sea Breeze	Shell Rock	10,800	2,748,912	0.422	1,590,121	5,978	0.250				
2014	LM	Arnolds	Ship John	15,500	6,168,587	0.485	3,174,627	12,025	0.220	2.33%	2.25%	6,403,869	6,134,370
	MMT	Middle	Shell Rock	6,600	1,553,053	0.381	961,033	3,640	0.250	2.33%	2.41%	3,517,430	3,473,086
		Sea Breeze	Shell Rock	7,300	1,922,420	0.390	1,173,115	4,444					
2013	VLM	Liston Range	Shell Rock	550	*VLM CLOSED in 2013, accidental transplant from this region*								
	LM	Round Island	Shell Rock	2,250	888,151	0.535	412,848	1,552	0.280	2.33%	< 2.33%	9,962,070	8,459,940
		Upper Arnolds	Shell Rock	15,550	6,238,792	0.553	2,787,160	10,478					
		Arnolds	Shell Rock	2,700	1,109,073	0.609	433,783	1,631					
	MMT	Upper Middle	Bennies Sand	3,200	890,008	0.338	588,950	2,214	0.270	2.33%	< 2.33%	5,465,140	3,798,531
		Middle	Bennies Sand	5,200	1,346,337	0.423	777,424	2,923					
		Sea Breeze	Bennies Sand	6,200	1,587,589	0.268	1,161,796	4,368					

Appendix C (cont.). Detailed history of transplant efforts since 2007. A transplant was initially planned for 2020, but due to the COVID-19 pandemic and associated impacts on the market the transplant was canceled. ND = No Data.

Year	Region	Donor Bed	Receiver Bed	Bushels Moved	Total # Oysters	Fraction Oysters < 2.5"	Number Oysters ≥ 2.5"	Added Quota Allocation	Fraction Cultch	Chosen Expl. Rate	Achieved Expl. Rate	# Oysters at Chosen (all sizes)	# Oysters at Achieved (all sizes)
2012	LM	Arnolds	Nantuxent	7,650	4,489,153	0.790	942,900	3,558	0.280	1.27%	< 1.27%	4,730,022	4,469,068
	MMT	Upper Middle	Nantuxent	2,100	797,489	0.648	280,788	1,060	0.260	1.88%	> 1.88%	7,245,772	9,221,809
		Middle	Bennies Sand	11,200	4,406,878	0.602	1,755,084	6,623					
		Sea Breeze	Bennies Sand	5,425	2,563,782	0.751	638,647	2,410					
		Sea Breeze	Nantuxent	3,100	1,463,987	0.733	391,610	1,478					
2011	VLM	Hope Creek	Cohansey	6,150	3,766,429	0.658	1,289,314	4,940	0.180	1.27%	< 1.27%	5,003,664	4,871,104
		Liston Range	Cohansey	1,800	1,085,283	0.615	417,586	1,600					
	LM	Round Island	Bennies	3,350	1,630,191	0.603	646,914	2,479	0.270	1.27%	> 1.27%	3,991,178	4,252,834
		Upper Arnolds	Bennies	2,800	1,008,104	0.608	394,902	1,513					
		Arnolds	Bennies	4,000	1,638,736	0.665	549,631	2,106					
	MMT	Middle	Bennies	17,750	5,900,036	0.533	2,753,351	10,549	0.250	1.88%	> 1.88%	5,255,322	5,848,372
2010	VLM	Hope Creek	Bennies	1,200	*ND*	*ND*	*ND*		0.400	1.27%	~1.27%	3,833,693	
		Fishing Creek	Bennies	200	*ND*	*ND*	*ND*	1,232					
		Fishing Creek	Shell Rock	1,800	*ND*	*ND*	*ND*						
		Liston Range	Shell Rock	4,750	*ND*	*ND*	*ND*	4,839					*ND*
	LM	Upper Arnolds	Shell Rock	1,200	*ND*	*ND*	*ND*	839	0.250	2.33%	< 2.33%	8,587,511	
		Upper Arnolds	Bennies	17,050	*ND*	*ND*	*ND*	14,814					*ND*
	MMM	Sea Breeze	Bennies	11,050	*ND*	*ND*	*ND*	5,502	0.390	1.88%	< 1.88%	4,155,570	
		Cohansey	Bennies	1,500	*ND*	*ND*	*ND*			ND	ND	*ND*	*ND*
2009	VLM	Hope Creek	Ship John	9,100	5,780,080	0.651	2,017,030	7,699	0.240	1.27%	> 1.27%	5,032,780	5,722,475
	LM	Arnolds	Bennies	10,400	4,942,416	0.485	2,544,755	9,713	0.250	1.88%	> 1.88%	4,621,870	4,946,939
	MMT	Upper Middle Middle	Bennies	14,100	4,559,705	0.548	2,060,715	7,865	0.270	2.33%	> 2.33%	4,716,070	4,566,296
2008	LM	Arnolds	Cohansey	9,450	4,089,861	0.483	2,113,742	8,161	0.350	1.27%	> 1.27%	3,664,083	4,012,758
	MMT	Middle	Bennies Sand	8,200	2,577,406	0.363	1,641,413	6,337		2.33%	> 2.33%	2,291,480	2,553,726
2007	MMT	Middle	Nantuxent	12,982	3,819,176	0.460	2,064,242	7,849	0.360	1.48%	~1.48%	*ND*	3,819,176

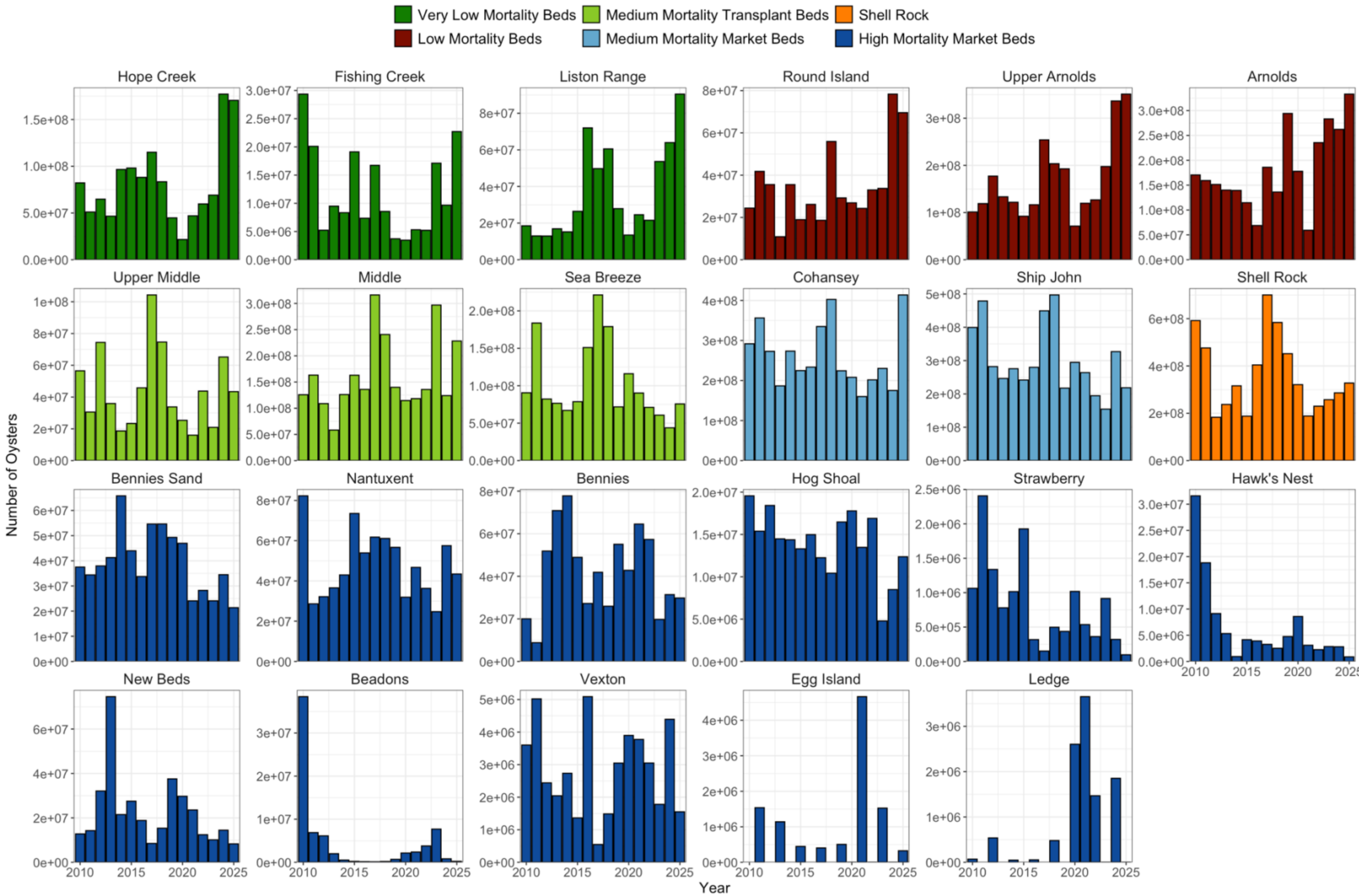
Appendix D. History of Shellplanting efforts since 2003.

Year	Region	Bed	Bushels of Shell
2025	HM	Bennies Sand	38,779
	MMM	Ship John	40,344
	SR	Shell Rock	41,461
2024	HM	Bennies	48,434
	SR	Shell Rock	44,528
2023	HM	Bennies	44,008
	MMM	Ship John	48,434
	SR	Shell Rock	44,528
2022	HM	Nantuxent	45,049
	SR	Shell Rock	67,442
2021	HM	Nantuxent	48,043
	SR	Shell Rock	47,566
2020	HM	Bennies Sand	58,697
2019	HM	Nantuxent	37,498
	HM	Bennies Sand	41,664
	MMM	Cohansey	37,237
	SR	Shell Rock	40,622
2018	HM	Hog Shoal	42,184
	MMM	Ship John	42,705
	SR	Shell Rock	63,276

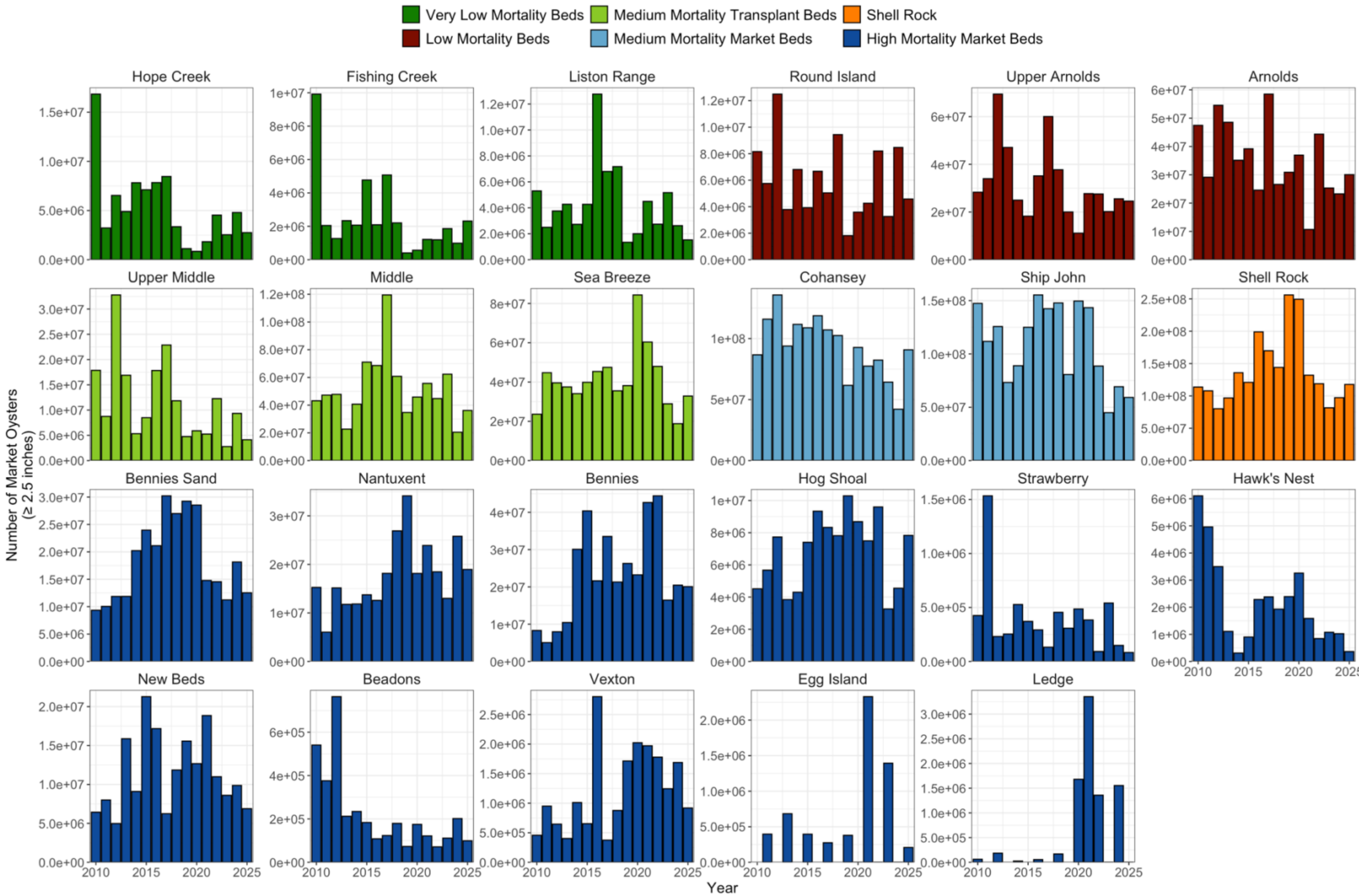
Year	Region	Bed	Bushels of Shell
2017	HM	Bennies Sand	65,522
	MMM	Cohansey	40,572
	SR	Shell Rock	42,091
2016	HM	Bennies	44,000
	MMM	Ship John	44,000
	SR	Shell Rock	44,000
2015	HM	Bennies	43,038
	MMM	Cohansey	38,539
	SR	Shell Rock	47,913
2014	HM	Nantuxent	42,704
	MMM	Ship John	52,740
	MMT	Middle	12,709
	SR	Shell Rock	55,394
2013	MMT	Middle	23,050
	SR	Shell Rock	100,000
2012	MMM	Ship John	100,000
	VLM	Hope Creek	12,000
2011	HM	Bennies Sand	50,000
	MMT	Middle	18,000
	SR	Shell Rock	50,000

Year	Region	Bed	Bushels of Shell
2010	HM	Bennies Sand	49,645
	SR	Shell Rock	40,199
2009	HM	Nantuxent	34,686
	HM	Bennies Sand	51,386
	SR	Shell Rock	58,233
2008	HM	Bennies Sand	70,947
	HM	Nantuxent	101,540
	MMM	Cohansey	21,898
2007	HM	Nantuxent	43,360
	MMM	Cohansey	19,881
	MMM	Ship John	168,642
	MMT	Middle	43,800
2006	HM	Hawk's Nest	17,850
	HM	Nantuxent	49,488
	HM	Bennies Sand	74,869
	SR	Shell Rock	125,354
2005	HM	Bennies Sand	12,250
	SR	Shell Rock	89,337
2004	*NO SHELLPLANTING OCCURRED*		
2003	HM	Bennies Sand	16,130

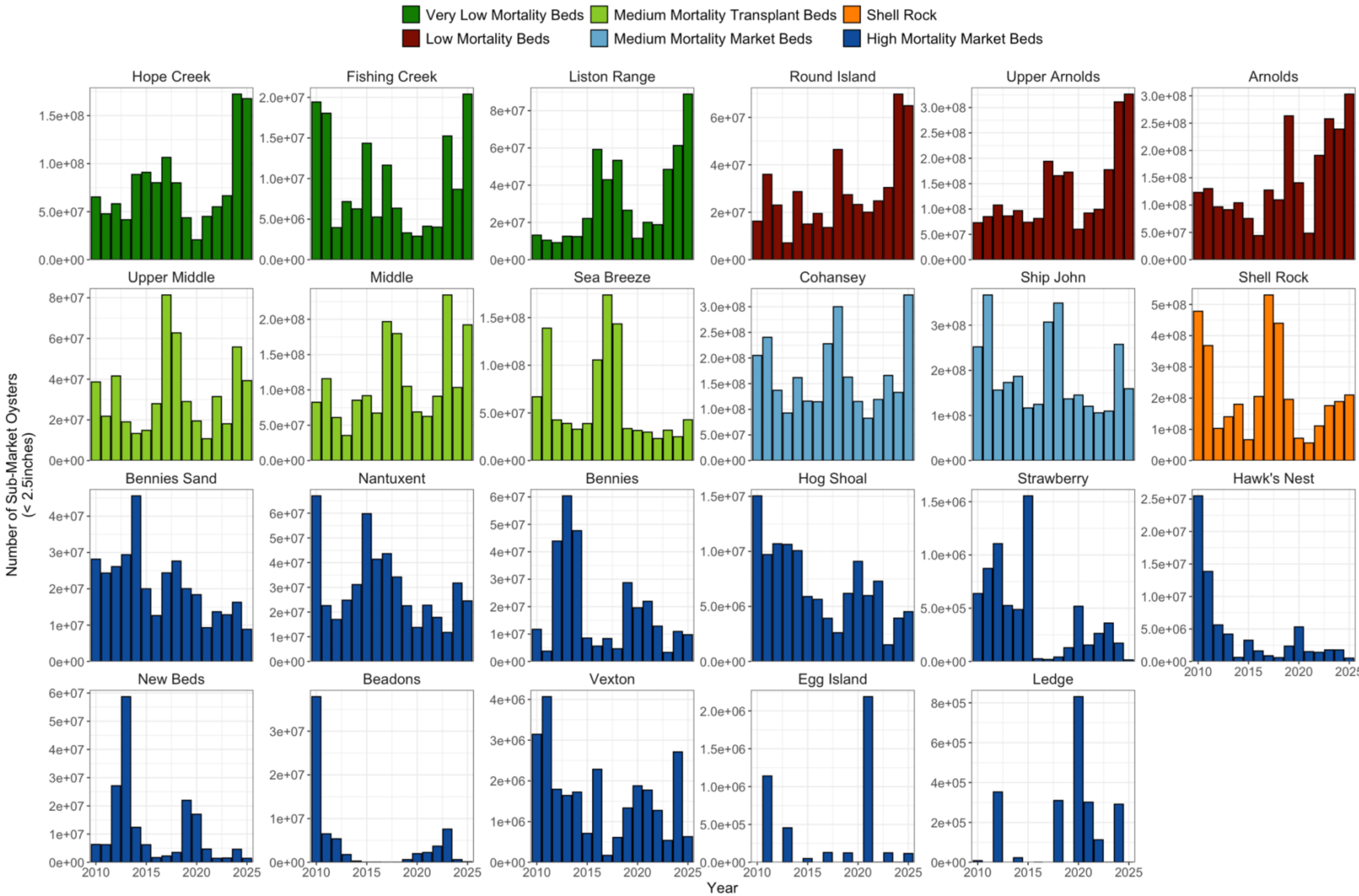
Appendix E. Bed-level oyster abundance (all oysters > 20 mm) for each region. Note y-scale varies.



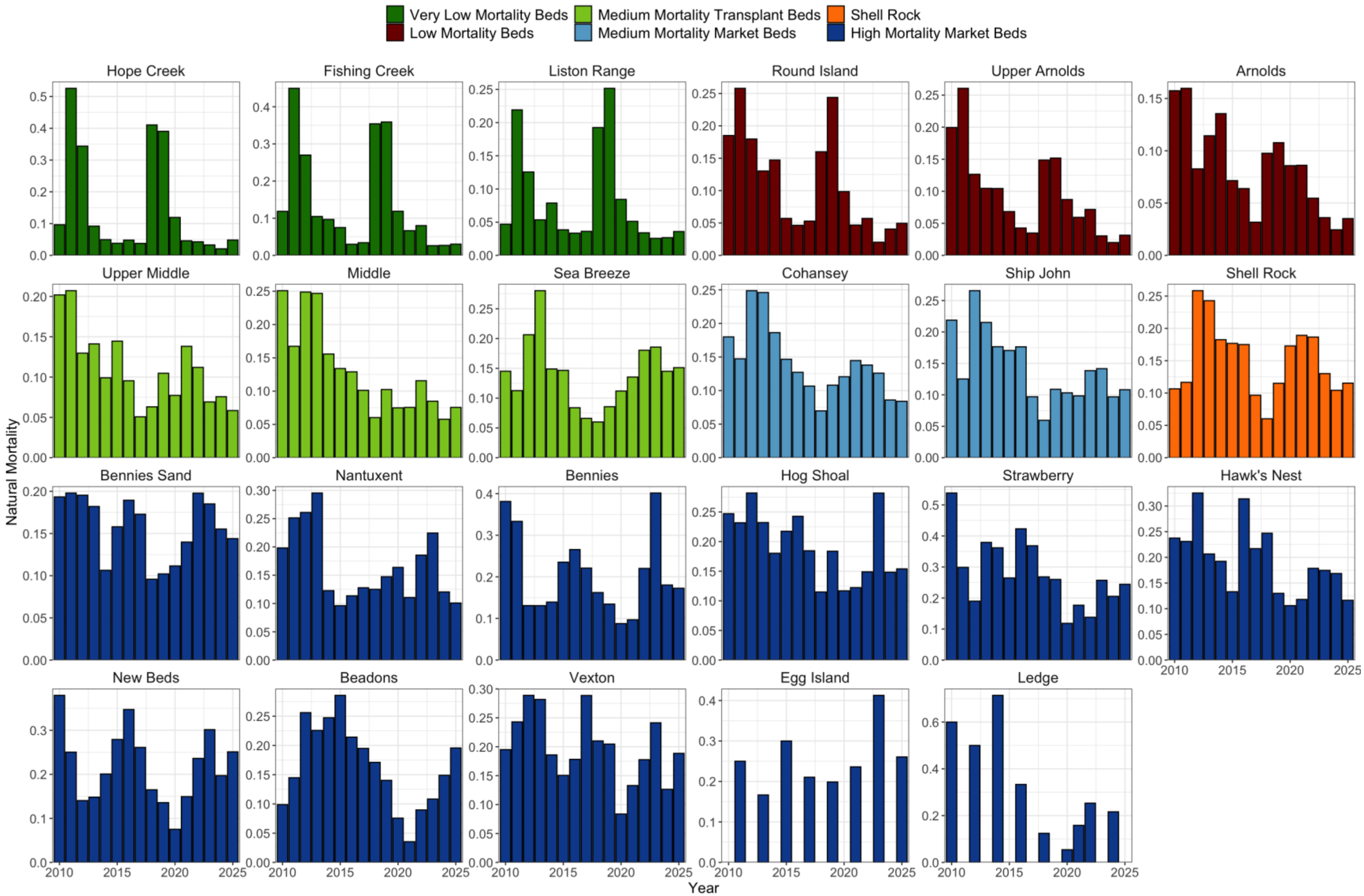
Appendix F. Bed-level market (> 63.5 mm) abundance for each region. Note y-scale varies.



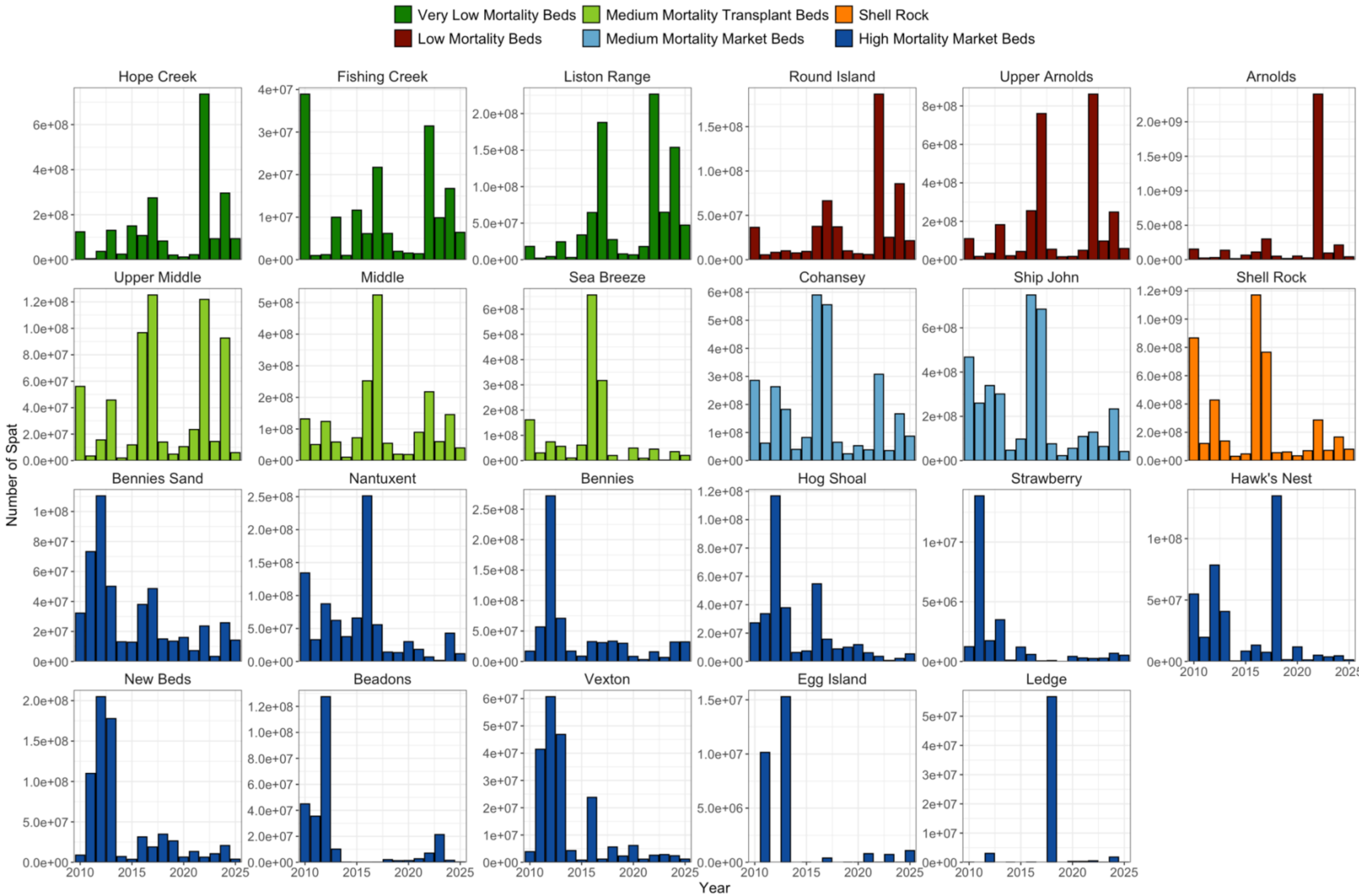
Appendix G. Bed-level sub-market (< 63.5 mm) abundance for each region. Note y-scale varies.



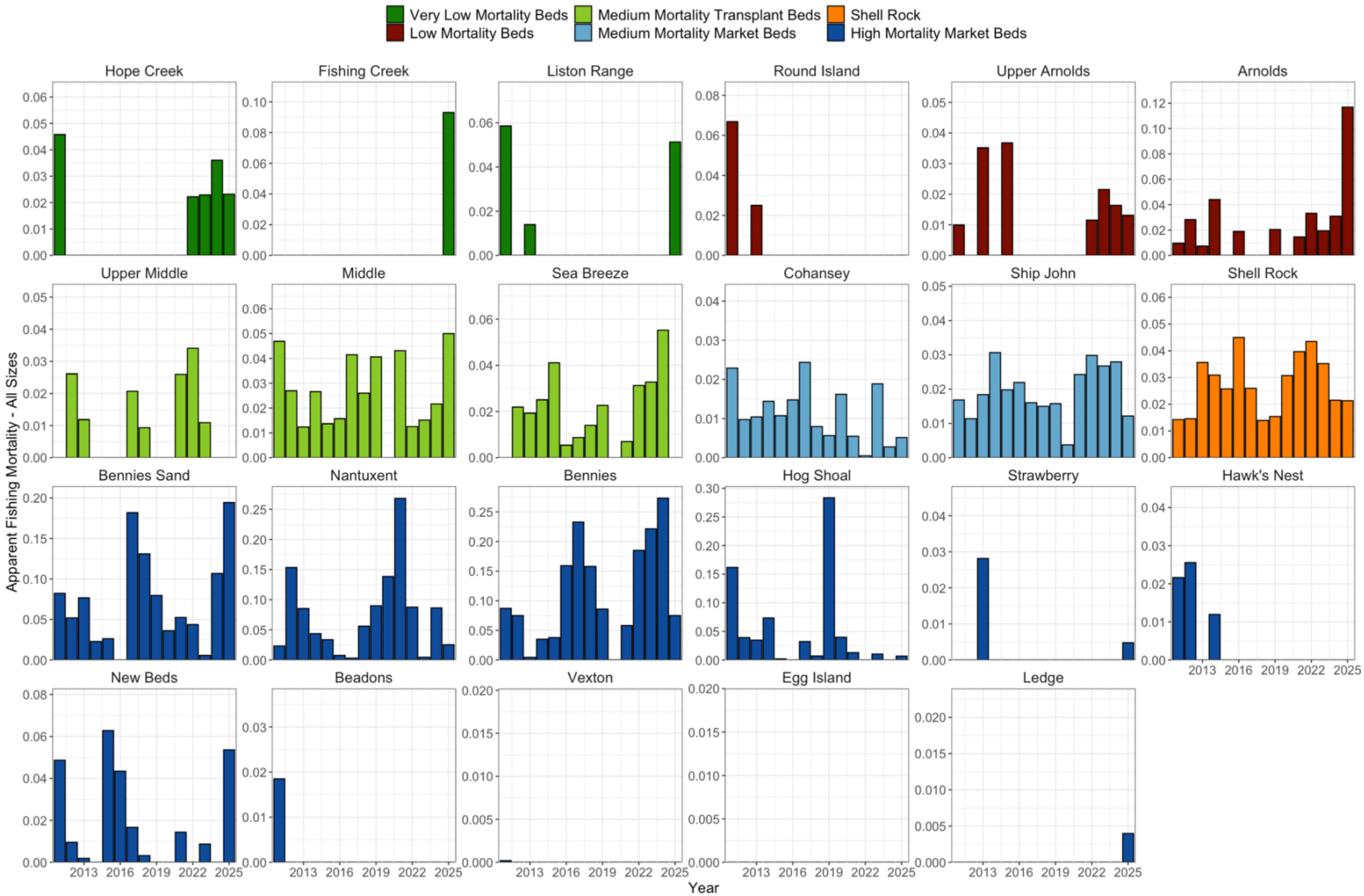
Appendix H. Bed-level mortality fraction for each region. Note y-scale varies.



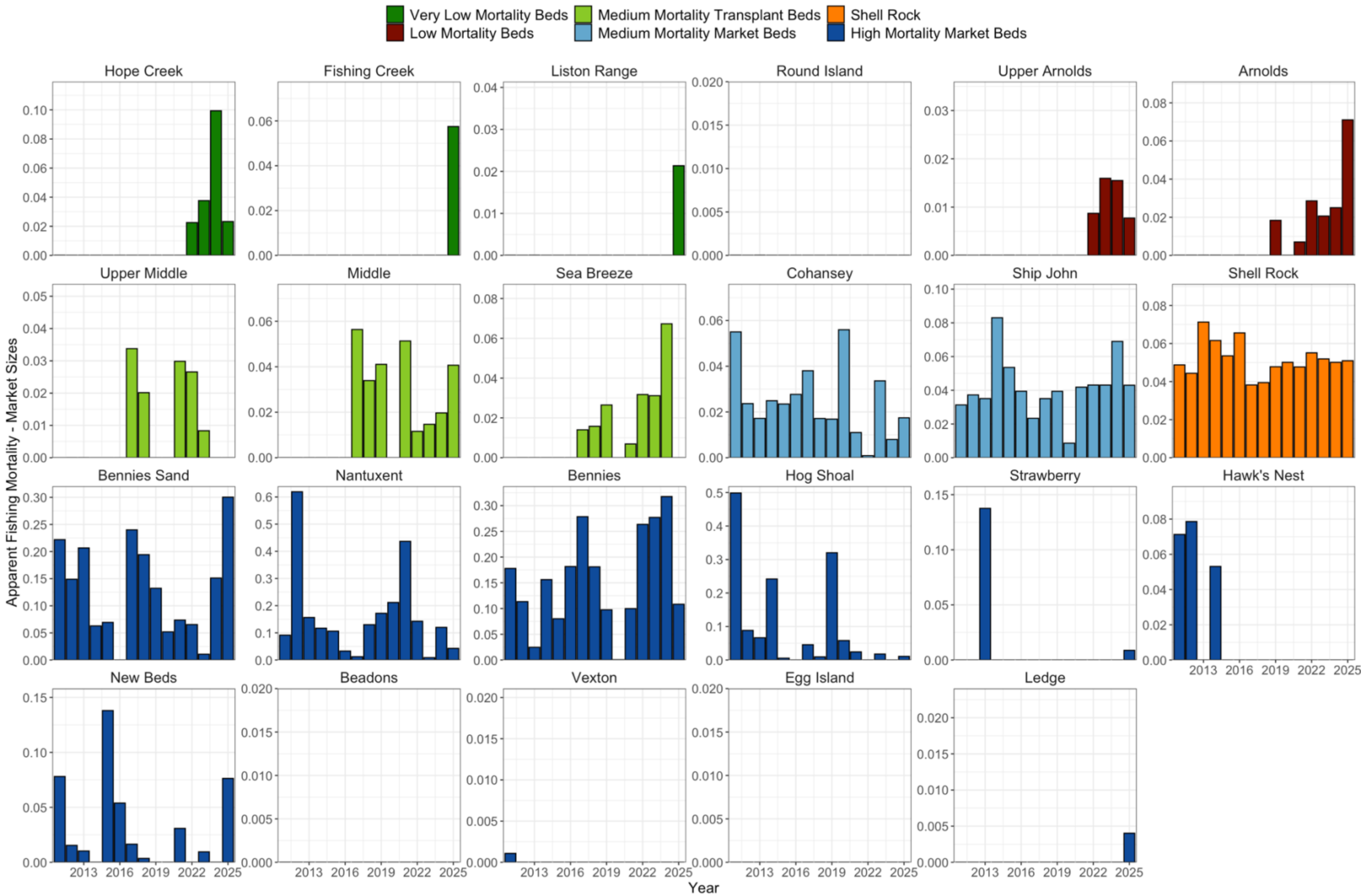
Appendix I. Bed-level spat (< 20 mm) abundance for each region. Note y-scale varies.



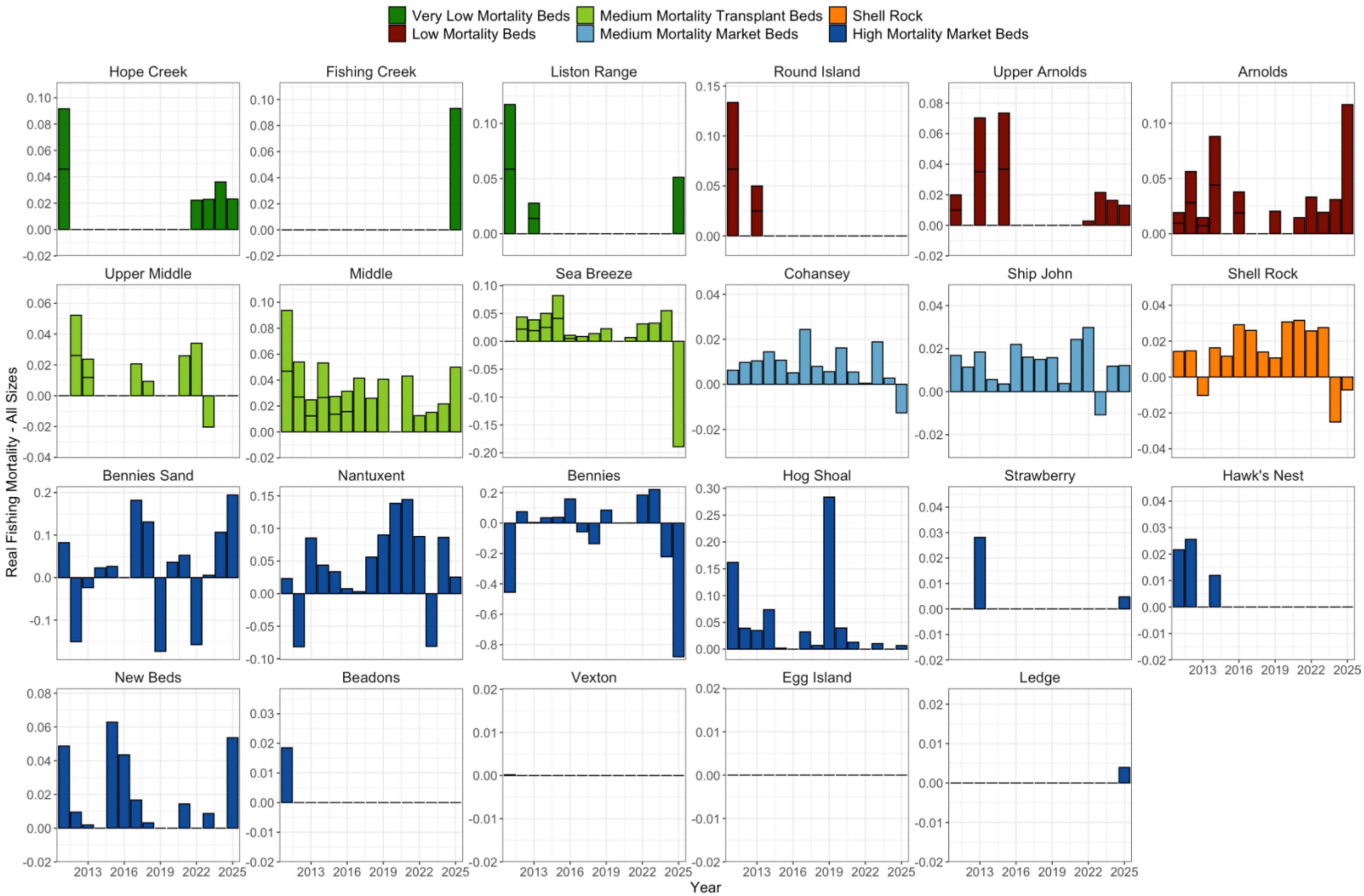
Appendix J.1 Bed-level apparent fishing mortality fraction relative to all sizes for each region. The apparent fishing mortality fraction is the number of total removals divided by the previous year's total abundance. Note y-scale varies.



Appendix J.2 Bed-level apparent fishing mortality fraction relative to market sizes for each region. The apparent fishing mortality fraction is the number of market removals divided by the previous year's market abundance. Note y-scale varies.



Appendix J.3 Bed-level realized fishing mortality fraction relative to all sizes for each region. The realized fishing mortality fraction is the net total removals (total number removed minus total number added through transplant) divided by the previous year's total abundance. Oysters are removed through transplant on the Transplant regions or through harvest on the Direct Market regions. Note y-scale varies.



Appendix J.4 Bed-level realized fishing mortality fraction relative to market sizes for each region. The realized fishing mortality fraction is the net market removals (number of markets removed minus number of markets added through transplant) divided by the previous year's market abundance. Oysters are removed through harvest on the Direct Market regions or through transplant on the Transplant regions. Note y-scale varies.